Egypt. J. Plant Breed. 12(2): 27-44 (2008)

GENERATION MEAN ANALYSIS FOR SOME GRAIN YIELD TRAITS IN THREE YELLOW MAIZE CROSSES UNDER FAVORABLE AND LATE SOWING DATES

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ABSTRACT

The present investigation was conduced during 2002, 2003 and 2004 to determine the nature and magnitude of gene action controlling the inheritance of grain yield and its components in three yellow maize crosses: Cross 1 (TL97B-6969-28 x TL99A-1226-4), Cross 2 (TL76B-6969-32 x TL99A-1226-4) and Cross 3 (TL99A-1225-39 x TL97A-1133-81) via generation mean analysis (P_1, P_2, F_1, F_2, BC_1 *and* BC_2) *under favorable (20th May,* D_1) *and late (20th June,* D_2) *sowing dates. Significant and positive heterotic effects over both mid- and better parents were found for most studied traits including grain yield plant*$^{-1}$ *in the three crosses under both environments. Also, significant and positive inbreeding depression values were observed for all studied traits in the three crosses under both environments, except for number of rows ear*$^{-1}$ *in the 2nd cross at* D_2. *In general, most estimates of inbreeding depression were higher under favorable than under late sowing date. In the three crosses, most studied traits under both environments, especially grain yield plant*$^{-1}$ *exhibited over dominance. High to moderate heritability estimates in broad-sense were found for most studied traits in both environments. Meanwhile, moderate to low narrow sense heritability values were detected. The results of scaling test (A, B and C) indicated the presence of non-allelic gene interactions for all studied traits except number of rows ear*$^{-1}$ *in Cross 2 at* D_2. *Both additive and dominance gene effects were significant for most of the studied traits under both environments. Among digenic interactions, additive x additive (i), additive x dominance (j) and dominance x dominance (l) were significant for most of the studied traits in all crosses under both environments. Gene action was found to be duplicate for most of the studied traits including grain yield/plant in the three studied crosses under both environments, suggesting that reciprocal recurrent selection can be a viable breeding strategy in such situation. The results also indicated that the gene effects for a certain trait should be identified from the particular cross used and the targeted sowing date for the success of the breeding program.*

Key words: ***Yellow maize, Zea mays, Crosses, Gene actions, Heterosis, Inbreeding Depression, Heritability.***

INTRODUCTION

Yellow maize (*Zea mays* L.) is recently receiving a special attention from maize breeders in Egypt as an important feed for poultry and domestic animals. About six million tons of yellow maize are imported annually to meet increasing animal consumption. Increasing yellow maize production is possible *via* vertical extension through the production of high yielding hybrids. To achieve this goal, basic information about combining ability, different types of gene action … etc. in different crosses are needed for conducting a successful breeding program. The breeding strategy should, therefore, be based on the gene action involved in a particular cross to get a desirable genotype.

Generation mean analysis (GMA) is an important tool to determine the gene action controlling grain yield and its contributing traits in order to develop an appropriate breeding procedure. Several models have been developed for analysis of generation means (Anderson and Kempthorne 1954; Hayman 1958, Van der Veen 1959 and Gardner and Eberhart 1966). The magnitude of genetic variation and the relative importance of additive and non-additive types of gene action would assist yield improvement. The maximum progress in improving a particular character would be expected in a selection program, when the additive gene action is the main component of the genetic variance. Whereas, the presence of non-additive gene action might suggest the use of cross breeding (Robertson and Reeve 1995). In this respect, Pferr and Lamkey (1992) mentioned that dominance component was important for ear height, number of kernels row^{-1}, 100-kernel weight and grain yield plant^{-1}. Moreover, Malver *et al* (1996) found that dominance variance was large for grain yield plant^{-1}, ear length and ear and plant heights. They also obtained large dominance gene effects and small additive gene effects for grain yield, indicating that an inter-population selection method would be effective.

The genotype x environment interaction plays a major role for the breeding program, since the environmental factors are usually in continuous state of changing (El-Absawy 2000 and Nawar *et al* 2003)

Therefore, the main objectives of this research were to study heterosis, inbreeding depression, potence ratio, heritability and the types of gene action controlling in the inheritance of grain yield and its contributors in three yellow maize crosses under favorable and late planting dates.

MATERIALS AND METHODS

The present study was conducted at the Agricultural Research Station of Ain Shams University, Shalakan, Kalubia Governorate, Egypt, during the three successive growing seasons of 2002, 2003 and 2004. Five exotic yellow maize inbred lines introduced from CIMMYT namely TL99A-1225-39 (P_1), TL97B-6969-28 (P_2), TL76B-6969-32 (P_3), TL97A-1133-81 (P_4) and TL99A-1226-4 (P_5) were used in the present work. The experimental material was generated from three crosses among these parents. These crosses were P_2 x P_5 (Cross 1), P_3 x P_5 (Cross 2) and P_1 x P_4 (Cross 3). Six basic generations, viz., two parents, F_1 and F_2 and first backcross generation with both parents (BC_1 and BC_2), where BC_1 was the cross between F_1 x female parent and BC_2 was from the cross F_1 x male parent. These six populations for each of the three crosses were evaluated in a randomized complete blocks design with three replicates in two parallel experiments, one sown on the 20th of May (favorable sowing date) and other sown on the 20th of June (late sowing date) in the same cropping season. Each replicate was divided into three compact blocks. The crosses, each consisting of six populations, were randomly allotted to the blocks. All the six generations were then randomly allotted to six plots within a block. The plots of various generations contained different number of ridges, i.e. plots of each parent and F_1 consisted of three ridges, those of each backcross generation contained eight ridges, and those of each F_2 contained 12 ridges. Each ridge was 3.5 m long accommodating 12 plants spaced 25 cm apart and the ridge to ridge distance was 70 cm. Border ridges were provided in each block. Normal agricultural practices of maize were followed during the growing seasons. Observations and measurements on plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of rows ear^{-1}, number of kernels row^{-1}, 100-kernel weight (g) and grain yield $plant^{-1}$ (g) were recorded on 20 random plants in each parent and F_1, 60 plants in each backcross generation and 80 plants in each F_2 generation in each replicate and under each environment.

Standard statistical procedures were used to obtain means and variances for each generation and each environment separately (Snedecor and Cochran, 1980). The genetic variance in F_2 population was firstly calculated. If it was significant, various genetic parameters were then estimated. The studied genetic parameters were; heterosis expressed as the percentage increase or decrease of the F_1 over the mid-parent (M.P) and better parent (B.P) values, inbreeding depression (I.D.%) estimated as the decrease in F_2 mean compared with F_1 mean, potence ratio (P) calculated according to Smith (1952) and heritability in broad- and narrow-sense computed according to Warner (1952). The significance of additive, dominance and the three digenic epistasis effects were determined by generation mean analysis (GMA) using the method of Hayman (1958). Gene effects were based on a six parameters model. The population means were calculated from the individual plant data (on a single plant basis). The variance of the population means was used in estimating the variance of the estimated parameters. The significance of the estimate was tested by the standard error of each of the six parameters.

RESULTS AND DISCUSSION

The significance of mean squares for eight agronomic and yield traits of six populations in three yellow maize crosses under two sowing dates is presented in Table (1). The results revealed that in each cross, the differences among the various populations were found to be highly significant for all studied traits, indicating that the populations within each cross were genetically different from each other for all studied traits. Also, mean squares due to sowing date and to generations x sowing dates interactions for all studied traits in each cross were significant, indicating

Table 1. Mean squares for eight agronomic traits of six populations in three yellow maize crosses evaluated at two sowing dates.

S.O.V.	d.f.	Plant height	Ear height	Ear length	Ear diameter	No. of rows ear^{-1}	No. of kernels row^{-1}	100-kernel weight	Grain yield plant^{-1}
Cross 1									
Replications	2	11.7	9.42	0.07	0.003	0.28	0.58	0.85	0.55
Sowing dates (D)	1	20330.48**	8128.22**	40.90**	0.04**	1.30**	58.75**	11.57**	1896.02**
Generations (G)	5	6226.54**	1070.16**	18.40**	0.34**	6.97**	134.12**	83.49**	5720.01**
G x D	5	660.21**	162.99**	2.84**	0.05**	1.31**	18.58**	0.87	637.07**
Cross 2									
Replications	2	41.13	31.28	0.48	0.003	0.12	0.16	1.69	15.29
Sowing dates (D)	1	34122.09**	6479.98**	67.13**	0.09**	18.52**	458.32**	10.87**	8415.31**
Generations (G)	5	3603,.99**	1418.85**	6.38**	0.94**	0.77**	107.58**	110.76**	8250.63**
G x D	5	239.19**	620.69**	2.73**	0.02**	2.99**	10.12**	6.35**	464.09**
Cross 3									
Replications	2	88.76	25.79	1.41	0.01	0.34**	3.30	0.59	46.47
Sowing dates (D)	1	23317.80**	6714.98**	28.09**	0.86**	13.26**	147.26**	13.81**	17212.13**
Generations (G)	5	5808.59**	1761.55**	34.60**	1.20**	1.11**	391.53**	65.63**	9738.59**
G x D	5	185.34**	62.26**	3.98**	0.14**	6.04**	27.71**	14.46**	943.07**

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

that the performance of the generations depended on the specific environmental conditions. The means of all generations with their standard errors for all studied traits in the three crosses under favorable and late sowing dates are given in Table (2). The validity of parental differences and the existence of genetic variance within F_2 populations were examined. Significant genetic variance was detected for all studied traits in the three crosses under both environments and therefore genetic parameters were estimated.

Investigating the degree of heterosis is important to determine deciding the direction of a further breeding program. As presented in Table (3), the percentages of heterosis as a deviation from both mid- and better-parent values were significant and positive for grain yield and its attributes in all studied crosses under both environments, with a few exceptions. As for Cross 1, heterosis values ranged from 7.71 and 6.55% for number of rows/ear to 98.10 and 166.05% for grain yield plant^{-1} relative to mid-parent, while they varied from -1.41% and -4.56% for number of rows ear^{-1} to 84.18% and 141.07% relative to the better-parent under favorable and late sowing dates, respectively. Regarding Cross 2, the heterotic effects ranged from 2.01 and 0.64% for number of rows ear^{-1} to 144.79 and 120.43% for grain yield plant^{-1} over the mid-parent, while they varied from -4.96 and -5.69% for number of rows ear^{-1} to 122.74 and 110.49% relative to better-parent under the two sowing dates, respectively. Concerning Cross 3, heterosis values ranged from 7.07 and 3.38% for number of rows ear^{-1} to 153.58 and 97.55% relative to mid-parent, while they ranged from -1.25 and -8.06% for number of rows ear^{-1} to 126.34 for grain yield plant^{-1} and 87.62% for ear height relative to the better-parent in favorable and late sowing dates, respectively. The highest heterosis estimate was observed for grain yield plant^{-1} in Cross 1 in the late sowing date, while the lowest one was detected for number of rows ear^{-1} in Cross 2 in late sowing date. It is worthy to note that heterotic effect for grain yield plant^{-1} was larger in magnitude than that for any of its major components. Also, the results indicated that number of kernels row^{-1} was the main contributing factor for increasing heterosis in grain yield plant^{-1}, followed by 100-kernel weight and number of rows ear^{-1} in these crosses under both favorable and late sowing dates.

From the previous results, it can be indicated that significant positive heterotic effects were found for most studied traits in the three crosses under the two studied environments, suggesting that the presence of heterosis in the studied traits might be due to significant estimates of non-additive gene effects. Similar findings were obtained by Nawar *et al* (1998 and 2003), El-Shamarka (1999), Khalil (1999) and El-Absawy (2000). The significant heterotic effects in the three crosses for most studied traits suggest that these crosses may be valuable in breeding programs for that these crosses may

Table 2. Mean ± standard error of the six populations for eight traits in three yellow maize crosses at two sowing dates (D_1 and D_2).

Trait	Population	Cross 1		Cross 2		Cross 3	
		D_1	D_2	D_1	D_2	D_1	D_2
Grain yield plant^{-1} (g)	P_1	90.05±2.87	66.37±3.01	73.83±2.37	60.38±2.69	87.03±3.10	68.46±2.78
	P_2	77.39±2.83	53.91±3.19	90.05±2.61	66.37±2.70	68.33±2.88	51.51±2.87
	F_1	165.85±3.08	160.00±3.20	200.58±2.99	139.70±2.74	196.98±2.98	118.50±3.05
	F_2	116.84±2.14	115.99±2.13	139.82±1.77	109.24±1.86	134.65±2.01	100.01±2.29
	BC_1	132.45±2.74	85.45±2.54	154.30±2.34	117.21±2.15	151.11±2.49	86.35±2.49
	BC_2	113.28±2.80	101.43±2.41	124.34±2.09	106.46±1.96	141.35±2.54	103.24±2.48
Ear length (cm)	P_1	15.07±0.19	11.82±0.22	13.59±0.15	9.56±0.15	13.38±0.14	9.09±0.15
	P_2	13.13±0.17	12.93±0.19	15.07±0.17	11.82±0.19	11.31±0.12	10.43±0.15
	F_1	19.04±0.17	16.56±0.22	17.65±0.15	14.91±0.19	17.82±0.15	17.06±0.18
	F_2	16.24±0.13	15.59±0.14	15.50±0.12	13.35±0.14	15.67±0.12	14.63±0.13
	BC_1	17.45±0.16	13.98±0.14	14.53±0.12	13.46±0.15	15.99±0.15	12.91±0.15
	BC_2	16.71±0.15	14.39±0.16	17.18±0.15	10.57±0.16	15.75±0.12	14.20±0.14
Ear diameter (cm)	P_1	3.96±0.03	3.73±0.04	3.76±0.03	3.53±0.03	4.09±0.03	3.27±0.02
	P_2	3.78±0.03	3.93±0.03	3.96±0.03	3.73±0.04	3.76±0.02	3.62±0.03
	F_1	4.51±0.03	4.45±0.04	4.96±0.02	4.69±0.03	4.96±0.02	4.72±0.03
	F_2	4.14±0.02	4.26±0.02	4.53±0.02	4.47±0.02	4.51±0.02	4.33±0.02
	BC_1	4.26±0.03	3.98±0.03	4.65±0.03	4.55±0.03	4.62±0.03	4.16±0.03
	BC_2	4.19±0.03	4.11±0.03	3.97±0.02	4.36±0.02	4.60±0.03	4.40±0.03
No. of rows ear^{-1}	P_1	13.59±0.16	13.35±0.21	15.74±0.15	11.67±0.13	14.18±0.15	16.14±0.19
	P_2	16.36±0.18	16.87±0.18	13.59±0.12	13.35±0.18	16.79±0.13	12.57±0.14
	F_1	16.13±0.17	16.10±0.18	14.96±0.16	12.59±0.18	16.58±0.17	14.84±0.15
	F_2	15.53±0.11	15.25±0.12	13.45±0.09	12.43±0.12	15.46±0.13	15.17±0.14
	BC_1	15.11±0.13	14.09±0.15	12.88±0.11	12.61±0.13	15.89±0.16	15.46±0.16
	BC_2	16.29±0.15	15.07±0.14	13.82±0.10	12.18±0.11	16.27±0.14	14.71±0.13

Table 2. Cont.

Trait	Population	Cross 1		Cross 2		Cross 3	
		D_1	D_2	D_1	D_2	D_1	D_2
No. of kernels row^{-1}	P_1	28.79±0.53	24.30±0.66	26.37±0.48	21.95±0.48	23.08±0.57	21.96±0.45
	P_2	25.33±0.64	19.54±0.72	28.79±0.50	24.30±0.59	18.90±0.44	17.53±0.39
	F_1	42.42±0.67	37.23±0.69	41.79±0.44	34.15±0.59	42.85±0.52	38.50±0.48
	F_2	33.37±0.38	31.69±0.41	34.13±0.29	27.44±0.39	36.10±0.35	31.09±0.37
	BC_1	34.21±0.46	30.19±0.44	36.34±0.33	28.50±0.38	37.19±0.42	28.59±0.38
	BC_2	31.44±0.47	29.28±0.50	34.32±0.35	24.92±0.43	36.49±0.39	31.43±0.40
100-kernel weight (g)	P_1	25.96±0.25	24.79±0.32	22.57±0.24	26.73±0.27	22.69±0.28	16.31±0.18
	P_2	18.49±0.19	17.98±0.29	25.96±0.23	24.79±0.25	24.38±0.24	25.53±0.25
	F_1	28.85±0.21	27.57±0.27	34.99±0.30	36.69±0.32	29.16±0.22	29.60±0.22
	F_2	25.51±0.25	25.03±0.29	30.30±0.25	33.35±0.26	24.21±0.20	24.39±0.20
	BC_1	26.41±0.31	26.59±0.33	31.72±0.30	30.69±0.33	26.46±0.22	22.69±0.21
	BC_2	22.72±0.26	20.18±0.27	28.45±0.26	31.93±0.28	26.68±0.24	27.63±0.25
Plant height (cm)	P_1	220.15±1.36	168.55±1.53	214.01±1.18	150.02±1.32	216.75±1.17	172.59±0.99
	P_2	208.58±1.73	201.13±2.26	220.15±1.23	168.55±1.37	201.90±0.93	146.91±1.23
	F_1	310.71±1.51	246.13±2.12	288.38±1.43	216.51±1.92	291.58±1.16	226.73±1.89
	F_2	277.65±1.35	234.23±1.43	253.01±1.03	200.68±1.19	261.59±1.09	208.59±1.24
	BC_1	281.49±1.56	223.76±1.55	251.12±1.25	197.16±1.31	265.65±1.27	215.12±1.36
	BC_2	272.08±1.60	211.68±1.77	258.21±1.39	185.84±1.45	254.60±1.41	206.73±1.28
Ear height (cm)	P_1	87.60±1.46	62.08±1.34	101.95±1.03	58.21±1.15	90.78±1.16	65.19±1.08
	P_2	82.25±1.59	66.88±1.65	87.60±1.32	62.08±1.21	81.62±1.26	49.77±0.71
	F_1	125.10±1.49	90.19±1.11	133.47±1.42	104.72±1.24	131.52±1.38	93.38±1.49
	F_2	113.68±1.14	82.95±1.06	118.95±0.74	93.14±0.72	111.35±0.90	87.87±1.01
	BC_1	118.41±1.21	71.77±1.07	103.97±0.95	98.83±0.81	112.28±0.98	91.28±1.07
	BC_2	108.25±1.42	81.11±1.26	130.37±0.91	76.10±0.75	106.70±1.09	82.88±1.19

be valuable in breeding programs for improving grain yield and its components. It is of interest to note that the magnitudes of heterosis were found to be different under favorable and late sowing dates. Therefore, the test of potential of parents for the expression of heterosis would be necessary conduced over a number of environments. Hence, the genetic diversity alone would not guarantee the expression of heterosis, but the suitability of the environmental conditions would be required.

Information on inbreeding depression is useful to test potentiality of F_2 seeds. The heterotic expression should be reduced in the F_2 generation as the dominance or dominance x dominance interaction effects dissipate due to reduced heterozygosity resulting from inbreeding (Falconer 1960). Significant inbreeding depression values were detected for most studied traits in the three crosses under the two sowing dates (Table 3). This result indicates that both heterosis and inbreeding depression are coincident to the same particular phenomenon; hence it is logic to anticipate that heterosis in the F_1 will be followed by an appreciable reduction in the F_2 performance. Similar trend was reported by Nawar *et al* (2003), El-Shamarka (1999), Khalil (1999) and El-Absawy (2000).

Concerning the average degree of dominance (Table 4), it was greater than unity for all studied traits in the three crosses in the two sowing environments with few exceptions, suggesting that over-dominance was involved in the control of these traits. Consequently, over-dominance effects were responsible for heterotic effects of those traits in the three studied crosses. Similar results were mentioned by Nawar *et al* (2003) and Younis *et al* (1994) for grain yield plant^{-1}. Moreover, El-Shamarka (1999), Khalil (1999) and El-Absawy (2000) found over dominance for grain yield and its attributes. On the contrary, Nawar *et al* (1996) found partial dominance for grain yield plant^{-1}.

As shown in Table (4), the scaling test (A, B and C) for eight studied traits revealed that at least one of the non-allelic interactions was significant for all the studied traits in the three crosses under both environments, except for number of rows/ ear in the 2nd cross under late sowing.

These results indicated that the additive-dominance model is not enough to explain the genetic variation of all studied traits in these crosses under such conditions. Therefore, the six genetic parameters model have to be used in order to assess the digenic epistatic effects, which control the traits under study.

The choice of the most efficient breeding procedures depends to a large extent on the knowledge of the genetic system controlling the characters to be selected. Therefore, nature of gene action was estimated for all studied traits in both environments according to Hayman (1958). Estimates of the various types of gene effects, i.e. mean (m), additive (d), dominance (h), additive x additive (i), additive x dominance (j) and

Table 3. Heterosis, inbreeding depression and potency ratio for eight traits in three yellow maize crosses at two sowing dates (D_1 and D_2).

Trait	Cross	Heterosis %				Inbreeding depression %		Potence ratio	
		Mid-parent		Better-parent					
		D_1	D_2	D_1	D_2	D_1	D_2	D	D_2
Grain yield/plant (g)	1	98.10**	166.05**	84.18**	141.07**	29.55**	27.51**	12.98	16.03
	2	144.79**	120.43**	122.74**	110.49**	30.29**	21.80**	14.63	25.48
	3	153.58**	97.55**	126.34**	73.09**	31.64**	15.60**	12.76	6.90
Ear length (cm)	1	35.04**	33.82*	26.34**	28.07**	14.71**	5.86**	5.09	7.54
	2	23.17**	39.48**	17.12**	26.14**	12.18**	10.46**	4.49	3.74
	3	44.35**	74.80**	33.18**	63.52**	12.07**	14.24**	5.29	10.90
Ear diameter (cm)	1	16.54**	16.19**	13.89**	13.23**	8.20**	4.27**	7.11	6.20
	2	28.50**	29.20**	25.25**	25.74**	8.67**	4.69**	11.00	10.60
	3	26.37**	37.01**	21.27**	30.39**	9.07**	8.26**	6.27	7.29
No. of rows ear^{-1}	1	7.71**	6.55**	-1.41	-4.56**	6.72**	5.28**	0.83	0.56
	2	2.01	0.64	-4.96**	-5.69**	10.09**	1.27	-0.65	0.10
	3	7.07**	3.38	-1.25	-8.06**	6.76**	-2.22	0.84	0.27
No. of kernels row^{-1}	1	56.76**	69.85**	47.34**	53.21**	21.33**	14.88**	8.88	6.43
	2	51.52**	47.68**	45.16**	40.54**	18.33**	19.65**	11.74	9.38
	3	104.15**	94.99**	85.66**	75.32**	15.75**	19.25**	10.46	8.47
100-kernel weight (g)	1	29.81**	28.92**	11.13**	11.21**	11.58**	9.21**	1.77	1.82
	2	44.20**	42.43**	34.78**	37.26**	13.40**	9.10**	6.33	11.27
	3	23.90**	41.49**	19.61**	15.94**	16.98**	17.60**	6.66	1.88
Plant height (cm)	1	44.94**	33.16**	48.96**	46.03**	10.64**	4.84**	16.65	3.76
	2	32.85**	35.93**	34.75**	44.32**	12.27**	7.31**	23.23	6.18
	3	36.05**	41.93**	37.60**	54.33**	10.29**	8.00**	31.86	5.22
Ear height (cm)	1	47.31**	39.87**	52.10**	45.28**	9.13**	8.03**	15.02	10.71
	2	40.83**	74.11**	52.36**	79.90**	10.88**	11.06**	5.39	23.04
	3	52.58**	62.46**	61.14**	87.62**	15.34**	5.90**	9.90	4.66

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

Table 4. Estimates of gene effects for eight studied traits in three yellow maize crosses at two sowing dates (D_1 and D_2).

Trait	Cross	Sowing date	Scaling test I			m	d	h	i	j	l	Type of epistasis
			A	B	C							
Grain yield plant^{-1} (g)	1	D_1	-	*	**	116.84**	19.17**	106.23**	24.10*	12.84	-16.42	D
		D_2	**	-	*	115.99**	-15.98**	9.66	-90.20**	-22.21**	156.72**	C
	2	D_1	**	**	-	139.82**	29.96**	116.64**	-2.00	21.85**	9.76	C
		D_2	**	*	**	109.24**	10.75**	86.71**	10.38	7.76	-51.57**	D
	3	D_1	**	**	-	134.65**	9.76**	165.62**	46.32**	0.41	-81.92**	D
		D_2	*	**	**	100.01**	-16.89**	37.66**	-20.86*	-25.37**	-1.35	D
Ear length (cm)	1	D_1	*	**	*	16.24**	0.74**	8.30**	3.36**	-0.23	-5.40**	D
		D_2	-	-	**	15.59**	-0.41*	-1.44*	-5.62**	0.15	6.75**	D
	2	D_1	**	**	**	15.50**	-2.65**	4.74**	1.42	-3.39**	0.88	D
		D_2	*	**	**	13.35**	2.89**	-1.12	-5.34**	1.76**	8.48**	D
	3	D_1	*	**	*	15.67**	0.24	6.28**	0.80	-0.80	-3.95**	D
		D_2	-	*	**	14.63**	-1.29**	3.00**	-4.30**	-0.62	3.72**	C
Ear diameter (cm)	1	D_1	-	-	*	4.14**	0.07	0.98**	0.34*	-0.02	-0.48*	D
		D_2	**	*	**	4.26**	-0.13**	-0.24	-0.86**	-0.03	1.24**	D
	2	D_1	**	**	**	4.53**	0.68**	0.22	-0.88**	0.58**	1.28**	C
		D_2	**	**	**	4.47**	0.19**	1.00**	-0.06	0.09	-1.12**	D
	3	D_1	**	**	*	4.51**	0.02	1.44**	0.40**	-0.15	-1.07**	D
		D_2	**	**	**	4.33**	-0.24**	1.08**	-0.20	-0.07	-0.59**	D
No. of rows ear^{-1}	1	D_1	*	-	-	14.45**	-0.94**	-0.11	-0.40	0.14	6.25**	D
		D_2	**	**	*	15.25**	-0.98**	-1.69*	-2.68**	0.78	6.78**	D
	2	D_1	**	**	**	13.45**	-0.94**	-1.10	-0.40	0.13	4.23**	D
		D_2	-	-	-	12.65**	0.84**	-0.82	-----	-----	-----	-
	3	D_1	**	*	**	15.46**	-0.38	3.58**	2.48**	0.93*	-2.67*	D
		D_2	-	**	**	15.17**	0.75**	0.15	-0.34	-1.04*	1.61*	C

Table 4. Cont.

Trait	Cross	Sowing date	Scaling test I			m	D	h	i	j	l	Type of epistasis
			A	B	C							
No. of kernels row^{-1}	1	D_1	*	**	*	33.37**	2.77**	13.18**	-2.18	1.04	9.84**	C
		D_2	-	-	**	31.69**	0.91	7.49**	-7.82**	-1.47	7.18*	C
	2	D_1	*	-	-	34.13**	2.02**	19.01**	4.80**	0.81	-7.38**	D
		D_2	-	**	*	27.44**	3.58**	8.11**	-2.92	2.41	10.63**	C
	3	D_1	**	**	**	36.10**	0.70	24.82**	2.96	-1.39	22.64**	C
		D_2	**	**	-	31.09**	-2.84**	14.44**	-4.32*	-5.06**	0.77	C
100-kernel weight (g)	1	D_1	**	**	-	25.51**	3.69**	2.85*	-3.78**	-0.05	7.67**	C
		D_2	-	**	-	25.03**	6.41**	-0.40	-6.58**	3.01**	10.95**	D
	2	D_1	**	-	*	30.30**	3.27**	9.87**	-0.86	1.58	-0.97	D
		D_2	-	-	**	33.35**	-1.24**	2.77	-8.16**	-0.27	7.82**	C
	3	D_1	-	-	**	24.21**	-0.22	15.07**	9.44**	0.63	-10.33**	D
		D_2	-	**	*	24.39**	-4.94**	14.76**	3.08*	-3.33**	-8.68**	D
Plant height (cm)	1	D_1	**	**	**	277.65**	9.41**	92.89**	-3.46	3.63	-53.53**	D
		D_2	**	**	**	234.23**	12.08**	-4.75	-66.04**	28.37**	57.10**	D
	2	D_1	-	**	-	253.01**	-7.09**	77.92**	6.62	-10.16**	-14.36	D
		D_2	**	-	**	200.68**	11.32**	20.51**	-36.72**	20.59**	22.31*	C
	3	D_1	**	**	**	261.59**	11.05**	76.40**	-5.86	3.63	-32.83**	D
		D_2	**	**	**	208.59**	8.39**	76.32**	9.34	-4.45	-80.08**	D
Ear height (cm)	1	D_1	**	**	**	113.68**	10.16**	38.78**	-1.40	7.49	-31.81**	D
		D_2	**	-	**	82.95**	-9.34**	-0.33	-26.04**	-6.94	29.62**	D
	2	D_1	**	**	-	118.95**	-26.40**	31.58**	-7.12	-19.23**	-5.07	D
		D_2	**	**	**	93.14**	22.73**	21.88**	-22.70**	20.80**	2.57	D
	3	D_1	-	-	*	111.35**	5.58**	37.88**	-7.44	1.00	4.92	D
		D_2	**	**	**	87.87**	8.40**	32.74**	-3.16	0.69	-43.44**	D

* and ** denote significance at 0.05 and 0.01 levels of probability, respectively.
Where: m=the mean of F_2 generation, d=Additive effect, h=Dominance effect, i=Additive x additive, j= Additive x dominance and l= Dominance x dominance type of gene interaction. C=Complementary and D= Duplicate

dominance x dominance (l) from generation mean analysis for the studied traits in all crosses under the two sowing dates are presented in Table (4). The results showed that additive gene effects appeared to be important in the inheritance of ear diameter, number of kernels row^{-1} and grain yield plant^{-1} in the 2nd cross, 100-kernel weight and plant height in the 1st cross and for plant and ear heights in the 3rd cross in both sowing dates. This result indicates that the traits which exhibited significant estimates of additive gene effects would give the potential for obtaining further improvement *via* selection. Significant positive dominance effects were detected for all studied traits except for number of rows ear^{-1} in the 1st and 2nd crosses in both sowing dates and in 3rd cross at D_2, plant and ear heights, ear length, ear diameter, 100-kernel weight and grain yield plant^{-1} in the 1st cross at D_2, ear length and 100-kernel weight in the 2nd cross at D_2 and ear diameter in the 1st cross at D_1 where insignificant or significant negative effects were obtained. This suggests that dominance gene effects had a significant contribution to the inheritance of these traits in all the studied crosses under such environmental conditions. With regard to the types of digenic epistatic effects, the significant positive additive x additive gene effects (i) were exhibited for grain yield plant^{-1} and ear diameter in the 1st and 3rd crosses at D_1, 100-kernel weight in the 3rd cross in both environments and for ear length in the 1st cross, number of rows ear^{-1} in the 3rd cross and number of kernels row^{-1} in the 2nd cross at D_1. Significant positive additive x dominance gene effects (j) were obtained for plant height in the 1st and 2nd crosses and ear height and ear length in 2nd cross at D_2, ear diameter and grain yield plant^{-1} in the 2nd cross and 100-kernel weight in the 1st cross at D_2.

Significant positive dominance x dominance type of epistatic effect (l) was detected for all studied traits in the 1st cross and plant height in the 2nd cross at D_2, ear length in the 2nd and 3rd crosses at D_2, ear diameter in the 2nd cross and number of rows ear^{-1} in the 1st and 2nd crosses at D_1, number of kernels row^{-1} in the 1st and 3rd crosses at D_1 and in the 1st cross at D_2 as well as 100-kernel weight in the 1st cross at D_1 and in the 2nd cross at D_2.

In the present study, both additive and dominance components were significant for most of the traits studied but dominance was greater in magnitude for most of the cases in the three crosses under both sowing dates, indicating preponderance of dominance gene effects in the expression of these traits under such environmental conditions. Similar results in maize have been reported by Gamble (1962), Kalla *et al* (2001), Atanaw *et al* (2003) and El-Shouny *et al* (2005). It is thus quite obvious that cross breeding can be a better strategy for maize improvement. Recurrent selection can also be useful in the sense that it will exploit both additive and non-additive components for bringing about improvement of grain yield and its attributes. Such strategy will help in increasing the frequency of favorable alleles, while maintaining the genetic variation in breeding populations (Doerksen *et al* 2003).

Epistatic effects detected for all traits in both environments have considered as a result of unique combinations of genes in specific crosses, which may contribute to increased heterosis in elite single crosses (Lamkey *et al* 1995). This result partially agreed with those obtained by Nawar *et al* (1992) who mentioned that the dominance and epistasis (additive x additive) gene effects were more important in the inheritance of grain yield plant^{-1}. The present results suggest that the inheritance of grain yield and its attributes did not differ in favorable and late sowing dates. Obviously, there are detrimental effects of the late sowing environment, mainly for grain yield, which cause the estimates of the genetic effects to be lower in late than in favorable sowing date.

From the abovementioned results it could be concluded that the dominance and/or epistasis are responsible for heterosis in the three studied crosses under both environments. Similar results were obtained by Gamble (1962), Galal *et al* (1987), Nawar *et al* (1998) and Khalil (1999). Furthermore, the magnitude and signs of genetic effects also differed depending on the sowing date.

In general, the relative magnitude of any significant gene effect determines its importance in the inheritance of a certain trait. The perusal of data indicated that the dominance gene effects were much more important followed by additive gene effects and then the three digenic epistatic effects for most of the studied traits in the two sowing dates. Non-additive gene effects were more important in the inheritance of some traits than the additive ones and the observed heterosis was mainly due to dominance and dominance X dominance types of gene action. Similar results were obtained by Abd El-Sattar *et al* (1999), El-Shamarka (1999), El-Absawy (2000), Nawar *et al* (2002 and 2003) and Amer and Mosa (2004). It is noteworthy that the opposite sign of (h) and (l) for most studied traits in the three crosses in both sowing dates suggested duplicate type of epistasis, which would limit the range of variability as thus slow down the pace of progress *via* selection. Therefore, cross breeding (hybrids) would be advantageous. Furthermore, it is of interest to mention that the estimation of different types of gene action would be significant under a certain sowing date for a certain trait in the same cross. These observations would indicate that the evaluation of different types of gene action should be conducted over a number of environmental conditions, because of the fluctuation in estimation of different types of gene action from sowing date to another. Moreover, the results indicated that the magnitude and sign of genetic effects also differed depending on the trait, the cross and the sowing date.

Heritability estimates in the broad- and narrow-sense for the studied traits in the three crosses in the two sowing dates are given in Table (5). The

Table 5. Heritability estimates (%) in broad- and narrow-sense for eight traits of three yellow maize crosses at two sowing dates (D_1 and D_2).

Trait	Heritability			
	Broad-sense		Narrow-sense	
	D_1	D_2	D_1	D_2
	Cross 1			
1. Grain yield plant^{-1} (g)	70.71	62.67	31.18	39.05
2. Ear length (cm)	74.24	58.33	62.46	56.77
3. Ear diameter (cm)	73.32	62.03	27.26	31.87
4. No. of rows ear^{-1}	62.81	59.65	40.15	27.97
5. No. of kernels row^{-1}	57.41	51.84	50.24	42.99
6. 100-kernel weight (g)	88.51	83.15	64.47	70.64
7. Plant height (cm)	80.26	65.37	62.17	38.08
8. Ear height (cm)	73.50	73.40	66.37	35.94
	Cross 2			
1. Grain yield plant^{-1} (g)	70.68	63.71	43.01	33.79
2. Ear length (cm)	78.34	69.98	68.71	27.77
3. Ear diameter (cm)	78.95	67.20	34.95	41.78
4. No. of rows ear^{-1}	68.04	63.27	66.84	51.90
5. No. of kernels row^{-1}	67.16	66.14	61.89	55.83
6. 100-kernel weight (g)	85.77	83.16	71.95	59.44
7. Plant height (cm)	80.03	67.71	37.81	42.93
8. Ear height (cm)	62.68	52.32	42.79	41.71
	Cross 3			
1. Grain yield plant^{-1} (g)	68.54	70.34	37.20	42.05
2. Ear length (cm)	80.89	72.01	72.53	39.15
3. Ear diameter (cm)	82.66	71.38	51.77	24.17
4. No. of rows ear^{-1}	80.12	76.81	65.43	54.84
5. No. of kernels row-1	68.35	73.43	60.72	54.07
6. 100-kernel weight (g)	80.11	87.48	61.40	55.29
7. Plant height (cm)	85.24	72.16	42.55	46.32
8. Ear height (cm)	70.20	73.43	61.84	30.67

results indicated that the differences in magnitude of both broad- and narrow-sense heritability estimates were found for most of the studied traits in the three crosses in both environments. This would ascertain the important role of both additive and non-additive genetic variances in the inheritance of these traits in both environments. As for Cross 1, moderate to high heritability estimates in the broad-sense were found for all studied traits which ranged from 57.41 and 51.84% for number of kernels row^{-1} to 88.51 and 83.15% for 100-kernel weight in favorable and late sowing dates, respectively. With regard to Cross 2, the broad-sense heritability values varied from 62.68 and 52.32% for ear height to 85.77 and 83.16% for 100-kernel weight under the two sowing dates, respectively. With regard to Cross 3, the heritability values in the broad-sense ranged from 68.35% for number of kernels row^{-1} to 85.24% for plant height at D_1 and from 70.34% for grain yield plant^{-1} to 87.48% for 100-kernel weight at D_2. Moreover, low to moderate heritability estimates in the narrow-sense were detected for the three crosses in both sowing dates. These estimates for Cross 1 ranged from 27.26% for ear diameter to 66.37% for ear height at D_1 and from 27.97% for number of rows ear^{-1} to 70.64% for 100-kernel weight at D_2.

Concerning Cross 2, the values varied from 34.95% for ear diameter to 71.95% for 100-kernel weight at D_1 and from 27.77% for ear length to 59.44% for 100-kernel weight at D_2. Regarding Cross 3, the heritability estimates ranged from 37.20% for grain yield plant^{-1} to 72.53% for ear length at D_1 and from 34.17% for ear diameter to 55.29% for 100-kernel weight at D_2. It is worthy to mention that the magnitude of heritability percentages appeared to be affected by the nature of the measurement, the cross and the magnitude of the environmental variation. These findings confirm more or less those previously reported by Nawar *et al* (1992), Younis *et al* (1994), El-Shamarka (1999), Khalil (1999) and El-Shouny *et al* (2005). From a breeder's point of view, the heritability estimates from both sowing dates showed that Cross 2 and Cross 3 have the greatest chance of genetic improvement in ear length, ear diameter, number of rows ear^{-1}, number of kernels row^{-1} and plant height, while Cross 1 has the greatest chance of increase in 100-kernel weight, ear height and grain yield plant^{-1}. These results showed the importance of gene effects for the improvement of a certain trait was dependent upon the particular cross and sowing date.

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تحليل متوسطات الأجيال لبعض الصفات المحصوليه فى ثلاثة هجن من الذرة الصفراء تحت ميعاد زراعة مناسب وميعاد متأخر

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٢- المركز القومى لبحوث وتكنولوجيا الاشعاع - مدينة نصر - القاهرة

تم أجراء هذا البحث بمحطة التجارب والبحوث الزراعية لكلية الزراعة- جامعة عين شمس بشلقان - محافظة القليوبية خلال ثلاثة مواسم زراعية ٢٠٠٢ و ٢٠٠٣ و ٢٠٠٤ بهدف دراسة قوة الهجين والانخفاض الناشئ عن التربية الداخلية ودرجة التوريث وتحديد طبيعة الفعل الجينى المتحكم فى وراثة المحصول ومكوناته. قد استخدمت فى هذة الدراسة ٥ سلالات نقية من الذرة الصفراء وهى TL ٩٧B ٦٩٦٩-٢٨ ($P_{١}$) ، TL ٩٩A ١٢٢٦-٤ ($P_{٢}$) ، TL ٧٦B ٦٩٦٩-٣٢ ($P_{٣}$) ، TL ٩٩A ١٢٢٥-٣٩ ($P_{٤}$) ، TL ٩٧A ١١٣٣-٨ ($P_{٥}$) ، وفى موسم ٢٠٠٢ تم تهجين هذه الاباء لانتاج الهجين الاول ($P_{١} x P_{٢}$) والهجين الثانى ($P_{٢} x P_{٣}$) والهجين الثالث ($P_{٤} x P_{٥}$) ، وفى موسم ٢٠٠٣ زرعت الآباء و $F_{١}$ بهدف الاكثار الذاتى والتهجينات المختلفة للحصول على بذرة الجيل الثانى $F_{٢}$ والجيلين الرجعيين وكذلك المحافظة على بذور الجيل الأول ، وفى موسم ٢٠٠٤ تمت زراعة حبوب العشائر الستة (الاب الاول - الاب الثانى - الجيل الاول - الجيل الثانى - الجيل الرجعى للأب الأول والجيل الرجعى للأب الثانى) لكل هجين تحت ميعادين للزراعة مناسب فى ٢٠ مايو ومتأخر فى ٢٠ يونية (تجربة لكل ميعاد) وزرعت كل تجربة بتصيم القطاعات كاملة العشوائية فى ثلاث مكررات. وتم أخذ القراءات والقياسات على صفات ارتفاع النبات ، أرتفاع الكوز، طول الكوز، قطر الكوز، عدد الصفوف بالكوز، عدد الحبوب بالصف ، وزن المائة حبة ، محصول النبات الفرى من الحبوب.

اظهرت النتائج وجود قوة هجين موجبة ومعنوية بالنسبة لمتوسط الابوين وكذلك بالنسبة للاب الاعلى لمعظم الصفات المدروسة بما فيها محصول النبات الفردى. تشير النتائج الى وجود تدهور ناتج عن التربية الداخلية فى جميع الصفات المدروسة تحت ميعادى الزراعة ماعدا صفة عددالسطورفى الكوز فى الهجين الثانى فى ميعاد الزراعة المتاخر. وعموما كان حجم التدهور الناتج اعلى عند الزراعة فى الميعاد الامثل. كما اظهرت معظم الصفات المدروسة وخصوصا المحصول سيادة فائقة تحت كلا من ميعادى الزراعة . وكانت قيم المكافئ الوراثى بالمعنى الضيق متوسطة الى منخفضة فى معظم الصفات المدروسة.

اشارت النتائج الى وجود تفاعل غير اليلى لكل الصفات عدا صفة عدد السطور فى الكوز فى الهجين الثانى فى ميعاد الزراعة المتاخر. ومما يدل على ان النموذج الوراثى ذوالستة مقاييس كاف لحساب تباين هذه العشائر

فى ميعادى الزراعة. اظهرت هذه الدراسة ان التأثير المضيف وكذلك السيادى كان معنويا فى معظم الصفات المدروسة وكذلك كان التفوق (التفاعل) من النوع المضيف x المضيف و المضيف x السيادى والسيادى x السيادى معنويا لكل الهجن فى كلا من ميعادى الزراعة تحت الدراسة وعلى ذلك فقد كان لتاثيرات التفوق دورا هاما فى وراثة محصول النبات الفردى ومكوناته فى هذه العشائر. كما وجد ان الفعل الجينى من النوع المتضاعف كان سائدا فى معظم الصفات المدروسة فى الهجن الثلاثة تحت ميعادى الزراعة. بصفة عامة يمكن استنتاج ان التاثيرات الوراثية على الصفات تحت الدراسة تتوقف على المادة الوراثية (الهجين) وكذلك على ميعاد الزراعة المناسب لنجاح برامج التربية فى الذرة الصفراء.

المجله المصريه لتربية النبات ١٢ (٢): ٢٧ ـ ٤٤ (٢٠٠٨)