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HETEROTIC PATTERN IN VARIETY CROSSES AMONG EIGHT WHITE MAIZE POPULATIONS (*Zea mays*, L.)

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ABSTRACT

Diallel crosses for a fixed set of 8 white maize populations characterized by earliness, short plants and high yield potentiality were made at Gemmeiza during 2000 summer season. The 8 parents, i.e. Pop-4956, Coposite-5, Giza-2,Tuxpino Pop-402, Across-8562, GWP and Laposta, along with their 28 F_1's (not including reciprocals) were evaluated at Sakha, Gemmeiza, Sids and Mallawy Agric. Res. Stats. during 2001 season. Eberhart and Gardner (1966) model was applied to determine different types of heterosis and other genetic components. Results indicated that the performance of variety crosses in terms of grain yield and other agronomic traits was superior over mid- and high parent values in most crosses. Both variety and average heterosis source of variation were highly significant for all traits. This indicate that all populations differed greatly in the heterotic pattern respecting studied traits. Specific heterosis was also significant for grain yield and other traits. Seventeen variety crosses out of the 28 F_1 crosses were significantly as high yielding as the highest parent variety viz, GWP (19.69 ard/fad). However, three of these variety crosses, i.e Across 8562 x Laposta (25.03 ard/fad), Comp-5 x Laposta (24.46 ard/fad) and GWP x Laposta (23.62 ard/fad) were significantly higher yielding than the common parent, Laposta. The average variety heterosis relative to mid-parent ranged from –13.52 to 17.65, -5.53 to 21.55, -21.68 to 26.51, -1.61 to 18.31, -0.76 to -66.00, and –48.69 to 44.79 for silking date, plant and ear height, number of ears/100 plants, grain yield per faddan and per plant, respectively. Generally, the highest mid-parent heterosis was manifested by the lowest yielding variety (Pop-402 and Laposta) and vice versa. However, 26, 14, 14, 14, 28 and 17 variety crosses exhibited significant values of mid-parent heterosis for all traits, respectively. It was concluded that non-additive gene effects and gene frequency of the two varieties Pop-402 and Laposta were differed greatly than that of other parents, for this reason it can be recommended to use these varieties for further breeding studies in the hybridisation program.

INTRODUCTION

Inter- and intra-population improvement in maize breeding program had great important in maize breeding since these populations can be used *per si* as an open-pollinated variety and/or as a valuable source for new inbred lines with good performance. Therefore, evaluation of a particular set of varieties or populations belonging to different and wide heterotic groups and their variety crosses aims to estimate different pattern of heterosis and combining ability. Burton *et al*, 1971, Eberhart, 1971, Horner *et al* (1972) and Russel *et al* (1973) mentioned that composite or synthetic maize varieties can be developed to increase the frequency of more desirable alleles for specific traits and to incorporate exotic germplasm into adapted variety. They added also that a diallel cross analysis of a fixed set of populations provides the basis for a preliminary analysis of heterotic pattern among studied population crosses.

A better understanding of the intervarietal heterosis in a series of variety crosses diallel expressed as components of means and different types of heterosis was given by Gardner and Eberhart (1966). They expressed an intervarietal cross mean by:

$$Yij^1 = u + \frac{1}{2}(v_i + v_j) + \bar{h} + hi + hj + sij'$$

where μ = mean of n parental lines

hi = varity heterosis of ith vaireties

hj = varity heterosis of jth vaireties

Sij = specific heterosis of the ith varietey crossed with jth varitey. Total heterosis is further partitioned into three components,

$$h_{ij'} = \bar{h} + h_i + h_{j'} + s_{ij'}$$

Hallauer and Miranda (1981) provided a suitable interpretation of different heterotic pattern, *i.e.* average heterosis (h_i), variety heterosis ($V_{jj'}$) and specific heterosis ($S_{j'j}$), which greatly coincide with that estimated by Griffing's (1956) model (Method 2 and/or method 4). They also mentioned that, in most instances, the choice of parental varieties for heterosis exploitation can be based on the average yield of varieties *per se* and on the superiority of their crosses in one or more of the most important traits (*e.g.* yield, plant type and disease resistance). However, many investigators (Castor *et al* 1968, Hallauer and Sears 1968, Sprague and Eberhart 1977, Hallauer and Miranda 1981, El Nagouly *et al* 1988 and Soliman *et al* 1999) revealed that the specific heterosis (or dominance effect) was more important when several widely divergent varieties with similar yield potential were crossed. The mean yield of such variety crosses was indicated to be higher than the average of the parental varieties when dominance effect was important.

Isolateting and releasing of new inbred lines of maize with better yield performance and resistant to different diseases are among the main targets of the National Maize Research Program of ARC. Therefore, an intervarietal diallel cross in, the recent study, was undertaken at Gemmeiza Research Stat between eight wide divergent varieties and populations in order to identify the outstanding varieties and/or populations and their crosses for further utilization in population improvement and hybridization program.

MATERIALS AND METHODS

The basic populations from which the present study was conducted were 8 open-pollinated white maize varieties and populations differed in their origin and belonging to different heterotic groups. These varieties are: Pop-4956, Composite 5 (Comp 5), Giza 2, Tuxpino, Pop-402, Across 8562, GWP (Gemmeiza white population) and Laposta.

The 8 varieties were intercrossed in 2000 season at Gemmeiza Agric. Res. Stat to produce 28 intervarietal crosses (F_1's) . More than 100 plants from each variety were used in the population to form F_1 cross. The varieties were increased by sib-mating for 100 plants within each variety.

The 8 varieties and there 28 F_1 crosses were evaluated at 4 locations, ***viz*** Sakha, Gemmeiza, Sids, and Mallawy Res. Stat, ARC during 2001 summer season. The experimental design used at each location was a randomized complete block design with 4 replicates. Plot size was 2 rows, 6 m long and 80 cm apart (9.6 m^2). Planting was done in hills (3-4 kernels/hill) spaced 25 cm along the row. Thinning to one plant/hill was done, 21 days after planting to achieve population density of 21875 plants/fad). All other agronomic and cultural practices were done as normally practiced in research stations. Field weight for each plot was calibrated to grain yield per faddan and per plant adjusted to 15.5% moisture.

Data were recorded for number of days from planting to 50% silking, plant and ear height (cm), number of ears/100 plants, grain yield in ard/fad and grain yield/plant in grams. Analysis of variance for separate location and combined was made according to Steel and Torrie (1969). The combined data for the studied characters were used herein since the homogeneity among error variances for separate location was found to be insignificant according to Partlett test. Different types of heterotic pattern were estimated following the model of Gardner and Eberhart (1966). To test the significances among different variety and specific heterosis as well as their effects, the least significant differences (LSD) were calculated according to Singh (1978). Also, significance of differences among mid-parent heterosis was calculated according to Bhatt (1971).

RESULTS AND DISCUSSION

Average performance of the 8 maize varieties and populations and their 28 intercrosses and heterotic pattern analysis (Table 1 and 2), indicated that highly significant differences were found among varieties and variety crosses for all studied traits. However, the differences attributable to the parental varieties were more than that of total heterosis ($h_{ij'}$) for all traits, except for number of ears/100 plants and grain yield.

According to Gardner and Eberhart (1966) model, the total heterosis was partitioned into average heterosis ($\bar{h}$), variety heterosis(hij') and specific heterosis ($s_{ij'}$). It was obviously clear that average heterosis was the major source of the total heterosis for all traits except days to 50% silking, followed by variety heterosis and specific heterosis. This indicated that the studied varieties differed in gene frequency and non-additive effects for all the studied traits and that the heterotic pattern of a particular variety is quite different from other when it was crossed with the remaining varieties. It is worth noting that all sources of heterosis were highly significant interacted with locations in case of all studied traits. This indicated that the heterotic expression differed remarkably in different environments.

Table 1: Means of grain yield and other agronomic traits for eight varieties and their 28 F_1 crosses , data are combined over 4 locations in 2001

Entry name	Days to 50% silking	Plant height cm	Ear height cm	No. of ears/100 plant	Grain Yield ard/fad	Grain yield/ plant g
Varieties per se						
Pop-4956	54.0	201.3	100.1	90.5	8.66	62.6
Composite 5	63.7	253.8	140.8	94.8	18.15	130.7
Giza 2	57.2	230.2	128.4	97.9	19.37	138.0
Tuxpino	57.4	232.4	127.4	95.0	17.69	119.5
Pop-402	60.3	189.3	102.4	80.6	7.11	51.7
Across-8562	64.7	232.1	135.2	99.3	14.23	109.1
G.W.P	57.7	244.2	135.8	94.4	19.69	136.6
Laposta	73.8	259.5	169.4	81.8	8.91	66.0
Variety crosses						
Pop–4956 x Composite 5	66.6	255.8	154.7	90.9	15.38	106.5
Pop–4956 x Giza 2	66.6	250.1	142.1	95.3	15.98	109.4
Pop–4956 x Tuxpino	56.9	223.6	121.0	95.0	18.47	127.0
Pop–4956 x Pop-402	59.3	244.3	135.6	103.4	21.14	139.9
Pop–4956 x Across-8562	59.8	250.3	136.7	94.9	20.85	140.2
Pop–4956 x GWP	63.3	250.0	141.9	94.1	19.92	135.4
Pop–4956 x Laposta	56.6	225.5	121.4	96.4	17.43	117.6
Composite-5 x Giza 2	67.3	253.3	152.5	93.9	15.99	114.0
Composite-5 x Tuxpino	57.0	221.1	120.3	96.3	17.00	119.0
Composite-5 x Pop-402	59.1	239.8	130.1	94.9	20.23	136.8
Composite-5 x Across-8562	57.0	221.9	120.6	96.3	18.28	122.1
Composite-5 x GWP	57.1	235.3	131.3	99.8	20.12	136.9
Composite-5 x Laposta	63.2	258.5	149.4	99.3	24.46	164.3
Giza 2 x Tuxpino	58.1	225.8	126.4	96.3	19.67	134.0
Giza 2 x Pop-402	56.8	241.5	134.2	99.8	20.38	140.1
Giza 2 x Across 8562	57.6	240.8	135.1	97.1	19.71	132.1
Giza 2 x GWP	61.4	246.2	141.5	92.0	20.37	137.3
Giza 2 x Laposta	59.3	231.8	126.6	100.2	22.47	150.5
Tuxpino x Pop-402	61.4	246.9	141.9	97.9	23.47	157.8
Tuxpino x Across 8562	61.4	262.6	153.4	101.6	22.85	153.7
Tuxpino x GWP	60.0	249.8	141.2	102.6	22.73	152.9
Tuxpino x Laposta	60.1	246.8	143.7	100.4	20.39	138.5
Pop-402 x Across 8562	58.7	230.9	129.2	98.4	18.15	123.7
Pop-402 x GWP	56.9	239.3	135.6	102.4	21.68	149.6
Pop-402 x Laposta	61.8	246.4	144.4	93.9	21.23	141.0
Across 8562 x GWP	58.1	252.8	137.6	95.9	19.60	134.9
Across 8562 x Laposta	61.8	259.7	146.6	101.3	25.03	170.7
GWP x Laposta	62.6	252.7	142.4	96.3	23.62	157.6
LSD 0.05	1.1	9.8	8.7	6.4	1.8	12.5
0.01	1.4	12.8	11.4	8.3	2.4	16.4

Table 2: Mean squares out of eight populations and their F_1's crosses for grain yield and some other agronomic traits, data are combined over four locations in 2001 season.

S.O.V	DF	Days to 50% silking	Plant height	Ear height	No. ears/100 plants	Grain yield (ard/fad)	Grain yield/plant
Locations (L)	3	289.85**	18698.27**	13541.71**	1067.60**	342.28**	10199.8**
Reps (L)	12	5.70	1659.01	1264.56	161.85	53.32	2616.9
Genotypes (G)	35	246.48**	4115.05**	2942.46**	379.62**	271.54**	10970.8**
Varieties (V)	7	316.91**	5344.31**	4250.85**	280.67**	246.06**	11395.3**
Heterosis (Het)	28	228.87**	3807.74**	2615.36**	404.36**	277.91**	10864.6**
Var. het.(hi)	7	414.59**	5039.67**	3737.88**	700.96**	408.87**	17906.2**
Aver. Het ($\bar{h}$)	1	77.98**	15842.98**	4994.01**	3109.18**	3595.35**	125413.6**
Spec. het (sij)	20	171.41**	2774.80**	2103.55**	165.31**	66.20**	2672.6**
G x L	105	6.92**	518.10**	337.60**	296.22**	32.49**	1504.4**
V x L	21	3.99*	643.32**	441.81**	344.22**	35.34**	1569.2**
Het x L	84	7.66**	486.79**	311.55**	284.22**	31.78**	1488.2**
Var. het x L	21	26.62**	461.19**	305.57**	591.63**	42.74**	2471.8**
Aver.het x L	3	14.83**	372.81**	303.84**	480.70**	51.68**	1540.1**
Spec. het x L	60	4.20**	501.45**	314.03**	166.81**	26.96**	1141.4**
Pooled error	420	2.32	199.16	158.51	84.89	7.09	326.5
CV %		2.52	5.80	9.29	9.85	14.09	13.9

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

These results are in agreement with those obtained by Lonnquist and Gardner (1961), El-Nagouly *et al* (1988) and Soliman, *et al* (1999). However. Falconer (1960) mentioned that heterotic response depends mainly on the number of contrasting loci and also on the level of dominance at each locus. Therefore heterotic response is expected to occur whenever there is difference in gene frequencies and some degree of directional dominance at one or more loci involved in the inheritance of the character. Also, Hallauer and Miranda (1981) stated that a specific population could be suitable for isolation of a good inbred lines if it had widely response to different environments.

Data for average, variety and specific heterosis are presented in Table (3). Highly significant differences in average heterosis were observed for all studied traits (Table 2). The average heterotic effects were positive and highly significant for all studied traits except for days to 50 % silking and grain yield per plant, which was negative and highly significant. This indicates that the studied varieties differed greatly in gene frequency and non-additive effects (Falconer 1960 and Hallauer and Miranda 1981).

The significant mean square for variety heterosis (Table 2) was confirmed when heterosis for each variety was estimated and found to be significant for any of the studied traits. All varieties had highly significant variety heterosis in case of silking date The latest varieties, Laposta (73.8 days) had the highest positive effect (12.70**) toward lateness. The tallest varieties, Laposta, Comp-5 and GWP (259.5, 253.8 and 244.2 cm, respectively) had the highest variety heterosis (29.15**, 23.45** and 13.85**, respectively), while the shortest variety, Pop-402 and Pop-4956 (189.3 and 201.3 .cm, respectively) had the lowest variety heterosis values (-41.05** and –29.05**, respectively). These results are in agreement with those obtained by Paterniani and Lonnquist (1963), Hallauer and Eberhart (1966), Nawar *et al* (1986) and El-Nagouly *et al* (1988). However, Falconer (1960) stated that the negative value of the variety heterosis (h_j) would occur when the gene frequency of the Jth variety was equal to the average gene frequency of all varieties assuming a positive dominance. On the other hand, the positive values for (h_j) would occur when gene frequency of the jth variety was higher or lower than the average gene frequency of all varieties. Hallauer and Eberhart (1966), Hallauer and Sears (1968), Mungoma and Pollak (1988) and Mostafa *et al* (1990) reported that average and variety heterosis were adequate to explain most of the variation for grain yield and some other traits among Corn Belt varieties.

Specific heterosis, which is equivalent to specific combining ability in Griffing's (1956) model, of different variety crosses for all studied traits are presented in Table (3). Twenty-four variety crosses exhibited significant specific heterosis (12 of them had negative effects toward earliness). For plant and ear height, 17 and 18 crosses, respectively had significant specific effects (7 and nine of them were toward short plants and low ear placement, respectively. Regarding number of ears per 100 plants, 4 out of 28 variety crosses showed significant effect, two of them were toward producing more than one ear per plant since it had positive values (+6.39** and 3.91*). For grain yield in ard/fad, 11 crosses had significant specific effects, 5 of them, *viz* Pop-4956 x Pop-402, Pop-4956 x Across-8562, Comp-5 x Laposta, Tuxpino x Pop-402 and Across 8562 x Laposta were positive (desirable) and other 6 crosses were negative (not desirable). However, non of the studied crosses possessed significant specific effects in case of grain yield per plant. In general, specific heterosis for all traits differed from cross to another in its magnitude and direction. However, the number of crosses having significant specific heterosis was more for days to 50% silking, plant height and ear height than that for grain yield. Paterniani and Lonnquist (1963) and Hallauer and Miranda (1981) mentioned that the greater values of specific heterosis are exhibited by varieties that are divergent in genes showing dominance effects.

Variety and heterotic effects (Table 4) in relation with the average performance of the varieties and variety crosses (Table 1) showed that the highest yielding varieties, *i.e.* GWP, Giza-2, Comp-5 and Tuxipino had positive and highly significant variety effects (5.63**, 5.12**, 3.90** and 3.45**, respectively) and *vice versa* for the lower yielding varieties. However, the heterotic effects did not coincide with the average performance of the crosses. The highest yielding crosses, Across 8562 x Laposta (25.03 ard/fad) and Comp-5 x Laposta (24.46 ard/fad) were relatively high in their heterotic effects (13.46** and 10.93**, respectively). On the other hand, the lower yielding crosses, Pop-4956 x Comp-5 (15.38 ard/fad) and Pop-4956 x Giza 2 (15.98 ard/fad) exhibited the lowest heterotic effects (1.97** and 1.96**, respectively). These results indicate that the choice of the parental varieties for heterosis exploitation can be based on the yield potential of the varieties *per se* and on the average performance of their crosses as well as their specific heterotic effects. Almost all crosses exhibited significant and directional heterotic effects respecting all studied traits. 23, 22, 24, 5, 26 and

28 variety crosses had significant heterotic effects for flowering date, plant height, ear height, number of ears/100 plant, grain yield in ard/fad and per plant, respectively.

Table 3: Average, variety and specific heterosis effects for grain yield and other agronomic traits of 8 populations and its F_1 variety crosses, data are combined over four locations.

Entry name	Days to 50% silking	Plant height cm	Ear height cm	No. of ears/100 plant	Grain Yield ard/fad	Grain yield/ plant g
Variety heterosis						
Pop-4956	-7.10**	-29.05**	-29.84**	- 1.29	-5.59**	-39.18**
Composite 5	2.60**	23.45**	10.86**	3.01	3.90**	28.93**
Giza 2	-3.90**	- 0.15	- 1.54	6.13**	5.12**	36.23**
Tuxpino	-3.70**	2.05	- 2.54	3.24	3.44**	17.73**
Pop-402	-0.80**	-41.05**	-27.54**	-11.17**	-7.15**	-50.08**
Across-8562	3.60**	1.75	5.26*	7.48**	-0.02	7.33*
G.W.P	-3.40**	13.85**	5.86*	2.60	5.63**	34.83**
Laposta	12.70**	29.15**	39.46**	- 9.98**	-5.34**	-35.78**
LSD 0.05	0.57	5.28	4.71	3.45	1.01	5.38
0.01	0.74	6.90	6.15	4.51	1.31	8.83
Specific heterosis						
Pop–4956 x Composite 5	4.183**	15.56**	18.70**	-2.85	-1.08	2.76
Pop–4956 x Giza 2	4.183**	9.22**	6.16**	1.05	-0.99	1.44
Pop–4956 x Tuxpino	-3.533**	-15.12**	-13.15**	-1.79	-0.17	-0.79
Pop–4956 x Pop-402	-0.900**	3.49	0.89	6.39**	2.21**	6.69
Pop–4956 x Across-8562	-0.517	4.51	0.65	-1.18	2.23**	-4.16
Pop–4956 x GWP	2.167**	3.02	3.79	-1.57	0.70	-7.44
Pop–4956 x Laposta	-5.583**	-20.69**	-17.21**	-0.06	-2.89**	1.49
Composite-5 x Giza 2	5.233**	14.74**	15.68**	-0.64	-1.37*	3.03
Composite-5 x Tuxpino	-3.083**	-15.30**	-14.75**	-0.81	-2.03**	2.09
Composite-5 x Pop-402	-0.750*	1.31	- 5.52*	-2.22	0.92	-2.42
Composite-5 x Across-8562	-2.967**	-21.57**	-16.33**	0.02	-0.73	0.73
Composite-5 x GWP	-3.683**	- 9.36**	- 7.69**	3.91*	0.52	-0.46
Composite-5 x Laposta	1.367**	14.63**	9.88**	2.61	3.76**	-5.72
Giza 2 x Tuxpino	-1.983**	-11.24**	- 8.61**	-1.31	0.12	-3.82
Giza 2 x Pop-402	-3.050**	2.37	- 1.31	2.08	0.55	-0.24
Giza 2 x Across 8562	-2.367**	- 3.31	- 1.74	0.30	0.18	3.81
Giza 2 x GWP	0.617	0.90	2.58	-4.43*	0.25	-2.67
Giza 2 x Laposta	-2.533**	-12.71**	-12.85**	2.96	1.25	-1.54
Tuxpino x Pop-402	3.533**	9.93**	8.13**	-2.34	1.98**	0.43
Tuxpino x Across 8562	3.417**	20.65**	18.26**	2.14	1.65	-2.62
Tuxpino x GWP	1.200**	6.66*	4.02	3.55	0.95	3.79
Tuxpino x Laposta	0.250	4.45	6.02**	0.53	-2.49**	0.93
Pop-402 x Across 8562	0.950**	-13.14**	- 6.45**	-1.19	-3.33**	-5.94
Pop-402 x GWP	-1.667**	- 5.93*	- 2.12	3.23	-0.39	1.08
Pop-402 x Laposta	2.183**	1.96	6.25**	-5.99**	-1.94**	0.41
Across 8562 x GWP	-0.583	2.59	- 1.49	-2.36	-2.17**	4.73
Across 8562 x Laposta	2.067**	10.28**	7.01**	2.25	2.16**	3.46
GWP x Laposta	2.050**	2.09	0.78	-2.33	0.15	0.98
LSD 0.05	0.631	5.84	5.21	3.82	1.10	7.48
0.01	0.824	7.63	6.81	4.98	1.44	9.77
Average heterosis	-0.893	12.63**	7.11**	5.59**	5.95**	-10.49**

Table 4: Estimates of variety and heterotic effects for grain yield and other agronomic traits of 8 populations and its F_1 variety crosses, data are combined over four locations.

Entry name	Days to 50% silking	Plant height cm	Ear Height cm	No. of ears/100 plant	Grain Yield ard/fad	Grain yield/plant g
			Variety effect			
Pop-4956	- 7.10**	-29.05**	-29.84**	- 1.29	-5.59**	-39.18**
Composite 5	2.60**	23.45**	10.86**	3.01*	3.90**	28.93**
Giza 2	- 3.90**	- 0.15	- 1.54	6.13**	5.12**	36.23**
Tuxpino	- 3.70**	2.05	- 2.54	3.24*	3.45**	17.73**
Pop-402	- 0.80**	-41.05**	-27.54**	-11.17**	-7.15**	-50.08**
Across-8562	3.60**	1.75	5.26**	7.48**	-0.03	7.33**
G.W.P	- 3.40**	13.85**	5.86**	2.60	5.63**	34.83**
Laposta	12.70**	29.15**	39.46**	- 9.98**	-5.34**	-35.78**
LSD 0.05	0.35	3.26	3.65	2.67	0.77	5.24
0.01	0.58	5.35	4.77	3.49	1.01	6.84
			Heterotic effect			
Pop–4956 x Composite 5	6.30**	27.25**	34.24**	0.18	1.97**	14.05**
Pop–4956 x Giza 2	6.30**	24.40**	27.81**	2.39	1.96**	14.80**
Pop–4956 x Tuxpino	1.45**	11.15**	7.25**	2.27	5.29**	12.85**
Pop–4956 x Pop-402	2.65**	21.50**	34.31**	6.43**	13.26**	17.35**
Pop–4956 x Across-8562	2.90**	24.50**	19.04**	2.18	9.40**	8.75*
Pop–4956 x GWP	4.65**	24.35**	23.93**	1.79	5.74**	9.25**
Pop–4956 x Laposta	1.30**	12.10**	-13.38**	2.95	8.65**	13.05**
Composite-5 x Giza 2	1.80**	- 0.25	17.90**	-0.47	- 2.77**	-16.70**
Composite-5 x Tuxpino	-3.35**	-16.35**	-13.79**	0.73	- 0.92	-18.00**
Composite-5 x Pop-402	-2.30**	- 7.00*	8.46**	0.09	7.60**	-19.50**
Composite-5 x Across-8562	-3.35**	-15.95**	-17.38**	0.76	2.09**	-21.10**
Composite-5 x GWP	-3.30**	- 9.25**	- 6.99**	2.52	1.19*	-19.55**
Composite-5 x Laposta	-0.25	2.35	- 5.73*	2.26	10.93**	-22.85**
Giza 2 x Tuxpino	0.45	- 2.20	- 1.53	-0.82	1.14*	-23.20**
Giza 2 x Pop-402	-0.20	5.65*	18.79**	0.95	7.14**	-20.65**
Giza 2 x Across 8562	0.20	5.30	3.32	-0.39	2.91**	-21.80**
Giza 2 x GWP	2.10**	8.00**	9.40**	-2.95	0.84	-22.90**
Giza 2 x Laposta	1.05**	0.80	-22.34*	1.14	8.33**	-23.00**
Tuxpino x Pop-402	2.00**	7.25**	26.98**	1.48	11.08**	-11.90**
Tuxpino x Across 8562	2.00**	15.10**	22.08**	3.26	6.88**	-16.60**
Tuxpino x GWP	1.30**	8.70**	9.59**	3.77**	4.05**	-11.25**
Tuxpino x Laposta	1.35**	7.20**	- 4.71	2.66	7.09**	-13.35**
Pop-402 x Across 8562	-0.80**	20.80**	10.39**	8.87**	7.48**	16.40**
Pop-402 x GWP	-1.70**	25.00**	16.46**	10.89**	8.28**	22.05**
Pop-402 x Laposta	0.75*	28.55**	8.54**	6.67**	13.22**	21.05**
Across 8562 x GWP	-3.30**	10.35**	2.06	- 1.68	2.64**	- 8.00*
Across 8562 x Laposta	-1.45**	13.80**	- 5.74*	1.01	13.46**	- 9.30**
GWP x Laposta	2.45	4.25	-10.23**	0.97	3.93**	-22.15**
LSD 0.05	0.59	5.45	4.87	3.56	1.03	6.98
0.01	0.77	7.12	6.36	4.65	1.34	9.12

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

Heterosis percentage relative to mid-parent for each variety and average for the studied traits are shown in Table (5).

Table 5: Heterosis expressed as percentage of mid-parents for crosses and average for each variety for grain yield and other agronomic traits, data are combined over four locations.

Entry name	Days to 50% silking	Plant height cm	Ear height cm	No. of ears/100 plant	Grain Yield ard/fad	Grain yield/plant g
Average variety heterosis						
Pop-4956	-13.52	17.092	26.51	5.43	53.07	29.14
Composite 5	4.17	-5.392	-2.78	1.17	3.34	-43.06
Giza 2	-6.67	4.623	6.22	-1.61	-0.76	-47.17
Tuxpino	-5.79	2.970	5.92	3.60	14.36	-29.41
Pop-402	1.93	21.550	24.63	18.31	66.00	44.79
Across-8562	8.50	5.486	1.33	-1.38	31.03	-23.70
G.W.P	-3.84	0.967	2.15	3.28	5.99	-48.69
Laposta	17.65	-5.525	-21.68	16.75	59.66	27.26
Mid-parent heterosis						
Pop–4956 x Composite 5	13.17**	12.42**	28.42**	- 1.93	14.70**	- 6.16
Pop–4956 x Giza 2	19.78**	15.92**	24.34**	1.15	14.01**	- 8.08
Pop–4956 x Tuxpino	2.15**	3.11	6.37	2.45	40.22**	- 3.02
Pop–4956 x Pop-402	3.76**	25.09**	33.89**	20.80**	168.17**	70.25**
Pop–4956 x Across-8562	0.76	15.51*	16.18**	- 0.02	82.15**	- 6.70
Pop–4956 x GWP	13.34**	12.23**	20.28**	1.78	39.57**	-18.57**
Pop–4956 x Laposta	-11.42**	- 2.13	- 9.93	11.90**	98.42**	37.95**
Composite-5 x Giza 2	11.33**	4.67	13.30**	- 2.60	- 14.77**	-27.58**
Composite-5 x Tuxpino	- 5.86**	- 9.05*	-10.28**	1.43	- 5.13**	-24.30**
Composite-5 x Pop-402	- 4.68**	8.24*	6.96	8.30**	60.20**	0.55
Composite-5 x Across-8562	-11.21**	- 8.66*	-12.59**	- 0.73	12.89**	-26.19**
Composite-5 x GWP	- 5.93**	- 5.50	- 5.05	5.53	5.78**	-31.46**
Composite-5 x Laposta	- 8.07**	0.72	- 3.69	12.48**	80.77**	-13.57**
Giza 2 x Tuxpino	1.40**	- 2.38	- 1.19	- 0.19	6.15**	-28.85**
Giza 2 x Pop-402	- 3.32**	15.14**	16.28**	11.82**	53.96**	1.95
Giza 2 x Across 8562	- 5.50**	4.17	2.52	- 1.48	17.30**	-23.59**
Giza 2 x GWP	6.88**	3.79	7.12	- 4.31	3.80**	-32.85**
Giza 2 x Laposta	- 9.47**	- 5.33	-15.00**	11.50*	58.89**	- 9.80*
Tuxpino x Pop-402	4.33**	17.09**	23.48**	11.56**	89.36**	11.80*
Tuxpino x Across 8562	0.57	13.07**	16.81**	4.53	43.12**	-24 50**
Tuxpino x GWP	4.26**	4.83	7.29	8.30**	21.03**	-24.25**
Tuxpino x Laposta	- 8.38**	0.35	- 3.18	13.50**	53.32**	0.05
Pop-402 x Across 8562	- 6.08**	9.58*	8.74*	9.36**	70.13**	5.10
Pop-402 x GWP	- 3.56**	10.40**	13.82**	17.02**	60.69**	1.75
Pop-402 x Laposta	- 7.83**	9.80*	6.28	15.69**	165.10**	59.39**
Across 8562 x GWP	- 5.07**	6.15	1.52	- 0.97	14.91**	-24.22**
Across 8562 x Laposta	-10.76**	5.66	- 3.77	11.88**	116.32**	3.37
GWP x Laposta	-15.18**	0.34	- 6.70	9.35**	64.05**	- 8.88
LSD 0.05	0.73	7.74	7.56	5.53	1.27	10.8
0.01	1.19	10.10	9.87	7.22	2.09	14.16

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

Regarding number of days to 50 % silking the mid-parent heterosis ranged from –15.18% to 19.78%, and it was positive and highly significant in 9 crosses. Also, 17 crosses exhibited negative and significant mid-parent heterosis. This indicated that 17 out of 28 crosses were earlier than the early parent. Since the majority of crosses showed negative heterosis relative to mid-parent, it could be indicated that heterosis for days to 50 % silking is directed toward earliness.

Respecting plant and ear height, 14 variety crosses possessed highly significant mid-parent heterosis. For both traits, ten of them had positive values toward the tallest plants and high ear placement. The two crosses, Pop-4956 x Pop-402 and Tuxpino x Pop-402 had the highest mid-parent values for plant height (25.09** and 17.09**, respectively). However, in case of ear height, the variety cross Pop-4956 x Comp-5 had the highest mid-parent value (28.42**) followed by Pop-4956 x Giza-2 (24.34**) and Tuxpino x Pop-402 (23.48**).

Fourteen variety crosses exhibited positive highly significant mid-parent heterosis values toward producing more than one ear/plant.. The three crosses, Pop-4956 x Pop-402, Pop-402 x Laposta and Across 8562 x GWP were more prolific since they exhibited the highest mid-parent values (20.80**, 17.02** and 15.69**, respectively).

For grain yield (ard/ad), mid-parent heterosis ranged from –5.13% % to 168.17 % (Table 5) and it was highly significant in 17 crosses. The crosses Pop-4956 x Pop-402, Pop-402 x Laposta and Across 8562 x Laposta exhibited the highest mid-parent heterosis values (168.17, 165.10 and 116.32% for the three crosses, respectively). On the other hand, the four varieties, Pop-4956, Pop-402, Across 8562 and Laposta, which showed high values of mid-parent heterosis in their crosses, exhibited also high average heterosis values relative to mid-parent (53.07, 66.00, 31.03 and 59.66%, respectively, Table 5).

Regarding grain yield per plant, 17 variety crosses had significant mid-parent values. The highest values were obtained from the crosses Pop-4956 x Pop-402 (70.25%), Pop-402 x Laposta (59.39%) and Pop-4956 x Laposta (37.95**). The three varieties included in the previous crosses, ***i.e.*** Pop-4956, Pop-402 and Laposta also exhibited high values of average mid-parent heterosis (29.14, 44.79 and 7.26, respectively).

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تحليل قوة الهجين فى الهجن الصنفية بين ثمان مجتمعات من الذرة الشامية بيضاء الحبوب

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تم عمل جميع الهجن الممكنة (عدا العكسية) بين ثمان عشائر بيضاء الحبوب من الذرة الشامية وذلك بمحطة بحوث الجميزة موسم عام ٢٠٠٠. وكانت العشائر موضع الدراسة هى: Pop-4956, Comp-5, Giza-2,Tuxpino, Pop-402, Across-8562, GWP and Laposta ، وفى عام ٢٠٠١ تم زراعة الآباء الثمانية والـ ٢٨ هجينا للجيل الأول الناتجة منها (٣٦ تركيب وراثى) فى تجربة حقلية فى محطات البحوث الزراعية بسخا والجميزة وسدس وملوى ، وقد استخدم موديل Eperhart and Gardner (1966) لتقدير الطرز المختلفة لقوة الهجين بالإضافة إلى التأثيرات الوراثية المختلفة ، ودلت النتائج على أن متوسط أداء الهجن الصنفية معبرا عنه بمحصول الحبوب وبعض الصفات الزراعية الأخرى كان مرتفعا وأعلى من أفضل الآباء فى معظم الهجن موضع الدراسة .وكانت مصادر الاختلاف الراجعة لقوة هجين الصنف ومتوسط قوة الهجين معنوية جدا لكل الصفات موضع الدراسة ، وقد دل ذلك على أن العشائر المستخدمة فى الدراسة تختلف بشدة فى مقدار قوة الهجين بها لكل الصفات موضع الدراسة . كانت قوة الهجين بمعناها الخاص عالية المعنوية فى جميع الصفات المدروسة ، فمن بين الـ ٢٨ هجينا أظهر ١٧ هجين قوة هجين بمعناها الخاص عالية المعنوية كما تفوقت هذه الهجن فى محصولها معنويا على محصول أعلا الآباء وهو GWP (١٩,٦٩ أردب/فدان) ، كما تفوق محصول ثلاث هجن صنفيه هى Across 8562 x Laposta, Comp-5 x Laposta and GWP x Laposta معنويا على متوسط محصول الأب المشترك Laposta . تراوح متوسط قوة الهجين بالنسبة لمتوسط الأبوين من -١٣,٥٢ إلى ١٧,٦٥ ؛ -٥,٣٣ إلي ٢١,٥٥ ؛ -٢١,٦٨ إلى ٢٦,٥١ ؛ -١,٦١ إلى ١٨,٣١ ؛ -٠,٧٦ إلى -٦٦,٠٠ ؛ -٤٨,٦٩ إلي ٤٤,٧٩ للصفات الستة موضع الدراسة على الترتيب . وقد لوحظ أن أعلا قوة هجين بالنسبة لمتوسط الأبوين أمكن الحصول عليها من هجن تشترك فيها أقل الآباء محصولا (Pop-402 , Laposta) والعكس بالعكس . أظهر ٢٦ ، ١٤ ، ١٤ ، ١٤ ، ٢٨ , ١٧ هجينا صنفيا قيم عالية المعنوية لقوة الهجين بالنسبة لمتوسط الأبوين وذلك لبيانات تاريخ التزهير ، ارتفاع النبات والكوز ، عدد كيزان النبات ، محصول الحبوب للفدان وللنبات على الترتيب ، ويمكن استنتاج أن التأثيرات الجينية الغير مضيفة والتكرار الجينى للعشيرتين (Pop-402 , Laposta) تختلف لحد كبير عن الآباء الأخرى المستعملة فى الدراسة ولهذا السبب فانه يمكن استعمال هاتين العشيرتين فى دراسات تربوية أخرى لاستنباط المزيد من السلالات الجيدة لإدخالها في البرنامج.