RESEARCH | Egyptian Journal of Agricultural Research | Field Crops

Combining ability, main performance, and superiority percentage of maize (*Zea mays* L.) inbred lines using line x testers analysis

Mohamed A.M. El Ghonemy, Hesham A. Aboyousef, Ahmed. M. Abu Shosha, Hautham M. EL-Shahed and Mohamed S. Shalof*

Address:

Maize Research Department, Field Crop Institute, Agricultural Research Center, Giza, Egypt

*Corresponding author: ***Abu Shosha, A. M.,*** e-mail: *ahmedabushosha5.5.5.i@gmail.com*

Received: 01-03-2023; **Accepted**: 21-08-2023; **Published:**21-08-2023 **DOI:** 10.21608/ejar.2023.196478.1375

ABSTRACT

Three field experiments were carried out during 2022 summer season at three diverse locations of Gemmeiza, Sakha and Mallawy Experimental Stations of Agricultural Research Center (ARC), Egypt. Thirty crosses (ten inbred lines crossed with three testers inbred line Sd. 7, Sk. 5 and SC 130) and four standard checks SC 10, SC 2031, TWC 321 and TWC 324 were evaluated for yield and yield related traits to evaluate using line × tester mating design. Analysis of variance revealed significant differences among genotypes for most traits indicating existence of variability among genotypes. Results showed that maternal parents play the most important role. The general combining ability effect showed that Gm. 1031, Gm.62 and Sk.5 are good combiners for earliest, shortened and lower ear placement. Four inbred lines (Gm. 267, Gm. 50, Gm.66 and Gm. 64) and testers Sk.5 were good general combiner for grain yield. The crosses (Gm. 62×Sc. 130), (Gm. 66× Sk.5) and (Gm. 64×sd. 7) had significant values of SCA for plant and ear height and the cross (Gm. 52 × SC. 130) had significant values of SCA for grain yield. Most of all crosses had better performance than check varieties for earliness, short plant and lower ear placement. The two crosses (Gm. 64×Sk.5) and (Gm. 64×SC. 130) were better than all check varieties for grain yield. For grain yield, the cross (Gm. 66×Sd. 7) had a significant superiority percentage over check (SC 2031) while the two crosses (Gm. 52×SC. 130) and (Gm. 64 × SC.130) had significant superiority percentages over checks (TWC321 and TWC324). Therefore, Identify superior crosses to improve the yielding ability in maize breeding programs.

Keywords: Maize, line × tester, general combining ability, specific combining ability.

INTRODUCTION

Following wheat and rice, maize (*Zea mays*, L.) is one of the world's most significant cereal crops. In many regions of the world, it is broadly applied for food, feed, fuel, and fiber. Because of its cross-pollinated nature, maize has a wide range of morphological variety and geographical adaptation. According to World Food and Agriculture [FAO] (2021), 2.8 million faddan produced 9.2 million tons. However, the local production of maize is sufficient for nearly 48:50 % of the consumption.

Maize is one of the most important crops in Egypt's agricultural and food economy. When compared to other cereals, it has the highest coverage of smallholder farmers and the highest production and consumption. Since 1952, researchers have worked to increase maize total productivity and production. Since 1970, various pest and disease-resistant open-pollinated and hybrid varieties have been created and released for different agroecology in Egypt by the Field Crops Research Institute, Maize Research Department, of Agricultural Research Center in partnership with regional research. However, overall yield produced and productivity improvements are far below maize's attainable potential in comparison to industrialized worlds. Small-scale farmers' slow adoption of new technology, scarcity of high-yielding varieties, and biotic and abiotic stresses (Worku *et al.,* 2002; Mosisa *et al.,* 2012) are the chief contributors to low yield. This issue can be addressed in part by generating high-yielding and stressed resistant types, which necessitate the identification of potential parents as well as their superior hybrid.

Hybrids are important for increasing maize yield and food security (Aslam *et al.,* 2017; Karim *et al.,* 2018). The production of hybrid maize varieties necessitates the identification of appropriate parents (inbred lines), which is the secret to hybrid maize effectiveness. Identification of high-yielding hybrids necessitates research and careful parent selection based on combining ability and genetic structure (Hallauer and Miranda 1988; Ceyhan 2003; Karim *et al.,* 2018). Newly produced inbred lines must be crossed with testers (inbred lines, single crosses, and open-pollinated varieties), and the performance of their hybrids can be measured. The merging ability of lines in hybrid combinations and their crossings is used to evaluate their performance. The ability of an inbred to transfer desired performance to its hybrid offspring is referred to as combining ability. Combining ability analysis is a useful genetic method for estimating parents' general combining ability (GCA) and crosses' specialised combining ability (SCA) and facilitating the selection of desirable parents and crosses (Griffing, 1956; Aliu *et al.,* 2008; Ahmed *et al.,* 2017) established that GCA is the average performance of a parent in a series of hybrid combinations, whilst SCA is the difference in performance of particular hybrid combinations in comparison to what would be expected based on the GCA. GCA represents additive gene effects, whereas SCA represents non-additive gene activities (Sprague and Tatum, 1942). A few novel inbred lines must be produced and tested for hybridization. Information and expertise on combining abilities are critical for the development of hybrid varieties. The purpose of this study was to find suitable inbred lines with good overall combining ability and single or three-way crossings with good specialized combining ability.

MATERIALS AND METHODS

Genetic materials:

Ten new inbreed lines were crossed with three testers (inbred line Sd 7, inbred line Sk.5 and Single Cross 130) will generate 30 crosses at Gemmeiza Research Station in the summer of 2021 using a Line by Tester mating design. Thirty crosses and four standard cheeks (SC 10, SC 2031, TWC 321 and TWC 324) were tested in Randomized Complete Block Design with three replications at three locations (Gemmeiza, Sakha and Mallawy) in 2022 in main cropping season. Initially, testers for crossing were created by Maize Research Department, Field Crop Institute, Agricultural Research Center, Egypt. Name and origin of the ten white maize inbred lines and three testers used in this study is presented in **Table (1).**

Table 1. Name and origin of the ten white maize inbred lines and three testers.

No.	Origen	Code	No.	Origen	Code
1	Gm.267	L_1	8	Gm.66	L_8
2	Gm.462	L_2	9	Gm.64	L_9
3	Gm.1031	L_3	10	Gm.72	L_{10}
4	Gm.50	L_4	11	Sd 7	T_1
5	Gm.52	L_5	12	Sk 5	T_2
6	Gm.55	L_6	13	SC 130	T_3
7	Gm.62	L_7			

Trail management:

Each cross was planted in a single row 6m long with 80 cm between rows and 25 cm between plants. Managements of fertilization and crop treatments were performed based on expectations of high yield. The fertilizer was applied at planting using 30 kg of P_2O_5 and 24 kg of K_2O per feddan. Also the nitrogen fertilizer was applied at the rate of 120 kg N/fed splitted into two equal doses and was added before the first and second irrigation in urea form (46.5%). The remaining agronomic practices were performed based on their recommendation.

Data collection and analysis:

Data for days to 50% silking, plant height and ear height (cm), and grain yield (ard./fed.) adjusted to 15% moisture were collected on five randomly selected plants on a plot basis. All suggested cultural practices for maize production were implemented at the appropriate time. Agrobase 21 software was used to analyze variance in all data collected. On a plot basis, data for days to 50% silking, plant height and ear height (cm), and grain yield (ard./fed.) adjusted to 15% moisture were collected on five randomly selected plants. All cultural practises for maize production that were advised were adopted at the proper time. The Agrobase 21 programme was used to perform variance analysis on all data gathered. The mean squares from the line x tester mating design, as well as the general GCA and special (SCA) combing ability effects, were estimated using Kempthorne's (1957) methodology, which Singh and Choudhry followed (1979). The F test was used to determine the relevance of the GCA and SCA effects. When the homogeneity test was calculated using snedecer on cochran, a combined analysis of variance across three locations was done (1967).

RESULTS

Analysis of variance:

Variance Analysis in Table 1 shows the combined analysis of variance of line x tester mating design for all analyzed variables across three locations (2). Significant changes were seen across the three locations due to variances in environmental variables and soil conditions, demonstrating that all of the analyzed features were influenced by environmental conditions prevalent in the two locations. Genetic variation was shown to be highly significant across inbred lines, testers, and lines x testers for all traits except lines x tester mean squares for days to 50% silking. Cro. x Loc., L x Loc., and L x T x Loc. were likewise extremely significant for all traits except days to 50% silking. Except for days to 50% silking and ear height, Testers x Loc. were very significant for grain yield and plant height.

The significance of 2GCA and 2SCA effects revealed the presence of both additive and non-additive gene effects for most traits. Table 2 revealed that 2 GCA-L was greater than 2 GCA-T for the examined traits, implying that the majority of GCA variance was related to inbred lines for these traits. On the other hand, the data showed that 2 SCA was greater than 2 GCA for all the examined parameters except grain yield. The non-additive gene effects were the more important component in determining the inheritance of all assessed traits.

Table 2. Analysis of variance and Mean squares for grain yield and yield-related parameters in maize (*Zea mays* L).

S. O. V	Df	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard./fed.)
Location (Loc.}	2	1326.470**	54187.544**	25616.744**	1019.764**
Rep/Loc.	6	14.626	186.485	203.552	20.457
Crosses	29	23.492**	790.469**	403.681**	148.607**
Line (L.)	9	53.722**	1196.621**	566.100**	158.764**
Tester (T.)	2	22.504**	3284.133**	1272.178**	33.91*
L. x T.	18	8.487	310.319**	225.972**	156.272**
Crosses/Loc.	58	3.585	268.770**	157.200**	67.169**
L. X Loc.	18	4.726	319.841**	260.193**	83.922**
T. X Loc.	4	4.104	330.428**	146.389	80.875**
L. x T. x Loc.	36	2.958	236.385**	106.905*	57.269**
Error	174	3.281	89.489	66.655	8.716
CV %		1.4	1.9	3.2	5.3
δ^2 GCA (average)		0.48	31.48	10.20	-1.45
δ^2SCA		0.61	8.21	13.23	11.00
δ2 GCA-L		1.61	29.74	6.92	-0.89
δ2 GCA-T.		0.14	32.00	11.19	-1.62
δ^2 GCAL x Loc.		0.20	9.27	17.03	2.96
δ^2 GCAT x Loc.		0.04	3.13	1.32	0.79
δ2 GCA x Loc.		0.07	4.55	4.94	1.29
δ2 SCA x Loc.		-0.11	48.97	13.42	16.18

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

The proportional contribution of lines, testers and their interaction to total variance:

The proportionate contributions of female lines, male testers, and their interactions (crosses) to overall variance for certain qualities Table 3 over locations revealed that female lines' (maternal) contribution was higher compared to male lines' (paternal) contribution and interaction due to line tester in days to 50% silking, plant height, and ear height. while line and tester contributions were higher compared to lines (female) and testers (male) for grain yield. According to the findings, maternal parents play the most crucial role. More initiatives should involve maternal parents to improve new hybrids. These findings could be explained by the general combining ability of cytoplasmic genes.

Table 3. Proportional contribution of lines, testers and their interactions to total variance.

Sours	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (ard./fed.)
Due to line	71.0	47.0	43.5	33.2
Due to tester	6.6	28.7	21.7	1.6
Due to line x tester	22.4	24.4	34.7	65.3

Mean performance and combining ability

Days to 50% silking date:

Mean performance of the thirty top-crosses and four check hybrids SC.10, SC. 2031, TWC 321 and TWC 324 For days to 50% silking, as presented in Table (4), the seventeen crosses showed significantly earlier silking than both checks SC 10 and SC 2031; these crosses ranged from 60 to 64.3 days, while the two check hybrids recorded SC 10 and SC 2031 recorded 66.5 and 67.17 days, respectively. Six three-way crosses: Gm. 267 SC. 130, Gm. 1031 SC. 130, Gm. 55 SC. 130, Gm. 62 SC. 130, Gm. 66 SC. 130, and Gm. 64 SC. 130 showed significantly higher earliness compared to the checks TWC 321 and TWC 324.

Table 4. Mean performance and combining ability effects for days to 50% silking.

Lines	Means			GCA effects	SCA effects		
	Sd. 7	Sk. 5	SC 130	Lines	Sd. 7	Sk. 5	SC 130
Gm.267	65.2	62.9	63.3	0.652**	1.01	-0.36	-0.65
Gm.462	64.2	64.3	64.7	1.244**	-0.58	0.49	0.09
Gm.1031	62.2	61.8	60.4	-1.681**	0.35	0.86	-1.21*
Gm.50	63.3	63.8	64.6	0.726**	-0.95	0.45	0.50
Gm.52	65.3	63.8	64.6	1.393**	0.39	-0.21	-0.17
Gm.55	63.3	63.6	62.7	0.022	-0.24	0.93	-0.69
Gm.62	60.7	60.0	60.4	-2.793**	-0.10	0.19	-0.10
Gm.66	63.2	61.3	63.6	-0.459**	0.13	-0.81	0.68
Gm.64	61.9	62.6	63.2	-0.607**	-1.06	0.56	0.50
Gm.72	66.1	62.0	65.9	1.504**	1.05	-2.10**	1.05
	SC 10	66.50		LSD g_i 5% 0.219	LSD s_{ij}	5%	1.202
	SC 2031	67.17		LSD g_i 1% 0.284	LSD s_{ij}	1%	1.558
	TWC 321	65.33		LSD g_i-g_j 5% 0.310	LSD s_{ij}-s_{ki}	5%	1.699
	TWC 324	67.00					
	LSD 5%	1.7		LSD g_i-g_j 1% 0.402	LSD s_{ij}-s_{ki}	1%	2.203
				Testers			
				Sd 7 0.393**			
				Sk 5 -0.563**			
				SC 130 0.170			
				LSD g_i 5% 0.380			
				LSD g_i 1% 0.493			
				LSD g_i-g_j 5% 0.537			
				LSD g_i-g_j 1% 0.697			

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

Estimates of general combining ability effects (GCA) of ten inbred lines for Days to 50% Silking date, Table (4) shows how three places were united. The greatest inbred lines for general ability combining effects (GCA)were Gm.1031, Gm. 62, Gm.66, Gm. 64 and Sk.5 for earliness, while, the best tester for this trait was Sk,5.

Specific combining ability (SCA) effects of thirty top crosses for days to 50% silking combined over the three locations are presented in Table (4). Two crosses (Gm. 1031 ×SC. 130 and Gm. 72 ×Sk. 5) showed desirable negative significant and highly significant SCA for days to 50% silking towards earliness, the cross (Gm. 72 ×Sk. 5) was the best one for SCA effects.

Plant height (cm):

The mean performance of crosses revealed the differences between plant height for crosses and four checks in Table (5). Regarding the plant height, the values of 20 single crosses ranged from 234.33 to 260.44 cm, while the values for check single crosses SC 10 and SC 2031 recorded 289.67 and 285.67 cm, respectively. On the other side, ten three-way crosses ranged from 224.11 to 252.22 cm, compared to checks three-way crosses 321 and 324 (272.67 and 263.33 cm).

GCA information is critical for selecting desirable parents and crosses. Table (5). Gm.1031, Gm.62, Gm.64, and Sk. 5 inbred lines produced negative GCA effects for plant height, indicating that these lines can be used to develop shorter hybrids to reduce yield loss due to root and stem lodging. Sk5 was the best GCA tester for plant height.

Table 5. Mean performance and combining ability effects for plant height (cm).

Lines	Means			GCA effects			SCA effects		
	Sd. 7	**Sk. 5**	**SC 130**	**Lines**			**Sd. 7**	**Sk. 5**	**SC 130**
Gm.267	255.22	250.44	239.22	3.552**			0.41	7.57*	-7.99**
Gm.462	259.00	245.89	252.22	7.626**			0.12	-1.06	0.94
Gm.1031	239.89	226.56	231.11	-12.226**			0.86	-0.54	-0.32
Gm.50	254.67	240.22	249.56	3.404**			0.01	-2.50	2.50
Gm.52	260.44	240.89	249.89	5.663**			3.53	-4.10	0.57
Gm.55	251.33	243.00	249.22	3.107**			-3.03	0.57	2.46
Gm.62	249.11	235.11	224.11	-8.633**			6.49*	4.42	-10.91**
Gm.66	257.11	236.44	252.00	3.774**			2.08	-6.65*	4.57
Gm.64	234.33	236.56	245.22	-6.041**			-10.88**	3.27	7.61*
Gm.72	251.44	238.11	244.00	-0.226			0.41	-0.99	0.57
	SC 10	289.67		LSD g_i	5%	1.146	LSD s_{ij}	5%	6.275
	SC 2031	285.67			1%	1.485		1%	8.135
	TWC 321	272.67		LSD g_i-g_j	5%	1.620	LSD s_{ij}-s_{ki}	5%	8.874
	TWC 324	263.33			1%	2.101		1%	11.505
	LSD 5%	8.87							
				Testers					
				Sd 7		6.511**			
				Sk 5		-5.422**			
				SC 130		-1.089			
				LSD gi	5%	1.984			
					1%	2.573			
				LSD gi-gj	5%	2.806			
					1%	3.638			

*, ** Indicating significance at 0.05 and 0.01 levels of probability, respectively

SCA effect analysis revealed that four crosses (Gm. 64 ×Sd.7, Gm. 66×Sk. 5, Gm. 267 ×SC.130 and Gm. 62×SC.130) had significant negative SCA effects for plant height indicating that these crosses are the best combinations for shortness. Table (5). showed SCA significant with negative values of effects for plant height, it could be used in the maize hybrid program.

Ear height (cm):

Data in Table (6) exhibited that, all crosses had lower ear placement compared to all checks, except the cross Gm. 52 x Sd.7.

estimates of GCA impacts for the ten maize inbred lines and three testers across three locations table (6). The results showed that four inbred lines, Gm. 1031, Gm.62, Gm.72, and Sk. 5, had negative and substantial GCA effects for ear height toward lower ear placement, indicating that parental inbred lines could be good general combiners for lower ear placement. Sk 5 showed both negative and desirable significance for this feature.

Table 6. Mean performance and combining ability effects for ear height (cm).

Lines	Means			GCA effects	SCA effects		
	Sd. 7	Sk. 5	SC 130	Lines	Sd. 7	Sk. 5	SC 130
Gm.267	132.44	135.56	127.78	3.459**	-2.59	7.81**	-5.21
Gm.462	133.22	124.33	133.22	1.793**	-0.15	-1.75	1.90
Gm.1031	124.22	117.11	118.56	-8.504**	1.15	1.33	-2.47
Gm.50	137.67	124.89	131.11	2.756**	3.33	-2.16	-1.18
Gm.52	141.44	128.22	136.11	6.793**	3.07	-2.86	-0.21
Gm.55	135.00	119.00	131.11	-0.096	3.52	-5.19	1.67
Gm.62	130.11	124.22	117.22	-4.615**	3.15	4.55	-7.70**
Gm.66	133.33	121.33	138.78	2.681**	-0.93	-5.64*	6.56**
Gm.64	124.44	128.00	133.22	0.089	-7.22**	3.62	3.60
Gm.72	123.89	120.22	128.22	-4.356**	-3.33	0.29	3.04

Checks	Means	GCA LSD			SCA LSD		
SC 10	158.50	LSD g_i	5%	0.989	LSD s_{ij}	5%	5.42
SC 2031	149.83		1%	1.282		1%	7.02
TWC 321	151.67	LSD g_i-g_j	5%	1.398	LSD s_{ij}-s_{ki}	5%	7.66
TWC 324	148.50						
LSD 5%	7.66		1%	1.813		1%	9.93

Testers		
Sd 7		3.111**
Sk 5		-4.178**
SC 130		1.067
LSD g_i	5%	1.713
	1%	2.220
LSD g_i-g_j	5%	2.422
	1%	3.140

*, ** Indicating significance at 0.05 and 0.01 levels of probability, respectively

SCA effects of the thirty top crosses for ear height over the three locations are presented in Table (6). The desirable SCA effects were obtained by three crosses (Gm. 64 ×Sd7, Gm. 66×Sk.5 and Gm. 62×SC 130) had significant negative SCA effects for ear height indicating that these crosses are the best combinations for lower ear placement.

Grain yield

The mean performance of the thirty top-crosses and four check hybrids SC.10, SC. 2031, TWC 321 and TWC 324 for all the studied traits over the three locations is shown in Table (7). Based on the combined analysis of the top crosses for grain yield, two single crosses, Gm. 66 Sd. 7 and Gm. 64 Sk. 5, exhibited significantly increased values compared to standard check SC 2031, followed by two three-way crosses, Gm. 52 SC. 130 and Gm. 64 130, which produced the highest grain yield over standard check TWC 321.

Table 7. Mean performance and combining ability effects for grain yield (ard. fed).

Lines	Means			GCA effects	SCA effects		
	Sd. 7	Sk. 5	SC 130	Lines	Sd. 7	Sk. 5	SC 130
Gm.267	29.677	31.719	24.584	0.948**	0.46	3.72**	-4.17**
Gm.462	28.704	31.822	23.070	0.153	0.28	4.61**	-4.89**
Gm.1031	26.741	25.491	21.923	-2.994**	1.46	1.43	-2.89**
Gm.50	29.528	29.455	27.381	1.076**	0.18	1.32	-1.50
Gm.52	27.235	21.419	33.947	-0.178	-0.86	-5.46**	6.32**
Gm.55	29.414	22.849	31.338	0.155	0.99	-4.36**	3.38**
Gm.62	30.518	23.736	24.649	-1.411**	3.66**	-1.91	-1.75
Gm.66	33.508	26.238	32.810	3.140**	2.10*	-3.96**	1.86
Gm.64	25.049	33.037	35.255	3.402**	-6.62**	2.58**	4.04**
Gm.72	22.348	24.792	23.125	-4.290**	-1.63	2.03*	-0.39

Checks	Means
SC10	31.20
SC2031	30.29
TWC321	30.35
TWC324	28.83
LSD 5%	2.769

GCA Lines LSD		
LSD g_i	5%	0.358
	1%	0.464
LSD g_i-g_j	5%	0.506
	1%	0.656

SCA LSD		
LSD S_{ij}	5%	1.96
	1%	2.54
LSD S_{ij}-S_{ki}	5%	2.77
	1%	3.59

Testers		
Sd 7		0.560
Sk 5		-0.656*
SC 130		0.096
LSD g_i	5%	0.619
	1%	0.803
LSD g_i-g_j	5%	0.876
	1%	1.135

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

Concerning of GCA effects for the ten maize inbred lines and the three testers over three locations are presented in Table (7). Results showed that four inbred lines Gm.267, Gm.50, Gm. 66 and Gm. 64 had significant positive GCA for grain yield. In the maize breeding programme, these lines could be employed as good combiners to develop new high-yielding crosses. It is worth mentioning that the inbred line with high GCA effects for grain yield had a desirable effect for one or more of the grain yield related characteristics.

The effects of specific combining ability. The thirty top crosses for all of the studied traits over the three locations are presented in Table (7). The desirable SCA effects were obtained by the crosses Gm. 62 ×Sd. 7, Gm. 66×Sd.7, Gm. 267×Sk.5, Gm. 462 ×Sk. 5, Gm. 64×Sk. 5, Gm. 72 ×Sk. 5, Gm. 52 ×SC. 130, Gm. 55 ×SC. 130 and Gm. 64 ×SC 130 respectively, for grain yield where they had the highest positive values of SCA for yield and its main components.

The Superiority percentage:

Superiority percentages related to the four checks SC 10, SC 2031, TWC 321 and TWC324 for the 30 F_1 crosses at combined data over locations are presented in Table (8). Results revealed that the cross Gm. 66 ×Sd.7 had the highest significant and positive superiority percentages over checks SC 10. The two three-way crosses (Gm. 52 ×SC 130 and Gm. 64 ×SC.130) had the highest significant and positive superiority percentages over check variety TWC 321 and 324, while the Cross Gm. 66 ×SC 130 had significant and positive superiority percentages over check TWC 324. Similarly, inbreeding depression is caused by the homozygosity of recessive alleles, which has negative consequences Kuselan *et al.* (2017).

Table 8. Superiority percentages of the 20 F_1 single crosses relative to checks SC 10, SC 2031 and ten three way crosses relative to checks TWC 321 and TWC 324 for grain yield.

Crosses	SC 10	SC 2031	Crosses	TWC 321	TWC 324
Gm.267 x Sd 7	-4.88	-2.02	Gm.267 x SC 130	-19.00	-17.59
Gm.267 x Sk. 5	1.66	4.72	Gm.462 x SC 130	-23.99	-22.66
Gm.462 x Sd 7	-8.00	-5.24	Gm.1031 x SC 130	-27.76	-26.51
Gm.462 x Sk. 5	1.99	5.06	Gm.50 x SC 130	-9.78	-8.21
Gm.1031 x Sd 7	-14.29	-11.72	Gm.52 x SC 130	11.85**	13.80**
Gm.1031 x Sk. 5	-18.29	-15.85	Gm.55 x SC 130	3.26	5.06
Gm.50 x Sd 7	-5.36	-2.52	Gm.62 x SC 130	-18.78	-17.37
Gm.50 x Sk. 5	-5.59	-2.76	Gm.66 x SC 130	8.10	9.99*
Gm.52 x Sd 7	-12.71	-10.09	Gm.64 x SC 130	16.16**	18.19**
Gm.52 x Sk. 5	-31.34	-29.29	Gm.72 x SC 130	-23.80	-22.48
Gm.55 x Sd 7	-5.72	-2.89	LSD. 5%	9.12	9.60
Gm.55 x Sk. 5	-26.76	-24.57	LSD. 1%	11.83	12.46
Gm.62 x Sd 7	-2.19	0.75			
Gm.62 x Sk. 5	-23.92	-21.64			
Gm.66 x Sd 7	7.39	10.62*			
Gm.66 x Sk. 5	-15.90	-13.38			
Gm.64 x Sd 7	-19.71	-17.30			
Gm.64 x Sk. 5	5.88	9.07			
Gm.72 x Sd 7	-28.36	-26.22			
Gm.72 x Sk. 5	-20.53	-18.15			
LSD. 5%	8.87	9.14			
LSD. 1%	11.51	11.86			

DISCUSSION

Analysis of Variance:

Variance Analysis The combined analysis of variance of line x tester mating design was reported for all studied variables across three sites. The genetic variation was found to be very significant among inbred lines for all qualities except the interaction variance of L x T were significant or highly significant for traits except days to 50% silking, also Cro. x Loc.,L x Loc. and L x T x Loc. were highly significant for all traits except days to 50% silking. Testers x Loc. were highly significant for grain yield and plant height except for days to 50% silking and ear height. These findings are consistent with those published by other writers, among them (Ahmed et al., (2017), Kamara *et al.,* (2014), Darshan and Marker (2019), and Mohamed *et al.,* (2020). The magnitude of σ2 SCA x Loc interaction was higher than σ2 GCA x Loc for all traits, except days to 50% silking indicating that the non-additive gene effects have interacted more with locations than additive gene effects for these traits, Mostafa *et al.,* (2013) for number days to 50% silking, Mosa (2004) and Motawei *et al.,* (2019) for plant height, Amer (2004) El-Gazzar and Khalil (2012) and El-Gazzar (2015) for ear height, Mostafa *et al.,* (2013) and El-Gazzar (2015) for grain yield.

According to the findings, maternal parents perform the most crucial role. More initiatives should involve maternal parents to improve new hybrids. These findings could be explained by the general combining ability expression of cytoplasmic genes. According to research, the proportionate contributions of line, tester, and line tester fluctuate for different traits in the inheritance of days to 50% silking, plant and ear heights, and grain yield. These results support the findings of Vasal *et al.,* (1992), Ibrahim *et al.,* (2007) and Mosa *et al*.(2008) for a number of days to 50% silking, Aboyousef *et al.,* (2016) for plant height, Attia *et al* (2015), EL-Hosary and Elgammaal (2013) for ear height and Alsebaey *et al.(*2021) for grain yield.

Mean performance:

Two factors are considered important, the first factors are the evaluation of an inbred line in the production of hybrid maize the second study of the line itself and behavior of the line in a particular hybrid combination. The mean performance of the thirty top-crosses and four check hybrids SC.10, SC. 2031, TWC 321 and TWC 324 For days to 50% silking, all crosses were significantly earlier (60 to 64.3 days) than the check hybrids SC.10, SC. 2031 (66.5 and 67.17 days), while six crosses showed significantly higher earliness than both checks TWC 321 and TWC 324 for all crosses were significantly earlier (62.7 to 63.6 days) than the check hybrids TWC 321and TWC 324 (65.33 and 67.00 days). The combining ability of maize inbred lines and concluded that the crosses outperformed the best standard check was investigated (Natol, 2017; Abebe *et al.,* 2018).

In the present study regarding the plant height, crosses ranged from 234.33 to 260.44 cm compared to crosses SC 10 and SC 2031 (289.67 and 285.67 cm), crosses ranged from 224.11 to 252.22 cm compared to crosses three way crosses 321 and 324 (272.67 and 263.33 cm). These findings are consistent with those published by numerous authors, including Matin *et al.,* (2016), Abebe *et al.,* (2018), and Alsebaey *et al.,* (2021), who evaluated the combining ability of maize inbred lines and found that the crosses outperformed the best standard check-in Plant height.

On the other hand the lowest ear height of the four cultivar checks were observed in all crosses under the environments had significantly lower ear placement compared with the lower check hybrids SC 10 and SC 2031, TWC 321 and 324 (158.50 cm, 149.83 cm, 151.67 cm and 148.50 cm) respectively and the top crosses ranged from 117.11 cm for top cross Gm.1031×Sk.5 to 141.44 cm for top cross Gm.52×Sd.7. Maize plant shortness reduces lodging percentage and consequently increases yield potential (EL-Hosary and Elgammaal, 2013).

Thus, our finding suggests Grain yield (ard/fed) ranged from 21.41 (ard/fed) for top cross Gm.52 x SK.5 to 33.50 (ard/fed) for top cross Gm.66 x Sd.7 compared to standard check SC 2031 to 30.29 (ard/fed). Four top crosses Gm.52 x SC.130, Gm.55 x SC.130, Gm.66 x SC.130 and Gm.64 x SC.130 were values (33.94, 31.33, 32.81 and 35.25 ard/fed) were significantly outyielded the check hybrid TWC324 (28.83 ard/fed). In general, the above four crossings had the best values for most yield components, implying that they could be used as good hybrids in maize breeding efforts. It is possible to deduce that these crosses may be useful for increasing maize grain production. Similar results were reported by Shah *et al.,* (2015), Matin *et al.,* (2016) and Abu shosha *et al.,* (2020).

General combining ability effects:

Analyses of general combining ability impacts (GCA) for the 10 inbred lines aggregated across three locations for Days to 50% Silking date are shown in. For earliness, the best inbred lines for general combining ability effects (GCA) were Inbred lines Gm.1031, Gm.62, Gm.66, Gm.64, and Sk.5.

Inbred lines Gm.1031, Gm.62, Gm. 64 and Sk. 5 produced negative GCA effects for plant height, indicating that these lines can be used to develop shorter hybrids to reduce yield loss due to root and stem lodging. Sk5 was the best GCA tester for plant height. Several researchers, including Aly (2013), Motawei *et al.,* (2019), and Mohamed (2020), have reported the superiority of the single cross as a suitable tester. The inbred lines mentioned above can be utilised in maize breeding programmes to improve these traits.

Four inbred lines Gm. 1031, Gm.62, Gm.72 and Sk. 5 possessed negative and significant GCA effects for ear height toward lower ear placement, indicating that parental inbred lines could be considered as a good general combiner for lower ear placement.

The capacity of available genotypes to combine is critical for establishing an effective hybrid programme through the identification of excellent parents. The line tester technique aids the breeder in classifying and selecting parent genotypes based on their probable performance in hybrid combinations. For grain yield, the general combining ability impacts were positive and substantial for four inbred lines, Gm.267, Gm.50, Gm.66, and Gm.64. In the maize breeding programme, these lines could be employed as good combiners to develop new high yielding crosses. It is worth mentioning that the inbred line with high GCA effects for grain yield had a desirable effect for one or more of the grain yield contributing characteristics. Meanwhile, the inbred lines with appropriate GCA effects for grain yield are possible to successfully contribute favorable alleles in a breeding program and could be useful as parents in constituting synthetic populations suitable to be improved for high production yield. These findings are consistent with those obtained by Shah *et al.,* (2015), Matin *et al.,* (2016) and Abdel-Moneam, *et al.,* (2020).

Specific combining ability effects:

Two crosses (Gm. 1031 SC. 130 and Gm. 72 Sk. 5) demonstrated desirable negative significant and extremely significant SCA for days to 50% silking towards earliness, with the cross (Gm. 72 Sk. 5) being the best for earliness. This indicates that these crosses are the best for earliness. Four crosses (Gm. 64 ×Sd.7, Gm. 66×Sk. 5, Gm. 267 ×SC.130 and Gm. 62×SC.130) had significant negative SCA effects for plant height indicating that these crosses are the best combinations for shortness. Showed SCA significance with negative values of effects for plant height, it could be used in the maize hybrid program. The desirable SCA effects for ear height were obtained by three crosses (Gm. 64 ×Sd7, Gm. 66×Sk.5 and Gm. 62×SC 130) had significant negative SCA effects for ear height indicating that these crosses are the best combinations for lower ear placement. This discovery is consistent with the outcome reported by Chemada *et al.,* (2015), Ahmed *et al.,* (2017), Natol (2017) Abebe *et* *al.,* (2018),and Alsebaey *et al.,* (2021) who reported both positive and negative significant SCA for Silking date, Plant height and ear height.

The desirable SCA effects were obtained by the crosses Gm. 62 ×Sd. 7, Gm. 66×Sd.7, Gm. 267×Sk.5, Gm. 462 ×Sk. 5, Gm. 64×Sk. 5, Gm. 72 ×Sk. 5, Gm. 52 ×SC. 130, Gm. 55 ×SC. 130 and Gm. 64 ×SC 130 respectively, for grain yield where they had the highest positive values of SCA for yield and its main components. These top crossings may be of interest in breeding programmes because they all had at least one good combiner for the traits in question. This discovery is consistent with the outcome reported by These top crossings may be of interest in breeding programmes because they all had at least one good combiner for the traits in question. This discovery is consistent with the outcome reported by Shah *et al.,* (2015) and Matin *et al.,* (2016).

The best combiner tester for beneficial GCA effects was SK.5 for days to 50% silking, plant and ear heights, which had negative and significant GCA values for these traits. The SC130 tester for grin yield (ard/fed) had positive and significant GCA effects for these traits. Single crosses were found to be preferable as good testers (Mosa 2010; Aly, 2013).

CONCLUSION

The general combining ability effect showed that three inbred lines, Gm. 1031, Gm. 62, and Sk. 5, had good combiners for earliest, shortened, and lower ear placement. Four inbred lines (Gm. 267, Gm. 50, Gm. 66, and Gm. 64) and Sk. 5 were good general combiners for grain yield. The three crosses (Gm. 62 SC. 130), (Gm. 66 Sk. 5), and (Gm. 64 Sd. 7) had significant values of SCA for plant and ear height, and (Gm. 52 SC. 130) had significant values of SCA for grain yield. Most of all crosses had better-than-check varieties for earliness, shortening, and lower ear placement. The two crosses (Gm. 64 Sk. 5) and (Gm. 64 SC. 130) were better than all check varieties for grain yield. Therefore, identify superior crosses to improve the yielding ability of maize breeding programs.

REFERENCES

Abdel–Moneam, M. A., Sultan, M.S., Abido, ÁgnesHadházy, W. A. E., Sadek, S. E., & Shalof, M. S. (2020). Investigation of combining ability and superiority percentages for yield and some related traits in yellow maize using line × tester analysis. *ACTA Agraria Debreceniensis* 1, 5-14.

Abebe, A., Wolde, L., & Gebreselassie, W. (2018). Combining ability and heterosis of maize inbred lines.

Aboyousef, H.A., Gamea, H.A.A., & Moshera, S.E. Sadek (2016). Evaluation of some new white maize top crosses for yield and some other traits. *Alexandria Journal Agriculture Science,* 61, (4) 409-418.

Abu shosha, A.M., El-Shahed, H.M., & Darwich, M.M.B. (2020). Utilization of line x tester analysis for estimating combining ability for some new yellow maize inbred lines. *Egypt Journal Plant Breed*. 24(3), 535 -547.

Agrobase 21 (2001). Agronomix Software, Inc. 171 Waterloo Street Winnipeg, Manitoba, Canada R3N OS_4 ,www. Agronomix.mb.ca.

Ahmed, S., Begum, S., Islam, A., Ratna, M., & Karim, R. (2017). Combining ability estimates in maize (*Zea Mays* L.) through line x tester analysis. *Bangladesh Journal of Agriculture Research*, 42(3), 425 436.

Aliu, S., Fetahu, S., & Salillari, A. (2008). Estimation of heterosis and combining ability in maize (*Zea Mays* l.) for ear weight (ew) using the diallel crossing method. *Latvian Journal of Agronomy*, 11(1), 7–12.

Alsebaey, R.H.A., Abu Shosha, A.M., El-Shahed, H.M., & Darwich, M.M. B. (2021). Evaluation Of Some New Yellow Three-Way Crosses Of Maize Derived Via Line × Tester Mating Method Under Conditions Of Two Locations. *Egyptian Journal Plant Breeding*. 25(1), 70 -83.

Aly RSH (2013) Relationship between combining ability of grain yield and yield components for some newly yellow maize inbred lines via line × tester analysis. *Alexandria Journal Agriculture Research* 58(2), 115-124.

Amer, E.A. (2004). Combining ability of new white inbred lines of maize with three testers tested over two locations. *Annals of Agricultural Sciences Moshtohor,* Vol. 42(2), 461-474.

Aslam, M., Sohail, Q., Maqbool, M.A., Ahmad, S., & Shahzad, R. (2017). Combining ability analysis for yield traits in diallel crosses of maize. *Journal of Animal and Plant Sciences*, 27(1), 136–143.

Attia, A.N., Sultan, M.S., Badawi, M.A., Abdel-Moneam, M.A., & Rawi, A.R.M. Al- (2015). Estimation of combining ability and heterosis for some maize inbred lines and its single crosses. *Journal Plant Production*, Mansoura University, 6 (1), 83-99.

Ceyhan, E. (2003). Determination of some agricultural characters and their heredity through line x tester method in pea parents and crosses. *Selcuk University Graduate School of Natural and Applied Science*, 10 (2), 130.

Chemada, G., Alamerew, S., Tadesse, B., & Menamo, T. (2015). Test cross performance and combining ability of maize (Zea mays L.) inbred lines at Bako, Western Ethiopia. *Global Journal of Science Frontier Research*, 15(6), 1–24.

Darshan, S. S., & Marker, S. (2019). Heterosis and combining ability for grain yield and its component characters in quality protein maize (*Zea mays* L.) hybrids. *Electronic Journal of Plant Breeding*, 10(1), 111-118

El-Gazzar, I.A.I. (2015). Combining ability for growth, yield and yield its attributes and resistance to downy mildew disease in maize. *Journal Agricultural Research Kafr El- Sheikh University*, 41(2), 477-487.

El-Gazzar, I.A.I., & Khalil, M.A.G. (2012). Combining ability analysis of new yellow inbred lines using line x tester analysis. *Journal Agricultural Research Kafr El- Sheikh University*, 38(3), 390-400.

EL-Hosary A.A., & Elgammaal, A.A. (2013). Utilization of line×tester model for evaluating the combining ability of some new white maize inbred lines. *Egyptian Journal of Plant Breeding*, 17(1), 79-72.

Griffing, B. (1956). Concept of general combining ability and specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Sciences*, 9, 463–493.

Hallauer, A. R., & Miranda, *JOURNAL* B. (1988). Quantitative genetics in maize breeding (2nd ed.). *Ames: Iowa State University Press.*

Ibrahim, M. H. A., Osman, M.M.A., & El- Ghonemy, M.A. (2007). Combining ability of new yellow maize inbred lines under two different locations. *Minufiya Journal Agricultural Research*. 32 (1), 185 – 201.

Kamara, M. M., El-Degwy, I. S., & Koyama, H. (2014). Estimation of combining ability of some maize inbred lines using line × tester mating design under two nitrogen levels. AJCS 8(9), 1336-1342.

Karim, A. N. M. S., Ahmed, S., Akhi, A. H., Talukder, M. Z. A., & Mujahidi, T. A. (2018). Combining ability and heterosis study in maize (*zea mays* l.) hybrids at different environments in Bangladesh. *Bangladesh Journal of Agricultural Research*, 43(1), 125–134.

Kempthorne, O. (1957). An introduction of genetics statistics. New York, NY: John Wiley and Sons.

Kuselan,K., Manivannan,N., Ravikesavan, R., Paranidharan,V., & Gupta,R.(2017). Combining ability of maize inbreeds for yield and component traits in multi environment diallel analysis. *International Journal Pure Application Bioscience*, 5(6), 725–729.

Matin, M. Q. I., Rasul, M. G., Islam, A. K. M. A., Mian, M. A. K., Ivy, N. A., & Ahmed, *JOURNAL* U. (2016). Combining Ability and Heterosis in Maize (*Zea mays* L.). *American Journal Bio Science*. 4(6), 84–90.

Mohamed, H. A. A. (2020). Combining ability of newly developed white maize (*Zea mays* L.) inbred lines via top cross analysis. *Zagazig Journal Agricultural Research*, 47(3), 657-668.

Mosa HE (2010) Estimation of combining ability of maize inbred lines using top cross mating design. *Journal Agricultural Research Kafr El- Sheikh University,* 36(1), 1-15.

Mosa, H.E. (2004). Comparison between two types of testers for evaluation of new white inbred lines of maize. *Annals of Agricultural Sciences*, Moshtohor, 42(2), 475-487.

Mosa, H.E., EL-Shenawy, A.A., & Motawei, A.A. (2008). Line x tester analysis for evaluation of new maize inbred lines. *Journal Agricultural Science Mansoura University*. 33, 1-12.

Mosisa, W., Legesse, W., Berhanu, T., Girma, D., Girum, A., Wende, A., & Getachew B. (2012). Status and future direction of maize research and production in Ethiopia (pp. 17–23). *Addis Ababa*.

Mostafa, M.A.A., Khalil M.A.G., & El-Gazzar, I.A.I. (2013). Estimation of combining ability of new white maize inbred lines using line x tester mating design. *Egypt Journal Plant Breed*. 17:(2), 297-305.

Motawei, A. A., Mosa, H. E., Khalil, M. A. G., Darwish, M. M. B., & Mohamed H. A. A. (2019). Combining ability and heterotic grouping of two sets of new maize inbred lines. *Egypt Journal Plant Breeding*, 23(4), 667-679.

Natol, B. (2017). Combining ability and heterotic grouping in maize (*Zea Mays* L.) inbred lines for yield and yield related traits. *World Journal of Agricultural Sciences*, 13(6), 212–219.

Shah, L., Rahman, H. U., Ali, A., Bazai, N. A., & Tahir, M. (2015). Combining Ability estimates from line x tester mating design in maize (*Zea mays* L.). *Academic Research Journal of Agricultural Science and Research*, 3(4), 71–75.

Singh, R. K. (1985). Biometrical methods in quantitative genetic analysis. Kalyani Pub. Ludhiana. *New Delhi, Revised Ed.*, *318*.

Snedecor, .W. & W.C. Cochran (1967). *Statistical Method. Indian Edition (Sixth Edition, 1986)*. Oxford & IBH Publishing Co.

Sprague, G.F. & Tatum, L.A. (1942). General vs. specific combining ability in single crosses of corn. *American Society of Agronomy*. 34, 923-932.

Vasal, S. K., Srinivasan, G., Han, G. C., & Gonzales, C. F. (1992). Heterotic patterns of eighty-eight white subtropical cimmyt maize lines. *Maydica*, 37, 319–327.

Worku, M., Abdurahaman, *JOURNAL*, Tulu, L., Tuna, H., Wolde, L., Yihun, K., & Zeleke, H. (2002). Improved germplasm development for the mid and low altitude sub-humid agro-ecologies of *Ethiopia Journal of Immunological Methods*,267, 27–30.

World Food & Agriculture Organization (FAO). (2021). World food and agriculture – *Statistical pocketbook 2019* (pp. 254). Rome.License:CCBY-NC-SA3.0 IGO.

القدرة علي الإئتلاف ومتوسط الأداء ونسبة التفوق للسلالات المرباه داخليا من الذرة الشامية باستخدام تحليل السلالة في الكشاف

محمد احمد محمد الغنيمي، هشام عبد الحميد ابويوسف ، أحمد مصطفي أبوشوشة* ، هيثم مصطفي الشاهد ، محمد صلاح شلوف

قسم بحوث الذرة الشامية ، معهد بحوث المحاصيل الحقلية ، مركز البحوث الزراعية ، الجيزة ، مصر.

*بريد المؤلف المراسل ahmedabushosha5.5.5.i@gmail.com

أجريت ثلاث تجارب حقلية خلال الموسم 2022 بمحطات البحوث الزراعية بالجميزة وسخا وملوي التابعة لمركز البحوث الزراعية بمصر، وذلك بهدف تقييم 30 هجين ناتجة بطريقة السلالة في الكشاف بين عشرة سلالات مرباه داخليا مع ثلاثة كشافات هما السلالتين (سدس 7 ، سخا 5 ، هـ.ف 130) وأربعة هجن مقارنة وهم الهجينين الفرديين (10 ، 2031) والهجينين الثلاثيين (321 ، 324) لصفة المحصول والصفات الاخري باستخدام تحليل السلاله في الكشاف. أظهر تحليل التباين وجود إختلافات معنوية بين الهجن مجزئاتها السلالة والكشاف والتفاعل بين السلالة والكشاف كان معنوياً. أظهرت النتائج ان سلالات (الأم) ساهمت بشكل أعلى في الاختلافات الوراثية مقارنة بالسلالات الابوية. تأثيرات القدرة العامة علي الائتلاف أظهرت ان السلالات (جميزة 1031 , جميزة 62 و الكشاف سخا 5) كانوا الافضل في الائتلاف للتبكير والارتفاع المنخفض للنبات والكوز. بينما كانت السلالات (جميزة 267 , جميزة 50 , جميزة 66 ,جميزة 64 و الكشاف سخا 5) كانوا الافضل للائتلاف في صفة محصول الحبوب. أظهرت الهجن (جميزة 62 × هـ ف 130), (جميزة 66 سخا 5) و (جميزة 64 × سدس 7) تقديرات معنوية للقدرة الخاصة علي الائتلاف لارتفاع النبات والكوز. بينما أظهر الهجين (جميزة 52 × هـ ف 130) تأثيرات معنوية علي القدرة الخاصة علي الائتلاف لصفة محصول الحبوب. أظهرت متوسطات جميع الهجن المقيمة أفضلية عن هجن المقارنة للتبكير وإرتفاع النبات المنخفض وإنخفاض موقع الكوز. تفوق الهجينان (جميزة 64 × سخا 5) (جميزة 64 × هـ ف 130) علي جميع هجن المقارنة لصفة محصول الحبوب. بينما كان الهجين (جميزة 66 × سدس 7) متفوق معنوي علي صنف المقارنة هـ ف 2031 والهجينان (جميزة 52 × هـ ف 130) ، (جميزة 64 × هـ ف 130) تفوقا معنويا علي صنفي المقارنة هـ ث 321 و هـ ث 324 . ومن ثم تحديد الهجن المتفوقة لتحسين القدرة الإنتاجية في برامج تربية الذرة.

الكلمات المفتاحية: الذرة، القدرة علي الإئتلاف، والتفاعل بين السلالة والكشاف