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COMBINING ABILITY EFFECTS FOR SELECTION AMONG NEW YELLOW MAIZE (*Zea mays* L.) INBRED LINES AND TESTERS

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ABSTRACT

Eleven yellow maize inbred lines, isolated from maize breeding nursery at Nubaria Agriculture Research Station, were used for the present study. These lines were topcrossed to three testers; i.e., Gm.96, Nb.241 and Nb.253. The thirty-three resultant topcrosses and the commercial check hybrid, SC.155, were evaluated in replicated grain yield trials conducted at three locations; i.e., Sakha, Sids and Nubaria. Data were recorded for number of days to mid-silking (d), plant and ear heights (cm) and ear rot percentage. Ears were weighed in kg/plot, shelled, adjusted to 15.5% grain moisture and converted to grain yield in tons / hectare (Mg ha^{-1}).

Significant differences were detected among locations, lines and testers for the studied traits at each location and their combined data. The most superior crosses for grain yield were Nb.252 x Gm.96, Nb.202 x Gm.96, Nb.218 x Gm.96, Nb.219 x Gm.96 and Nb.217 x Gm.96, which yielded 11.41, 11.11, 10.88, 10.86 and 10.43 Mg ha^{-1}, across the three tested locations, respectively. Nb.202, Nb.218 and Nb.252 inbred lines had highly significant GCA effects for grain yield, but they had unfavorable alleles for other traits. Nb.212 and Nb.229 inbred lines had favorable alleles for early maturity, short plants, low ear placement and resistance to ear rot, but possessed significant negative GCA values for grain yield. The most superior inbred line was Nb.218 and was recommended for developing new yellow maize hybrids. For the tester, Gm.96, it had favorable alleles for grain yield and ear rot resistance. Therefore, Gm.96 was recommended as a good tester for determining the superior crosses. The most superior SCA effects, combining grain yield and the other studied traits, were recorded for Nb.221 x Nb.253 and Nb.252 x Gm.96. Results showed that both GCA and SCA effects should be taken into consideration when planning maize breeding programs for developing new inbred lines and crosses.

Key words: *Maize, topcross, testcross, combining ability, GCA, SCA.*

INTRODUCTION

The increased demand for yellow maize grains to provide the needs of the growing poultry industry and animal feed, has emphasized the importance of breeding yellow maize inbred lines to develop superior yellow grain maize hybrids.

Successful development of superior maize hybrids is dependent upon accurate evaluation of inbred lines when crossed. The identification of parental inbred lines, that form superior hybrids, is the most costly and time-consuming phase in maize hybrid development. Per se performance of maize inbred lines does not predict the grain yield performance of their hybrids (Hallauer and Miranda, 1988).

The national maize research program exerts great efforts for developing high yield maize hybrids and continuously finds better inbreds higher in combining ability to replace those in currently used hybrids.

The topcross procedure has been widely used to evaluate lines for combining ability. Topcross testing, as suggested by Davis (1927) with broad and/or narrow base tester, is the most common procedure to evaluate the combining ability of inbred lines and to determine their usefulness for hybrid development. Developing a higher yielding maize hybrid is based mainly on recognizing those inbred lines of better combining ability (Habliza and Khalifa, 2005).

The choice of suitable testers for evaluating the newly developed inbred lines is an important decision (Sadek *et al*, 2002). Rawlings and Thompson (1962) and Hallauer (1975) showed that a suitable tester should include simplicity in use, provide information that correctly classified the relative merit of lines and maximize genetic gain.

Hallauer and Miranda (1988) stated that both general combining ability (GCA) and specific combining ability (SCA) effects should be taken into consideration when planning the maize breeding programs to produce and release new inbred lines and crosses. Also, Zhang *et al* (2005) reported that GCA and SCA provided useful genetic information to help plant breeders for devise appropriate breeding and selection strategies, such as the choice of suitable testers in hybrid crop breeding programs. Soliman and Sadek (1999), Soliman (2000), Mahmoud *et al* (2001), Soliman *et al* (2001) and Sadek *et al* (2002) estimated GCA and SCA among different inbred lines of maize by topcross analysis and they found that SCA effects were more important than GCA effects in the inheritance of grain yield.

The objectives of this study were: (*i*) to estimate the general (GCA) and specific (SCA) combining ability effects for eleven yellow maize inbred lines and their resultant top-crosses, using three new testers, (*ii*) to identify the most superior line(s) to be utilized in the national maize breeding program, and (*iii*) to determine the line which can be used as a good tester.

MATERIALS AND METHODS

Eleven new yellow maize inbred lines were isolated from F_2 population of three exotic hybrids in maize breeding nursery at Nubaria Agriculture Research Station and were used for the present study.

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In 2006 growing season, these lines were topcrossed to three testers; namely, Gemmiza-96 (Gm.96) and Nubaria-241 and 253 (Nb.241 and Nb.253). In 2007, the 33 resultant topcrosses and the commercial check hybrid Single Cross, Giza-155 (SC.155) were evaluated in replicated yield trials, conducted at three locations; i.e., Sakha, Sids and Nubaria Agric. Res. Stations, representing North Delta, South Delta and North West Delta, respectively.

A randomized complete block design, with four replications, was used at each location. Plot size was one row, six meters long and 80 cm apart. Sowing was made in hills evenly spaced at 25 cm along the row. Seedlings were thinned, three weeks after planting, to one plant per hill to provide a plant population density of, approximately, 55000 plants/hectare. All cultural practices were performed as recommended for maize growing. Data were recorded for number of days from planting to mid-silking (d), plant and ear heights (cm), ear rot percentage and grain yield. For grain yield, ears were weighed in kg/plot, shelled and grain weight was adjusted to 15.5% moisture content, then, converted to grain yield (Mg ha^{-1}).

Analysis of variance was carried out for each location and their combined data, using proc. ANOVA (SAS software, 1997), according to Steel and Torrie (1980), followed by the procedure of Singh and Chaudhary (1979), using proc. IML (SAS software, 1997) to estimate combining ability of inbred lines and testers. Testing the homogeneity of error variances were carried out, according to Steel and Torrie (1980). Crosses effects were considered fixed and locations random in the analysis of variance.

RESULTS AND DISCUSSION

Variance analysis for the studied traits at each location and across locations (combined) is presented in Tables 1 and 2. Results showed that the differences were highly significant among locations, indicating that the three studied locations differed in their environmental conditions. Significant and highly significant differences were detected among inbred lines for the studied traits at each location and their combined data. Also, significant and highly significant differences were detected among the three testers for the studied traits at each location and their combined data. Similar results were obtained by El-Itriby *et al* (1990), Soliman and Sadek (1999) and Soliman (2000) for all studied traits; Soliman *et al* (1995), Shehata *et al* (1997) and Habliza and Khalifa (2005) for grain yield and plant height; Salama *et al* (1995) and El-Zeir *et al* (2000) for grain yield, number of days to mid-silking and plant height. Significant and highly significant differences were detected between lines x testers interaction at each location and their combined analysis, except for number of days to mid-silking at Sakha, plant height at Sids and ear height at Nubaria. Highly significant differences were observed between locations x testers interaction for all studied traits, except for ear height. Meanwhile, the interaction of locations with lines was highly significant for all studied traits. These interactions with locations indicated that the studied testcrosses differently performed at the three locations. These results, also, indicated that it would be worthwhile to evaluate testcrosses at many environments, especially for grain yield, which was regarded as a complex polygenic trait (Darrah and Hallauer, 1972).

Highly significant differences were observed between locations and testers x lines interaction for the studied traits. These results revealed that the crosses (lines and testers) performed, differently, from location to another. These results are in agreement with those obtained by El-Itriby *et al* (1990), Salama *et al* (1995), Soliman *et al* (1995), Uhr and Goodman (1995), Abdel-Aziz *et al* (1996), Mahgoub *et al* (1996), Shehata *et al* (1997), El-Zeir (1999), Soliman and Sadek (1999), Soliman (2000), Sadek *et al* (2000), Gado *et al* (2000), Sadek *et al* (2002) and Habliza and Khalifa (2005).

Grain yield:

Grain yield performance of the topcrosses of the eleven studied inbred lines (topcrossed to three testers) is given in Table 3 for each location and their combined data. Out of the 33 resultant topcrosses, 21 crosses significantly outyielded the check single cross hybrid, Giza-155, for the separate locations performance. All the topcrosses, involving the tester Gm.96, significantly outyielded the check hybrid, SC.155, at all locations, except for the topcrosses of inbred, Nb.239, at Sids and Nubaria locations. Highly significant differences were detected among the three locations, where the overall means of grain yield were 10.31, 9.88 and 6.87 Mg ha^{-1} for Sakha, Sids and Nubaria, respectively, reflecting that the tested locations differed in their environmental conditions.

For the combined data, grain yield ranged from 6.94 to 11.41 Mg ha^{-1} (Table 3). Considering the overall mean of the studied 11 inbred lines, seven inbreds had significantly more grain yield than the check hybrid SC.155. These lines are in a descending order according to yield, Nb.218, Nb.202, Nb.252, Nb.239, Nb.217, Nb.219 and Nb.221.

Topcrosses of Nb.218, Nb.202 and Nb.252 lines had the highest grain yield and were significantly different than the check hybrid, which yielded 9.72, 9.46 and 9.45 Mg ha^{-1}, respectively, while the check hybrid SC.155 yielded 8.26 Mg ha^{-1} (Table 3). In addition these inbred lines had highly significant positive values of GCA effects, (0.702, 0.441 and 0.428, respectively) as showed in Table 5. These results indicated that these inbred lines had favorable alleles for grain yield and contributed in obtaining good yields in the crosses involving these lines. On the other hand, inbred lines Nb.212, Nb.216, Nb.229 and Nb.251 yielded the lowest grain yield (8.57, 8.57, 8.32 and 8.79 Mg ha^{-1}, respectively), and had significant negative GCA effects (-0.449, -0.452, -0.707 and -0.235, respectively (Tables 3 and 5).

Table 1. Mean square for grain yield and other characters of eleven yellow lines topcrossed to three testers for each location in 2007 season.

S.O.V	df	Grain yield	Number of days to mid-silk	Plant height	Ear height	Ear rot [(1)] susceptibility
			SAKHA			
Replicates	3	0.31	0.66	63.33	242.36	0.132
Testers (Tes)	2	76.72 **	32.48 **	6024.23 **	3173.34 **	0.159 *
Lines (Lin)	10	5.75 **	8.61 **	1554.80 **	745.87 **	0.259 **
Tes x Lin	20	1.53 **	2.54	144.30 *	132.69 **	0.087 **
Lin / Tes.1	10	1.82 **	8.40 **	765.82 **	429.75 **	0.067
Lin / Tes.2	10	2.96 **	2.50	493.51 **	391.64 **	0.131 **
Lin / Tes.3	10	4.03 **	2.77	584.07 **	189.86 **	0.234 **
Error	96	0.59	1.54	84.25	55.92	0.039
C.V.		7.5	1.9	3.4	5.2	16.9
			SIDS			
Replicates	3	2.70	9.39	134.13	199.58	0.141
Testers (Tes)	2	86.99 **	33.78 **	3884.84 **	4903.11 **	2.147 **
Lines (Lin)	10	3.06 *	17.22 **	760.00 **	1148.30 **	0.513 **
Tes x Lin	20	4.95 **	3.88 **	109.55	259.94 **	0.146 *
Lin / Tes.1	10	6.29 **	11.94 **	327.97 **	826.06 **	0.164 *
Lin / Tes.2	10	2.85	8.95 **	234.52	445.10 **	0.114
Lin / Tes.3	10	3.81 *	4.09 **	419.62 **	397.01 **	0.527 **
Error	96	1.39	1.63	97.61	103.28	0.075
C.V.		11.9	2.1	3.9	7.1	16.6
			NUBARIA			
Replicates	3	0.25	1.48	388.38	291.32	0.145
Testers (Tes)	2	60.74 **	34.55 **	4667.09 **	3034.87 **	0.337 **
Lines (Lin)	10	2.44 **	72.06 **	1903.17 **	1204.46 **	0.340 **
Tes x Lin	20	1.59 **	5.47 **	391.18 **	108.35	0.132 **
Lin / Tes.1	10	2.07 **	22.34 **	1104.60 **	553.26 **	0.267 **
Lin / Tes.2	10	0.92	13.75 **	599.32 **	476.52 **	0.182 **
Lin / Tes.3	10	2.65 **	46.90 **	981.61 **	391.36 **	0.153 **
Error	96	0.47	0.85	106.01	81.83	0.052
C.V.		9.9	1.5	4.3	7.0	16.2

***, ** Significant differences at 0.05 and 0.01 levels of probability.**
(1) Data were transformed by arcsine.

Comparison of SCA effects for grain yield indicated that the superior crosses were Nb.239 x Nb.253, Nb.221 x Nb.253, Nb.252 x Gm.96 and Nb.251 x Nb.241 (Table 6), which had significant values of SCA effects (1.257, 0.781, 0.665 and 0.683, respectively). Shehata and Dhawan (1975) and Sadek *et al* (2000) showed that SCA effects were more important than GCA effects in the inheritance of grain yield.

In case of the testers, the highest significant differences of lines, within each tester, for grain yield were detected for Nb.253 at Sakha and Nubaria, while Gm.96 tester had the highest differences at Sids (Table 1). For combined data, Nb.253 had the highest differences among lines for grain yield and ear rot disease susceptibility, while, Gm.96 had the highest values for number of days to mid-silking and plant and ear heights (Table 2). Locations x lines interaction, within Gm.96 tester possessed the highest significant differences for grain yield and plant height. Also, Gm.96 tester had the highest significant positive GCA effects for grain yield (1.294). These results reflected the superiority of Gm.96 as a good combiner tester.

Number of days to mid-silking:

Number of days to mid-silking, for the topcrosses, ranged from 58.8 (Nb.229 x Nb.253) to 65.3 d (Nb.239 x Gm.96) (Table 4). Out of the 33 tested topcrosses, thirteen were significantly earlier than the check hybrid, SC.155. The overall mean of inbred lines ranged from 59.8 (Nb.229) to 63.6 (Nb.239) with an average of 61.6 d. Results of Table 4 showed that the earlier topcrosses were Nb.229 and Nb.212 lines, which had highly significant negative GCA effects (-1.816 and -0.927). Meanwhile, topcrosses of Nb.239, Nb.219 and Nb.202 lines were the latest and had highly significant positive GCA effects (1.989, 1.545 and 1.157, respectively). The topcrosses of the testers, Nb.241 and Nb.253, were significantly earlier than the check hybrid, while, the topcrosses of Gm.96 were later than Sc.155.

Results of Table 6 showed that four topcrosses had significantly negative SCA values; i.e., Nb.212 x Nb.253, Nb.219 x Nb.241, Nb.252 x Gm.96 and Nb.239 x Nb.241 (-0.937, -0.818, -0.717 and -0.679, respectively).

Plant height:

Results of Table 4 showed that all topcrosses were shorter than the check hybrid, except for those crosses of Nb.202, Nb.219, Nb.239 and Nb.252 lines, with the tester, Gm.96. Plant height ranged from 229.9 (Nb.229 x Nb.253) to 286.9 (Nb.219 x Gm.96) with an average of 252.8 cm. Data over the testers showed that plant height ranged from 237.1 (Nb.229) to 266.3 cm (Nb.219). Generally, the shortest plants were obtained for the topcrosses of Nb.241 tester (244.4 cm), while, the tallest plants were recorded for the topcrosses of Gm.96 (264.4 cm).

Results in Table 5 showed that the shorter topcrosses were those of Nb.229, Nb.212 and Nb.221 lines, which had highly significant negative GCA effects (-15.659, -13.770 and -7.214, respectively). While, the topcrosses of Nb.219, Nb.202, Nb.239 and Nb.252 lines were the tallest and had highly significant positive GCA effects. At the same time, the topcrosses of Nb.241 and Nb.253 testers were shortest than SC.155 and had significant negative GCA effects (-8.462 and -3.106, respectively).

Table 2. Mean square for grain yield and other characters of eleven yellow lines topcrossed to three testers for combined analysis over locations in 2007.

S.O.V	df	Grain yield	Number of days to mid-silk	Plant height	Ear height	Ear rot [(1)] susceptiblility
			COMBINED			
Locations (Loc)	2	462.41 **	368.51 **	27625.46 **	8975.61 **	7.388 **
Replicates/Loc	9	1.09	3.84	195.28	244.42	0.139
Testers (Tes)	2	218.17 **	87.55 **	1419.14 **	10806.87 **	1.734 **
Lines (Lin)	10	6.67 **	45.57 **	3499.49 **	2128.00 **	0.543 **
Tes x Lin	20	4.89 **	5.36 **	260.58 **	230.74 **	0.172 **
Lin / Tes.1	10	5.93 **	24.70 **	1637.72 **	1261.78 **	0.209
Lin / Tes.2	10	3.32 **	8.97	903.27 **	713.97 **	0.108
Lin / Tes.3	10	7.20 **	22.62	1479.67 **	613.74 **	0.572 **
Loc x Tes	4	3.13 **	6.63 **	193.02 **	152.23	0.455 **
Loc x Lin	20	2.29 **	26.15 **	359.24 **	485.31 **	0.285 **
Loc x Tes x Lin	40	1.59 **	3.26 **	192.22 **	135.12 **	0.096 **
Loc x Lin / Tes.1	20	2.12 **	8.99 **	278.84 **	273.65 **	0.145 **
Loc x Lin / Tes.1	20	1.70 **	8.11 **	212.03 **	299.64 **	0.160 **
Loc x Lin / Tes.1	20	1.65 **	15.57 **	252.81 **	182.25 **	0.171 **
Error	288	0.82	1.38	95.96	80.34	0.055
C.V.		10.0	1.9	3.9	6.5	16.7

*, ** Significant differences at 0.05 and 0.01 level of probability, respectively.
(1) Data were transformed by arcsine.

Table 3. Mean performance of grain yield (Mg ha^{-1}) for eleven inbred lines topcrossed to three testers, and the commercial check (SC.155) for each location and combined data in 2007.

Lines	Tester	Grain yield (Mg ha^{-1}) SAKHA	SIDS	NUBRIA	COMBINED	Mean
Nb.202 x	Gm.96	12.31*	12.83*	8.21*	11.11*	
	Nb.241	9.33	8.36	6.41	8.03	
	Nb.253	11.31*	9.34	7.06*	9.24*	9.46*
Nb.212 x	Gm.96	11.13*	10.60*	7.64*	9.79*	
	Nb.241	9.31	8.82	5.28	7.80	
	Nb.253	9.46	8.58	6.33	8.13	8.57
Nb.216 x	Gm.96	11.19*	10.90*	8.49*	10.19*	
	Nb.241	7.98	7.89	4.96	6.94	
	Nb.253	9.79	9.02	6.92*	8.58	8.57
Nb.217 x	Gm.96	11.78*	11.19*	8.30*	10.43*	
	Nb.241	9.01	9.69	5.48	8.06	
	Nb.253	10.12*	9.76	6.55	8.81	9.10*
Nb.218 x	Gm.96	11.58*	12.01*	9.05*	10.88*	
	Nb.241	9.96	9.44	5.59	8.33	
	Nb.253	11.28*	10.95*	7.65*	9.96*	9.72*
Nb.219 x	Gm.96	12.46*	13.01*	7.10*	10.86*	
	Nb.241	8.49	7.89	5.26	7.21	
	Nb.253	11.11*	10.14*	6.23	9.16*	9.08*
Nb.221 x	Gm.96	11.26*	10.41*	8.54*	10.07*	
	Nb.241	7.73	8.62	5.59	7.31	
	Nb.253	10.75*	10.27*	8.52*	9.85*	9.08*
Nb.229 x	Gm.96	10.58*	11.29*	7.27*	9.71*	
	Nb.241	7.95	7.38	5.72	7.02	
	Nb.253	9.49	8.98	6.16	8.21	8.32
Nb.239 x	Gm.96	11.03*	9.22	6.83	9.03*	
	Nb.241	9.42	8.68	5.77	7.96	
	Nb.253	12.49*	10.92*	7.64*	10.35*	9.11*
Nb.251 x	Gm.96	10.67*	10.77*	8.57*	10.00*	
	Nb.241	8.27	10.19*	6.13	8.19	
	Nb.253	9.32	9.47	5.71	8.17	8.79
Nb.252 x	Gm.96	12.42*	13.31*	8.50*	11.41*	
	Nb.241	10.30*	8.24	6.47	8.34	
	Nb.253	11.08*	7.77	6.97*	8.61	9.45*
Mean		10.31	9.88	6.87	9.02	
Testers						
Gm.96		11.49*	11.41*	8.05*	10.32*	
Nb.241		8.89	8.65	5.69	7.75	
Nb.253		10.57*	9.56*	6.89*	9.00*	
Check						
SC.155		9.42	9.03	6.32	8.26	
LSD $_{0.05}$ (Lin.)		0.62	0.96	0.55	0.71	
LSD $_{0.05}$ (Tes.)		0.33	0.50	0.29	0.37	
LSD $_{0.05}$ (Loc.)		—	—	—	0.20	

* Significantly different than check hybrid at 0.05 level of probability.

Table 4. Mean performance of eleven inbred lines topcrossed to three testers, and the commercial check for number of days to mid-silking, plant height, ear height and ear rot susceptibility over three locations in 2007.

Lines	Tester	Number of days to mid-silking (d)	Plant height (cm)	Ear height (cm)	Ear rot susceptibility (%)
Nb.202 x	Gm.96	64.3	276.2	160.3	5.27
	Nb.241	61.9	259.0*	144.4*	4.10*
	Nb.253	62.2 (62.8)	256.4* (263.9)	136.3*(147.0)	4.99*(4.79)
Nb.212 x	Gm.96	61.7	248.0*	138.1*	1.08*
	Nb.241	61.2*	238.5*	131.5*	2.80*
	Nb.253	59.3 (60.7)	230.5* (239.0)	121.8*(130.5)	1.88*(1.92)
Nb.216 x	Gm.96	62.0	262.0*	147.4*	3.46*
	Nb.241	61.6*	243.0*	138.4*	6.64
	Nb.253	60.5* (61.4)	249.0* (251.3)	132.6*(139.5)	7.76 (5.95)
Nb.217 x	Gm.96	61.8	260.4*	146.9*	5.28
	Nb.241	61.0*	240.0*	128.8*	4.89*
	Nb.253	61.1* (61.3)	251.5* (250.6)	138.6*(138.1)	5.34 (5.17)
Nb.218 x	Gm.96	61.8	264.5*	144.8*	3.52*
	Nb.241	60.3*	245.5*	130.3*	4.19*
	Nb.253	60.8* (61.0)	252.5* (254.2)	132.9*(136.0)	5.59 (4.43)
Nb.219 x	Gm.96	64.6	286.9	168.9	4.26*
	Nb.241	61.9	250.5*	145.3*	5.98
	Nb.253	63.0 (63.2)	261.4* (266.3)	139.6*(151.3)	8.85 (6.36)
Nb.221 x	Gm.96	61.9	256.4*	144.2*	1.69*
	Nb.241	61.9	23.8.2*	133.0*	5.71
	Nb.253	60.5* (61.4)	242.1* (245.6)	128.5*(135.2)	5.16 (4.19)
Nb.229 x	Gm.96	60.8	249.3*	137.0*	1.36*
	Nb.241	59.8*	232.2*	128.6*	3.66*
	Nb.253	58.8* (59.8)	229.9 (237.1)	118.1*(127.9)	4.53*(3.18)
Nb.239 x	Gm.96	65.3	274.6	161.5	4.19*
	Nb.241	62.5	255.3*	145.7*	4.31*
	Nb.253	63.1 (63.6)	261.5* (263.8)	140.7*(149.3)	11.76 (6.75)
Nb.251 x	Gm.96	62.3	260.7*	141.9*	4.66*
	Nb.241	60.2*	234.5*	123.1*	5.53
	Nb.253	61.0* (61.2)	253.8* (249.7)	132.5*(132.5)	11.36 (7.18)
Nb.252 x	Gm.96	61.8	268.9	155.8	1.47*
	Nb.241	60.8*	250.9*	130.9*	6.48
	Nb.253	62.0 (61.5)	258.0* (259.3)	130.5*(139.1)	4.11*(4.02)
Mean		61.6*	252.8*	138.8*	4.90*
Testers					
Gm.96		62.6	264.4*	148.8*	3.29*
Nb.241		61.2*	244.4*	134.6*	4.94*
Nb.253		61.1*	249.7*	132.1*	6.49
Check					
SC.155		62.7	276.3	162.4	6.22
$LSD_{0.05}$		1.0	7.9	7.4	1.19

*** Significantly different than check hybrid at 0.05 level of probability.**

Ear height:

Regarding ear height, all topcrosses had lower ear placement than the check hybrid, except for those of Nb.202, Nb.219, Nb.239 and Nb.252 inbred lines with the tester, Gm.96 (Table 4). Ear height of topcrosses ranged from 118.1 cm (Nb.229 x Nb.253) to 168.9 cm (Nb.219 x Gm.96) with an average of 138.8 cm. The lowest ear placement among inbred lines was that of Nb.229 topcrosses (127.9 cm), while, the highest was that of topcrosses of Nb.219 line (151.3 cm). Also, the lowest ear placement among testers, was that of topcrosses of the tester, Nb.253 (132.1 cm).

Results in Table 5 showed that the topcrosses of Nb.229, Nb.212 and Nb.251 lines had the lowest ear height and had highly significant negative GCA effects (-10.570, -7.959 and -5.959, respectively). Topcrosses of the inbred lines, Nb.219, Nb.239 and Nb.202, had highly significant positive GCA effects. Also, topcrosses of the testers, Nb.241 and Nb.253, were, in general, of low ear placement and had significant negative GCA effects.

Regarding SCA effects, data in Table 6 showed that the topcrosses of Nb.217 x Nb.241, Nb.219 x Nb.253 and Nb.251 x Nb.241 significantly possessed negative SCA values (-5.393, -5.204 and -5.532, respectively), which was desirable for developing new hybrids with low ear height.

Ear rot susceptibility:

Generally, out of the 33 resultant topcrosses, nineteen crosses were significantly lower in ear rot susceptibility than the check hybrid (Table 4). Percentage of ear rot for the topcrosses ranged from 1.08 (Nb.212 x Gm.96) to 11.76 (Nb.239 x Nb.253) with an average of 4.90%. The topcrosses of Nb.212 and Nb.229 inbred lines, over the three testers, had the lowest values in ear rot susceptibility (1.92 and 3.18%), while, the topcrosses of Nb.251 and Nb.239 lines had the highest percentages.

Results in Table 5 showed that topcrosses of Nb.212 and Nb.229 inbred lines were the lowest in ear rot susceptibility and had significant negative GCA effects (-2.986 and -1.723, respectively), while topcrosses of Nb.251 and Nb.239 inbred lines were the highest in ear rot susceptibility and had significant positive GCA values (2.276 and 1.850, respectively). Also, topcrosses of the tester, Gm.96, had significant negative GCA effects (-1.609).

Comparison of SCA effects, in Table 6, showed that Nb.239 x Nb.241 cross was the lowest in ear rot susceptibility, since it had a significant negative SCA value (-2.472), while Nb.239 x Nb.253, Nb.251 x Nb.253, Nb.252 x Nb.241 and Nb.202 x Gm.96 crosses were the highest in ear rot susceptible and had significant positive SCA values (3.420, 2.598, 2.427 and 2.086, respectively).

Finally, it may be concluded that the most superior crosses for grain yield were Nb.252 x Gm.96, Nb.202 x Gm.96, Nb.218 x Gm.96, Nb.219 x Gm.96 and Nb.217 x Gm.96. Nb.218 inbred line was the most superior and might be utilized in developing new yellow maize hybrids. For the testers, Gm.96 inbred line had favorable alleles for grain yield and ear rot resistance; therefore, it was a good tester for determining superior crosses. The most superior SCA effects, combining grain yield and other studied traits, were recorded for Nb.221 x Nb.253 and Nb.252 x Gm.96 crosses. Both GCA and SCA effects should be taken into consideration when planning the maize breeding programs to produce new inbred lines and crosses.

Table 5. General combining ability (GCA) effects of the eleven inbred lines for grain yield and the other studied traits across the three locations in 2007.

Line	Grain yield	Silking date	Plant height	Ear height	Ear rot susceptibility
Lines					
Nb.202	0.441**	1.157**	11.063**	8.540**	- 0.117
Nb.212	- 0.449**	- 0.927**	- 13.770**	- 7.959**	- 2.986**
Nb.216	- 0.452**	- 0.260	- 1.464	1.012	1.047
Nb.217	0.075	- 0.343	- 2.159	- 0.348	0.265
Nb.218	0.702**	- 0.621*	1.368	- 2.459	- 0.468
Nb.219	0.054	1.545**	13.479**	12.818**	1.459
Nb.221	0.054	- 0.177	- 7.214**	- 3.237*	- 0.718
Nb.229	- 0.707**	- 1.816**	- 15.659**	- 10.570**	- 1.723**
Nb.239	0.089	1.989**	11.007**	10.873**	1.850**
Nb.251	- 0.235*	- 0.455	- 3.103	- 5.959**	2.276**
Nb.252	0.428**	- 0.093	6.452**	- 2.709	- 0.886
Testers					
Gm.96	1.294**	0.939	11.568	10.345	- 1.609**
Nb.241	- 1.277	- 0.432**	- 8.462**	- 3.911**	0.029
Nb.253	- 0.018	- 0.507**	- 3.106**	- 6.434**	1.579
SE lines (g_i)	0.151	0.266	1.632	1.493	0.526
($g_i - g_j$)	0.213	0.376	2.308	2.112	0.745
SE testers (g_i)	0.079	0.139	0.852	0.780	0.275
($g_i - g_j$)	0.111	0.196	1.205	1.103	0.389

*, ** Significantly different from zero at 0.05 and 0.01 levels of probability, respectively.

Table 6. Specific combining ability (SCA) effects of eleven inbred lines for grain yield, number of days to mid-silking, plant and ear heights and ear rot disease across the three locations in 2007.

Lines	Tester	Grain yield	Number of days to mid-silking	Plant height	Ear height	Ear rot susceptibility
Nb.202 x	Gm.96	0.360	0.533	0.793	2.959	2.086*
	Nb.241	- 0.152	- 0.429	3.573	1.300	- 0.717
	Nb.253	- 0.208	- 0.104	- 4.366	- 4.260	- 1.369
Nb.212 x	Gm.96	- 0.076	0.033	- 2.540	- 2.707	0.766
	Nb.241	0.506	0.904*	7.907*	4.967	0.849
	Nb.253	- 0.430	- 0.937*	- 5.366	- 2.260	- 1.616
Nb.216 x	Gm.96	0.328	- 0.301	- 0.846	- 2.429	- 0.878
	Nb.241	- 0.351	0.654	0.101	2.828	0.654
	Nb.253	0.023	- 0.353	0.745	- 0.398	0.224
Nb.217 x	Gm.96	0.034	- 0.467	- 1.818	- 1.568	1.722
	Nb.241	0.236	0.154	- 2.205	- 5.393*	- 0.309
	Nb.253	- 0.269	0.313	4.022	6.962*	- 1.412
Nb.218 x	Gm.96	- 0.139	- 0.106	- 1.263	- 1.540	0.693
	Nb.241	- 0.115	- 0.235	- 0.149	- 1.782	- 0.268
	Nb.253	0.254	0.341	1.412	3.323	- 0.424
Nb.219 x	Gm.96	0.486	0.477	9.043**	7.265*	- 0.492
	Nb.241	- 0.587*	- 0.818*	- 7.260*	- 2.060	- 0.415
	Nb.253	0.101	0.341	- 1.783	- 5.204*	0.908
Nb.221 x	Gm.96	- 0.302	- 0.467	- 0.762	- 1.345	- 0.884
	Nb.241	- 0.485	0.904*	1.101	1.661	1.490
	Nb.253	0.787**	- 0.437	- 0.338	- 0.315	- 0.606
Nb.229 x	Gm.96	0.104	0.088	0.598	- 1.262	- 0.212
	Nb.241	- 0.020	0.376	3.545	4.661	0.443
	Nb.253	- 0.084	- 0.465	- 4.143	- 3.398	- 0.231
Nb.239 x	Gm.96	- 1.379**	0.699*	- 0.735	1.876	- 0.948
	Nb.241	0.122	- 0.679*	- 0.038	0.300	- 2.472*
	Nb.253	1.257**	- 0.020	0.773	- 2.176	3.420**
Nb.251 x	Gm.96	- 0.079	0.227	- 0.540	- 0.957	- 0.915
	Nb.241	0.683*	- 0.568	- 6.677*	- 5.532*	- 1.682
	Nb.253	- 0.603*	0.341	7.217*	6.489*	2.598**
Nb.252 x	Gm.96	0.665*	- 0.717*	- 1.929	- 0.290	- 0.936
	Nb.241	0.163	- 0.262	0.101	- 0.949	2.427*
	Nb.253	- 0.828**	0.979**	1.828	1.239	- 1.491
SE (s_{ij})		0.261	0.334	2.827	2.587	0.912
SE ($s_{ij} - s_{kl}$)		0.369	0.472	3.999	3.659	1.290

***, ** Significantly different from zero at 0.05 and 0.01 levels of probability, respectively.**

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الملخص العربى

تأثيرات القدرة على التآلف للانتخاب بين السلالات والكشافات الجديدة من الذره الشاميه الصفراء

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هجنت قميا لحدى عشر سلالة نقية صفراء من الذره الشامية – مستنبطة من مصادر وراثية مختلفة – مع ثلاثة كشافات (السلالات جميزه ٩٦ ، نوباريه ٢٤١ ونوباريه ٢٥٣) وذلك فى موسم ٢٠٠٦. تم تقييم الـ ٣٣ هجينا قميا بالاضافة الى هجين المقارنة (هجين فردى ١٥٥) فى تصميم قطاعات عشوائية كاملة في أربع مكررات ونفذت التجربة في ثلاث محطات بحثية هى: سخا وسدس والنوبارية خلال موسم ٢٠٠٧. تم قياس صفات محصول الحبوب وعدد الأيام من الزراعة حتى ظهور ٥٠% من الحرابر وارتفاعى النبات والكوز والنسبة المئويه للاصابة بأعفان الكوز.

أوضحت النتائج ما يلى:

- وجود فروق معنوية بين المواقع والسلالات والكشافات لكل الصفات تحت الدراسة فى كل موقع على حدة وكذلك للتحليل المجمع للمواقع.
- تفوقت بعض الهجن الناتجة فى محصول الحبوب مثل Nb.252 x Gm.96 ، Nb.202 x Gm.96 ، Nb.218 x Gm.96 ، Nb.219 x Gm.96 و Nb.217 x Gm.96 حيث حققت محصولا قدره ١١,٤١ و ١١,١١ و ١٠,٨٨ و ١٠,٨٦ و ١٠,٤٣ ميجا / هكتار كمتوسط لكل المواقع على الترتيب.
- أعطت السلالات " Nb.202 ، Nb.218 و Nb.252 " قيما موجبة وعالية المعنوية لتأثيرات الـ GCA لصفة المحصول ، لكنهـا تحمل اليلات غير مرغوبة للصفات الأخرى.
- تحمل السلالتان " Nb.212 و Nb.229 " اليلات مرغوبة لصفات التبكير وانخفاض ارتفاع النبات وارتفاع الكوز والمقاومة بأعفان الكوز ، لكنها أعطت قيما سالبة لتأثيرات الـ GCA لصفة محصول الحبوب.
- كانت أفضل السلالات المختبرة هى السلالة " Nb.218 " ويوصى باستخدامها فى برنامج انتاج الهجن الجديدة صفراء الحبوب من الذره الشامية.
- كان أفضل الكشافات هى السلالة " Gm.96 " حيث تحمل اليلات مرغوبة لصفة محصول الحبوب والمقاومة لأعفان الكوز.
- أعطت الهجن " Nb.221 x Nb.253 و Nb.252 x Gm.96 " أفضلية بالنسبة لتأثيرات الـ SCA لصفة محصول الحبوب وأيضا للصفات الأخرى.
- يجب الأخذ فى الاعتبار كل من تأثيرات الـ GCA و SCA عند التخطيط لبرامج تربية الذره الشامية لانتاج سلالات وهجن جديدة.