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GENETIC PARAMETERS OF SOME MAIZE GENOTYPES UNDER DIFFERENT SOIL MOISTURE CONDITIONS

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ABSTRACT

Two field experiments were carried out during 2003 and 2004 summer seasons to study the genetic parameters of some maize genotypes under drought stress treatments (irrigation every 14, 18 and 22 days). Grain yield/plant at moderate drought (MD) was highly significant and positive associated with plant height, ear height, leaves /plant and ear leaf area, ear weight/plant, ear length, 100-kernel weight, shelling % and ears /plant in both seasons. Grain yield/plant under severe drought (SD) was highly significant and negative associated with anthesis-silking interval (ASI), and positively correlated with 50% anthesis and most studied vegetative traits and with ear weight/plant, ear length, kernels no. /row, 100-kernel weight and shelling % in both seasons, and with ears /plant in the first season. It is worthy to note that magnitude of correlation coefficients between grain yield and yield components were higher under stress conditions than under control (no-drought) in most cases. Drought stress treatments resulted in lower broad-sense heritabilities than control treatment (no-drought) for 50% anthesis, ASI, leaves no./plant, ear leaf area, grain yield and ear weight/plant, ears no./plant, rows no./ear and shelling %, due to decreasing genotypic variances and increased error variances under drought treatments. Expected gains in grain yield from indirect selection for studied traits and their percentages to gain from direct selection were of high magnitude for ear leaf area, ear height and plant height, ear weight/plant, ear length and 100-kernel weight in both seasons under no-drought (ND), ear height, plant height, ear weight/plant, ear length, 100-kernel weight and shelling % in both seasons under moderate (MD) and ear height, ear leaf area, ear weight/plant, ear length, 100-kernel weight and shelling % in both seasons under severe drought (SD). It is concluded that for studied traits, the expected gain from direct selection for grain yield under stressed or non-stressed environments would improve the trait under consideration in a way better than the indirect selection.

Key words: ***Maize, Drought, Correlation, Heritability, Selection gains***

INTRODUCTION

Among the environmental stresses, drought is considered the most single limiting factor of plant productivity in most areas of the world. When drought is prolonged, crops fail. Over the past few years, there has been little serious drought in the world, but it is easy to recall the grim years of the early 1970's when severe drought occurred in Asia and Africa in the latitudes just below the Tropic of Cancer. Many thousands of people and animals were affected and many lives were lost (Swindale and Bidinger 1981).

During the last 50 years considerable efforts have been devoted to improve yield performance of maize under water-stress conditions through breeding, and to understand the mechanisms involved in drought tolerance (Edmeades *et al* 1992). The problems were the proper techniques of identifying and selecting tolerant genotypes to soil water stress and conducting an efficient breeding program to such a complicated character. This also requires understanding the physiology and genetics of characters affecting water-stress tolerance and identifying the proper morphological, physiological traits which, should be recommended to maize breeder as most suitable for screening genotypes for drought tolerance.

Correlation between yield and its attributes was studied under drought stress conditions to determine the most important traits related to yield, which could be used as rapid and accurate selection criteria for soil moisture stress tolerance.

Drought tolerant genotypes of maize were characterized by shorter anthesis-silking interval (ASI) (Bolanos and Edmeadas 1993), higher number of ears per plant and higher number of kernels per ear (Ribaut *et al* 1997) than susceptible genotypes. Bolanos and Edmeades (1996) showed a strong dependence of grain yield (GY) on number of ears per plant (r_g = 0.90) and number of grains per ear (r_g = 0.71), while, the correlation between GY and weight per grain was weak (r_g = 0.14). A moderately strong negative correlation (r_g = -0.60) was reported between GY and ASI. Similar results were observed by Diallo *et al* (1996).

Moursi (1997), found that grain yield/fad appears to be positively and significantly correlated with each of plant height, ear height, number of kernels/row and kernels weight/ear, under normal irrigated conditions. Thus, these characters could be used as selection criteria aiming to improve grain yield under normal irrigated conditions. However under water stress conditions, grain yield/fad correlated positively and significantly with ear length, ear weight and kernels weight per ear. Therefore, grain yield of maize could be improved under water stress conditions through selecting for these traits. Many other investigators including Chapman and Edmeades (1999), Al-Naggar *et al.* (2000) and El-Morshidy *et al.* (2003) reached similar conclusion.

Choosing the optimal environment in which to achieve maximum genetic gain is an important factor for crop breeders. Different opinions were reported in the literature regarding the best evaluation environment for practicing selection to increase grain yield under stress conditions.

Byrne *et al* (1995) suggested that selection under managed levels of drought stress at one location together with multilocation testing may be desirable components of maize breeding programs for drought-prone tropical areas. Bolanos and Edmeades (1996) reported that genetic variances for grain yield, grains/cob, grains/plant and grain weight were decreased, but those for ASI and cobs/plant were increased with increasing drought. Also, they found that broad-sense heritability for grain yield averaged around 0.6, but fell to values near 0.4 at very low grain yield levels.

Eadmeades *et al* (1997) concluded that it is possible through selection to increase grain yields under severe drought stress (mean yield of 2 t ha^{-1}) by 24-40 %, while at the same time increasing yield potential by around 5-10 %. The key to success is carefully managed drought stress coinciding with flowering and the choice of elite germplasm, followed by selection for grain yield, ears per plant, ASI, stay green and a constant 50% anthesis. Banziger *et al* (1999) and Zaidi *et al* (2004), observed that selection for tolerance to mid season drought stress appears to increase grain yield across a range of nitrogen stress levels and may lead to morphological and physiological changes that are of particular advantages under N stress.

Al-Naggar *et al* (2000) showed that heritability estimates under drought stress environments for grain yield and number of kernels/row were lower but those for ASI, and ears/plant traits were higher than estimates under non-stressed environment. Also, they showed that 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). Similar results were reported by Atta (2001) and Banziger and Cooper (2001).

The aim of this investigation was to study the phenotypic and genotypic correlation coefficients between grain yield and other traits in maize under no-drought, moderate and severe drought and to identify the most associated characters with yield under water stress, estimate the heritability under different soil moisture regimes and compare these moisture regimes as evaluation environments based on expected genetic advance from direct and indirect selection.

MATERIALS AND METHODS

In 2002 growing season, six maize parental inbred lines (L.81 B, G 278, G 507 A, G 516, Rg 5 and Rg 8) were crossed in all possible combinations including reciprocals by using a complete diallel cross mating design to obtain 30 single crosses. F_1 single crosses were evaluated through two years (2003 and 2004 growing seasons) under 3 irrigation treatments in 3 separate filed experiments. Irrigation treatments were normal irrigation every 14 days (no drought, ND), irrigation every 18 days (moderate drought, MD) and irrigation every 22 days (severe drought, SD).

Each experiment was arranged in a randomized complete blocks design (RCBD) with 2 replications in the 2003 growing season, and 3 replications in the 2004 growing season. The plot size was 3 ridges, 1.5 meters long and 70 cm wide, in 2003 growing season. While in 2004 growing season, the experimental plot consisted of 3 ridges, 3 meters long and 70 cm wide.

Experiments of 2003 growing season were carried out at the Experiments Station of the Faculty of Agriculture, Mansoura University, whereas the experiments of 2004 growing season were conducted at El-Taweela Village, Talkha Center, El-Dakahlia Governorate.

The soils of the experimental sites are clayey in texture, contains organic matter of 2.90 and 3.60% , available N of 17 and 38 ppm, available P of 6 and 25 ppm, available K of 310 and 323 ppm and PH of 7.8 and 8.9 in the first and second seasons, respectively.

Maize grains were hand sown on May 28 and May 1 in 2003 and 2004 seasons, respectively. Two grains were sown per hill at 25 cm spacing. Hills were thinned after seedling emergence to secure one plant per hill. Each experiment was hoed twice, before the first and the second irrigation. Phosphorus in the form of calcium superphosphate (15.5% P_2O_5%) at 200 kg/fed., was added to the soil during seedbed preparation, and potassium sulphate (48% K_2O) at 50 kg/fed was applied after thining. Nitrogen in the form of Urea (46.5% N) at 120 kg N/fed was added in two equal split applications, before the first and the second irrigation. Other agricultural practices were done as recommended.

The following measurements were recorded: days to 50% anthesis, days to 50% silking, anthesis-silking interval (ASI), number of leaves/plant, plant height, ear height, stem diameter, ear leaf area/plant, number of ears/plant, ear diameter, ear length, number of rows/ear, number of kernels/row, 100-kernel weight, ears yield per plant, grain yield per plant, shelling percentage, drought tolerance index (DTI)= yield under severe drought / yield under no drought) according to El-Sayed (1998) and Atta (2001) .

Data on entries in each experiment for each of irrigation treatments (I_{14}, I_{18} and I_{22}) were subjected to separate analysis of variance of RCBD design and analysis of covariance between grain yield and other traits in the forms given in Table 1.

Table 1. Mean squares and expected mean squares for variance and covariance components.

S.V	d.f	MS	EMS	MP	EMP
Replicates (r)	r-1				
Crosses (c)	c-1	M_2	$\sigma^2_e + r\sigma^2_G$	MP_2	$\sigma^2 e_{ij} + r\sigma^2 G_{ij}$
Error	(r-1)(c-1)	M_1	σ^2_e	MP_1	$\sigma^2 e_{ij}$

genetic and phenotypic variances were estimated from expected mean squares as follows: $\sigma^2_G = (M_2 - M_1) / r$ $\sigma^2_P = \sigma^2_G + (\sigma^2_e / r)$.
The percentage of heritability of plot means was estimated as:

$$h^2_b = (\sigma^2_G / \sigma^2_P) \times 100$$

Phenotypic (r_{ph}) and genotypic (r_g) correlations were calculated between grain yield per plant and other traits for no drought (ND), moderate drought (MD) and severe drought (SD) conditions by the following formulae: (Banziger et al., 1997)

$r_{pij} = \sigma^2 p_{ij} / (\sigma^2 pi \times \sigma^2 p_j)^{1/2}$ $\quad$ $r_{gij} = \sigma^2 Gij / (\sigma^2 G_i \times \sigma^2 G_j)^{1/2}$.

Where, rp_{ij} and rg_{ij} refer to phenotypic and genotypic correlation coefficient, respectively, $\sigma^2 p_{ij}$ and $\sigma^2 Gij$ indicate phenotypic and genotypic covariance, respectively, $\sigma^2 p$ and $\sigma^2 G$ indicate phenotypic and genotypic variance, repectively and subscripts i and j refer to yield and correlated trait, respectively.

Expected gain from direct selection for grain yield/plant under each irrigation treatment was calculated by using the following formula according to Banziger and Lafitte (1997)

$$\Delta S = K \cdot h^2_b \cdot \sigma_{Pi} = K \sigma^2_{Gi} / \sigma_{Pi}$$

where. K is the selection differential; σ^2_{Gi} and σ_{Pi} are the genotypic and phenotypic standard deviation for grain yield, respectively.

Expected gain in grain yield from selection for a yield-related trait (indirect selection) was calculated by the following formula according to Banziger and Lafitte (1997)

Indirect selection gain = k $\sigma_{Gij} / \sigma_{Pj}$

where. σ_{Gij} = genetic covariance between grain yield and related trait j,

σ_{Pj} = phenotypic standard deviation for trait j.

A standard value of k = 1 was assumed for both direct and indirect selection.

RESULTS AND DISCUSSION

Associated Traits

Grain yield and flowering and vegetative traits

Grain yield plant^{-1} under no-drought was positively and significantly correlated with 50% anthesis (r_{ph}= 0.38*, r_g= 0.40) and 50% silking (r_{ph}= 0.39*, r_g= 0.42) in the first season, but the correlation in the second season was non-significant (Table 1). The association between grain yield plant^{-1} under no-drought and anthesis-silking interval (ASI) was negative and non-significant in the first season, and significant in the second season (r_{ph}= 0.35*, r_g= 0.37). All studied vegetative traits were positively and highly significantly correlated with grain yield/plant under no-drought i.e. plant height (r_{ph}= 0.56**, 0.60** and r_g= 0.57, 0.62), ear height (r_{ph}= 0.58**, 0.54** and r_g= 0.59, 0.55) and ear leaf area (r_{ph}= 0.66**, 0.48** and r_g= 0.68. 0.49) in the first and second season. respectively, and stem diameter in the first season (r_{ph}= 0.42** and r_g= 0.43) and only significant in the second season (r_{ph}= 0.40** and r_g= 0.47) except leaves/plant which was non-significantly correlated with grain yield/plant in the second season.

Grain yield/plant under moderate drought (MD) was highly significantly and positively associated with plant height (r_{ph}= 0.58**, 0.74**

and r_g= 0.60, 0.77), ear height (r_{ph}= 0.81**, 0.63** and r_g= 0.85, 0.65), leaves /plant (r_{ph}= 0.62**, 0.46** and r_g= 0.72, 0.51) and ear leaf area (r_{ph}= 0.69**, 0.44* and r_g= 0.71, 0.49) in the first and second season, respectively, and stem diameter (r_{ph}= 0.50** and r_g= 0.51) in the first season. While, grain yield/plant was moderately correlated with 50% anthesis (r_{ph}= 0.45*, 0.38* and r_g= 0.47, 0.40), 50% silking (r_{ph}= 0.36*, 0.26 and r_g= 0.39, 0.29) in the first and second season, respectively, and anthesis-silking interval (ASI) (r_{ph}= 0.45* and r_g= 0.47) in the first season, while it showed a negative correlation with ASI (r_{ph}= -0.37* and r_g=- 0.40) in the second season, as shown in Table (2) .

Regarding to the correlations under severe drought (SD), data in Table (2) showed that grain yield/plant was highly significantly and negatively associated with anthesis-silking interval (ASI) (r_{ph}= -0.64**, -0.49** and r_g= -0.95, -0.55), and positively correlated with 50% anthesis (r_{ph}= 0.53**, 0.41* and r_g= 0.57, 0.45), and non-significantly associated with 50% silking (r_{ph}= 0.28, 0.14 and r_g= 0.32, 0.15) in the first and second seasons, respectively.

Grain yield under severe drought was positively and highly significantly associated with all studied vegetative traits in both seasons except with stem diameter in the second season which was only significant, and leaves/plant in the second season which was not significant.

Table 2. Phenotypic (r_{ph}) and genotypic (r_g) correlations between grain yield/plant of maize and flowering and vegetative traits under no-drought (ND), moderate drought (MD) and severe drought (SD) conditions during 2003 and 2004 growing seasons.

Trait		Grain yield / plant					
Irrigation		ND		MD		SD	
Season		2003	2004	2003	2004	2003	2004
50% anthesis	r_{ph}	0.38*	0.34	0.45*	0.38*	0.53**	0.41*
	r_g	0.40	0.34	0.47	0.40	0.57	0.45
50% silking	r_{ph}	0.39*	0.23	0.36*	0.26	0.28	0.14
	r_g	0.42	0.24	0.39	0.29	0.32	0.15
ASI	r_{ph}	-0.10	-0.35*	0.45*	-0.37*	-0.64**	-0.49**
	r_g	-0.19	-037	0.47	-0.40	-0.95	-0.55
Plant height	r_{ph}	0.56**	0.60**	0.58**	0.74**	0.50**	0.71**
	r_g	0.57	0.62	0.60	0.77	0.52	0.74
Ear height	r_{ph}	0.58**	0.54**	0.81**	0.63**	0.69**	0.60**
	r_g	0.59	0.55	0.85	0.65	0.71	0.63
Stem diameter	r_{ph}	0.42**	0.40*	0.50**	0.34	0.51**	0.45*
	r_g	0.43	0.47	0.51	0.36	0.51	0.47
Leaves/plant	r_{ph}	0.66**	0.34	0.62**	0.46**	0.71**	0.30
	r_g	0.71	0.39	0.72	0.51	0.78	0.36
Ear leaf area	r_{ph}	0.66**	0.48**	0.69**	0.44*	0.69**	0.55**
	r_g	0.68	0.49	0.71	0.49	0.72	0.57

Grain yield and yield components traits

Under control (ND) treatment (Table 3), highly significant and positive correlation coefficients were observed between grain yield/plant and each of ear weight/plant (r_{ph}= 0.99**, 0.93** and r_g= 0.99, 0.93), ear length (r_{ph}= 0.93**, 0.81** and r_g= 0.97, 0.82), kernels no./row (r_{ph}= 0.53**, 0.60** and r_g= 0.83, 0.64) and 100-kernel weight (r_{ph}= 0.82**, 0.76** and r_g= 0.85, 0.78) in the first and second season, respectively, and shelling % (r_{ph}= 0.82** and r_g= 0.85) in the first season. Whereas, only significant and positive correlation coefficients were observed between grain yield and each of ears /plant (r_{ph}= 0.45*, 0.41* and r_g= 0.46, 0.41) in the first and second season, respectively, and shelling % (r_{ph}= 0.40* and r_g= 0.36) in the second season. Significant and negative correlation coefficient was observed between grain yield and rows no./ear (r_{ph}=-0.39* and r_g= -0.43) in the second season.

Table 3. Phenotypic (r_{ph}) and genotypic (r_g) correlations between grain yield/plant and maize yield and yield components traits under no-drought (ND), moderate drought (MD) and severe drought (SD) conditions during 2003 and 2004 growing seasons.

Trait		Grain yield / plant					
Irrigation		ND		MD		SD	
Season		2003	2004	2003	2004	2003	2004
Ear weight/plant	r_{ph}	0.99**	0.93**	0.98**	0.99**	0.98**	0.96**
	r_g	0.99	0.93	0.99	0.99	0.99	0.97
Ear length	r_{ph}	0.93**	0.81**	0.91**	0.66**	0.91**	0.69**
	r_g	0.97	0.82	0.93	0.73	0.94	0.72
Ear diameter	r_{ph}	0.02	0.16	-0.08	0.50**	-0.11	0.22
	r_g	0.04	0.17	-0.11	0.55	-0.13	0.24
Ears/plant	r_{ph}	0.45*	0.41*	0.45*	0.41*	0.54**	0.30
	r_g	0.46	0.41	0.45	0.43	0.55	0.32
Rows/ear	r_{ph}	-0.23	-0.39*	-0.19	-0.26	-0.29	-0.23
	r_g	-0.28	-0.43	0.26	-0.27	-0.45	-0.29
Kernels /row	r_{ph}	0.53**	0.60**	0.44*	0.65**	0.48**	0.66**
	r_g	0.83	0.64	0.46	0.72	0.52	0.72
100-kernel weigth	r_{ph}	0.82**	0.76**	0.83**	0.82**	0.84**	0.76**
	r_g	0.85	0.78	0.86	0.87	0.89	0.78
Shelling %	r_{ph}	0.82**	0.40*	0.80*	0.61**	0.85**	0.51**
	r_g	0.85	0.36	0.84	0.96	0.91	0.55

Under moderate drought (MD), grain yield/plant had significant and positive correlation coefficients with each of ear weight/plant (r_{ph}= 0.98**, 0.99** and r_g= 0.99, 0.99), ear length (r_{ph}= 0.91**, 0.66** and r_g= 0.93, 0.73), 100-kernel weight (r_{ph}= 0.83**, 0.82** and r_g= 0.86, 0.87), shelling % (r_{ph}= 0.80**, 0.61** and r_g= 0.84, 0.96) and ears /plant (r_{ph}= 0.45*, 0.41** and r_g= 0.45, 0.43) in the first and second season, respectively, and ear diameter (r_{ph}= 0.50** and r_g= 0.55) in the second season (Table 3).

Under severe drought (SD), grain yield/plant was significantly and positively associated with ear weight/plant (r_{ph}= 0.98**, 0.96** and r_g= 0.99, 0.97), ear length (r_{ph}= 0.91**. 0.69** and r_g= 0.94, 0.72), kernels no./row (r_{ph}= 0.48**, 0.66** and r_g= 0.52, 0.72), 100-kernel weight (r_{ph}= 0.84**, 0.76** and r_g= 0.89, 0.78) and shelling % (r_{ph}= 0.85**, 0.51** and r_g= 0.91, 0.55) in the first and second season, respectively, and with ears /plant (r_{ph}= 0.54** and r_g= 0.55) in the first season (Table 3).

It is worthy to note that magnitude of correlation coefficients between grain yield and yield components was higher under stress conditions than under control (no-drought) in most cases. This result is consistent with that reported by Bolanos and Edmeades (1996), Ribaut *et al* (1997), Moursi (1997), Chapman and Edmeades (1999), Al-Naggar *et al* (2000) and Atta (2001).

Genetic and environmental variances

Flowering and vegetative traits

Genetic variance (σ^2G) for studied hybrids under drought stresses (MD and SD) was lower than that under no-drought (ND) for ear leaf area, stem diameter. ear height, plant height. anthesis-silking interval (ASI) in both seasons. as well as 50% anthesis and 50% silking and leaves/plant in the second season. However, genetic variance for experimental hybrids under severe drought (SD) was higher than that under no-drought (ND) for 50% anthesis and 50% 50% silking s and leaves /plant in the first season (Table 4).

Regarding to the environmental variance Table (4) showed that environmental (σ^2e) variance for the experimental hybrids under drought stresses (MD and SD) was higher than that under no-drought (ND) for 50% anthesis and 50% silking in both seasons, leaves/plant in the second season, and plant height in the first season. However, environmental variance for hybrids under drought stress treatments (MD and SD) was lower than that under control (ND) treatment for anthesis-silking interval (ASI), ear height, stem diameter, ear leaf area in both seasons, and plant height in the second season.

Table 4. Genetic variance (σ^2 G), environmental variance (σ^2 e) and heritability (h^2) for maize flowering and vegetative traits under no-drought (ND), moderate drought (MD) and severe drought (SD) conditions during 2003 and 2004 growing seasons.

Trait		Genetic variance (σ^2 G)		Environmental variance (σ^2 e)		Heritability (h^2)	
	Season	2003	2004	2003	2004	2003	2004
50% anthesis	ND	1.08	2.73	0.15	0.078	87.8	97.2
	MD	1.66	2.46	0.15	0.095	91.8	96.3
	SD	1.23	1.25	0.22	0.086	84.8	93.6
50% silking	ND	0.77	0.740	0.10	0.084	88.7	89.7
	MD	0.83	0.774	0.12	0.079	87.2	90.7
	SD	0.88	0.707	0.11	0.094	88.7	88.3
ASI	ND	0.07	0.908	0.25	0.122	21.7	88.2
	MD	1.66	0.845	0.15	0.155	91.8	84.5
	SD	0.06	0.457	0.25	0.068	19.2	87.0
Plant height	ND	356.60	521.2	3.95	37.97	98.9	93.2
	MD	167.50	405.8	6.65	1.225	96.2	99.7
	SD	223.88	238.46	11.24	1.469	95.2	99.4
Ear height	ND	149.46	291.81	3.72	4.48	97.6	98.5
	MD	80.86	191.34	6.46	1.85	92.6	99.0
	SD	54.26	117.87	2.83	1.754	95.0	98.5
Stem diameter	ND	0.020	0.021	0.001	0.008	96.9	73.6
	MD	0.017	0.025	0.0002	0.0001	98.8	99.7
	SD	0.018	0.014	0.0005	0.0003	97.3	97.6
Leaves/plant	ND	0.572	0.610	0.078	0.150	88.1	80.7
	MD	0.549	0.712	0.203	0.113	73.1	86.3
	SD	0.729	0.436	0.181	0.149	80.2	74.6
Ear leaf area	ND	3015.7	4456.8	176.7	111.52	94.5	97.6
	MD	2703.5	2281.1	113.4	95.89	96.0	96.0
	SD	1853.2	1069.8	126.4	86.63	93.6	92.5

It could be concluded that genetic variance was higher than environmental variance for all studied flowering and vegetative traits under different drought stress and non-stress treatments in both seasons, except ASI under no-drought (ND) and severe drought (SD) treatments in the first season.

Yield and yield components traits

Results in Table (5) showed that genetic variance for hybrids under drought stresses (MD and SD) was lower than that under control treatment (ND) for grain yield/plant, ear weight/plant, ear length, ear diameter, ears /plant and rows no./ear in both seasons, and 100-kernel weight and shelling % in the second season, and vice versa for kernels no./row in both seasons, 100-kernel weight and shelling % in the first season.

With respect to environmental ($\sigma^2 e$) variance, data in Table (5) showed that environmental variance for hybrids under drought stress treatments (MD and SD) was higher than that under control treatment (ND) for grain yield/plant, ear weight/plant, ears /plant and shelling % in both seasons, and ear diameter and kernel no./row in the second season, and rows no./ear in the first season, and vice versa for ear length in both seasons, and kernels no./row and ear diameter in the first season, and 100-kernel weight and rows no./ear in the second season.

It could be concluded that genetic variance was higher than environmental variance for all studied yield and yield components under different drought stress and non-stress treatments in both seasons, except rows no. /ear under severe drought, kernels no./row under no-drought in the first season, and shelling % under moderate and severe drought in the second season.

Heritability estimates

Flowering and vegetative traits

Broad-sense heritability estimates for flowering and vegetative traits ranged from 19.2% for ASI under severe drought to 98.9% for plant height under no-drought in the first season, and from 73.6% for stem diameter under no-drought to 99.7% for plant height and stem diameter under moderate drought in the second season (Table 4).

Broad-sense heritability estimates ranged under control (ND) from 21.7% for ASI to 98.9% for plant height in the first season, and form 73.6% for stem diameter to 98.5% for ear height in the second season. While it ranged under moderate drought (MD) from 73.1% for leaves/plant to 98.8% for stem diameter in the first season and from 84.5% for ASI to 99.7% for plant height and stem diameter in the second season. However, it ranged under severe drought (SD) from 19.2% for ASI to 97.3% for stem diameter in the first season, and from 74.6% for leaves/plant to 99.4% for plant height in the second season.

In both seasons, all studied flowering and vegetative traits show larger heritability estimates under control (no-drought) treatment than under drought stresses treatments (MD and SD) except 50% anthesis, ASI and ear leaf area under moderate drought in the first season, and 50% silking, plant height, ear height and leaves/plant under moderate drought in the second season, as well as stem diameter in both seasons, as shown in Table (4).

Yield and yield components traits

Broad-sense heritability estimates for yield and its components ranged under control (ND) treatment from 41.4% for kernels/row to 99.3% for ears/plant in the first season, and from 87.4% for rows/ear to 99.7% for ear weight/plant in the second season. Whereas, it ranged under moderate drought (MD)from 60.3% for rows no./ear to 99.6% for grain yield/plant in the first season, and from 33.3% for shelling percentage to 99.2% for ears /plant in the second season. However, it ranged under severe drought (SD) from 47.5% for rows/ear to 99.1% for ear weight/plant in the first season, and from 50.0% for shelling percentage to 98.3% for ear length in the second season, as shown in Table (5).

Table 5. Genetic variance (σ^2 G), environmental variance (σ^2 e) and heritability (h^2) for yield and yield components traits under no-drought (ND), moderate drought (MD) and severe drought (SD) conditions during 2003 and 2004 growing seasons.

Trait	Season	Genetic variance (σ^2 G) 2003	Genetic variance (σ^2 G) 2004	Environmental variance (σ^2 e) 2003	Environmental variance (σ^2 e) 2004	Heritability (h^2) 2003	Heritability (h^2) 2004
Grain yield plant^{-1}	ND	1636.98	2230.23	12.02	17.31	99.2	99.2
	MD	1403.19	1619.47	14.16	111.72	99.6	93.5
	SD	1167.90	1182.05	15.78	71.37	98.6	94.3
Ear weight plant^{-1}	ND	1898.32	2569.4	7.167	7.592	99.0	99.7
	MD	1635.10	2098.6	17.44	151.41	98.9	93.3
	SD	1395.23	1582.8	12.70	55.88	99.1	96.6
Ear length	ND	4.095	6.284	0.472	0.198	89.7	96.9
	MD	3.664	4.640	0.101	0.295	97.3	94.0
	SD	2.888	2.743	0.092	0.045	96.9	98.3
Ear diameter	ND	0.035	0.027	0.022	0.003	61.9	88.9
	MD	0.024	0.026	0.013	0.007	64.4	79.0
	SD	0.018	0.021	0.011	0.004	62.5	84.0
Ears plant^{-1}	ND	0.149	0.144	0.001	0.0007	99.3	99.5
	MD	0.124	0.123	0.002	0.001	98.8	99.2
	SD	0.097	0.083	0.003	0.002	97.4	98.0
Rows ear^{-1}	ND	0.966	3.127	0.465	0.450	67.5	87.4
	MD	0.561	3.393	0.369	0.300	60.3	91.9
	SD	0.437	1.997	0.483	0.312	47.5	86.5
Kernels row^{-1}	ND	3.687	12.788	5.081	1.479	41.4	89.6
	MD	9.670	18.638	1.082	2.149	89.9	89.7
	SD	8.087	17.901	1.640	2.394	83.1	88.2
100-kernel weight	ND	13.983	36.26	0.81	1.233	94.5	96.7
	MD	16.15	32.78	0.756	2.810	95.5	92.1
	SD	16.15	33.63	1.073	0.828	93.8	97.6
Shelling %	ND	0.001	0.003	0.0001	0.0003	87.9	88.9
	MD	0.002	0.0003	0.0002	0.0007	87.9	33.3
	SD	0.003	0.001	0.0005	0.001	83.3	50.0

Under severe drought treatment (SD), the largest heritability estimates were reported by ear weight/plant (99.1%) followed by grain yield/plant (98.6%), ears/plant (97.4%), ear length (96.9%), 100-kernel weight (93.8%) in the first season, and ear length (98.3%) followed by ears /plant (98.0%) then 100-kernel weight (97.6%), ear weight/plant (96.6%) and grain yield/plant (94.3%) in the second season.

All studied yield and yield components (Table 5) showed high heritability estimates under stress and non-stress treatments in both seasons, except ear diameter and rows/ear in the first season, and shelling % in the second season.

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 heritabilities of ear length, kernels/row and 100-kernel weight would be under drought stress, and that for maximizing heritabilities of grain and ear yields/plant, ears/plant and shelling % would be under no-drought conditions.

In general, it could be concluded thunder drought stress treatments resulted in lower broad-sense heritabilities than control treatment (no-drought) for 50% anthesis , ASI, leaves /plant, ear leaf area, grain yield and ear weight/plant, ears/plant, rows/ear and shelling %, due to decreasing genotypic variances and increased error variances under drought treatments.

Similar to our results, some investigators found decreases in genetic variance magnitude and heritabilities under stress environments (Asay and Johnson 1990). In contrast, other researchers reported that the component of genetic variance and consequently heritability estimates were increased in stress environments (Bolanos and Edmeades 1996 and Ribaut *et al* 1997).

Expected gain from direct and indirect selection

Flowering and vegetative traits

Expected gains in grain yield from indirect selection for flowering and vegetative traits under no-drought (ND), and their percentages to gain from direct selection were high values for ear leaf area (26.87, 66.7%), leaves/plant (26.80, 66.5%), ear height (23.49, 58.3%) and plant height (22.98, 57.0%), and of moderate values for stem diameter (17.06, 42.3%), 50% silking (16.02, 39.7%) and 50% anthesis (15.33, 38.0%), and of low values for ASI (-3.64, -9.0%) in 2003 season, respectively. However in 2004 season, plant height (28.49, 60.6%), ear height (25.56, 54.3%) and ear leaf area (22.66, 48.2%) recorded the highest values of expected gains in grain yield from indirect selection and their percentages to direct selection, respectively, as shown in Table (6). These results were attributed to increasing the genotypic correlation coefficients for these traits with grain yield/plant under no-drought.

Table 6. Expected gain in yield from indirect selection for maize flowering and vegetative traits, and indirect gain in percent of direct gain from selection for grain yield under no-drought (ND), moderate drought (MD) and severe drought (SD) conditions during 2003 and 2004 growing seasons.

Trait		Expected gain from indirect selection (%)		Indirect gain / direct gain (in percent)	
	Season	2003	2004	2003	2004
50% anthesis	ND	15.33	15.80	38.0	33.6
	MD	16.85	15.77	45.2	40.5
	SD	17.87	14.80	52.6	44.3
50% silking	ND	16.02	10.75	39.7	22.9
	MD	13.54	11.15	36.3	28.6
	SD	10.16	4.95	29.9	14.8
ASI	ND	-3.64	-16.49	-9.00	-35.1
	MD	16.85	-14.94	45.2	-38.4
	SD	-20.32	-17.50	-59.8	-52.4
Plant height	ND	22.98	28.49	57.0	60.6
	MD	21.99	30.75	59.0	79.0
	SD	17.30	25.23	51.0	75.6
Ear height	ND	23.49	25.56	58.3	54.3
	MD	30.67	26.17	82.3	67.2
	SD	23.64	21.36	69.6	64.0
Stem diameter	ND	17.06	18.99	42.3	40.4
	MD	18.84	14.29	50.5	36.7
	SD	17.25	15.99	50.8	47.9
Leaves /plant	ND	26.80	16.73	66.5	35.6
	MD	23.15	19.20	62.1	49.3
	SD	23.95	10.58	70.6	31.7
Ear leaf area	ND	26.87	22.66	66.7	48.2
	MD	25.88	18.85	69.4	48.4
	SD	23.67	18.94	69.7	56.7

* Expected gains from direct selection for grain yield under no-drought were 40.31 and 47.04, under moderate drought 37.27 and 38.92, and under severe drought 33.95 and 33.39 g/plant in 2003 and 2004 seasons, respectively

Expected gains in grain yield from indirect selection for flowering and vegetative traits under moderate drought (MD), and their percentages to gain from direct selection were of high values for ear height (30.67, 82.3%), ear leaf area (25.88, 69.4%), leaves /plant (23.15, 62.1%) and plant height (21.99, 59.0%) in 2003 season, respectively (Table 6).

However in 2004 season, plant height (30.75, 79.0%) and ear height (26.17, 67.2%) show the highest values of expected gains form indirect selection and their percentages to gain from direct selection, respectively.

Under severe drought (SD), leaves/plant (23.95, 70.6%), ear leaf area (23.67, 69.7%), ear height (23.64, 69.6%) and ASI (-20.32, -59.8%) recorded the highest values of expected gains form indirect selection and their percentage to gain from direct selection in the first season, respectively. However in the second season, the highest values of expected gains form indirect selection and their percentages to gain from direct selection were observed by plant height (25.23, 75.6%), ear height (21.36, 64.0%) and ear leaf area (18.94, 56.7%), respectively, as shown in Table (6).

Yield and yield components traits

Expected gains form direct selection for grain yield under no-drought (ND) were 40.31 and 47.04 g/plant, under moderate drought (MD) were 37.27 and 38.92 g/plant, and under severe drought (SD) were 33.95 and 33.39 g/plant at 2003 and 2004 seasons, respectively, (Table 6,7 footnotes). Under control treatment (ND), the highest values of expected gains in grain yield from indirect selection for yield component traits, and their percentages to direct selection were recorded by ear weight/plant (40.26, 99.9% and 43.85, 93.2%), ear length (37.52, 93.0% and 38.24, 81.3%) and 100-kernel weight (33.34, 82.7% and 36.39, 77.4%) in 2003 and 2004 seasons, respectively, and shelling % (32.26, 80.0%) in the first season, and kernels/row (28.61, 60.8%) in the second season, as shown in Table (7).

Under moderate drought (MD), ear weight/plant (36.99, 99.3% and 38.92, 99.9%), ear length (34.31, 92.0% and 28.35, 72.8%), 100-kernel weight (31.42, 84.3% and 33.7, 86.6%) and shelling % (29.55, 79.3% and 22.29, 57.3%) recorded the highest values of expected gains in grain yield from indirect selection for yield components traits, and their percentages to direct selection in 2003 and 2004 seasons, respectively. Also, these traits recorded the highest values of expected gains in grain yield from indirect selection, and their percentages to direct selection under severe drought (SD) in both seasons, as well as kernels/row in the second season, as shown in Table (7). These results were attributed to increasing genotypic correlation coefficients for these traits with grain yield/plant.

In general, a value of 100% for indirect selection / direct selection (100 x IR/R) indicates that indirect and direct selections are predicted to be equally efficient. While, when this percent is less than 100, direct selection is predicted to be more efficient than indirect selection, and vice versa when this percent is more than 100. Thus, results show that direct selection for grain yield under no-drought or drought stress conditions was likely to be

Table 7. Expected gain in yield from indirect selection for maize yield components, and indirect gain in percent of direct gain from selection for grain yield under no-drought (ND), moderate drought (MD) and severe drought (SD) conditions during 2003 and 2004 growing seasons.

Trait	Season	Expected gain from indirect selection (%) 2003	2004	Indirect gain / direct gain (in percent) 2003	2004
Ear weight/plant	ND	40.26	43.85	99.9	93.2
	MD	36.99	38.92	99.3	99.9
	SD	33.77	32.94	99.4	98.6
Ear length	ND	37.52	38.24	93.0	81.3
	MD	34.31	28.35	92.0	72.8
	SD	31.54	24.72	92.9	74.0
Ear diameter	ND	1.173	7.44	2.9	15.8
	MD	-3.230	19.80	-8.7	50.9
	SD	-3.629	7.61	-10.7	22.8
Ears /plant	ND	18.498	19.35	45.9	41.1
	MD	16.857	17.26	45.2	44.3
	SD	18.558	10.77	54.7	32.3
Rows/ear	ND	-9.330	-19.18	-23.1	-40.8
	MD	-7.570	-10.57	-20.3	-27.2
	SD	-10.556	-8.90	-31.1	-26.6
Kernels/row	ND	21.566	28.61	53.5	60.8
	MD	16.324	27.46	43.8	70.6
	SD	16.102	23.36	47.4	70.0
100-kernel weigth	ND	33.34	36.39	82.7	77.4
	MD	31.419	33.70	84.3	86.6
	SD	29.294	26.70	86.3	79.9
Shelling %	ND	32.256	16.24	80.0	34.5
	MD	29.552	22.29	79.3	57.3
	SD	28.355	13.44	83.5	40.3

Expected gains from direct selection for grain yield under no-drought were 40.31 and 47.04, under moderate drought 37.27 and 38.92, and under severe drought 33.95 and 33.39 g/plant in 2003 and 2004 seasons, respectively.

more efficient than indirect selection for all studied flowering, vegetative and yield components traits.

It is concluded that for studied traits, the expected gain from direct selection under stressed or non-stressed environments 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 (Braun *et al* 1992).

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القياسات الوراثية لبعض التراكيب الوراثية للذرة الشامية تحت ظروف مختلفة من رطوبة التربة

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أجريت تجربتان حقليتان خلال موسمى 2003 و 2004 وذلك لدراسة الإرتباط المظهرى والوراثى بين صفة محصول الحبوب والصفات الأخرى تحت ظروف عدم الجفاف (الرى كل 14 يوم) والجفاف المتوسط (الرى كل 18 يوم) والشديد (الرى كل 22 يوم) وتحديد أكثر الصفات إرتباطاً بمحصول الحبوب تحت ظروف الجفاف ، دراسة نسبة التوريث والتحسين المتوقع من الإنتخاب المباشر لصفة محصول الحبوب وغير المباشر للصفات الأخرى تحت ظروف الجفاف أو عدم الجفاف. ويمكن تلخيص أهم النتائج المتحصل عليها فى الآتى:

إرتبط محصول الحبوب/نبات إرتباطاً موجباً وقوياًمع صفات إرتفاع النبات ، إرتفاع الكوز ، وعدد أوراق النبات ، ومساحة ورقة الكوز ، ووزن الكيزان/نبات ، وطول الكوز ، ووزن 100 حبة ، ونسبة التفريط و عدد الكيزان/نبات فى كلا الموسمين تحت ظروف الجفاف المتوسط. فى حين تحت ظروف الجفاف الشديد إرتبط محصول الحبوب/نبات إرتباطاً سالباً وعالى المعنوية مع صفة الفترة بين اللقاح والحريرة ، وموجباً مع صفة عدد الأيام حتى إنتثار اللقاح ومع معظم الصفات الخضرية ، ومع وزن الكيزان/نبات ، طول الكوز ، وعدد الحبوب/صف ، ووزن 100 حبة و نسبة التفريط فى كلا الموسمين ومع عدد الكيزان/نبات فى الموسم الأول. ومن الجدير بالذكر ملاحظة أن معاملات الإرتباط بين المحصول وصفات مكونات المحصول كانت أعلى تحت ظروف الجفاف من عدم الجفاف فى معظم الحالات.

أدت معاملات الجفاف إلى إنخفاض معامل التوريث بمعناه الواسع مقارنة بمعاملة عدم الجفاف (المقارنة) لصفات عدد الأيام حتى إنتثار اللقاح ، والفترة بين اللقاح والحريرة ، وعدد أوراق النبات ، ومساحة ورقة الكوز ، ومحصول الحبوب/نبات ووزن الكيزان/نبات ، وعدد الصفوف/كوز و نسبة التفريط وذلك راجع إلى إنخفاض التباينات الوراثية وزيادة التباينات البيئية تحت ظروف الجفاف.

كانت قيم التحسين المتوقع فى محصول الحبوب من الإنتخاب غير المباشر للصفات المدروسة منسوبة إلى قيمة التحسين المتوقع من الإنتخاب المباشر مرتفعة لصفات مساحة ورقة الكوز ، وإرتفاع النبات ، ووزن الكيزان/نبات ، وطول الكوز ، ووزن 100 حبة فى كلا الموسمين تحت ظروف عدم الجفاف (الرى الجيد) ، ولصفات إرتفاع الكوز والنبات ، ووزن الكيزان/نبات ، وطول الكوز ، ووزن 100 حبة و نسبة التفريط فى كلا الموسمين تحت ظروف الجفاف الشديد. ويمكن إستخلاص أن الإنتخاب المباشر لصفة محصول الحبوب تحت ظروف الجفاف أو عدم الجفاف سوف يحسن الصفة موضع الإعتبار أفضل من الإنتخاب غير المباشر لأى من الصفات الأخرى تحت الدراسة.

مجلد المؤتمر الخامس لتربيه النبات – الجيزه ٢٧ مايو ٢٠٠٧

المجله المصريه لتربية النبات ١١(١): ١٨١ –١٩٨ (عدد خاص)