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Combining Ability and Heterotic Groups for some New Whit Maize Inbred Lines

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Cross Mark

ABSTRACT

The main objectives of this study was to estimate combining ability and heterotic groups for 16 white maize inbred lines using line × tester mating design.Thirty-two whitethree-way crosses resulting fromcrosses between 16 inbred lines with two testers(SC 131 and SC Gm 1)and the check TWC 321 were evaluated at three Research Stations; Gemmeiza, Sakha and Mallawyin 2020 season.Mean square analysis cleared the variability among lines and testers and their interaction for most studied traits. The non-additive gene effects were more important than additive ones in the inheritance of days to 50% silking and grain yield, while the additive ones were the predominant for ear height and plant height. The best inbred lines for general combining effects were Gm5, Gm 6 and Gm 7 for days to silking (earliness),plant height (shortness) and ear height(lower ear position),and Gm 12,Gm 13 and Gm 14 for grain yield. The two crosses; Gm 14 x SC131 and Gm 14 x SC Gm 1 were significantly out-yielded compared with the check TWC 321 (31.3 ard./fed), therefore they will be taken in the next stage for more accurate evaluation in the national program of maize. Sixteen inbred lines were classified into the following two heterotic groups using HSGCA for grain yield group-1 (tester SC131) included inbred lines Gm 2, Gm 5, Gm 6, Gm7,Gm8, Gm13 and Gm 16while group-2 (tester SC Gm1) included inbred lines Gm1,Gm9, Gm 11 and Gm 15. These groups could be used in breeding programs for selecting the best parents in making hybrids.

Keywords: *Zea mays*, General combining ability, Specific combining ability, Additive gene effects, Non additive gene effects.

INTRODUCTION

Maize (*Zea mays*, L.) crop is extensively grown as grain for human and fodder for livestock consumption. Maize is one of the most important grain crops in Egypt, Area devoted to maize cultivation is about 2.7 million feddan. Maize productivity increased from 1.5 ton/fed in 1980 to 3.3 ton/fed in 2020 season. Assessment of combining ability and genetic variance components are important in the breeding programs for hybridization. In any breeding program, the choice of the correct parents is the secret of the success. One of the most important criteria in breeding programs for identifying the hybrids with high yield is knowledge of parent genetic structure and information regarding their combining ability (Ceyhan *et al*., 2008).

Line × tester mating design was developed by Kempthorne (1957), which provides reliable information on the general and specific combining ability effects of parents and their hybrid combinations in applied breeding programs (Sharma *et al*., 2004). However the effectiveness of this test depends mainly upon the type of tester to be used in the evaluation program. El-Ghawas (1963), Sokolov and kostyuchenko (1978), Sedhom (1992) and Mosa (2001) indicated the superiority of maize single cross as tester for the evaluation of inbred lines.

For grain yield, it was observed that the importance of general combining ability was relatively more than specific combining ability for unselected inbred lines, while specific combining ability was more important than general combining ability for previously selected lines. General combining ability is a good estimate of additive gene action, whereas specific combining ability is a measure of non-additive gene action (Sharief *et al*. 2009). Melchinger and Gumber (1998) defined a heterotic group as a group relatedor unrelatedgenotypes from the same or different populations, which display similar combining ability and heterotic response when crossed with the genotypes from other genetically distinct germplasm group.

The present study aimed to determine the general and specific combining ability effects and heterotic groups for 16 new white inbred lines and select the superior hybrids compared.

MATERIALS AND METHODS

In 2019 growing season, 16 new white inbred lines and two testers *i.e.* SC. 131 and SC. Gm-1, were sown in separate plots and crossed between lines and testers at Gemmeiza Experimental Station according to line × tester method by Kempthorne (1957). In 2020 summer season, 32 three-way crosses resulting from the first season and commercial checks TWC 321 were evaluated at three locations at Gemmeiza, Sakha and Mallawy Experimental Stations. A randomized complete blocks design (RCBD) with three replications was used for each location. Each plot consists of one row, 6 meter-long and 80 cm wide, plant to plant hill at 25 cm apart. All agricultural practices were applied as recommended in the proper time. Data were collected on the following characters: days to 50% silking, plant height (cm), ear height (cm) and grain yield (ard./fed). Combining ability effects weredetermined by using line × tester analysis as described by

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Kempthrone (1957). Before calculating the combined analysis, test of homogeneity error mean squares between locations was done by Snedecor and Cochran (1980). Heterotic groups using specific and general combining ability (HSGCA) was made according to Fan *et al*. (2009)

RESULTS AND DISCUSSION

Combined analysis of variance for four traits across the three locations is presented in Table 1. Locations (Loc) mean squares were highly significant for all the studied traits, meaning that the circumstances differed from location to another. Mean squares of crosses (Cr) exhibited highly significant for all studied traits, indicating that there were differences among the crosses. Partition sum of squares due to crosses into its components showed that mean squares due to lines (L) and testers (T) were highly significant for all studied traits, except of testers for days to 50% silking, revealing great diversity existed among testers and lines. Considering the interaction between lines x testers (L x T) was highly significant for days to 50% silking and grain yield, indicating that lines did not express similar orders of ranking according to performance of their crosses with the two testers. Mean squares of Cr x Loc. and their partitions; L x Loc, T x Loc and L x T x Loc were highly significant for all traits, except L x LocandT x Loc for days to 50% silking, indicating that performance of lines, testers and their interaction differed from location to another. These results are in agreement with conclusions reached by Ashish and Singh (2002), Duarta *et al*. (2003) and Mosa *et al*. (2017).

Table 1. Line x tester analysis of variance for 32 crosses for four traits across three locations.

SOV	df	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard./fed)
Locations(loc)	2	1781.51**	63928.72**	26578.76**	665.99**
Rep /loc	6	26.54	725.22	525.10	8.75
Crosses (Cr)	31	8.81**	1452.07**	762.40**	55.08**
Lines (L)	15	11.97**	2560.73**	1270.71**	73.88**
Testers (T)	1	2.92	3472.22**	2508.68**	17.61**
L x T	15	6.03**	15.00	15.00	38.84**
Cr x loc	62	3.60**	211.55**	136.00**	21.74**
L x loc	30	3.15	215.18**	156.94**	24.42**
T x loc	2	5.85	937.96**	616.91**	13.14**
L x T x loc	30	3.90**	159.48**	83.00**	19.63**
Error	186	2.21	81.84	70.48	8.01

**** , indicating significant at 0.01 levels of probability.**

Mean performance of 32 crosses and check TWC 321 for four traitsacross three locations are presented in Table 2. For days to 50% silking, most of the crosses were significantlyearly than check TWC 321. The earliest cross was top cross Gm 7 x SC 131 (61 days). For plant height (cm), the shortest plant was Gm 5 x SCGm1, while the tallest crosswasGm10 x SC 131.With respect to ear height (cm), means of the studied 3-way crosses for this trait ranged between 117 cm for crosses Gm 5 x SC Gm1 and Gm 6 x SC Gm1 to 148 cm for cross Gm 15 x SC131also, fourteencrosses out of the 32 studied crosses exhibited significantly lower position in ear height than the check TWC. 321. For grain yield (ard./fed), the result in Table 2, revealed that the differences between crosses were highly significant and ranged from 26.27 (ard./fed) for cross Gm 11 x SC Gm1 to 35.69 for cross Gm 14 x SCGm1. In addition, there were 16 crosses out of the studied 32 crosses were not significant out-yield than check TWC 321 (31.34ard./fed), The best from them were Gm 10 x SC 131, Gm 12 x SC Gm 1, Gm 14 x SC 131 and Gm 14 x SC Gm 1.These crosses could be utilized in maize hybrids breeding programs.

Table 2. Mean performance of 32white maize crosses and check TWC 321 for four traits across three locations.

Inbred line	Days to 50% Silking		Plant height (cm)		Ear height (cm)		Grain yield (ard./fed)	
	SC131	SCGm1 GGGgGm	SC 131	SCGm1 GGGgGm	SC 131	SCGm1 GGGgGm	SC131	SCGm1 GGGgGm
Gm 1	63	64	263	249	137	129	33.05	29.59
Gm 2	63	62	250	238	134	127	29.53	33.09
Gm 3	65	63	248	240	137	131	31.71	33.37
Gm 4	63	65	261	259	143	142	33.78	31.43
Gm 5	62	62	232	217	119	117	29.37	29.74
Gm 6	62	62	238	238	128	117	29.62	30.13
Gm 7	61	62	227	227	121	118	30.70	30.77
Gm 8	65	65	254	237	135	124	28.10	28.53
Gm 9	63	63	235	230	125	120	30.84	26.40
Gm 10	63	63	269	264	147	137	34.19	31.32
Gm 11	63	63	255	250	138	133	32.29	26.27
Gm 12	63	63	251	254	141	135	33.39	35.26
Gm 13	62	64	255	259	138	147	31.61	34.13
Gm 14	64	63	254	245	144	134	35.58	35.69
Gm 15	63	63	261	244	148	132	33.51	30.00
Gm 16	62	62	240	233	129	126	30.05	33.72
TWC. 321	67		266		145		31.34	
LSD at0.05	2.30		14.03		13.02		4.39	
LSD at 0.01	3.15		19.20		17.82		6.01	

Estimates of additive gene effects (K2 GCA) and non-additive gene effects (K2 SCA) for four traits are shown in Table 3. The results showed that (K2 GCA) was higher than (K2 SCA) for plant height and ear height, meaning that the additive gene effectswere the predominant over the non-additive ones, while(K2 SCA) was higher than (K2 GCA) for days to 50% silking and grain yield, indicating that non-additive gene effects were more important than additive ones in the inheritance of these traits. Thereare in harmony with the findings of several investigators; Nawara and El-Hosary (1984), Mosa et al. (2017), El-Hosary(2020) and Ismail (2020).

Table 3. Estimates of K^2 GCA, K^2 SCA effects for four study traits.

Parameters	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard./fed)
K^2 GCA	0.065	36.230	14.818	0.813
K^2 SCA	0.424	0.001	0.001	3.426

Estimates of general combining ability effects of the new 16 inbred lines and the two testers for four studied traitsacross three locations are presented in Table 4. For days to 50% silking, four inbred lines; Gm 5, Gm 6, Gm 7 and Gm 16 exhibited negative and significant or highly significant general combining ability effects towards earliness, therefore these inbred lines are considered the best general combiners for earliness. Also, the tester SC 131 exhibited negative general combining ability effects, but it was not reach to significant level.With respect to plant height,the results showed that five inbred lines; Gm 5, Gm 6, Gm 7, Gm 9 and Gm 16, and tester SCGm1 showed negative and highly significant general combining ability effects towards plant shortness. This means that these five lines and the tester SC Gm1 could be considered as the best general combiners for plant height trait (shortness). On the other side, inbred lines Gm 1, Gm 4, Gm 10, Gm 11, Gm 12, Gm 13 and Gm 15, and tester SC 131 showed positive and highly significant general combining ability effects towards plant tallness.For ear height, the results showed that the best inbred lines were Gm 5, Gm 6, Gm 7, Gm 9 and Gm 16 and tester SCGm 1 for lower ear height.For grain yield (ard./fed), three inbred lines,Gm 12, Gm 13 and Gm 14 showed positive and significant or highly significant general combining ability effects, indicating that these inbred lines could be considered as the best general combining ability effects for increasing grain yield.

Estimates of SCA effects of 32 crosses for four traits across three locations are presented in Table 5.

Table 4. Estimates of general combining ability effects for 16 inbred lines and two testers for four traits across three locations.

Inbred line		Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard./fed)
Gm 1		0.247	9.792**	0.931	-0.142
Gm 2		-0.476	-2.319	-2.014	-0.150
Gm 3		1.080**	-1.875	1.764	1.083
Gm 4		0.802*	13.681**	9.931**	1.145
Gm 5		-1.087**	-22.042**	-14.347**	-1.909**
Gm 6		-0.865*	-7.931**	-9.903**	-1.585*
Gm 7		-1.142**	-19.097**	-12.625**	-0.728
Gm 8		1.913**	-0.764	-2.569	-3.146**
Gm 9		-0.142	-13.431**	-10.125**	-2.844**
Gm 10		0.024	20.347**	10.042**	1.295
Gm 11		0.080	6.458**	2.931	-2.181**
Gm 12		0.024	6.014**	6.153**	2.864**
Gm 13		-0.142	10.736**	10.375**	1.407*
Gm 14		0.413	3.403	6.653**	4.176**
Gm 15		0.135	6.403**	7.597**	0.294
Gm 16		-0.865*	-9.375**	-4.792	0.422
LSD g_i	5%	0.697	4.243	3.938	1.327
	1%	0.904	5.501	5.105	1.721
TesterSC 131		-0.101	3.472**	2.951**	0.247
TesterSC Gm 1		0.101	-3.472**	-2.951**	-0.247
LSD gi	5%	0.247	1.500	1.392	0.469
	1%	0.320	1.945	1.805	0.608

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

Table 5. Estimates of specific combining ability effects of 32 crosses for four traitsacross three locations.

Inbred line		Days to 50% Silking		Plant height (cm)		Ear height (cm)		Grain yield (ard./fed)	
		SC 131	SCGm1 GGGgGm	SC 131	SCGm1 GGGgGm	SC 131	SCGm1 GGGgGm	SC 131	SCGm1 GGGgGm
Gm 1		-0.288	0.288	3.083	-3.083	0.938	-0.938	1.485	-1.485
Gm 2		0.212	-0.212	2.861	-2.861	0.326	-0.326	-2.028	2.028
Gm 3		0.990*	-0.990*	0.639	-0.639	-0.118	0.118	-1.077	1.077
Gm 4		-1.066*	1.066*	-2.139	2.139	-2.618	2.618	0.926	-0.926
Gm 5		-0.177	0.177	4.028	-4.028	-2.118	2.118	-0.431	0.431
Gm 6		0.045	-0.045	-3.417	3.417	2.771	-2.771	-0.500	0.500
Gm 7		-0.344	0.344	-3.694	3.694	-1.174	1.174	-0.281	0.281
Gm 8		0.378	-0.378	5.306	-5.306	2.438	-2.438	-0.461	0.461
Gm 9		0.212	-0.212	-0.806	0.806	-0.451	0.451	1.973*	-1.973*
Gm 10		-0.177	0.177	-1.250	1.250	2.160	-2.160	1.187	-1.187
Gm 11		-0.233	0.233	-0.917	0.917	-0.285	0.285	2.765**	-2.765**
Gm 12		0.490	-0.490	-4.806	4.806	0.049	-0.049	-1.177	1.177
Gm 13		-1.233*	1.233*	-5.083	5.083	-7.285**	7.285**	-1.506	1.506
Gm 14		0.656	-0.656	0.917	-0.917	1.993	-1.993	-0.305	0.305
Gm 15		0.156	-0.156	5.361	-5.361	4.826	-4.826	1.511	-1.511
Gm 16		0.378	-0.378	-0.083	0.083	-1.451	1.451	-2.080	2.080
LSD s_{ij}	5%	0.99		6.00		5.57		1.88	
	1%	1.28		7.78		7.22		2.43	
LSD s_{ij}-s_{kL}	5%	1.39		8.49		7.88		2.65	
	1%	1.81		11.04		10.24		3.45	

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

For days to 50% silking, three crosses, Gm 4 x SC 131, Gm 13 x SC 131 and Gm 3 x SCGm1 exhibited desirable specific combining ability effects towards earliness. For plant height and ear height, the desirable crosses for SCA effects were Gm 13 x SC 131and Gm15 x SCGm1.For grain yield two crosses, Gm 9x SC 131 and Gm 11 x SC 131 exhibited desirable specific combining ability effects towards high grain yield.

Estimates of heterotic groups based on specific and general combining ability (HSGCA) effects for grain yield according to Fan *et al* (2009) is presents in Table 6. The inbred lines were divided into groups according to the following, step 1, place all the inbred lines in the same heterotic group as their tester, step 2, keep the inbred line with the heterotic group where its HSGCA effects had the smallest value (or largest negative value) and remove it from other heterotic group. Step 3, if the inbred line had positive HSGCA effects with all represented testers, it will be cautious to assign that line to any heterotic group because the line might belong to a heterotic group different from the testes used in the investigation.Hence for grain yield group 1 (tester SC131) included, Gm2, Gm5,Gm6,Gm7, Gm 8, Gm13 and Gm 16, while group 2 (tester SC Gm1) included, Gm1, Gm9, Gm11 and Gm 15. However the method was not able to classify the inbred linesGm3, Gm4, Gm10,Gm 12, and Gm14. Lee (1995)stated that a heterotic group is a collection of closely related inbred lines tend to result in vigorous hybrids when crossed with lines from a different heterotic group but, not when crossed to other lines of the same heterotic group.

Table 6. Estimates of heterotic groups using specific and general combining ability for grain yield.

Inbred	Grain yield	
Line	SC 131	SCGm1 GGGgGm
Gm 1	1.343	-1.627
Gm 2	-2.178	1.878
Gm 3	0.006	2.160
Gm 4	2.071	0.219
Gm 5	-2.340	-1.478
Gm 6	-2.085	-1.085
Gm 7	-1.009	-0.447
Gm 8	-3.607	-2.685
Gm 9	-0.871	-4.817
Gm 10	2.482	0.108
Gm 11	0.584	-4.946
Gm 12	1.687	4.041
Gm 13	-0.099	2.913
Gm 14	3.871	4.481
Gm 15	1.805	-1.217
Gm 16	-1.658	2.502

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القدرة على الائتلاف والمجاميع الهجينية لبعض سلالات الذرة الشامية الجديدة البيضاء

رفيق حليم عبد العزيز السباعي

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تهدف هذه الدراسة لتقدير القدرة على الائتلاف لـ 16 سلالة جديدة بيضاء من الذرة الشامية من خلال تصميم التزاوج السلالة x الكشاف. تم تقييم 32 هجين ثلاثي جديد ناتجة بطريقة التلقيح القمي بين 16 سلالة مرباة داخليا مع اثنين من الكشافات هما هـ.ف 131 و هـ.ف جميزة-1 بالاضافـة للهجين الثلاثى التجارى 321 في ثلاث محطات بحثية هم الجميزة وسخا وملوي موسم 2020. اشار تحليل التباين إلى وجود اختلافات معنوية بين السلالات والكشافات والتفاعل بينهما فى معظم الصفات تحت الدراسة. كانت تأثيرات الفعل الوراثى غير المضيف اكثر اهمية من تاثيرات الفعل الوراثى المضيف فى وراثة صفات تاريخ تزهير 50% من الحريرة ومحصول الحبوب بينما تاثيرات الفعل الوراثى المضيف اكثر اهمية فى وراثة صفتى ارتفاع النبات وارتفاع الكوز. كانت أفضل السلالات في القدرةالعامة على الائتلاف هي السلالات جميزة(5 و6 و7) لصفات التبكير و قصر ارتفاع النبات والكوز، والسلالات جميزة(12 و 13 و 14) لصفة محصول الحبوب.تفوق هجينين ثلاثيين هما (السلالة جميزة 14xهـ.ف جميزة 1) و (السلالة جميزة 4 x هـ.ف 131)على هجين المقارنة هـ.ث 321 (31.3 أردب/فدان), لذا سيتم تصعيدهما الى المرحلة التالية للتقييم على نطاق اوسع بالبرنامج القومى للذرة الشامية. تم تقسيم السلالات الى مجموعتين هجينيتين لصفة المحصول باستخدام طريقة HSGCA. اشتملت المجموعة الهجينية الاولى (هـ.ف 131) على السلالات جميزة (2, 5, 6, 7, 8, 13, 16) بينما اشتملت المجموعة الهجينية الثانية (هـ.ف جميزة 1) على السلالات جميزة (1, 9, 11, 15). هذه المجاميع تستخدم فى برامج التربية لاجل انتخاب افضل السلالات لعمل الهجن.