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Estimation of Genetic Parameters in Three Maize Crosses for Yield and its Attributes

M.El.M. El-Badawy
Department of Agronomy, Faculty of Agriculture, Moshtohor, Benha University, Egypt

ABSTRACT

The experiments reported herein were carried out at the Research and Experimental Center of the Faculty of Agriculture at Moshtohor, Benha University, Egypt, during 2009, 2010 and 2011 seasons. The aim of this study was to determine some genetic parameters for grain yield and its components in six populations. Genetic variance in F_2 plants, positive heterotic effects and inbreeding depression were significant for all studied traits. Over dominance towards the higher parent was detected for all traits under test. The additive gene effects (a) were significant for No. of kernels row^{-1}, ear weight plant^{-1} in the three crosses, No. of rows ear^{-1}, grain yield plant^{-1} and 100-kernel weight in the first and second cross, ear length in the third cross and ear diameter in the second cross. Dominance gene effect (d) was significant for all traits in the three crosses except ear length in the third cross. Additive x additive, additive x dominance and dominance x dominance epistatic types of gene action were significant for most traits. High genetic coefficient of variation for ear diameter, ear weight plant^{-1} and grain yield plant^{-1}, in the three crosses was detected. High heritability values in broad sense were detected for mot traits. High heritability in narrow sense was detected for ear diameter and ear weight plant^{-1} in all crosses, No. of kernels row^{-1} in the third cross and grain yield plant^{-1} in the first and second cross and 100-kernel weight in the second cross. Genetic advance expressed as the percentage of the mean was moderate to high for all the studied traits.

Key words: Maize, genetic parameters, heritability, additive, dominance, epistasis, six populations

INTRODUCTION

Maize production is of great national insert in Egypt for the growers and consumers. Highest productivity is the main target of corn breeders. For achieving this goal more information is needed for the successful breeding programs such as heritability and nature gene action for yield and its components which were studied previously by Warner (1952), Gamble (1962), Fadhi (1978), Sedhom (1988), Barakat (2003), El-Shouny *et al.* (2005), Abou-Deif (2007), Nigussie and Saleh (2007), Hefny (2010), Rashwan (2010), Wannows *et al.* (2010), El-Hosary (2011) and Nawar *et al.* (2011). Among the other important information for the successful breeding program is the information heterotic effect, potence ratio, inbreeding depression, predicted genetic advance under selection which were studied previously by Smith (1952), Johnson *et al.* (1955), Sedhom (1988), El-Shouny *et al.* (2005), Abou-Deif (2007), Rashwan (2010) and El-Hosary (2011). Saleh *et al.* (2002) reported that broad sense heritability for grain yield of corn were moderate. Barakat (2003) found that heritability and the expected genetic values were 61.4 and 7.97% for grain yield plant^{-1}, respectively. Ali *et al.* (2003) found that broad sense heritability for the sweet corn population was moderate to high for the studied traits. The highest heritability was for ear height (99.8%), while the lowest was revealed by ear diameter (61.9%). Kashiani *et al.* (2010) reported moderate heritability for number of kernels row^{-1} (42.6%) and ear diameter (46.7). Hefny (2011) obtained highest GA at both planting dates and high heritability values for yield plant^{-1} and 100-kernel weight. Amer and Mosa (2004), El-Shouny *et al.* (2005) and El-Hosary (2011) reported that heterosis and inbreeding depression were significant for grain yield and its components. Also, Amer and Mosa (2004), El-Shouny *et al.* (2005), El-Hosary (2011) and Nawar *et al.* (2011) found that the additive, dominance and epistatic gene effects were important in the inheritance of yield and its components; however the magnitude of dominance and epistatic gene effects contributed to a greater extent than the additive gene effects. Sofi and Rather (2006) and Hefny (2010) found that the dominance variance was greater than additive component for yield and its component in corn.

Estimates of the parameters do provide an indication of the relative importance of the various types of gene effects affecting the total genetic variation of a plant attribute. Therefore, the present work was carried out to study genetic variance, gene action, heritability and predicted genetic gain for yield and its components in three crosses of corn.

MATERIALS AND METHODS

Plant materials: Six inbred lines of yellow corn (*Zea mays* L.) i.e., P_1 (1012), P_2 (103), P_3 (100), P_4 (161), P_5 (120-B) and P_6 (313-A) developed by Prof. Dr. Ali Abd El-Maksoud El-Hosary Prof. of Agronomy, Fac. of Agric., Moshtohor, Benha Univ. were used to generate the experimental material for this study.

Field experiments: The experiments reported herein were carried out at the Research and Experimental Center of the Faculty of Agriculture at Moshtohor, Benha University, Egypt, during the three successive seasons 2009, 2010 and 2011. In summer season 2009 grains of six parents were sown on 17th and 23th May. The parents were crossed to obtain more enough hybrid seeds (F_1s) for three crosses i.e. ($P_1 \times P_2$ high diversity), ($P_3 \times P_4$ low diversity) and ($P_5 \times P_6$ moderate diversity). In summer season 2010, the F_1 grains of three crosses with their inbred lines were sown on 1st and 7th May and the F_1 plants were backcrossed to both inbred lines to produce Bc_1 ($F_1 \times P_1$) and Bc_2 ($F_1 \times P_2$) for each cross. In addition the F_2 seeds were obtained by selfed of F_1-plants. In 2011 season, the three experiments involved parents, F_1, F_2, Bc_1 and Bc_2 populations of each the three crosses were sown on 16th of May. Randomized Complete Block Design (RCBD) with three replications was used. For each cross, two ridges of each inbred lines and F_1; six ridges of each of the two backcrosses and 10 ridges of F_2 population were grown in ridges 6 m long and 70 cm width in one replication. Hills were spaced by 25 cm with three kernels per hill on one side of the ridge. The seedlings were thinned to one plant per hill. The plots were irrigated after sowing. The first irrigation was given after 21 days from sowing. The plants were irrigated at intervals of 10-15 days. The cultural practices were followed as usual for ordinary maize field in the area. The plots were informally fertilized at the rate of 120 kg of nitrogen per faddan given before the first and second irrigations, respectively. The other cultural practices of maize growing were properly practiced. Data were recorded for all guarded plants for ear length (cm), ear diameter (cm), No. of kernels row^{-1}, No. of rows ear^{-1}, 100-kernel weight (g), ear weight plant^{-1} (g) and grain yield plant^{-1} (g).

Statistical analysis of obtained data: Data of studied traits were statistically analyzed based on the genetic variance within F_2 population which was firstly evaluated if that variance is significant; various genetical parameters were then derived. Heterosis (H%) was expressed as percent increase of the F_1 performance above the mid-parent value. Inbreeding depression (I.d.%) was estimated as the average part decrease of F_2 from the average of F_1-F_2 deviation (E1) and backcross deviation (E2) were estimated as suggested by Mather and Jinks (1971). In addition, the six-parameter model proposed by Gamble (1962) was followed. Both broad and narrow-sense heritabilities (h^2b and h^2n, respectively) were calculated according to Mather's procedure (Mather, 1949). The expected genetic advance (ΔG) and genetic coefficient of variation (GCV%) were calculated according to Johnson *et al*. (1955). Also, potancy ratio (p) was calculated according to Smith (1952). All calculations were computed using Excel software.

RESULTS AND DISCUSSION

Number of plants, mean, variance, variances of mean and coefficient of variation of the traits studied in the three crosses for parents, F_1, F_2, Bc_1 and Bc_2 are presented in Table 1. These data represent the base for calculating other genetic parameters of this study. However, mean performance, variance and CV% of most first cross populations were much higher that other two crosses.

Table 1: Number of plants, generation mean, variance, mean variance and CV for the six generations of the three crosses and the studied characters

			Population					
Trait	Cross		P_1	P_2	F_1	F_2	Bc_1	Bc_2
Ear length (cm)	I ($P_1 \times P_2$)	No.	30	30	30	400	250	250
		Mean	13.67	14.07	19.37	18.54	19.00	18.92
		Variance	1.95	0.89	3.07	7.78	7.01	6.50
		Variance of mean	0.07	0.03	0.10	0.02	0.03	0.03
		CV	10.23	6.71	9.04	15.05	13.93	13.48
	II ($P_3 \times P_4$)	No.	30	30	30	400	250	250
		Mean	12.63	13.47	14.03	12.36	11.82	11.58
		Variance	0.06	1.15	1.13	5.78	5.82	4.18
		Variance of mean	0.00	0.04	0.04	0.01	0.02	0.02
		CV	1.99	7.98	7.56	19.46	20.41	17.66
	III ($P_5 \times P_6$)	No.	30	30	30	400	250	250
		Mean	15.40	13.47	18.63	14.45	13.39	14.03
		Variance	1.28	1.15	1.30	6.98	5.83	6.58
		Variance of mean	0.04	0.04	0.04	0.02	0.02	0.03
		CV	7.35	7.98	6.12	18.29	18.03	18.28
Ear diameter (cm)	I ($P_1 \times P_2$)	No.	30	30	30	400	250	250
		Mean	2.94	2.42	3.41	2.65	3.15	3.29
		Variance	0.03	0.03	0.05	1.39	0.80	1.20
		Variance of mean	0.00	0.00	0.00	0.00	0.00	0.00
		CV	6.29	6.72	6.49	44.57	28.42	33.27
	II ($P_3 \times P_4$)	No.	30	30	30	400	250	250
		Mean	2.26	2.36	3.11	2.18	1.98	2.27
		Variance	0.01	0.02	0.10	1.16	0.81	0.95
		Variance of mean	0.00	0.00	0.00	0.00	0.00	0.00
		CV	4.59	5.95	10.16	49.52	45.49	42.87

Table 1: Continue

Trait	Cross		Population					
			P_1	P_2	F_1	F_2	Bc_1	Bc_2
	III ($P_5\times P_6$)	No.	30	30	30	400	250	250
		Mean	2.14	2.36	3.21	1.89	0.95	0.85
		Variance	0.01	0.02	0.18	1.80	1.30	1.40
		Variance of mean	0.00	0.00	0.01	0.00	0.01	0.01
		CV	5.15	5.95	13.24	70.99	120.02	139.20
No. of rows ear^{-1}	I ($P_1\times P_2$)	No.	30	30	30	400	250	250
		Mean	10.93	11.20	16.80	14.62	15.44	15.28
		Variance	1.03	0.99	0.99	3.52	2.80	2.70
		Variance of mean	0.03	0.03	0.03	0.01	0.01	0.01
		CV	9.28	8.90	5.93	12.83	10.83	10.75
	II ($P_3\times P_4$)	No.	30	30	30	400	250	250
		Mean	13.53	13.52	15.47	14.96	12.04	12.56
		Variance	0.74	0.74	0.44	3.00	2.60	2.54
		Variance of mean	0.02	0.02	0.01	0.01	0.01	0.01
		CV	6.36	6.36	4.27	11.58	13.37	12.69
	III ($P_5\times P_6$)	No.	30	30	30	400	250	250
		Mean	11.67	13.53	15.00	13.41	13.01	14.00
		Variance	0.85	0.74	0.60	3.39	3.55	2.75
		Variance of mean	0.03	0.02	0.02	0.01	0.01	0.01
		CV	7.91	6.36	5.16	13.73	14.49	11.85
No. of kernel row^{-1}	I ($P_1\times P_2$)	No.	30	30	30	400	250	250
		Mean	18.73	15.00	31.07	26.00	29.21	27.15
		Variance	2.82	2.14	2.06	8.52	7.50	6.58
		Variance of mean	0.09	0.07	0.07	0.02	0.03	0.03
		CV	8.97	9.75	4.62	11.23	9.38	9.45
	II ($P_3\times P_4$)	No.	30	30	30	400	250	250
		Mean	17.90	22.63	33.57	23.35	20.72	23.58
		Variance	1.82	2.93	3.87	5.86	4.70	4.57
		Variance of mean	0.06	0.10	0.13	0.01	0.02	0.02
		CV	7.53	7.56	5.86	10.36	10.46	9.07
	III ($P_5\times P_6$)	No.	30	30	40	400	250	250
		Mean	18.80	22.63	38.00	28.69	28.01	32.09
		Variance	2.79	2.93	2.16	7.90	5.60	6.60
		Variance of mean	0.09	0.10	0.05	0.02	0.02	0.03
		CV	8.88	7.56	3.86	9.79	8.45	8.00
100-kernel weight (g)	I ($P_1\times P_2$)	No.	30	30	30	400	250	250
		Mean	27.90	28.00	35.77	30.95	33.38	31.04
		Variance	7.68	4.83	9.63	18.32	16.67	13.48
		Variance of mean	0.26	0.16	0.32	0.05	0.07	0.05
		CV	9.93	7.85	8.68	13.83	12.23	11.83
	II ($P_3\times P_4$)	No.	30	30	30	400	250	250
		Mean	26.23	28.77	33.90	22.73	22.09	24.31
		Variance	0.46	5.91	2.10	11.79	7.79	8.22
		Variance of mean	0.02	0.20	0.07	0.03	0.03	0.03
		CV	2.59	8.45	4.27	15.11	12.63	11.79

Table 1: Continue

Trait	Cross		Population P$_1$	P$_2$	F$_1$	F$_2$	Bc$_1$	Bc$_2$
	III (P$_5$× P$_6$)	No.	30	30	30	400	250	250
		Mean	31.97	28.30	35.40	30.50	23.56	23.15
		Variance	2.62	0.42	2.17	16.61	14.03	12.27
		Variance of mean	0.09	0.01	0.07	0.04	0.06	0.05
		CV	5.07	2.30	4.16	13.36	15.90	15.13
Ear weight plant^{-1} (g)	I (P$_1$× P$_2$)	No.	30	30	30	400	250	250
		Mean	93.07	79.13	205.16	107.19	152.24	165.04
		Variance	12.83	17.50	18.43	641.22	423.50	359.60
		Variance of mean	0.43	0.58	0.61	1.60	1.69	1.44
		CV	3.85	5.29	2.09	23.62	13.52	11.49
	II (P$_3$× P$_4$)	No.	30	30	30	400	250	250
		Mean	58.42	92.23	174.15	84.93	80.10	101.51
		Variance	47.84	36.41	30.51	593.25	455.52	352.65
		Variance of mean	1.59	1.21	1.02	1.48	1.82	1.41
		CV	11.84	6.54	3.17	28.68	26.65	18.50
	III (P$_5$× P$_6$)	No.	30	30	30	400	250	250
		Mean	63.87	83.30	220.20	155.66	104.23	108.47
		Variance	15.09	17.79	18.60	673.26	545.90	490.56
		Variance of mean	0.50	0.59	0.62	1.68	2.18	1.96
		CV	6.08	5.06	1.96	16.67	22.42	20.42
Grain weight plant^{-1} (g)	I (P$_1$× P$_2$)	No.	30	30	30	400	250	250
		Mean	74.17	57.27	159.88	104.50	127.34	113.09
		Variance	54.56	7.10	55.67	922.40	703.35	663.77
		Variance of mean	1.82	0.24	1.86	2.31	2.81	2.66
		CV	9.96	4.65	4.67	29.06	20.83	22.78
	II (P$_3$× P$_4$)	No.	30	30	30	400	250	250
		Mean	48.59	69.36	140.50	69.17	64.15	76.74
		Variance	28.74	25.26	36.58	700.25	661.34	560.37
		Variance of mean	0.96	0.84	1.22	1.75	2.65	2.24
		CV	11.03	7.25	4.30	38.25	40.09	30.85
	III (P$_5$× P$_6$)	No.	30	30	30	400	250	250
		Mean	31.90	69.36	95.73	56.87	85.43	85.43
		Variance	17.54	22.26	25.57	563.96	523.50	305.26
		Variance of mean	0.58	0.74	0.85	1.41	2.09	1.22
		CV	13.13	6.80	5.28	41.76	26.78	20.45

At first, parental mean differences and genetic variances among F$_2$ plant were calculated and tested for statistical significance Table 2. All characters studied showed significant genetic variance in F$_2$ plants in three crosses and therefore other parameters needed were estimated in appropriate manner. Consequently the genetic parameters can be calculated according to the proposed equations of Mather and Jinks (1971) and Gamble (1962).

Heterosis, potancy ratio, inbreeding depression, F$_2$-deviation and backcross deviation in the three crosses are given in Table 3. Highly significant positive heterotic effects were detected for all studied traits. As it well known, number of rows and No. of kernels row^{-1} and 100-kernel weight are the main components for grain yield in corn. Hence, heterotic increase, if it is found in one or

Table 2: Mean performance of parents, T-test of difference between parents and F-test of genetic variance among F_2 plants of the three crosses for the studied traits

Character	Cross	P_1	P_2	t-test	F-test
Ear length (cm)	I ($P_1\times P_2$)	13.67	14.07	-1.30	3.95**
	II ($P_3\times P_4$)	12.63	13.47	-4.17**	7.41**
	III ($P_5\times P_6$)	15.40	13.47	6.78**	5.61**
Ear diameter (cm)	I ($P_1\times P_2$)	2.94	2.42	11.56**	38.04**
	II ($P_3\times P_4$)	2.26	2.36	-3.14**	26.79**
	III ($P_5\times P_6$)	2.14	2.36	-6.64**	25.40**
No. of rows ear^{-1}	I ($P_1\times P_2$)	10.93	11.20	-1.03	3.50**
	II ($P_3\times P_4$)	13.53	13.52	0.06	4.70**
	III ($P_5\times P_6$)	11.67	13.53	-8.11**	4.64**
No. of kernel row^{-1}	I ($P_1\times P_2$)	18.73	15.00	9.18**	3.64**
	II ($P_3\times P_4$)	17.90	22.63	-11.90**	2.04**
	III ($P_5\times P_6$)	18.80	22.63	-8.78**	3.01**
100 - kernel weight (g)	I ($P_1\times P_2$)	27.90	28.00	-0.15	2.48**
	II ($P_3\times P_4$)	26.23	28.77	-5.50**	4.18**
	III ($P_5\times P_6$)	31.97	28.30	11.50**	9.55**
Ear weight plant^{-1} (g)	I ($P_1\times P_2$)	93.07	79.13	13.86**	39.46**
	II ($P_3\times P_4$)	58.42	92.23	-20.18**	15.51**
	III ($P_5\times P_6$)	63.87	83.30	-18.56**	39.24**
Grain yield^{-1}	I ($P_1\times P_2$)	74.17	57.27	11.79**	23.59**
	II ($P_3\times P_4$)	48.59	69.36	-15.48**	23.19**
	III ($P_5\times P_6$)	31.90	69.36	-32.52**	25.88**

*and **indicated significance at 0.05 and 0.01 levels of probability, respectively

Table 3: Heterosis, potence ratio, inbreeding depression, F_2, deviation and backcross deviation in the three crosses for studied traits

Character	Cross	Heterosis Mp	Potence ratio	Inbreeding depression	Deviation E1	Deviation E2
Ear length (cm)	I ($P_1\times P_2$)	39.66**	27.50	4.27**	1.92**	4.68**
	II ($P_3\times P_4$)	7.56**	2.35	11.95**	-1.18**	-3.69**
	III ($P_5\times P_6$)	29.10**	4.34	22.47**	-2.09**	-5.64**
Ear diameter (cm)	I ($P_1\times P_2$)	27.11**	2.79	22.36**	-0.40**	0.35**
	II ($P_3\times P_4$)	34.46**	15.92	29.91**	-0.53**	-1.16**
	III ($P_5\times P_6$)	42.56**	8.85	41.12**	-0.84**	-3.66**
No. of rows ear^{-1}	I ($P_1\times P_2$)	51.81**	43.00	13.00**	0.68**	2.86**
	II ($P_3\times P_4$)	14.34**	291.01	3.28**	0.46**	-4.39**
	III ($P_5\times P_6$)	19.05**	2.57	10.62**	-0.39**	-0.59*
No. of kernels row^{-1}	I ($P_1\times P_2$)	84.19**	7.61	16.31**	2.03**	8.42**
	II ($P_3\times P_4$)	65.63**	5.62	30.44**	-3.57**	-9.53**
	III ($P_5\times P_6$)	83.43**	9.02	24.51**	-0.67**	1.39**
100 - kernel weight (g)	I ($P_1\times P_2$)	27.97**	156.33	13.47**	-0.91*	0.71
	II ($P_3\times P_4$)	23.27**	5.05	32.95**	-7.97**	-15.00**
	III ($P_5\times P_6$)	17.48**	2.87	13.83**	-2.26**	-18.83**
Ear weight plant^{-1} (g)	I ($P_1\times P_2$)	138.29**	17.09	47.76**	-38.45**	26.02**
	II ($P_3\times P_4$)	131.21**	5.85	51.23**	-39.80**	-67.87**
	III ($P_5\times P_6$)	199.25**	15.09	29.31**	8.77**	-81.08**
Grain yield plant^{-1}	I ($P_1\times P_2$)	143.28**	11.14	34.64**	-8.30**	14.84**
	II ($P_3\times P_4$)	138.24**	7.85	50.77**	-30.56**	-58.58**
	III ($P_5\times P_6$)	89.08**	2.41	40.60**	-16.31**	24.49**

*,**Significanct at 0.05 and 0.01 levels of probability, respectively

more of the three traits, may lead to considerable yield increase in hybrids. It is worth noting that heterotic effect for grain yield was larger in magnitude than for any one of its components which is logically expected. The significance of heterotic effects show that non-additive genetic type of gene action affects such traits. These results were previously reported by El-Shouny *et al.* (2005) and Abou-Deif (2007).

Potence ratio (P) was calculated to study the nature and degree of dominance for all characters studied. The results indicated that (P) values exceeded the unity in all traits. Over dominance towards the higher parent was detected for all traits under test. Generally, potence values followed the same trend as heterotic effects for all traits. These results are in agreement with those obtained by Sedhom (1988), El Hosary and Abd El Satar (1998), Edwards and Lamkey (2002), El-Shouny *et al.* (2005) and Abou-Deif (2007). However, Sofi and Rather (2006) reported that the degree of dominance was in the range of over dominance for studied traits.

Highly significant positive inbreeding depression was detected for all studied traits. Both heterosis and inbreeding depression effects as it is well known are two coincides to a same particular phenomenon. Therefore, it is logically to expect that heterosis in F_1 will be followed by an appreciable reduction in the F_2 performance and vice versa. These results were harmony with the previous results obtained by Sedhom (1988), Amer and Mosa (2004), El-Shouny *et al.* (2005) and Abou-Deif (2007).

Significant F_2 deviations (E1) and backcrosses deviations (E2) were obtained for all traits except (E2) for 100-kernel weight in the first cross. It is worth noting that F_2 deviation was mostly accompanied by backcross deviation of significance. Also, the presence of appreciable epistatic deviations along with the large heterotic effects and the existence of over-dominance detected herein in most cases may reveal the great role of inter-allelic gene effects on the performance of these cases.

Nature of gene action was studied according to the relationships illustrated by Gamble (1962). The estimated values for each of the six parameters with their test of significance in all traits studied are shown in Table 4. In the all traits studied, the estimated mean effect parameters (m), which reflects the contribution due to the over-all mean plus the locus effects and interaction of the fixed loci, was highly significant.

Significant additive gene effects were found for No. of kernels row^{-1}, ear weight plant^{-1} in the three crosses, No. of rows ear^{-1}, grain yield plant^{-1} and 100-kernel weight in the first and second cross, ear length in the third cross and ear diameter in the second cross. These results are agreement with those obtained by Sedhom (1988), Khalil (1999), Amer and Mosa (2004), El-Shouny *et al.* (2005), Abou-Deif (2007) and El-Hosary (2011). Sofi (2007) reported that the genetic components of variance revealed that both additive and dominance components were significant for all studied traits except ear diameter where dominance variance was non-significant.

The dominance gene effect (d) was significant for all traits in the three crosses except ear length in the third cross. Dominance effects were higher in magnitude than additive gene effect. The negative value of dominance demonstrates that the smaller mean value parent had the dominant genes responsible for these cases.

Additive × additive (aa) epistatic type of gene action was significant for all traits, except ear diameter and grain yield plant^{-1} in the second cross and No. of rows ear^{-1} in the third cross. Also, additive × dominance gene effects were significant for all traits except ear length, No. of rows ear^{-1} and No. of kernel row^{-1} in the first cross, No. of kernels row^{-1} and grain yield plant^{-1} in the second cross and No. of rows ear^{-1} in the third cross. Dominance x dominance gene effects were significant

Table 4: Parameters of gene effects relating to studied traits in the three crosses

		Gene action six parameters (Gamble producer)					
Trait	Cross	Main effect	Additive (a)	Dominance (d)	add. X add. (aa)	add.xdom. (ad)	dom.xdom. (dd)
Ear length (cm)	I ($P_1 \times P_2$)	18.54**	0.08	7.17**	1.67*	0.28	-11.04**
	II ($P_3 \times P_4$)	12.36**	0.24	-1.65*	-2.64**	0.66**	10.01**
	III ($P_5 \times P_6$)	14.45**	-0.64**	1.26	-2.94**	-1.61**	14.23**
Ear diameter (cm)	I ($P_1 \times P_2$)	2.65**	-0.15	3.02**	2.30**	-0.41**	-3.00**
	II ($P_3 \times P_4$)	2.18**	-0.29**	0.59*	-0.20	-0.24**	2.53**
	III ($P_5 \times P_6$)	1.89**	0.10	-3.00**	-3.96**	0.21*	11.28**
No. of rows ear^{-1}	I ($P_1 \times P_2$)	14.62**	0.16	8.72**	2.99**	0.29	-8.71**
	II ($P_3 \times P_4$)	14.96**	-0.51**	-8.70**	-10.64**	-0.52**	19.43**
	III ($P_5 \times P_6$)	13.41**	-0.99**	2.80**	0.40	-0.06	0.78
No. of kernels row^{-1}	I ($P_1 \times P_2$)	26.00**	2.07**	22.91**	8.71**	0.20	-25.55**
	II ($P_3 \times P_4$)	23.35**	-2.86**	8.50**	-4.80**	-0.49	23.87**
	III ($P_5 \times P_6$)	28.69**	-4.08**	22.75**	5.46**	-2.17**	-8.24**
100-kernel weight (g)	I ($P_1 \times P_2$)	30.95**	2.34**	12.87**	5.06**	2.39**	-6.48**
	II ($P_3 \times P_4$)	22.73**	-2.21**	8.28**	1.88*	-0.94**	28.12**
	III ($P_5 \times P_6$)	30.50**	0.41	-23.34**	-28.60**	-1.43**	66.26**
Ear weight plant^{-1} (g)	I ($P_1 \times P_2$)	107.19**	-12.81**	324.88**	205.82**	-19.77**	-257.86**
	II ($P_3 \times P_4$)	84.93**	-21.41**	122.31**	23.48**	-4.50*	112.25**
	III ($P_5 \times P_6$)	155.66**	-4.23*	-50.62**	-197.24**	5.48**	359.41**
Grain yield plant^{-1}	I ($P_1 \times P_2$)	104.50**	14.24**	157.03**	62.87**	5.79*	-92.55**
	II ($P_3 \times P_4$)	69.17**	-12.59**	86.61**	5.08	-2.20	112.08**
	III ($P_5 \times P_6$)	56.87**	0.01	159.33**	114.23**	18.73**	-163.22**

*,**Significanct at 0.05 and 0.01 levels of probability, respectively

for all traits in the three crosses except No. of rows ear^{-1} in the third cross. The majority of dominance x dominance gene effects were of negative values for nine cases from twenty one. The absolute relative magnitudes of the epistatic gene effects to the mean effects were somewhat variable depending on the cross and trait studied. Generally, the absolute magnitudes of the epistatic effects were larger than both additive or dominance gene effects for most traits. These results agree with the idea that the inheritance of quantitative character is generally more complex than simple qualitative characters. By other words, the study further revealed that epistatic gene effects, especially additive x additive and dominance x dominance gene effects for most traits of the studied traits were as important as additive and dominance gene effects. The failure to detect epistatic gene effects, based on the generation mean analysis dose not necessarily indicates that nonallelic interactions play no role in the determination of phenotypic values. Ngaboyisonga *et al.* (2009) found that the grain yield was controlled by additive, non-additive and maternal effects of gene action. El-Hosary (2011) has also reported the importance of the three types of epistasis. However, Sofi and Rather (2006) found that the dominance variance was greater than additive component for all traits. Hefny (2010) the results showed that, the magnitude of non-additive variance was higher than additive for all studied traits, except ear diameter.

Heritability in broad and narrow sense, genetical gain and genetic coefficient of variation (GCV%) for the studied traits are presented in Table 5. High genetic coefficient of variation for ear diameter, ear weight/plant and grain yield plant^{-1}, in the three crosses was detected. However, moderate values were obtained for the remain traits. Using the genetic coefficient of variation

Table 5: Heritability estimates, genetic advance (Δg), genetic advance expected as a percentage of the mean for the studied traits and genetic coefficient of variation GCV% in the three crosses

Cross parameter	Ear length I ($P_1 \times P_2$)	Ear length II ($P_3 \times P_4$)	Ear length III ($P_5 \times P_6$)	Ear diameter I ($P_1 \times P_2$)	Ear diameter II ($P_3 \times P_4$)	Ear diameter III ($P_5 \times P_6$)	No. of rows ear^{-1} I ($P_1 \times P_2$)	No. of rows ear^{-1} II ($P_3 \times P_4$)	No. of rows ear^{-1} III ($P_5 \times P_6$)	No. of kernels row^{-1} I ($P_1 \times P_2$)	No. of kernels row^{-1} II ($P_3 \times P_4$)	No. of kernels row^{-1} III ($P_5 \times P_6$)
h^2. broad	74.67	86.50	82.16	97.37	96.27	96.06	71.42	78.71	78.43	72.51	50.94	66.76
h^2. narrow	26.37	27.16	22.37	56.12	48.54	50.00	43.66	28.83	13.85	34.74	41.77	45.50
Δg	1.52	1.35	1.22	1.36	1.08	1.38	1.69	1.03	0.52	2.09	2.08	2.63
(Δg%)	8.17	10.89	8.43	51.53	49.51	73.12	11.54	6.88	3.92	8.03	8.92	9.18
GCV%	13.00	18.10	16.58	43.98	48.58	69.58	10.84	10.27	12.16	9.56	7.40	8.00

Cross parameter	100-kernel weight I ($P_1 \times P_2$)	100-kernel weight II ($P_3 \times P_4$)	100-kernel weight III ($P_5 \times P_6$)	Ear weight plant^{-1} I ($P_1 \times P_2$)	Ear weight plant^{-1} II ($P_3 \times P_4$)	Ear weight plant^{-1} III ($P_5 \times P_6$)	Grain yield plant^{-1} I ($P_1 \times P_2$)	Grain yield plant^{-1} II ($P_3 \times P_4$)	Grain yield plant^{-1} III ($P_5 \times P_6$)
h^2. broad	59.72	76.05	89.53	97.47	93.55	97.45	95.76	95.69	96.14
h^2. narrow	35.40	64.24	41.67	77.87	63.77	46.05	51.79	25.53	53.05
Δg	3.12	4.54	3.50	40.62	32.00	24.62	32.40	13.92	25.95
(Δg%)	10.09	19.99	11.47	37.90	37.67	15.81	31.00	20.12	45.63
GCV%	10.69	13.17	12.64	23.32	27.74	16.46	28.44	37.42	40.94

*,**Significant at 0.05 and 0.01 levels of probability, respectively, Δg%: Genetic advance%

alone, however, it is impossible to estimate the magnitude of heritable variation. The heritable portion of the variation could be found out with the help of heritability estimates and genetic gain under selection (Swarup and Chaugale, 1962).

High heritability values in broad sense were detected for all traits in the three crosses except No. of kernels row^{-1} and 100-kernel weight in the second and first cross, respectively. For the exceptional case, moderate heritability values were obtained. Saleh *et al.* (2002) reported that broad sense heritability estimates for grain yield in maize were generally moderate. Barakat (2003) found that heritability was 61.4% for grain yield plant^{-1}. Ali *et al.* (2003) found that broad-sense heritability in sweet corn population was moderate to high for the traits studied. The highest estimate was for ear height (99.8%), while the lowest was revealed by ear diameter (61.9%). Kashiani *et al.* (2010) reported moderate heritability for number of kernels row^{-1} (42.6%) and ear diameter (46.7).

Heritability in narrow sense was computed according to Mather's procedure on the basis of F_2 and back crosses.

High heritability in narrow sense was detected for ear diameter and ear weight plant^{-1} in the three crosses, No. of kernels row^{-1} in the third cross and grain yield plant^{-1} in the first and second cross and 100-kernel weight in the second cross. Moderate to low heritability values in narrow sense were detected for the other cases in the three crosses.

For No. of kernels row^{-1} and 100-kernel weight in the second cross heritability in narrow sense was high in magnitude and equals its corresponding in the broad. This revealed that the genetic variance for both traits in this cross was mostly attributed to additive effects of genes.

For ear diameter, ear weight plant^{-1} in the three crosses, grain yield plant^{-1} in the first cross and No. of kernels row^{-1} and 100-kernel weight in the third cross, heritability values in narrow sense were high to moderate. It is interesting to note that the resultant values in these cases were more or less of equal magnitude with the corresponding broad ones. This finding logically leads to the conclusion that additive genetic action was predominant, the results which was not reached by means of gene action studies. In these cases, estimates for epistatic types were significant and of large magnitude, side by side with appreciable values for the additive ones. As previously mentioned, values for additive genetic variation computed by means of genetics models assuming negligible epistasis would be higher than the anticipated ones, causing an upward estimate for heritability in narrow sense. This is exactly the case obtained herein where high values for heritability in narrow means were computed while rather moderate ones were expected. In addition Comstock (1955) stated that the presence of epistatic gene effects will cause an upward bias in the estimate of additive genetic variance. Gamble (1962) also reported that genetic model assuming negligible epistasis may be an important source of bias in the estimate of additive genetic variance and inclusion of epistasis in such models would perhaps decrease the amount of additive one.

For other or reaming cases in the three crosses narrow sense heritability values were low and much lower than those of broad sense indicating that most of genetic variance was due to non-additive effects i.e., dominance and/ or epistasis. This finding ascertained the previously studies on the nature of gene action where the non-additive gene effects were found to have a great role in these traits. Such results are in agreement with that obtained by several investigators, Khalil (1999), El-Shouny *et al.* (2005) and Abou-Deif (2007) who obtained high to moderate heritability values for ear length and ear diameter. Hefny (2011) obtained high heritability values for yield plant^{-1}. Warner (1952), El-Ebrashy (1961), Fadhi (1978) and Sedhom (1988) reported low values of heritability in narrow sense for grain yield plant^{-1}.

With the exception of ear length, No. of rows ear^{-1}, No. of kernels row^{-1} and 100-kernel weight in the three crosses, the results indicated that the predicted genetic advance expressed as the percentage of the mean was moderate to high for all the studied traits. For the exceptional cases, low GA% was detected (Table 5). Johnson *et al.* (1955) reported that heritability estimates along with genetic gain are usually more useful than the heritability values alone in predicting the resultant effect for selecting the best individuals. On the other hand, heritability is not always associated with high genetic advance, but to make effective selection, high heritability should be associated with high genetic gain. Barakat (2003) found that heritability and the expected genetic values were 61.4 and 7.97% for grain yield plant^{-1}, respectively. Hefny (2011) obtained highest GA at both planting dates and high heritability values for yield plant^{-1} and 100-kernel weight. In the present work relative high genetic gain was found to be associated with rather high to moderate heritability estimates for ear diameter and ear weight plant^{-1} in the three crosses, grain yield plant^{-1} in the first and third crosses and 100-kernel weight in the second cross. Therefore, selection for these cases in these particular populations should be effective and satisfactory for successful breeding purposes. For grain yield plant^{-1} in the second cross, high genetic gain was associated with low heritability values. In spite of the relative low heritability in narrow sense computed in this case, estimates of additive genetic effects were highly significant therefore, it could be suggested that selection for these traits in subsequent generations will be relatively more effective than in the early F_2 generation. It could be concluded that the highest genetic advance detected for this trait, in spite of low heritability estimates, may be due to a relatively range of variability in this population.

For No. of rows ear^{-1} in the first cross, No. of kernels row^{-1} in the second and third cross and 100-kernel weight in the third cross moderate genetic advance was associated with moderate heritability values. In spite of the relative moderate heritability in narrow sense computed in these traits, estimates of additive or additive by additive genetic effects was highly significant. Therefore, it could be suggested that selection for these traits in subsequent generations will be relatively more effective than the early F_2 generation. Relatively low genetic gain was associated with low heritability values were detected for other cases. Hence, selection for these cases may be less effective.

CONCLUSION

From the previous results it could be concluded that heterosis values were positive and highly significant for all studied traits and over dominance towards the higher parent was detected for all traits since the potence ratio (P) values exceeded the unity in the three crosses. Non additive gene action seemed to play the most important role in the inheritance of most studied traits in the three crosses since the magnitude of dominance and different types of epistasis were much higher in magnitude that of additive effects. High heritability values in narrow sense were accompanied with either higher or moderate genetic advance upon selection particularly for ear diameter, ear weight and grain yield in at least two studied crosses. Such results indicated the effectiveness of selection processes in subsequent generations for these traits. For ear length where low heritability values in broad sense were associated with low genetic advance in the three crosses the selection may be less effective.

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