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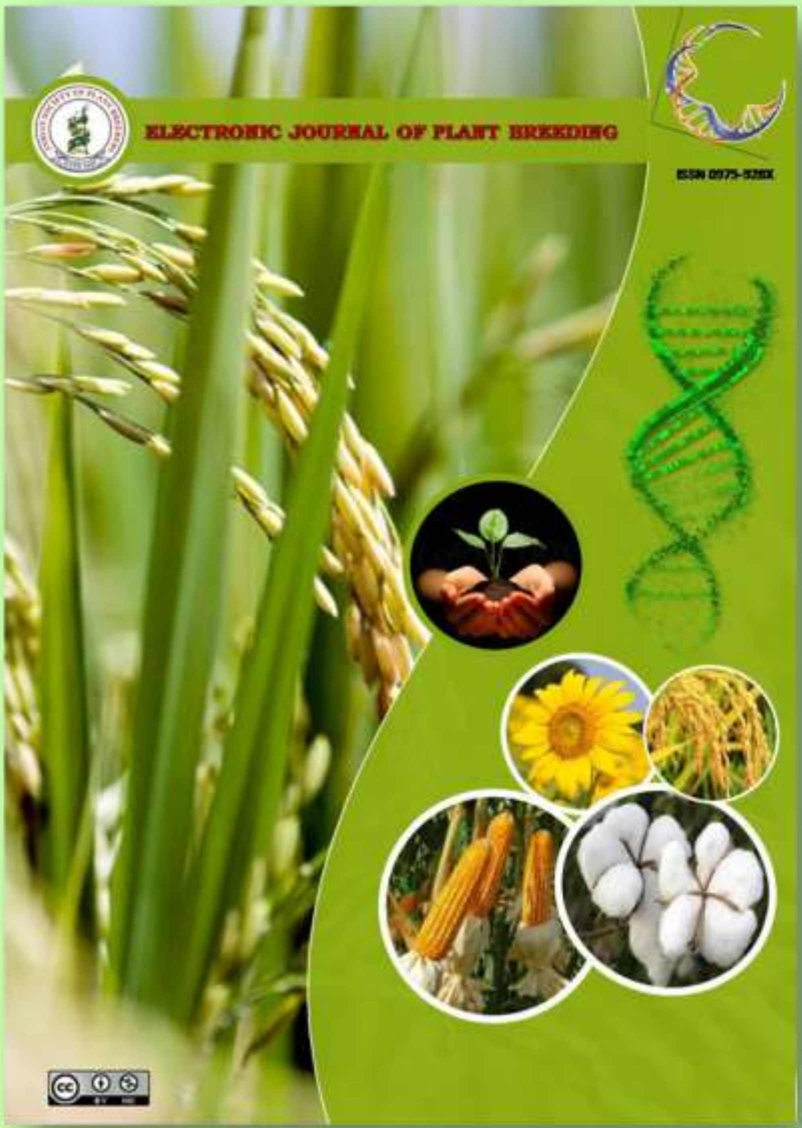

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Research Article

Assessment of combining ability effects using quality protein maize donors as testers for yield and yield traits in maize

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Abstract
The present study was accomplished to assess the general combining ability effects of parents and specific combining ability effects of hybrids for yield and yield related traits in maize. Sixty three F1 hybrids were developed and by crossing nine productive maize inbred lines with seven quality protein maize inbred testers in Line x Tester mating design and evaluated for twelve yield and yield related characters at CCSHAU, Regional Research Station, Karnal, Haryana. The combining ability analysis revealed the presence of higher magnitude of SCA than GCA variance for all characters under study except for number of grains per cob. The preponderance ratio of *sca/gca* variance revealed presence of non additive gene action in the expression of all the characters under study. Among the sixteen parents inbred lines *viz*., HKI 1040-4, HKI 323, HKI 161 and HKI 163 were found to be the best parent for grain yield and among the hybrids, HKI 1128 x HKI 163, HKI 659-3 x HKI 194-6, HKI 1126 x HKI 161, HKI 536YN x HKI 193-1 and HKI 488 x HKI 170(1+2) exhibited highest significant and favourable *sca* effects for yield and yield attributing characters.

Key words
gca, lines, QPM donors, *sca* and testers

Introduction

Maize (2n=2x=20) , also known as corn is an allogamous crop which is widely cultivated staple food crop after wheat and rice in tropical and subtropical regions throughout the world. This crop has tremendous potential for being used in diversified sectors like human food, animal and livestock feed *viz*., cattle, poultry and piggery both in the form of seeds and fodder. It is also an important industrial crop as it can be used for biofuel and in starch industries. The average grain yield of maize is highest as compared to other major cereal crops such as wheat and rice. Earlier, it was much used as important staple food in Africa and Central America, and now it is gaining remarkable importance in almost all other counties including India for its diversified uses. With the increasing demand for food and fodder, India is also on threshold of maize revolution (Sharma *et al.* 2017). It is therefore, inferred that improvement in yield addressed through release of single cross hybrids. The yield potential is realized in maize mainly due to success in hybrid breeding for exploitation of heterosis in the form of hybrids and synthetics. Furthermore, the increased yield caused by heterozygosity due to outcrossing has been well documented in maize. The identification of better combining lines by evaluating parents is most essential and critical for successful exploitation of heterosis. Moreover, the combining ability and effects provide imperative insight in selection of parents that could give rise to better hybrids when they are crossed. The value of any population depends on its potential *per se* and it's combining ability in crosses. In this context, L × T analysis (Kempthorne, 1957) has widely been used for evaluation of inbred lines by crossing them with testers (Kanagarasu *et al*., 2010, Sundararajan and Kumar, 2011, Abrha *et al.*, 2013, Elmyhum, 2013, Kambe *et al.*, 2013). Hence, the present study has been made through systematic experimentation to study the combining ability by using QPM donors as testers for yield and yield related traits in maize and to select the appropriate parental lines, hybrid combinations with useful *gca* and *sca* effects.

Materials and Methods

Nine productive maize inbred lines (referred to as female line) were crossed with seven quality protein maize inbred lines (referred to as male tester) in Line x Tester mating design to generate sixty three experimental hybrids during *kharif* and *rabi* of 2013-14 (Table 1).The field experiment consisted of sixty three experimental hybrids and parental inbred lines along with two standard checks HQPM 1 and HM 5 was conducted at research area of maize section of Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Karnal. The experiment was laid out in Randomized Complete Block Design in a two rows of 3m length along with three replications and border rows were also planted at each replication in order to avoid border effect. The inter-row and intra row was kept 75 cm and 20 cm respectively. All the recommended agricultural practices of CCS Haryana Agricultural University were adopted to maintain healthy crop. Ten highly competitive plants were selected and tagged in each plot and in each replication to record the observations on various yield and yield contributing traits *viz*., days to 50 per cent tasseling, days to 50 per cent silking; days to 50 per cent maturity, plant height, ear height, number of cobs per plant, cob length, cob diameter, number of grains per cob, hundred grain weight, grain yield per plant and shelling percentage. Mean values of each observation were collected to carry out analysis of variance for each character. At first the test of significance among all the genotypes including crosses and parents were estimated and when that were found significant then Line × Tester analysis was performed. Combining ability analysis was performed using OPSTAT software program, to partitioned treatment sum of square into sum of squares due to parents, crosses and parents vs. crosses with appropriate degree of freedom (Singh and Chaudhary, 1985). Heritability estimates in broad sense of each trait was computed as per Falconer (1989) to determine the progress under selection. The estimates of genetic advance were obtained as per Singh and Choudhary (1985) by computing the difference between the mean of the progeny of selected individuals and the base population.

Results and Discussion

The significant differences for parents vs. hybrids indicated the presence of heterosis and further indicated significant amount of genetic variability among lines and testers for all the characters (Table 2). The results revealed that different lines as well as testers showed markedly varied combining ability effects for all the characters except for number of cobs per plant (where only *sca* effects were significant for only one cross) and cob diameter (where none of the cross exhibits significant *sca* effects) which in turn revealed importance of additivity and non-additivity in the inheritance of these characters. This warranted further estimation of *gca* and *sca* effects for characters being studied. Significant differences for *gca* and *sca* effects for the characters under study were also reported by Mutimaamba *et al.,* (2010), Singh *et al.,* (2013), Elmyhum (2013) and Hemalatha *et al*., (2014).

The data in table 3 indicated a wide range of variability for gca effects among the parents for different characters. Good combiners were identified on the basis of high and significant *gca* effects towards the desired direction. Perusal of the table revealed that no line was observed to be a good combiner for all the traits, however good combiners for more than two characters identified. Among the lines, HKI 1040-4 and HKI 323 exhibited significant positive *gca* effects for most of the traits including grain yield. Among the testers, HKI 161 and HKI 163 were considered good combiners for grain yield and other traits. Such parents contribute favourable alleles in the process of synthesis of new varieties and these potential lines and testers could be efficiently utilized. Earlier similar reports of good combiner for more than three characters were also reported by Singh and Gupta (2009); Ruth *et al.,* (2010); Elmyhum (2013); Kambe *et al.,* (2013); Hemalatha *et al.,* (2014).

High and positive *sca* effect is desirable for grain yield, cob length, cob diameter, number of grains per cob, shelling percentage and 100 grain weight. Both negative and positive and significant estimates of *sca* effects were observed among the crosses for grain yield per plant (Table 4). Magnitude of *sca* effect for grain yield per plant revealed that fifteen crosses showed significant positive *sca* effects for grain yield per plant and majority of crosses were having at least one average combiner parent. A critical evaluation of the results with respect to specific combining ability effects expressed that none of the cross combinations exhibited desirable significant *sca* effects for all the characters. The crosses HKI 1128 x HKI 163, HKI 659-3 x HKI 194-6, HKI 1126 x HKI 161, HKI 536YN x HKI 193-1 and HKI 488 x HKI 170(1+2) with high positive and significant estimates of *sca* effects for more than two traits could be selected for their specific combining ability to use in maize improvement. The *sca* effects of the crosses did not show any specific trends in cross combinations between parents possessing high, medium and low *gca*. In most of the cases, the crosses those showed high *sca* effects involved at least one good general combiner. The superiority of crosses involving high × low combiners as parents could be explained on the basis of interaction between positive alleles from good combiners and negative alleles for the poor combiners as parents. The high yield of such crosses would be non-fixable and thus could be exploited for heterosis breeding. These results are in agreement with the findings of Iqbal *et al.* (2007) and Shams *et al.* (2010), Lal *et al*. (2011), Ruswandi *et al*. (2015), Yerva *et al*. (2016) who reported high and significant level of *sca* effects in most of the crosses they studied for grain yield in maize. Earlier reports of Xingming *et al.* (2002) also suggested that good *gca* parents play positive role in high yielding crosses. Amiruzzaman *et al.* (2011) also pointed out that the *sca* effect is a result of the interaction of *gca* effects of the parents and that it can improve or deteriorate the hybrid expression compared to the expected effect based on *gca* only. These results are supported by, Hemavathy and Balaji (2008) while in contrary, Ivy and Howlader (2000) obtained high *sca* effect for grain yield in low × low general combining parents and revealed that crosses with high *sca* effects did not always had parents with good *gca* effects. For other yield contributing traits most of the top ranking specific combiners revealed average specific combining ability and from the results it was concluded that *gca* effects of the parents did not reflected in their *sca* effects for all the traits. Such a relationship between *gca* and *sca* indicates the importance of epistasis and crosses are expected to produce desirable transgressive segregants. The results obtained in the present study are mostly in conformity with the earlier findings of Mahto and Ganguli (2003), Malik *et al.* (2004) and Kanagarasu *et al.* (2010) for grain yield and other component characters.

Results regarding gene action, based on variance of GCA: SCA presented in Table 5 revealed that the preponderance ratio (GCA: SCA) was less than unity for all the characters except number of grains per cob, thus, indicated that non additive gene action had played more role in these characters. The SCA variances were in general higher than the GCA variances which depict that one can go for hybrid breeding programme in future with the present set of breeding material. Similar results were reported by Jabeen *et al*. (2007), Ruth *et al.* (2010), Abrha *et al.* (2013), Singh *et al.* (2013), Elmyhum (2013), Kapoor and Lata (2013), Hemalatha *et al.* (2014), Chahar *et al.* (2014). Contrarily, importance of additive gene effects was reported by Sharma *et al*. (2004) and Alamnie *et al.* (2006). The percentage contribution of line × tester interactions was found higher than testers for all the characters except for days to 50 percent tasseling and 50 percent silking. Similar findings were reported for ear length and ear diameter by Kanta *et al*. (2005).

The study impetus that on the basis of overall performance of F_1 hybrids and parental lines, it is possible to select some lines with good *gca* and yield potential and hybrids with good *sca*. Hence, the present study contently helped in identifying superior parents such as HKI 323, HKI 1040-4, HKI 161 and HKI 163 and crosses HKI 1128 x HKI 163, HKI 659-3 x HKI 194-6, HKI 1126 x HKI 161, HKI 536YN x HKI 193-1 and HKI 488 x HKI 170(1+2) could be exploited in the production high yielding hybrids with good protein quality combination since testers are promising QPM lines. The performance of such desirable crosses need to be evaluated first at a few location and subsequently for the top one or two hybrids in multilocation trial at farmer field to confirm their superiority

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Table 1. List of inbred lines used to develop experimental hybrids

S. No.	♀ (Normal and productive inbreds)	S. No.	♂ (Quality protein maize inbreds)
1	HKI 1128 (L1)	**1**	HKI 163 (T1)
2	HKI 288-2 (L2)	**2**	HKI 161 (T2)
3	HKI 659-3 (L3)	**3**	HKI 170(1+2) (T3)
4	HKI 323 (L4)	**4**	HKI 194-6 (T4)
5	HKI 1126 (L5)	**5**	HKI 193-1 (T5)
6	HKI 1105 (L6)	**6**	HKI 193-2 (T6)
7	HKI 536YN (L7)	**7**	HKI 5072-BT(1-2)-2 (T7)
8	HKI 488 (L8)		HQPM 1 (Check 1)
9	HKI 1040-4 (L9)		HM 5 (Check 2)

Table 2. Analysis of variance (MSS) of parents, hybrids and combining ability for different traits in a line x tester crosses of maize

Sources of variation	d.f	Days to 50 % tasselling	Days to 50 % silking	Days to maturity	Plant height (cm)	Ear height (cm)	No. of cobs per plant	Cob length (cm)	Cob diameter (cm)	Number of grains / cob	100 grain weight (g)	Grain yield per plant (g)	Shelling percentage
Replication	2	1.987	1.549	1.447	103.085	21.444	1.392	2.941	0.17	229.99	3.734	75.541	22.781
Genotypes	78	18.92**	14.93**	24.73**	2923.57**	431.53**	3.51**	11.93**	0.47**	34148.92**	21.82**	1999.45**	21.32**
Females	8	19.92**	5.17**	25.91**	337.95**	352.87**	2.07**	5.78**	0.65**	4368.28**	25.09**	209.53**	18.36**
Males	6	14.93**	13.52**	25.42**	178.63**	176.54**	10.3**	6.05**	0.74**	4616.15**	13.94**	74.44	40.78**
Hybrids	62	15.16**	14.48**	13.63**	2007.08**	141.57**	3.09**	4.73**	0.20**	8731.36**	16.98**	939.18**	16.92**
Males Vs Females	1	7.64**	14.03**	8.67**	8.89	7.05	0.62	5.21*	0.35	296.56	0.1	8.28	1.02
Parents Vs Hybrids	1	279.26**	130.42**	715.49**	99815.5**	20993.1**	2.77	548.97**	14.67**	2059331.9**	365.09**	95596.8**	221.56**
Error	**156**	**1.26**	**1.39**	**1.17**	**86.25**	**26.14**	**0.02**	**0.87**	**0.15**	**59.03**	**2.36**	**38.17**	**5.99**
Line	8	60.31**	67.32**	31.14	6363.57**	185.33**	0.03**	4.03**	0.02	17537.68**	5.70**	1324.49**	24.34**
Tester	6	3.22**	2.91**	13.79	1216.19**	155.03**	0.06**	6.19**	0.13	5457.01**	28.81**	1182.40**	26.99**
LinexTester	48	5.70**	7.11**	10.69	1379.82**	132.59**	0.06**	4.67**	0.13**	7838.70**	17.38**	844.56**	14.42**
Error	**124**	**1.21**	**1.34**	**0.95**	**91.23**	**29.47**	**0.02**	**1.06**	**0.18**	**47.13**	**1.91**	**45.18**	**2.76**

*:**Significant at 5 and 1% levels respectively

Table 3. Estimates of *gca* effects for different traits in lines and testers of maize

Parents	Days to 50 % tasselling	Days to 50 % silking	Days to maturity	Plant height (cm)	Ear height (cm)	No. of cobs per plant	Cob length (cm)	Cob diameter (cm)	Number of grains / cob	100 grain weight (g)	Grain yield per plant (g)	Shelling percentage
Lines												
HKI 1128	2.772*	2.661**	1.603**	22.423**	-0.365	0.077	0.401	-0.024	-35.646**	0.546	-5.358**	-0.457
HKI 288-2	1.963*	1.947**	1.651**	25.804**	6.063**	0.039	0.387	-0.01	-14.788**	-0.915*	-7.492**	-0.186
HKI 659-3	-0.323	-0.672	-0.349	-16.624**	-3.556*	-0.018	-0.747*	0.009	7.354**	0.518	2.606	0.101
HKI 323	-2.466**	-2.339**	-0.873**	-8.72**	-3.556*	-0.028	0.087	-0.024	18.164**	-0.457	7.393**	-0.034
HKI 1126	-2.942**	-2.720**	-1.778**	-8.386**	1.397	0.001	0.311	0.052	10.831**	0.239	2.478	-0.771
HKI 1105	0.201	0.090	0.413	-18.624**	-3.032	-0.037	-0.037	0.047	-51.503**	-0.176	-13.82**	-1.718**
HKI 536YN	0.915**	0.947**	0.937**	-16.196**	1.635	-0.056	-0.642*	-0.029	11.545**	-0.386	0.219	-0.155
HKI 488	0.487	0.566	-0.594*	13.09**	0.968	0.001	0.430	-0.029	12.116**	0.065	1.353	1.244*
HKI 1040-4	-0.668*	-0.481	-1.111**	7.233*	-0.698	0.02	-0.289	0.009	41.926**	0.565	12.621**	1.976**
SE± GCA (Lines)	0.339	0.357	0.302	2.947	1.675	0.042	0.318	0.133	2.1187	0.4267	2.0743	0.5127
C.D (5 %)	0.666	0.701	0.592	5.777	3.284	0.082	0.624	0.261	4.153	0.836	4.066	1.005
C.D (1 %)	0.875	0.922	0.778	7.593	4.316	0.108	0.820	0.343	5.458	1.099	5.343	1.321
Testers												
HKI 163	0.386	0.397	1.032**	4.148	3.947**	0.083*	-0.337	0.071	0.524	1.155**	7.15**	0.274
HKI 161	-0.206	-0.122	0.143	8.63**	1.54	0.046	-0.119	0.063	-6.624**	1.539**	8.001**	1.099*
HKI 170(1+2)	-0.593*	-0.655*	-1.339**	-6.926**	-3.312*	-0.006	-0.137	-0.022	-19.365**	0.167	-3.149	1.209**
HKI 194-6	0.09	0.101	-0.153	-5.481*	-2.349	-0.051	0.819**	-0.118	13.153**	-0.501	0.342	-0.534
HKI 193-1	0.597*	0.286	0.254	-0.926	0.058	-0.043	0.063	0.026	-15.328**	-1.255**	-11.175**	-1.650**
HKI 193-2	0.127	0.175	0.254	7.333**	0.095	-0.029	0.363	0.045	12.487**	-0.896*	-3.036	0.092
HKI 5072-BT(1-2)-2	-0.392	-0.381	-0.19	-6.778**	0.021	0.001	-0.652*	-0.066	15.153**	-0.209	1.866	-0.49
SE± GCA (Testers)	0.299	0.315	0.266	2.599	1.477	0.037	0.280	0.117	1.8685	0.3763	1.8294	0.4522
C.D (5 %)	0.587	0.618	0.522	5.095	2.896	0.073	0.550	0.230	3.662	0.738	3.586	0.886
C.D (1 %)	0.772	0.813	0.686	6.697	3.806	0.096	0.723	0.303	4.813	0.969	4.713	1.165

*:**Significant at 5 and 1% levels respectively

Table 4. Estimates of *sca* effects for different traits in lines and testers of maize

Sr. No.	Crosses	Days to 50% tasselling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height (cm)	No. of cobs per plant	Cob length (cm)	Cob diameter (cm)	Number of grains/cob	100 grain weight (g)	Grain yield per plant (g)	Shelling per centage
1	L1×T1	1.376	1.413	**2.730****	**46.947****	**12.624****	**0.508****	1.466	0.258	**120.238****	0.511	**27.729***	-1.705
2	L1×T2	0.635	0.931	0.619	**-19.201***	-2.968	-0.055	-0.653	0.032	**-57.947****	1.610	**-11.322***	-1.877
3	L1×T3	0.598	0.265	0.101	**-44.312****	**-8.783***	**-0.270***	1.099	0.217	**59.794****	**-2.958****	1.438	**2.844***
4	L1×T4	0.339	0.376	-1.085	-7.423	-1.413	-0.025	0.477	-0.253	**-45.392****	**3.180****	-0.300	0.63
5	L1×T5	-0.069	0.19	0.508	7.354	2.18	0.034	-1.001	0.369	**-24.91****	1.581	-0.469	0.035
6	L1×T6	-1.365	-1.698	-0.825	12.429	-1.524	-0.181	0.232	-0.416	**28.608****	0.291	8.988	1.534
7	L1×T7	**-1.713***	-1.476	**-2.048***	4.206	-0.116	-0.011	-1.62	-0.205	**-80.392****	**-4.215****	**-26.064****	-1.461
8	L2×T1	-1.148	-1.206	-1.317	**-16.101***	-7.138	-0.054	-0.787	-0.09	**-18.286****	-1.202	**-11.317***	2.081
9	L2×T2	-0.889	-0.688	-1.095	**26.751****	-5.063	-0.084	-1.572	0.117	4.862	-0.216	7.426	**3.459***
10	L2×T3	1.407	0.979	0.72	-3.693	1.455	0.168	1.28	-0.264	**-39.063****	-1.058	**-11.581***	-1.62
11	L2×T4	1.148	1.09	**2.868****	14.862	4.825	0.013	-1.309	-0.268	**-25.249****	1.897	-1.402	**-3.365***
12	L2×T5	0.074	-0.095	-0.54	-3.026	1.751	-0.195	0.08	0.021	**58.566****	**-2.658***	0.888	0.828
13	L2×T6	-0.556	0.016	**-2.54****	**17.714***	**9.048***	0.057	0.447	0.236	**19.418****	1.459	**13.379***	0.016
14	L2×T7	-0.037	-0.095	**1.905***	**-36.508****	-4.878	0.094	**1.861***	0.247	-0.249	1.779	2.607	-1.399
15	L3×T1	1.471	0.746	0.349	-14.339	-1.852	-0.063	-0.287	0.158	**17.905****	**2.289***	**17.485****	1.988
16	L3×T2	-2.270	**-2.402***	**-1.862***	**-30.153****	-8.111	-0.093	1.161	-0.035	0.053	-1.650	-10.242	-1.338
17	L3×T3	-0.307	-0.069	0.386	**24.735****	5.407	-0.108	-0.587	-0.05	**21.794****	-0.863	-2.973	-0.454
18	L3×T4	0.767	0.709	-1.466	-4.709	5.111	-0.130	0.424	-0.087	**62.608****	**2.784***	**27.82****	**3.612****
19	L3×T5	0.360	0.857	**2.127****	-0.265	4.704	0.129	0.480	-0.331	**-25.243****	**-3.927****	**-18.406****	**-4.319****
20	L3×T6	**-2.937****	**-2.698****	**-2.206****	12.810	-5.000	0.181	-0.920	0.017	**-36.392****	1.726	-0.139	1.906
21	L3×T7	**2.915****	**2.857****	**2.571****	11.921	-0.259	0.085	-0.272	0.328	**-40.725****	-0.334	**-13.544***	-1.396
22	L4×T1	-0.386	0.079	1.206	**-41.243****	**-10.328***	0.013	0.013	-0.576	**18.762****	0.188	10.381	0.839
23	L4×T2	0.206	0.265	0.095	**-27.058****	-6.921	0.05	1.395	-0.135	6.243	1.443	**15.761****	1.181
24	L4×T3	-0.497	-0.402	0.243	-1.503	0.598	0.102	0.113	-0.150	**-24.349****	0.495	**-12.109***	-0.639
25	L4×T4	-0.423	-0.291	**-0.275**	-3.947	-1.698	-0.054	-0.476	0.113	**-26.868****	**-3.587****	**-23.18****	-0.933
26	L4×T5	0.836	0.524	**-1.016**	**41.164****	7.561	-0.128	-1.42	0.269	0.614	0.124	2.570	1.819
27	L4×T6	1.540	1.635	1.317	**42.238****	**12.19****	-0.010	-0.653	0.050	**-25.201****	-1.012	**-12.199***	**-2.916***
28	L4×T7	-1.275	**-1.860***	**-1.571***	-9.651	-1.402	0.028	1.028	0.428	**50.799****	**2.348***	**18.776****	0.649
29	L5×T1	0.090	-0.206	-0.556	**15.423***	2.196	**-0.283***	1.356	0.048	**51.762****	**-2.372***	-0.891	1.333
30	L5×T2	-0.651	-0.688	**-2.333****	-7.058	1.270	-0.046	0.604	0.056	**37.577****	1.930	**21.225****	-0.686
31	L5×T3	-1.354	-1.354	**-1.852***	4.497	3.455	-0.060	0.456	0.074	**-23.349****	1.742	10.572	1.005
32	L5×T4	-0.280	0.090	0.630	-1.947	3.492	0.117	0.501	0.37	**-22.868****	**-3.537****	**-19.763****	-0.553
33	L5×T5	-0.021	-0.095	1.222	4.831	0.751	0.110	1.023	-0.241	8.614	0.434	-0.589	0.333

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34	L5×T6	1.016	0.683	-0.444	-12.762	**-10.619***	0.095	**-2.144***	0.141	**-77.201****	1.051	**-19.128****	**-3.805****
35	L5×T7	1.201	1.571	**3.333****	-2.984	-0.545	0.066	**-1.796***	-0.448	**25.466****	0.751	8.573	2.373
36	L6×T1	**-1.720***	**-1.883***	**-1.746***	2.661	5.291	0.089	0.704	-0.314	**-25.905****	0.056	-8.719	-2.654
37	L6×T2	-0.127	-0.164	0.476	3.513	6.698	-0.074	-0.448	-0.04	**35.243****	**-4.318****	**-11.55***	-0.089
38	L6×T3	-0.164	0.169	-1.376	-0.598	-6.783	-0.089	**-2.396****	0.179	**-88.349****	**2.690***	-6.160	-1.975
39	L6×T4	0.577	0.28	-0.894	2.958	-3.413	0.022	0.748	0.308	**-25.201****	**-2.835***	**-13.661***	**-3.019***
40	L6×T5	-0.164	0.095	0.698	5.402	5.847	-0.052	**1.67***	-0.103	**43.614****	1.406	**13.936***	**3.576****
41	L6×T6	**2.206***	**2.206***	**3.698****	-9.190	-2.190	0.200	0.404	-0.154	**14.132***	1.427	9.313	**2.915***
42	L6×T7	-0.608	-0.905	-0.857	-4.746	-5.450	-0.096	-0.681	0.123	**46.466****	1.573	**16.841***	1.246
43	L7×T1	0.233	0.460	-0.603	-3.767	-0.376	-0.025	-0.292	0.262	**-67.286****	1.216	**-14.035***	-1.383
44	L7×T2	**2.159***	1.979*	**4.619****	5.751	2.032	0.078	1.59	0.237	1.862	-0.511	-6.792	0.572
45	L7×T3	**2.122***	**2.312***	**2.434****	**15.640***	2.550	0.197	-0.625	-0.245	-0.063	-0.723	-1.963	-1.318
46	L7×T4	0.196	0.090	-0.418	-5.804	-2.079	-0.092	-0.014	0.118	**21.418****	0.935	9.186	1.304
47	L7×T5	**-2.312****	**-2.429***	-1.492	-13.693	-7.487	0.034	0.008	-0.326	**39.899****	**4.663****	**27.937****	-1.903
48	L7×T6	-1.175	-1.317	-0.825	**-16.286***	3.143	-0.114	0.442	-0.045	**76.418****	-0.630	**19.614****	**3.892****
49	L7×T7	-1.323	-1.095	**-3.714****	**18.159***	2.217	-0.077	-1.110	-0.001	**-72.249****	**-4.950****	**-33.948****	-1.163
50	L8×T1	0.661	0.841	-0.841	-2.386	3.291	-0.216	**-2.196***	0.129	**-89.857****	**-3.152****	**-31.269****	-1.045
51	L8×T2	**1.921***	**2.026***	0.714	**30.132****	**10.032***	0.021	-0.415	0.203	**-31.376****	0.660	-7.313	-0.047
52	L8×T3	0.550	0.693	0.862	1.688	**-9.116***	0.140	0.504	0.155	**61.698****	0.146	**13.387***	-0.56
53	L8×T4	-0.042	-0.196	**1.677***	-13.423	-8.746	0.117	-0.885	-0.215	**55.18****	1.553	**19.876****	2.029
54	L8×T5	0.217	-0.048	-1.397	**-17.646***	-6.153	-0.09	1.304	0.440	**-16.672****	0.572	-0.407	-0.222
55	L8×T6	-1.413	-1.603	-0.063	**-22.238****	2.143	-0.038	0.537	-0.378	**21.18****	**-2.658***	-6.666	-0.193
56	L8×T7	**-1.894****	-1.714	-0.952	**23.873****	8.550	0.066	1.152	-0.334	-0.153	**2.879***	**12.392***	0.038
57	L9×T1	-0.577	-0.444	0.778	12.804	-3.709	0.032	0.023	0.124	-7.333	**2.465***	10.637	0.546
58	L9×T2	-0.984	-1.259	-1.333	**17.323***	3.032	0.202	**-1.662***	-0.435	3.481	1.077	2.806	-1.176
59	L9×T3	**-2.354****	**-2.593****	-1.519	3.545	**11.217***	-0.079	0.156	0.084	**31.889****	0.529	9.389	**2.718***
60	L9×T4	**-2.380***	**-2.148***	-1.037	**19.434***	3.921	0.032	0.534	-0.087	6.370	-0.390	1.425	0.294
61	L9×T5	0.979	1.000	-0.111	**-24.122****	**-9.153***	0.158	**-2.144***	-0.098	**-84.481****	**-2.295***	**-25.461****	-0.147
62	L9×T6	**2.683****	**2.778****	**1.889***	**-24.714****	-7.190	-0.190	**1.656***	0.550	**-20.963****	-1.655	**-13.164***	**-3.349***
63	L9×T7	**2.534****	**2.667****	1.333	-4.270	1.884	-0.153	1.438	-0.139	**71.037****	0.169	**14.367****	1.113
Standard Error		0.8991	0.9466	0.7993	7.7987	4.4326	0.1112	0.8421	0.3527	5.6055	1.1289	5.4882	1.3565
C.D (5 %)		1.762	1.855	1.567	15.285	8.688	0.218	1.651	0.691	10.987	2.213	10.757	2.659
C.D (1 %)		2.316	2.438	2.059	20.089	11.418	0.286	2.169	0.909	14.440	2.908	14.138	3.494

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Table 5. Proportional contribution of lines, testers and their interactions to genetic components of variance or estimates of the variance due to GCA, SCA, dominance variance and additive variance for different traits in maize crosses

Sr. no.	Character	σ^2 gca	σ^2 sca	Ratio gca : sca	σ^2 (A) Additive	σ^2 (D) Dominance	σ^2 (A) / σ^2 (D)	Percentage Contribution of		
								Lines	Testers	Interaction
1	Days to 50 % tasseling	1.32	1.90	0.69	5.27	7.60	0.69			
2	Days to 50 % silking	1.07	2.15	0.50	4.29	8.60	0.50	1.94	60.00	38.06
3	Days to maturity	1.37	3.10	0.44	5.48	12.42	0.44	9.79	29.48	60.73
4	Plant height (cm)	103.39	633.08	0.16	413.54	2532.33	0.16	5.86	40.91	50.23
5	Ear height (cm)	25.91	44.99	0.58	103.64	179.97	0.58	10.60	16.89	72.51
6	No. of cobs per plant	0.00	0.002	0.00	0.00	0.01	0.20	9.75	7.21	83.04
7	Cob length (cm)	0.95	1.52	0.62	3.80	6.08	0.62	12.65	10.97	76.37
8	Cob diameter (cm)	0.02	0.08	0.24	0.07	0.30	0.24	3.58	1.35	92.07
9	Number of grains / cob	3329.38	3056.90	1.09	13317.52	12227.60	1.09	5.96	25.54	68.50
10	100 grain weight (g)	503.14	6368.27	0.08	2012.57	25473.07	0.08	16.42	4.33	79.25
11	Grain yield per plant (g)	88.95	296.52	0.30	355.08	1186.09	0.30	12.18	18.20	69.62
12	Shelling percentage	75.93	84.94	0.89	303.73	339.74	0.89	15.43	18.56	66.01