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Combining Ability and Genetic Action Studies for Yield and Its Related Traits in Maize (*Zea mays* L.)

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A B S T R A C T

Forty five hybrids were generated from crossing fifteen lines with three testers in line × tester design. The hybrids along with parents were evaluated for yield and yield component traits to study combining ability and gene action in maize. The general combining ability (*gca*) and specific combining ability (*sca*) were significant for all the characters, which indicates the importance of both additive and non-additive genetic components. However it is found that there was predominance of non-additive gene action was recorded for all the characters. Among the female lines, BM 5050, BM 1234, BM 3511-2 and BM 3521 A-2 and in testers *viz.*, BML 10 and BML 7 were found to be good general combiners for grain yield and yield component traits. The most promising specific combiners for grain yield and other traits were BM 5050 × BML 10, BM 3511-2 × BML 7, BM 1234 × BML 10, BM 1234 × BML 13 and BM 5050 × BML 7. These hybrids can be further tested over locations before releasing as commercial hybrids.

Keywords

Maize, combining ability, *gca*, *sca*, additive, dominance

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Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops ranks next to rice and wheat in area and production in the world and grown under diverse agro-climatic conditions in India. Maize being a C_4 plant is physiologically more efficient, has higher grain yield and wider adaptation over wide range of environmental conditions. Maize had assumed greater significance due to its demand for human food, animal feed and industrial utilization. Being a highly allogamous crop, it had been successfully exploited in the production of hybrids which played a vital role in increasing acreage and productivity of maize. Combining ability is the ability of a genotype to transmit its desirable performance to its crosses. Combining ability studies are to identify superior parents with good combining ability which may be used to build-up a population with favourable and fixable genes for effective yield improvement. The variance due to general combining ability (*gca*) is an indicator of the extent of additive type of gene action, whereas specific combining ability (*sca*) is the measure of non- additive type of gene actions in heterosis breeding. Hence the present study was under taken to estimate the combining ability of parents and hybrids, the nature and magnitude of gene action for yield and yield component traits in maize by using Line x Tester analysis (Kempthorne, 1957).

Materials and Methods

The experimental material comprised of fifteen lines and three testers. These were crossed in line x tester design during *rabi*, 2010-11at Maize Research Centre, Rajendranagar. The resultant 45 hybrids along with their parents and 2 checks (DHM 115 and DHM 117) were evaluated in randomized block design with three replications for combining ablility at Research farm, College of Agriculture, PJTSAU (formerly part of ANGRAU), Rajendranagar, Hyderabad during *kharif*, 2011. Each entry was raised in two rows with a row length of 4m and the spacing maintained was 75cm between rows and 20cm between plants. The recommended package of practices was followed to raise a good crop.

Observations were recorded on five randomly selected plants for plant height, ear height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, 100-kernel weight and grain yield per plant. However, observations for the characters namely days to 50 percent tasseling, days to 50 percent silking, days to maturity were recorded on plot basis. The mean values were analyzed for combining ability using Line x Tester analysis (Kempthorne, 1957).

Results and Discussion

The analysis of variance for combining ability revealed highly significant differences among the parents and hybrids for all the characters studied presented in Table 1. Partitioning of crosses into lines, testers and line x tester revealed that the variance due to lines was significant for days to 50% tasseling and number of kernels per row whereas in testers significance was found for plant height, ear height and ear length. Interaction effect, line x tester was significant for all the characters indicating genetic difference among them and also importance of specific combining ability. The estimates of variance due to *sca* were higher than *gca* variance indicating the predominance of non-additive gene action for all the characters presented in Table 2. The role of non-additive gene action for grain yield and its component traits had been reported earlier by Ruswandi *et al.,* (2015), Atif Ibrahim Abuali *et al.,* (2013), Afshar Estakhr and Bahram Heidari (2012), Ram Reddy *et al.,* (2011), Kanagarasu *et al.,* (2010) and Jayakumar and Sundram (2007).

Five lines BM 5050, BM 1234, BM 3511-2 and BM 3521 A-2 and two testers *viz.,* BML 10 and BML 7 recorded high gca values and found to be good general combiners for grain yield presented in Table 3. The line BM 5050 was good general combiner for days to 50 percent tasseling, days to 50 percent silking, ear length, ear girth, number of kernels per row, 100-kernel weight and grain yield per plant. The line 1234 was good general combiner for days to 50 percent tasseling, days to 50 percent silking, ear length, ear girth, number of kernel rows per ear and 100-kernel weight. The line BM 3511-2 was good general combiner for ear length, ear girth, number of kernel rows per ear, number of kernels per row and 100-kernel weight. Whereas line BM 3521A-2-3was good general combiner for ear height, ear length, ear girth, number of kernel rows per ear and number of kernels per row. The line BM 5040 was good general combiner for ear height and 100-kernel weight. Whereas, line BM 5059was good general combiner for 100-kernel weight. Among testers, BML 10 was good general combiner for days to 50 percent tasseling, days to 50 percent silking, ear height, ear girth, number of kernel rows per ear and 100-kernel weight. Whereas, tester BML 7 was good general combiner for plant height, ear girth and number of kernels per row.

Table.1 Analysis of variance for combining ability for yield and yield component characters in maize

Source	d.f	Days to 50% tasseling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height(cm)	Ear length(cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100 kernel weight (g)	Grain yield (g perplant)
Replications	2	2.13	3.11	6.68	444.45 *	226.27 **	1.46 *	0.89 *	0.02	0.13	0.06	2.13
Genotypes	62	42.27 **	43.48 **	38.40**	1650.06 **	497.19**	12.39 **	4.40 **	3.76**	79.98**	45.75 **	4590.39**
Parents	17	65.49 **	69.34**	49.73**	1748.84 **	391.99**	10.06**	2.41**	3.69**	96.54**	29.53 **	3571.86 **
Parent vs crosses	1	720.57 **	697.30**	267.47**	37354.67**	11020.24**	411.60**	128.59**	46.23**	2608.55**	1048.83 **	175151.61**
Crosses	44	17.88 **	18.63**	28.82**	800.43**	298.67**	4.21**	2.35**	2.83**	16.12**	29.22 **	1107.52 **
Lines	14	30.59 **	26.48	42.41	545.12	243.81	5.13	3.11	3.50	28.10 *	33.98	1557.75
Testers	2	26.58	19.48	35.46	3712.28 *	1708.98 **	17.64 **	3.43	3.21	5.05	19.41	1272.01
Line x Testers	28	10.90 **	14.63**	21.55**	720.10**	225.37**	2.80 **	1.90**	2.46**	10.92**	27.54**	870.66**
Error	124	1.809	1.836	2.424	134.187	36.018	0.342	0.180	0.134	0.541	0.197	3.577

***** Significant at 5 per cent level; ****** Significant at 1 per cent level.

Table.2 Estimation of *gca* and *sca* variance for yield and yield component characters in maize

Source	Days to50% tasseling	Days to 50% silking	Days to maturity	Plant height(cm)	Ear height(cm)	Ear length(cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100 kernel weight (g)	Grain yield (g per plant)
σ^2 *gca*	0.0888	0.0508	0.0926	1.0228	0.9333	0.0180	0.0058	0.0046	0.0662	0.0214	3.0156
σ^2 *sca*	3.0310	4.2676	6.3765	195.3042	63.1183	0.8203	0.5750	0.7777	3.4606	9.1159	289.0285
σ^2 *gca*/σ^2 *sca*	0.0292	0.0119	0.0145	0.0052	0.0147	0.0219	0.0101	0.0059	0.0191	0.0023	0.0104

Table.3a Estimates of general combining ability (gca) effects for yield and yield component characters in maize

S. No	Source	Days to 50% tasseling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height(cm)	Ear length(cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100 kernel weight (g)	Grain yield (g perplant)
	Lines											
1.	**BML 14**	-2.32**	-2.26**	-0.86	0.82	-0.29	-0.68**	0.25	-0.12	-3.09**	3.35**	-2.25**
2.	**PVT MH, 08-09**	0.45	0.73	2.91**	-3.55	0.74	-0.14	-0.38**	-0.39 **	-2.80**	-2.62**	-13.26**
3.	**BM 3511-2**	-0.77	-0.37	-0.75	-7.57	1.65	0.47*	1.14**	1.43**	3.23**	1.74**	16.07**
4.	**BM 3530-3**	0.11	-0.15	-0.42	-10.81 **	-4.01 *	-0.45*	-0.54**	-0.16	0.59 *	-0.11	-7.91**
5.	**BM 3521-3-1**	1.34**	1.40 **	-2.42**	10.22 **	1.87	-0.83**	-0.45**	-0.39 **	-1.69**	-2.40**	-22.64**
6.	**BM 3521 A-2-3**	3.56**	3.06**	1.46 **	3.40	7.79**	1.01**	0.30*	0.67**	1.21**	-0.09	12.93**
7.	**CML 284**	3.00**	2.95**	0.91	18.71**	3.25	0.45*	0.21	0.01	-1.03**	-0.35*	-13.48**
8.	**CML 409**	0.67	0.28	-1.97**	-7.75 *	-3.98 *	-0.65**	-0.83**	-0.61**	0.39	-2.32**	-12.76**
9.	**CML 423**	0.01	-0.15	-2.75**	-1.03	-3.85	-0.52**	-0.18	0.18	0.61 *	-0.50 **	-0.82
10.	**Z56-5**	-3.65**	-3.26**	-2.20**	6.71	-3.72	0.05	-1.07**	-0.65**	1.63**	-0.85**	-6.86**
11.	**BM 5040**	0.11	0.28	-0.86	-3.57	6.43 **	0.36	0.59**	-0.30 *	0.16	1.11**	6.80**
12.	**BM 5050**	-0.99 *	-1.26 **	2.91**	-7.88 *	3.34	0.87**	0.50**	-0.34 **	2.36**	1.16**	20.62**
13.	**BM 5059**	0.67	0.73	4.13**	3.38	-2.74	0.18	0.19	-0.43**	-0.94**	3.04**	6.66**
14.	**BM 5076**	-0.88	-0.60	-1.53 **	-1.10	5.67 **	-1.37**	-0.11	-0.03	-0.49*	-2.42**	-1.27 *
15.	**BM 1234**	-1.32 **	-1.37 **	1.46 **	0.01	-12.16**	1.27**	0.37*	1.16**	-0.14	1.28**	18.17**
	Range for Lines	-3.65 to 3.56	-3.26 to 3.06	-2.75 to 4.13	-10.81 to 18.71	-12.16 to 7.79	-1.37 to 1.27	-1.07 to 1.14	-0.65 to 1.43	-3.09 to 3.23	-2.62 to 3.35	-22.64 to 20.62
	S.E. (gca for line)	0.44	0.45	0.51	3.86	2.00	0.19	0.14	0.12	0.24	0.14	0.63
	S.E. (gi-gj) line	0.63	0.63	0.73	5.46	2.82	0.27	0.20	0.17	0.34	0.20	0.89

Table.3b Estimates of general combining ability (gca) effects for yield and yield component characters in maize

S. No	Source	Days to 50% tasseling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height(cm)	Ear length(cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100 kernel weight (g)	Grain yield (g perplant)
	Testers											
1.	**BML 10**	-0.83**	-0.68**	0.44	-1.09	3.36**	-0.36**	0.25**	0.25**	-0.11	0.48**	5.74**
2.	**BML 13**	0.16	0.06	-1.02**	-8.48**	-7.11**	-0.36**	-0.29**	-0.27**	-0.26*	0.26**	-4.75**
3.	**BML 7**	0.67**	0.62**	0.57*	9.57**	3.74**	0.72**	0.04	0.01	0.37**	-0.74**	0.98**
	Range for Testers	-0.83 to 0.67	-0.68 to 0.62	-1.02 to 0.57	-8.48 to 9.57	-7.11 to 3.74	-0.36 to 0.72	-0.29 to 0.25	-0.27 to 0.25	-0.26 to 0.37	-0.74 to 0.48	-4.75 to 5.74
	S.E. (gca for tester)	0.20	0.20	0.23	1.72	0.89	0.08	0.06	0.05	0.10	0.06	0.28
	S.E. (gi-gj) tester	0.28	0.28	0.32	2.44	1.26	0.12	0.08	0.07	0.15	0.09	0.39

***** Significant at 5 per cent level; ****** Significant at 1 per cent level.

Table.4 Estimates of specific combiningability (sca) effects for yield and yield component characters in maize

S. No	Source	Days to 50% tasseling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height(cm)	Ear length(cm)	Ear girth (cm)	Number of kernel rows per ear	Number of kernels per row	100 kernel weight (g)	Grain yield (g perplant)
	Hybrids											
1.	**BML 14 x BML 10**	0.28	-0.31	-3.33**	3.38	-5.39	-0.01	-0.36	-0.74**	-0.99*	-2.79**	-23.32**
2.	**BML 14 x BML 13**	0.61	0.60	-0.86	1.57	-2.91	0.71*	0.31	0.18	0.61	1.68**	12.51**
3.	**BML 14 x BML 7**	-0.89	-0.28	4.20**	-4.95	8.29*	-0.70*	0.04	0.56**	0.37	1.11**	10.80**
4.	**PVT MH x BML 10**	0.17	0.68	2.22*	-5.64	-1.10	-0.21	0.35	0.32	0.31	3.69**	14.09**
5.	**PVT MH x BML 13**	-1.83*	-2.06	-3.64**	-1.04	-0.95	0.65	-0.23	0.32	-1.20**	-3.85**	-15.41**
6.	**PVT MH x BML 7**	1.65*	1.37	1.42	6.68	2.05	-0.43	-0.11	-0.64**	0.88*	0.16	1.31
7.	**BM 3511-2 x BML 10**	0.72	0.80	-1.44	5.71	-0.34	-0.37	-0.51*	-0.30	0.40	-1.19**	-3.40**
8.	**BM 3511-2 x BML 13**	0.05	0.37	-0.31	2.57	4.33	0.89**	-0.77**	-1.10**	-1.44**	1.10**	-10.15**
9.	**BM 3511-2 x BML 7**	-0.78	-1.17	1.75	-8.29	-3.99	-0.52	1.28**	1.40**	1.04*	0.08	13.55**
10.	**BM 3530-3 x BML 10**	2.83**	2.91**	2.88**	-4.64	-0.21	0.09	-0.62*	-0.96**	-1.81**	0.52*	-16.21**
11.	**BM 3530-3 x BML 13**	-0.83	-0.51	-0.97	3.48	4.73	0.09	0.11	0.09	0.59	-1.95**	-3.84**
12.	**BM 3530-3 x BML 7**	-2.00*	-2.40**	-1.91*	1.15	-4.52	-0.19	0.51*	0.87**	1.22**	1.42**	20.06**
13.	**BM 3521-3-1 x BML 10**	-0.38	-0.64	-1.44	-0.75	-7.43*	0.01	0.95**	0.85**	2.27**	0.97**	27.09**
14.	**BM 3521-3-1 x BML 13**	0.94	0.93	-1.31	29.91**	16.77**	1.40**	0.69**	-0.48*	0.48	3.72**	8.02**
15.	**BM 3521-3-1 x BML 7**	-0.56	-0.28	2.75**	-29.15**	-9.34**	-1.41**	-1.64**	-0.37	-2.75**	-4.69**	-35.11**
16.	**BM 3521A-2-3 x BML10**	-0.60	-0.31	1.66	8.20	1.05	-1.30**	0.52*	1.25*	-0.24	-2.62**	-0.30
17.	**BM 3521A-2-3 x BML13**	0.05	-0.40	-3.20**	1.72	4.53	-0.57	0.34	0.05	0.50	0.47	4.53**
18.	**BM 3521A-2-3 X BML7**	0.54	0.71	1.53	-9.93	-5.59	1.87**	-0.86**	-1.30**	-0.26	2.15**	-4.23**
S. No	**Source**	**Days to 50% tasseling**	**Days to 50% silking**	**Days to maturity**	**Plant height (cm)**	**Ear height(cm)**	**Ear length(cm)**	**Ear girth (cm)**	**Number of kernel rows per ear**	**Number of kernels per row**	**100 kernel weight (g)**	**Grain yield (g perplant)**
19.	**CML 284 x BML 10**	0.61	0.80	-3.77**	-5.50	-0.67	-0.88*	-0.31	-0.88**	-1.19**	-1.33**	-3.67**
20.	**CML 284 x BML 13**	-0.71	1.04	4.68**	-4.44	-5.06	0.38	0.09	0.32	-0.38	0.94**	14.09**
21.	**CML 284 x BML 7**	0.10	-1.84*	-0.91	9.95	5.74	0.49	0.22	0.56**	1.57**	0.39	-10.41**

22.	**CML 409 x BML 10**	1.61*	0.46	-0.88	5.82	-2.50	-0.30	0.52*	0.54*	1.31**	1.17**	-0.27
23.	**CML 409 x BML 13**	0.28	1.71*	3.24**	27.48**	13.77**	0.62	1.20**	0.40	0.72	2.08**	19.64**
24.	**CML 409 x BML 7**	-1.89*	-2.17**	-2.35*	-33.31**	-11.27**	-0.32	-1.73**	-0.95**	-2.04**	-3.26**	-19.36**
25.	**CML 423 x BML 10**	-2.38**	-2.42**	0.55	6.44	10.23**	-0.43	0.41	-0.65**	0.82	2.84**	14.53**
26.	**CML 423 x BML 13**	1.61*	1.48	1.68	-1.49	2.24	0.56	-0.57*	0.80**	0.04	-1.81**	-4.99**
27.	**CML 423 x BML 7**	0.77	0.93	-2.24*	-4.95	-12.47**	-0.12	0.15	-0.15	-0.86*	-1.02**	-9.54**
28.	**Z56-5 x BML 10**	-1.38	-1.97*	-0.66	-2.10	3.76	0.85*	-0.29	0.05	2.27**	0.03	6.43*
29.	**Z56-5 x BML 13**	-0.71	-1.06	1.46	-14.91*	-7.28*	-1.28**	-0.01	-0.74**	-2.71**	2.89**	-7.69**
30.	**Z56-5 x BML 7**	2.10**	3.04**	-0.80	17.02*	3.521	0.43	0.31	0.69**	0.44	-2.93**	1.26
31.	**BM 5040 x BML 10**	0.17	1.80*	-0.33	-2.55	3.47	0.40	-0.49*	0.23	-3.59**	-1.36**	-13.35**
32.	**BM 5040 x BML 13**	-0.83	-2.28**	-0.20	-8.75	-13.97**	-1.32**	-0.08	-0.96**	2.15**	2.36**	0.34
33.	**BM 5040 x BML 7**	0.65	0.48	0.53	11.31	10.49**	0.92**	0.57*	0.73**	1.44**	-1.00**	13.01**
34.	**BM 5050 x BML 10**	2.28**	2.35**	2.88**	4.55	3.56	0.49	0.39	0.27	0.27	3.30**	4.17**
35.	**BM 5050 x BML 13**	0.61	0.60	-1.97*	-21.64**	-8.95*	-1.43**	-0.79**	-0.25	0.55	-2.89**	-8.82**
36.	**BM 5050 x BML 7**	-2.89**	-2.95**	-0.91	17.08*	5.38	0.94**	0.39	-0.01	-0.82	-0.41	4.65**
37.	**BM 5059 x BML 10**	-2.38**	-2.31**	0.66	-11.97	-7.07*	0.85*	-0.42	-1.23**	-3.08**	2.24**	-15.91**
38.	**BM 5059 x BML 13**	1.61*	1.60*	2.46**	-11.44	-4.19	-0.41	-0.34	1.29**	1.72**	-3.54**	1.29
S. No	**Source**	**Days to 50% tasseling**	**Days to 50% silking**	**Days to maturity**	**Plant height (cm)**	**Ear height(cm)**	**Ear length(cm)**	**Ear girth (cm)**	**Number of kernel rows per ear**	**Number of kernels per row**	**100 kernel weight (g)**	**Grain yield (g perplant)**
39.	**BM 5059 x BML 7**	0.77	0.71	-3.13**	23.42**	11.27**	-0.43	0.77**	-0.06	1.35**	1.30**	14.62**
40.	**BM 5076 x BML 10**	-3.49**	-3.97**	0.33	3.71	2.43	0.67*	0.08	0.09	2.53**	-0.43	6.55**
41.	**BM 5076 x BML 13**	-0.16	-0.40	1.13	-6.49	1.84	-0.79*	-0.50*	0.23	-2.51**	-3.25**	-23.34**
42.	**BM 5076 x BML 7**	3.65**	4.37**	-1.46	2.77	-4.27	0.12	0.42	-0.32	-0.02	3.68**	16.78**
43.	**BM 1234 x BML 10**	1.94*	2.13**	0.66	-4.66	0.21	0.16	-0.20	1.16**	0.71	-5.06**	3.59**
44.	**BM 1234 x BML 13**	-0.71	-1.62*	-2.20*	3.46	-4.91	0.49	0.54*	-0.16	0.86**	2.04**	13.83**
45.	**BM 1234 x BML 7**	-1.23	-0.51	1.53	1.19	4.69	-0.65	-0.33	-0.99**	-1.57**	3.01**	-17.42**
	Range for Hybrids	-3.49to 3.65	- 3.97to4.37	-3.77to 4.68	-33.31to 29.91	-13.97to 16.77	-1.43to 1.87	-1.73to 1.28	-1.30 to1.40	-3.59to2.53	- 5.06to3.72	-35.11to 27.09
	S.E. (sca effects)s_{ij}	0.77	0.78	0.89	6.68	3.46	0.33	0.24	0.21	0.42	0.25	1.09
	S.E. (s_{ij}-s_{kl})	1.09	1.10	1.27	9.45	4.90	0.47	0.34	0.29	0.60	0.36	1.54

* Significant at 5 per cent level; ** Significant at 1 per cent level.

Positive significant *sca* effects for grain yield per plant were exhibited by 20 hybrids presented in Table 4. Among which BM 3521-3-1 x BML 10 recorded the highest positive significant *sca* effect (27.09) followed by 3530-3 x BML 7 (20.06), CML 409 x BML 13 (19.64), 5076 x BML 7 (16.78), and 5059 x BML 7 (14.62) for grain yield per plant. Out of these 20 hybrids, BM 5050 × BML 10, BM 3511-2 × BML 7, BM 1234 × BML 10, BM 1234 × BML 13 and BM 5050 × BML 7 were the top five hybrids recorded high per se performance and significant positive *sca* effects for grain yield per plant. The hybrids BM 5050 × BML 10, BM 3511-2 × BML 7, BM 1234 × BML 10 and BM 5050 × BML 7 had both the parents with significant positive gca effects possessing additive x additive type of gene action. The hybrid BM 1234 × BML 13 possessed only one parent with significant positive gca effects indicating the involvement of additive and dominance genetic interaction. The results, thus obtained in the present study are mostly in conformity with the earlier findings of Dar *et al., (*2017), Kambe Gouda *et al.,* (2013), Shushay *et al.,* (2013), Sumalini and Shobha Rani (2011), Gowhar Ali *et al.,* (2007), Malik *et al.,* (2004) and Venugopal *et al.,* (2002) for grain yield and other component characters.

The lines *viz.,* BM 5050, BM 1234, BM 3511-2, BM 3521 A-2 and testers *viz.,* BML 10 and BML 7 were found to be good general combiners for grain yield per plant.

The hybrids BM 5050 × BML 10, BM 3511-2 × BML 7, BM 1234 × BML 10, BM 1234 × BML 13 and BM 5050 × BML 7 were identified as most promising hybrids based on per se performance and sca effects for grain yield per plant can be used for the development of single cross hybrids since non additive gene action for most of the traits was observed. These hybrids can be further tested over locations and years before commercial exploitation.

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