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TYPE OF GENE ACTION FOR GRAIN YIELD USING TESTCROSS ANALYSIS IN NEW DEVELOPED MAIZE INBRED LINES

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ABSTRACT

Nineteen selected S_5 white maize lines derived from the wide genetic base population Tepalicinco (Tep#5), from SIMMYT, were topcrossed to each of two commercial inbred testers, i.e. Sd 7 and Gm 22 in 2003 summer season. The resultant 38 testcrosses were evaluated in 2004 growing season at Gemmeiza and Mallawy Agricultural Research Stations, for grain yield and its components as well as days to 50% silking. Results obtained revealed that the additive component of gene action had the major role in the inheritance of the most studied traits compared with the non-additive ones. Highly significant differences were detected among the tested lines and their testers, as well as, the interaction between them. The tested lines L-1, L-5, L-8, L-9, L-14, L-17 and L-19 manifested the best general combining ability (GCA) effects based on the combined analysis. Parental lines L-1, L-2, and L-18 and their testcrosses were earlier than the check hybrids SC 10 and SC 124. Moreover, single crosses of L-1 and L-2 with Sd 7 significantly outyielded the commercial check hybrid SC 124. Meanwhile, the inbred tester Sd 7 crossed to the tested lines L-3, L-4, L-5, L-8, L-9, L-13, L-14, L-17 and L-19 produced the best single crosses which significantly outyielded the check hybrid SC 124 with an average increase from 3.4 to 8.0 ard/fad. Furthermore, the most outstanding crosses, i.e. L-8 x Sd 7, L-14 x Sd 7, L-19 x Sd 7, and L-1 x Sd 7 (37.2, 36.5, 36.3 and 35.9 ard/fad, respectively) outyielded the best commercial check hybrid SC 10 (35.4 ard/fad) by 1.8, 1.1, 0.9 and 0.5 ard/fad, respectively.

Keywords: Maize, Testcrosses, Inbred, Testers, Combining ability.

INTRODUCTION

Successful development of improved maize hybrids is dependent upon the accurate evaluation of inbred lines performance in crossing. The standard topcross procedure as suggested by Davis (1927) has been widely used to evaluate the general combining ability of inbred lines in hybrid maize-breeding programs. Inbreds of high general combining ability are crossed to detect particular combinations that result in superior single cross, two line combination for commercial use. Procedures for developing and improving inbred lines of maize were reported by Geadlman and Peterson (1976), Kuhn and Stucker (1976), Bauman (1981) and Hallauer and Miranda (1981) who concluded that improving inbred lines increased grain yield and modified maturity of their hybrids.

Testcross procedure is practiced commonly in the Egyptian maize breeding program to develop new inbred lines highly tolerant to late wilt disease and to study the combining ability pattern between lines and testers for the final goal of developing high yielding single cross hybrids.

The choice of a tester to test the developed inbred lines is an important decision. Matzinger (1953) showed that a narrow genetic-base tester contributes more to line x tester interaction than does a heterogeneous one.

Moreover, he defined a desirable tester as one that combines the greatest simplicity in use with the maximum information on performance to be expected from tested lines when used in other combinations. Darrah *et al* (1972) and Horner *et al* (1973) reported that inbred testers have the advantage of no sampling errors of genetic variability within the testers and greater genetic variation among testcrosses.

Several results concerning the genetic analysis of grain yield, as well as other agronomic traits reported by Singh *et al* (1971), El-Itriby *et al* (1990), Diab *et al* (1994), Sultan (1998) and Gado *et al* (2000) indicated that the relative importance of different components of genetic variance may vary with the type of genetic materials under study. Studies conducted with homozygous base populations indicated the importance of over-dominance in grain yield performance (Robinson *et al,* 1949; Gardner *et al,* 1953; Gardner and Lonnquest, 1959; Gamble, 1962; Findly *et al*, 1972; Vedeneev, 1988 and El-Zeir *et al*, 2000). In addition, Matzinger *et al* (1959), Russell *et al* (1973), El-Hosary (1985), Salama *et al* (1995), Sultan (1998) and Sadek *et al* (2001 and 2002), reported that the variance component due to SCA for grain yield and other agronomic traits was relatively larger than that due to GCA. This indicated that the non-additive type of gene action appeared to be more important in materials or lines selected previously for grain yield performance. On the other hand, Rojas and Sprague (1952), Shehata and Dhawan (1975), El-Itriby *et al* (1990), Abdel-Aziz *et al* (1994), Shehata *et al* (1997) and Soliman *et al* (2001 and 2005) stated that when the lines were relatively unselected, GCA or the additive type of gene action became more important.

The objectives of this study were to (i) estimate combining ability variances and effects of nineteen inbred lines, (ii) determine the type of gene action involved in the manifestation of grain yield and yield attributes and (iii) identify the most superior line(s) and single crosses for further use in the breeding program.

MATERIALS AND METHODS

Nineteen S_5 white maize inbred lines were used in this study. These lines derived from an exotic open pollinated variety Tapalicinco (Tep#5) from CIMMYT, Mexico, through selection from segregating generations in the disease nursery field at Gemmeiza Agric. Res. Stn. In 2003 growing season. The 19 S_5 lines were topcrossed to each of the two narrow base inbred testers, ***viz*** Sd 7 and Gm 22 at Gemmeiza Res. Stn. The two testers are being used in seed production of commercial single and three-way cross hybrids. In the growing season of 2004, the 38 resultant test-crosses along with two commercial check hybrids; SC 10 and SC 124 were evaluated in replicated yield trials conducted at Gemmeiza and Mallawy Agric Res Stn, representing Delta and Middle Egypt regions, respectively.

A randomized complete block design with four replications was used in each location. Plot size was one row, 6 m long and 80 cm apart and hills were spaced 25 cm along the row. Two kernels were planted per hill and thinned later to one plant per hill to provide a population of approximately 22,000 plants/fad (faddan=4200 m^2). All cultural practices for maize production were applied as recommended. Data were recorded for adjusted grain yield at 15.5% grain moisture and converted to ardab/fad (ardab=140 kg), number of ears/100 plants, ear length (cm), ear diameter (cm), number of rows/ear, number of kernels/row, 100-kernel weight and number of days to 50% silking. Analysis of variance was performed for the combined data over locations according to Steel and Torrie (1980). Procedures of Kempthorne (1957) were performed to obtain valuable information about the combining ability of lines and testers as well as their topcrosses. Also, to estimate type of gene effects controlling grain yield and other studied attributes.

RESULTS AND DISCUSSION

I. Analysis of variance:

The combined analysis of variance for the eight studied traits is presented in Table (1). Highly significant differences were detected between locations for all studied traits, except ear length and 100-kernel weight(gm), indicating that the two locations differed in their environmental conditions. Mean squares among crosses were highly significant for all traits. Partitioning the sum of squares due to crosses into its components showed that mean squares due to lines and testers were highly significant for all traits, revealing that greater diversity existed among testers and lines. Meanwhile, mean squares of the lines x testers interaction were highly significant for all traits, indicating that female lines differed in their performance in crosses with each of the male testers. Mean squares due to the interaction of both lines and testers with locations were highly significant for all studied traits, except ear diameter for lines x locations interaction and weight of 100 kernels for the testers x locations interactions. These interactions with locations were indicative of different ranking of genotypes of lines and testers from one location to another. Significant lines x testers x locations mean squares were detected for all studied traits, except number of days to mid silking, revealing that the hybrids between lines and testers behaved somewhat differently from location to another. These results are in agreement with those obtained by El-Hosary (1985), Shehata *et al* (1997), Gado *et al* (2000), Soliman *et al* (2001) and Sadek *et al* (2002). The magnitude of the variances due to testers and testers x locations interaction for all studied traits was higher than variances of lines and lines x locations interaction, respectively. This indicates that the testers contributed much more to the total variation and were more affected by the environmental conditions than the lines. Similar findings were obtained by El-Itriby *et al* (1990), Gado *et al* (2000), Soliman *et al* (2001) and Sadek *et al* (2002).

II. Mean performance and combining ability effects:

Grain yield of the 19 lines across the two testers (Table 2) ranged from 23.84 to 30.90 ard/fad for testcrosses with lines L-11 and L-19, respectively. The most preferable lines were L-1, L-5, L-8, L-9, L-14, L-17 and L-19. These lines produced the highest average grain yield (ranging from 29.34 to 30.90 ard/fad).

Table 1. Analysis of variance for grain yield and its components of 19 inbred lines topcrossed with two testers, combined over locations in 2004 growing season.

S.O.V	DF	Grain yield Ard/Fad	Ears/100 plants	Ear length	Ear diameter	Rows/ ear	kernels/ row	100-kernel weight g	days to 50% silking
Locations (Loc)	1	1350.50**	16334.76**	0.770	21.849**	2.921**	1140.80**	2.15	95.07**
Rep/Loc	6	118.20	373.84	4.460	0.163	1.507	3.64	6.83	8.32
Crosses (C)	37	200.49**	509.95**	8.066**	0.259**	1.810**	41.45**	89.20**	6.90**
Lines (L)	18	53.97**	605.82**	3.818**	0.154**	1.673**	34.85**	77.22**	3.23**
Testers (T)	1	5587.45**	1042.66**	149.380**	4.146**	2.921**	426.55**	1286.72**	116.26**
L x T	18	47.73**	384.47**	4.464**	0.147**	1.885**	26.65**	34.66**	4.49**
C x Loc x	37	41.35**	232.80**	5.807**	0.209**	2.719**	34.21**	32.63**	0.57
L x Loc	18	27.27**	164.22**	4.980**	0.111	3.817**	33.82**	38.15**	0.55
T x Loc	1	722.70**	1284.13**	79.336**	3.347**	6.900**	220.83**	3.24	0.05
L x T x Loc	18	17.57*	242.98**	2.550**	0.132*	1.388**	24.23**	28.73**	0.62
Pooled error	222	10.16	79.68	1.055	0.077	0.410	4.21	4.76	0.55
CV%		12.09	8.20	4.94	5.35	4.52	4.90	6.42	1.26

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

However, grain yield of eleven testcrosses of Sd-7 with lines L-1, L-2, L-3, L-4, L-5, L-8, L-9, L-13, L-14, L-17 and L-19 significantly outyielded the commercial check hybrid SC 124 (29.24 ard/fad) with minimum of 3.44 ard/fad (11.8%) and maximum of 7.98 ard/fad (27.3%). Meanwhile, these eleven outyielding crosses did not differ significantly from the commercial hybrid SC 10 (35.41 ard/fad). Moreover, the four top-most outyielding crosses, *i.e.* L-8 x Sd 7, L-14 x Sd 7, L-19 x Sd 7 and L-1 x Sd 7, insignificantly surpassed SC 10 by 1.81, 1.11, 0.89 and 0.46 ard/fad, respectively. Considering the inbred tester line "Sd 7" produced higher grain yield (32.53 ard/fad) over all parental lines than the tester line Gm 22 (23.95 ard/fad). These results were reflected in the combining ability effects (Table 3), where L-8, L-9, L-14 and L-19 were the best lines in GCA effects (which had good yield in their crosses with the two testers followed by L-1, L-3, L-4, L-5 and L-17. The inbred tester Sd 7 had also highly significant and positive GCA effect, whereas, the inbred tester Gm 22 had high negative value in its GCA effect for grain yield In other words, the above mentioned nine lines in addition to the inbred tester Sd 7 had accumulated favorable alleles for grain yield and contributed to upgrading grain yield of all crosses involving these lines. Similar findings were also obtained by Diab *et al* ((1994), Salama *et al* (1995) and Sadek *et al* (2001 and 2002) for the inbred tester Sd 7.

Comparison of SCA effects (Table 4) indicated that 4 out of the 38 testcrosses, *i.e.* (L-8 x Sd 7, L-14 x Sd 7, L-19 x Sd 7 and L-1 x Sd 7) exhibited significantly positive SCA estimates (3.085**, 2.518*, 2.216* and 2.242*), respectively and gave the highest grain yield (37.22, 36.52, 36.30 and 35.87 ard/fad), respectively (Table 2). In addition, the testcross (L-6 x Gm 22) also exhibited positive and highly significant SCA effect (3.133**), however, was lower in grain yield (26.94 ard/fad), but not significantly less than the check hybrid "SC 124". Topcross which ranks highest for SCA effects in a certain trait and in the same time ranks best in its performance are considered to be good breeding material to improve this trait. Thus, the crosses L-1 x Sd 7, L-8 x Sd 7, L-14 x Sd 7 and L-19 x Sd 7 appeared to be promising single crosses, since they had positively significant SCA effects (Table 4) and insignificantly surpassed the best commercial hybrid "SC 10" (Table 2). It is worth noting that a cross exhibiting high SCA value may come from two parents possessing good GCA or from one parent with good GCA and another with poor GCA. For example, The best SCA effects for grain yield was exhibited between parents with poor and good GCA (L-1 x Sd 7 and L-6 x Gm 22). Similar findings were obtained by Nawar *et al* (1979), Nawar and El-Hosary (1985), Soliman *et al* (2001) and Sadek *et al* (2002).

Considering number of ears/100 plants, data in Tables (2 and 3) illustrated that the tester line Sd 7 showed more favorable effect on number of ears than the tester line Gm 22, since it manifested significantly higher average number of ears/plant and highly significant positive GCA effect. These results are supported by the findings of Sadek *et al* (2000 and 2002). For the tested lines, the best general combiners over testers were L-3, L-12, L-14 and L-19 (Tables 2 and 3), since they exhibited more ears per plant and had highly significant positive GCA effects (117.3, 114.2, 125.2 and 113.6 as well as 8.516**, 6.872**, 16.341** and 4.803*), respectively.

Table 2. Mean performance of 38 testcrosses between 19 lines and two testers for grain yield and its components, *combined* over two locations, 2004 growing season.

LINES	Grain yield (Ard/Fad)			Ears/100 plants			Ear length (cm)			Ear diameter (cm)		
	Gm 22	Sd 7	Average	Gm 22	Sd 7	Average	Gm 22	Sd 7	Average	Gm 22	Sd 7	Average
L - 1	22.81	35.87	29.34	106.4	103.3	104.8	20.8	20.8	20.8	5.1	5.4	5.3
L - 2	24.07	32.72	28.39	102.7	99.1	100.9	20.5	21.5	21.0	5.2	5.3	5.3
L - 3	22.59	34.77	28.68	109.2	125.5	117.3	19.4	21.2	20.3	5.1	5.3	5.2
L - 4	22.72	35.14	28.93	103.2	114.1	108.6	19.9	22.1	21.0	5.1	5.2	5.1
L - 5	24.18	35.12	29.65	99.8	106.2	103.0	19.9	21.9	20.9	5.0	5.3	5.1
L - 6	26.94	29.25	28.09	107.0	104.0	105.5	20.8	21.1	20.9	5.0	5.3	5.1
L - 7	21.14	29.92	25.53	112.0	108.5	110.2	20.6	20.9	20.8	4.7	5.1	4.9
L - 8	22.48	37.22	29.85	99.8	124.1	111.9	21.6	22.9	22.2	5.1	5.4	5.3
L - 9	26.53	33.11	29.82	101.1	104.8	102.9	20.2	22.1	21.1	5.4	5.3	5.4
L - 10	23.61	28.42	26.01	104.6	100.5	102.5	20.7	21.5	21.1	5.2	5.2	5.2
L - 11	20.36	27.32	23.84	102.3	104.5	103.4	21.0	21.0	21.0	5.2	5.2	5.2
L - 12	25.56	30.85	28.20	104.1	124.4	114.2	20.7	20.3	20.5	5.1	5.2	5.1
L - 13	21.98	32.72	27.35	108.1	112.8	110.5	19.2	21.4	20.3	4.9	5.5	5.2
L - 14	24.90	36.52	30.71	122.6	127.8	125.2	19.7	21.4	20.5	5.1	5.2	5.1
L - 15	25.46	30.54	28.00	103.5	108.1	105.8	18.3	21.7	20.0	5.2	5.5	5.4
L - 16	22.98	29.29	26.13	109.0	106.9	107.9	19.2	21.0	20.1	5.2	5.3	5.3
L - 17	26.10	32.68	29.39	110.7	101.4	106.0	20.2	21.8	21.0	5.1	5.5	5.3
L - 18	25.19	30.27	27.73	117.5	106.5	112.0	20.6	21.3	20.9	5.0	5.5	5.3
L - 19	25.50	36.30	30.90	109.4	117.9	113.6	19.0	22.4	20.7	5.0	5.5	5.3
Average	**23.95**	**32.53**		**107.0**	**110.7**		**20.1**	**21.5**		**5.1**	**5.3**	
Checks												
SC 10	35.41			105.5			22.8			5.5		
SC 124	29.24			102.0			20.9			5.4		
LSD												
0.05	3.12			8.75			1.01			0.27		
0.01	4.10			11.47			1.32			0.36		

Table 2. Continue ....

LINE	Rows/ear			kernels/row			100-kernel weight g			Days to 50% silking		
	Gm 22	Sd 7	Average	Gm 22	Sd 7	Average	Gm 22	Sd 7	Average	Gm 22	Sd 7	Average
1	15.0	14.3	14.7	41.6	43.7	42.7	31.0	35.6	33.3	57.0	59.1	58.1
2	14.3	14.4	14.3	41.5	42.9	42.2	33.6	37.6	35.6	58.0	57.9	58.0
3	14.2	14.1	14.2	40.2	43.4	41.8	33.5	38.1	35.8	57.9	59.5	58.7
4	15.0	13.8	14.4	46.1	46.1	46.1	30.2	33.1	31.7	57.5	59.5	58.5
5	14.4	13.7	14.1	38.6	42.1	40.4	33.0	36.2	34.6	57.9	59.5	58.7
6	14.1	14.6	14.4	43.3	41.1	42.2	35.6	35.9	35.8	58.0	59.9	59.0
7	13.7	13.7	13.7	42.4	41.3	41.9	26.0	34.8	30.4	58.4	58.8	58.6
8	15.0	14.1	14.6	40.4	44.4	42.4	29.3	39.3	34.3	57.9	60.0	59.0
9	15.1	14.5	14.8	40.9	44.1	42.5	30.8	36.7	33.8	57.8	60.6	59.2
10	14.2	13.9	14.1	40.2	42.2	41.2	32.5	36.3	34.4	59.6	59.1	59.4
11	14.3	13.7	14.0	41.3	40.7	41.0	29.1	31.0	30.1	57.9	59.6	58.8
12	14.5	14.4	14.5	41.1	39.5	40.3	29.1	33.5	31.3	59.3	59.5	59.4
13	13.9	14.9	14.4	40.4	44.3	42.4	32.2	36.5	34.4	58.8	59.8	59.3
14	13.5	14.0	13.8	37.9	41.6	39.8	31.5	38.5	35.0	58.3	58.9	58.6
15	14.9	13.2	14.1	37.7	42.4	40.1	30.1	37.4	33.8	58.1	59.9	59.0
16	13.5	13.6	13.6	39.6	42.7	41.2	30.4	34.8	32.6	57.8	59.4	58.6
17	13.6	14.5	14.1	40.8	47.6	44.2	36.8	39.2	38.1	59.4	59.5	59.5
18	14.3	14.1	14.2	40.8	42.9	41.9	38.9	36.6	37.8	58.5	58.0	58.3
19	13.8	14.0	13.9	38.2	45.1	41.7	32.4	33.1	32.8	57.9	60.8	59.4
Average	**14.3**	**14.1**		**40.7**	**43.1**		**31.9**	**36.0**		**58.2**	**59.4**	
Checks												
SC 10	14.0			45.1			37.4			60.9		
SC 124	13.7			41.7			31.9			59.4		
LSD												
0.05	0.63			2.01			2.14			0.72		
0.01	0.82			2.64			2.80			0.95		

Table 3. General combining ability effects ($\hat{g}_i$) of 19 inbred lines and two testers for grain yield and its components, combined over two locations in 2004 growing season.

arents	Grain yield(Ardab/Fad.)	Ears/100 plants	Ear length(cm)	Ear Diameter(cm)	Rows/ ear	Kernels/ row	100-kernel weight(g)	Days to 50% silking
Inbred lines								
L-1	1.100	- 4.022	0.010	0.042	0.487**	0.767	-0.678	-0.747**
L-2	0.150	- 7.953**	0.184	0.017	0.162	0.354	1.655**	-0.872**
L-3	0.440	8.516**	-0.503	-0.033	-0.062	-0.071	1.843**	-0.122
L-4	0.686	- 0.184	0.172	-0.033	0.237	4.229**	-2.292**	-0.309
L-5	1.412	- 5.834**	0.097	-0.021	-0.100	-1.514**	0.605	-0.122
L-6	-0.143	- 3.378	0.159	-0.058	0.187	0.342	1.793**	0.128
L-7	-2.711**	1.391	-0.015	-0.333**	-0.475**	-0.046	-3.569**	-0.247
L-8	1.612*	3.109	1.422**	0.054	0.350*	0.542	0.378	0.128
L-9	1.582*	- 5.915**	0.334	0.154*	0.550**	0.604	-0.184	0.378**
L-10	-2.223**	- 6.309**	0.309	-0.002	-0.100	-0.671	0.439	0.566**
L-11	-4.400**	- 5.459*	0.197	0.017	-0.175	-0.858	-3.938**	-0.059
L-12	-0.037	6.872**	-0.315	-0.046	0.300	-1.571**	-2.638**	0.566**
L-13	-0.886	1.622	-0.528*	0.017	0.187	0.479	0.391	0.441*
L-14	2.469**	16.341**	-0.265	-0.071	-0.437**	-2.121**	1.063*	-0.247
L-15	-0.238	- 3.047	-0.790**	0.104	-0.137	-1.808**	-0.219	0.191
L-16	-2.109**	- 0.903	-0.715*	0.042	-0.637**	-0.721	-1.363*	-0.247
L-17	1.149	- 2.809	0.222	0.054	-0.100	2.304**	4.094**	0.628**
L-18	-0.513	3.159	0.153	0.054	0.025	-0.008	3.808**	-0.559**
L-19	2.661**	4.803*	-0.128	0.042	-0.262	-0.233	-1.188*	0.503**
Testers								
Gm 22	-4.287**	- 1.853**	-0.701**	-0.117**	0.098*	-1.184**	-2.057**	-0.618**
Sd 7	4.287**	1.853**	0.701**	0.117**	-0.098*	1.184**	2.057**	0.618**
SE for								
Lines $\hat{g}_i$	0.797	2.232	0.257	0.069	0.160	0.513	0.545	0.185
$\hat{g}_i$-$\hat{g}_i$	1.127	3.156	0.363	0.098	0.226	0.726	0.771	0.262
Testers $\hat{g}_i$	0.258	0.724	0.083	0.023	0.050	0.166	0.177	0.060
$\hat{g}_i$-$\hat{g}_j$	0.366	1.024	0.118	0.032	0.073	0.235	0.250	0.085

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

On the other hand, lines L-2, L-5, L-9, L-10 and L-11 showed negative and significant GCA effects in the direction of lower ears per plant.

Regarding the testcrosses, data in Table (2) showed that the average number of ears per 100 plants ranged from 99.1 (L-2 x Sd 7) to 127.8 (L-14 x Sd 7). Generally, most of the testcrosses involved the inbred tester "Sd 7" showed more ears/plant than those involving the tester line "Gm 22". The difference between the two checks, SC 10 (105.5 ears/100 plants) and SC 124 (102.0 ears/100 plants) was insignificant. However, five testcrosses of Sd 7 with lines L-3, L-8, L-12, L-14 and L-19, as well as, two testcrosses of Gm 22 with L-14 and L-18 exhibited significantly more ears/plant than SC 10 in addition to other three testcrosses (L-4 x Sd 7, L-13 x Sd 7 and L-7 x Gm 22)which significantly exceeded SC 124. Five testcrosses, *i.e.* L-3 x Sd 7, L-8 x Sd 7, L-12 x Sd 7, L-17 x Gm 22 and L-18 x Gm 22 showed positive and significant SCA effects for number of ears/100 plants (Table 4).

Considering ear length and ear diameter, results obtained in Tables (2 and 3) revealed that the tester line Sd 7 showed more favorable effect on both traits than the other tester line Gm 22, since it manifested significantly higher average ear length and ear diameter. The average performance (Table 2) reveal that the tester line Sd 7 induced longer and thicker ears over all parental lines, and had significant positive GCA effects than the tester line Gm 22(Table 3). This result indicates that Sd 7 had favorable dominant genes for increasing ear length and ear diameter. Similar findings were obtained by Shehata *et al* (1997) and El-Zeir et al (2000). For the parental lines, the best general combiners were L-8 and L-9 for ear length and ear diameter, respectively, since they had significantly positive GCA effects and had the longest and thickest ears, respectively (Tables 2 and 3). Regarding SCA effects, 5 testcrosses, ***i.e.*** L-12 x Gm 22, L-15 x Sd 7 and L-19 x

For number of rows/ear, results in Tables (2 and 3) indicate that the tester line Gm 22 showed more favorable effect on number of rows/ear than the tester line Sd 7, since it manifested significantly higher average number of rows/ear (14.3 rows/ear) and significant positive GCA effect (0.098*). These results support the findings of Shehata *et al* (1997) and El-Zeir *et al* (2000). For the tested lines across the two testers, L-1, L-8 and L-9 showed significantly the highest number of rows/ear (14.6, 14.6 and 14.8 rows/ear), respectively, which corresponded with their significant negative GCA effects. On the other hand, three parental lines (L-7, L-14 and L-16) exhibited the lowest average for number of rows/ear (13.7, 13.8 and 13.6 rows/ear), respectively, with highly significant positive GCA effects.

Number of rows/ear of the 38 testcrosses (Table 2) ranged from 13.2 rows/ ear (L-15 x Sd 7) to 15.1 rows/ear (L-9 x Gm 22). Five testcrosses of Gm 22 with lines L-1, L-4, L-8, L-9 and L-15) in addition to the test cross L-13 x Sd 7 exhibited significantly more number of rows/ear than the commercial hybrid "SC 10". Four testcrosses, ***i.e.*** L-4 x Gm 22, L15 x Gm 22, L-13 x Sd 7 and L-17 Sd 7 showed positive and significant SCA effects for number of rows/ear (Table 4).

Table 4. Specific combining ability ($\hat{S}_{ij}$) of 38 testcrosses for grain yield and its components, combined over locations in 2004 growing season.

Lines	Grain yield ard/fad		Ears/100 plants		Ear length(cm)		Ear Diameter(cm)	
	Gm 22	Sd 7	Gm 22	Sd 7	Gm 22	Sd 7	Gm 22	Sd 7
L- 1	-2.242*	2.242*	3.402	- 3.402	0.676	-0.676	-0.021	0.021
L- 2	-0.037	0.037	3.658	- 3.658	0.176	-0.176	0.079	-0.079
L- 3	-1.800	1.800	-6.298*	6.298*	-0.211	0.211	0.004	-0.004
L- 4	-1.922	1.922	-3.610	3.610	-0.385	0.385	0.054	-0.054
L- 5	-1.183	1.183	-1.323	1.323	-0.286	0.286	-0.033	0.033
L- 6	3.133**	-3.133**	3.358	- 3.358	0.526	-0.526	-0.021	0.021
L- 7	-0.099	0.099	3.564	- 3.564	0.476	-0.476	-0.071	0.071
L- 8	-3.085**	3.085**	-10.279**	10.279**	0.038	-0.038	-0.008	0.008
L- 9	0.996	-0.996	-0.017	0.017	-0.274	0.274	0.192*	-0.192*
L-10	1.882	-1.882	3.914	- 3.914	0.276	-0.276	0.073	-0.073
L-11	0.807	-0.807	0.714	- 0.714	0.663	-0.663	0.129	-0.129
L-12	1.641	-1.641	-9.779**	9.779**	0.901*	-0.901*	0.067	-0.067
L-13	-1.083	1.083	-0.492	0.492	-0.386	0.386	-0.196*	0.196*
L-14	-2.518*	2.518*	-0.773	0.773	-0.149	0.149	0.067	-0.067
L-15	1.748	-1.748	-0.473	0.473	-0.999**	0.999**	-0.033	0.033
L-16	1.134	-1.134	2.946	- 2.946	-0.224	0.224	0.054	-0.054
L-17	0.998	-0.998	6.514*	- 6.514*	-0.111	0.111	-0.083	0.083
L-18	1.749	-1.749	7.358*	- 7.358*	0.307	-0.307	-0.133	0.133
L-19	-2.216*	2.216*	-2.385	2.386	-1.011**	1.011**	-0.121	0.121
SE for								
$\hat{S}_{ij}$	1.127		3.156		0.363		0.098	
$\hat{S}_{ij} - \hat{S}_{ik}$	1.594		4.463		0.514		0.139	

Table 4. Continued ……….

Lines	Rows/ear		kernels/ row		100-kernel weight		days to 50% silking	
	Gm 22	Sd 7	Gm 22	Sd 7	Gm 22	Sd 7	Gm 22	Sd 7
L- 1	0.252	-0.252	0.147	-0.147	-0.238	0.238	-0.444	0.444
L- 2	-0.148	0.148	0.484	-0.484	0.076	-0.076	0.681**	-0.681**
L- 3	-0.048	0.048	-0.390	0.390	-0.233	0.233	-0.194	0.194
L- 4	0.527*	-0.527*	1.209	-1.209	0.609	-0.609	-0.382	0.382
L- 5	0.264	-0.264	-0.559	0.559	0.463	-0.463	-0.194	0.194
L- 6	-0.348	0.348	2.297**	-2.297**	-1.865*	1.865*	-0.319	0.319
L- 7	-0.135	0.135	1.709*	-1.709*	-2.347**	2.347**	0.431	-0.431
L- 8	0.339	-0.339	-0.828	0.828	-2.948**	2.948**	-0.444	0.444
L- 9	0.139	-0.139	-0.415	0.415	-0.911	0.911	-0.819**	0.819**
L-10	0.064	-0.064	0.184	-0.184	0.200	-0.200	0.868**	-0.868**
L-11	0.189	-0.189	1.497*	-1.497*	1.090	-1.090	-0.257	0.257
L-12	-0.035	0.035	1.984**	-1.984**	-0.165	0.165	0.493	-0.493
L-13	-0.598*	0.598*	-0.740	0.740	-0.072	0.072	0.118	-0.118
L-14	-0.323	0.323	-0.665	0.665	-1.419	1.419	0.306	-0.306
L-15	0.752**	-0.752**	-1.178	1.178	-1.616*	1.616*	-0.257	0.257
L-16	-0.123	0.123	-0.390	0.390	-0.108	0.108	-0.194	0.194
L-17	-0.535	0.535	-2.215**	2.215**	0.828	-0.828	0.556*	-0.556*
L-18	-0.035	0.035	0.122	-0.122	3.191**	-3.191**	0.868**	-0.868**
L-19	-0.198	0.198	-2.253**	2.253**	1.735	-1.735	-0.819**	0.819**
SE for								
$\hat{s}_{ij}$	0.226		0.726		0.771		0.262	
$\hat{s}_{ij} - \hat{s}_{ik}$	0.320		1.026		1.091		0.370	

Sd 7 for ear length, L-9 x Gm 22 and L-13 x Sd 7 for ear diameter showed positively significant SCA effects towards increasing both ear length and ear diameter.

Considering number of kernels/row, average performance (Table 2) revealed that the tester line Sd 7 induced higher number of kernels/row over all parental lines, and had significant positive GCA effects than the tester line Gm 22 (Table 3). This result indicates that Sd 7 had favorable dominant genes for increasing number of kernels/row. Similar results were obtained by Shehata *et al* (1997) and El-Zeir *et al* (2000). For the tested lines across the two testers, L-4 and L-17 showed significantly the highest number of kernels/row (46.1 and 44.2 grains/row), respectively, which corresponded with their highly significant positive GCA effect. On the other hand, four parental lines (L-5, L-12, L-14 and L-15) exhibited the lowest average for number of kernels/row with highly significant negative GCA effects. Number of kernels/row of the 38 testcrosses (Table 2) ranged from 37.7 to 47.6 kernels/row for the two crosses L-15 x Gm 22 and L-17 x Sd 7, respectively. The testcross L-17 x Sd 7 was significantly higher in number of kernels/row than the commercial check "SC 10" (45.1 grains/row). Regarding SCA effects, 4 testcrosses of Gm 22 with lines L-6, L-7, L-11, L-12 in addition to L-17 x Sd 7 and L-19 x Sd 7 showed positively significant SCA effects toward increasing the number of kernels per row (Table 4).

In respect of 100-kernel weight, results obtained in Tables (2 and 3) reveal that the tester line Sd 7 showed more favorable effect on 100-kernel weight than the tester line Gm 22, since it showed significantly higher average weight of 100 kernels and highly significant positive GCA effect. These results are in the same line with those obtained by Shehata *et al* (1997) and El-Zeir *et al* (2000) for Sd 7. For the tested lines, the best general combiners over the two testers were L-2, L-3, L-6, L-14, L-17 and L-18, since they exhibited higher 100-kernel weight and highly significant positive GCA effects (Tables 2 and 3). On the contrary, lines L-4, L-7, L-11, L-12, L-16 and L-17 showed negative and significant GCA effects in the direction of lower 100-kernel weight. Regarding test-crosses, data of Table 2 show that the average weight of 100 kernels ranged from 26.0 g (L-7 x Gm 22) to 39.3 g (L-8 x Sd 7). In general, all testcrosses involving the inbred tester Sd 7 showed higher grain weight than those involving the tester line Gm 22. Four testcrosses of Sd 7 with Lines L-6, L-7, L-8 and L-15 in addition to the testcrosses of L-18 x Gm 22 and L-19 x Gm 22 showed positive and significant SCA effects for 100 kernels weight (Table 4).

With respect to number of days to 50% silking, Table (2) shows that in general all the testcrosses were significantly earlier than the commercial check hybrid "SC 10" (60.9 days), except L-9 x Sd 7 and L-19 x Sd 7. For GCA effects (Table 3), the parental lines L-1, L-2 and L-18, as well as the inbred tester Gm 22 had highly significant GCA effects towards earliness (-0.747**, - 0.872**, -0.559** and – 0.618**), respectively. In other words, testcrosses involving these lines and/or Gm 22 as a tester were earlier. This indicates that these inbreds posses favorable genes for earliness. On the contrary, parental lines L-9, L-10, L-12, L-13, L-17 and L-19, as well as the tester line Sd 7 had significantly positive GCA effects marked by lateness in silking appearance. The same trend for Sd 7 was also reported by El-Itriby (1990), Shehata *et al* (1997), El-Zeir *et al* (2000) and Sadek *et al* (2000). However, data of Table 4 showed that the best specific combinations (negatively significant SCA effects) resulted from L-2 x Sd 7, L-10 x Sd 7, L-17 x Sd 7, L-18 x Sd 7, L-9 x Gm 22 and L-19 x Gm 22 confirming their earliness. On the other hand, six testcrosses had positively significant SCA effects in relation to lateness(Table 4).

III. Type of gene action:

The estimates of combining ability variances (σ^2gca and σ^2sca) and its interaction with locations (σ^2gca x loc and σ^2sca x loc) for grain yield, its components and days to 50% silking (Table 5) showed that gca variance played the major role in determining the inheritance of all studied traits, except number of ears/plant and number of rows/ear. This indicates that the largest part of the total genetic variability associated with these traits was the result of additive gene action. On the other hand, non-additive genetic variance was predominant and played an important role in the inheritance of number of ears/plant and number of rows/ear. Similar findings were also obtained by Comstock and Robinson (1963), Eberhart *et al* (1966), Drrah and Hallauer (1972). Also, Russell *et al* (1973), Hallauer and Mirinda (1981), El-Itriby *et al* (1990) and Soliman *et al* (2001) indicated the importance of additive gene action in affecting grain yield of maize. The non-additive gene action, however, interacted more with different environmental conditions prevailing in the two locations than the additive gene effects for all studied traits, except grain yield, ear length and ear diameter, where the opposite was true (Table 5). This finding indicates non-additive types of gene

Table 5. Estimates of general (σ^2gca) and specific (σ^2sca) combining ability variances and their interaction with locations for grain yield and its components.

Traits	σ^2gca	σ^2sca	σ^2gca x Loc	σ^2sca x loc
Grain yield	28.756	3.77	8.510	1.853
Ears/100 plants	-0.493	17.686	11.457	40.825
Ear length	0.387	0.239	0.943	0.374
Ear diameter	0.005	0.002	0.038	0.014
Rows/ ear	-0.042	0.062	0.095	0.245
kernels/ row	1.201	0.303	2.455	5.004
100-kernel weight	7.802	0.740	-0.191	5.994
days to 50% silking	0.662	0.483	-0.008	0.018

Negative estimates are considered equal to zero (Robinson *et al*, 1955).action to be more affected by environment than additive and additive x additive types of gene action. This result is in agreement with the finding of several investigators who reported specific combining ability to be more sensitive to environmental changes than general combining ability (Gilbert, 1958). Shehata and Dahawan, (1975) and Sadek *et al* (2000 and 2002) also found that the non-additive genetic variation interacted more with the environment than the additive component. On the other hand, El-Itriby *et al* (1990), El-Zeir *et al* (2000) and Soliman *et al* (2001) reported that the additive types of gene action were more affected by environment than non-additive ones.

The study suggested that four testcrosses (L-1 x Sd 7, L-8 x Sd 7, L-14 x Sd 7 and L-19 x Sd 7) should be tested further for the commercial use. Moreover, the four inbreds included in these crosses (L-1, L-8, L-14 and L-19) in addition to the parental lines L-9 had good GCA effects for grain yield and some of its components, as well as, earliness (Table 3). These inbreds should be intermated to form a new synthetic variety of white maize, which can be used as a base population for the extraction of more favorable white lines for the development of high yielding and earlier single cross hybrid of white maize.

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الفعل الجينى لمحصول الحبوب فى سلالات حديثة الإستنباط من الذرة الشامية بتحليل الهجن الإختبارية

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تم إجراء التهجين القمى لـ ١٩ سلالة بيضاء من الذرة الشامية المستنبطة من الصنف المفتوح (Tep#5) الوارد من المركز الدولى لتربية الذرة والقمح بالمكسيك (CIMMYT) مع السلالتين التجاريتين الكشافتين سدس ٧ ، جميزة ٢٢ فى صيف ٢٠٠٣، وتم تقييم الهجن القمية الـ ٣٨ الناتجة فى محطتي البحوث الزراعية بالجميزة وملوى فى صيف موسم ٢٠٠٤ لصفات محصول الحبوب ومكوناته وكذلك صفة موعد خروج الحراير وكانت أهم النتائج التى تم التوصل اليها هى : كان لتأثير الفعل الجينى المضيف الدور الرئيسي فى وراثة معظم الصفات المدروسة مقارنة بالتأثير الجينى الغير مضيف ، كما وجدت فروق عالية المعنوية بين كل من السلالات المختبرة وأبانها الكشافة والتفاعل بينهما لكل الصفات المدروسة ، أظهرت السلالات المختبرة أرقام ١ ،٥ ، ٨ ، ٩ ، ١٤ ، ١٧ ، ١٩ افضل التقديرات المعنوية للقدرة العامة على التألف من خلال التحليل المشترك باستخدام الأبوين. كانت السلالات المختبرة أرقام ١، ٢، ١٨ وهجنها الناتجة مبكرة معنويا عن هجن المقارنة ومحصول السلالتين ١، ٢ مع السلالة الأبوية الكشافة سدس ٧ يتفوق معنويا عن هجين المقارنة الفردى الأبيض جيزة ١٢٤ ، كما أعطت هجن السلالة الكشافة سدس ٧ مع السلالات المختبرة أرقام ٣، ٤، ٥، ٨، ٩، ١٣، ١٤، ١٧ ، ١٩ قوة هجين عالية ومحصول حبوب يتفوق معنويا على الهجين الفردى جيزة ١٢٤ بمدى يتراوح من ٣,٤ إلي ٨,٠ اردب للفدان. أعطت هجن السلالات المختبرة ٨، ١٤، ١٩ ، ١ مع الأب الكشاف سدس ٧ محصول حبوب افضل من محصول هجين المقارنة جيزة ١٠ (٣٥,٤ إردب) حيث كان محصولها ، ٣٧,٢ ، ٣٦,٥ ، ٣٦,٣ ، ٣٥,٩ إردب للفدان بالترتيب بمعدل زيادات قدرها ، ١,٨ ، ١,١ ، ٠,٩ ، ٠,٥، اردب للفدان بنفس الترتيب قياسا" بمعدل افضل هجن المقارنة الفردية .