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National Academy of Agricultural Science (NAAS) Rating : 3.03

Combining ability studies for grain yield and its components in maize (*Zea mays* L.)

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Abstract: *Combining ability analysis for grain yield and its contributing characters in maize were carried out in 10 x 10 diallel cross. The mean sum of squares due to GCA and SCA were significant for all the characters indicating the presence of variability in combining ability of parents involved. Variances due to SCA were larger than GCA for all the characters indicating the predominance of non-additive gene action in expression of various traits studied. The parents BML-6, BML-7 and BML-5233-5 were good general combiners for yield and majority of the yield contributing traits. These parents can be used in crossing and further exploited for improvement of traits in the population. BML-5233-5 and BML-2 was good general combiner among the parents for earliness* i.e. *days to 50 per cent tasseling, days to 50 per cent silking and days to maturity. The hybrids BML-15 X BML-2910, BML-6 X BML-3044, BML-2782 X BML-7 and BML-2486 X BML-3044 were identified as potential ones for yield and yield components based on high sca effects along with high per se performance. These hybrids may be exploited for commercial cultivation by testing them over locations and years for their yield stability.*

Key words: *Combining ability, diallel cross, gene action, maize.*

Maize (*Zea mays* L.) is the third most important cereal in India after rice and wheat (Centre for Monitoring Indian Economy 2014). It provides food, feed, fodder, fuel and several as a source of basic raw material for number of industrial products *viz.*, starch, oil, protein, alcohol beverages, food sweeteners, cosmetics and bio fuels etc. Maize average and production have an increasing tendency with the introduction of hybrids due to these high yield potentials. So maize can play an important role in increasing food production in India.

The nature and magnitude of gene action is an important factor in developing an effective breeding programme. Combining ability analysis is useful to assess the potential inbred lines and also helps identifying nature of gene action involved in various quantitative characters. This information is helpful to plant breeders for formulating hybrid breeding programmes. Therefore, the present investigation with 10 x 10 diallel cross was under taken for isolating superior inbred lines and better combining parents for suitable hybrids.

MATERIALS AND METHODS

The experimental material for the present study comprised of 10 parents were mated in diallel mating design (excluding reciprocals) during *Kharif*, 2011 at College Farm, College of Agriculture, Rajendranagar, Hyderabad-500 030, Telangana State, India. The resultant 45 F_1s and 10 parents were grown in Randomized Complete Block Design with three replications during *Rabi*, 2011-12 at College Farm, College of Agriculture, Rajendranagar, Hyderabad, Telangana State. Each entry was sown in a row of 4 meters length with a spacing of 75 cm between rows and 20 cm between the plants. One plant per hill was maintained. The recommended fertilizers of Nitrogen, Phosphorus and Murate of Potash were applied in the ratio of 120:80:60 kg ha^{-1}. The entire phosphorus and Murate of potash and half dose of Nitrogen was applied as basal, while remaining half dose of nitrogen in two equal split doses at knee height stage and tasseling stages. Intercultural operations like weeding and irrigation schedules were taken to protect the crop from pests and diseases, so as to raise a healthy crop. At flowering and maturity stages,

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observations were recorded on days to 50 per cent tasseling, days to 50 per cent silking, days to maturity, plant height (cm), ear height (cm), ear girth (cm), ear length (cm), number of kernel rows per ear, number of kernels per row, 100-seed weight (g)and grain yield per plant (g).

Data were analyzed for variance for all the characters studied. General combining ability (GCA) and specific combining ability (SCA) were estimated by following Griffing's method 2 of model II (1956). The mean squares for GCA and SCA were tested against error variance desired.

RESULTS AND DISCUSSION

The analysis of variance for combining ability revealed that the genotypes exhibited highly significant differences among themselves for all the characters studied (Table 1). The parents exhibited significant differences for all the traits indicating greater diversity in the parental lines. The crosses exhibited significant differences indicating varying performance of cross-combinations. The parent Vs crosses which indicates average heterosis, was also significant for all traits, thus considerable amount of average heterosis was reflected in hybrids. This indicates the presence of non-additive gene action.

The magnitudes of variance due to SCA were larger than GCA for all the characters indicating the predominance of non-additive gene action in expression of various traits studied (Table 4). This was supported by less than one ratio of $ó^2$ *gca*: $ó^2$ *sca* of Murthy *et al.* (1981); Sanghi *et al.* (1982); Debnath and Sarkar (1990); Mathur and Bhatnagar (1995); Dodiya and Joshi (2002); Joshi *et al.* (2002); Venugopal *et al.* (2002); Kabdal *et al*. (2003); Gowhar *et al.* (2007); Jayakumar and Sundram (2007); Lata *et al.* (2008); Jagadish Kumar (2010); Premalatha and Kalamani (2010); Bhavana *et al.* (2011); Ram Reddy *et al.* (2011); Sumalini and Shobha Rani (2011); Chakraborthy (2012); Aly (2013); Melkamu *et al.* (2013); Sana *et al.* (2014); Ruswandi *et al.* (2015).

The *gca* effects revealed that (Table 2) the parents with high *gca* effects differed for various traits. Among the parents, BML-6 had favorable genes for grain yield per plant and other traits including plant height, ear height and ear girth. While the parent BML-7 was the best general combiner for grain yield per plant, plant height, ear girth, ear length, number of kernels per row and 100-seed weight. However, BML-5233-5 contributed positive alleles for days to 50 per cent tasseling, days to 50 per cent silking, days to maturity, number of kernel rows per ear, number of kernels per row and grain yield per plant. Some other good general combiners that had also contributed positive genes for various characters were; CM-211 recorded good general combining ability for earliness, plant height, ear height and ear girth, BML-2 for earliness, ear girth, ear length, number of kernels per row and 100-seed weight.

In general, good combiner for grain yield also had good or average combining ability for one or more of the yield components. Selection of such parents will be effective in synthetic or composite breeding programme (Sain Dass 2000; Mahto and Ganguli (2003); Malik *et al.* 2004).

The *sca* effects (Table 3) revealed that the crosses, BML-15 X BML-2910, BML-6 X BML-3044, BML-2782 X BML-7 and BML-2486 X BML-3044 exhibited highest magnitude of positively significant *sca* effects for grain yield along with positively significant *sca* effects for other yield contributing characters. The *per se* performances of these crosses also good. Like wise the cross combinations CM-211 X BML-2486, BML-2782 X BML-5233-5 and BML-2486 X BML-2 for days to 50 per cent tasseling, BML-2782 X BML-5233-5 and CM-211 X BML-5233-5 for days to 50 per cent silking, CM-211 X BML-5233-5 for days to maturity, CM-211 X BML-15 for plant height, BML-6 X BML-2910 and CM-211 BML-3044 for ear height, BML-2486 X BML-2 for ear girth, BML-2486 X BML-2 for number of kernels per row and BML-5233-5 X BML-15 for 100-seed weight were identified as the best specific combiners for the respective characters as they have significant *sca* effect (Pal and Prodhan (1994); Rao *et al.* (1996); Ali *et al.* (2012) and Ajay Singh *et al.* (2013).

Considering the overall performances, the parents BML-6, BML-7 and BML-5233-5 were the good general combiners and genetically worthy parents, as they contributed favorable genes for grain yield and its components. Hence these high yielding parents with good attributes for different yield components may be crossed to pool the genes in desirable direction to improve the yield potential. Whereas the crosses, BML-15 X BML-2910, BML-6 X BML-3044, BML-2782 X BML-7 and BML-2486 X BML-3044 were identified as most promising crosses for yield based on *sca* effects, better *per se* and both or one of the parents with high *gca* for grain yield per plant also, could be exploited profitably for yield in maize.

ACKNOWLEDGEMENT

The authors would like to thank the Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad for their technical and financial help.

Table 1
Analysis of variance for combining ability for yield and yield components in maize

Source of variation	*d.f*	*Days to 50% tasseling*	*Days to 50% silking*	*Days to maturity*	*Plant height (cm)*	*Ear height (cm)*	*Ear girth (cm)*	*Ear length (cm)*	*Number of kernel rows per ear*	*Number of kernels per row*	*100- seed weight (g)*	*Grain yield per plant (g)*
Replicates	2.00	2.25	1.32	2.75	143.86	103.79	0.68	0.40	0.63	26.71	0.21	78.66
Treatments	54.00	52.70**	52.38**	84.80**	2838.39**	1065.48**	7.23**	24.29**	4.83**	150.87**	65.31**	4658.26**
Parents	9.00	101.78**	84.83**	84.03**	1959.31**	915.90**	6.61**	24.18**	3.57**	166.34**	86.49**	1377.85**
Hybrids	44.00	42.78**	46.15**	61.34**	2079.24**	916.74**	5.00**	15.21**	4.89**	103.38**	52.10**	3368.81**
Parent Vs. Hybrids	1.00	47.85**	34.26**	1123.88**	44153.05**	8956.51**	110.53**	425.00**	13.23**	2101.18**	456.19**	90918.20**
Error	108.00	4.25	4.28	2.44	153.58	33.03	0.45	0.63	0.56	5.27	0.57	46.63
Total	164.00	20.18	20.08	29.56	1037.48	373.85	2.69	8.42	1.96	53.47	21.88	1565.48

* Significant at 5 per cent level, ** Significant at 1 per cent level

Table 2
Estimates of general combining ability (*gca*) effects for yield and yield components in maize

	Days to 50% tasseling	*Days to 50% silking*	*Days to maturity*	*Plant height (cm)*	*Ear height (cm)*	*Ear girth (cm)*	*Ear length (cm)*	*Number of kernel rows per ear*	*Number of kernels per row*	*100- seed weight (g)*	*Grain yield per plant (g)*
Parents											
CM-211	-0.93**	-1.27**	-1.71**	7.60**	5.95**	0.52**	-0.11	-0.03	-1.09**	-0.42**	-7.52**
BML-2782	0.37	0.46	2.43**	-3.36	-5.37**	-0.13	-1.17**	0.06	-4.55**	1.81**	3.44**
BML-5233-5	-4.35**	-4.32**	-3.01**	-5.21**	-9.04**	0.04	0.00	0.51**	0.08	0.31*	7.94**
BML-2486	0.46	1.34**	0.35	-4.84*	-4.93**	-0.07	-0.45**	0.01	-1.62**	-1.64**	-15.03**
BML-6	0.79*	0.43	0.10	8.38**	12.30**	0.59**	0.15	0.01	-0.38	1.42**	15.64**
BML-15	2.51**	2.15**	1.74**	10.04**	7.35**	-0.82**	-0.45**	-0.21	-1.71**	-2.26**	-12.93**
BML-7	0.96**	1.23**	-0.54*	6.70**	-1.62	0.28**	1.52**	-0.52**	3.48**	0.35**	10.87**
BML-2910	-0.43	-0.52	-0.32	-13.38**	-10.97**	-0.99**	0.53**	0.02	2.13**	-1.61**	-6.98**
BML-2	-1.82**	-1.43**	-0.82**	-4.60*	-2.12*	0.23*	1.14**	-0.19	3.33**	2.52**	2.27*
BML-3044	2.46**	1.93**	1.77**	-1.32	8.45**	0.34**	-1.15**	0.34**	0.33	-0.49**	2.29*
SE (gi)	0.32	0.32	0.24	1.95	0.90	0.10	0.12	0.11	0.36	0.11	1.07
SE (gi-gj)	0.48	0.48	0.36	2.92	1.35	0.15	0.18	0.17	0.54	0.17	1.60

* Significant at 5 per cent level, ** Significant at 1 per cent level

Table 3
Estimates of specific combining ability (*sca*) effects for yield and yield components in maize

Crosses	*Days to 50% tasseling*	*Days to 50% silking*	*Days to maturity*	*Plant height (cm)*	*Ear height (cm)*	*Ear girth (cm)*	*Ear length (cm)*	*Number of kernel rows per ear*	*Number of kernels per row*	*100- seed weight (g)*	*Grain yield per plant (g)*
CM-211 X BML-2782	1.60	0.28	-5.22**	22.60**	16.05**	0.72	3.71**	-0.35	0.26	0.37	30.96**
CM-211 X BML-5233-5	-4.34**	-5.94**	-8.78**	-1.48	-18.65**	-0.01	1.74**	3.19**	5.73**	4.27**	22.02**
CM-211 X BML-2486	-6.81**	0.39	0.19	28.08**	3.98	-0.07	1.63**	-2.11**	8.29**	5.28**	44.79**
CM-211 X BML-6	1.19	-0.69	-0.56	1.72	21.29**	1.66**	0.75	-0.31	1.85	2.76**	39.29**
CM-211 X BML-15	1.13	1.58	0.80	64.83**	18.93**	-0.72	-1.51**	-0.08	-1.01	-3.96**	-3.67
CM-211 X BML-7	1.35	1.50	2.08*	-3.03	1.40	0.74*	2.96**	0.23	1.73	2.16**	30.29**
CM-211 X BML-2910	-2.92*	-5.08**	-2.47*	-1.19	-5.25	-0.28	-1.46**	-1.45**	-0.72	2.12**	17.04**
CM-211 X BML-2	-3.20**	-1.83	-3.31**	-41.06**	-22.03**	-1.74**	-0.40	-0.11	-5.72**	-10.54**	-39.24**
CM-211 BML-3044	0.19	-0.19	2.78**	-10.62	29.07**	1.21**	-0.12	1.37**	1.01	-6.73**	-43.99**
BML-2782 X BML-5233-5	-5.98**	-7.67**	-5.59**	15.35*	-6.59*	0.47	4.13**	3.11**	9.99**	-1.96**	14.76**
BML-2782 X BML-2486	0.88	0.00	2.05*	-4.03	-6.89*	-0.56	-0.68	-0.19	-2.84*	-4.87**	-20.04**
BML-2782 X BML-6	1.55	1.58	3.97**	4.15	1.61	0.94*	0.51	-0.59	-1.15	3.53**	19.16**
BML-2782 X BML-15	-2.51*	-2.14	-2.34**	-0.58	-4.65	-0.37	-0.25	-0.16	3.59**	2.11**	13.43**
BML-2782 X BML-7	-0.29	-1.22	0.94	33.90**	15.33**	1.32**	0.28	0.14	2.40	4.60**	70.83**
BML-2782 X BML-2910	0.77	3.53**	2.39**	0.57	-3.92	0.70	0.07	-0.4	0.55	0.06	-26.69**
BML-2782 X BML-2	-0.84	-2.56*	-7.78**	-39.27**	-1.04	0.87*	-1.47**	0.01	-3.46**	0.72	28.53**
BML-2782 X BML-3044	-2.45*	-0.92	-4.36**	39.51**	15.26**	1.29**	3.44**	-0.72	5.81**	3.84**	30.15**
BML-5233-5 X BML-2486	6.60**	7.44**	7.50**	-16.11*	2.14	-1.19**	-2.52**	-0.44	-8.68**	-0.91*	-43.81**
BML-5233-5 X BML-6	4.94**	5.36**	6.08**	-16.47*	-17.46**	0.85*	-1.43**	1.16**	-4.38**	-3.50**	-20.31**
BML-5233-5 X BML-15	3.88**	2.64*	-1.89*	6.04	-0.58	2.33**	1.94**	-0.62	-1.05	8.51**	29.76**
BML-5233-5 X BML-7	3.77**	5.56**	2.39**	3.01	1.86	-0.07	-0.32	-0.71	-0.91	2.70**	-5.74
BML-5233-5 X BML-2910	-4.17**	-3.69**	-7.17**	15.56*	4.48	0.93*	1.16**	1.15**	-1.89	0.55	35.24**
BML-5233-5 X BML-2	0.55	0.22	4.66**	-1.39	4.50	-0.02	-2.21**	0.49	-5.96**	0.43	6.06
BML-5233-5 X BML-3044	3.94**	3.86**	3.08**	-16.50*	-6.14	0.23	-0.66	-0.91*	-2.09	3.24**	24.64**
BML-2486 X BML-6	-0.87	-0.31	-2.61**	33.43**	10.10**	1.96**	2.86**	-0.14	4.32**	0.81*	4.37
BML-2486 X BML-15	-0.26	-1.36	0.75	21.53**	12.12**	1.81**	2.53**	0.28	5.05**	3.46**	9.10*
BML-2486 X BML-7	-0.70	0.89	1.03	-18.22**	-15.71**	-1.80**	-0.90*	0.46	-4.87**	0.78	-19.34**
BML-2486 X BML-2910	-3.98**	-3.36**	-7.20**	5.98	-0.36	1.18**	2.05**	1.65**	3.94**	0.45	29.45**
BML-2486 X BML-2	-4.92**	-5.44**	-6.70**	-15.52*	-10.14**	2.72**	7.14**	-0.14	12.94**	4.21**	42.93**
BML-2486 X BML-3044	0.46	0.19	0.72	30.22**	5.29	0.71	0.83	1.33**	5.01**	1.12**	29.35**
BML-6 X BML-15	-1.59	-1.11	-4.00**	0.75	-3.25	-1.59**	0.52	-2.12**	2.74*	0.14	40.33**
BML-6 X BML-7	-1.70	-2.19	-3.72**	3.15	2.59	1.17**	0.83	-1.81**	2.29	5.50**	6.23

contd. table 3

Crosses	*Days to 50% tasseling*	*Days to 50% silking*	*Days to maturity*	*Plant height (cm)*	*Ear height (cm)*	*Ear girth (cm)*	*Ear length (cm)*	*Number of kernel rows per ear*	*Number of kernels per row*	*100- seed weight (g)*	*Grain yield per plant (g)*
BML-6 X BML-2910	-0.31	-1.44	-5.95**	35.96**	35.14**	0.14	2.35**	1.65**	3.71**	-8.30**	-44.29**
BML-6 X BML-2	-0.26	-1.53	2.55**	14.25*	-8.17*	-0.85*	-1.66**	-0.08	8.37**	1.98**	33.86**
BML-6 X BML-3044	-2.54*	-2.89*	-5.03**	-3.37	-12.14**	0.54	2.62**	-0.67	9.70**	3.43**	56.08**
BML-15 X BML-7	-1.76	-1.92	-6.03**	-2.77	5.07	0.32	0.56	0.41	3.62**	-2.53**	-4.80
BML-15 X BML-2910	1.63	1.83	5.75**	47.83**	20.29**	1.80**	3.55**	-0.03	10.11**	7.44**	80.25**
BML-15 X BML-2	1.02	0.75	-2.09*	22.69**	10.27**	0.57	0.94*	0.88*	-0.23	2.30**	-12.10**
BML-15 X BML-3044	-0.92	-0.61	-3.67**	-51.83**	-1.53	-1.54**	-0.78	0.95*	-6.30**	-4.67**	-46.28**
BML-7 X BML-2910	-2.81*	-3.25**	-5.31**	-0.62	6.99*	1.29**	1.38**	2.18**	1.12	2.35**	10.44**
BML-7 X BML-2	0.24	1.33	-2.81**	12.67	12.28**	-1.20**	-1.73**	0.39	-2.49*	-1.91**	-6.91
BML-7 X BML-3044	-2.37*	-2.69*	-4.39**	43.98**	8.11*	2.15**	2.36**	1.13**	6.64**	1.70**	20.48**
BML-2910 X BML-2	5.30**	5.42**	5.64**	10.88	3.03	-0.26	0.86*	-1.55**	5.86**	0.45	1.44
BML-2910 X BML-3044	2.69*	1.06	-2.61**	17.72*	8.50**	-0.87*	-3.76**	-0.48	-4.81**	2.86**	-15.00**
BML-2 X BML-3044	3.41**	4.97**	0.89	54.68**	25.08**	-0.10	2.23**	-0.01	7.66**	-1.07*	28.91**
SE	1.09	1.09	0.83	6.59	3.05	0.35	0.42	0.39	1.22	0.39	3.63
Sij-Sik	1.61	1.61	1.22	9.68	4.49	0.52	0.62	0.58	1.79	0.58	5.33
Sij-Skl	1.53	1.54	1.16	9.23	4.28	0.50	0.59	0.55	1.71	0.56	5.08

* Significant at 5 per cent level, ** Significant at 1 per cent level

Table 4
Estimates of general and specific combining ability variances and proportionate gene action in maize for 11 characters

Character	*Source of variation*		
	s^2 *gca*	s^2 *sca*	s^2 *gca*/s^2 *sca*
Days to 50 per cent tasseling	4.05	9.66	0.42
Days to 50 per cent silking	3.73	10.28	0.36
Days to maturity	2.74	26.38	0.10
Plant height (cm)	55.44	940.86	0.06
Ear height (cm)	62.91	262	0.24
Ear girth (cm)	0.27	2.06	0.13
Ear length (cm)	0.76	7.64	0.10
Number of kernel rows per ear	0.07	1.55	0.04
Number of kernels per row	6.01	43.81	0.14
100-seed weight (g)	2.51	19.88	0.13
Grain yield per palnt (g)	103.86	1595.39	0.07

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