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GENETIC VARIANCE, HERITABILITY, CORRELATION AND PATH COEFFICIENT ANALYSIS IN MAIZE CROSSES UNDER VARIABLE ENVIRONMENTS

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ABSTRACT

The present research was undertaken to study the effect of certain environmental treatments on the nature of gene action, narrow sense heritability, correlations among the studied traits and path coefficient analysis for grain yield and its contributing traits. Eight inbred lines of white maize were crossed in 2003 season using a half diallel pattern. During 2004 season, 28 F_1 crosses were evaluated at two sowing dates, i.e. 20^{th} of May (normal sowing) and 30^{th} of June (late sowing) under two plant densities, i.e. 30000 plants/fed (high density) and 20000 plants/fed (low density). A field experiment was devoted for each sowing date and laid out in a split plot design with three replications in which the plant densities and 28 maize entries were distributed at random within the main and sub-plots, respectively. The results indicated that all estimates of additive and dominance genetic variances were significant for all studied traits under the four environmental treatments. The narrow sense heritability estimates for days to 50% silking, ear height, number of rows/ear, number of kernels/row and 100-kernel weight at normal sowing under both densities were higher than those under the two other environments, while the opposite was true for other studied traits. The results of narrow sense heritability estimates suggest the importance of choosing suitable environments for exhibiting the best expression of genes of different characters in the studied hybrids for improving traits. The phenotypic correlation coefficients indicated that grain yield/plant exhibited significant and positive correlations with each of plant height, ear height and 100-kernel weight in all environments, ear diameter in three environments and number of rows/ear and days to 50% silking in two environments. Such results could help the breeder to select high yielding genotypes through selection for one or more of these traits under target environment. Results of path coefficient analysis indicated that ear diameter, number of kernels/row and 100-kernel weight proved to be the major contributors to grain yield variation in most environments. Therefore, these traits should be considered as selection criteria for grain yield improvement in white maize under target environmental treatments.

Key words: ***Maize, Gene action, Narrow sense heritability, Correlation and path coefficient analysis.***

INTRODUCTION

Nowadays, the need for increasing maize production in Egypt received considerable attention to overcome the serious gap between production and the huge consumption of maize by human and animal. Increasing maize production per unit area could be possible rather than increasing the area devoted for maize production through the extensive growing of high yielding hybrids along with the most favorable environmental conditions.

Yield of maize (*Zea mays* L) is considered as a complex inherited trait, that is greatly influenced by environmental conditions Therefore, direct selection for yield may not be the most efficient method for its improvement, but indirect selection for other yield related traits, which closely associated with yield and have high heritability values will be more effective. However, environmental fluctuations had greatly influenced the phenotypic expression of quantitative traits and consequently different estimates of variability and covariability may have an effect on various traits sensitive to environmental modifications. Furthermore, evaluation of genotypes across different environments comes more important in planning selection programs for improving yield and would help the breeders to decide the traits showing consistent associations with grain yield in different or particular environments. Such traits should be taken into account, when selection is practiced for superior maize genotypes.

Several researchers (Ibrahim 2004, Ali *et al* 2009 and Wannows *et al* 2010) studied the environmental effects on genetic variability in maize populations. Most of them obtained variable estimates. Concerning heritability estimate, it was found to be high for days to 50% silking and moderate for grain yield/plant (Ali *et al* 2009). Moreover, Amer and Mosa (2004) reported that heritability estimates in narrow sense were 44% for silking date, 39% for plant height, 44% for ear height, 27% for ear length, 31% for ear diameter, 29% for number of rows/ear, 23% for number of kernels/row and 36% for grain yield/plant. Yassien (1993) found that the narrow sense heritability estimates were 65% for plant height, 51% for ear length, 63% for ear diameter, 44% for number of rows/ear, 66% for number of kernels/row, 42% for 100-kernel weight and 27% for grain yield.

Studying the correlation and path coefficient analysis are helpful for the breeder to determine the importance of yield components in influencing grain yield. Many investigators determined the associations among different characters in maize under different environments. El-Beialy (2003) found that grain yield/plant correlated positively and significantly with each of ear length, number of rows/ear and number of kernels/row, but it had negative and significant correlation with 100-kernel weight. Also, Wannows *et al* (2010) indicated that grain yield was positively and significantly associated with ear length and number of kernels/row. Efforts were made to determine the relative contributions of yield related characters to grain yield variation and revealed that the most sources of variation in plant yield were the direct effects of number of kernels/row (Ojo *et al* 2006 and Wannows *et al* 2010). Moreover, the direct effect of the ear diameter and number of kernels/row had the highest effect on yield variation (Yasien 2000). Amin *et al* (2003) and Ibrahim (2004) also indicated that number of kernels/row and 100-kernel weight were the highest contributors to grain yield variation directly or indirectly.

The main objective of the present investigation was to study the effect of four environmental treatments on the estimates of genetic variance, heritability, correlations and path coefficients for grain yield and some agronomic traits of 28 F_1 hybrids of white maize.

MATERIALS AND METHODS

The field work of the present investigation was conducted during the two successive growing seasons of 2003 and 2004.

Eight inbred lines of maize namely; Giza 4, Rg-11, Rg-29, Rg-34, Rg-39, Rg-59, L216A and L232A, obtained from Maize Dept., Agric. Res. Cent., Giza, were used in this study. These parental lines were chosen on the basis of the existence of wide differences between them with respect to certain plant characteristics.

A half diallel set of crosses was performed among the eight parents in 2003 summer season at the Experimental Farm of the Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima and 28 F_1 seeds were obtained. In 2004 growing season, the seeds of the 28 F_1 hybrids were grown in the Agricultural Research Station of the Faculty of Agric., Ain Shams Univ., Shalakan, Kalubia Governorate, Egypt, on two sowing dates, i.e. 20th of May (normal sowing, S_1) and 30th of June (late sowing, S_2) in two separate adjacent field experiments. Each experiment was designated in a split plot design with three replications in which plant densities were allocated to the main plots and the subplots included the 28 maize entries. Two planting spaces, i.e. 20 and 30 cm between hills gave the two plant densities, i.e. 30000 plants/fed (high density, D_1) and 20000 plants/fed (recommended density, D_2). Each experimental plot consisted of one ridge, four meters long and 70 cm width. Hills were thinned at one plant for each. The other recommended cultural practices for maize production were followed during growing season. The combinations between the two sowing dates and the two plant densities were considered as the four different environmental treatments under study. These environments were designated as normal sowing and 30000 plants/fed (S_1D_1), normal sowing and 20000 plants/fed (S_1D_2), late sowing and 30000 plants/fed (S_2D_1) and late sowing and 20000 plants/fed (S_2D_2).

Observations and measurements were recorded on ten guarded plants chosen at random from each plot for the following traits; 1- Days to 50% silking, 2- Plant height (cm), 3- Ear height (cm), 4- Ear length (cm), 5- Ear diameter (cm), 6- Number of rows/ear, 7- Number of kernels/row, 8- 100-kernel weight (g), 9- Grain yield /plant (g).

Genetic analysis:

Data were subjected to analysis of variance assuming all genetic components to be random. Environments representing the combination between two sowing dates and two plant densities were considered as fixed effects. An additive-dominance (AD) model was employed for data analysis. A mixed model, minimum norm quadratic unbiased estimation (MINQUE) approach was used to estimate genetic variance components (additive variance V_A, dominance variance V_D, additive x environment variance V_{AE}, dominance x environment variance V_{DE} and residual variance V_e) in the AD model (Zhu *et al* 1993). Estimates of V_A/V_P resulted in estimate of narrow-sense heritability (h^2). MINQUE and analysis of variance estimators are similar if the data set are balanced (Searle *et al* 1992). Zhu *et al* (1993) found close agreement between MINQUE estimates and analysis of variance estimates of Griffing (1956) in a balanced diallel data set. The data were balanced and normally distributed; however, MINQUE with a mixed model was used to take advantage of a computer program by Zhu *et al* (1993) to compute the genetic variances.

The phenotypic correlation coefficients were calculated as described by Snedecor and Cochran (1981) for all possible pairs of the studied characters. To obtain more information about the relative contribution of specific characters to grain yield and remaining characters, the path coefficient analysis was performed for all crosses. Partitioning correlation coefficients into direct and indirect effects at phenotypic level was made by determining path coefficients using the method proposed by Wright (1934) and utilized by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance

As shown in Table (1), mean squares of sowing dates and plant densities were significant for all the studied traits. These results indicated that these traits are influenced by environmental treatments under study. The variances of the crosses for all traits were highly significant, indicating the existence of wide genetic variability among these maize entries. The effect of interaction between the crosses and sowing dates was highly significant, proving that the rank of crosses was affected by varying sowing dates. On the other hand, the crosses x plant densities interactions were insignificant for all studied traits, except days to 50% silking, ear diameter and grain yield/plant, revealing that the hybrids performed consistently under plant

Table 1. Significance of mean squares for grain yield/plant and other agronomic traits across two sowing dates and two plant densities.

SOV	d.f.	Mean squares								
		Days to 50% silking	Plant height	Ear height	Ear length	Ear diameter	No. of rows/ ear	No. of kernels/ row	100-kernel weight	Grain yield/ plant
Sowing dates (S)	1	1199.18**	74914.99**	6119.84**	1438.38**	7.75**	11.14**	1879.67**	1977.31**	142758.9**
Replications / S	4	3.15	92.23	68.63*	2.20*	0.02	2.37*	5.87	3.48	250.2
Plant densities (D)	1	206.39**	3909.18**	3658.68**	111.45**	5.52**	7.79**	112.27*	167.15**	9387.8**
S x D	1	15.74*	5.15	0.24	5.00*	0.20**	3.54*	1.31	46.89*	261.9
Error (a)	4	1.20	27.8	4.55	0.28	0.01	0.29	6.11	2.97	125.6
Crosses (C)	27	125.80**	1889.44**	2311.61**	21.48**	1.34**	18.51**	117.97**	145.66**	4750.0**
C x S	27	12.67**	819.31**	441.33**	6.53**	0.12**	1.30*	12.28**	4.69**	1358.5**
C x D	27	1.43**	16.26	8.22	1.05	0.04**	0.45	5.49	0.59	136.2**
C x S x D	27	1.50**	27.16**	13.33	0.89	0.04**	0.46	5.46	0.55	120.6**
Error (b)	216	0.60	12.18	13.03	0.71	0.006	0.72	4.44	1.21	52.9

*** and ** denote significant at 0.05 and 0.01 levels of probability, respectively.**

densities used in this study. The second order interaction of crosses x sowing dates x plant densities was highly significant for days to 50% silking, plant height, ear diameter and grain yield/plant, indicating that maize hybrids performed differently from one environment to another concerning these traits. Such result suggested that these traits are highly affected by the different environmental conditions used in this study.

Genetic variance and heritability estimates

Variance components for general (V_{gca}) and specific (V_{sca}) combining abilities estimated for the studied traits in four environmental treatments (combinations between two sowing dates and two plant densities) and their combined data were translated in terms of additive (V_A) and dominance (V_D) genetic variances according to Griffing (1956) and are summarized in Table (2). The results revealed that all estimates of V_A and V_D were significant for all studied traits in all environmental treatments and combined data. Moreover, the magnitude of V_A was larger than that of V_D for days to 50% silking, plant height, ear height, ear diameter and 100-kernel weight in all environments and combined data, for number of rows/ear in three environments and combined data, for ear length in three environments and for number of kernels/row in one environment. Whereas, V_D values were greater than V_A for grain yield/plant in all environments and combined data, for number of kernels/row in three environments and combined data, ear length in one environment and combined data and for number of rows/ear in one environment. This finding indicates that the additive genetic variance was more important than the dominance genetic variance in the inheritance of most studied traits under such environments as well as the effectiveness of selection in the early segregating generations in the studied crosses under any environment for improving these traits. These results agreed with those obtained by Ibrahim (2004), El-Shouny *et al* (2005), Ali *et al* (2009) and Wannows *et al* (2010).

The data in Table (2) revealed that the interactions of both additive and dominance genetic variances with environments (V_{AE} and V_{DE}) turned to be significant for all studied traits, except V_{DE} for number of rows/ear, indicating that the environmental factors used in this study had great effects on these parameters concerning these traits. Such result indicated also that the combinations between sowing dates and plant densities could be considered as stress conditions for declaring additive and dominance variances. These results are in coincidence with those mentioned by Sedhom (1994) and Khalil and Khattab (1998). For number of rows/ear, the V_{AE} interaction was highly significant, while V_{DE} interaction was insignificant, suggesting that the additive genetic variance was influenced more with environments, while the dominance variance was more stable across the studied environmental treatments for this trait. This finding was supported

Table 2. Estimates of genetic variance components and narrow sense heritability (h^2) for grain yield and its contributing traits of 28 F_1 maize hybrids under four environments and combined data.

Parameter	Days to 50% silking					Plant height (cm)					Ear height (cm)				
	S_1D_1#	S_1D_2	S_2D_1	S_2D_2	Comb	S_1D_1	S_1D_2	S_2D_1	S_2D_2	Comb.	S_1D_1	S_1D_2	S_2D_1	S_2D_2	Comb
V_A	14.54**	13.16**	9.57**	8.83**	11.41**	167.45**	153.83**	119.44**	137.59**	118.45**	233.39**	251.35**	130.79**	103.69**	169.57**
V_D	1.70**	1.02**	4.01**	3.47**	1.15**	122.56**	137.87**	87.00**	74.34**	49.11**	85.16**	73.46**	73.07**	82.83**	48.35**
V_{AE}					0.12**					26.13**					10.24**
V_{DE}					1.40**					56.34**					30.28**
V_e	0.67	0.69	0.66	0.64	0.66	20.61	11.81	9.74	12.42	13.64	16.48	13.85	14.05	11.43	13.95
V_P	16.90**	14.87**	14.23**	12.94**	14.74**	310.61**	303.51**	216.18**	224.35**	263.66**	335.02**	338.67**	217.91**	197.94**	272.39**
h^2	86.00	88.52	67.25	68.21	77.41	53.91	50.68	55.25	61.33	44.93	69.66	74.22	60.02	52.38	80.01

*, ** Significant different from zero at 0.05 or 0.01 level of probability, respectively.

Table 2. Cont.

Parameter	Ear length (cm)					Ear diameter (cm)					No. of rows/ear				
	S_1D_1	S_1D_2	S_2D_1	S_2D_2	Comb	S_1D_1	S_1D_2	S_2D_1	S_2D_2	Comb	S_1D_1	S_1D_2	S_2D_1	S_2D_2	Comb
V_A	0.62**	0.64**	2.08**	1.80**	0.64**	0.10**	0.07**	0.18**	0.19**	0.13**	1.63**	1.31**	1.58**	0.56**	1.26**
V_D	0.59**	0.69**	0.57**	1.53**	0.65**	0.02**	0.02**	0.02**	0.03**	0.01**	0.35**	0.23**	0.26**	0.75**	0.43**
V_{AE}					0.64**					0.01**					0.014**
V_{DE}					0.19**					0.01**					0.0
V_e	0.94	0.88	0.64	0.66	0.78	0.005	0.007	0.007	0.006	0.006	0.598	0.757	0.797	1.064	0.804
V_P	2.14**	2.22**	3.29**	3.99**	2.91**	0.13**	0.10**	0.21**	0.23**	0.17**	2.58**	2.30**	2.63**	2.38**	2.50**
h^2	28.74	28.94	63.23	45.11	22.10	79.51	75.33	86.15	84.78	78.50	63.33	57.08	59.99	23.67	50.28

*, ** Significant different from zero at 0.05 or 0.01 level of probability, respectively.

Table 2. Cont.

Parameter	No. of kernels/row					100-kernel weight (g)					Grain yield/plant (g)				
	S_1D_1	S_1D_2	S_2D_1	S_2D_2	Comb	S_1D_1	S_1D_2	S_2D_1	S_2D_2	Comb	S_1D_1	S_1D_2	S_2D_1	S_2D_2	Comb
V_A	3.31**	6.62**	2.13**	3.41**	3.65**	10.94**	8.88**	6.95**	7.01**	8.21**	194.22**	126.13**	245.22**	259.35**	184.58**
V_D	3.98**	5.79**	5.84**	7.26**	4.72**	3.24**	2.72**	4.01**	4.79**	3.65**	214.53**	285.67**	340.05**	396.26**	162.35**
V_{AE}					0.22**					0.23**					21.65**
V_{DE}					0.98**					0.05**					146.78**
V_e	4.68	4.80	4.04	4.64	4.54	1.05	1.34	1.39	1.38	1.29	70.67	70.46	36.84	56.05	58.51
V_P	11.92**	17.20**	12.01**	15.30**	14.11**	15.23**	12.94**	12.35**	13.17**	13.42**	479.41**	482.26**	622.11**	711.66**	573.86**
h^2	27.79	38.49	17.77	22.25	25.85	71.82	68.60	56.26	53.17	61.19	40.51	26.15	39.42	36.44	32.17

*, ** Significant different from zero at 0.05 or 0.01 level of probability, respectively.

S_1D_1 is normal sowing date under 30000 plants/fed, S_1D_2 is normal sowing date under 20000 plants/fed,
S_2D_1 is late sowing date under 30000 plants/fed and S_2D_2 is late sowing date under 20000 plants/fed.

by Sedhom (1994) and Khalil and Khattab (1998). Furthermore, the magnitude of V_{AE} was greater than that of V_{DE} for ear length and 100-kernel weight, suggesting higher sensitivity of additive genetic variance to these environmental factors than dominance one for these traits. These results agreed with those obtained by El-Shamarka (1995). Whereas, the opposite was true for days to 50% silking, plant height, ear height, number of kernels/row and grain yield/plant, indicating that the dominance genetic variance was more sensitive to change in environments than additive one as well as reflecting the differential response of F_1 hybrids under different environments. Similar findings were obtained by Ibrahim (2004). Meantime, the magnitudes of both V_{AE} and V_{DE} were equal for ear diameter, indicating that the sensitivity of both kinds of genetic effects to the variation under various environments. Also, the obtained results of interaction indicated that no clear trend can be drawn between the magnitudes of genetic variance components and environments, suggesting the importance of choosing suitable environments for exhibiting the best expression of genes for different traits.

Heritability estimates

Narrow sense heritability is the ratio of the additive genetic variance to the phenotypic variance among maize population studied and it is indication of the expected response from selection. Estimates of heritability in narrow sense for the studied traits under four environmental treatments are presented in Table (2). The results showed that the heritability values ranged from 27.79% for number of kernels/row to 86.00% for days to 50% silking at normal sowing under high plant density (S_1D_1), from 26.15% for grain yield/plant to 88.52% for days to 50% silking at normal sowing under low density (S_1D_2), from 17.77% for number of kernels/row to 86.15% for ear diameter at late sowing under high density (S_2D_1) and from 22.25% for number of kernels/row to 84.78% for ear diameter at late sowing under low density (S_2D_2). This wide range of such estimates attributable to different environmental treatments used in this study indicated that heritability percentages for these traits relatively altered from one environment to another, suggesting the existence of genotype x environment interaction resulted in high phenotypic variance due to the presence of sizeable magnitude of environmental variance. It is obvious that overall the four environmental treatments, the low heritability values were observed for ear length, number of kernels/row and grain yield/plant, indicating that these traits are greatly influenced by agricultural treatments. Whereas, the high heritability estimates were detected for days to 50% silking, ear diameter and 100-kernel weight, proving the main role of genetic constitution in the expression of these traits. Therefore, the breeder can select maize plants with desirable traits according to his breeding objectives, especially in the environment exhibiting the highest heritability values. Moreover, the heritability estimates for days to 50% silking, ear height, number of rows/ear, number of kernels/row and 100-kernel weigh at normal sowing under both densities were higher than those under the two other environments, while the opposite was true for other studied traits. These results are in harmony with those obtained by Yasien (2000), Abd El-Sattar (2003), Ibrahim (2004), Ojo *et al* (2006), Ali *et al* (2009) and Rafiq *et al* (2010).

The present results of narrow sense heritability estimates emphasized the portion of additive genetic variance for most studied traits and suggest the importance of choosing suitable environments for exhibiting the best expression of genes of different characters in the studied hybrids for improving such traits.

Correlations among studied traits

For selecting high yielding genotypes, correlation studies supply reliable information on the nature, extent and direction of selection. The interrelationships among different yield attributes help the breeder to find out the nature and magnitude of the associations between traits, which are mostly used to attain better yield under target environments.

Values of phenotypic correlation coefficients estimated for all pairs of the studied traits under four environmental treatments are presented in Table (3). The results revealed that grain yield/plant exhibited significant and positive correlations with plant height, ear height and 100-kernel weight in all environments, with ear diameter in three environments (S_1D_1, S_2D_1 and S_2D_2), with number of rows/ear in S_1D_1 andS_1D_2 and with days to 50% silking in S_2D_1 and S_2D_2. Such results could help the breeder to select high yielding genotypes through selection for one or more of these traits under target environment. Similar results were reported by Hassan (2000), Yasien (2000), Abd El-Aty and Katta (2002), Ibrahim (2004), Sadek *et al* (2006), Soengas *et al* (2006) and Aydin *et al* (2007). However, insignificant correlations were observed between grain yield and any of the other studied traits. In addition, it is appeared that the correlation values between grain yield and 100-kernel weight gave approximately similar magnitudes or signs under different environments, indicating the important role of this trait in selection of high grain yield in maize. While, its correlation values with other studied traits exhibited different magnitudes or signs under the four environments, suggesting that the phenotypic expression of such traits was altered under different environmental treatments. Other inter-character correlations showed that days to 50% silking exhibited significant and positive correlations with each of ear height, ear diameter and number of rows/ear in all environments, with plant height in S_1D_1 and S_1D_2 and with

Table 3. Phenotypic correlation coefficients between grain yield per plant and its contributing traits under four different environmental treatments in maize crosses.

Character	Env.#	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Days to 50% silkig (X_1)	S_1D_1	0.672**	0.775**	-0.599**	0.654**	0.764**	-0.430*	0.314	0.318
	S_1D_2	0.624**	0.717**	-0.391*	0.663**	0.758**	-0.509**	0.349	0.192
	S_2D_1	0.220	0.444*	-0.081	0.705**	0.556**	-0.383*	0.458*	0.557**
	S_2D_2	0.212	0.477*	0.088	0.769**	0.489**	-0.331	0.483**	0.572**
Plant height (X_2)	S_1D_1		0.943**	-0.253	0.587**	0.464*	0.015	0.411*	0.496**
	S_1D_2		0.913**	-0.073	0.324	0.465*	-0.128	0.404*	0.494**
	S_2D_1		0.450*	0.596**	0.239	0.357	0.448*	0.187	0.420*
	S_2D_2		0.369	0.720**	0.198	0.212	0.597**	0.046	0.455*
Ear height (X_3)	S_1D_1			-0.394*	0.619**	0.538**	-0.130	0.361	0.469*
	S_1D_2			-0.290	0.356	0.531**	-0.167	0.325	0.392*
	S_2D_1			0.275	0.384*	0.267	0.165	0.010	0.429*
	S_2D_2			0.232	0.442*	0.247	0.147	0.021	0.443*
Ear length (X_4)	S_1D_1				-0.434*	-0.369	0.729**	-0.132	0.044
	S_1D_2				-0.290	-0.099	0.414*	0.021	0.285
	S_2D_1				-0.166	-0.153	0.627**	-0.107	0.058
	S_2D_2				0.058	-0.025	0.683**	0.179	0.345
Ear diameter (X_5)	S_1D_1					0.726**	-0.479**	0.543**	0.615**
	S_1D_2					0.655**	-0.585**	0.529**	0.270
	S_2D_1					0.627**	-0.248	0.599**	0.714**
	S_2D_2					0.533**	-0.274	0.595**	0.727**
No. of rows/ear (X_6)	S_1D_1						-0.387*	0.459*	0.503**
	S_1D_2						-0.396*	0.472*	0.435*
	S_2D_1						-0.225	0.519**	0.323
	S_2D_2						-0.457*	0.269	0.173
No. of kernels/row (X_7)	S_1D_1							-0.238	0.158
	S_1D_2							-0.404*	0.266
	S_2D_1							-0.142	0.077
	S_2D_2							-0.126	0.163
100-kernel weight (X_8)	S_1D_1								0.391*
	S_1D_2								0.417*
	S_2D_1								0.397*
	S_2D_2								0.415*
Grain yield/plant (X_9)	S_1D_1								
	S_1D_2								
	S_2D_1								
	S_2D_2								

* and ** denote significant differences at 0.05 and 0.01 levels of probability, respectively.

S_1D_1 is normal sowing date under 30000 plants/fed, S_1D_2 is normal sowing date under 20000 plants/fed, S_2D_1 is late sowing date under 30000 plants/fed and S_2D_2 is late sowing date under 20000 plants/fed.

100-kernel weight in S_2D_1 and S_2D_2. While, it gave significant and negative correlations with ear length in S_1D_1 and S_1D_2 and with number of kernels/row in S_1D_1, S_1D_2 and S_2D_1. These results are in accordance with the findings of Amin *et al* (2003), Ojo *et al* (2006), Asrar *et al* (2007) and Najeeb *et al* (2009). Plant height was significantly and positively associated with ear height in S_1D_1, S_1D_2 and S_2D_1, with ear length and number of kernels/row in S_2D_1 and S_2D_2, number of rows/ear and 100-kernel weight in S_1D_1 and S_1D_2 and ear diameter in S_1D_1. Similar findings were obtained by Ahsan (1999), Guzman and Lamkey (2000), Mohammadi *et al* (2003), Ojo *et al* (2006), Sadek *et al* (2006) and Abou- Deif (2007). Concerning ear height, significant and positive correlations were detected with each of ear diameter in S_1D_1, S_2D_1 and S_2D_2 and with number of rows/ear in S_1D_1 and S_1D_2, while it gave significant and negative association with ear length in S_1D_1. Such results are in accordance with the findings of Amin *et al* (2003), Sadek *et al* (2006) and Abou-Deif (2007). Ear length gave significant and positive correlations with number of kernels/row in all environments, while it gave significant and negative correlation with ear diameter in S_1D_1. These results agreed with those mentioned by Salama *et al* (1994), Soliman *et al* (1999), Yasien (2000), El-Beially (2003), Mohammadi *et al* (2003) and Sadek *et al* (2006). Ear diameter exhibited significant and positive associations with number of rows/ear and 100-kernel weight in all environments, while it exhibited significant and negative correlation with number of kernels/row in S_1D_1 and S_1D_2. Such results are in harmony with those obtained by Yasien (2000), Amin *et al* (2003) and Mohammadi *et al* (2003). Number of rows/ear showed significant and positive associations with 100-kernel weight in S_1D_1, S_1D_2 and S_2D_1, while it exerted significant and negative correlations with number of kernels/row in S_1D_1, S_2D_1 and S_2D_2. Similar results were obtained by Amin *et al* (2003), El-Beially (2003) and Mohammadi *et al* (2003). With respect to number of kernels/row, significant and negative correlation was found with 100-kernel weight in S_2D_1.

In general, the existence of positive correlations between grain yield and each of ear diameter, 100-kernel weight, plant height and ear height in the present study suggests that an increment of production may be achieved upon improving either one or more of these traits.

The foregoing results indicated that both planting dates and plant densities had considerable effects on the magnitude and sign of correlation coefficients between grain yield and other studied traits or between different pairs of the traits. Thus, selection criteria for improving grain yield depend, in a great extent, upon the environmental conditions, under which the maize genotypes are grown.

Path coefficient analysis

It is worthy to mention that the simple correlation coefficient measures only mutual associations, by which it becomes difficult to understand the direct and indirect effects of the studied characters. Plant breeder uses the path coefficient analysis as a method of partitioning correlation coefficient into direct and indirect effects. Estimates of direct and indirect effects of the four yield related traits, viz. ear length, ear diameter, number of kernels/row and 100-kernel weight on plant yield variation as well as the components in percent of plant yield variation under four environments are presented in Tables (4 and 5).

As shown in Table (4), the direct effects of ear diameter on grain yield/plant were high and positive in S_1D_1, S_2D_1 and S_2D_2 (0.861, 0.813 and 0.853, respectively) and moderate in S_1D_2 (0.464). Whereas, the indirect effects of this trait through other studied traits were very low and negative.

100-kernel weight seemed to have moderate and positive direct effect (0.432) on grain yield/plant in S_1D_2. The indirect effects of this trait through ear diameter were moderate in S_1D_1, S_2D_1 and S_2D_2 and low in S_1D_2. Whereas, its indirect effects through other traits were negligible or negative in all environments.

Number of kernels per row expressed high and positive direct effects on grain yield per plant in S_1D_1 (0.587) and S_1D_2 (0.655) compared to low and positive direct effects in S_2D_1 (0.253) and S_2D_2 (0.335). However, it had moderate to low and negative indirect effects through ear diameter in all environments (-0.412, -0.271, -0.202 and -0.234, respectively). Meanwhile, its indirect effects through other traits were negligible or negative in all environments.

Ear length exhibited low positive direct effect on grain yield per plant in S_1D_2. The indirect effects of this trait *via* number of kernels/row were moderate or low in all environments. While, its indirect effects through other traits were negligible or negative. These results indicated that the environmental treatments altered the contribution of the four studied traits on grain yield/plant.

To show the relative importance of the four studied causal variables on plant grain yield, as so far they affect the variation in grain yield, the coefficient of determination was calculated and values are tabulated in Table (5). For normal sowing under 30000 plants/fed (S_1D_1), the main sources of plant yield variation in order of importance were; the direct effect of ear diameter (36.94%) and its joint effect with number of kernels/row (24.12%), followed by the direct effect of number of kernels/row (17.17%) and the joint effect of ear diameter with 100-kernel weight (2.94%). It is obvious that these four traits and their interactions accounted for 82.40% of plant yield variation, while the residual effect amounted to 17.60% of the total variation.

Table 4. Phenotypic path coefficient analysis for grain yield/plant and its contributors under four environmental treatmens in maize crosses.

Source of variation	S_1D_1[#]	S_1D_2	S_2D_1	S_2D_2
1- Ear length vs. grain yield/plant:				
Direct effect	-0.002	0.139	0.029	0.078
indirect effect *via* ear di	-0.374	-0.135	-0.135	0.050
indirect effect *via* No. of	0.428	0.271	0.159	0.229
indirect effect *via* 100-ke	-0.008	0.009	0.006	-0.012
Total	0.044	0.285	0.058	0.345
2- Ear diameter vs. grain yield/plant:				
Direct effect	0.861	0.464	0.813	0.853
indirect effect *via* ear le	0.001	-0.040	-0.005	0.005
indirect effect *via* No. of	-0.281	-0.383	-0.063	-0.092
indirect effect *via* 100-ke	0.034	0.229	-0.031	-0.039
Total	0.615	0.269	0.715	0.727
3- No. of kernels/row vs. grain yield/plant:				
Direct effect	0.587	0.655	0.253	0.335
indirect effect *via* ear le	-0.002	0.058	0.018	0.053
indirect effect *via* ear di	-0.412	-0.271	-0.202	-0.234
indirect effect *via* 100-ke	-0.015	-0.175	0.007	0.008
Total	0.158	0.267	0.077	0.163
4- 100-kernel weight vs. grain yield/plant:				
Direct effect	0.063	0.432	-0.051	-0.065
indirect effect via ear le	0.001	0.003	-0.003	0.014
indirect effect *via* ear di	0.468	0.246	0.487	0.508
indirect effect via No. of	-0.140	-0.265	-0.036	-0.042
Total	0.391	0.416	0.397	0.414

\# S_1D_1 is normal sowing date under 30000 plants/fed, S_1D_2 is normal sowing date under 20000 plants/fed, S_2D_1 is late sowing date under 30000 plants/fed and S_2D_2 is late sowing date under 20000 plants/fed.

Table 5. Phenotypic components (direct and joint efects) in percent of grain yield/plant variation under four environmental treatments in maize crosses.

Source		S_1D_1[#]		S_1D_2		S_2D_1		S_2D_2	
		CD	RI %	CD	RI %	CD	RI %	CD	RI %
Ear length	(X_1)	0.0001	0.01	0.0193	0.86	0.0008	0.06	0.0061	0.42
Ear diameter	(X_2)	0.7413	36.94	0.2153	9.60	0.6610	50.11	0.7276	50.22
No. of kernels/row	(X_3)	0.3446	17.17	0.4290	19.13	0.0640	4.85	0.1122	7.75
100-kernel weight	(X_4)	0.0040	0.20	0.1866	8.32	0.0026	0.20	0.0042	0.29
	(X_1) x (X_2)	0.0015	0.07	-0.0374	1.67	-0.0078	0.59	0.0077	0.53
	(X_1) x (X_3)	-0.0017	0.09	0.0754	3.36	0.0092	0.70	0.0357	2.46
	(X_1) x (X_4)	0.0001	0.01	0.0025	0.11	0.0003	0.02	-0.0018	0.13
	(X_2) x (X_3)	-0.4842	24.12	-0.3556	15.85	-0.1020	7.73	-0.1566	10.81
	(X_2) x (X_4)	0.0589	2.94	0.2121	9.45	-0.0497	3.77	-0.0660	4.55
	(X_3) x (X_4)	-0.0176	0.88	-0.2286	10.19	0.0037	0.28	0.0055	0.38
Residual effect		0.3532	17.60	0.4814	21.46	0.4179	31.68	0.3253	22.46
Total		1.0000	100.00	1.0000	100.00	1.0000	100.00	1.0000	100.00

CD : Coefficient of determinition and RI% : Relative importance.

[#] S_1D_1 is normal sowing date under 30000 plants/fed, S_1D_2 is normal sowing date under 20000 plants/fed, S_2D_1 is late sowing date under 30000 plants/fed and S_2D_2 is late sowing date under 20000 plants/fed.

Concerning the normal sowing under 20000 plants/fed (S_1D_2), the main sources of plant yield variation in order of importance were the direct effect of number of kernels/ row (19.13%) and its joint effects with either ear diameter (15.85%), 100-kernel weight (10.19%), followed by the direct effect of ear diameter (9.60%) and its joint effect with 100-kernel weight (9.45%). The total contribution of the four traits was 78.54%, while the residual effect amounted to 21.46% of the total variation.

Regarding the late sowing under 30000 plants/fed (S_2D_1), the main sources of plant yield variation in order of importance were the direct effect of ear diameter (50.11%) and its joint effect with number of kernels/row (7.73%), followed by the direct effect of number of kernels/row (4.85%) and the joint effect of ear diameter with 100-kernel weight (3.37%). The total contribution of the four traits was 68.32%, while the residual effect was amounted to 31.68% of the total variation.

With regard to the late sowing under 20000 plants/fed (S_2D_2), the main sources of plant yield variation in order of importance were the direct effect of ear diameter (50.22%) and its joint effect with number of kernels/row (10.81%), followed by the direct effect of number of kernels/row (7.75%), the joint effect of ear diameter with 100-kernel weight (4.55%) and the joint effect of ear length with number of kernels/row (2.46%). The total effect of the four traits was 77.54%, while the residual effect was 22.46% of the total variation. The total contributions of the four studied traits were 82.40, 78.54, 68.32 and 77.54% in the four environmental treatments, respectively. Whereas, the residual effects amounted to 17.60, 21.46, 31.68 and 22.46% of the total phenotypic variation in the corresponding sequence, respectively. From the aforementioned results, it can be indicated that most of the factors involved in plant yield were identified. These findings supported those mentioned before in Table (4). Ear diameter, number of kernels/row and 100-kernel weight were the most important factors contributing to plant yield variation in the four environmental treatments. It would be worthy to consider the three factors as main selection criteria for high yielding ability in maize breeding programs. These results coincide with those obtained by Hassan (2000), Yasien (2000), Amin *et al* (2003), Ibrahim (2004) and Ojo *et al* (2006), who mentioned also that number of grains per row and 100-kernel weight were the main sources of plant yield variation in maize.

In general, it is noticeable that there is some contradiction between the results of the four environments. This contradiction is mainly due to the differences between correlation values that could be altered by environmental conditions.

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التباين الوراثى وكفاءة التوريث والارتباط ومعامل المرور فى هجن الذرة الشامية تحت بيئات متباينة

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اجرى هذا البحث بهدف دراسة تأثير بيئات معينة على طبيعة الفعل الجينى وتقديرات كفاءة التوريث بالمعنى الضيق ومعاملات الارتباط وتحليل معامل المرور لمحصول الحبوب ومكوناته. فى الموسم الزراعى ٢٠٠٣ تم عمل دائرة تهجينات تبادلية فى اتجاه واحد بين ثمانية سلالات تربية ذاتية من الذرة الشامية فى مزرعة كلية الزراعة جامعة عين شمس بشبرا الخيمة للحصول على ٢٨ هجين فردى. تمت زراعة الهجن الفردية خلال الموسم الزراعى ٢٠٠٤ بمحطة التجارب والبحوث الزراعية لكلية الزراعة جامعة عين شمس بشلقان بمحافظة القليوبية فى ميعادين للزراعة احدهماعادى فى ٢٠ مايو والآخرمتأخر فى ٣٠ يونية (تجربة لكل ميعاد) وتحت كثافتين نباتيين هما ٢٠ الف نبات/فدان (كثافة منخفضة) و ٣٠ الف نبات/فدان (كثافة عالية) مكونه اربعة بيئات متباينة. وكان التصميم التجريبى قطع منشقة مرة واحدة فى ثلاث مكررات حيث احتلت فيها مواعيد الزراعة القطع الرئيسية ووضعت الهجن المختلفة فى القطع الفرعية. أخذت البيانات على صفات محصول النبات الفردى من الحبوب – طول الكوز – قطر الكوز – عدد السطور بالكوز – عدد الحبوب بالسطر – وزن المائة حبة – طول النبات – ارتفاع الكوز – عدد الايام من الزراعة حتى ظهور ٥٠% من الحراير. وتشير النتائج المتحصل عليها الى ما يلى:

١- كانت التباينات الوراثية المضيفة والسيادية معنوية لجميع الصفات المدروسة تحت الاربع بيئات.

٢- كانت تقديرات كفاءة التوريث فى ميعاد الزراعة العادى تحت كل من الكثافتين النباتيين أعلى منها فى الميعاد المتأخر لصفات عدد الايام حتى ظهور ٥٠% من الحراير وارتفاع النبات وعدد السطور بالكوز وعدد الحبوب بالسطر ووزن ال ١٠٠ حبة ، بينما كانت النتائج عكسية للصفات الاخرى.

٣- أظهرت النتائج أهمية اختيار البيئات المناسبه التى تعطى افضل تعبير وراثى للصفات المختلفة فى الهجن تحت الدراسة.

٤- كان هناك ارتباطا مظهريا موجبا ومعنويا بين محصول النبات من الحبوب وكل من طول النبات وارتفاع الكوز ووزن ال ١٠٠ حبة فى كل من البيئات تحت الدراسة ومع قطر الكوز فى ثلاث بيئات و مع عدد

السطور بالكوز وعدد الايام حتى ظهور ٥٠% من الحرايرفى بينتين. وتفيد هذه النتائج المربى لاختيار التراكيب الوراثية عالية المحصول من خلال الانتخاب لواحدة او اكثر من هذه الصفات تحت البيئة المستهدفة.

٥- تشير نتائج تحليل معامل المرور الى ان صفات قطر الكوز وعدد الحبوب بالسطر ووزن ال ١٠٠ حبه تمثل أهم الصفات مساهمة فى تباين المحصول فى معظم البيئات. وعلى هذا يمكن اعتبار هذه الصفات كمعايير للانتخاب تستخدم فى تحسين محصول الذرة الشامية تحت البيئات المستهدفة.

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