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PHYLOGENETIC RELATIONSHIP, HETEROSIS AND COMBINING ABILITY IN SOME MAIZE LINES

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ABSTRACT

A half set of crosses among eight S_4 inbred lines of yellow maize were evaluated in 2002 and 2003 seasons at the Agricultural Experimental Station, Faculty of Agriculture, Minufiya University to estimate, a) the relative magnitude of general and specific combining ability and their interactions with years. b) the heterotic effects and the economic heterosis relative to the check variety (S.c156). c) the genetic diversity and the phylogenetic relationship among these lines and their hybrids. d) the correlation coefficients between genetic distance and each of heterosis, specific combining ability (S.C.A.) and mean performance.

The crosses (1x4), (6x7), (6x9), (1x3) and (3x4) were the best for grain yield and its components, and earliness; while crosses (7x9) and (8x9) were the best for plant height (towards shortness) and ear height (towards low ear placement). Significant differences for general combining ability (G.C.A.) mean squares were detected for grain yield/plot, ear length, and number of kernels/row. Meanwhile, non-significant differences were found for ear diameter, number of rows/ear, 100-kernel-weight, plant and ear heights, days to tasseling and days to silking. Specific combining ability mean squares exhibited significant differences for most studied traits except for plant and ear heights. Ratios of k^2 G.C.A/k^2 S.C.A were less than unity for all the studied traits except plant and ear heights exhibited prevalent dominance gene effects. Generally, for grain yield/plot and some of its components, most sources of variations were highly significant including their interaction with years. Generally, the most desirable values of general combining ability effects (gi) were obtained from Pop_{59-4} for grain yield/plot, number of rows/ear and number of kernels/row, Pop_{59-6} for ear length and ear diameter; Pop_{59-8} for days to silking (towards lateness); and Pop_{59-3} (towards earliness). Crosses (1x4), (1x3), (1x5), (3x4), (3x5), (3x7), (4x9), (6x7) and (6x8) showed mean performances, (S.C.A.) and heterotic effects which may be of prime importance for breeding programs. The correlation coefficients between genetic distance between parents and heterosis, and *per se* hybrids performance exhibited positive significant correlation coefficients (0.43) and (0.41) for grain yield per plot and significant negative correlation coefficients (-0.41) and (-0.41) for days to tasseling. However, of the ten characters only ear length showed positive significant correlation coefficient (0.38) between the genetic distances between the parental genotypes of 28 hybrids and their SCA values. Generally, from these results it appeared that heterosis could not be considered as a function of genetic divergence and it is impossible to predict hybrid performance from genetic distance.

INTRODUCIION

Maize is one of the most important crops for food , feed and industrial use (Dowswell *et al.* 1996). Extensive research has been done in different disciplines on this novel crop. One of the main objectives of the National

Maize Program is breeding and releasing high yielding maize hybrids to increase the national production of maize, (Barakat *et al.* 2003). Populations of maize *(Zea Mays L.)*, either open – pollinated varieties or derived synthetics, may be useful sources for inbred lines if improved for agronomic traits. Development of commercially acceptable hybrids requires that the various types of hybrid combinations are evaluated in yield trials.

Many investigators used diallel cross mating scheme to estimate general and specific combining ability for grain yield and other quantitative characters for determining the most suitable breeding programs to improve these traits. They also showed that general and specific combining ability effects should be taken in consideration to evaluate and release new inbreed lines and hybrid maize, i.e. Hallauer and Miranda (1981), Nawar and El-Hosary (1985), El-Hosary *et al.* (2001), Barakat *et al.* (2003). They found that both general (G.C.A.) and specific combining ability (S.C.A.) effects were of equal importance in the inheritance of grain yield and other agronomic traits. Another Researchers found that S.C.A. was predominantly, i.e., Leon *et al.* (1989), Alika (1994), Konak *et al.* (1999), Leon (2000), Vacor *et al.* (2002) and Alamnie *et al.* (2003).

Genetic diversity is one of the important source of the genetic variation in germplasm which provides the plant breeders with the best knowledge to achieve the progress in their programs. Several investigators studied the genetic diversity at the phenotypic levels to assess maize genetic diversity (Smith (1986), Gonzalez (1997), Melo *et al.* (2001), Mohammdi and Prasanna (2003), Betran *et al.* (2003), Menkir *et al.* (2004) and Mohamed (2005).

The present study is an attempt to estimate, a) the relative magnitude of general and specific combining ability and their interactions with years. b) the heterotic effects relative to the check variety (economic heterosis). c) the genetic diversity and the phylogenetic relationship among these lines and their hybrids to assess the possible relationship between combining ability, heterosis and *per se* hybrid performance in these lines and their hybrids and the genetic diversity as determined by morpho -agronomic traits.d) the correlation coefficients between genetic distance and each of heterosis, specific combining ability (S.C.A.) and mean performance.

MATERIALS AND METHODS

Eight S_4 inbred lines of corn, i.e., Pop_{59-1} (P_1), Pop_{59-3} (P_2), Pop_{59-4} (P_3), Pop_{59-5} (P_4), Pop_{59-6} (P_5), Pop_{59-7} (P_6), Pop_{59-8} (P_7) and Pop_{59-9} (P_8) were used in this study. Pop_{59} maize population, which was used in this study, was developed by the Agricultural Research Center (ARC), and was planted at the Agricultural Experimental Station, Faculty of Agriculture, Minufiya University.

In 2000 season, 25 ears of S_3 from Pop_{59} maize population were planted and crossed to produce S_4 lines. In 2001 season, all possible combinations, without reciprocals were made among the eight S_4 lines to produce 28 hybrids.

The hybrids and their eight parents were tested in the two successive seasons 2002 and 2003. Randomized complete block design with three replications was used. Each hybrid was represented by five rows, 6m. long and 70cm. a part with two kernels per hill on one side of the ridge. The seedlings were thinned to one plant per hill. The normal cultural practices were followed during the two growing seasons. Data were measured on ten quantitative characters i.e., grain yield/plot, ear length, ear diameters, number of rows/ ear, number of kernels/row, 100-kernel– weight, plant height, ear height, days to tasseling, and days to silking. Random samples of 10 guarded plants in each plot were taken to measure the previous characters except yield of ears/plot which recorded on yield of three guarded rows for each entry. Grain yield/plot was adjusted based on 15.5% moisture and shelling percentage. Data were analyzed by using Griffing's (1956) procedure, Method-4, Model-1 (fixed model) for each year. The combined analysis of the two years was done whenever homogeneity of variance was not significant. Genotypes for all studied morpho-agronomic characters of the maize genotypes were subjected to a multivariate analysis (Johnson and Wichern, 1988). Data were analyzed using the hierarchical Euclidean cluster analysis. The cluster analysis and dendrogram construction were performed using the SPSS (1995).

RESULTS AND DISCUSSION

The present study was carried out to investigate the heterosis and combining ability and their interactions with years in eight S_4 inbred lines of Pop_{59} maize population by means of diallel mating scheme for ten quantitative traits. To achieve this target, half diallel cross was studied. The data obtained was devided into the following, i.e., mean performance, analysis of variance, combining ability, economic heterosis, genetic distance and cluster analysis.

Mean performances:

Mean performances of twenty-eight single crosses resulted from eight S_4 inbred lines derived of the Pop_{59} maize population. The combined data are presented in Table (1).

For grain yield/plot, number of rows/ear, and 100-kernel-weight, the best cross was (1 x 4) where showed the highest mean values for these characters. For grain yield/plot, the best cross was (9x1). For ear length, 100-kernel-weight and two flowering dates, towards earliness, the best cross was (1x3). For grain yield/plot, ear diameter and ear length, the best cross was (6x9). For ear diameter the best crosses were (6x6) and (4x9). For number of rows/ear and plant and ear heights the best cross-exhibited dwarfism was (4x6). For number of kernels/row and days to silking, the best cross exhibited earliness was (3x4). For 100-kernel-weight and number of kernels/row the best cross was (3x4). For plant and ear height towards shortness the best crosses were (7x9) and (8x9). For flowering dates towards earliness the best cross was (3x5).

Generally, the crosses (1x4), (6x7), (6x9), (1x3) and (3x4) were the best for grain yield and its components, and towards earliness; while crosses (7x9) and (8x9) were the best for plant height (towards shortness) and ear height (towards low ear placement).

Table (1): Mean performance of 28 crosses resulted from eight inbred lines of maize evaluated two years.

Characters / Crosses	Grain yield/ plot (kg.)	Ear Length (cm.)	Ear diameter (cm.)	No. of rows/ear	No. of kernels /row	100 kernel weight (gm.)	Plant height (cm.)	Ear height (cm.)	Days to tasseling (day)	Days to silking (day)
1x3	6.39	18.17	5.67	14	36.83	46.33	203.54	112.92	50.83	53
1x4	9.32	15.2	5.57	15.33	43.67	47.33	206.25	115.21	52.33	55.17
1x5	5.84	15.07	4.9	12.67	35	39.67	189.17	102.08	52.33	54.83
1x6	5.02	15.45	4.97	15.5	30.58	35.67	194.38	98.33	52.67	55.5
1x7	5.94	15.48	5.25	14.7	32.33	36.67	205.42	110.42	52	54.5
1x8	4.86	14.28	4.9	14.5	38.33	37.33	191.5	101.42	54.33	57
1x9	7.79	16.03	5.15	12.67	39.5	41.17	211.88	115.42	54.17	57
3x4	6.57	16.87	5.63	15	41.5	43	195.83	99.58	52.67	53.83
3x5	6.08	17.13	5.63	13.33	37.33	40	205.21	118.75	52.17	54.33
3x6	5.6	16.27	6.32	14.67	39.67	42.83	209.58	108.75	53.33	56
3x7	5.74	15.43	5	14.67	34.58	35.17	197.81	104.58	53	55.67
3x8	4.38	14.12	5	13.92	33.07	40.67	202.71	109.38	54	56.67
3x9	5.46	15.47	5.03	14.33	41.33	39.17	196.67	107.92	52.17	54.67
4x5	5.79	15.63	5.2	15.67	33.33	40.5	200.21	95.83	52.83	55.17
4x6	6.25	16.33	5.32	16.27	38.33	39.33	167.92	96.25	53.67	56.5
4x7	6.45	15.65	4.92	15.87	38.83	39.33	201.88	100.21	54.83	56
4x8	5.25	14.37	4.98	15.33	38.33	38	224.38	106.88	52.83	55
4x9	6.5	17.47	5.83	15.27	40.5	40.67	207.71	107.29	53.17	56.17
5x6	5.14	16	5.58	13.52	36.17	37.67	210.63	110.42	53.5	56.83
5x7	4.96	15.07	4.9	13.07	28	36	197.08	101.04	54	56.67
5x8	6.54	15.87	4.98	13.92	34	39.83	192.29	102.29	53.33	57.83
5x9	5.28	15.23	5.07	14.83	34.83	40	197.29	102.71	54.33	57.33
6x7	7.07	19.25	5.3	15	37.83	40	193.33	107.29	51.67	54.67
6x8	5.34	16.08	5.08	15	38	42.67	195	100	53.17	56
6x9	8.07	18.53	5.82	14	39.17	39.33	197.29	101.67	54.67	57.17
7x8	5.88	17.1	5.43	15.95	40.57	36.67	215.21	121.88	54.17	57.17
7x9	5.33	15.67	5.72	13.57	32.97	41.67	184.79	97.08	53.33	56.17
8x9	5.02	16.43	5.25	13	36.5	38.67	175	99.79	56	58.5
L.S.D.0.05	0.91	1.55	0.45	1.57	2.63	3.72	41.92	13.75	2.66	2.25
L.S.D.0.01	1.21	2.05	0.61	2.08	3.47	4.92	55.75	18.19	3.53	2.97

Analysis of variance and general and specific combining ability:

The analysis of variance for the studied traits of hybrids are presented in Table (2).Estimates of year mean squares in combined data were significant for grain yield/plot, ear length, 100-kernel-weight, and ear height, while the other characters exhibited non-significant differences.

Mean squares of hybrids were significant for all studied traits except for ear height.

Significant differences for general combining ability (G.C.A.) mean squares were detected for grain yield/plot, ear length, and number of kernels/row. Meanwhile, non- significant differences were found for ear diameter, number of rows/ear, 100-kernel-weight, plant and ear heights, days to tasseling and days to silking.

Specific combining ability mean squares exhibited significant differences for most studied traits except for plant and ear heights.

Ratios of k^2 G.C.A/k^2 S.C.A were less than unity for all the studied traits except plant and ear heights.

Generally, for the combined data, all traits exhibited prevalent dominance gene effects except plant height and ear height, thus the dominance variance effects played the major part in total genetic variance. This finding was also obtained by Nawar *et al.* (1979 and 2002), Leon *et al.* (1989), Sedhom (1992), El-Shamarka (1995), Rabie *et al.* (1997), EL-Hosary *et al.* (1999); Konak *et al.* (1999), EL-Absawy (2000), Leon (2000), Singh *et al.* (2000), Vacor *et al.* (2002) Turgut (2001), El-Shenawy *et al.* (2002), Amer (2003), Barakat *et al.* (2003), GuangChang *et al.* (2003), Mousa (2003), Alamnie *et al.* (2003) and Mohamed (2005) for grain yield and some of its components.

Hybrid x years mean squares interactions showed significant differences for most of the studied traits except few cases i.e., number of rows/ear, ear height and the two flowering dates.

General combining ability x years mean squares were significant for most of the studied traits except number of rows/ear, plant height and ear height. Meanwhile, specific combining ability x years mean squares were not significant for most of the studied traits except grain yield/plot, ear length, number of kernels/row and ear height.

The Ratios of G.C.A x years/S.C.A x years interactions showed that, for most of the studied traits the G.C.A effects were found to be more influenced by the effects of the growing season. Meanwhile, S.C.A were found to be less influenced by the year seasonal effects for number of rows/ear, and ear height.

Generally, for grain yield/plot and some of its components, most sources of variations were highly significant including their interaction with year. This means that, the behavior of that sources, i.e., hybrids, G.C.A and S.C.A were markedly differed from one year to another. This finding was also obtained by EL-Rouby and Galal (1972), Rabie *et al.* (1997), EL-Shamarka (1999), EL-Absawy (2000), EL-Hosary *et al.* (1999). On the other hand, Sadek *et al.* (2000) and Barakat *et al.* (2003) found that S.C.A. interaction exceed G.C.A. interaction.

Table (2): Analysis of variance of all traits studied of diallel cross of maize evaluated at two years.

Mean Squares											
S.O.V	D.F	Grain yield/plot (kg.)	Ear Length (cm.)	Ear diameter (cm.)	No. of rows/ ear	No. of kernels/ row	100-kernel-weight (gm.)	Plant height (cm.)	Ear height (cm.)	Days to tasseling (day)	Days to silking (day)
	Comb.	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined
Years	1	5.07*	12.52*	0.25	3.03	21.93	125.10**	1143.31	668.03*	16.98	17.24
Rep/Years	4	24.19**	89.32**	8.6**	20.58**	126.19**	1659.43**	575.72	331.52	240.48**	210.38**
crosses	27	6.94**	9.12**	0.80**	6.18**	77.73**	49.64**	802.16*	284.31	8.14**	9.81*
G.C.A	7	3.09**	7.67**	0.45	3.06	43.29**	25.12	531.24	434.37	11.73	10.39
S.C.A	20	8.73**	10.02**	1.06**	14.57**	129.22**	59.94**	239.24	205.79	16.27*	23.71**
crosses x Years	27	6.31**	8.81**	0.71**	3.25	59.71**	46.04**	999.18**	311.79	5.3	4.94
G.C.A x Years	7	4.24**	10.59**	0.66*	2.49	45.05**	49.87**	529.04	390.50	22.54*	14.4*
S.C.A x Years	20	2.69**	6.65**	0.38	3.26	42.67**	16.46	325.1	449.73**	7.95	8.99
Error	108	0.95	2.74	0.24	2.82	7.88	15.82	457.21	216.01	8.12	5.78
K^2 G.C.A / K^2S.C.A	-	0.35	0.77	0.43	0.21	0.33	0.42	2.22	2.11	0.72	0.44
K^2 G.C.A x Y/ K^2 S.C.A x Y	-	1.58	1.59	1.7	0.77	1.06	3.03	1.62	0.87	2.84	1.6

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

Estimates of general combining ability effects (gi) are presented in Table (3).Desirable significant effects were obtained from the lines Pop$_{59-4}$ for number of rows/ear and number of kernels/row; Pop$_{59-6}$ for ear length and diameter; and Pop$_{59-8}$ for days to silking (towards lateness) and Pop$_{59-3}$ (towards earliness).

Generally, the most desirable values of general combining ability effects (gi) were obtained from Pop$_{59-4}$ for grain yield/plot, number of rows/ear and number of kernels/row, Pop$_{59-6}$ for ear length and ear diameter; Pop$_{59-8}$ for days to silking (towards lateness); and Pop$_{59-3}$ (towards earliness).

Estimates of specific combining ability (S.C.A.) show significant effects (Sij) for the studied traits are tabulated in Table (4). The single hybrids, (1x4), (1x9), (5x8), (6x7),and (6x9) for grain yield/plot; (1x3,and (6x7) for ear length; (3x6),and (7x8) for ear diameter; (5x9) for number of rows/ear; (1x4), (6x7) and (7x8) for number kernels/row; (1x3), (1x4) and (6x8) for 100-kernel-weight; (4x8) and (8x9) for plant height (toward tallness) and (toward shortness) respectively and (7x8) for ear height (toward ear high placement.

Generally, the best crosses were (5x8), (6x9), (1x3) (1x4), and (7x8). These crosses may be of prime importance for breeding programs of hybrids maize providing the additive genetic system which is present in the good combiner as the complementary and epistatic effects and acts in the same trend to reduce undesirable plant characteristics and hence maximize the character in view. These results were partially in agreement with those obtained by EL-Hosary *et al.* (1990 a, and b), Nawar *et al.* (1994 and2002), Nigussie and Zelleke (2001), Rabie *et al.* (1997), Tulu and Ramachandrappa (1998), EL-Absawy (2000), Abd El-Maksoud *et al.* (2003and 2004) and Abd El-Hadi *et al.* (2004).

Economic heterosis:

Economic heterosis effects were computed only relative to the check variety (S.c156) for grain yield/plant and some of its components and are presented in Table (5). Most of the crosses showed desirable heterotic values relative to the check variety (S.c. 156). Almost all the studied traits showed desirable economic heterosis effects except ear diameter and the two flowering dates. On the other hand, no differences, either positive or negative were detected for plant and ear height. These results are in agreement with those of EL-Hosary *et al.* (1999), EL-Absawy (2000), Mousa (2001 and 2003), Nawar *et al.* (2002), GuangCheng (2003) Abd El-Maksoud *et al.* (2003 and 2004) and Abd El-Hadi *et al.* (2004).

Such promising genetic materials which showed desirable values of mean performances, (S.C.A.) and heterotic effects i.e., hybrids (1x4), (1x3), (1x5), (3x4), (3x5), (3x7), (4x9), (6x7) and (6x8) may be used in improving yielding ability and some other agronomic characters in maize breeding programs.

Genetic diversity and cluster analysis:

The level of genetic diversity based on morpho- agronomical characters among maize genotypes was assayed using the hierarchical Euclidean cluster analysis. A matrix of genetic distance values among the (36) maize populations is presented in Table (6).

Table (3): Estimation of general combining ability (G.C.A.) effects of eight parental inbred lines for the studied characters at the combined data.

Characters / Parental inbred Lines	Grain yield/ plot (kg.)	Ear Length (cm.)	Ear diameter (cm.)	No. of rows/ ear	No. of kernels /row	100-kernel-weight (gm.)	Plant height (cm.)	Ear height (cm.)	Days to tasseling (day)	Days to silking (day)
	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined
1	0.53*	-0.45	-0.12	-0.34	-0.25	0.89	1.61	2.75	-0.78	-0.72
3	-0.29	0.17	0.2	-0.24	1.09	1.39	3.13	3.76	-0.87	-1.19*
4	0.7**	-0.15	0.06	1.23**	2.79**	1.56	1.95	-2.91	-0.17	-0.58
5	-0.39	-0.40	-0.14	-0.73*	-3.18**	-0.86	-0.1	-0.93	0.19	0.28
6	0.09	0.92*	0.21*	0.43	0.33	-0.22	-4.06	-2.66	-0.12	0.22
7	-0.1	0.21	-0.1	0.24	-2.11**	-2.22*	0.49	0.64	-0.06	-0.08
8	-0.78**	-0.69	-0.24*	0.04	0.17	-0.83	0.60	0.49	1.08	1.14*
9	0.25	0.40	0.13	-0.62	1.17	0.31	-3.64	-1.14	0.74	0.94
L.S.D. (gi) 0.05	0.43	0.72	0.21	0.73	1.23	1.74	9.35	6.43	1.25	1.05
L.S.D.(gi) 0.01	0.56	0.96	0.28	0.97	1.63	2.30	12.38	8.51	1.65	1.39
L.S.D. (gi-gj) 0.05	0.64	1.09	0.32	1.11	1.86	2.63	14.14	9.72	1.88	1.59
L.S.D. (gi-gj) 0.01	0.85	1.45	0.43	1.47	2.46	3.48	18.72	12.87	2.49	2.10

Table (4): Estimation of specific combining ability effects for all traits studied at the combined data.

Characters / Crosses	Grain yield/ plot (kg.)	Ear Length (cm.)	Ear diameter (cm.)	No. of rows /ear	No. of kernels/ row	100-kernel-weight (gm.)	Plant height (cm.)	Ear Height (cm.)	Days to tasseling (day)	Days to silking (day)
	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined
1x3	0.15	2.39**	0.29	0.10	-0.83	4.22*	-0.12	0.26	-0.85	-0.99
1x4	2.10**	-0.25	0.33	-0.04	4.31**	5.06*	3.76	9.84	-0.05	0.57
1x5	-0.3	-0.14	-0.14	-0.75	1.61	-0.19	-11.27	-5.26	-0.41	-0.63
1x6	-1.6**	-1.07	-0.43	0.93	-6.32**	-4.83*	-2.10	-7.28	0.23	0.1
1x7	-0.49	-0.33	0.16	0.31	-2.13	-1.83	4.39	1.51	-0.49	-0.6
1x8	-0.89	-0.63	-0.04	0.31	1.59	-2.56	-9.64	-7.35	0.70	0.68
1x9	1.01*	0.03	-0.16	-0.86	1.76	0.14	14.98	8.28	0.87	0.87
3x4	0.17	0.78	0.08	-0.46	0.8	0.22	-8.17	-6.8	0.37	-0.29
3x5	0.76	1.30	0.28	-0.18	2.60	-0.36	3.25	10.39	-0.49	-0.65
3x6	-0.19	-0.88	0.61*	0	1.42	1.83	11.58	2.13	0.98	1.07
3x7	0.14	-1.00	-0.4	0.19	-1.22	-3.83*	-4.84	-5.34	0.59	1.04
3x8	-0.54	-1.42	-0.25	-0.36	-5.02**	0.28	0.05	-0.40	0.45	0.82
3x9	-0.49	-1.17	-0.59**	0.71	2.25	-2.36	-1.75	-0.24	-1.05	-0.99
4x5	-0.51	0.13	-0.02	0.69	-3.09*	-0.03	-0.57	-5.86	-0.52	-0.43
4x6	-0.53	-0.49	-0.26	0.13	-1.61	-1.83	-28.90	-3.71	0.62	0.96
4x7	-0.14	-0.47	-0.34	-0.08	1.33	0.17	0.51	-3.05	1.73	0.76
4x8	-0.66	-0.85	-0.13	-0.41	-1.45	-2.56	22.9*	3.76	-1.41	-1.46
4x9	-0.43	1.15	0.35	0.18	-0.28	-1.03	10.47	5.81	-0.74	-0.1
5x6	-0.55	-0.57	0.21	-0.66	2.2	-1.08	15.86	8.48	0.09	0.43
5x7	-0.55	-0.8	-0.16	-0.93	-3.53*	-0.75	-2.24	-4.19	0.54	0.57
5x8	1.72**	0.90	0.07	0.13	0.19	1.69	-7.14	-2.8	0.73	0.51
5x9	-0.57	-0.83	-0.22	1.7*	0.02	0.72	2.11	-0.76	0.06	0.21
6x7	1.09*	2.07*	-0.17	-0.15	2.79*	2.61	-2.03	3.79	-1.49	-1.38
6x8	0.04	-0.2	-0.19	0.05	0.68	3.89*	-0.47	-3.35	-1.13	-1.27
6x9	1.74**	1.15	0.18	-0.29	0.84	-0.58	6.06	-0.06	0.70	0.1
7x8	0.76	1.53	0.48*	1.19	5.68**	-0.11	15.19	15.22*	-0.19	0.21
7x9	-0.81	-1.00	0.39	-0.54	-2.92*	3.75	-10.99	-7.94	-0.69	-0.6
8x9	-0.44	0.66	0.07	-0.90	-1.67	-0.64	-20.89*	-5.09	0.84	0.51
L.S.D. (Sij) 0.05	0.94	1.60	0.47	1.63	2.72	3.85	20.70	14.23	2.76	2.33
L.S.D. (Sij) 0.01	1.25	2.12	0.63	2.15	3.6	5.1	27.4	18.83	3.65	3.08
L.S.D. (Sij-Sik) 0.05	1.44	2.45	0.73	2.48	4.15	5.88	31.62	21.73	4.21	3.55
L.S.D. (Sij-Sik) 0.01	1.91	3.24	0.96	3.29	5.49	7.79	41.85	28.77	5.58	4.70
L.S.D. (Sij-Skl) 0.05	1.29	2.19	0.65	2.22	3.71	5.26	28.28	19.44	3.77	3.18
L.S.D. (Sij-Skl) 0.01	1.71	2.9	0.86	2 94	4.91	6.96	37.43	25.73	4.99	4.21

Table (5): Estimation of economic heterosis effects of the F_1 hybrids relative to the check variety (S. c 156) from the combined data.

Characters / Crosses	Grain yield/ plot (kg.)	Ear Length (cm.)	Ear diameter (cm.)	No. of rows/ ear	No. of kernels/ row	100-kernel-weight (gm.)	Plant height (cm.)	Ear Height (cm.)	Days to tasseling (day)	Days to silking (day)
1x3	12.73**	29.30**	-0.58*	1.45	14.04**	21.93**	1.84	1.48	-7.58**	-8.62**
1x4	64.44**	8.19**	-2.34**	11.11**	35.19**	24.56**	-0.53	4.12	-4.85**	-4.89**
1x5	3.07**	7.45**	-14.46**	-8.21**	8.61**	4.52*	-9.03	-7.97	-4.99**	-5.62**
1x6	-11.53**	9.96**	-12.87**	12.32**	-5.31**	-6.14**	-6.26	-11.13	-4.24**	-4.31**
1x7	4.78**	10.20**	-7.89**	6.52**	0.10	-3.51	-0.93	-0.21	-5.45**	-6.03**
1x8	-14.34**	1.66*	-14.04**	5.07**	18.68**	-1.75	-7.64	-8.34	-1.21	-1.72
1x9	37.34**	14.12**	-9.65**	-8.21**	22.29**	8.33**	2.18	4.31	-1.52	-1.72
3x4	15.93**	20.05**	-1.17**	8.70**	28.48**	13.16**	-5.55	-10.00	-4.24**	-7.18**
3x5	7.20**	21.95**	-1.17**	-3.38**	15.58**	5.26**	-1.03	7.32	-5.15**	-6.32**
3x6	-1.22**	15.78**	10.82**	6.28**	22.81**	12.72**	1.08	-1.71	-3.03*	-3.45**
3x7	1.29**	9.85**	-12.28**	6.28**	7.07**	-7.46**	-4.65	-5.48	-3.64**	-4.02**
3x8	-22.70**	0.47	-12.28**	0.85	2.37	7.02**	-2.24	-1.15	-1.82	-2.30*
3x9	-3.68**	10.08**	-11.70**	3.86**	27.97**	3.07	-5.15	-2.47	-5.15**	-5.75**
4x5	2.10**	11.27**	-8.77**	13.55**	3.20*	6.58**	-3.44	-13.39	-3.94**	-4.89**
4x6	10.18**	16.25**	-6.73**	17.87**	18.68**	3.51	-19.02	-13.01	-2.42	-2.59*
4x7	13.70**	11.39**	-13.74**	14.98**	20.23**	3.51	-2.64	-9.44	-0.30	-3.45**
4x8	-7.41**	2.25**	-12.57**	11.11**	18.68**	0.00	8.21	-3.41	-3.94**	-5.17**
4x9	14.71**	24.32**	2.34**	10.63**	25.39**	7.02**	0.17	-3.04	-3.33*	-3.16**
5x6	-9.40**	13.88**	-2.05**	-2.05*	11.97**	-0.88	1.58	-0.21	-2.73*	-2.01
5x7	-12.56**	7.24**	-14.04**	-5.31**	-13.51**	-5.26**	-4.95	-8.68	-1.82	-2.30*
5x8	15.26**	12.93**	-12.57**	0.85	5.26**	4.82*	-7.26	-7.55	0.61	-0.29
5x9	-6.93**	8.42**	-11.11**	7.49**	7.84**	5.26**	-4.85	-7.18	-1.21	-1.15
6x7	24.76**	37.01**	-7.02**	8.70**	17.13**	5.26**	-6.76	-3.04	-6.06**	-5.75**
6x8	-5.91**	14.47**	-10.82**	8.70**	17.65**	12.28**	-5.96	-9.62	-3.33*	-3.45**
6x9	42.29**	31.91**	2.05**	1.45	21.26**	3.51	-4.85	-8.12	-0.61	-1.44
7x8	3.62**	21.71**	-4.68**	15.58**	25.59**	-3.51	3.79	10.14	-1.52	-1.44
7x9	-5.93**	11.51**	0.29	-1.69*	2.06	9.65**	-10.88	-12.26	-3.03*	-3.16**
8x9	-11.46**	16.96**	-7.89**	-5.80**	13.00**	1.75	-15.60	-9.81	1.82	0.86

Table (6): Euclidean genetic distances among studies maize genotypes based on their morpho-agronomical characters.

	P1	P2	P3	P4	P5	P6	P7	P8	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27
P2	6.72																																		
P3	6.84	4.07																																	
P4	5.54	6.23	5.61																																
P5	4.91	4.09	4.75	4.2																															
P6	5.33	5.23	4.31	3.69	4.5																														
P7	5.73	3.88	3.05	4.87	4.61	4.5																													
P8	5.47	4.13	5.48	3.68	3.63	3.49	4.43																												
C1	13.92	13.28	13.4	12.55	13.24	12.11	14.7	12.85																											
C2	18.43	17.77	17.2	17.17	18.62	16.05	18.49	17.45	7.92																										
C3	9.45	9.06	8.67	7.68	9.09	7.59	9.58	8.37	6.83	10.21																									
C4	7.92	7.87	7.11	6.17	7.01	4.9	8.39	6.88	7.77	12.57	4.8																								
C5	9.62	8.96	9.08	8.33	9.15	7.02	10.16	8.28	5.71	10.11	3.85	3.4																							
C6	8.89	8.82	7.78	7.02	8.11	6.57	9.12	7.92	7.44	11.38	3.79	4.13	4.55																						
C7	13.88	13.49	13.57	12.71	14.11	11.97	14.35	12.67	5.38	5.95	5.78	9	6.23	7.75																					
C8	13.73	13.74	12.87	12.03	13.34	11.51	14.39	12.96	3.91	7.07	5.57	7.29	5.85	5.99	5.43																				
C9	12.05	11.65	12.16	10.88	11.64	10.44	13.12	10.94	3.32	8.78	4.65	6.71	4.05	5.94	4.55	4.61																			
C10	12.98	12.83	12.56	12.2	12.47	11.43	14.2	12.62	4.2	8.93	6.25	7.27	5.59	6.08	6.61	3.81	3.88																		
C11	8.96	8.96	8.52	7.2	8.62	6.24	9.54	7.72	6.44	10.51	3.29	2.84	1.97	3.15	6.51	5.62	4.71	5.98																	
C12	8.17	6.85	6.95	7.28	6.8	6.44	8.33	7.06	7.21	12.38	4.2	4.18	4.32	3.49	8.38	7.47	5.89	6.36	4.26																
C13	11.27	10.77	10.23	9.16	10.4	8.87	11.51	9.81	5.55	9.4	3.88	5.66	4.54	2.87	5.94	4.08	4.14	4.7	3.66	4.84															
C14	15.37	13.09	12.54	12.51	13.32	11.87	14.13	13.08	9.89	13.35	9.68	9.44	9.2	10.28	11.83	9.66	10.2	10.56	4.49	10.39	9.82														
C15	11.95	12.62	11.24	9.96	11.8	9.57	12.56	11.57	6.4	9.27	5.58	5.55	5.57	5.08	7.55	4	6.36	6.03	4.69	7.14	4.77	10.06													
C16	11.64	11.66	10.6	9.93	11.4	8.8	11.09	10.57	5.81	8.14	4.77	5.24	4.29	4.27	5.68	3.61	5.36	5.52	3.53	6.13	3.49	9.63	3.51												
C17	10.59	9.47	8.99	9.09	9.49	7.59	10.62	8.83	6.84	10.32	5.13	4.93	4	3.45	7.03	5.81	5.42	5.43	3.64	4.24	3.37	9.74	6.34	3.86											
C18	13.44	13.84	13.23	12.18	13.23	11.39	14.62	12.73	3.76	7.4	6.12	7.14	5.21	6.26	5.2	2.32	3.63	3.04	5.33	7.38	4.35	10.41	4.8	3.92	5.43										
C19	9.66	9.61	9.87	8.84	9.17	8.21	11	8.89	5.37	10.77	4	4.87	3.27	3.98	6.37	5.52	3.11	3.99	3.39	3.78	3.63	10.36	6.27	5.15	3.84	4.7									
C20	6.24	6.34	6.55	5.55	5.95	4.85	7.14	6.62	5.28	13.45	4.2	3.34	4.2	5.18	8.86	8.63	6.84	8.2	4.09	3.88	6.71	10.55	7.64	7.02	5.25	8.48	4.94								
C21	9.95	10.37	9.84	8.86	10.31	8.11	10.75	9.44	5.26	8.94	2.72	4.67	3.33	4.64	4.94	4.82	4.53	5.95	3.04	5.24	4.48	10.15	4.5	3.47	5.27	5	4.42	4.9							
C22	9.13	8.97	8.29	7.82	8.51	6.9	9.7	8.34	5.78	10.48	3.23	3.08	3.03	2.53	6.91	5.15	4.85	5.11	2.42	2.92	3.39	9.73	4.48	3.51	3.4	5.2	3.24	4.27	3.09						
C23	13.67	14.02	13.77	11.87	13.54	11.5	14.74	12.61	3.93	7.85	6.19	7.3	5.58	7.4	5.33	3.83	4.41	5.9	5.65	8.43	5.62	10.29	4.9	4.67	3.13	3.4	6.15	8.48	4.75	6.07					
C24	10.95	10.7	9.81	9.18	10.05	8.68	11.37	9.99	4.85	9.72	3.86	4.67	4.45	3.28	6.76	3.72	4.79	4.49	3.82	4.35	2.77	9.51	3.89	3.18	3.95	4.34	4.02	6.07	3.79	2.18	5.32				
C25	14.58	15.58	15.09	13.51	15.27	12.98	16.04	14.31	5.45	8.69	7.22	9.09	7.06	8.77	4.66	4.5	5.65	6.47	7.13	10.01	7.14	11.78	6.22	5.9	8.53	4.2	7.3	9.77	5.6	7.64	3.49	7.11			
C26	12.65	12.57	12.73	11.43	12.23	10.42	13.83	11.38	5.89	9.18	6.97	6.98	6.02	6.02	6.34	5.39	4.16	4.84	5.12	6.94	4.41	11.22	6.28	4.75	4.6	3.67	4.58	8.44	6.12	5.47	5.24	5.41	6.84		
C27	9.63	9.89	9.26	8.71	9.3	8.43	10.63	9.74	5.46	10.98	3.49	4.5	4.36	4.64	7.5	5.39	5.09	4.94	4.33	4.35	5.11	9.79	6.12	5.58	5.97	5.78	3.95	4.55	3.86	3.23	6.48	3.72	7.4	7.32	
C28	8.84	10.12	9.54	7.57	8.87	8.13	10.35	8.99	6.47	11.7	3.39	5.03	5.21	3.67	7.52	5.83	5.28	5.95	4.2	4.69	4.29	10.97	5.06	5.59	6.12	6.15	4	4.93	4.13	3.57	6.5	3.85	7.63	6.93	3.19

The genetic distances for all (630) pairs ranged from (1.97) to (18.62). The highest genetic distance of (18.62) was detected between (P_5) and (C_2) this was followed by a distance (18.49) between (P_7) and (C_2). This indicated that (P_5) is the most divergent genotype from all other maize genotypes. Meanwhile, the minimum Euclidean distance of (1.97) was observed between the most similar genotypes (C_5) and (C_{11}), followed by a distance of (2.18), between (C_{22}) and (C_{24}).

The dendrogram produced from genetic distance based on morpho-agronomical characters among maize genotypes is shown in Figure (1).

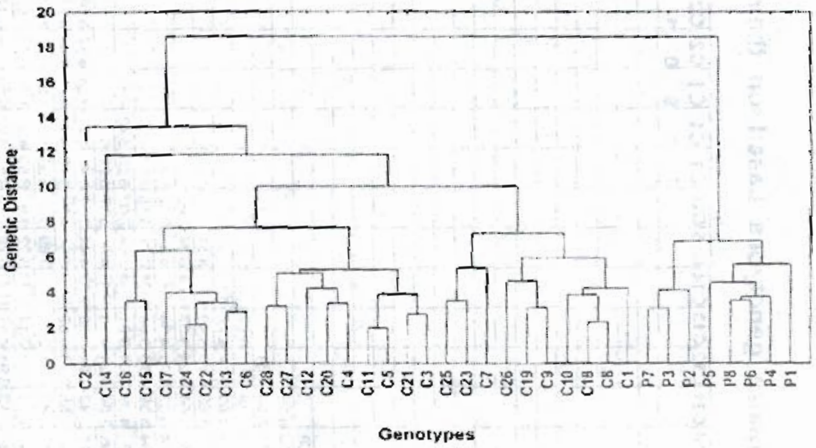

Figure (1): Linkage dendrogram for studied maize genotypes based on their morpho-agronomical characters.

Table (7): Grouping pattern of parents and F1 hybrids based on their morpho-agronomical characters.

Cluster	No. of Genotypes	Maize Genotypes (parents and F1 crosses) falling in cluster
I	1	C14:(M4xM5)
II	7	C6:(M1xM8),C13:(M3xM9),C15:(M4xM6),C1:(M4xM7),C17:(M4xM8),C22: (M5xM9),C24(M6xM8)
III	9	C3:(M1xM5),C4:(M1xM6),C5:(M1xM7),C11:(M3xM7),C12:(M3xM8),C20:(M5xM7),C21:(M5xM8),C27:(M7xM9),C28:(M8xM9)
IV	10	C1:(M1xM3),C7:(M1xM9),C8:(M3xM4),C9:(M3xM5),C10:(M3xM6),C18:(M4xM9),C19:(M5xM6),C23:(M6xM7),C25:(M6xM9),C26:(M7xM8)
V	1	C2:(M1xM4)
VI	8	P1:M1,P2:M3,P3:M4,P4:M5,P5:M6,P6:M7,P7:M8,P8:M9

Based on the extent of relative dissimilarity among maize genotypes, the 36 maize populations were grouped into (6) clusters. Cutoff point at (8.0). Euclidean distance was fixed as minimum dissimilarity.

Cluster I contained the single genotype (C_{14}). Cluster II consisted of seven genotypes, (C_6,C_{13}, C_{15}, C_{16}, C_{17}, C_{22} and C_{24}).Cluster analysis further united C_6 and C_{13}; $C_{22}$and C_{24} ;and C_{15} and C_{16} into discrete group within a larger cluster. Cluster III consisted of nine genotypes; C_3, C_4,C_5, C_{11}, C_{12}, C_{20}, C_{21}, C_{27} and C_{28}. Cluster analysis further united C_3 and C_{21}; C_5 and C_{11}; C_4 and C_{20}; and C_{27} and C_{28}. Cluster IV comprised ten genotype; C_1, C_7, C_8, C_9, C_{10}, C_{18}, C_{19}, C_{23}, C_{25}, and C_{26}. Cluster analysis further united C_8 and C_{18}; C_9 and C_{19}; and C_{23} and C_{25}. Cluster V comprised the single genotype C_2. Cluster VI comprised of eight genotype, P_1, P_2, P_3, P_4, P_5, P_6, P_7, and P_8. Cluster analysis further united P_6 and P_8; and P_3, and P_7 (Fig.1). However, in none of the hybrids which are derived from one parent are grouped together into one cluster. It is worthy to mention the performance of either C_{14} and C_2 crosses which each occupied single cluster was quite different from each other and from the rest of all crosses and parental lines as well.

The parents were distributed in one cluster. The distribution of hybrids was also over five clusters, which revealed that diversity in hybrids was greater than that in their parents. These data indicated that distribution of genotypes into different clusters was at random and was not influenced by their parentage distribution. Moreover, considerable genetic divergence induced by hybridization in this set of maize genotypes. The existence of such a wide genetic diversity was previously reported by Smith (1986), Autrique *et al.* (1996), Gonzalez (1997), Melo *et al.* (2001), Vacor *et al.* (2002), Alamnie *et al.* (2003), and partially with Mohamed (2005).

The average intra-cluster and inter-cluster genetic distances are presented in Table (8).

Table (8): Euclidean average intra- and inter- cluster genetic distances among six clusters of studied maize genotypes based on their morpho-agronomical characters.

No. of Cluster	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Cluster I	0.000	9.032	9.272	9.901	14.094	16.634
Cluster II		0.746	0.919	1.508	4.74	8.496
Cluster III			0.862	2.317	6.126	5.461
Cluster IV				0.877	2.329	14.487
Cluster V					0.000	21.378
Cluster VI						0.996

The maximum inter-cluster distance (21.378) was found between cluster (VI) and (V), which were followed by the distance (16.634) between clusters (VI) and (I) ;and (14.487) between clusters (VI) and (IV), suggesting the presence of wide genetic diversity between them.

The minimum inter-cluster distance (0.919) was observed between cluster (III) and (II), which were followed by (1.508) between cluster (IV) and (II), indicating close relationship among the genotypes included within these clusters.

Generally the Euclidean genetic distances observed indicated that the magnitude of inter-cluster distance reflects the diversity which exists among the genotypes.

The intra-cluster distance was maximum (0.996) in cluster (VI) and followed by cluster (IV) and (III); and was the minimum (0.000) in cluster (I) and (V), indicating that the maize genotypes C_{14} and C_2 in cluster (I) and (V), respectively to be the most heterogeneous.

Relationship between genetic distance and each of heterosis, specific combining ability (S.C.A.) and mean performance:

The correlation coefficients between genetic distance between parents and heterosis, and *per se* hybrids performance exhibited positive significant correlation coefficients (0.43) and (0.41) for grain yield per plot and significant negative correlation coefficients (-0.41) and (-0.41) for days to tasseling. In addition, significant negative correlation coefficient (-0.37) was also observed between genetic distance and heterosis for days to silking.

However, rest characters showed insignificant correlation coefficients between genetic distance and heterosis. Since significant association between heterosis and parental divergence would depend on several factors including availability of optimum environmental for the expression of heterosis and the extent of internal cancellation or balancing of the various components of heterosis (Falconer,1989). However, non correspondence between genetic divergence and heterosis have been reported by Behl *et al.* (1985) in tritical; Martin *et al.* (1995) in wheat; and Rosa *et al.* (2000) in maize.

However, of the ten characters only ear length showed positive significant correlation coefficient (0.38) between the genetic distances between the parental genotypes of 28 hybrids and their SCA values. Meanwhile, non-significant correlation coefficients were obtained for rest of the ten characters. In this regard Wang *et al* (2002). Reported that although specific combining ability for yield can be predicted from the divergence of inbred lines of sweet corn, no definite relationship could be found for the other characters. Generally, from these results it appeared that heterosis could not be considered as a function of genetic divergence and it is impossible to predict hybrid performance from genetic distance. Similar results were detected by Mohamed (2005).

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علاقات القرابة الوراثية وقوة الهجين والقدرة على الائتلاف لبعض سلالات الذرة الشامية

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أجرى هذا البحث بمزرعة كلية الزراعة بشبين الكوم–جامعة المنوفية خلال أعـوام ٢٠٠٢ و٢٠٠٣م بهدف دراسة القدرة العامة و القدرة الخاصة على الائتلاف وتفاعلاتها مع السنوات وكذا تأثيرات القدرة العامة و القدرة الخاصة على الائتلاف وقوة الهجين على أساس الصنف الاختباري هجـين فـردى ١٥٦ وأيـضا علاقات القرابة الوراثية ومعامل الارتباط بين قيم التباعد الوراثى وكلا من القدرة الخاصة على الائتلاف وقوة الهجين والمتوسط وذلك باستخدام نظام الهجن التبادلية لعدد ثمانية سلالات من الذرة الشامية وقـد لخـصت النتائج فيما يلى:

(١) تفوقت متوسطات الهجن الفردية (١×٤)، (٦×٧)، (٦×٩)، (١×٣)، (٣×٤) بالنسبة لصفة المحـصول ومكوناتها والتبكير بينما تفوقت متوسطات الهجن (٧×٩)، (٨×٩) بالنسبة لارتفاع النبات تجاه القـصر ولارتفاع الكوز المنخفض.

(٢) أظهرت القدرة العامة على الائتلاف تباينا عالى المعنوية لصفات محصول الحبـوب للقطعـة وطـول الكوز وعدد الحبوب بالسطر.

(٣) أظهرت القدرة الخاصة على الائتلاف تباينا عالى المعنوية لمعظم الصفات المدروسة عدا صفتى ارتفاع النبات وارتفاع الكوز.

(٤) سجلت النسبة بين القدرة العامة والقدرة الخاصة على الائتلاف قيما أقل من الواحد الـصحيح لمعظـم الصفات المدروسة عدا صفتى ارتفاع النبات وارتفاع الكوز مما يشير إلى فعل الجين غير المضيف فى وراثة تلك الصفات.

(٥) كان التداخل بين محصول الحبوب للقطعة وبعض مكوناته مع السنوات عالى المعنوية.

(٦) أظهرت تأثيرات القدرة العامة على الائتلاف لصفات محصول الحبوب للقطعة ولعدد الصفوف بالكوز ولعدد الحبوب بالسطر قيما معنوية ومرغوبة للسلالة Pop 59-8 ، ولصفات طول الكوز وقطر الكـوز للسلالة Pop 59-6 ، ولصفة التزهير للنورة المؤنثة تجاه التأخير للـسلالة Pop 59-8 ولـصفة التبكيـر الـسلالة Pop 59-3.

(٧) حازت الهجـن (١×٤)، (١×٣)، (١×٥)، (٣×٤)، (٣×٥)، (٣×٧)، (٤×٩)، (٦×٧)، (٦×٨) قيمـا مرتفعة وعالية المعنوية لتأثيرات القدرة الخاصة على الائتلاف.

(٨) أظهرت النتائج وجود ارتباط معنوى بين مقدار التباعد الوراثى وتأثيرات قوة الهجين والمتوسط وذلك لصفة المحصول ولصفة التزهير للنورة المذكرة بينما وجد ارتباط معنوى بين مقدار التباعـد الـوراثى القدرة الخاصة على الائتلاف لصفة طول الكوز فقط.

(٩) توضح النتائج أنه من غير الممكن استخدام التباعد الوراثى المحسوب من الصفات المحـصولية فـى التنبؤ بقوة الهجين والقدرة الائتلافية.