J. Agric. Sci. Mansoura Univ., 25 (6): 3087 - 3097, 2000.

GENE EFFECTS AND INHERITANCE OF QUANTITATIVE TRAITS IN TWO MAIZE CROSSES

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ABSTRACT

This study was carried out at in the Agricultural Experimental Farm of Alexandria University during 1996 – 98 seasons. The main objectives of the study were determing the genetic effects that control yield, yield components, plant height and silking date in maize. Two crosses were used for applying Gamble model (1962). One of the two crosses represented early maturing parents, whereas, the second included full season parents. Data from parents, F_1, F_2, BC_1 and BC_2 were used in the analysis. The main results of the study were;

1. Heterotic effects were positive and significant for most characters in both crosses except for silking date in both crosses and ear height in cross II relative to the high parent, over-dominance was responsible for heterotic effects of grain yield and its components in both crosses.
2. Negative heterotic effects were found for silking date suggesting fruitful selection for earlier hybrids from in these populations.
3. Dominance effects were significant for most characters except for, silking date in cross II. Also, additive effects were significant except for ear height in cross I. Epistatic effects were found responsible and significant for most of the studied traits.
4. Heritability estimates for all studied characters ranged between high estimates for grain yield/plant, ear length, ear diameter and ear height in both crosses through moderate estimates for plant height and 100 – kernels weight in cross II to low estimates for silking date in cross I.
5. Estimates of heritability were reflected on expected genetic advance from selection within F_2,.The present estimates of genetic gain of selection are expected to be higher than anticipated due to the presence of epistasis. However, they showed that the selection would be effective in improving grain yield in both populations. The first cross is recommended for the breeder interesting in developing high yielding earlier synthetics.

INTRODUCTION

Since the 1940's , researchers have been very active in estimation of genetic and environmental components of variance for different types of maize populations. Additionally, they have attempted to determine the relative proportions of total genetic variance that are attributable to additive and non-additive effects. The papers by Jenkins (1940), Hull (1945), and Comstock and Robinson (1948) integrated possible effects of types of gene action on efficiency of selection and simulated interest in maize populations and their improvement by breeders. Several different population types have been sampled because of the interest in possible differences of genetic variability among populations. Inheritance of grain yield was found related to additive genetic variance more than dominance variance (Hallauer (1971),. Younis *et al,* (1994) and Nawar *et al*. (1998). From another studies , dominance variance was greater than additive for the inheritance of grain yield (Nawar (1985), Nawar et al, (1992), Dawood et al (1994), Nawar et al (1996)and El-Shamarka (1999) . Epistatic effects were found to control the inheritance of some maize traits (Gamble 1962); Darrah and Hallauer, 1972; Sprague and Suwantaradon, 1975; Hallauer and Miranda,1981; Nawar et al,1992; and El-Shamarka, 1999 . It was conluded that the type of gene action within maize population would depend upon the gene frequency within populations and the estimation procedure.

The main objectives of the present study are; a) to determine the type of gene actions and heterosis effects for yield, yield components and other agromic characters of two maize crosses using newly developed inbred lines with divergent ancestor (P_1, P_2, F_1, F_2, BC_1 and BC_2 generations) b) to estimate the heritability and expected genetic advance from selection.

MATERIALS AND METHODS

The present study was carried out at the Agricultural Experimental Station of Alexandria University 10 km South to Alexandria. In 1996 , two crosses were made to produce F_1 generation. The first cross included two early maturing yellow seed inbred lines AL_1 and AL_2 , which were drived from Vispo "a three –way cross from Germany" and Alexandria XI " new synthetic variety", respectively. The second cross was between two full season white seed inbred lines AL_3 and AL_4. These inbreds were obtained from Giza 310 "a 3-way cross" and Alexandria III "a synthetic variety".All the inbred lines were developed by Alex. University. In 1997, F_1 plants of each cross were self pollinated and back crossed to both parents of each cross to produce F_2 and back crosses seeds . In 1998 season, seeds from the six populations of each cross i.e P_1, P_2, F_1, F_2, BC_1, and BC_2 were sown in two separate experiments. Each experiment consisted of three blocks. Each block included 20 rows of F_2 plants, 10 rows from each of F_1 BC_1 and BC_2 plants and 5 rows for each inbred line. Rows were 5.0 m long and 0.70 m apart. Each row included 20 single plants. Recommended practices for maize planting were applied to the experiments. Data were recorded on guarded plants within each row for grain yield /plant (g) adjusted to 15.5% moisture content, ear length and diameter (cm), 100 kernel weight, plant and ear height (cm) and silking date (days).Means and variances within each row were combined over the different rows for each population for each cross.

Data were statistically analyzed according to Gamble's procedure (1962) to estimate the six parameters, i.e. mean (m), additive (a), dominance (d), dominance x dominance (dd), additive dominance (ad) and additive x additive (aa). The method out- lined by Mather (1949) was used for the estimation of heritability in narrow (h^2_n) sense, inbreeding depression (I.D%)and potence ration (P).Expected genetic advance from selection (Ag%)was calculated for a selection intensity of 10% as shown by Johnson et al, 1955. Heterotic effects were computed relative to mid (MP) and high parent (HP) for all traits.

RESULTS AND DISCUSSION

Table 1 shows the values of mean (x), variance ($6\Delta^2$) and coefficient of variability of the six populations for the two maize crosses. Parental means of the second cross (AL_3 x AL_4) were higher than the first cross (AL_1 x AL_2) in yield, yield components and plant characters (plant height and ear height). Meanwhile, parents of the first cross were about 20 days earlier than those of the second cross. Although F_1 of the second cross out- yielded that of the first cross by 25.5% it was two weeks late in silking.In general the variance ($6\Delta^2$) of cross I was higher for all studied traits than that of cross II.,especially the variance of grain yield, plant and ear height in both crosses.

Estimates of heterosis, inbreeding depression (I.D%) and potence ratios (P) for the studied traits of the two crosses are presented in Table 2. Significant positive heterotic effects were found for most traits in both crosses, except for silking date to the high parent which showed significant negative heterotic values in both crosses (-6.0% and – 6.0% for cross I and II, respectively) and ear height to the high parent in cross II (-0.80). Heterotic effects in cross I ranged from 3.0% for silking date to 45.8% for grain yield /plant relative to midparent, while varied from – 6.0% for silking date to 31.76% for grain yield/plant relative to high parent. In cross II the range of heterotic effects were from 1.21% for silking date to 65.11% for grain yield/plant relative to mid-parents and from – 5.56% or silking date to 55.70% for grain yield/plant relative to high parent. The presence of heterotic effects for the studied traits might be due to high and significance estimates of non-additive types of gene action as shown in Table 3. Negative heterotic estimates for silking date relative to high parent in both crosses are useful indicators for the possibility of breeding for earliness. Also, there might be a possibility for lower ear height in cross II population if selected. The heterotic effects for grain yield/plant from maize crosses were cited variably. Darrah and Hallauer (1972) reported heterosis of 315% in one set of diallel crosses. Mohamed (1979) obtained values of 443.54% and 376.9% as percent of mid and high parent. Grogan and Francis (1972) recorded heterosis of 106.2% and 26% relative to mid-and high parent, respectively. Hallauer and Miranda (1981) summarizing several studies, showed that the amount of heterosis would depend on the tested genotypes. Nawar (1985) reached values of 35.3% and 15.6% for one set of diallel crosses and 15.6% and 44.3% for another set of crosses relative to mid-and high parent, respectively Nawar et al (1992) showed that the heterotic effect was slightly affected by the soil fertility level. They estimated values of 29.05%, 30.52% and 30.10% for the first cross under the three levels of nitrogen (125,200 and 300 kg /ha) respectively relative to mid parent, while they obtained 24.17%, 27.20% and 21.44 relative to high parent. From a second cross they reached values of 35.67%, 43.07% and 53.49% relative to mid-parent and 27.93%, 34.27% and 40.80% relative to high parent.

Table 1: Means (x) and Variance (6^2) of maize crosses six populations for all studied triats.

Characters	Population	Cross I AL_1 x AL_2		Cross II AL_3 x AL_4	
		X	O^{-2}	X	O^{-2}
Grain yield / plant (g)	P_1	139.8	50.74	148.5	21.34
	P_2	112.8	58.36	131.6	11.46
	F_1	184.2	46.66	231.2	18.97
	F_2	144.1	435.45	216.4	120.36
	BC_1	163.4	253.50	225.9	40.16
	BC_2	151.9	266.72	189.3	46.18
Ear length (cm)	P_1	15.1	1.56	16.0	0.49
	P_2	11.7	1.65	14.9	0.56
	F_1	18.6	1.91	19.6	0.73
	F_2	17.1	4.50	17.9	3.23
	BC_1	18.0	2.31	18.9	2.23
	BC_2	17.1	3.86	18.6	1.35
Ear diameter (cm)	P_1	4.4	0.02	4.5	0.02
	P_2	3.9	0.03	4.1	0.02
	F_1	4.8	0.02	4.9	0.02
	F_2	4.4	0.08	4.5	0.08
	BC_1	4.5	0.05	4.6	0.05
	BC_2	4.4	0.06	4.4	0.05
100-kernel weight (g)	P_1	28.0	1.29	31.1	0.63
	P_2	23.8	1.09	29.9	0.65
	F_1	31.1	1.12	32.4	0.99
	F_2	27.5	3.75	30.6	3.06
	BC_1	29.5	1.50	31.4	2.44
	BC_2	26.8	2.09	30.5	2.10
Days to mid silking	P_1	36.1	0.94	58.5	1.04
	P_2	34.7	1.07	51.5	1.08
	F_1	41.0	0.78	55.6	1.09
	F_2	41.1	3.26	55.6	6.13
	BC_1	37.0	2.68	56.8	1.57
	BC_2	43.7	2.81	54.4	1.35
Plant height (cm)	P_1	190.1	82.07	240.0	9.01
	P_2	201.4	97.40	234.4	8.79
	F_1	229.8	61.58	269.4	11.31
	F_2	216.7	259.30	262.9	58.61
	BC_1	219.4	162.58	264.9	44.83
	BC_2	222.1	135.16	262.7	47.24
Ear height (cm)	P_1	99.4	44.27	135.3	4.56
	P_2	97.5	43.18	124.5	7.14
	F_1	113.9	37.67	134.2	5.83
	F_2	108.5	128.22	129.4	43.72
	BC_1	109.1	74.65	132.8	23.37
	BC_2	107.5	69.55	129.2	27.00

Significance positive values of inbreeding depression were obtained for all traits in both crosses except for silking date which was not significant. The magnitude of inbreeding depression in cross I was higher for most traits than in cross II. Heterosis and inbreeding depression are coincided to the same particular phenomenon, therefore it is logic to anticipate that heterosis in the F_1 will be followed by an appreciable reduction in the F_2 performance. This statement match with most of the cited results, however with few exceptions.

Silking date in both crosses showed significant heterosis but, insignificant inbreeding depression. The conflicting results of heterosis and inbreeding depression might be due to the presence of linkage between genes in these materials (Van der Veen, 1959).

Values of potence ratio (Table 2) were more than the unity for most studied characters indicating the major role of the over dominance or linkage, while, the value of potence ratio for silking date in both crosses and ear height in cross II were less than unity indicating partial or no dominance . Concequently, over dominance effects were responsible for heterotic effects of grain yield and its components in the two studied crosses. Nawar et al (1992) and Younis et al (1994), using S.C. 107 obtained similar results for grain yield/plant. However, Younis et al (1994) and Nawar et al (1996) using the single cross 10 reported partial dominance for grain yield/plant. Gardner (1963) showed that the higher values of potence in the F_2 disappeared in the advanced generations of random mating suggesting that this phenomenon is due to Linkage rather than to true over dominance.

Table 2 : Estimates of heterosis(MP: midparent, H.P higher parent), inbreeding depression (I.D%) and potence ratio (P) for the studied triats of the two maize crosses.

Characters	Cross I AL_1 x AL_2				Cross II AL_3 x AL_4			
	Heterosis		I.D%	P	Heterosis		I.D%	P
	M.P	H.P			M.P	H.P		
Grain yield / plant (g)	45.8**	31.8**	21.8**	4.29	65.1**	55.7**	6.39**	10.78
Ear length (cm)	38.3**	22.5**	8.0**	2.97	27.1**	22.9**	8.67**	7.88
Ear diameter (cm)	14.6**	8.4**	7.2**	2.51	14.1**	9.3**	9.58**	3.34
100-kernel weight (g)	19.9**	11.1**	11.5**	2.49	6.2**	4.2**	5.53**	3.24
Silking date	3.0**	-6.0**	-0.04	0.31	1.2**	-6.0**	0.04	0.19
Plant height (cm)	17.4**	14.1**	5.7**	6.04	13.6**	12.2**	2.40**	11.49
Ear height (cm)	15.7**	14.7**	4.7**	16.73	3.3**	-0.80**	3.61**	0.80

**** Significant at the 0.01 level of probability.**

Types of gene effects for all studied traits of maize crosses are presented in Table 3. Significant positive additive and dominance gene effects were obtained for most traits except for ear height in cross I that showed insignificant additive gene effect and silking date in cross II that presented insignificant dominant gene effect. In cross I, significant additive x additive gene effects were detected positive for grain yield/plant, ear diameter length, 100-kernels weight and plant height, while, negative for silking date . The same gene effect diameter ear height was not significant. Additive x dominance gene effects were insignificant for grain yield/plant, and ear height, significant negative for ear length , ear diameter and silking date and significant positive for 100-kernels weight and plant height. Dominance x dominance effects were significant and negative for most traits except for ear diameter, 100-kernels weight and ear height which were insignificant . In cross II additive x additive gene effects were significant negative for grain yield/plant, positive for ear length, ear diameter, 100-kernels weight and ear height and insignificant for silking date and plant height. Additive x dominance gene effects were negative for most traits except for grain yield/plant and 100-kernels weight . Also, dominance x dominance gene effects were negative and significant for grain yield/plant, and plant height, insignificant for ear length, ear diameter,100-kernels weight, silking date and ear height. Generally, the relative magnitude of any of the significant gene effect determines its importance in the inheritance of the respective trait. In this concern, grain yield/plant was mainly due to the dominance in both crosses and/or epistatsis (additive x additive) in cross I and (additive x dominance) in cross II. Yield components i.e; ear length , ear diameter and 100-kernels weight were related to dominance gene effect and/or (additive x additive) for ear length and 100-kernels weight in both crosses and (additive x dominance) for ear width in cross I and (dominance x dominance) for the same trait in cross II.Silking date was attributed to dominance gene effects and/or epistasis (dominance x dominance) in cross I and additive gene effect and/or (additive x dominance) epistatic effect in cross II. Plant height and ear height were attributed to dominance gene effect and /or additive x additive espistatic effects in both crosses. This indicates that both additive and dominance played major role in the inheritance of the studied characters. Also epistatic effects were important source of variation. Nawar et al (1992, 1994, 1996 and 1998) and Abdel-Sattar et al, (1999) obtained similar results.

The total phenotypic variance among the F_2 plants was partitioned to additive (σA^2), dominance (σD^2) and environmental (σE^2) variances as given by Mather (1949). Their values are given in Table 4. Additive genetic variance was the main source of the total genetic for all characters in the two crosses (Table 4) Most of the estimates of σD^2 were negative and were considered as an estimate of zero. The validity of the estimates of σA^2 and σD^2 would depend on the assumption of no epistasis. However the gene effect study showed that the epistasis played a significant contribution to the genetic variability within the two crosses under study. Therefore we would expect that the calculated additive genetic variance would be higher than anticipated and consequently the dominance variance would be smaller than expected.

Estimates of the different variances were used to calculate heritability in narrow sence (h^2_n) and expected genetic advance (Ag) and they are presented in Table 4.

For cross I h^2_n ranged between 31.7 for days to silking to 80.5 for grain yield. For the other characters h^2 value was around 70%. For the other cross ranged between 42.9 for plant height up to 89.9 for grain yield. Ear length, days to silking, ear height and ear diameter showed high values of heritability while it was intermediate for kernel weight.

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Table 4: Estimates of additive (σ^2_A), dominance (σ^2_D), environmental (σ^2_E), phenotypic (σ^2_{ph}), variances, heritability in narrow sence (h^2_n) and expected genetic advance (Δg) for the different characters of the two maize crosses.

Character	σ^2_A	σ^2_D	σ^2_E	σ^2_{ph}	H^2_n	Δg %
Cross I						
Grain yield	350.68	32.85	51.92	435.45	80.5	20.5
Ear length	2.83	-0.04	1.71	4.54	62.3	13.8
Ear diameter	0.0618	-0.0051	0.0233	0.0851	72.6	8.0
100-kernel weight	3.91	-1.33	1.17	5.08	77.0	9.5
Silking date	1.04	1.30	0.93	3.27	31.7	2.4
Plant height	221	-42.4	80.4	301.4	73.3	9.5
Ear height	112	-25.7	41.7	153.7	72.9	13.3
Cross II						
Grain yield	154.38	-51.32	17.3	171.68	89.9	10.4
Ear length	2.88	-0.20	0.55	3.43	84.0	15.4
Ear diameter	0.06	0.00	0.02	0.08	75.0	8.4
100-kernel weight	1.58	0.73	0.75	3.06	51.6	4.9
Silking date	9.34	-4.28	1.07	10.41	89.7	9.2
Plant height	25.15	23.76	9.70	58.61	42.9	2.2
Ear height	37.07	0.81	5.84	43.72	84.8	7.6

The values of heritability would suggest that selection within either cross would be promising . The expected genetic advance upon selecting the best 10% of the plants was calculated and it is presented in Table 4 as percent of F_2. For cross1, it is expected that mass selection for grain yield would increase the yield by 20.5% for each cycle. Advance from selection for ear diameter, kernel weight or plant height is expected to give an advance of between 5-10%. Selection would be ineffective for earlier plants as its genetic advance was 2.4%.

For the second cross, the advance from selection ranged between 2.2 for plant height up to 15.4% for ear length . Small advance would be expected from selection for kernel weight and plant height. Intermediate advance is expected for grain yield, ear height and ear diameter. The advance from selection for ear length is expected to be high.

Expected genetic advance is function of heritability and selection differential. The latter is function of selection intenisty and phenotypic standard deviation. Therefore, the expected genetic advance would be better indicator for effectiveness of selection than heritability.

The present estimates of genetic gain of selection are expected to be higher than anticipated due to the presence of epistasis. However, they showed that the selection would be effective in improving grain yield in both population. The first cross is recommended for the breeder interesting in developing high yielding earlier synthetics.

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J. Agric. Sci. Mansoura Univ., 25 (6), June, 2000.

طبيعة فعل الجينات وتوريث الصفات الكمية في هجينين من الذرة الشامية

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أجريت هذه الدراسة بمزرعة كلية الزراعة جامعة الإسكندرية خلال أعوام ٩٦، ٩٧، ١٩٩٨ بهدف تقدير التأثيرات الوراثية المتحكمة في صفات المحصول ومكوناته وصفات ارتفاع النبات وميعاد التزهير لمحصول الذرة الشامية استخدم لذلك هجينيين أحدهما بين آباء مبكرة النضج والآخر لاباء متأخرة وقد استخدم في التقدير البيانات المحسوبة من الآباء وهجن الجيل الأول والثاني والهجن الرجعية للأب الأول والثاني وذلك بتطبيق طريقة Gamble (١٩٦٢). وقد أظهرت النتائج ما يلي :

1- كانت تأثيرات قوة الهجين موجبة ومعنوية لاغلب الصفات في كلا الهجينيين فيما عدا صفة ميعاد التزهير في كلا الهجينيين وصفة ارتفاع الكوز في الهجين الثاني منسوبة إلى الأب الأعلى وتعتبر السيادة الفائقة هي المسئولة عن تأثيرات قوة الهجين لصفات محصول الحبوب ومكوناته في كلا الهجينيين.
2- أظهرت صفة ميعاد التزهير تأثير قوة هجين سالبة مما يوضح إمكانية الأنتخاب للتبكير في تلك العشائر.
3- كانت التأثيرات السيادية معنوية لمعظم الصفات فيما عدا صفة ميعاد التزهير في الهجين الثاني وكذلك كانت التاثيرات المضيفة معنوية لمعظم الصفات المدروسة فيما عدا صفة ارتفاع الكوز في الهجين الاول كما كانت الأختلافات التفوقية تأثيرات معنوية على معظم الصفات المدروسة.
4- اختلفت تقديرات معامل التوريث وتأثيرات فعل الجين في كلا الهجينيين فقد تراوحت تقديرات معامل التوريث بالمعنى الضيق بين المرتفعة لصفات محصول/ الحبوب نبات وطول قطر الكوز وارتفاع الكوز في كلا الهجينيين الى قيم متوسطة لصفات ارتفاع النبات ووزن ١٠٠ حبة في الهجين الثاني إلى القيم المنخفضة لصفة ميعاد التزهير في الهجين الأول.
5- انعكست تقديرات معامل التوريث على قيم التحسن الوراثي المتوقع من الانتخاب في الجيل الثاني. ومن المتوقع أن التقديرات الحالية للتحسن الوراثي أعلى من الواقع وذلك بسبب تأثيرات التفوق الموجودة. وعموماً فقد أظهرت النتائج أن الانتخاب من الممكن أن يكون فعال في تحسين صفة محصول الحبوب في كلا العشيرتين. ويوصي باستخدام الهجين الأول للمربين المهتمين بتكوين أصناف تركيبية عالية الإنتاج ومبكرة.

Table 3: Value of additive (a), dominance (d), additive x additive (aa), additive x dominance (ad) and dominance x dominance (dd) effects from cross I and II for all studied characters.

Characters	Cross I AL_1 x AL_2						Cross II AL_3 x AL_4					
	Gene effect						Gene efect					
	m	a	d	aa	ad	Dd	m	a	d	aa	ad	dd
Grain yield / plant (g)	144.07**	11.46**	112.25**	54.36**	-2.03	-64.05**	216.43**	36.63**	55.95**	-35.21**	28.17**	-52.22**
Ear length (cm)	17.07**	0.86**	7.10**	1.96**	-0.87**	-8.26**	17.91**	0.22	7.49**	3.31**	-0.31*	-8.17
Ear diameter (cm)	4.44**	0.12**	0.76**	0.15**	-0.13**	-0.15	4.46**	0.14**	0.81**	0.20**	-0.04	0.26*
100-kernel weight (g)	27.49**	2.76**	7.81**	2.65**	0.69**	-1.34	30.60*	0.93**	3.25**	1.37**	0.35*	0.66
Silking date	41.06**	-6.71**	-1.67**	-2.86**	-2.92**	3.28**	55.60**	2.34**	0.60	-0.06	-1.15**	-1.13
Plant height (cm)	216.69**	-2.72**	50.24**	16.14**	2.93**	-48.03**	262.90**	2.23**	35.70**	3.53	-0.57	-45.52**
Ear height (cm)	108.53**	1.54	14.45**	-1.02	0.62	-7.44	129.35**	3.68**	10.90**	6.59**	-1.70**	-2.45

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