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Combining Ability of Maize (*Zea mays* L.) Inbreed Lines for Grain Yield and Some Agronomic Traits Using Topcross Mating Design

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Abstract: The present study was carried out to determine the combining ability, type of gene action and genetic variance components of yield and other agronomic traits. For these purpose, chosen fifteen newly inbred lines developed by the breeding program at Ismailia Agricultural Research Station. These lines were topcrossed to two testers i.e. Giza (Gz-649) and Gemmeiza (Gm-1001) at Ismailia Agricultural Research Station during 2009 growing season. In the growing season 2010, the 30 topcrossess in addition to two checks commercial cross hybrids; SC-155 and SC-162 were evaluated at two locations; Sakha and Ismailia Agricultural Research Station. Highly significant differences were found between the two locations for the studied traits. Mean squares due to crosses (C) and their partitions; lines (L), testers (T) and (LxT) interactions were significant and highly significant for almost studied traits. Eleven topcrossess exhibited similar grain productivity to the high check hybrids Sc-162 for grain yield, since no significant. But, three topcrossess only; L5 x T1 (32.06), L9 x T1 (33.42) and L11 x T1 (30.76 ard/fed.) significantly superior to the high yielding check Sc-162 (27.77 ard/fed.) for grain yield. Results indicating that most of topcrossess for silking date toward earliness, all topcrossess for plant height and ear height toward shorter plants and lower ear placement, respectively were significantly superior to the superior check Sc-162. On the other hand, most topcrosses for ear position%, ear length, ear diameter and no. of row ear^{-1} were significantly superior to the check Sc-162. The results exhibited that the inbred lines L_6 and L_9 had negative and significant GCA effects for silking date toward earliness; the lines L_3, L_6, L_{11} and L_{15} gave highly negative and significantly values GCA effects for plant height toward shorter plants; lines L_2, L_3, L_6 and L_{15} showed highly significant and negative GCA effects for ear height toward lower ear placement. The inbred lines L_2, L_3 and L_8 had a negative and significant GCA effects for ear position%. Furthermore, Lines L_1, L_2, L_3, L_8, L_9 and L_{11} exhibited GCA positive and significant for ear length; lines L_5, L_8, L_{10}, L_{11} L_{12} and L_{13} had positive and significant GCA effects for ear diameter; Lines L_2, L_4, L_5, L_{10}, L_{11} and L_{13} showed positive and significant GCA effects for no. of rows ear^{-1} and lines L_9 and L_{11} had positive significantly GCA effects for grain yield. In addition that, the T_1 as tester was the best general combiner for ear position, ear length and grain yields. While, the T_2 as a tester was the best combiner for plant height, ear diameter and no. of rows ear^{-1}. SCA effects were obtained in the topcrosses L_6 x T_1 and L_8 x T_2 for grain yield; L_4 x T_1, L_5 x T_1, L_8 x T_2 and L_{11} x T_2 for plant height; L_7 x T_1 for ear height and ear position%. While, the topcrosses L_1 x T_2, L_{10} x T_1 and L_{13} x T_1 for ear length; L_2 x T_2, L_5 x T_1 and L_{10} x T_1 for ear diameter and L_1 x T_2 and L_7 x T_1 for no. of rows ear^{-1}. General combining ability variance components σ^2GCA was larger than that σ^2SCA for ear length, no. of rows ear^{-1} and grain yield, indicating that the additive gene action played the major role than non-additive gene action in the inheritance of these traits. While, the σ^2SCA was larger than σ^2GCA for silking date, plant height, ear height, ear position% and ear diameter, indicating that non-additive gene action important than additive gene action in the inheritance for these traits under study. Combined data revealed that the variance of σ^2GCA x location interaction was either smaller or negligible than the variance of σ^2SCA x location interaction for almost studied traits. These results indicated that the non-additive type of gene action was more affected by environmental conditions than additive effects.

Key words: Maize · *Zea mays L* · Topcross · Combining ability · Gene action · Genetic components

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INTRODUCTION

The main objectives of maize hybrids breeding program are to develop new improved inbred lines and hybrids. In both instances, maize breeders have to choose the tester for evaluating new inbred lines. Choices of an appropriate tester play an important role in the ultimate success of a hybrid development program such as Testers that are genetically either narrow-or broad-based, testers that are either related or unrelated to the lines being evaluated, testers that have either a high or low frequency of favorable alleles and testers that are either high or low yielding pre seed. Maize inbred lines are developed from segregation base populations due to self-pollination, through visual selection among and within ear-to-row progenies and testing for performance in hybrid combinations [1]. The line x tester analysis methods is used to breed both self and cross pollinated plants and to estimate favorable parent and crosses and their general and specific combining abilities [2]. Early testing relies on the assumption that the combining ability of a line is determined during the early stages of selfing and does not change substantially with continued inbreeding [3-4].

Bernardo [5] found the effectiveness of early testing is limited mainly by non genetic effects. Because phenotypic correlations between early and late generation, topcross performance are expected to be > 1.0, early testing always involved some risk of discarding lines that would be genetically superior in topcrossess at homozygosity. Hallauer and Miranda [6] stated that both general and specific combining abilities (GCA and SCA) effects should be taken in consideration when planning the maize breeding programs to produce and release new inbred lines and crosses. Furthermore, successful development for improving high yielding maize hybrid and related traits such as earliness, shorter plant, lower ear placement and high yielding is based mainly on accurate evaluation of inbred lines under selection and that is a major aim the national maize research program. Genetic variations are the basis of genetic improvement in any crop. Crossing of diverse inbred lines provided sufficient variability for an effective selection of desirable traits. Suitable inbred lines and their specific combinations may be selected on the basis of combining ability effects with better mean performance. The success to identify parental inbred lines that combine well and produce productive crosses, mainly depend on gene action that controls the traits to be improved. Variance components due to general combining ability (GCA) for grain yield were larger than those due to specific combining ability (SCA). Aly and Amer [7], Aly and Mousa [8] and Mosa [9] showed that the GCA plays the major role in the inheritance of plant height, ear height and silking date. In addition that, Mosa [9], Nawar and El-Hosary [10] and Amer *et al.* [11] found that the additive gene action (GCA) was more than non-additive gene action (SCA) for ear diameter.

Numerous investigators reported that the SCA effects were more important than the GCA effects for grain yield and other traits; Amer *et al.* [12] and Mosa [13] for grain yield and El-Kielany [14] for ear length. The variance of GCA/SCA ratio is useful in estimating that variability existed whether due to additive or non-additive or both types of gene action. Bello and Olaoye [15] found that the GCA/SCA were more than unity for silking date and less than unity for plant height and grain yield, indicating that the important role of additive and non-additive gene action in these traits, respectively. Abdel-Moneam [16] who found that the GCA/SCA ratio were less than unity for ear diameter, ear length, silking date and grain yield, indicating the important role the non-additive gene action.

Data of GCA x environmental interactions were significant for grain yield and ear length, indicating that the GCA was more affected by environment than SCA. Aly and Mousa [8], El-Moula *et al.* [17] and Parvez and Rather [18] for grain yield. Amer *et al.* [19] for grain yield and ear length, El-Shenawy *et al.* [20] for plant height, ear height and ear length. On the other hand, others reported that the non-additive gene action is more affected by environmental conditions than additive gene action; Mosa [9] for silking date, ear diameter, no. of rows ear^{-1} and grain yield , Amer *et al.* [11] and Silva and Hallauer [21] for ear diameter; Aly and Amer [7] and Aly [22] for plant height.

Therefore, the present study was carried out to, first, estimate of the combining ability for some newly yellow maize inbred lines of maize. Second, determine the most important mode of gene action that control traits under this study; silking date, plant height, ear height, ear position%, ear length, ear diameter, no. of rows ear^{-1} and grain yield. Third, define the superior topcrossess to be used for improving and developing superior hybrids yielding ability in maize breeding programs.

MATERIALS AND METHODS

Fifteen S_4 newly yellow maize inbred lines were developed by the breeding program at Ismailia Agricultural Research Station and chosen for this study. These lines were topcrossed to two testers i.e.

Giza (Gz-649) and Gemmeiza (Gm-1001) at Ismailia Agricultural Research Station during 2009 growing season. In the growing season 2010, the 30 topcrossess in addition to two checks commercial cross hybrids; SC-155 and SC-162 were evaluated at two locations; Sakha and Ismailia Agricultural Research Station. Each experimental was arranged in a randomized compete block design with four replications. Plot size was one row, 6 m. long and 80 cm. apart. Seed was planted in hills evenly spaced at 25 cm. along the row at the rate of three kernels per hill. Seedling was thinned to one plant per hill after 21 days from planting. All agronomic field practices were applied as recommended. Data were recorded for number of days from planting to date of 50% silking emergency, plant height, ear height, ear position%, ear length, ear diameter, no. of rows ear^{-1} and grain yield (ard/fed), adjusted to 15.5% moisture content (one ardab = 140 Kg. and one feddan = 4200 m^2).

Statistical analysis were performed for each location then combined over locations according to Steel and Torrie [23]. The combining ability analysis was estimated using the line x tester procedure suggested by Kempthorne [2]. Combined analysis among the two locations was done on the based of homogeneity test.

RESULTS AND DISCUSSION

Analysis of variances for all the studied traits, i.e. silking date, plant height, ear height, ear position%, ear length, ear diameter, no. of rows ear^{-1} and grain yield combined over both locations are presented in Table 1. Results revealed that locations mean squares were highly significant for all the studied traits. Mean squares due to crosses (C) and their partitions; lines (L), testers (T) and (LxT) interactions were significant and highly significant for all studied traits, except lines for plant height, ear position%, ear length and grain yield; testers for silking date, ear height and ear diameter. These results indicated that both inbred lines and testers were significant different from one each to another in topcrossess and the inbred lines behaved differently in their respective topcrossess and that greater diversity exist between the two testers. Mean squares due to (LxT) interactions were significant for all the studied traits, suggests that inbred lines may have different combining ability patterns and performed differently in crosses depending on type of tester used. Similar results were reported by Aly and Amer [7], Mosa [9], Aly [22], El-Itriby *et al.* [24], Habliza and Khalifa [25] and Parvez *et al.* [26]. On the other hand, the interactions between (C x Loc) were significant for plant height, ear height, ear diameter, no. of rows ear^{-1} and grain yield, indicating that the topcrossess presented differential performance in the testing locations. Furthermore, the (L x Loc) and (T x Loc) interactions were significant for ear diameter and grain yield, indicating that the mean inbred lines performed differently as reflected in their respective topcrossess from one location to another. Similar results were recorded by Aly and Amer [7], Aly and Mousa [8] and Mosa [9]. The interactions for (L x T x Loc) were not significant for all the studied traits, except for ear diameter, no. of rows ear^{-1} and grain yield. These findings indicated that these are different ranks of interaction of inbred lines in their topcrossess from one location to another appeared in grain yield.

Mean performances of topcrossess and the two checks for all the studied traits combined over the two locations are presented in Table 2. The results showed that eleven topcrossess have high yielding compared with the highest check hybrids Sc-162 for grain yield, but three topcrossess only; L_5 x T_1 (32.06), L_9 x T_1 (33.42) and L_{11} x T_1 (30.76 ardab/fed.) significantly superior to the high yielding check Sc-162 (27.77 ard/fed.) for grain yield. Results indicating that most of topcrossess for silking date toward earliness, all topcrossess for plant height toward shorter plants and all topcrossess for ear height toward lower ear placement were significantly superior to the superior check Sc-162. On the other hand, most topcrosses for ear position%, ear length, ear diameter and no. of row ear^{-1} were significantly superior to the check Sc-162.

Table 3 showed that the general combining ability (GCA) effects for fifteen inbred lines and the two testers as combined over both locations. The results exhibited that the inbred lines L_6 and L_9 had negative and significant GCA effects for silking date toward earliness; the lines L_3, L_6, L_{11} and L_{15} gave highly negative and significantly values GCA effects for plant height toward shorter plants; lines L_2, L_3, L_6 and L_{15} showed highly significant and negative GCA effects for ear height toward lower ear placement. The inbred lines L_2, L_3 and L_8 had a negative and significant GCA effects for ear position%. Furthermore, Lines L_1, L_2, L_3, L_8, L_9 and L_{11} exhibited GCA positive and significant for ear length; lines L_5, L_8, L_{10}, L_{11} L_{12} and L_{13} had positive and significant GCA effects for ear diameter; Lines L_2, L_4, L_5, L_{10}, L_{11} and L_{13} showed positive and significant GCA effects for no. of rows ear^{-1} and lines L_9 and L_{11} had positive significantly GCA effects for grain yield. In addition that, the obtained results in the same table showed that the T_1 as tester was the best general combiner for ear position, ear length and grain yield. While, the T_2 as a tester was the best combiner for plant height, ear diameter and no. of rows ear^{-1}.

Table 1: Analysis of variances for all the studied traits over both locations

S.O.V	d.f	Silking date (days)	Plant height (cm.)	Ear height (cm.)	Ear position %	Ear length (cm.)	Ear diameter (cm.)	No. of rows ear^{-1}	Grain yield (ardab/fed.)
Locations (Loc.)	1	410.82**	6406.7**	33867.5**	3239.8**	438.5**	5.58**	19.5*	8131.7**
Reps/Loc.	6	6.206	606.5	225.5	3.08	0.27	0.05	3.7	20.0
Crosses (C)	29	3.396**	670.4**	271.6**	19.5**	18.5**	0.18**	12.0**	67.9**
Lines (L)	14	4.96*	805.0	403.8*	22.6	5.3	0.27*	11.3**	27.8
Testers (T)	1	4.27	2065.1*	1.504	89.8*	418.7**	0.20	161.5**	972.9**
Lines x Testers	14	1.77*	436.2**	158.7**	11.4**	3.1**	0.09**	2.0**	43.3**
C x Loc.	29	1.44	170.6*	104.3*	5.8	0.98	0.09**	1.1*	27.4**
Lines x Loc.	14	1.57	191.6	109.5	4.0	0.94	0.12**	1.0	33.3*
Testers x Loc.	1	1.67	504.6	210.9	1.8	2.20	0.25*	0.1	106.5*
L x T x Loc	14	1.29	125.7	91.6	7.9	0.93	0.05*	1.2*	15.9*
Pooled error	186 +	1.056	93.918	56.168	5.300	0.905	0.025	0.708	8.908

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

Table 2: Mean performances of the topcrosses and the two checks for all studied traits combined over the two locations.

Crosses	Silking date (days)	Plant height (cm.)	Ear height (cm.)	Ear position %	Ear length (cm.)	Ear diameter (cm.)	No. of rows ear^{-1}	Grain yield (ardab/fed)
L_1 x T_1	57.75	250.88	128.25	51.14	19.93	4.71	15.30	29.13
L_1 x T_2	57.75	252.50	133.75	52.90	18.73	4.89	18.35	26.67
L_2 x T_1	57.13	244.88	121.38	49.55	20.03	4.71	17.00	27.51
L_2 x T_2	57.00	250.00	126.38	50.59	18.24	5.00	18.10	27.13
L_3 x T_1	57.75	242.88	119.00	49.01	20.04	4.78	15.46	26.93
L_3 x T_2	57.88	238.25	122.75	51.46	17.95	4.89	17.50	23.91
L_4 x T_1	57.38	244.13	129.88	53.16	19.29	4.98	17.20	29.60
L_4 x T_2	57.63	253.63	138.25	54.35	17.70	4.90	19.75	27.07
L_5 x T_1	57.13	245.88	124.50	50.54	19.64	5.10	17.15	32.06
L_5 x T_2	58.38	254.25	128.88	50.56	17.14	4.86	18.05	24.69
L_6 x T_1	56.00	249.25	123.25	49.39	19.79	4.58	15.00	30.50
L_6 x T_2	56.86	232.50	119.38	51.31	16.20	4.63	16.95	20.21
L_7 x T_1	56.75	252.88	125.75	49.61	19.51	4.80	16.45	30.00
L_7 x T_2	58.25	248.63	139.25	55.49	16.86	4.74	16.75	22.13
L_8 x T_1	57.50	272.25	133.75	49.10	20.64	4.90	16.40	27.95
L_8 x T_2	56.38	252.00	127.88	50.65	17.93	5.04	17.90	29.14
L_9 x T_1	56.38	249.13	128.50	51.58	20.59	4.71	15.50	33.42
L_9 x T_2	56.63	252.25	127.88	50.60	17.44	4.79	17.85	25.37
L_{10} x T_1	57.13	257.50	133.25	51.66	20.83	5.11	17.10	30.40
L_{10} x T_2	57.13	249.50	127.63	51.05	16.73	4.93	18.50	25.67
L_{11} x T_1	57.63	255.25	131.63	51.61	19.10	4.75	15.45	30.76
L_{11} x T_2	57.88	229.88	125.13	54.29	16.21	4.80	16.40	24.88
L_{12} x T_1	57.63	257.75	136.25	52.75	19.20	4.89	16.60	28.72
L_{12} x T_2	57.38	248.00	129.88	52.31	15.90	5.03	18.25	24.97
L_{13} x T_1	58.25	264.00	136.50	51.61	20.18	4.96	18.25	27.29
L_{13} x T_2	58.00	260.88	135.88	51.98	16.10	5.20	19.48	27.29
L_{14} x T_1	56.50	257.00	132.13	51.28	19.81	4.91	16.40	27.45
L_{14} x T_2	57.50	248.50	130.38	52.45	17.93	4.94	17.90	24.83
L_{15} x T_1	58.25	245.88	123.63	50.19	19.21	4.66	15.45	26.46
L_{15} x T_2	58.50	230.75	116.75	50.54	17.10	4.81	17.60	23.80
SC 155	57.88	288.75	150.88	52.16	18.18	4.75	14.38	26.09
SC 162	59.13	289.88	155.75	53.41	21.48	4.70	14.68	27.77
LSD 0.05	1.01	9.50	7.34	2.26	0.93	0.15	0.82	2.92
0.01	1.32	12.48	9.65	2.97	1.23	0.20	1.08	3.84

Table 3: General combining ability (GCA) effects for the fifteen inbred lines and the two testers for all the studied traits combined over both locations.

Crosses	Silking date (days)	Plant height (cm.)	Ear height (cm.)	Ear position %	Ear length (cm.)	Ear diameter (cm.)	No. of rows ear^{-1}	Grain yield (ardab/fed)
Line-1	0.34	1.99	2.41	0.60	0.80**	-0.07	-0.31	0.70
Line-2	-0.35	-1.25	-4.71*	-1.35*	0.61*	-0.11**	0.42*	0.12
Line-3	0.40	-9.14**	-7.71**	-1.19*	0.46	-0.13**	-1.65**	-2.78**
Line-4	0.09	-0.83	5.48**	2.33**	-0.94**	0.07	1.34**	1.14
Line-5	0.34	-1.37	-1.90	-0.87	-0.84**	0.12**	0.47*	1.17
Line-6	-0.97**	-8.83**	-7.28**	-1.07	-0.64**	-0.27**	-1.16**	-1.84*
Line-7	0.09	1.80	3.91*	1.13*	-0.39	-0.10**	-0.53*	-2.13**
Line-8	-0.47	12.43**	2.23	-1.55**	0.75**	0.10**	0.02	1.35
Line-9	-0.91**	0.99	-0.40	-0.34	0.48*	-0.12**	-1.46**	2.20**
Line-10	-0.28	3.80	1.85	-0.07	0.25	0.15**	0.67**	0.84
Line-11	0.34	-7.14**	-0.21	1.53**	0.87**	0.09*	1.42**	1.62*
Line-12	0.09	3.18	4.48*	1.11	-0.98**	0.09*	0.29	-0.35
Line-13	0.72**	12.74**	7.60**	0.37	-0.39	0.22**	1.73**	0.09
Line-14	-0.41	3.05	2.66	0.44	0.34	0.06	0.02	-1.06
Line-15	0.97**	-11.39**	-8.40**	-1.06	-0.37	-0.13**	-1.24**	-1.07
LSD(L) 0.05	0.50	4.75	3.67	1.13	0.47	0.08	0.41	1.46
0.01	0.66	5.24	4.83	1.48	0.61	0.10	0.54	1.92
Tester-1	-0.13	2.93	-0.08	-0.61	1.32	-0.03	-0.82	2.01
Tester-2	0.13	-2.93	0.08	0.61	-1.32	0.03	0.82	-2.01
LSD(T) 0.05	0.24	1.73	1.34	0.41	0.17	0.03	0.15	0.53
0.01	0.18	2.28	1.76	0.54	0.22	0.04	0.20	0.70

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

Table 4: Specific combining ability (SCA) effects for thirty topcrosses for all the studied traits as a combined over all the two locations.

Crosses	Silking date (days)	Plant height (cm.)	Ear height (cm.)	Ear position %	Ear length (cm.)	Ear diameter (cm.)	No. of rows ear^{-1}	Grain yield (ardab/fed)
L_1 x T_1	0.133	-3.746	-2.671	-0.270	-0.721*	-0.058	-0.705*	-0.782
L_1 x T_2	-0.133	3.746	2.671	0.270	0.721*	0.058	0.705*	0.782
L_2 x T_1	0.196	-5.496	-2.421	0.093	-0.427	-0.115*	0.270	-1.824
L_2 x T_2	-0.196	5.496	2.421	-0.093	0.427	0.115*	-0.270	1.824
L_3 x T_1	0.071	-0.621	-1.796	-0.613	-0.277	-0.027	-0.198	-0.503
L_3 x T_2	-0.071	0.621	1.796	0.613	0.277	0.027	0.198	0.503
L_4 x T_1	0.008	-7.683*	-4.108	0.018	-0.527	0.067	-0.455	-0.749
L_4 x T_2	-0.008	7.683*	4.108	-0.018	0.527	-0.067	0.455	0.749
L_5 x T_1	-0.492	-7.121*	-2.108	0.599	-0.071	0.148*	0.370	1.673
L_5 x T_2	0.492	7.121*	2.108	-0.599	0.071	-0.148*	-0.370	-1.673
L_6 x T_1	-0.304	5.442	2.017	-0.351	0.473	0.004	-0.155	3.128*
L_6 x T_2	0.304	-5.442	-2.017	0.351	-0.473	-0.004	0.155	-3.128*
L_7 x T_1	-0.617	-0.808	-6.671*	-2.326*	0.004	0.060	0.670*	1.923
L_7 x T_2	0.617	0.808	6.671*	2.326*	-0.004	-0.060	-0.670*	-1.923
L_8 x T_1	0.696	7.192*	3.017	-0.163	0.035	-0.040	0.070	-2.610*
L_8 x T_2	-0.696	-7.192*	-3.017	0.163	-0.035	0.040	-0.070	2.610*
L_9 x T_1	0.008	-4.496	0.392	1.099	0.254	-0.008	-0.355	2.010
L_9 x T_2	-0.008	4.496	-0.392	-1.099	-0.254	0.008	0.355	-2.010
L_{10} x T_1	0.133	1.067	2.892	0.918	0.729*	0.123*	0.120	0.353
L_{10} x T_2	-0.133	-1.067	-2.892	-0.918	-0.729*	-0.123*	-0.120	-0.353
L_{11} x T_1	0.008	9.754*	3.329	-0.726	0.123	0.004	0.345	0.923
L_{11} x T_2	-0.008	-9.754*	-3.329	0.726	-0.123	-0.004	-0.345	-0.923
L_{12} x T_1	0.258	1.942	3.267	0.830	0.329	-0.040	-0.005	-0.138
L_{12} x T_2	-0.258	-1.942	-3.267	-0.830	-0.329	0.040	0.005	0.138
L_{13} x T_1	0.258	-1.371	0.392	0.430	0.717*	-0.090	0.208	-2.016
L_{13} x T_2	-0.258	1.371	-0.392	-0.430	-0.717*	0.090	-0.208	2.016
L_{14} x T_1	-0.367	1.317	0.954	0.024	-0.377	0.017	0.070	-0.704
L_{14} x T_2	0.367	-1.317	-0.954	-0.024	0.377	-0.017	-0.070	0.704
L_{15} x T_1	0.008	4.629	3.517	0.437	-0.265	-0.046	-0.255	-0.683
L_{15} x T_2	-0.008	-4.629	-3.517	-0.437	0.265	0.046	0.255	0.683
LSD 0.05	0.712	6.716	5.193	1.5495	0.659	0.11	0.583	2.068
0.01	0.936	8.826	6.826	2.097	0.866	0.144	0.766	2.718

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

Table 5: Estimates of genetic variance components for all studied traits over the two locations and their interaction with location.

Genetic parameters	Silking date (days)	Plant height (cm.)	Ear height (cm.)	Ear position %	Ear length (cm.)	Ear diameter (cm.)	No. of rows ear^{-1}	Grain yield (ardab/fed)
σ^2 L = σ^2GCA (Lines)	0.200	23.053	15.317	0.695	0.135	0.011	0.578	-0.972
σ^2T = σ^2GCA (Testers)	0.021	13.574	-1.310	0.653	3.463	0.0010	1.329	7.747
σ^2GCA = σ^2 GCA (aver.)	0.042	14.689	0.646	0.658	3.072	0.0022	1.241	6.721
σ^2LxT= σ^2SCA (aver.)	0.089	42.782	12.823	0.769	0.277	0.008	0.169	4.302
σ^2 GCA/σ^2 SCA = σ^2GCA aver /σ^2SCAaver.	0.472	0.343	0.050	0.856	11.082	0.284	7.334	1.562
σ^2L x Loc = σ^2GCA (L) x Loc	0.034	8.240	2.234	-0.488	0.002	0.009	-0.016	2.170
σ^2T x Loc = σ^2 GCA (T) x Loc	0.006	6.315	1.989	-0.102	0.021	0.003	-0.018	1.510
σ^2GCA x Loc = σ^2 GCA aver. x Loc	0.010	6.542	2.018	-0.148@	0.019	0.004	-0.017@	1.588
σ^2L x T x Loc. = σ^2S CA average x Loc	0.059	7.943	8.858	0.649	0.006	0.006	0.113	1.756
Contribution of Lines	70.553	57.970	71.767	55.820	13.794	72.533	45.409	19.757
Contribution of Tester	4.332	10.622	0.019	15.861	78.057	3.949	46.317	49.429
Contribution of L x T	25.114	31.409	28.214	28.319	8.149	23.518	8.274	30.813

@ Variance estimate proceeded by negative sign is considered zero, Robinson *et al.* [33], (T) Denote tester, (L) inbred lines and (Loc) locations.

Estimates of specific combining ability (SCA) effects for thirty topcrosses for all the studied traits as a combined over all the two locations are shown in Table 4. The results showed that the best SCA effects were obtained in the topcrosses L_6 x T_1 and L_8 x T_2 for grain yield; L_4 x T_1, L_5 x T_1, L_8 x T_2 and L_{11} x T_2 for plant height; L_7 x T_1 for ear height and ear position%. While, the topcrosses L_1 x T_2, L_{10} x T_1 and L_{13} x T_1 for ear length; L_2 x T_2, L_5 x T_1 and L_{10} x T_1 for ear diameter and L_1 x T_2 and L_7 x T_1 for no. of rows ear^{-1}.Genetic variance components for all the studied traits over all the two locations and their interaction with locations are illustrated in Table 5. Results revealed that estimates of $\sigma^2GCA_{(L)}$ were higher in magnitude than those of $\sigma^2GCA_{(T)}$ for silking date, plant height, ear height, ear position% and ear diameter, indicating that most of the total GCA variances were due to the inbred lines and the contribution of lines were higher than the contribution of the testers for these traits. General combining ability variance components σ^2GCA was larger than that σ^2SCA for ear length, no. of rows ear^{-1} and grain yield, indicating that the additive gene action played the major role than non-additive gene action in the inheritance of these traits. While, the σ^2SCA was larger than σ^2GCA for silking date, plant height, ear height, ear position% and ear diameter, indicating that non-additive gene action important than additive gene action in the inheritance for these traits under study. These results are similar with those reported by Mosa [9] for ear length, Shanghai *et al.* [27] and Paul and Debanth [28] for grain yield, Bello and Olaoye [15], Kumar *et al.* [29] and Joshi *et al.* [30] for silking date and Nawar and El-Hosary [10] for no. of rows ear^{-1} and grain yield and, no. of rows ear^{-1} and grain yield. Moreover, results showed that variance interactions of σ^2GCA_L x location was higher than σ^2GCA_T x location for silking date, plant height, ear height, ear position%, ear diameter and grain yield, indicating that the σ^2GCA for lines was affected more by environmental than by testers for these traits. Combined data revealed that the variance of σ^2GCA x location interaction was either smaller or negligible than the variance of σ^2SCA x location interaction for almost studied traits. These results indicated that the non-additive type of gene action was more affected by environmental conditions than additive effects. Similar results were reported by Aly and Mousa [8] and Mosa [9], Silva and Hallauer [21], Matzinger [31] and Lonnquist and Gardner [32].

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