Combining ability for grain yield and yield components in local inbred lines and introduced open pollinated varieties of maize (*Zea mays* L).

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ABSTRACT

The development of hybrids is the main objective of maize breeding. However, success depends largely on the identification of the best parents to ensure maximum combining ability. This study was conducted to estimate genetic variability and combining ability for grain yield and yield components of seven local inbred lines and four introduced open pollinated varieties of maize (*Zea mays* L.) across two irrigated locations, Medani and Matuq, Gezira, Sudan in 2008. The experiment was arranged in a randomized complete block design with three replicates. The traits measured were days to 50% tassel, plant height, ear length, ear diameter, hundred kernels weight and grain yield. Significant differences were observed among the parents and crosses for most of studied traits in both seasons. The crosses showed high genetic variability and tall plants than their parents which suggested some degree of hybrid vigor. The tallest hybrids across locations were T3 x L5 and T4 x L3. This indicates that the crosses were late maturing than their parents. The highest yielding hybrids had long ears and better shape, e.g., T2 x L1 and T1 x L7.The top five ranking crosses for grain yield across locations were T2 x L7 (3.45 t/ha), T1 x L2 (3.44 t/ha), T2 x LI (3.32 t/ha), T4 x L4 (3.30 t/ha) and T1 x L1 (3.13 t/ha). The inheritance of most traits was controlled by non-additive gene action except ear height and grain yield. The best combiners for grain in Medani were T4, L4 and L5, while in Mutaq were L2, L4 and L6. The ratio of GCA to SCA variance for the most traits was less than one, suggesting that the inheritance was due to non additive gene effect with the exception of grain yield being more than one, indicating that inheritance of this trait was due to GCA effects, and was largely controlled by additive gene action in the base material. From these results it is recommended that parents T4, L1 and L6 to be used in recurrent selection, while, crosses T3 x L5, T1 x L5 and T4 x L6 to be tested in multi-locations trials for commercial utilization.

INTRODUCTION

Maize generally is one of the most diverse crop both genetically and phenotypically. Due to its wide adaptability and productivity, maize spread rapidly around the world after the Europeans brought the crop from the Americas in the 15^{th} and 16^{th} centuries (McCann, 2005). The Portuguese introduced the crop to Africa at the beginning of the 16^{th} century and since then the crop has replaced sorghum and millet as the main staple food in most of the continent where the climatic conditions are favorable (McCann, 2005). Today, there is an increasing interest in maize production in Sudan due to its suitability to cultivation in the agricultural irrigated schemes, especially in the Gezira.It can occupy an important position in the economy of the country due to the possibility of blending it with wheat for making bread (Nour *et al.,* 1997; Meseka, 2000).

The grain yield of existing maize varieties and local landraces in Sudan is low. Also, maize hybrids have been reported to show high potential for grain yield than the open pollinated varieties and landraces (Alhussein, 2007). Advantages of hybrids over open pollinated cultivars are higher yield, uniformity, high quality and resistance to diseases and pests. In spite of having yield potential, the production of maize in Sudan is very low. One of the reasons for this is the cultivation of exotic hybrids, which are not well adapted to our agro-climatic conditions. One of the strategies of the Agricultural Research Corporation (ARC) of the Sudan for maize breeding program is to develop new hybrids as an attempt to incorporate both advantages for higher yield and adaptability to environmental conditions. Thus, getting the benefit from the use of hybrids is the main purpose in maize breeding program of ARC. Therefore, the objective of this study is to estimate the magnitude of combining ability in 28 topcross hybrids of maize for grain yield and its components across two irrigated locations and to identify high yielding topcross hybrids for future testing and commercial utilization.

MATERIALS AND METHODS

The plant material used consisted of 7 local inbred lines used as lines (L), and 4 introduced open pollinated varieties used as testers (T) crossed in line x tester arrangement (Table 1). Hand pollination was used to develop the breeding material. Pollen grain was collected into a paper bag from the tassel of male parent (tester) and then dusted on the silk of the female parent (line). The ear was covered with a bag and information regarding the cross was written on the bag. A total of 28 cross combinations was obtained through hand pollination. In July 2008, the 11 parental material and 28 cross hybrids were grown and evaluated at two irrigated locations, Medani, Gezira Research Station (GRS) and Matuq, Matuq Research Station (MRS), Gezira State, Sudan. The trials were arranged a randomized complete block design with three replicates. The plot size was maintained as 2 rows x 3 m long with inter and intra row spacings of 80 and 25 cm, respectively. Seeds were sown at the rate of 3- 4 seeds per hill. Plants were thinned to one plant per hill after three weeks from sowing. Nitrogen was applied at 86 kg/ha in a split dose after thinning and before flowering. The crop was irrigated at intervals of 10-14 days, and plots were kept free of weeds by hand weeding. Data were analyzed using the Statistical Analysis System (SAS) computer package. The analysis was done for each season for characters days to 50% tasseling, plant height, ear length, ear diameter, kernels weight and grain yield and then combined. Mean performance was separated using Duncan's Multiple Range Test (DMRT). Data from each location was analyzed separately and across locations to determine the general and specific combining ability of each line was measured according to Griffing's Method 2 (1956).

Table 1. Pedigree of the lines and testers used in the study.

Parents	Pedigree	Source
L1	RING-B-S_1-2	Inbred line developed by ARC
L2	PR-89 B-5655-S_1-1	Inbred line introduced from CIMMYT, Mexico
L3	RING-B- S_1-3	Inbred line developed by ARC
L4	RING- B-S_1-1	Inbred line developed by ARC
L5	RING-A-S_1-1	Inbred line developed by ARC
L6	RING-A-S_1-2	Inbred line developed by ARC
L7	PR-89 B-5655-S_1-3	Inbred line introduced from CIMMYT, Mexico
T1	SOBSIY-HG AB	OPV introduced from CIMMYT, Kenya
T2	ACROSS- 500 HGY-B	OPV introduced from CIMMYT, Kenya
T3	CORRALE10 -02 SIYQ	OPV introduced from CIMMYT, Kenya
T4	BAILO- 02SIYQ	OPV introduced from CIMMYT, Kenya

RESULTS AND DISCUSSION

The performance of the material tested for most traits is high across the two locations. However, significant differences among the parents and their hybrids for most traits were shown indicating the diversity of the material.

Mean separation and ranking

Mean days to 50% tasseling indicates that the pollen shedding ability of maize genotypes is an indicator of the earliness of genotypes. Mean days to tasseling across locations for parents scored 52 days as the general mean. Mean of parents ranged between 49 and 55 days for L6 and T3, respectively (Table 2). The mean of crosses ranged between 46 days for (T4 x L5) to 52 days for (T2 x L1) (Table 3). Identification of early tasseling genotypes is very important in developing hybrids and choosing hybrids to suit different agro-ecological zones as well as grower's requirements. Earliness was a desirable trait especially under rainfed conditions. It is important for better use of water resources and avoidance of late season infestation with stem borers. Hence, the earliest crosses were T1 x L7 (47 days), T4 x L7 (47 days), T4 x L4 (48 days) and T4 x L6 (48 days) (Table 3).

Table 2. Mean performance of eleven parents for the measured traits in maize at the two locations, season 2008.

Traits / Parents	DT Mean	DT Rank	PH Mean	PH Rank	EL Mean	EL Rank	ED Mean	ED Rank	KW Mean	KW Rank	GY Mean	GY Rank
L1	49.1	10	131.4	10	14.2	4	3.7	3	20.7	6	2.8	2
L2	50.0	9	148.5	4	15.0	1	3.6	7	19.9	11	2.6	5
L3	51.7	6	145.2	6	13.2	9	3.6	6	20.7	8	2.4	8
L4	50.0	8	152.0	3	14.3	3	4.1	1	20.3	10	2.1	11
L5	51.7	5	145.6	5	13.7	5	3.6	4	22.6	2	2.7	3
L6	49.1	11	139.1	9	13.4	8	3.4	11	22.1	3	2.2	9
L7	50.1	7	131.1	11	12.7	11	3.4	10	20.7	7	2.4	7
T1	52.7	4	139.3	8	13.6	7	3.9	2	21.3	5	2.2	10
T2	54.2	2	155.9	2	14.8	2	3.6	5	21.7	4	2.4	6
T3	55.2	1	157.7	1	13.7	6	3.5	8	22.8	1	2.6	4
T4	52.8	3	143.2	7	12.9	10	3.5	9	20.5	9	2.9	1
Mean	52.3		144.4		13.5		3.5		21.4		2.4	
CV%	6.7		10.0		13.0		9.8		14.5		27.8	
S.E±	0.98		2.33		0.38		0.08		0.81		0.15	

DT= days to 50% tasseling, PH= plant height (cm), EL= ear length (cm), ED= ear diameter (cm), KW= kernels weight (g), GY= grain yield (t/ha).

Tallness is not a good character in grain maize production, since tall maize plants tend to be susceptible to stem and root lodging. Highly significant differences for tallness were detected among the studied parents with the general mean being of 144.4 cm. The trends in breeding work are to develop cultivars that are dwarf or of moderate height to avoid lodging of the crop which adversely affects yield. In the studied parents mean plant height ranged between 131.1 cm for L7 to 158 cm for T3 which was the tallest and latest parent across locations (Table 2). The crosses mean varied from 135.1 cm for (T3 x L7) to 155.9 cm for (T2 x L1).The tallest hybrids across locations were T4 x L6 and T4 x L3 (154 cm) (Table 3).

Table 3. Performance of 28 crosses for the measured traits in maize at the two locations combined, season 2008.

Traits/ Crosses	DT Mean	DT Rank	PH Mean	PH Rank	EL Mean	EL Rank	ED Mean	ED Rank	KW Mean	KW Rank	GY Mean	GY Rank
T1 x L1	48.5	22	14.6	13	14.2	6	3.8	4	22.0	9	3.1	5
T1 x L2	48.5	20	148.3	14	14.2	7	3.5	22	23.2	1	3.4	2
T1 x L3	50.0	13	149.8	7	13.7	18	3.7	9	21.7	14	2.9	12
T1 x L4	50.1	12	145.0	18	13.3	22	3.7	14	22.1	7	2.9	11
T1 x L5	49.0	19	145.6	16	12.9	25	3.5	23	22.2	6	3.0	10
T1 x L6	50.1	11	152.3	4	14.3	5	3.7	11	21.8	18	2.7	21
T1 x L7	46.8	27	138.9	25	15.2	2	3.4	26	20.3	24	2.9	16
T2 x L1	52.3	1	155.9	1	14.1	8	4.0	1	20.8	22	3.3	3
T2 x L2	49.5	17	149.2	10	13.2	21	3.7	15	19.9	27	2.4	26
T2 x L3	51.2	4	145.2	17	12.2	27	3.7	16	22.8	3	3.1	7
T2 x L4	50.2	9	141.0	22	13.2	24	3.7	17	22.1	8	2.4	15
T2 x L5	49.5	18	140.8	24	14.0	10	3.7	13	21.3	17	2.0	28
T2 x L6	50.0	14	143.4	19	14.6	4	3.3	27	20.1	25	3.1	8
T2 x L7	48.2	21	149.1	11	13.9	14	3.4	25	19.7	28	3.5	1
T3 x L1	50.3	7	150.3	6	13.9	12	3.6	20	21.6	16	2.8	18
T3 x L2	49.7	16	149.8	8	13.7	16	3.7	7	21.7	13	2.9	13
T3 x L3	48.0	23	139.2	24	13.3	20	3.8	2	22.4	5	2.7	22
T3 x L4	50.2	10	142.9	21	11.9	28	3.7	12	20.6	23	3.0	9
T3 x L5	51.2	3	151.4	5	16.1	1	3.6	21	22.5	4	2.9	17
T3 x L6	50.8	5	138.8	26	13.9	13	3.3	28	20.9	21	2.6	24
T3 x L7	52.2	2	135.1	28	14.1	9	3.5	24	21.0	20	2.2	27
T4 x L1	50.3	8	146.1	15	12.8	26	3.7	18	21.7	12	2.5	25
T4 x L2	50.0	15	149.8	9	13.7	17	3.7	8	21.7	15	2.9	14
T4 x L3	50.3	6	154.2	3	14.0	11	3.8	5	23.2	2	3.1	6
T4 x L4	47.5	25	148.9	12	13.6	19	3.7	6	21.8	10	3.3	4
T4 x L5	45.7	28	135.1	27	13.8	15	3.7	10	21.8	11	2.8	19
T4 x L6	48.0	24	154.2	2	13.2	23	3.8	3	20.1	26	2.7	20
T4 x L7	47.2	26	143.1	20	15.2	3	3.6	19	21.2	19	2.6	23
Mean	49		145.9		13.8		3.7		21.3		2.8	
CV%	6.7		10		13		9.8		14.5		27.8	
S.E±	0.64		3.8		0.46		0.08		0.56		0.14	

DT= days to 50% tasseling, PH= plant height (cm), EL= ear length (cm), ED= ear diameter (cm), KW= kernels weight and GY= grain yield (t/ha).

DT= days to 50% tasseling, PH= plant height, EL= ear length, ED= ear diameter, KW= kernels weight, GY= grain yield.

*, ** Significant at, 0.05 and 0.01 levels of probability, respectively.

The results indicate that crosses were later than their parents. Also, the taller crosses were late maturing than short ones. Generally, the crosses were taller than their parents which suggested some degree of hybrid vigor.

Ear length trait is an important selection index for grain yield in maize. The ear length means of parents, as expected, were found to be shorter than those of the crosses at the two sites, with the general mean of 13.5 cm. The parents mean ranged between 12.7 cm for L7 to 15 cm for L2 (Table 2). The crosses mean varied from 11.9 cm for (T3 x L4) to 16.1 cm for (T3 x L5). However, long ear length were recorded for crosses T1 x L7 (15.2 cm), and T2 x L6 (14.6cm) (Table 3).Vedia and Claure (1995) found that ear length was the most important yield component and when used as a selection index genetic gain in recurrent selection reached 9.94% for yield and 5.75% for the ear traits. Therefore, any increase in ear length would be expected to increase number of kernels/row and hence increase grain yield.

Ear diameter is a good indicator of the number of kernel rows/ear. The mean of ear diameter across sites for parents ranged between 3.4 cm for L6 and L7 to 4.1 cm for L4 (Table 2). Among the crosses, the large ear diameter ranged from 3.3 cm for T3 x L6 to 4.0 cm for T2 x L1. The crosses which had a big ear diameter were T3 x L3 and T4 x L6 (3.8cm) (Table 3). This result was in agreement with the findings of Tracy (1990) who found that the maize hybrids with high yield had more ears/plant, longer ears and a better ear shape and row configuration.

The mean of one hundred kernels weight for parents was 21.4 g, and it ranged between 19.9 g for L2 to 22.8 g for T3 (Table 2). Among the crosses, the mean was 21.3 g. The best crosses which obtained the highest kernel weight were T1 x L2 and T4 x L3 (23.2) followed by T2 x L3 (22.8 g) (Table 3).

Yield is a polygenic character is influenced by the fluctuating enviro-nment. Moreover, it is a complex trait depending on many components (Sharaan and Ghallab, 1997). In this study, there was a considerable amount of variability among the genotypes for this trait. The studied parents in the two locations showed a general mean of 2.4 t/ha. The parents means ranged between 2.12 t/ha for L4 to 2.93 t/ha for T4 (Table 2), while, the crosses means ranged between 2.0 t/ha for (T2 x L5) to 3.55 t/ha for (T2 x L7) (Table 3). Most of the crosses (19 hybrids) had significantly higher mean grain yield than the overall mean. It is of interest to mention that the top ranking and the best yielder hybrids were T1 x L2 (3.4 t/ha), T2 x L1 (3.3 t/ha), T4 x L4 (3.3 t/ha), T1 x L1 (3.30 t/ha) and T4 x L3 (3.1 t/ha). These results agreed with those of Khalafalla and Abdalla (1997), who pointed to the fact that hybrids (crosses) produce higher grain yields than the open pollinated varieties due to the good performance of hybrids under Sudan conditions.

Combining ability

The breeding method to be adopted for improvement of a crop depends primarily on the nature of gene action involved in the expression of quantitative traits of economic importance. Combining ability leads to identification of parents with general combining ability effects and in locating cross combining showing high specific combining ability effects. In this study the ratio of GCA to SCA mean variance for most traits was less than one, suggesting that the inheritance of these traits was due to non additive gene action, with the exception of grain yield being more than one, indicating that inheritance of this trait was due to GCA effects, and largely

Table 4. Mean squares of six agronomic traits for maize parents and 28 lines x tester crosses tested at two locations, Medani and Mutaq 2008.

Source of variation	DF	DT	PH	EL	ED	KW	GY
Location	1	3322.70**	13721**	4.48**	50.90**	287.8**	26.9**
Line	6	04.22	119.19	4.03	0.02	5.69	0.27
Tester	3	18.81	46.63	0.85	0.07	3.06	0.28
Line x tester	18	05.85**	93.70*	2.38*	0.05*	1.62*	0.44*
Line x tester x location	18	11.91**	217.90**	2.80	0.11	6.68	0.63
Pooled error	76	05.24	108.60	1.76	0.04	3.08	0.19
GCA		0.2	-5.0	0.2	0.00	-0.7	0.08
SCA		0.6	13.7	0.5	0.02	0.7	0.03
GCA/SCA		0.4	-0.4	0.4	-0.15	-1.0	3.07

DT= days to 50% tasseling, PH= plant height, EL= ear length, ED= ear diameter, KW= kernels weight, GY= grain yield.

*, ** Significant at, 0.05 and 0.01 levels of probability, respectively.

controlled by additive gene action in the base material (Table 4). This result indicates that dominance and epistatic interaction effects seemed to be predomint for this trait and therefore heterosis breeding may be gratifying. The good combiner parents, those having negative GCA effects in Medani, for 50% days to tasseling were L5 followed by T4, T1 and L7, indicating earliness for flowering time, while, the latest, having positive GCA effect was T3 (Table 5).The earliest crosses having negative SCA effects were T3 x L6, T2 x L7 and T2 x L4, while, the latest crosses were T2 x L5, T4 x L5 and T4 x L4 (Table.6).

The earliest parent in Mutaq was L7 (Table 5) and the earliest crosses were T2 x L4, T4 x L4 and T3 x L4 (Table 6). Common parents across locations that contributed to earliness were T4 and L5. The latest were L6 followed by T3 and T2 (Table 5). Parent L4 had good contribution for earliness to their hybrids progeny across locations.

Thus, the inbred lines which exhibited good general combining ability for at least one character can be used for development of early maturity and high grain yield. The contribution of the total variance for general and specific combining ability for this trait differs from location to another, but SCA was high in both locations (50.4% and 71.7%) compared with GCA which indicates that this trait is controlled by additive gene action (Figs 1 and 2).

Trends in breeding work are to develop cultivars that are dwarf or of moderate height to avoid lodging of the crop which adversely affects yield. Only three top cross hybrid parents in Medani have negative GCA effects for plant height, i.e., L7, L3 and T3; they were best combiners for short plant type. Tallness which is an undesirable trait is shown by parents L1, L2 and T1 (Table 5). Crosses having negative SCA effects and consequently short plant type were T4 x L2, T1 x L4 and T2 x L4, while, tall hybrids with positive SCA effects were T3 x L1, T2 x L5 and T4 x L5 (Table 6).

Table 5. Estimates of GCA effects for measured traits on 11 parents of maize populations and lines Medani(GRS)and Mutaq (MRS) season,2008.

Traits	DT		PH		EL		ED		KW		GY	
Parents	GRS	MRS	GRS	MRS	GRS	MRS	GRS	MRS	GRS	MRS	GRS	MRS
L1	0.94*	1.05*	10.49**	0.22**	-0.03**	0.28	-0.24	0.05	0.15**	-1.72	0.23	-0.14
L2	0.44	-0.67*	3.69**	-0.05*	0.11**	0.24	-0.13	-0.44**	0.42**	3.11*	-0.70*	-0.07
L3	0.44	0.31	-4.33**	0.06*	0.11**	1.04*	0.94*	0.19*	0.01	-2.44*	-0.43	-0.47**
L4	0.02	-0.17	0.62	0.04*	0.11**	0.14	0.31	0.24**	0.13**	1.57	-1.17**	-0.32*
L5	-2.06**	0.80*	-1.76*	0.10**	-0.10**	0.08	0.84*	0.14*	-0.53**	-3.41*	0.87*	0.13
L6	0.52*	0.13	-0.85	-0.15**	-0.07**	-1.54*	-0.16	-0.22**	0.01	3.56*	0.34	0.18
L7	-0.31	-1.45**	-7.85**	-0.21**	-0.13**	-0.23	-1.57**	0.04	-0.18**	-0.67	0.86*	0.68**
T1	-0.44	-0.45	2.84*	0.02	-0.08**	1.08**	-0.31	0.26**	0.04**	-1.72	0.56*	-0.11
T2	0.65	0.59	-0.50	-0.03	0.03**	-0.36	- 0.65*	-0.06	0.13**	0.45	-0.18	-0.03
T3	1.70**	0.00	-3.10*	-0.03	-0.05**	-0.64*	0.67*	-0.32**	-0.05**	-0.73	-0.28	0.50**
T4	-1.92**	-0.14	0.76	0.04*	0.10**	-0.08	0.29	0.12*	-0.12**	2.01	-0.10	-0.37**
S.E±	0.52	0.56	1.73	0.04	0.21	0.54	0.46	0.12	0.76	2.44	0.46	2.11

DT= 50% days to tasseling, PH= plant height, EL= ear length, ED= ear diameter, KW = kernel weight and GY= grain yield.
*, ** Significant at, 0.05 and 0.01 levels of probability, respectively.

Table 6. Estimates of SCA effects for the measured traits of 28 crosses of maize at Medani (GRS) and Mutaq (MRS) season, 2008.

Traits/ Crosses	DT		PH		EL		ED		KW		GY	
	GRS	MRS	GRS	MRS	GRS	MRS	GRS	MRS	GRS	MRS	GRS	MRS
T1 x L1	-0.89	-1.49*	-5.34*	1.01	-0.63	1.16**	0.03	0.07*	0.67	-0.35	0.03	0.02
T1 x L2	0.68	1.85*	10.67**	0.70	0.98	-0.06	0.31**	0.06*	0.54	-1.01	0.33*	0.35*
T1 x L3	-1.70*	-0.25	3.60	0.42	0.03	0.01	-0.18*	0.01	0.09	-0.01	0.02	0.11
T1 x L4	1.92*	-0.11	-8.92**	-2.12	-0.38	-1.11*	-0.15*	-0.14**	-1.30	1.37	-0.38*	-0.48**
T1 x L5	0.27	-1.24	-6.21*	3.31	0.46	0.89*	-0.34**	0.10**	0.63	1.87*	0.22	0.68**
T1 x L6	-0.15	-0.90	-2.87	2.80	0.73	-0.69	0.11*	0.09*	-1.39*	-0.79	-0.32*	-0.58**
T1 x L7	-2.20*	1.00	6.47*	-1.68	1.16*	-0.54	0.15*	-0.02	0.66	-0.73	-0.14	-0.08
T2 x L1	2.08*	1.14	2.61	-4.42	-2.35**	0.34	0.08	-0.17**	0.10	-0.35	0.23	-0.01
T2 x L2	0.61	0.51	0.22	4.86	-0.34	0.48	-0.05	0.01	-1.86*	-0.81	-0.55*	0.24*
T2 x L3	-0.82	2.18*	-4.52*	-6.65*	-0.83	-1.05*	0.02	-0.14**	0.58	1.14	0.02	0.17
T2 x L4	-2.87**	-2.58*	-6.59*	-11.47**	0.03	-0.25	0.15*	0.08*	0.30	-0.52	0.36*	-0.57**
T2 x L5	3.08**	-0.11	10.89**	13.26**	1.15*	0.82*	-0.12*	0.05*	0.97	0.19	0.17	0.16

table 6. Continued

T2 x L6	1.02	1.01	-3.88	-0.20	0.30	-0.17	-0.06	0.09*	0.07	0.19	-0.22	-0.25*
T2 x L7	-0.07	0.01	-0.53	-2.37	1.04*	-0.26	-0.01	-0.01	1.52*	0.54	0.11	-0.34*
T3 x L1	0.21	-0.42	3.80	7.39*	-2.70**	0.19	0.17*	-0.10**	-1.36*	-0.89	-0.13	0.39*
T3 x L2	-1.17	-0.61	0.61	-4.82	1.36*	0.23	-0.10	0.01	-0.23	0.16	0.25	0.21
T3 x L3	0.44	0.76	4.91*	-1.38	-0.81	-2.31**	0.09	-0.26**	-0.17	-0.10	0.59*	-0.30*
T3 x L4	2.35*	-2.24*	-5.08*	0.25	-1.10	0.94*	-0.20*	0.30**	0.41	-0.76	-0.85**	-0.52**
T3 x L5	1.96*	1.00	8.85*	11.23**	2.49**	1.08*	0.21**	-0.18**	-0.41	1.58*	0.10	0.71**
T3 x L6	-4.75**	0.48	-8.67*	-10.11*	-0.58	0.29	-0.10	0.13**	0.17	-0.71	0.16	0.11
T3 x L7	-1.14	2.76*	11.99**	-2.88	0.96	-0.86*	0.27**	0.18**	1.82*	-0.77	-0.04	-0.41*
T4 x L1	-0.24	-0.57	-4.33*	-3.25	0.27	1.13*	-0.11*	-0.30**	-0.68	0.57	0.15	0.41*
T4 x L2	1.71*	-1.33	-9.40**	-3.47	-0.81	0.36	-0.34**	-0.01	0.51	-0.09	0.01	0.01
T4 x L3	-0.33	-0.86	1.74	9.59*	-0.42	-0.63	0.19*	0.13**	-1.65*	0.29	-0.13	-0.01
T4 x L4	-0.31	-2.32*	-1.68	-4.71	0.07	0.81*	0.06	-0.20**	-1.16	-0.02	-0.03	0.02
T4 x L5	-1.74*	-0.32	6.67*	8.52*	-1.09	-0.01	-0.12*	0.00	-0.98	0.32	0.56*	0.52**
T4 x L6	2.88*	2.58*	-6.7**	-2.43	-0.2	-0.87*	-0.15*	0.21**	0.20	0.66	-0.22	-0.56**
T4 x L7	-0.83	0.06	1.74	-1.37	1.22*	0.07	0.21**	-0.01	1.94*	-0.96	-0.31*	0.02
S.E±	1.29	1.37	4.23	5.98	1.14	0.72	0.11	0.05	1.31	1.52	0.31	

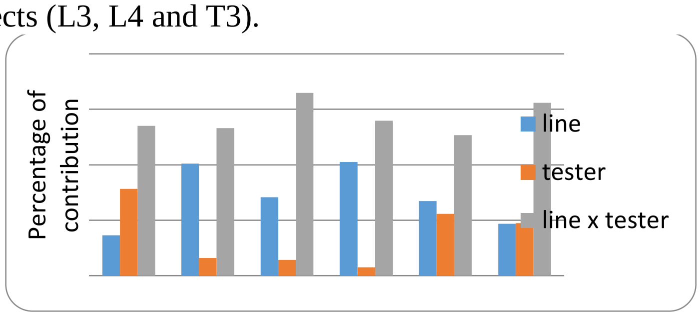
DT= 50% days to tasseling, DS= 50% days to silking, PH= plant height, EL= ear length, ED= ear diameter, KW = kernel weight
and GY= grain yield.
*, ** Significant at, 0.05 and 0.01 levels of probability, respectively.

The best combiners for the short plant type with negative GCA in Mutaq were L7, L6 and L2 while, the taller parents with high positive GCA effects were L5 and L1 (Table 5). Among the crosses the shortest hybrids were T2 x L4, followed by T3 x L5 and the tallest hybrids were T2 x L5 and T3 x L4 (Table 6). This showed that, there is a relationship between late flowering and tall plant type. This is quite obvious among the hybrids such as T3 x L1 and T3 x L4. Contribution for this trait is higher in crosses (80% and 53%) compared to parents (20% and 40%) at the two locations (Figs 1 and 2). The earliness and shortness are desirable traits especially under rainfed conditions for better water use efficiency and the escape of drought and avoidance of late season infestation with stem borer.

Ear length is a good index for higher grain yield, therefore any increase in ear length would be expected to increase number of kernels/row and hence directly improve grain yield. In Medani site, the long ear length parents having a positively significant GCA effects such as L5, L7 and T1, while parents showing the short ear length were L4 and L2 (Table 5). The best crosses for this trait having a positive SCA effects and hence the longest ear length were T2 x L5 and T4 x L7. On the other hand the best combiners in Mutaq were L7 and T3 (Table 5), while the best crosses were T1 x L1 and T4 x L4 (Table 6). In the two locations, the best contribution was (73% and 65.9%) obtained by SCA compared with (27% and44.1) for GCA (Figs1 and 2). These results emphasized that ear length has a direct effect for improving grain yield. This is in agreement with the finding of Vedia and Claure (1995) who found that ear aspect was the most important yield component.

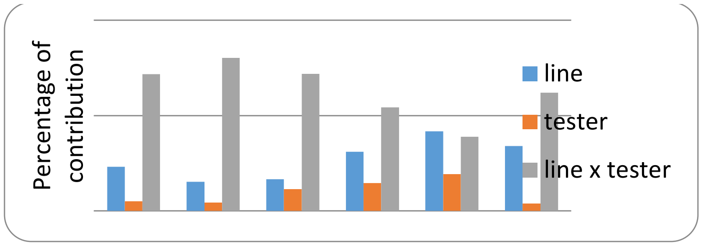
Based on GCA estimates, the best combiners for ear diameter and length in Medani are L1 and L5, while best crosses were T1 x L2, T3 x L5 and T3 x L7. The good combiners in Mutaq site are L2, L3 and L4, while the best crosses are T3 x L4, T4 x L1 and T1 x L5 (Tables 5 and 6). A higher contribution among this trait is obtained by SCA (55.9% and 65.9%) in both locations compared with GCA (Figs 1and 2).

Favorable GCA values were given by T1 and L3 as the good combiners for kernel weight in Medani and the best crosses were T4 x L7 and T2 x L7. Among the studied parent material in Mutaq, only three parents have positive GCA effects (L3, L4 and T3).



DT= days to 50% tasseling, PH= plant height (cm), EL= ear length (cm)
ED= ear diameter (cm), KW= kernels weight (g), GY= grain yield (t/ha)

Figure 1. Parent contribution of the maize GCA and SCA to the total variance of yield and its componets at Medani, season 2008.



DT= days to 50% tasseling, PH= plant height (cm), EL= ear length (cm)
ED= ear diameter (cm), KW= kernels weight (g), GY= grain yield (t/ha)

Figure 2. Parent contribution of the maize GCA and SCA to the total variance of yield and its componets at Mutaq, season 2008.

The best crosses were shown by T1 x L4 and T3 x L4 (Tables 5 and 6). The higher average contribution was given by the SCA (50.8% and 61) compared with the GCA at two locations (Figs 1and 2). This indicted that the inheritance of this trait was controlled by non additive gene effects.

At Medani site, all the results depicted in Table 5 showed that the parents differ considerably with respect to estimate of GCA effects for grain yield. The parents having positive GCA effects were T1 followed by L4 and L6. Parents having negative GCA effects were L2 and L6. The best crosses having positive SCA effects were T3 x L3 followed by T4 x L5 and T1 x L2. Negative SCA effects were shown by T3 x L4, T2 x L2 and T1 x L4 (Table 6). The higher combiner in Mutaq, were L2, L1 and L4. The best crosses were T3 x L5, T1 x L5 and T4 x L5, while negative SCA effects were shown by T1 x L3, T2 x L5 and T4 x L3 (Tables 5 and6). The great contribution was given by SCA (62.4% and 62%) compared with GCA at the two locations (Figs1 and 2).

General combing ability variance for grain yield is greater than the mean square for specific combining ability indicating the importance of additive gene action in controlling grain yield. This finding is in agreement with that of Barakat and Osman (2008) who found GCA effects are larger than SCA effects for grain yield indicating that the additive genetic variance is a major source of variations responsible for inheritance of grain yield.

CONCLUSION

The ratio of general combining ability variance for grain yield was greater than specific combining ability indicating the importance of additive gene action in controlling this trait hence the good combiner parent for grain yield across locations was L4 so it could be used in recurrent selection. Also enormous variability was detected in the studied population which makes cyclic selection more effective. The best cross was T4 x L5 indicating that dominance and epesitic interaction seemed to be predomint, hence, higher heterosis gratified and recommended cross T4 x L5 for future testing in multi-locations trials for commercial utilization in order to be released as a hybrid.

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المقدرة علي التآلف لإنتاجية الحبوب ومكوناتها في سلالات تربية داخلية وأصناف مستقدمة مفتوحة التلقيح من الذرة الشامية(*Zea mays* L.)

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الخلاصة

تحسين صفات الإنتاجية لمحصول الذرة الشامية هي الغاية المنشودة من خلال التربية لإنتاج الهجن. لذا يعتمد نجاحها على اختيار افضل الاباء مقدرة علي التالف .هذه التجربة اجريت لتقدير التباين الوراثى والمقدرة على التألف للانتاجية ومكوناتها لأربعة سلالات تربية داخلية وسبعة أصناف مستقدمة مفتوحة التلقيح من الذرة الشامية (*Zea mays* L.) باستخدام تحليل Line x tester في محطتي بحوث الجزيرة ومعتوق بالسودان، موسم. 2008 واستخدم تصميم القطاعات العشوائية الكاملة بثلاث مكررات لتنفيذ التجربة. الصفات التي تمت دراستها شملت 50% لعدد أيام الإزهار المذكر ، طول النبات، طول الكوز، حجم الكوز ، وزن المائة حبة وإنتاجية الحبوب.كذالك تمت دراسة الصفات الوراثية التى شملت تقدير التباين الوراثى والمقدرة العامة والخاصة على التألف. أظهرت النتائج فروق معنوية لكل الصفات في الموقعين ،الهجن التى كانت اكثر طولا وتباينا وراثيا وقوة هجين هى T4 xL3وT3 xL5 .افضل الهجن انتاجية وافضلها حجما وشكلا وطولا للقندول هىT2 xL1 و T1 xL7 و أعلى الهجن إنتاجية T1 x L2(3.45 t/ha)، T2 x L7 (3.44 t/ha)، T4 x L4 T2 xL4(3.32) , (3.30 t/ha) و T1 x L1 (3.13 t/ha). اظهر تحليل المقدرة علي التالف أن تأثيرات الفعل غير الإضافي للجين كانت أهم لتوريث كل الصفات ماعدا ارتفاع الكوز و إنتاجية الحبوب. الأباء T4,L4و L5 أعطوا أفضل مقدرة على التالف لإنتاجية الحبوب في مدني وبينما في معتوق أفضل الآباء هي L2,L4وL6 . ومن خلال هذه الدراسة نوصى باستخدام التهجين الرجعى للآباء T4 وL1 وL6 للاختيار المتكرّر. والهجن المتفوّقة والتي تشمل T3 x L5 و T4 x Lو T1 x L5 والتي يمكن إجازتها بعد إجراء بعض الاختبارات الخاصة بالإنتاجية في مواقع ومواسم مختلفة.