Minufiya J. Agric. Res. Vol. 32 No.1: 219 - 235 (2007)

COMMERCIAL INBRED LINES AS TESTERS FOR COMBINING ABILITY IN NEW DEVELOPED MAIZE LINES

A. M. M. Abd El-Aal

Maize Res. Prog., Field Crops Res. Inst., ARC, Egypt

(Received: Jan. 14, 2007)

ABSTRACT: *Eighteen selected S_3 yellow maize lines developed from different heterotic groups (Pop 45 Ev-4, DTP-2-C_5, Astrong H.D., AS-785, Bonner H.D. and PAV9 F_2) were topcrossed to each of two commercial yellow inbred testers, i.e. Gm 1004 and Gm 1021 in 2004 summer season. The resultant 36 topcrosses were evaluated in 2005 growing season at Gemmeiza, Sids and Nubaria Agric. Res. Stns for grain yield, number of ears/100 plants, days to 50% silking, plant and ear height. Testers contributed much more than the lines to the total genetic variation and were more affected by the environmental conditions. The inbred testers ranked the 18 inbreds differently. The tested lines L-7, L-9, L-10, L-14, L-15 and L-16 were found to be the best general combiners for high yielding ability. Potential females, L-1, L-4, L-5, L-7, L-8 and L-9 were significantly better general combiners for earliness. Parental lines L-1 and L-15 were good donors for prolificacy. The inbred tester Gm 1021 manifested better general combining ability GCA effects and higher average performance of grain yield as compared to testcrosses of the other inbred tester Gm 1004. Results showed that the inbred tester Gm 1021 crossed to the tested lines L-1, L-4, L-7< L-9< L-14, L-15 and L-16 would produce the best single crosses which significantly outyielded the check single cross hybrid Pioneer 3084 with an average increase from 2.23 to 5.78 ard/fad. Furthermore, the most outstanding crosses, i.e. L-7 x Gm 1021, L-16 x Gm 1021 and L-9 x Gm 1021 (32.98, 32.28 and 31.78 ard/fad), respectively significantly outyielded the best commercial yellow check hybrid SC 155 (29.10 ard/fad) by 3.88, 3.18 and 2.68 ard/fad, respectively. The magnitude of the ratio of general to specific combining ability variances ($\sigma^2_{gca}/\sigma^2_{sca}$) revealed that the additive component of gene action had the major role in determining the inheritance of all studied traits. The non additive gene action, however, interacted more with the environmental conditions (σ^2_{sca} x location) than the additive component (σ^2_{gca} x locations) for grain yield and number of ears/plant.*

Key words: Maize, Zea mays L., topcrosses, combining ability.

INTRODUCTION

To increase maize production in Egypt, the National Maize Research Program, ARC exerts great efforts for developing highyielding maize hybrids and continuously searches for good inbreds that possess higher combining ability effects to replace those currently used hybrids. Performance of inbred lines *per se* does not provide an entirely adequate measure of either value in hybrid combinations. Successful development of improved maize hybrids is dependent upon accurate evaluation of performance of inbred lines in crossing. The standard procedure currently followed by the program is to use the best available commercial inbreds as testers to screen newly developed inbred lines.

The choice of a tester to test the developed inbred lines is an important decision. Matsinger (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. Also, Rowlings and Thompson (1962) and Hallauer (1975) indicated that a suitable tester should include simplicity in use, provide information that correctly classifies the relative merit of lines and maximize genetic gain. Russell *et al* (1973) and Zambezi *et al* (1986) suggested that inbred testers could be used for evaluation of both specific and general combining ability. Furthermore, Hallauer and Lopez-Perez (1979), Mahgoub *et al* (1996) and Soliman *et al* (2001) suggested that narrow genetic base tester can be effectively used to identify lines having good GCA and the most efficient is one having a low frequency of favorable alleles. Darrah *et al* (1972), Horner *et al* (1973) and Russell and Eberhart (1975) indicated the use of inbred lines as testers instead of broad genetic base tester because of the increased genetic variance among testcross progenies to about twice the case for broad-base testers. However, despite the definite advantage of inbred testers, there has been little available information on the relationship of the performance of the tester and its ability to expose differences in combining ability among tested inbreds.

Balko and Russell (1980), Nawar and El-Hossary (1984) and Sadek *et al* (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 lines selected previously for grain yield. In addition, Paterniani and Lonnquist (1963), Shehata and Dhawan (1975) and Beck *et al* (1991) compared the importance of dominance gene effects in the expression of yield, days to 50% silking, plant height and ear position in case of advanced generation of selfing. On the other hand, Rojas and Sprague (1952), El-Zeir *et al* (2000), Soliman *et al* (2001) and Abd El-Azeem *et al* (2004) stated that when the lines were relatively unselected, GCA or additive type of gene action becomes more important. Comstock and Robinson (1963) defined the genotype x environment interaction as the differential response of phenotype to the change in environments. However, Rojas and Sprague (1952), Darrah and Hallauer (1972) and Landi and Conti (1983) stated the non-additive component of genetic variation significantly interacted with the environments more than the additive component. In contrast, El-Itriby *et al* (1981), El-Zeir *et al* (1993) and Abd El-Azeem *et al* (2004) reported that GCA x environment interaction was significantly larger than the interaction of SCA x environment even though the variance estimate for SCA was more than that of SCA.

The inbred tester "Gm 1004 and Gm 1021" used in this study, had been found to have high GCA and contribute to the high grain yield potential of their crosses (Soliman, 2000; Soliman *et al*, 2001 and Abd El-Azeem *et al*, 2004). The inbred line Gm 1021 was found to contribute earliness genes to their hybrids (Soliman, 2000 and Abd El-Azeem *et al*, 2004), whereas, Gm 1004 contribute genes for shortness and lower ear placement in testcrosses (Abd El-Azeem *et al*, 2004). Testcross procedure is practiced commonly in the National 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 objectives of this study were to (i) assess the value of two inbred lines testers in the evaluation of combining ability between eighteen newly developed yellow inbred lines, (ii) Identify the most superior line(s) and single crosses for further use in the breeding program and (iii) determine GCA and SCA as well as the type of gene action involved in the manifestation of grain yield and other agronomic traits.

MATERIALS AND METHODS

Eighteen selected yellow maize inbred lines in S_3 generation (L_1 through L-18) derived from different heterotic groups (Pop-45, L- to L-9, DTP-2-C_5, L-10, Alstrong H.D., L-11, AMS-785, L-12 to L-16, Bonner H.D., L-17 and PAV 9 F_2, L-18) through selection from segregating generations in the disease nursery field at Sids Agric. Res. Stn., were used for the purpose of this study. In 2004 growing season, the 18 lines were topcrossed to each of two narrow base inbred tester, *i.e.* Gemmeiza 1004 (Gm 1004) and Gemmeiza 1021 (Gm 1021) at Sids Exp. Stn. The two testers are being used in seed production of commercial single and three way cross hybrids. In 2005 growing season, the 36 resultant topcrosses along with two commercial check hybrids; SC 155 and SC Pioneer 3084 were evaluated in replicated yield trials conducted at Gemmeiza, Sids and Nubaria Agric. Res. Stn. The experimental design was a randomized complete block design with four replications. Plot size was one ridge, 6 m long and 80 cm apart and hills were spaced 25 cm along the ridge . Two kernels were planted per hill and thinned later to one plant per hill to provide a population of approximately 22000 plants/Faddan (Faddan = 4200 m^2). All cultural practices for maize production were applied as recommended. Data were recorded for number of days to 50% silking, plant height (cm), ear height (cm), number of ears/100 plants and grain yield adjusted to 15.5% grain moisture content and converted to ardabs/faddan (ard=140 kg). Analysis of variance was performed for the combined data over locations according to Steel and Torrie (1980). The combining ability and types of gene effects were computed for all studied traits according to Kempthorne (1957).

RESULTS AND DISCUSSION

The combined analysis of variance for the five studied traits is presented in table 1. Highly significant differences were detected among locations for all studied traits, indicating that the three 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

Table (1): Mean squares and degrees of freedom for grain yield and other agronomic traits of 18 inbred lines topcrossed with two testers combined over two locations, 2005 growing season.

S.O.V.	DF	Mean Squares				
		Grain yield	Ears/100 plants	Days to 50% silking	Plant height	Ear height
Locations (Loc)	2	6767.50**	2235.52**	8265.18**	29130.32**	5134.32**
Rep/Loc	6	25.08	87.80	9.56	1328.30	279.20
Crosses	35	120.87**	394.67**	8.59**	1331.19**	817.07**
Lines (L)	17	86.81**	240.49**	14.59**	1448.73**	847.16**
Testers (T)	1	2039.28**	6678.01**	18.34**	17748.52**	7676.02**
L x T	17	24.95**	190.78**	2.25*	232.17	230.51**
Loc x Crosses	70	28.31**	169.07**	2.50**	320.60**	187.69**
Loc x L	34	35.58**	132.03*	3.34**	537.43**	267.39**
Loc x T	2	40.47**	1056.12**	1.21	415.19	479.31**
Loc x L x T	34	20.77**	147.38	1.30	117.86	97.07
Pooled error	315	7.29	83.70	1.23	177.27	94.74
CV %		10.19	8.68	1.98	5.56	7.34

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

due to lines and testers were highly significant for all traits, revealing that greater diversity was existed among testers and lines. At the same time, mean squares of lines x testers interaction were highly significant for all the studied traits, except plant height silking, indicating that the lines (females) differed in order of performance in crosses with each of the testers (males). Mean squares due to the interaction of both lines and testers with locations were highly significant for all traits, except days to 50% silking and plant height for testers x locations. These interactions with locations were indicative of different ranking of genotypes of lines and testers from one location to another. Highly significant lines x testers x locations mean square was detected for grain yield, revealing that the hybrids between lines and testers behaved somewhat differently from location to location. These results are in accordance with those obtained by El-Itriby *et al* (1990), Sadek *et al* (2000), Gado *et al (*2000) and Soliman *et al* (2001).

The magnitude of the variances due to testers and testers x locations interaction for all studied traits was higher than variance of lines and lines x locations interactions, respectively. This indicates that testers contributed much more to the total variation and which 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).

Considering grain yield, the obtained data in Table 2 showed that mean of top crossas between, inbred tester Gm 1021 and each of the tested lines produced the highest grain yield (28.68 ard/fad) compared to the inbred tester Gm 1004 (24.34 ard/fad). This result was reflected in the combining ability effects (Table 3), where Gm 1021 was the best tester line in GCA effect which had a good yield in its crosses with all tested lines (female lines) These results indicated that the inbred tester Gm 1021 possesses a high frequency of favorable dominant alleles, which contributed to the grain yield of the testcrosses. On the contrary, the inbred tester Gm 1004 had a highly negative GCA effect. Similar results were obtained by Soliman (2000) and Soliman *et al* (2001) for Gm 1021 and Abd El-Azeem *et al* (2004) for both Gm 1021 and Gm 1004.

Grain yield of the 18 tested lines across the two testers (Table 2) ranged from 22.39 to 29.32 ard/fad for testcrosses with lines L-11 and L-7, respectively. The most preferable lines were L-7, L-9, L-10, L-14, L-15 and L-16. These lines produced the highest average grain yield (ranging from 27.75 to 29.32 ard/fad) and exhibited the best significantly positive GCA effects (Table 3). In other words, these lines in addition to the inbred tester Gm 1021 had accumulated favorable alleles for grain yield and contributed to upgrading grain yield of all crosses involving these lines. On the other hand, L-3, L-6, L-11, L-12, L-13 and L-18 gave the lowest grain yield (ranged from 22.39 to 25.37 ard/fad) and had a high negative GCA effects (Table 2 and 3). Results reported herein are in accordance with those previously reached by

Table (2): Average performance of 36 topcrosses (18 inbred line and 2 testers) and two check hybrids for grain yield and other agronomic traits combined over three locations, 2005 growing seasons.

Lines	Grain yield			Ears/100 plants			Days to 50% silking			Plant height			Ear height		
	Gm 1004	Gm 1021	mean	Gm 1004	Gm 1021	mean	Gm 1004	Gm 1021	mean	Gm 1004	Gm 1021	mean	Gm 1004	Gm 1021	mean
L- 1	22.47	30.72	26.59	101.5	120.3	110.9	55.3	54.0	54.7	220.2	242.8	231.5	123.7	138.5	131.1
L- 2	24.60	26.53	25.57	104.0	111.4	107.7	57.0	56.0	56.5	225.7	243.3	234.5	126.3	134.5	130.4
L- 3	23.48	26.86	25.17	99.5	109.5	104.5	56.0	56.3	56.2	237.6	258.3	248.0	127.6	147.6	137.6
L- 4	25.24	29.43	27.33	100.3	111.8	106.0	55.2	55.6	55.4	236.9	243.5	240.2	132.9	135.2	134.0
L- 5	26.65	28.28	27.47	102.6	102.4	102.5	55.5	54.8	55.2	233.8	249.1	241.5	124.8	138.0	131.4
L- 6	22.24	25.76	24.00	99.7	103.8	101.7	55.8	56.3	56.0	232.2	244.4	238.3	130.8	140.3	135.5
L- 7	25.66	32.98	29.32	99.4	106.4	102.9	55.0	54.8	54.9	243.3	251.1	247.2	131.3	139.9	135.6
L- 8	24.23	27.48	25.86	100.8	108.3	104.0	55.2	54.9	55.0	247.2	250.5	248.8	137.0	141.4	139.2
L- 9	25.02	31.78	28.40	102.4	105.6	104.0	55.8	55.0	54.4	243.9	252.3	248.1	136.2	143.0	139.6
L-10	26.83	28.89	27.86	106.5	108.8	107.7	56.4	56.3	56.4	244.8	257.9	251.4	131.9	142.1	137.0
L-11	21.24	23.54	22.39	99.2	105.0	102.1	56.5	56.9	56.7	217.3	233.1	225.2	112.7	123.3	118.0
L-12	21.98	26.93	24.45	102.8	105.3	104.0	56.5	55.9	56.2	216.9	232.1	224.5	120.3	131.9	126.1
L-13	23.04	27.69	25.37	102.2	110.3	106.3	57.3	56.0	56.6	224.8	246.6	235.7	124.0	134.4	129.2
L-14	27.19	29.84	28.52	102.7	107.2	105.0	56.0	55.9	56.0	224.7	245.8	235.3	123.3	132.8	128.0
L-15	24.83	30.67	27.75	102.1	124.7	113.4	57.5	56.6	57.0	239.2	249.3	244.3	132.1	143.1	137.6
L-16	25.93	32.28	29.11	98.5	108.1	103.3	57.7	57.2	57.4	237.3	243.5	240.4	146.0	136.5	141.3
L-17	25.53	28.44	26.99	105.4	111.6	108.5	57.3	56.1	56.7	233.3	239.4	236.4	127.9	129.5	128.7
L-18	21.90	28.18	25.04	97.6	108.1	102.8	56.1	55.9	56.0	234.1	2408	237.5	122.7	131.3	127.0
Mean	24.34	28.68	26.51	101.5	109.4	105.4	56.2	55.8	56.0	232.9	245.8	239.4	128.4	136.8	132.6
Checks															
SC 155		29.10			97.1			56.1			248.8			139.5	
SC Pioneer 3084		27.20			101.6			60.4			249.2			138.9	
LSD 0.05		2.16			7.3			0.9			10.6			7.8	
0.01		2.83			9.6			1.1			14.0			10.2	

Table (3): General combining ability effects ($\hat{g}_i$) of 18 inbred lines and 2 testers for grain yield and other agronomic traits combined over three locations, 2005 growing season.

Lines	Grain yield	Ears/100 plants	Days to 50% silking	Plant height	Ear height
Lines L- 1	0.082	5.449**	-1.350**	- 7.901**	-1.539
L- 2	-0.943	2.278	0.484*	- 4.859	-2.206
L- 3	-1.343*	-0.905	0.151	8.500**	4.961*
L- 4	0.824	0.951	-0.641**	0.850	1.419
L- 5	0.957	-2.964	-0.850**	2.100	-1.206
L- 6	-2.509**	-3.680*	0.026	- 1.067	2.877
L- 7	2.812**	-2.551	-1.141**	7.808**	2.961
L- 8	-0.651	-0.872	-0.975**	9.475**	6.586**
L- 9	1.887*	-1.435	-0.600**	8.725	6.961**
L-10	1.349*	2.245	0.359	12.016**	4.377*
L-11	-4.118**	-3.339	0.692**	-14.151**	-14.664**
L-12	-2.055**	-1.385	0.192	-14.859**	- 6.498**
L-13	-1.143*	0.828	0.609**	- 3.651	- 3.414
L-14	2.007**	-0.476	-0.058	- 4.109	- 4.623*
L-15	1.237*	7.936**	1.026**	4.891	4.961
L-16	2.599**	-2.143	1.401**	1.016	8.627**
L-17	0.458	3.036	0.692**	- 2.984	- 3.914*
L-18	-1.472**	-2.614	-0.016	- 1.901	- 5.664**
Testers Gm 1004	-2.173**	-3.932**	0.206**	- 6.410**	- 4.215
Gm 1021	2.173**	3.932	-0.206**	6.410**	4.215
SE for					
Lines g_i	0.551	1.867	0.227	2.718	1.987
$g_i - g_j$	0.780	2.641	0.321	3.843	2.810
Testers g_i	0.184	0.622	0.076	0.906	0.662
$g_i - g_j$	0.260	0.880	0.107	1.281	0.937

Rawlings and Thempson (1962), Liakat and Teparo (1986), Zambezi *et al* (1986), El-Hosary (1988), Mahgoub *et al* (1996), Al-Naggar *et al* (1997) and Soliman *et al* (2001), who reported that the inbred tester method was more effective to select lines which combine well with unrelated tester. They emphasized that inbred testers were more effective in detecting small differences in combining ability than the wide genetic base testers.

Grain yield of the 36 topcrosses (Table 2) ranged from 21.24 to 32.98 ard/fad for L-11 x Gm 1004 and L-7 x Gm 1021, respectively. Out of 36 top-crosses, 13 were superior and outyielded the commercial yellow check hybrid SC Pioneer 3084 (27.20 ard/fad) with minimum of 0.28 ard/fad and maximum of 5.78 ard/fad. Furthermore, the seven top crosses outyielding crosses, *i.e.* L-7 x Gm 1021, L-16 x Gm 1021, L-9 x Gm 1021, L-1 x Gm 1021, L-15 x Gm 1021, L-14 x Gm 1021 and L-4 x Gm 1021 gave the highest grain yield (32.98, 32.28, 31.78, 30.72, 30.67, 29.84 and 29.43 ard/fad), respectively and significantly outyielded the check hybrid SC Pioneer 3084 by 5.78, 5.08, 4.58, 3.52, 3.47, 2.64 and 2.23 ard/fad), . respectively. Moreover, the most outstanding three crosses (L-7 x Gm 1021, L-16 x Gm 1021 and L-9 x Gm 1021) significantly surpassed the best yellow check hybrid SC 155 (29.10 ard/fad) by 3.88, 3.18 and 2.68 ard/fad, respectively (Table 2)

However, data in Table 4 showed that the best specific combination (positively significant SCA effect) resulted from L-1 x Gm 1021 confirming its outstanding. 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 S_{ij} for grain yield was exhibited between parents with poor and good GCA; L-1 x Gm 1021. Similar findings were obtained by Nawar *et al* (1979), Soliman *et al* (2001) and Sadek *et al* (2002).

With respect to number of ears/100 plants, data in Tables 2 and 3 illustrated that the inbred tester Gm 1021 showed more favorable effect on number of ears than the inbred tester Gm 1004, 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) and Soliman (2006). For the tested lines, the best general combiners over testers were L-1 and L-15 (Tables 2 and 3), since they exhibited more ears per plant (110.9 and 113.4 ears/100 plants), respectively and had highly significant positive GCA effects. On the other hand, the tested line L-6 showed negative and significant GCA effects in the direction of fewer ears per plant.

Regarding the topcrosses, data in Table 2 showed that the number of ears per 100 plants ranged from 97.6 (L-18 x Gm 1004) to 124.7 (L-15 x Gm 1021). Generally, all of the topcrosses involved the inbred tester Gm 1021 showed more ears/plant than those involving the inbred tester Gm 1004. The difference between the two checks; SC 155 and SC 3084 (97.1 and 101.6 ears/100 plant), respectively was not significant. However, the topcrosses of

Table (4): Specific combining ability ($\hat{s}_{ij}$) effects of 36 topcrosses (18 inbred line and 2 testers) for grain yield and other agronomic traits combined over three locations, 2005 growing seasons.

Lines	Grain yield		Ears/100 plants		Days to 50% silking		Plant height		Ear height	
	Gm 1004	Gm 1021	Gm 1004	Gm 1021	Gm 1004	Gm 1021	Gm 1004	Gm 1021	Gm 1004	Gm 1021
L- 1	-1.952*	1.952*	-5.418*	5.418*	0.461	-0.461	-4.882	4.882	-3.201	3.201
L- 2	1.206	-1.206	0.211	-0.211	0.294	-0.294	-2.424	2.424	0.132	-0.132
L- 3	0.481	-0.481	-1.072	1.072	-0.373	0.373	-3.965	3.965	-5.785*	5.785*
L- 4	0.081	-0.081	-1.835	1.835	-0.414	0.414	3.118	-3.118	3.090	-3.090
L- 5	1.356	-1.356	4.028	-4.028	0.127	-0.127	-1.215	1.215	-2.368	2.368
L- 6	0.414	-0.414	1.853	-1.853	-0.498	0.498	0.285	-0.285	-0.535	0.535
L- 7	-1.490	1.490	0.440	-0.440	-0.081	0.081	2.493	-2.493	-0.118	0.118
L- 8	0.548	-.548	0.203	-0.203	-0.081	0.081	4.743	-4.743	2.007	-2.007
L- 9	-1.207	1.207	2.357	-2.357	0.211	-0.211	2.243	-2.243	0.799	-0.799
L-10	1.139	-1.139	2.769	-2.769	-0.164	0.164	-0.132	0.132	-0.868	0.868
L-11	1.023	-1.023	1.019	-1.019	-0.414	0.414	-1.465	1.465	-1.076	1.076
L-12	-0.298	0.298	2.648	-2.648	0.086	-0.086	-1.174	1.174	-1.577	1.577
L-13	-0.152	0.152	-0.156	0.156	0.419	-0.419	-4.465	4.465	-0.993	0.993
L-14	0.848	-0.848	1.665	-1.665	-0.164	0.164	-4.174	4.174	-0.535	0.535
L-15	-0.748	0.748	-7.356**	7.356**	0.252	-0.252	1.326	-1.326	-1.285	1.285
L-16	-1.002	1.002	-0.852	0.852	0.044	-0.044	3.285	-3.285	8.965**	-8.965**
L-17	0.719	-0.719	0.819	-0.819	0.419	-0.419	3.368	-3.368	3.424	-3.424
L-18	-0.965	0.965	-1.320	1.320	-0.123	0.123	3.035	-3.035	-0.076	0.076
SE for										
s_{ij}	0.780		2.641		0.321		3.843		2.810	
$s_{ij} - s_{kl}$	1.103		3.735		0.454		5.435		3.974	

Gm 1021 with all tested lines, except L-5 and L-6 in addition to topcrosses of Gm 1004 with L-10 and L-17 exhibited significantly more ears/plant than SC 155. Whereas, seven topcrosses of Gm 1021 with lines L-1, L-2, L-3, L-4, L-13, L-15 and L-17 significantly surpassed SC 3084 (Table 2). However, data of Table 4 showed that the best specific effects (positively significant SCA effects) resulted from L-1 x Gm 1021 and L-15 x Gm 1021 (120.3 and 124.7 ears/100 plants), respectively confirming their outstanding.

In respect to number of days to 50% silking, Table 2 shows that, in general, all the topcrosses were significantly earlier than the commercial single cross hybrid Pioneer 3084. However, eight out of the 36 topcrosses were significantly earlier than the check hybrid SC 155.For GCA effects (Table 3), the parental lines L-1, L-4, L-5, L-7, L-8 and L-9, in addition to the inbred tester Gm-1021 had highly significant GCA effects towards earliness. In other words, topcrosses involving these lines and/or Gm 1021 as a tester were earlier. This indicates that these inbreds possess favorable genes for earliness. The same trend for Gm 1021 was reported by Soliman (2000), Soliman *et al* (2001) and Abd El-Azeem *et al* (2004). On the contrary, parental lines L-2, L-11, L-13, L-15, L-16 and L-17 as well as the inbred tester Gm 1004 had positive and highly significant GCA effects marked by lateness in silk appearance. However, non of the topcrosses showed negatively significant SCA effect (Table 4).

Considering plant height, data presented in Table 2 revealed significant differences between the two testers. The inbred tester Gm 1004 induced shorter plants over all parental lines, than the tester line Gm 1021. This result was reflected in the combining ability effects (Table 3), where Gm 1004 had highly significant and negative (desirable) GCA effect towards shortness. This indicates that Gm 1004 had favorable dominant genes for shortness. On the contrary, the inbred tester Gm 1021 had positive and highly significant (undesirable) GCA effect. In this regard, Soliman *et al* (2001) and Abd El-Azeem *et al* (2004) obtained similar findings. For parental lines, the best general combiners were L-1, L-11 and L-12, since they had highly significant and negative (desirable) GCA effects and the shortest plants (Table 2 and 3).

Plant height of the 36 topcrosses (Table 2) ranged from 216.9 to 258.3 cm for crosses L-12 x Gm 1004 and L-3 x Gm 1021, respectively. In general, all topcrosses involving the inbred tester Gm 1004 showed shorter plants than those involving the inbred tester Gm 1021. Moreover, all the topcrosses of the inbred testers Gm 1004, except with the tested lines L-7, L-8, L-9, L-10 and L-15, in addition to the crosses of L-11 and L-12 with Gm 1021 were significantly shorter than SC 155 (248.8 cm). Non of the topcrosses, however showed significantly negative SCA effect for plant height (Table 4). Although, 18 out of the 36 topcrosses exhibited negative (desirable) SCA effects, but did not reach the level of significance.

Considering ear height, the obtained results (Tables 2 and 3) reveal that the inbred tester Gm 1004 showed more favorable effect on ear placement than inbred tester Gm 1021, since it exhibited significantly lower average ear height with highly significant negative GCA effect (towards low ear placement). The same findings were obtained by Soliman *et al* (2001) and Abd El-Azeem *et al* (2004). For the parental lines across the two testers, L-11, L-12, L-14, L-17 and L-18 ranked the best with an average of 118.0, 126.1, 128.0, 128.7 and 127.0 cm, respectively, and with distinct GCA effects (negatively significant) towards low ear placement. On the other hand, six parental lines exhibited the highest average for ear height (137.0 to 141.3 cm) with significant or highly significant positive GCA effects. Average ear height for topcrosses (Table 2), ranged from 112.7 to 147.6 cm for L-11 x Gm 1004 and L-3 x Gm 1021, respectively. Generally, all topcrosses involving the inbred tester Gm 1004 showed lower ear height than those involving the inbred tester Gm 1021. Moreover, topcrosses involved the lines L-1, L-2, L-3, L-5, L-6, L-7, L-11, L-12, L-13, L-14, L-17 and L-18 with inbred tester Gm 1004, in addition to the crosses of L-11, L-17 and L-18 with Gm 1021 manifested significantly lower ear placement than SC 155. Regarding SCA effects, two topcrosses, *i.e.* L-3 x Gm, 1004 and L-16 x Gm 1021 showed negatively significant SCA effects towards low ear placement (Table 4). On the other hand, the highest positive SCA effects, towards higher ear placement were shown in the topcrosses L-16 x Gm 1004 and L-3 x Gm 1021.

The estimates of combining ability variances (σ^2_{gca} and σ^2_{sca}) and its interaction s with locations (σ^2_{gca} x Loc and σ^2_{sca} x Loc) for grain yield other studied traits (Table 5) showed that gca variance played the major role in determining the inheritance of all studied traits. This indicates that the largest part of the total genetic variability associated with these traits was the result of additive gene action. Similar findings were also obtained by Comstock and Robinson (1963), Eberhart *et al* (1966), Darrah and Hallauer (1972), Soliman *et al* (2001) and Abd El-Azeem *et al* (2004). Also, Russell *et al* (1973), Hallauer and Mirinda (1981), El-Itrby *et al* (1990) and Soliman and

Table (5): Estimates of general (σ^2_{gca}) and (σ^2_{sca}) combining ability variances and their interaction with locations for grain yield and other agronomic traits.

Estimates	Grain yield	Ears/100 plants	Days to 50% silking	Plant height	Ear height
σ^2_{gca}	8.507	23.514	0.110	75.067	31.290
σ^2_{sca}	0.348	3.617	0.079	9.526	11.120
σ^2_{gca} x Loc	0.432	11.167	0.027	8.962	6.907
σ^2_{sca} x Loc	3.370	15.920	0.017	-14.852*	0.582

* Negative estimates are considered zero.

Osman (2006) indicated the importance of additive gene action in affecting grain yield of maize. More-over, the additive gene effects interacted more with different environmental conditions prevailing in the three locations than the non-additive gene action for days to 50% silking, plant and ear heights (Table 5). The non-additive gene action, however, interacted more with the environmental conditions than the additive component for grain yield and number of ears/100 plants. This finding indicates non-additive types of gene action to be more affected by environment than additive and additive x additive types of gene action. This result is in agreement with the findings of several investigators who reported specific combining ability to be more sensitive to environmental changes than general combining ability (Gilbert, 1958). Also, 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-Itrby *et al* (1990), Soliman *et al* (2001) and Abd El-Azeem *et al* (2004) reported that the additive types of gene action were more affected by environment than non-additive ones.

The study suggested that the seven testcrosses, *i.e.* L-1 x Gm 1021, L-4 x Gm 1021, L-7 x Gm 1021, L-9 x Gm 1021, L-14 x Gm 1021, L-15 x Gm 1021 and L-16 x Gm 1021 should be tested further for the commercial use. In addition, the seven inbreds included in these crosses (L-1, L-4, L-7, L-9, L-14, L-15 and L-16) had good GCA effects for yield, prolificacy and earliness (Table 3). These inbreds should be intermated to form a new synthetic variety of yellow maize, which can be used as a base population for the extraction of more favorable yellow lines for the development of high yielding, earlier single cross hybrids of yellow maize.

REFERENCES

Abd El-Azeem, M. E. M., A. A. Mahmoud and A. A. M. Atia (2004). Combining ability analysis of yellow maize inbred lines. Egypt. J. Plant Breed., 8: 239-254.

Al-Naggar, A. M., H. Y. El-Sherbieny and A. A. Mahmoud (1997). Effectiveness of inbreds, single crosses and populations as testers for combining ability in maize. Egypt. J. Plant Breed., 1: 35-46.

Balko, L. G. and W. A. Russell (1980). Response of maize inbred lines to N fertilizer. Agron. Jor. 72: 723 -728.

Beck, D. L., S. K. Vasal and J. Crossa (1991). Heterosis and combining ability among sub-tropical and temperate intermediate maturity maize germplasm. Crop Sci., 31:68-73.

Comstock, R. E. and R. H. Moll (1963). Genotype-environmental interactions. National Academy of Science, National Research Council, Publication No. 982: 164-196.

Darrah, L. L. and A. R. Hallauer (1972). Genetic effects estimated from generation means in four diallel sets of maize inbreds. Crop Sci. 12: 615-621.

Darrah, L. L., S. A. Eberhart and L. H. Penny (1972). A maize breeding method study in Kenya. Crop Sci., 12: 605-608.

Eberhart, S. A., R. H. Moll, H. F. Robinson and C. C. Cockrham (1966). Epistatic and other genetic variance in two variety of maize. Crop Sci. 3: 275-280.

El-Hosary, A. A. (1988). Evaluation of twenty new inbred lines by top crosses in corn (*Zea mays* L.). Proc. 3rd Egyptian Con. Agron., Kafr El-Shekh, (11): 48-56.

El-Itriby, H. A., A. R. Selim and A. H. Shehata (1981). Genotype x environment interaction from combining ability estimates in maize (*Zea mays* L.). Egypt. J. Genet. and Cytol. 10: 175-186.

El-Itriby, H. A., M. M. Ragheb, H. Y. El-Sherbieny and M. A. K. Shalaby (1990). Estimates of combining ability of maize inbred lines in top crosses and its interaction with environments. Egypt. J. Appl. Sci. (5): 354-370.

El-Zeir, F. A. A., A. A. Abd El-Aziz and A. A. Galal (1993). Estimates of heterosis and combining ability effects in some new top crosses of maize. J. Agric. Res., Minoufiya. 18:2179-2190.

El-Zeir, F. A. A., E. A. Amer, A. A. Abd El-Aziz and A. A. Mahmoud (2000). Combining ability of new maize inbred lines and type of gene action using top crosses of maize. Egypt J. Appl. Sci., 15 (2): 116-128.

Gado, H. E., M. S. M. Soliman and M. A. K. Shalaby (2000). Combining ability analysis of white maize (*Zea mays* L.) inbred lines. J. Agric. Sci., Mansoura Univ., 25:3719-3729.

Gilbert, N. E. G. (1958). Diallel cross in plant breeding. Heredity, 12:477-492.

Hallauer, A. R. (1975). Relation of gene action and type of tester in maize breeding procedures. Proc. Ann, Corn and Sorghum Res. Conf. 30: 150-165.

Hallauer, A. R. and E. Lopez-Perez (1979). Comparison among testers for evaluating lines of corn. Proc., Ann. Corn Sorghum Res. Conf., 34:57-75.

Hallauer, A. R. and I. B. Miranda (1981). Quantitative genetics in maize breeding. Iowa State Univ. Press, Ames, Iowa, USA.

Horner. E. S., H. W. Lundy, M. C. Lutrick and W. H. Chapman (1973). Comparison of three methods of recurrent selection in maize. Crop Sci., 13: 485-489.

Kempthorne, O. (1957). An introduction to Genetic Statistics. John Wiley and Sons Inc. New York, USA.

Landi, P., Pe, E. and S. Conti (1983). Effects of selection at medium and high competition levels on the performance of local maize (*Zea mays* L.) lines. Maydica 28 (1): 41-51.

Liakat, M. A. and N. M. Teparo (1986). Comparative performance of four types of testers for evaluating corn inbred lines from two populations. Philippine J. Crop. Sci. 11(5): 175-179.

Mahgoub, G. M. A., H. Y. Sh., El-Sherbieny, M. A. N. Mostafa and A. A. Abd El-Aziz (1996). Combining ability between newly developed yellow inbred lines of maize. J. Agric., Sci. Mansoura Univ., 21 (5): 1619-1627.

Matzinger, D. F. (1953). Comparison of three types of testers for the evaluation of inbred lines of corn. Agron. J., 45:493-495.

Nawar, A. A. and A. A. El-Hossary (1984). Evaluation of eleven testers of different genetic sources of corn. Egypt. J. Genet. Cytol., 13:227-237.

Nawar, A. A., M. E. Gomaa and M. S. Rady (1979). Genetic analysis of maize inbred lines. 1. Genetic analysis of grain yield and some of its cpmonents. Bull. Fac. Agric., Ain Shams Univ. No. 1168: 11 P.

Paterniani, E. and J. H. Lonnquist (1963). Heterosis in interracial crosses of corn (*Zea mays* L). Crop Sci. 3: 504-507.

Rawlings, J. O. and D. L. Thompson (1962). Performance level as criterion for the choice of maize testers. Crop Sci. 2: 217- 220.

Rojas, B. A. and G. F. Sprague (1952). A comparison of variance components in corn yield trials. III. General and specific combining ability and their interactions with locations and years. Agron. J. 44: 462-466.

Russell, W. A. and S. A. Eberhart (1975). Hybrid performance of selected maize lines from reciprocal recurrent and testcross selection programs. Crop Sci., 15:1-4.

Russell, W. A., S. A. Eberhart and U. A. Vega (1973). Recurrent selection for specific combining ability for yield in two maize populations. Crop Sci. 13: 257-261.

Sadek, S. E., H. E. Gado and M. S. M. Soliman (2000). Combining ability and type of gene action for maize grain yield and other attributes. J. Agric. Sci., Mansoura Univ., 25:2491-2502.

Sadek, S. E., M. S. M. Soliman, A. A. Barakat and K. I. Khalifa (2002). Top-crosses analysis for selecting maize lines in the early self generations. Minufiya J. Agric. Res., 27:197-213.

Shehata, A. H. and N. L. Dhawan (1975). Genetic analysis of grain yield in maize as manifested in genetically diverse varietal populations and their crosses. Egypt. Jour. Genet. and Cytol., 4: 96 - 116.

Singh, R. K. and D. B. Chaudhary (1979). Biometrical methods in quantitative genetic analysis. Kalyani Publishers. Ludhiana, New Delhi, India.

Soliman, F. H. S. (2000). Comparative combining ability of newly developed inbred lines of yellow maize (*Zea mays* L.). Egypt. J. Appl. Sci., 15:87-102.

Soliman, M. S. M. and M. M. A. Osman (2006). Type of gene action for grain yield using testcross analysis in new developed maize inbred lines. J. Agric. Sci., Mansoura Univ., 31:2615-2630.

Soliman, M. S. M., A. A. Mahmoud, Afaf A. I. Gabr and F. H. S. Soliman (2001). Utilization of narrow base testers for evaluating conb1l1ing ability of newly developed yellow maize inbred lines (*Zea mays* L.). Egypt. J. Plant Breed. 5: 61-76.

Steel, R. G. D. and J. H. Torrei (1980). Principles and Procedures of Statistics. A Biometrical Approach. 2nd Ed, McGrow Hill Book Company, New York, U.S.A.

Zambezi, B. T., E. S. Horner and F. G. Martin (1986). Inbred lines as testers for general combining ability in maize. Crop Sci., 26:908-910.

السلالات التجارية كمختبرات للقدرة على التآلف لسلالات حديثة الإستنباط من الذرة الشامية

أيمن محمد محمد عبد العال

قسم بحوث الذرة الشامية – معهد بحوث المحاصيل الحقلية– مركز البحوث الزراعية– جيزة – مصر

الملخص العربي

تم إجراء التهجين القمى لـــ ١٨ سلالة صفراء الحبوب من الذرة الشامية مستنبطة فى الجيل الإنعزالى الثالث من مجاميع أئتلافية مختلفة (pop 45 Ev-4, DTP-2-C5, H.D., AMS-785, Bonner H.D. and PAV 9 E2) مع السلالتين التجاريتين الكشافتين صفراء الحبوب جميزة ١٠٠٤ ، جميزة ١٠٢١ فى موسم ٢٠٠٤ ، وتم تقييم الهجن القمية الـــ ٣٦ الناتجة فى تجارب مكررة تم تنفيذها فى محطات البحوث الزراعية بالجميزة وسدس والنوبارية فى موسم ٢٠٠٥ لصفات محصول الحبوب ، عدد الكيزان/١٠٠ نبات ، موعد خروج الحرايرة ، إرتفاع النبات ، وإرتفاع الكوز وكانت أهم النتائج التى تم التوصل اليها هى: وجد أن التباين بين السلالات الكشافة كان أكبر من التباين بين السلالات المختبرة ، كما كان تباين السلالات الكشافة أكثر تأثرا بالظروف البيئية من السلالات المختبرة . وقد رتبت السلالات الكشافة السلالات المختبرة بصورة مختلفة . أظهرت السلالات المختبرة أرقام ٧ ، ٩ ، ١٠، ١٤، ١٥، ١٦ أفضل التقديرات المعنوية للقدرة العامة على التآلف لصفة المحصول . وكذلك كانت القدرة العامة على التآلف للسلالتين رقمى ١ ، ١٥ موجبة ومعنوية لصفة عدد الكيزان/١٠٠ نبات ، بينما بالنسبة لصفة التزهير فإن السلالات الأبوية أرقام ١، ٤، ٥، ٧، ٨، ٩ أظهرت تأثيرات سالبة ومعنوية أى مرغوبة (تجاه التبكير) للقدرة العامة على التآلف ، لذلك توصى الدراسة بإستخدام السلالات الأبوية أرقام ١، ٤، ٧، ٩، ١٤، ١٥، ١٦ فى برنامج التربية للهجن عالية المحصول مع التبكير وكذلك استعمالها فى تكوين مجتمع وراثى جديد يخدم برنامج عزل السلالات . هذا وقد أعطت السلالة الكشافة جميزة ١٠٢١ أعلى محصول بالنسبة لهجنها الإختبارية إذا ما قورنت بالسلالة الكشافة جميزة ١٠٠٤. كما أعطت هجن السلالة الكشافة

جميزة ١٠٢١ مع السلالات المختبرة أرقام ١، ٤، ٧، ٩، ١٤، ١٥، ١٦ قوة ههجين عالية ومحصول حبوب يتفوق معنويا على هجين المقارنة الفردى بيونير ٣٠٨٤ بمدى يتراوح من ٢,٢٣ الى ٥,٧٨ أردب للفدان. علاوة على ذلك أعطت هجن السلالات المختبرة أرقام ٧، ١٦، ٩ مع الأب الكشاف جميزة ١٠٢١ محصول حبوب أفضل معنويا من محصول هجين المقارنة التجارى الأصفر جيزة ١٥٥ (٢٩,١٠ أردب/فدان) حيث كان محصولها ٣٢,٩٨، ٣٢,٢٨، ٣١,٧٨ أردب للفدان بالترتيب بمعل زيادات قدرها ٣,٨٨، ٣,١٨، ٢,٦٨ أردب/فدان بنفس الترتيب قياسا بمعدل أفضل هجن المقارنة الفردية الصفراء. أظهر التباين الراجع للفعل الوراثى المضيف دورا أكثر أهمية بالمقارنة بالتباين الراجع للفعل الوراثى الغير مضيف فى وراثة جميع الصفات تحت الدراسة ومع ذلك كان التفاعل بين التأثير الغير مضيف والبيئة أعلى من التفاعل بين التأثير المضيف والبيئة لصفتى محصول الحبوب وعدد الكيزان/١٠٠ نبات.