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EVALUATION OF SOME WHITE MAIZE INBRED LINES FOR COMBINING ABILITY BASED ON TOP-CROSSES

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ABSTRACT

Nine white maize inbred lines *i.e*., Gm 305, Gm 309, Gm 310, Gm 315, Gm 316, Gm 317, Gm 318, Gm 319 and Gm 320 were developed at Gemmeiza (Gm) Agricultural Research Station and top-crossed with three inbred line testers *i.e*., Gm 30, Sd 7 and Sd 63 during 2006 summer season at Gemmeiza Station. Twenty seven top crosses and three commercial checks single crosses 10, 122 and 129 were evaluated in replicated field trials at Gemmeiza and Sakha Agricultural Research Station, ♀♀♀Agriculture Research Center (ARC), Egypt during 2007 summer season. Mean performance, General (GCA) and Specific (SCA) combining abilities as well as proportion association of all inbred lines and testers lines and their interaction were estimated for, days to 50% silking, plant and ear heights, ear kernels number of per, 100-kernel weight and grain yield characters. The obtained results showed; highly significant differences among lines, testers and lines x testers for most of the studied traits. Highly significant differences were found between locations, locations x lines and locations x testers. Some of promising lines showed significantly positive GCA effects under both locations. Tester inbred line Sd 7 was found to be the best general combiner for high yielding ability followed by Gm 30 inbred line. However, the tested inbred lines Gm 319, Gm 305, Gm 309 and Gm 320 were significantly and respectively better general combiner for grain yield ability. The top cross Gm 320 x Sd 7 was significantly better than the commercial S.C.10 by (4.27 ard/fed). However, seven top crosses *i.e.*, Gm 318 x Sd 7, Gm 309 x Sd 7, Gm 318 x Gm 30, Gm 310 x Sd 7, Gm 310 x Sd 63, Gm 316 x Sd 7 and Gm 305 x Sd 63 were significantly better than the control single crosses 122 (30.02 ard/fed), 129 (29.26 ard/fed) with productivity of 37.08, 36.90, 36.83, 36.28, 35.88 and 34.40 ard/faddan, respectively with significant positive SCA effects for grain yield. Therefore, these eight crosses should be going to advanced testing steps for releasing as new white single crosses.
Keywords: Maize, Combining ability and Top-crosses.

INTRODUCTION

Successful development of improved maize hybrids is dependents upon the accurate evaluation of inbred lines performance in crossing. One of the most widely approaches to evaluate the new improved inbred lines for combining ability in maize breeding programs is top-crosses procedure. This method suggested by Davis (1927) then suggested by Jenkins (1935) and Sprague (1939) under the early testing scheme for new inbreds. Sprague and Tatum (1942) were the first researchers partition the total combining ability effects of the lines in two concepts of general combining ability (GCA) and specific combining ability (SCA), which are useful for characterizing inbred lines in their crosses. Hallauer (1975) indicated that suitable tester should be characterized by its simplicity in use and provide information that correctly classifies the relative merits of lines and maximizes genetic gain. Mahmoud and Abd El-Azeem (2004) and Abd El-Azeem *et al* (2004) found that highly

significant variation due to lines, testers and its interaction for most of studied traits.

Matzinger *et al* (1953), Russell *et al* (1973), El-Hosary (1985), Salama *et al* (1995), Sultan (1998), Sadek *et al* (2001), Sadek *et al* (2002)and El-Shenawy *et al* (2003) reported that the variance component due to SCA for some agronomic *i.e*. plant height and ear height traits was relatively larger than that due to GCA. This result indicates that the non-additive effects were important in the inheritance of previous agronomic traits. On the other hand, Rojas and Sprague (1952), Shehata and Dhawan (1975), El-Itriby *et al*, (1990), Abdel-Aziz *et al* (1994), Mosa (1996) and Ibrahim (2001) and Soliman *et al* (2001), Ibrahim (2004) and Soliman *et al* (2005) reported that the additive effects were more important for some agronomic traits inheritance, especially when the lines are relatively unselected.

The top-crosses methodology is commonly practiced to develop the new maize inbred lines for high yielding and other desirable agronomic traits and to study the combining ability among each others and testers. So, the choice of a tester to test the inbred lines is an important decision. Many researchers defined a desirable tester as one that combines the greatest simplicity in use with the maximum information on performance to be expected from tested inbred lines when used in other combinations. Darrah *et al* (1972) and Horner *et al* (1973) reported that the inbred lines testers have the advantage of no sampling errors of genetic variability within the testers and greater genetic variation among top crosses.

The aims of this study were (1) Estimating general and specific combining ability variances and effects of nine inbred lines of white maize in top crosses with three testers under two locations. (2) Calculating the proportional contribution of inbred lines and testers and their interactions to total variance for all studied characters and (3) Identifying the desirable superior inbred line(s) and the resulting single crosses for yielding potentiality and other related traits for further use in the breeding program.

MATERIALS AND METHODS

The used materials (Table 1) were nine white inbred lines of maize and developed at Gemmieza Agriculture Research Station, Agriculture Research Center (ARC), Egypt. These inbred lines were derived from three different populations *i.e*. American Early Dent (AED), Giza 2 EV-6 and Laposta. In the first season *i.e*., 2006, all of the used inbred lines were used as females and top-crossed to each of the three testers, *viz* Gm 30, Sd 7 and Sd 63 at Gemmeiza Station for Agricultural Research. The three previous testers are being used in maize sees production of commercial single and three-way crosses. In the 2007 second season of growing, the all 27 resultant top crosses along with three commercial check hybrids *i.e*. SC 10, SC 129 and SC 122 were evaluated at Gemmeiza and Sakha Agriculture Research Stations in randomized complete block design with four replications in each location. Plot size was one row, 6 m long and 80 cm apart and hills space were 25 cm along the row. Two kernels were planted per hill and thinned later to one plant per hill to provide a population of 21,000 plants/fad (faddan = 4200 m^2). All recommended practices for maize production were applied.

Table 1. Names and origin of the used inbred lines and testers.

No	Inbred lines and testers	Origin
1 - 3	Gm 305, Gm 315 and Gm 316	American Early Dent
4	Gm 317	Giza 2 EV-6
5 - 9	Gm 309, Gm 310, Gm 318, Gm 319 and Gm 320	Laposta
10, 11	Gm 30 and Sd 7	AED
12	Sd 63	Tepalcinco Composite (Tep # 5)

The recorded data were; days from planting to 50% silking, plant height (cm), ear height (cm), kernels ear number (as multiplication of number of rows per ear x number of kernels per row), 100-Kernel weight (gm) and grain yield (ard/fed). The analysis of variance for each location and it's combined - based on the homogeneity test - were computed according to Stell and Torrie (1980). The procedures of Kempthorne (1957) and Singh and Chaudhary (1985) were performed to obtain valuable information about the combining ability of lines and testers as well as their top crosses. In addition, proportional contribution of inbred lines and testers and their interactions to total variance for the studied vegetative growth and yield traits were estimated.

RESULTS AND DISCUSSION

I. Analysis of variance

The analyses of variance for each location and their combined are presented in Table (2). Highly significant differences were detected between locations for all studied traits except kernels ear number trait, which had significant differences; this may be due to the environmental effect of each location. Lines mean squares were highly significant for all tested traits. Mean squares due to testers were highly significant for all of the studied growth, yield attributes and grain yield characters. The highly significant differences of mean square due to lines and testers may be revealing difference existed among inbred lines and their order of performance.

The interaction between lines and testers was highly significant for all of the studied traits through each location and combined. Highly significant differences due to the interaction between lines x locations were observed for plant height, ear height and grain yield traits, on the other hand, there is no significant differences for testers x locations observed for studied traits except for grain yield which was significant, This indicated that the contribution of inbred lines was greater than testers to the total variance for most traits (Table 6). Similar results were obtained by Solimain *et al*. (1995), Gado *et al.* (2000), Amer *et al*. (2003), Ibrahim (2004), Ibrahim and Osman (2005), Ibrahim (2006) and Soliman and Osman (2006).

II. Top crosses performance

Mean performance for the studied traits of the twenty seven top cross each location and it's combined data are presented in Table (3). From the combined data over locations, there are many crosses gave the desirable mean values for the studied traits and superior relative to commercial check hybrids (S.C. 10, S.C. 122 and S.C. 129). Concerning days to 50% siliking, the earliest top crosses were Gm 310 x Sd 63 (58.25 day), then Gm 309 x Sd 7 (59.39) with no significant differences between them. The crosses; Gm 310 x Gm 30 (180.50 cm), Gm 315 x Sd 63 (220.88 cm), Gm 317 x Sd 63 (240.75 cm), Gm 309 x Gm 30 (242.25 cm) and Gm 316 x Sd 63 (245.63 cm) were significantly the shortest in plant height crosses relative to the three commercial check single crosses 10, 122 and 129. However, top crosses *i.e.*, Gm 310 x Gm 30, Gm 315 x Sd 63, Gm 309 x Gm 30, Gm 317 x Sd 63, Gm 310 x Sd 63 and Gm 316 x Sd 63 were significantly lowest and desirable for ear height relative to the check single crosses 10, 122 and 129.

On the other hand, the greatest number of kernels per ear was obtained from the crosses; Gm 318 x Sd 7 (604.86) and Gm 318 x Gm 30 (600.88) with no significant difference. The 100-Kernel weight was better relative to all of the check hybrids for cross; Gm 309 x Sd 7 (53.53 g), while many crosses showed high 100-kernel weight values relative to check hybrids 122 and 129, *i.e.*; Gm 310 x Sd 63 (49.73 g), Gm 317 x Sd 7 (46.91 g), Gm 315 x Sd 7 (46.76 g), Gm 305 x Sd 7 (45.78 g) and Gm 318 x Sd 7 (45.17 g). Regarding to the grain yield, the single crosses; Gm 320 x Sd 7 (38.26 ard.) and Gm 318 x Sd 7 (37.08 ard) were significantly more grain yield as compared with all the check single crosses. While top crosses Gm 309 x Sd 7 (36.90 ard), Gm 318 x Gm 30 (36.83 ard), Gm 310 x Sd 7 (36.28 ard), Gm 310 x Sd 63 (35.88 ard), Gm 316 x Sd 7 (35.06 ard) and Gm 305 x Sd 63 (34.40 ard) gave the highest value of grain yield per fed and were significant more productivity relative to the check single crosses 122 and 129. These crosses which desirable and the earliest, shortest, lowest ear height and gave the highest grain yield per fed. must be selected and evaluated in advanced testing trials for the vegetative growth and yield attributes traits for registration and releasing steps.

III. Combining ability effects

Data in Table (4) show the general combining ability effects of inbred lines and testers in two locations and it's combined through 2007 season. Regarding to combined data, many parental inbred lines exhibited desirable significant and/or highly significant and negative ($\hat{g}_i$), i.e., the inbred lines; Gm 305 and Gm 309 and the tester; Sd 7 for days to 50% siliking towards earliness, while, both inbred lines; Gm 315, Gm 309 and Gm 310 and testers; Sd 63 and Gm 30 for plant height towards shortness, in addition the inbred lines Gm 315, Gm 309, Gm 310 and the tester Sd 63 for ear height trait. The tabulated data showed that, the most potent general combiners which induced significant and/or highly significant and negative ($\hat{g}_i$) for days to 50% siliking, plant height and ear height characters are Gm 309 (inbred line) and Sd 63 (tester).

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Table 4. General combining ability effects of nine inbred lines and three testers over two locations and it's combined through 2007 season.

Character		Days to 50% silking			Plant height (cm)			Ear height (cm)		
Parents		Gm	Sk	Com	Gm	Sk	Com	Gm	Sk	Com
Inbred lines										
Gm 305		-1.39	-1.81**	-1.60*	13.24**	16.52**	14.88**	0.81	0.69	0.75
Gm 315		0.11	0.19	0.15	-10.34**	-9.56*	-9.95**	-5.53	-11.47**	-8.50**
Gm 316		-0.22	-0.89*	-0.56	-2.09	-2.06	-2.08	4.31	3.36	3.83
Gm 317		0.28	0.36	0.32	7.07*	-8.06*	-0.50	6.06*	-9.81**	-1.88
Gm 309		-1.56	-1.47**	-1.51*	-9.43**	-11.23**	-10.33**	-8.19**	-4.97	-6.58*
Gm 310		-1.39	-1.14**	-1.26	-28.76**	-35.65**	-32.20**	-23.36**	-27.06**	-25.21**
Gm 318		-1.31	-1.06**	-1.18	1.82	16.02**	8.92**	-0.94	5.94*	2.50
Gm 319		2.86**	3.36**	3.11**	7.91*	12.60**	10.25**	8.72**	15.19**	11.96**
Gm 320		2.61**	2.44*	2.53**	20.57**	21.44**	21.00**	18.14**	28.11**	23.13**
Testers										
Gm 30		0.42	0.69**	0.56	-0.43	-2.73	-1.58*	2.44	-0.33	1.06
Sd 7		-0.89	-0.78**	-0.83*	10.94**	15.07**	13.00**	1.22	4.83**	3.03
Sd 63		0.47	0.08	0.28	-10.51**	-12.34**	-11.43**	-3.67*	-4.50*	-4.08*
LSD for										
Lines $\hat{g}_i$	5%	2.10	0.68	1.36	6.08	7.50	6.70	5.68	5.88	5.66
	1%	2.78	0.90	1.79	8.06	9.94	8.81	7.53	7.79	7.44
$\hat{g}_i - \hat{g}_j$	5%	2.98	0.96	1.93	8.60	10.61	9.47	8.02	8.30	8.00
	1%	3.95	1.27	2.54	11.40	14.07	12.44	10.63	11.00	10.51
Testers $\hat{g}_i$	5%	1.22	0.38	0.78	3.50	4.34	3.86	3.28	3.40	3.27
	1%	1.62	0.50	1.03	4.64	5.75	5.07	4.35	4.51	4.30
$\hat{g}_i - \hat{g}_j$	5%	1.72	0.54	1.11	4.96	6.14	5.47	4.64	4.80	4.63
	1%	2.28	0.72	1.46	6.57	8.14	7.19	6.15	6.36	6.08

Table 4. Cont.

Character		Ear kernels number			100-Kernel weight (gm)			Grain yield (ard/fed)		
Parents		Gm	Sk	Com	Gm	Sk	Com	Gm	Sk	Com
Inbred lines										
Gm 305		35.39**	27.16*	31.28**	3.22**	-0.19	1.52	4.77**	2.64**	3.71**
Gm 315		-40.76**	-61.79**	-51.28**	-2.20**	-1.75*	-1.98*	-2.95**	-5.90**	-4.43**
Gm 316		-3.19	31.22**	14.02	-3.53**	-4.00**	-3.77**	-2.29**	-2.03**	-2.16**
Gm 317		-42.32**	-32.74**	-37.53**	-2.18**	-0.51	-1.35	-4.37**	-3.81**	-4.09**
Gm 309		-17.76	-24.25*	-21.01	5.04**	4.24**	4.64**	2.59**	3.45**	3.02**
Gm 310		1.49	0.91	1.20	3.08**	3.80**	3.44**	-1.34*	-0.66	-1.00
Gm 318		52.97**	47.57**	50.27**	-0.51	0.96	0.23	1.12*	7.97**	4.55**
Gm 319		21.77*	22.86*	22.32*	0.13	-0.70	-0.29	3.22**	-5.27**	-1.03
Gm 320		-7.59	-10.93	-9.26	-3.03**	-1.84*	-2.44**	1.26*	3.60**	2.43**
Testers										
Gm 30		-3.34	3.69	0.18	-1.60**	-2.17**	-1.89**	0.02	-0.95*	-0.47
Sd 7		21.61**	17.55**	19.58	3.54**	3.81**	3.68**	4.53**	5.48**	5.01**
Sd 63		-18.27**	-21.24**	-19.76	-1.94**	-1.63**	-1.79**	-4.56**	-4.53**	-4.55**
LSD for										
Lines $\hat{g}_i$	5%	21.15	21.25	21.20	1.58	1.76	1.67	1.08	1.30	1.19
	1%	28.03	28.17	28.10	2.10	2.33	2.22	1.44	1.73	1.59
$\hat{g}_i - \hat{g}_j$	5%	29.91	30.05	29.98	2.24	2.48	2.36	1.53	1.84	1.69
	1%	39.64	39.83	39.74	2.96	3.29	3.13	2.03	2.44	2.24
Testers										
$\hat{g}_i$	5%	12.21	12.27	12.24	0.91	1.01	0.96	0.63	0.75	0.69
	1%	16.18	16.26	16.22	1.21	1.34	1.28	0.83	1.00	0.92
$\hat{g}_i - \hat{g}_j$	5%	17.27	17.35	17.31	1.29	1.43	1.36	0.89	1.06	0.98
	1%	22.89	23.00	22.95	1.71	1.90	1.81	1.17	1.41	1.29

On the other side, the inbred lines; Gm 318, Gm 305 and Gm 319 gave the highest and positive general combining ability effects as regards to kernels ear number and inbred lines Gm 309, Gm 310 and the tester; Sd 7 for 100-Kernel weight as well as the inbred lines; Gm 318, Gm 305 and Gm 309 and the tester; Sd 7 at the same time as grain yield characters.

Specific combining ability effects of the 27 top crosses in two locations and combined through 2007 season are presented in Table (5). Data showed that, many top crosses exhibited desirable, negative and significant and highly significant specific combining ability for the three vegetative growth traits i.e., days to 50% siliking, plant height and ear height in both Gemmeiza and Sakha. The highest desirable and negative SCA effects were obtained from the top crosses; Gm 310 x Sd 63, Gm 315 x Gm 30 and Gm 319 x Sd 7 for days to 50% siliking and the crosses; Gm 310 x Gm 30, Gm 315 x Sd 63 and Gm 317 x Sd 63 for plant height, plus the top crosses; Gm 310 x Gm 30, Gm 315 x Sd 63 and Gm 309 x Gm 30 for ear height. On other point of view, the highest desirable and positive SCA effects were obtained from top crosses; Gm 315 x Gm 30 and Gm 309 x Sd 63 for number of kernels per ear and Gm 315 x Gm 30 and Gm 310 x Sd 63 for 100-Kernel weight in addition to the crosses; Gm 310 x Sd 63 then; Gm 315 x Gm 30, Gm 305 x Sd 63, Gm 309 x Sd 63, Gm 317 x Gm 30, Gm 310 x Sd 7 and Gm 316 x Gm 30 for grain yield per fed. These top crosses which gave the desirable SCA effects has to be insert in a progress field experimental steps to test it's stability for grain yield productivity and to select the better to crosses for releasing as commercial new hybrids. Such results were reported by Mahgoub et al. (1996), Luis et al. (2003),Abd EL-Azeem et al. (2004), Ibrahim and Osman (2005), Ibrahim (2006) and Soliman and Osman (2006).

IV. Proportional contribution of all genotypes to total variance.

According to the procedure of Singh and Chaudhary (1985) the proportional contribution of all genotypes *i.e*., nine inbred lines and three testers and their interactions relative to the total variance for all of the studied characters over locations and combined through 2007 season were calculated and offered in Table (6). The combined proportional contributions of inbred lines for all of the tested traits were higher than those of testers, in the same time, the interaction between lines x testers gave the highest contributions relative to the total variance for the most, days to 50% silking, plant height, 100-Kernel weight and grain yield per fed., tested traits. This point had been studied by many investigators; Soliman and Sadek (1999), Sadek *et al*., (2002), Abd EL-Azeem *et al*.,(2004) and Soliman and Osman (2006).

In general, from the results of this study, it could be concluded that, the good tested inbred lines and top crosses, which exhibited desirable significant and/or highly significant and negative or positive general and specific combining abilities has great values and ver important for maize breeding program to improve vegetative growth characters then the potential grain yield ability.

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تقييم قدرة التآلف لبعض سلالات الذرة الشاميه البيضاء بالتهجين القمى

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تم تهجين تسع سلالات نقية من الذرة الشامية البيضاء - تم إستنباطها بمحطة بحوث الجميزة - هى جميزة ٣٠٥، جميزة ٣٠٩، جميزة ٣١٠، جميزة ٣١٥، جميزة ٣١٦، جميزة ٣١٧، جميزة ٣١٨، جميزة ٣١٩ و جميزة ٣٢٠ مع ثلاثة كشافات من السلالات النقية البيضاء هى جميزة ٣٠، وسدس ٧ وسدس ٦٣. أجريت التهجينات القمية بين هذه المواد الوراثية خلال الموسم الصيفى لعام ٢٠٠٦ بمحطة البحوث الزراعية بالجميزة. تم تقييم الهجن القمية الناتجة (٢٧هجين فردى) فى تجارب حقلية مع مقارنتها بثلاثة هجن فردية تجارية هى: هجين فردى ١٠، هجين فردى ١٢٢ وهجين فردى ١٢٩ فى موقعين زراعيين هما محطة بحوث الجميزة ومحطة بحوث سخا ، بمركز البحوث الزراعية خلال الموسم الصيفى لعام ٢٠٠٧. تم تقيم سلوك السلالات والهجن القمية تحت ظروف الموقعين الزراعيين وكذلك التحليل المشترك لهما لقدرتها العامة والخاصة على الإئتلاف بالإضافة إلى تقدير المساهمات النسبية لجميع السلالات والكشافات وكذلك التفاعل بينهما لبعض صفات النمو الخضرى والمحصول خلال مراحل نمو النبات وتشمل عدد الأيام من الزراعة حتى ظهور ٥٠% من الحرابر، إرتفاع النبات والكوز، عدد حبوب الكوز، وزن الـ ١٠٠ حبة ومحصول الحبوب. وقد أظهرت النتائج وجود إختلافات عالية المعنوية بين جميع السلالات المختبرة، الكشافات والسلالات x الكشافات لمعظم الصفات تحت الدراسة. كذلك وجدت إختلافات عالية المعنوية بين الموقعين الزراعيين، المواقع الزراعية x السلالات المختبرة و المواقع الزراعية x الكشافات لمعظم الصفات تحت الدراسة. أظهرت بعض السلالات (جميزة ٣١٩، جميزة ٣٠٥، جميزة ٣٢٠ بالإضافة إلى السلالة الكشاف سدس ٧) وبعض الهجن الفردية (جميزة ٣٢٠ x سدس ٧، جميزة ٣١٨ x سدس ٧، جميزة ٣٠٩ x سدس ٧، جميزة ٣١٨ x جميزة ٣٠، جميزة ٣١٠ x سدس ٧، جميزة ٣١٠ x سدس ٦٣، جميزة ٣١٦ x سدس ٧ و جميزة ٣٠٥ x سدس ٦٣) الناتجة قدرة إئتلافية عامة وخاصة عالية (موجبة او سالبة) تحت كلا الموقعين للصفات تحت الدراسة ومن ثم يمكن إستعمال هذه السلالات والهجن فى برامج تربية الذرة الشامية لإنتاج هجن ذات مواصفات نمو خضرى ومكونات محصول جيدة والتى تعتبر منابع المحصول النهائى. كما أوضحت النتائج وجود عدد من الهجن القمية (أهمها جميزة ٣٢٠ x سدس ٧) ذات مواصفات نمو خضرى ومكونات محصول أعلى من مواصفات النمو الخضرى ومكونات المحصول ومحصول الحبوب للهجن الفردية المحلية موضع المقارنة.

Table 2. Observed mean squares from analyses of variance of 9 inbred lines top-crossed with three testers over two locations and it's combined through 2007 season.

Character	df		Days to 50% silking			Plant height (cm)			Ear height (cm)		
SOV	Single	Com	Gm	Sk	Com	Gm	Sk	Com	Gm	Sk	Com
Locations (Loc)		1			433.50**			4845.04**			5797.04**
Rep / Loc	3	6	3.05**	11.86**	7.45**	252.53	1027.00**	639.76**	450.62**	692.01**	571.31**
Lines (L)	8	8	34.69**	39.10**	73.01**	2612.70**	4058.18**	6284.24**	1657.94**	3079.06**	4361.52**
Testers (T)	2	2	21.36**	19.69**	38.89**	4143.68**	6966.51**	10877.92**	376.44*	787.00**	970.39**
L x T	16	16	10.06**	8.22**	15.78**	2240.99**	3082.97**	5092.32**	662.17**	1155.35**	1591.47**
L x Loc		8			0.78			386.64**			375.48**
T x Loc		2			2.17			232.26			193.06
L x T x Loc		16			2.49**			231.64			226.06**
Error	78	156	0.65	1.35	1.00	110.85	169.12	139.99	96.64	103.47	100.05
C. V. %			1.34	1.84	1.62	3.95	4.71	4.36	6.41	6.21	6.31

*** and ** significant at 0.05 and 0.01 levels of probability, respectively, Sk: Sakha , Gm: Gemmeiza and Com: Combined data.**

Table 2. Cont.

Character	df		Ear kernels number			100-Kernel weight (gm)			Grain yield (ard/fed)		
SOV	Single	Com	Gm	Sk	Com	Gm	Sk	Com	Gm	Sk	Com
Locations (Loc)		1			6563.40*			737.56**			565.28**
Rep / Loc	3	6	1799.69	1458.98	1629.34	51.48**	2.51	26.99**	3.22	19.84	11.53*
Lines (L)	8	8	12555.13**	15143.72**	26296.45**	115.14**	84.93**	184.89**	130.26**	265.44**	286.18**
Testers (T)	2	2	14610.45**	13911.77**	27850.01**	339.00**	393.68**	728.18**	743.48**	926.28**	1653.13**
L x T	16	16	6699.85**	4860.74**	10730.43**	57.45**	49.92**	98.55**	195.66**	265.45**	430.88**
L x Loc		8			1402.40			15.18			109.53**
T x Loc		2			672.21			4.50			16.63*
L x T x Loc		16			830.16			8.83			30.24**
Error	78	156	1342.81	1355.75	1349.28	7.51	9.27	8.39	3.53	5.10	4.32
C. V. %			6.79	6.68	6.74	6.73	6.86	6.81	6.67	7.19	6.97

Table 3. Mean performance of 27 top crosses between nine inbred lines and three testers over two locations and it's combined through 2007 season.

Character	Days to 50% silking									Plant height (cm)								
Locations	Gm			Sk			Com			Gm			Sk			Com		
Lines	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63
Gm 305	59.25	59.00	58.50	61.00	60.25	62.75	60.13	59.63	60.63	284.50	276.25	278.50	295.25	296.75	285.50	289.88	286.50	282.00
Gm 315	59.00	58.50	63.75	62.25	62.25	65.50	60.63	60.38	64.63	276.75	274.50	217.25	291.50	283.25	224.50	284.13	278.88	220.88
Gm 316	59.25	59.00	62.00	62.25	61.75	62.75	60.75	60.38	62.38	289.00	262.00	242.25	291.75	281.00	249.00	290.38	271.50	245.63
Gm 317	60.50	59.25	62.00	64.00	63.00	63.50	62.25	61.13	62.75	289.00	279.50	252.25	290.50	284.00	229.25	289.75	281.75	240.75
Gm 309	58.50	58.25	59.50	62.75	60.50	61.75	60.63	59.38	60.63	246.75	248.50	276.00	237.75	275.00	281.50	242.25	261.75	278.75
Gm 310	60.25	59.25	57.25	65.00	61.75	59.25	62.63	60.50	58.25	186.25	279.00	248.00	174.75	290.00	256.25	180.50	284.50	252.13
Gm 318	59.25	59.25	58.50	62.00	62.75	61.50	60.63	61.00	60.00	263.25	281.25	260.50	299.25	295.50	281.25	281.25	288.38	270.88
Gm 319	65.25	60.75	63.50	68.25	64.25	67.00	66.75	62.50	65.25	283.00	279.00	261.25	299.25	287.50	279.00	291.13	283.25	270.13
Gm 320	65.25	61.50	62.00	67.00	64.75	65.00	66.13	63.13	63.50	276.25	317.00	268.00	279.25	326.50	286.50	277.75	321.75	277.25
Checks																		
Sc 10		59.75			62.75			61.25			295.00			294.75			294.88	
Sc 122		59.50			62.00			60.75			261.25			262.75			262.00	
Sc 129		59.50			62.00			60.75			286.00			280.25			283.13	
LSD 5 %		1.14			1.65			1.39			14.88			18.38			16.40	
1 %		1.51			2.18			1.82			19.73			24.37			21.55	

Table 3. Cont.

Character	Ear height (cm)									Ear kernels number								
Locations	Gm			Sk			Com			Gm			Sk			Com		
Lines	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63
Gm 305	158.25	147.50	157.00	177.50	162.00	154.00	167.88	154.75	155.50	579.64	560.27	585.88	596.32	555.12	582.74	587.98	557.70	584.31
Gm 315	168.75	152.25	122.75	164.25	156.25	136.50	166.50	154.25	129.63	557.85	546.73	392.76	542.44	527.66	397.22	550.15	537.20	394.99
Gm 316	173.25	146.75	153.25	178.75	164.25	158.50	176.00	155.50	155.88	552.16	559.06	498.83	569.81	620.52	556.03	560.99	589.79	527.43
Gm 317	164.00	160.25	154.25	166.75	161.75	133.50	165.38	161.00	143.88	494.87	533.24	464.58	535.06	528.28	491.15	514.97	530.76	477.87
Gm 309	139.50	140.25	156.00	138.25	168.00	170.25	138.88	154.13	163.13	491.84	538.14	536.38	494.12	525.44	560.40	492.98	531.79	548.39
Gm 310	108.75	143.75	137.75	96.00	162.00	152.25	102.38	152.88	145.00	536.91	602.24	484.94	559.84	596.10	499.50	548.38	599.17	492.22
Gm 318	158.50	158.00	141.00	176.25	170.50	162.50	167.38	164.25	151.75	591.57	597.74	589.24	610.18	611.97	573.26	600.88	604.86	581.25
Gm 319	167.00	163.00	156.50	186.25	173.00	177.75	176.63	168.00	167.13	528.51	572.64	583.80	565.32	584.24	571.72	546.92	578.44	577.76
Gm 320	165.00	180.25	169.50	187.25	200.00	188.50	176.13	190.13	179.00	495.47	543.30	558.10	518.21	566.77	534.94	506.84	555.04	546.52
Checks																		
Sc10		163.50			174.50			169.00			559.93			566.48			563.21	
Sc 122		150.75			154.25			152.50			597.60			601.29			599.45	
Sc 129		161.50			160.75			161.13			590.42			596.66			593.54	
LSD 5%		13.90			14.38			13.86			51.80			52.05			51.93	
1 %		18.42			19.06			18.22			68.67			69.00			68.84	

Table 3. Cont.

Character	100-Kernel weight (gm)									Grain yield (ard/fed)								
Locations	Gm			Sk			Com			Gm			Sk			Com		
Lines	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63
Gm 305	41.20	46.18	44.40	42.55	45.38	44.71	41.88	45.78	44.56	32.25	32.34	34.27	32.97	34.71	34.53	32.61	33.53	34.40
Gm 315	40.78	44.83	29.93	45.43	48.69	33.85	43.11	46.76	31.89	30.95	34.70	10.07	34.60	31.41	10.56	32.78	33.06	10.32
Gm 316	35.85	41.45	34.23	35.96	47.97	37.27	35.91	44.71	35.75	31.54	31.17	14.98	29.42	38.95	19.82	30.48	35.06	17.40
Gm 317	37.74	44.97	32.89	41.58	48.85	41.25	39.66	46.91	37.07	25.11	33.56	12.78	32.92	34.25	15.67	29.02	33.91	14.23
Gm 309	43.35	51.35	42.55	45.34	55.71	44.89	44.35	53.53	43.72	29.67	32.63	30.02	28.60	41.16	34.88	29.14	36.90	32.45
Gm 310	43.03	39.92	48.43	46.25	47.35	51.02	44.64	43.64	49.73	30.23	33.39	30.92	32.30	39.16	40.84	31.27	36.28	35.88
Gm 318	37.19	43.33	40.08	41.45	47.01	47.64	39.32	45.17	43.86	31.83	30.81	25.27	41.83	43.34	32.99	36.83	37.08	29.13
Gm 319	37.37	43.22	41.93	41.71	46.51	42.92	39.54	44.87	42.43	30.93	32.95	30.35	29.15	25.60	23.72	30.04	29.28	27.04
Gm 320	35.55	43.00	34.49	39.84	46.45	41.40	37.70	44.73	37.95	31.36	32.95	24.02	32.44	43.57	29.06	31.90	38.26	26.54
Checks																		
Sc10		48.75			51.37			50.06			35.45			32.52			33.99	
Sc 122		33.20			47.4			40.30			25.51			34.52			30.02	
Sc 129		36.80			49.71			43.26			23.10			36.02			29.56	
LSD 5%		3.87			4.30			4.09			2.66			3.19			2.93	
1 %		5.13			5.71			5.42			3.52			4.23			3.88	

Table 5. Specific combining ability effects of nine inbred lines and three testers over two locations and it's combined through 2007 season.

Character	Days to 50% silking									Plant height (cm)								
Locations	Gm			Sk			Com			Gm			Sk			Com		
Lines	Gm30	Sd7	Sd63	Gm30	Sd7	Sd63	Gm30	Sd7	Sd63	Gm30	Sd7	Sd63	Gm30	Sd7	Sd63	Gm30	Sd7	Sd63
Gm 305	-0.08	0.97	-0.89	-1.03	-0.31	1.33*	-0.56	0.33	0.22	5.18	-14.44**	9.26	5.48	-10.82	5.34	5.33	-12.63*	7.30
Gm 315	-1.83	-1.03	2.86	-1.78**	-0.31	2.08**	-1.81	-0.67	2.47*	21.01**	7.40	-28.41**	27.81**	1.76	-29.57**	24.41**	4.58	-28.99**
Gm 316	-1.25	-0.19	1.44	-0.69	0.28	0.42	-0.97	0.04	0.93	25.01**	-13.35*	-11.66*	20.56**	-7.99	-12.57	22.79**	-10.67	-12.12*
Gm 317	-0.50	-0.44	0.94	-0.19	0.28	-0.08	-0.35	-0.08	0.43	15.84**	-5.02	-10.82*	25.31**	1.01	-26.32**	20.58**	-2.00	-18.57**
Gm 309	-0.67	0.39	0.28	0.39	-0.39	0.00	-0.14	0.00	0.14	-9.91	-19.52**	29.43**	-24.27**	-4.82	29.09**	-17.09**	-12.17*	29.26**
Gm 310	0.92	1.22	-2.14	2.31**	0.53	-2.83**	1.61	0.88	-2.49*	-51.07**	30.31**	20.76**	-62.85**	34.59**	28.26**	-56.96**	32.45**	24.51**
Gm 318	-0.17	1.14	-0.97	-0.78	1.44*	-0.67	-0.47	1.29	-0.82	-4.66	1.98	2.68	9.98	-11.57	1.59	2.66	-4.80	2.13
Gm 319	1.67	-1.53	-0.14	1.06	-1.47*	0.42	1.36	-1.50	0.14	9.01	-6.35	-2.66	13.40*	-16.16*	2.76	11.20	-11.25	0.05
Gm 320	1.92	-0.53	-1.39	0.72	-0.06	-0.67	1.32	-0.29	-1.03	-10.41*	18.98**	-8.57	-15.44*	14.01*	1.43	-12.92*	16.50**	-3.57
LSD at	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**
$\hat{s}_{ij}$	3.64		4.82	1.16		1.54	2.35		3.09	10.51		13.94	12.99		17.23	11.60		15.25
$\hat{s}_{ij} - \hat{s}_{lk}$	5.16		6.84	1.64		2.17	3.33		4.51	14.87		19.72	18.39		24.38	16.41		22.18

Table 5. Cont.

Character	Ear height (cm)									Ear kernels number								
Locations	Gm			Sk			Com			Gm			Sk			Com		
Lines	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63
Gm 305	1.56	-7.97	6.42	13.33**	-7.33	-6.00	7.44	-7.65	0.21	7.72	-36.60	28.88	14.57	-40.49*	25.92	11.15	-38.55*	27.40
Gm 315	18.39**	3.11	-21.50**	12.25*	-0.92	-11.33*	15.32*	1.10	-16.42*	62.08**	26.01	-88.09**	49.65**	21.00	-70.65**	55.87**	23.51	-79.37**
Gm 316	13.06**	-12.22*	-0.83	11.92*	-7.75	-4.17	12.49	-9.99	-2.50	18.82	0.77	-19.59	-16.00	20.85	-4.85	1.41	10.81	-12.22
Gm 317	2.06	-0.47	-1.58	13.08*	2.92	-16.00**	7.57	1.22	-8.79	0.65	14.07	-14.72	13.21	-7.44	-5.78	6.93	3.32	-10.25
Gm 309	-8.19	-6.22	14.42**	-20.25**	4.33	15.92**	-14.22*	-0.94	15.17*	-26.94	-5.59	32.53	-36.22	-18.77	54.99**	-31.58	-12.18	43.76*
Gm 310	-23.78**	12.44*	11.33*	-40.42**	20.42**	20.00**	-32.10**	16.43**	15.67*	-1.11	39.27*	-38.16*	4.34	26.73	-31.07	1.62	33.00	-34.62
Gm 318	3.56	4.28	-7.83	6.83	-4.08	-2.75	5.19	0.10	-5.29	2.06	-16.72	14.66	8.02	-4.06	-3.97	5.04	-10.39	5.35
Gm 319	2.39	-0.39	-2.00	7.58	-10.83*	3.25	4.99	-5.61	0.63	-29.80	-10.62	40.42*	-12.13	-7.07	19.20	-20.97	-8.85	29.81
Gm 320	-9.03	7.44	1.58	-4.33	3.25	1.08	-6.68	5.35	1.33	-33.48	-10.60	44.08*	-25.45	9.24	16.21	-29.47	-0.68	30.15
LSD at	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**
$\hat{s}_{ij}$	9.84		13.04	10.00		13.25	13.62		17.90	36.63		48.55	36.80		48.79	36.715		48.67
$\hat{s}_{ij} - \hat{s}_{lk}$	10.17		13.49	73.12		96.94	14.09		19.05	51.80		68.67	52.05		69.00	51.925		68.835

Table 5. Cont.

Character	100-Kernel weight (gm)									Grain yield (ard/fed)								
Locations	Gm			Sk			Com			Gm			Sk			Com		
Lines	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63	Gm 30	Sd 7	Sd 63
Gm 305	-1.13	-1.29	2.42	0.51	-2.64	2.13	-0.31	-1.97	2.28	-0.72	-5.15**	5.87**	-0.14	-4.84**	4.98**	-0.43	-5.00**	5.43**
Gm 315	3.86**	2.78*	-6.64**	4.94**	2.22	-7.17**	4.40**	2.50	-6.91**	5.69**	4.93**	-10.61**	10.03**	0.40	-10.44**	7.86**	2.67*	-10.53**
Gm 316	0.27	0.74	-1.01	-2.27	3.77*	-1.50	-1.00	2.26	-1.26	5.62**	0.73	-6.36**	0.98	4.07**	-5.05**	3.30**	2.40*	-5.71**
Gm 317	0.80	2.90*	-3.70**	-0.14	1.15	-1.01	0.33	2.03	-2.36	1.27	5.21**	-6.48**	6.26**	1.15	-7.41**	3.77**	3.18**	-6.95**
Gm 309	-0.80	2.06	-1.26	-1.13	3.26*	-2.13	-0.97	2.66	-1.70	-1.13	-2.67**	3.80**	-5.33**	0.80	4.53**	-3.23**	-0.94	4.17**
Gm 310	0.83	-7.41**	6.58**	0.22	-4.66**	4.45**	0.53	-6.04**	5.52**	-4.63**	4.01**	10.63**	-7.51**	2.91*	14.60**	-6.07**	3.46**	12.62**
Gm 318	-1.41	-0.41	1.82	-1.75	-2.16	3.91*	-1.58	-1.29	2.87	2.50**	-3.03**	0.53	3.39**	-1.53	-1.87	2.95**	-2.28*	-0.67
Gm 319	-1.88	-1.15	3.03*	0.17	-1.01	0.84	-0.86	-1.08	1.94	-0.50	-2.99**	3.49**	3.94**	-6.03**	2.09	1.72	-4.51**	2.79**
Gm 320	-0.54	1.78	-1.24	-0.55	0.08	0.48	-0.55	0.93	-0.38	1.90*	-1.03	-0.87	-1.63	3.06**	-1.44	0.14	1.02	-1.16
LSD at	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**	**5%**		**1%**
$\hat{s}_{ij}$	2.74		3.63	3.04		4.03	2.89		3.83	1.88		2.49	2.26		2.99	2.07		2.74
$\hat{s}_{ij} - \hat{s}_{ik}$	3.87		5.13	4.30		5.71	4.085		5.42	2.66		3.52	3.19		4.23	2.93		3.88

Table 6. Proportional contribution (%) of the studied nine inbred lines and three testers and their interactions to total variance for all studied characters over two locations and it's combined through 2007 season.

Character	Days to 50% silking			Plant height (cm)			Ear height (cm)			Ear kernels number			100-Kernel weight (gm)			Grain yield (ard/fed)		
Location	Gm	Sk	Com	Gm	Sk	Com	Gm	Sk	Com	Gm	Sk	Com	Gm	Sk	Com	Gm	Sk	Com
Lines (L)	32.13	64.68	44.76	32.13	33.92	32.75	53.89	55.12	56.01	42.41	53.43	48.06	36.58	29.99	32.78	18.41	25.82	18.33
Testers (T)	12.74	8.14	2.28	12.74	14.56	14.17	3.06	3.52	3.12	12.34	12.27	12.72	26.92	34.75	32.28	26.27	22.53	26.47
L x T	55.12	27.18	52.96	55.12	51.53	53.08	43.05	41.36	40.87	45.26	34.30	39.22	36.50	35.26	34.94	55.31	51.65	55.20

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