INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES

IJPAES

Volume-4, Issue-4, Oct-Dec-2014

ISSN 2231-4490

Coden : IJPAES www.ijpaes.com

Received: 10th Aug-2014 *Revised: 13th Sept-2014* *Accepted: 18th Sept-2014*

Research article

COMBINING ABILITY STUDIES IN NEWLY DEVELOPED INBRED LINES IN MAIZE (*Zea mays* L.)

G. Praveen Kumar[1], V. Narsimha Reddy[2], S. Sudheer kumar[3], P. Venkateshwara Rao[4]

[1]Department of Genetics and Plant Breeding, College of Agriculture, Rajendranagar, Hyderabad-30.
[2]Principal Scientist (Plant Breeding), Maize Research Centre (MRC), A.R.I, Rajendranagar, Hyderabad-30
[3]Professor, Department of Genetics and Plant Breeding, College of Agriculture, Rajendranagar, Hyderabad-30.
[4]Professor, Department of plant physiology, College of Agriculture, Rajendranagar, Hyderabad-30.

ABSTRACT: Combining ability analysis was conducted in newly developed inbred lines in maize (Zea mays L.). Twenty lines were crossed with 3 testers in Line × Tester (L × T) mating design during Kharif, 2012. The resulting 60 crosses along with parents and standard checks DHM 117, 900M Gold and NK 6240 were evaluated in a randomized Block Design replicated thrice, during Rabi, 2012-13. Both additive and non-additive gene effects were present in the material under study. Variance due to *sca* was larger than *gca* variance for all the characters indicating the preponderance of non additive gene action in the expression of various traits. Among the parents MRC 14, MRC 4, MRC 9, MRC 8, MRC 7 and MRC 6 and tester BML 14 were good general combiners for grain yield and important yield contributing characters. The crosses MRC 13 × BML 14, MRC 7 × BML 7, MRC 3 × BML 14, MRC 12 × BML 7 and MRC 14 × BML 7 showed high *sca* effects for grain yield and other important yield component characters.

Key words: Maize, Inbred lines, Combining ability study

INTRODUCTION

Maize (*Zea mays* L.), belonging to the family Poaceae and tribe Maydeae, is one of the most important cereal crops and occupies a prominent position in global agriculture after wheat and rice. Among cereals, maize is rich in starch, proteins, oil and sucrose, due to which it has assumed significant industrial importance. Maize and its main by-products starch, syrup, glucose, gluten and oil are used in diversified industries like alcohol production, textile, paper, pharmaceuticals, cosmetic industry, edible oil industry, poultry feed and many chemical industries. Maize protein "Zien" has significant quantities of vitamin A, nicotinic acid, riboflavin, vitamin E and phosphorus. Maize oil obtained from germ of kernel is rich in polyunsaturated fatty acids and also contains high level of natural anti-oxidants, hence maize oil is ideal for heart patients. The main goal of maize breeding is to obtain new hybrids with high genetic potential for yield and positive features that exceed the existing commercial hybrids. The commercial production of hybrids however, depends upon two factors *viz.*, the behavior of the line itself and the behavior of line in hybrid combination. The behavior of a line in hybrid combination is assessed through the estimation of general combining ability (*gca*) and specific combining ability (*sca*) effects. Combining ability of the inbred lines is the ultimate factor for determining future usefulness of the lines and helps in classifying inbred lines relative to their cross combinations. Combining ability analysis is an important method to evaluate the prepotency of cultures to be used in breeding programme and to assess the gene action involved in various characters so as to design an appropriate and efficient breeding method. Combining ability analysis provides this information and is frequently used by plant breeders to choose parents with a high general combining ability and hybrids with high specific combining ability effects. Variance for GCA is associated with additive genetic effects, while that of SCA includes non-additive genetic effects, arising largely from dominance and epistatic deviations with respect to certain traits. In a systematic breeding program, it is essential to identify superior parents for hybridization and crosses to expand the genetic variability for selection of superior genotypes.

The Line × Tester mating design as suggested by Kempthorne [8] is an appropriate method to identify superior parents and hybrids based on general combining ability and specific combing ability, respectively.

MATERIALS AND METHODS

Twenty newly developed inbred lines of maize *viz.*, MRC 1, MRC 2, MRC 3, MRC 4, MRC 5, MRC 6, MRC 7, MRC 8, MRC 9, MRC 10, MRC 11, MRC 12, MRC 13, MRC 14, MRC 15, MRC 16, MRC 17, MRC 18, MRC 19 and MRC 20 were crossed with three testers *viz.*, BML 7, BML 14 and BML 15 during *Kharif*, 2012. Subsequently, during *Rabi*, 2012-13 the resulting 60 F_1 crosses along with three standard checks (DHM 117, 900M Gold and NK 6240) and parents (lines and testers) were evaluated in randomized block desighn with three replications. Both the crossing and evaluation works were carried out at Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad. Each entry was sown in two rows of four meters length with a spacing of 75 cm between rows and 20 cm between the plants. The data on twelve quantitative characters namely, plant height, ear height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, 100 kernel weight, shelling percentage and grain yield per plant were recorded on five randomly selected competitive plants in each replication, whereas days to 50 per cent tasseling, days to 50 per cent silking, days to maturity were recorded on plot basis. Combining ability analysis was computed according to the model given by Kempthorne [8].

RESULTS AND DISCUSSION

Analysis for combining ability was carried out for yield and yield contributing characters and the mean sum of squares, are presented in Table 1. The analysis of variance revealed that genotypes exhibited highly significant differences among themselves for all the traits studied. 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 parents vs. crosses which indicates average heterosis, was also significant for all traits, thus considerable amount of average heterosis was reflected in hybrids. When the effects of crosses partitioned into lines, testers and line × tester effects, the interaction effects (line × testers) were found to be significant for all the traits under study indicating that hybrids differed significantly in their *sca* effects.

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

Source	d.f.	Days to 5o % 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)	Shelling percentage	Grain yield per plant (g)
Replications	2	3.48	2.48	0.41365	28.51	201.16*	0.89	0.59	0.26	1.09	4.22	1.15	136.68
Genotypes	82	35.02**	38.47**	18.28**	5107.23**	1603.36**	20.77**	6.74**	4.00**	113.65**	118.42**	32.88**	6172.84**
Parents	22	47.75**	44.87**	23.67**	871.33**	243.53**	6.56**	1.79**	6.95**	46.34**	39.45**	55.76**	750.99**
Parents Vs crosses	1	872.40**	1120.71**	24.76**	379223.99**	109157.28**	1425.33**	348.06**	0.17	7209.41**	6238.61**	563.95**	428033.74**
Crosses	59	16.09**	17.74**	16.16**	345.76**	287.47**	2.26**	2.80**	2.96**	18.48**	44.14**	15.34**	1044.36**
Lines	19	26.84**	31.41**	35.24**	802.09**	454.84**	3.27	2.40**	5.45**	23.58*	53.40**	18.96	1081.92
Testers	2	99.83**	113.77**	41.87**	1055.12**	2079.65**	1.33	41.53**	20.81**	108.02**	487.69**	55.87*	7661.56**
Line × Testers	38	6.30**	5.85**	5.26**	80.26**	109.45**	1.81**	0.97**	0.78**	11.22**	16.17**	11.40**	677.30**
Error	164	1.48	1.23	0.58	26.37	51.1288	0.68	0.37	0.42	2.72	4.79	3.39	53.82

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

A comparison of the magnitude of variance components due to *gca* and *sca* confirms the gene action in controlling the expression of traits. The ratio of GCA and SCA variance for all the traits under study *viz*., days to 50 per cent tasseling (0.05), days to 50 per cent silking (0.07), days to maturity (0.06), plant height (0.14), ear height (0.08), ear length (0.01), ear girth (0.08), number of kernel rows per ear (0.17), number of kernels per row (0.02), 100 kernel weight (0.07), shelling percentage (0.01) and grain yield per plant (0.01) was less than one which indicates that all these characters were predominantly governed by non-additive gene effects (Table 2). Similar findings were reported by Kanagarasu *et al.* [7] for grain yield per plant, cob diameter, cob length, plant height, ear height, 100 grain weight, grain rows per cob, days to 50 per cent tasseling and days to 50 per cent silking. Ali *et al.* [1] for number of grain rows per cob and 100-grain weight. Kumar *et al*. [9]] for plant height, days to 50 % tasseling, days to 50 % silking, cob length, cob girth, number of grain rows per cob, number of grains per row, 100-grain weight and grain yield per plant.

The general combining ability (*gca)* effects of 20 lines (females) and 3 testers (males) and the specific combining ability (*sca*) effects of 60 hybrids for yield and yield contributing characters were estimated and were presented in Tables 3 and 4 respectively. Among the lines, six lines recorded significant negative *gca* effects, of which MRC 1 recorded the lowest significant negative *gca* effect (-3.67) followed by MRC 6 (-2.78), MRC 4 (-1.78), MRC 7 (-1.56) and MRC 19 (-1.12) and one tester, BML 14 (-1.42) recorded the lowest significant negative *gca* effect indicating that they were good general combiners for earliness regarding days to 50 per cent tasseling. Bhavana *et al*. [2] and Jawaharlal *et al*. [5] who reported the additive gene action for days to 50 per cent tasseling. In respect of days to 50 per cent tasseling, seven hybrids recorded significant negative *sca* effects, among which, MRC 1 × BML 15 recorded lowest significant negative *sca* effect (-3.10). Seven lines recorded significant negative *gca* effects, among which MRC 1 recorded the lowest significant negative *gca* effect (-3.73) and among the hybrids, four hybrids recorded significant negetive *sca* effects, among which, MRC 1 × BML 15 recorded the lowest significant negative *sca* effect (-3.15) regarding days to 50 per cent silking. In respect of days to maturity, nine lines recorded significant negative *gca* effects, Ten hybrids recorded significant negative *sca* effects, among which, MRC 17 × BML 15 and MRC 15 × BML 15 recorded lowest significant negative *sca* effect. Among the lines, eight lines recorded significant positive *gca* effects, of which MRC 10 recorded highest significant positive *gca* effect (14.68) and one tester, BML 15 (3.90) recorded the significant positive *gca* effect indicating that they were good general combiners for tallness. Two hybrids recorded significant positive *sca* effects, among which MRC 16 × BML 15 recorded highest significant positive *sca* effect (8.36) for this trait. These results are comparable with findings of Jagadish Kumar *et al*. [4], Ram Reddy *et al*. [11] and Sunil Kumar *et al*. [12] who reported the non-additive gene action for plant height.

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

Source	Days to 5o % 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)	Shelling percentage	Grain yield per plant (g)
σ^2 gca	0.0945	0.1148	0.1052	2.5633	1.7186	0.0044	0.0177	0.0211	0.0701	0.2701	0.0381	3.5438
σ^2 *sca*	1.6083	1.5387	1.5618	17.962	19.4461	0.3752	0.1991	0.1182	2.8312	3.7924	2.6688	207.8267
σ^2 *gca*/σ^2 *sca*	0.0587	0.0746	0.0673	0.1427	0.0883	0.0117	0.0889	0.1785	0.0247	0.0712	0.0142	0.0170

Table 3. Estimates of general combining ability (*gca*) effects for lines and testers for yield and yield component characters in Maize

Parents	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)	Shelling percentage	Grain yield per plant (g)
Lines												
MRC 1	-3.67 **	-3.73 **	-1.55 **	-11.31 **	-5.70 *	0.38	-0.243	1.25 **	1.54 *	-3.10**	0.86	-3.59
MRC 2	-0.78	-0.95 *	-0.43	-8.93 **	-3.15	-0.54*	-0.179	0.10	-0.38	-1.50 *	-0.54	-17.29 **
MRC 3	0.10	0.26	-0.66 *	12.09 **	6.34**	-0.28	0.708 **	0.34	-0.86	-2.19 **	-0.95	-8.73 **
MRC 4	-1.78 **	-1.84 **	-2.21 **	-5.07 **	-4.05	1.33 **	-0.872 **	0.50 *	3.09 **	-3.45 **	2.37 **	10.81**
MRC 5	-0.34	-0.40	-1.32 **	4.78**	-0.06	-0.34	0.281	0.10	-0.26	-0.52	1.18	4.95*
MRC 6	-2.78 **	-3.17 **	-2.10 **	-0.65	6.71**	-0.33	0.154	0.36	-1.10*	0.38	-0.11	6.09*
MRC 7	-1.56 **	-2.06 **	-1.21 **	5.15**	-0.03	-0.33	0.088	-0.20	1.69 **	-2.57 **	-1.64 **	7.27**
MRC 8	1.21 **	1.37 **	4.67 **	-7.04 **	-5.65*	0.74 **	0.319	-1.38 **	1.74 **	3.92 **	1.32*	7.76**
MRC 9	-0.56	-0.62	0.89 **	-14.28 **	-11.47 **	-0.54	0.150	0.32	-0.81	2.38 **	1.80 **	8.50**
MRC 10	-0.45	-0.62	-2.10 **	14.68 **	12.69**	0.67 *	-1.003 **	-1.05 **	-1.40 *	2.14 **	0.73	-5.84 *
MRC 11	0.65	0.93	-1.55 **	13.96 **	12.29**	-0.14	-0.728 **	-0.72 **	0.82	-1.50 *	-0.90	3.15
MRC 12	1.21 **	1.60 **	-0.21	8.16**	10.25**	0.04	0.814 **	0.30	-1.14 *	-2.52 **	0.26	2.91
MRC 13	0.54	0.60	3.33 **	2.00	0.64	0.22	0.272	0.68 **	2.00 **	-1.08	0.27	4.48
MRC 14	1.65 **	1.82**	0.78 **	-1.49	-6.21 *	-0.07	0.074	0.19	0.001	4.23 **	1.68 **	11.48**
MRC 15	2.54 **	2.48 **	2.11 **	-11.89 **	-5.64 *	-0.14	0.794 **	-0.16	-1.33 *	2.63 **	0.79	5.76*
MRC 16	2.10 **	2.37 **	2.67 **	6.32**	-0.24	-1.46 **	-0.303	1.74 **	-2.73 **	-1.21	-2.68 **	-22.91 **
MRC 17	2.54 **	2.60 **	-0.21	11.74 **	5.75*	0.80 **	-0.650 **	-0.78**	2.36 **	0.58	0.60	4.05
MRC 18	-1.01 *	-1.06 **	-0.43	0.86	2.99	0.13	0.168	-1.14 **	-1.01	3.85 **	0.52	5.72*
MRC 19	-1.12 **	-1.17 **	-1.88 **	-13.01 **	-8.92 **	0.10	-0.052	-0.16	0.05	-0.23	0.02	2.13
MRC 20	1.54 **	1.60**	1.45 **	-6.06 **	-6.50 **	-0.23 **	0.208	-0.29	-2.27	-0.21	-3.24 **	-26.73 **
Range for lines	-3.67 to 2.54	-3.73 to 2.48	-2.21 to4.67	-14.28to14.68	-11.47to12.69	-1.46to1.33	-1.00 to 0.81	-1.38 to 1.74	-2.73 to 3.09	-3.45 to 4.23	-3.24 to 2.37	-26.73to10.81
S.E. (gca for line)	0.40	0.37	0.25	1.71	2.38	0.27	0.2039	0.21	0.55	0.72	0.61	2.44
S.E. (gi-gj) line	0.57	0.52	0.36	2.42	3.37	0.39	0.2883	0.30	0.77	1.03	0.86	3.45
Testers												
BML 7	1.09 **	1.22 **	0.93 **	0.53	-1.44	-0.14	0.448 **	0.33 **	-0.08	-0.62 *	-1.10**	-1.780
BML 14	-1.42 **	-1.48 **	-0.27 **	-4.43 **	-5.03 **	0.15	0.512 **	0.35 **	-1.30 **	3.11 **	0.65**	12.08**
BML 15	0.32 *	0.26	-0.66 **	3.90 **	6.47 **	-0.01	-0.960 **	-0.68 **	1.38 **	2.48 **	0.45	-10.30**
Range for testers	-1.42 to 1.09	-1.48 to 0.26	-0.66 to 0.93	-4.43 to 3.90	-5.03 to 6.47	-0.14 to 0.15	-0.960 to 0.512	-0.68 to 0.35	-1.30 to 1.38	-0.62 to 3.11	-1.10 to 0.65	-10.30 to 12.08
S.E. (gca for tester)	0.15	0.14	0.09	0.66	0.92	0.10	0.0790	0.08	0.21	0.28	0.23	0.94
S.E. (gi-gj) tester	0.22	0.20	0.13	0.93	1.30	0.15	0.2883	0.11	0.30	0.39	0.33	1.33

Table 4. Estimates of specific combining ability (*sca*) effects for single crosses for yield and yield component characters in maize

Hybrids	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)	Shelling percentage	Grain yield per plant (g)
MRC 1 × BML 7	2.12 **	2.21 **	1.28 **	-0.80	-2.82	-0.43	0.585	0.15	1.20	-1.59	-0.17	-1.70
MRC 1 × BML 14	0.97	0.93	-0.83	6.60 *	3.36	0.59	-1.038 **	-0.39	-0.02	-0.13	-0.67	-3.80
MRC 1 × BML 15	-3.10 **	-3.15 **	-0.45	-5.80	-0.54	-0.15	0.453	0.23	-1.18	1.72	0.84	5.51
MRC 2 × BML 7	0.23	0.43	0.83	-2.88	4.23	-1.56 **	-0.553	-0.28	-1.6	0.40	-0.34	-15.37 **
MRC 2 × BML 14	0.75	0.82	0.05	4.42	2.17	0.73	0.271	-0.43	0.71	0.53	0.65	1.69
MRC 2 × BML 15	-0.99	-1.26	-0.89 *	-1.54	-6.40	0.83	0.282	0.72	0.89	-0.93	-0.30	13.67 **
MRC 3 × BML 7	1.35	1.21	-0.60	3.56	-3.60	-1.01 *	-0.006	0.27	-4.96 **	-1.83	0.66	-23.50 **
MRC 3 × BML 14	-0.13	-0.06	-0.38	-2.89	1.58	0.05	0.271	-0.01	3.92 **	2.48	1.98	20.91 **
MRC 3 × BML 15	-1.21	-1.15	0.99 *	-0.67	2.01	0.95 *	-0.264	-0.25	1.04	-0.64	-2.64 *	2.59
MRC 4 × BML 7	-0.09	-0.006	-0.71	2.53	-0.38	-0.40	0.101	-0.01	2.41 *	-1.10	1.31	-11.68 **
MRC 4 × BML 14	0.42	0.04	-0.16	-3.16	5.98	0.36	0.031	0.76 *	-1.03	0.22	-0.48	4.98
MRC 4 × BML 15	-0.32	-0.03	0.88 *	0.63	-5.59	0.03	-0.131	-0.74	-1.38	0.88	-0.83	6.70
MRC 5 × BML 7	-1.53 *	-1.78 **	-0.27	-2.75	-4.93	0.75	0.407	0.38	-1.09	1.42	-3.41 **	7.33
MRC 5 × BML 14	-0.68	-0.40	0.27	4.04	1.31	0.51	0.751 *	-0.70	2.05 *	2.75 *	0.06	8.15
MRC 5 × BML 15	2.22 **	2.18 **	-0.006	-1.29	3.61	-1.27 **	-1.158 **	0.32	-0.95	-4.18 **	3.35 **	-15.48**
MRC 6 × BML 7	2.23 **	0.99	-0.82	3.30	3.29	0.13	-0.199	-0.55	-1.45	-1.14	-0.73	-11.54**
MRC 6 × BML 14	-0.57	0.04	-0.94 *	-5.65	-6.20	-0.61	-0.029	0.09	0.43	0.37	2.39 *	2.50
MRC 6 × BML 15	-1.66 *	-1.03	1.77 **	2.34	2.91	0.48	0.229	0.45	1.02	0.77	-1.66	9.03 *
MRC 7 × BML 7	0.01	-0.11	-0.05	-1.56	-6.12	0.49	0.381	0.15	1.28	2.00	-2.09	22.38 **
MRC 7 × BML 14	-0.46	-1.06	0.16	1.55	1.13	0.42	0.224	0.13	0.43	0.53	1.21	-6.81
MRC 7 × BML 15	0.45	1.18	-0.11	0.006	4.99	-0.91	-0.604	-0.29	-1.71	-2.53 *	0.88	-15.57 **
MRC 8 × BML 7	1.23	1.10	-0.27	-3.16	0.90	0.27	0.009	-0.66	2.36 *	-0.62	-1.58	-0.14
MRC 8 × BML 14	0.42	0.48	-0.05	4.49	2.35	-0.27	0.026	1.05 **	-1.14	0.58	0.46	3.63
MRC 8 × BML 15	-1.66 *	-1.59 *	0.32	-1.32	-3.26	-0.008	-0.036	-0.38	-1.22	0.03	1.12	-3.49
MRC 9 × BML 7	1.68 *	1.77 **	-0.49	4.47	6.69	0.17	-0.062	-0.10	0.79	0.91	-1.45	9.29 *
MRC 9 × BML 14	-0.46	-0.51	-1.61 **	-4.84	-3.85	-0.74	-0.272	0.13	-2.52 **	-3.15 *	2.33 *	-9.10 *
MRC 9 × BML 15	-1.21	-1.26	2.10 **	0.37	-2.84	0.56	0.333	-0.03	1.73	2.24	-0.88	-0.18
MRC 10 × BML 7	-1.42 *	-1.22	-1.16 **	-8.96 **	20.97 **	-0.15	0.278	0.20	0.01	-1.23	2.21 *	9.38 *
MRC 10 × BML 14	0.75	0.15	0.72	4.07	-15.37 **	-0.04	-0.352	-0.21	1.20	-0.58	-0.81	-0.88
MRC 10 × BML 15	0.67	1.07	0.43	4.88	-5.60	0.19	0.073	0.01	-1.21	1.81	-1.39	-8.49 *
MRC 11 × BML 7	0.12	0.21	-0.71	-1.24	-3.02	1.33 **	-0.697	-0.59	2.81 **	-0.12	-2.10	-2.55
MRC 11 × BML 14	-2.02 **	-2.06 **	-0.83	2.05	0.68	-0.12	0.119	0.11	-1.56	-0.26	-0.81	-0.28
MRC 11 × BML 15	1.89 **	1.85 **	1.55 **	-0.81	2.34	-1.21 *	0.578	0.48	-1.24	0.39	2.92 **	2.83
MRC 12 × BML 7	-0.42	-0.45	2.28 **	3.99	-1.10	0.77	0.321	0.04	-0.07	1.29	2.44 *	20.88 **
MRC 12 × BML 14	0.75	0.60	-0.83	-5.71	-2.79	-0.36	0.411	-0.17	-0.32	-0.44	-2.31 *	-17.58 **
MRC 12 × BML 15	-0.32	-0.15	-1.45 **	1.72	3.90	-0.41	-0.731 *	0.12	0.39	-0.84	-0.12	-3.29
MRC 13 × BML 7	-0.42	-0.11	-0.27	-0.95	0.03	-0.31	0.203	-0.06	-1.23	-2.68 *	-0.58	0.24
MRC 13 × BML 14	-0.24	-0.73	0.61	-3.84	-1.14	0.43	0.099	0.45	0.25	2.57 *	0.33	23.64 **
MRC 13 × BML 15	0.67	0.85	-0.33	4.79	1.11	-0.11	-0.302	-0.38	0.97	0.10	0.24	-23.89 **
MRC 14 × BML 7	-0.5	-0.67	-2.05 **	-6.46 *	-2.94	-0.79	0.287	0.69	0.62	4.00 **	2.69 *	13.64 **
MRC 14 × BML 14	-0.68	-0.62	1.16 **	4.67	2.30	-0.09	-0.696	-0.66	-0.60	-1.86	-2.73 *	-9.95 *
MRC 14 × BML 15	1.22	1.29 *	0.88 *	1.78	0.63	0.89	0.409	-0.03	-0.01	-2.13	0.04	-3.69
MRC 15 × BML 7	-0.42	-0.006	1.28 **	4.22	-6.95	0.91	0.614	0.11	-0.75	1.07	0.14	11.10 **
MRC 15 × BML 14	-0.57	-0.62	1.16 **	-6.40 *	-0.31	0.16	0.591	0.22	2.00 *	0.66	-0.98	10.20 *
MRC 15 × BML 15	1.00	0.62	-2.45 **	2.18	7.26	-1.07 *	-1.204 **	-0.34	-1.24	-1.73	0.84	-21.30 **
MRC 16 × BML 7	-0.98	-1.22	-0.93 *	3.06	0.11	-0.24	-0.535	-0.73	1.38	3.98 **	1.54	7.37
MRC 16 × BML 14	0.20	0.48	-0.05	-11.43 **	-1.95	0.36	-0.038	0.05	-0.36	-3.15 *	-1.36	-10.35 *
MRC 16 × BML 15	0.78	0.73	0.99 *	8.36**	1.83	-0.12	0.573	0.68	-1.01	-0.82	-0.17	2.97
MRC 17 × BML 7	0.23	0.21	1.61 **	0.24	1.50	-0.30	-0.048	0.33	-0.38	-4.47 **	2.10	-15.05 **
MRC 17 × BML 14	-0.24	-0.06	0.83	5.61	-0.49	0.11	0.162	0.31	-1.96 *	1.80	0.36	6.78
MRC 17 × BML 15	0.006	-0.15	-2.45 **	-5.85	-1.00	0.18	-0.113	-0.65	2.35 *	2.67 *	-2.46 *	8.27
MRC 18 × BML 7	-0.87	-0.45	1.17 **	1.61	-4.11	0.65	-0.413	0.42	0.92	0.38	0.22	7.94
MRC 18 × BML 14	0.64	0.93	-0.61	2.56	4.68	-0.80	-0.203	-0.39	0.34	-2.42	-0.94	-18.14 **
MRC 18 × BML 15	0.22	-0.48	-0.56	-4.17	-0.57	0.14	0.616	-0.03	-1.26	2.04	0.72	10.20 *
MRC 19 × BML 7	-3.09 **	2.67 **	-1.05 *	1.93	1.80	-0.29	-0.086	-0.01	-0.74	-2.19	-2.27 *	-5.33
MRC 19 × BML 14	1.75 *	2.04 **	1.16 **	-1.64	1.91	-0.69	-0.363	-0.30	-1.24	0.39	1.50	-11.79 **
MRC 19 × BML 15	1.33	0.62	-0.11	-0.29	-3.72	0.98 *	0.449	0.32	1.99 *	1.79	0.76	17.12 **
MRC 20 × BML 7	0.57	0.55	0.95 *	-0.14	-3.55	-0.01	-0.586	0.24	-1.48	1.51	1.44	-22.69**
MRC 20 × BML 14	-0.57	-0.40	0.16	5.49	4.63	-0.005	0.037	-0.03	-0.56	-0.89	-0.15	6.20
MRC 20 × BML 15	0.006	-0.15	-1.11 *	-5.34	-1.07	0.01	0.549	-0.20	2.05 *	-0.62	-1.28	16.49 **
Range for hybrids	-3.10 to 2.23	-3.15 to 2.21	-2.45 to 2.28	-8.96 to 8.36	-15.37 to 20.97	-1.56 to 1.33	-1.204 to 0.751	-0.74 to 1.05	-4.96 to 3.92	-4.47 to 4.00	-3.41 to 3.35	-23.89 to 23.64
S.E. (sca effects) s_{ij}	0.70	0.64	0.44	2.96	4.12	0.47	0.35	0.37	0.95	1.26	1.06	4.23
S.E. (s_{ij}-s_{kl})	0.99	0.90	0.62	4.19	5.83	0.67	0.49	0.53	1.34	1.78	1.50	5.99

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

For ear height, six lines and tester, BML 15 (6.47) recorded significant positive *gca* effects and hybrid, MRC 10 × BML 7 (20.97) recorded the highest significant positive *sca* effect. In respect of ear length, five lines recorded significant positive *gca* effects, of which MRC 4 recorded highest significant positive *gca* effect (1.33) and three hybrids recorded significant positive *sca* effects. Three lines and testers, BML 14 and BML-7 recorded the significant positive *gca* effect for ear girth. Hybrid, MRC 5 × BML 14 (0.75) recorded the highest significant positive *sca* effect and is the best specific cross for ear girth. Four lines and two testers recorded significant positive *gca* effects for number of kernel rows per ear. These results are comparable with findings of Jawaharlal *et al*. [5] and Mohammad *et al*. [10] who reported the additive gene action for number of kernel rows per ear. Two hybrids, MRC 8 × BML 14 (1.05) and MRC 4 × BML 14 (0.76) are considered as better crosses for number of kernel rows per ear. Six lines recorded significant positive *gca* effects, of which (MRC 4) recorded the highest significant positive *gca* effect (3.09) where as the tester BML 15 (1.38) recorded the highest significant positive *gca* effect and among the hybrids, nine hybrids recorded significant positive *sca* effects, of which MRC 3 × BML 14 recorded the highest significant positive *sca* effect (3.92) for number of kernels per row. The line MRC 14 recorded the highest significant positive *gca* effect (4.23) and tester, BML 14 (3.11) recorded the highest significant positive *gca* effect for 100-kernel weight. Five hybrids recorded significant positive *sca* effects, among which MRC 14 × BML 7 recorded the highest significant positive *sca* effect (4.00) for 100-kernel weight. For shelling percentage four lines recorded significant positive *gca* effects, of which MRC 4 recorded the highest significant positive *gca* effect (2.37) and tester, BML 14 (0.65) recorded the highest significant positive *gca* effect. Among the hybrids, seven hybrids recorded significant positive *sca* effects, of which MRC 5 × BML 15 recorded the highest significant positive *sca* effect (3.35) which is considered as potential specific cross for shelling percentage. These results are comparable with findings of Jayakumar *et al*. [6] who reported the non-additive gene action for shelling percentage. In respect of grain yield per plant, lines MRC 14, MRC 4, MRC 9, MRC 8, MRC 7, MRC 6, MRC 15, MRC 18 and MRC 5 and tester BML 14 which recorded significant positive *gca* effects are considered as good combiners for grain yield per plant. Fourteen hybrids recorded significant positive *sca* effects, of which, MRC 13 × BML 14 recorded the highest significant positive *sca* effect (23.64) followed by MRC 7 × BML 7 (22.38), MRC 3 × BML 14 (20.91), MRC 12 × BML 7 (20.88) and MRC 20 × BML 15 (16.49) regarding grain yield per plant. These results are comparable with the findings of Venugopal *et al.* [13] Gowhar Ali *et al.* [3], Jawaharlal *et al*. [5] and Sunil Kumar *et al*. [12] who reported the non-additive gene action for grain yield per plant.

Among the lines, MRC 4, MRC 6, MRC 7, MRC 8, MRC 9 and MRC 14 can be considered as good general combiners and genetically worthy parents as they exhibited desirable *gca* effects for yield and important yield contributing characters. These parents had resulted in the production of superior single crosses. The line MRC 4 was good general combiner for days to 50 per cent silking, days to 50 per cent tasseling, days to maturity, number of kernel rows, number of kernels per row, shelling percentage and grain yield per plant. The line MRC 6 was good general combiner for days to 50 per cent silking, days to 50 per cent tasseling, days to maturity, ear height and grain yield per plant. The line MRC 7 was good general combiner for days to 50 per cent silking, days to 50 per cent tasseling, days to maturity, number of kernels per row, plant height and grian yield per plant. The line MRC 8 was good general combiner for ear length, number of kernels per row, 100-kernel weight, shelling percentage and grain yield. The line MRC 9 was good general combiner for 100-kernel weight, shelling percentage and grain yield. The line MRC 14 was good general combiner for 100-kernel weight, shelling percentage and grain yield per plant. Among testers, BML 14 was good general combiner for days to 50 per cent silking, days to 50 per cent tasseling, days to maturity, number of kernel rows, 100-kernel weight, shelling percentage and grain yield per plant. Whereas, BML 15 was good general combiner for days to maturity, plant height, ear height and number of kernels per row. Hence, these high yielding parents with good attributes for different yield components may be inter-crossed to pool the genes in desirable direction to improve the yield potential. The crosses, MRC 13 × BML 14, MRC 7 × BML 7, MRC 3 × BML 14, MRC 12 × BML 7 and MRC 14 × BML 7 can be considered as good specific combiners and genetically worthy crosses as they were superior for yield and important yield contributing characters. The cross MRC 13 × BML 14 was good specific combiner for 100-kernel weight and grain yield per plant. The hybrid MRC 7 × BML 7 was good specific combiner for grain yield per plant. The cross MRC 3 × BML 14 was good specific combiner for number of kernels per row and grain yield per plant. The cross MRC 12 × BML 7 was good specific combiner for shelling percentage and grain yield per plant. The cross MRC 14 × BML 7 was good specific combiner for shelling percentage, 100- kernel weight and grain yield per plant. Hence, these high yielding hybrids with good attributes can be checked under different field trials and can be developed as commercial hybrids.

CONCLUSION

This study revealed that high general combining ability effects for yield and important yield contributing characters were noticed in the inbred lines MRC 4, MRC 6, MRC 7, MRC 8, MRC 9, MRC 14 and tester BML 14. These parents had resulted in the production of superior single crosses. Hence, these inbred lines have the potential application in the crop improvement programmes. High specific combining ability effects for grain yield and important yield contributing characters were noticed in the hybrids MRC 13 × BML 14, MRC 7 × BML 7, MRC 3 × BML 14, MRC 12 × BML 7 and MRC 14 × BML 7. These crosses may be checked under different field trials and can be developed as commercial hybrids or advanced for selfing for the isolation of transgressive segregants or homozygous lines for use in breeding programmes.

REFERENCES

[1] Ali, G., Ahmed, I., Dar, S.A and Iqbal, A.M. 2012. Combining ability analysis for yield and its component traits in high altitude maize (*Zea mays* L.) inbreds. Advances in life sciencecs. 1 (1): 66-69.

[2] Bhavana, P., Singh, R.P and Gadag, R.N. 2011. Gene action and heterosis for yield and yield components in maize (*Zea mays)*. Indian Journal of Agricultural Sciences. 81 (2): 163-166.

[3] Gowhar Ali, Ishfaq, A., Rather, A.G., Wani, S.A., Gul Zaffar and Makhdoomi, M.I. 2007. Heterosis and combining ability for grain yield and its components in high altitude maize inbreds (*Zea mays* L.). Indian Journal of Genetics and Plant Breeding. 67 (1): 81-82.

[4] Jagadish Kumar, Sanjeev Kumar and Sood, B.C. 2010. Gene action for yield and yield contributing characters in indigenous maize (*Zea mays* L.) germ plasm of Himachal Pradesh. Crop Improvement. 37 (2): 114-19.

[5] Jawaharlal, J., Reddy G.L and Kumar, R. S. 2012. Heterosis for yield component traits in maize (*Zea mays* L.). Indian Journal of Agricultural Research. 46 (2): 184-187

[6] Jayakumar, J and Sundaram, T. 2007. Combining ability studies for grain yield and other yield components in maize (*Zea mays* L.). Crop Research. 33 (1): 179-186.

[7] Kanagarasu, S., Nallathambi, G. and Ganesan, K.N. 2010. Combining ability analysis for yield and its component traits in maize (*Zea mays* L.). Electronic Journal of Plant Breeding. 1 (4): 915-920.

[8] Kempthorne, O. 1957. *An introduction to genetic statistics*. New York, John Wiley and Sons, Inc. London: Chapman and Hall Limited.

[9] Kumar, B. S., Prakash, M., Sathyanarayanan, G. and Padmavathi, S. 2012. Studies on combining ability and heterosis through line x tester analysis in maize (*Zea* mays L.). Crop Research (Hisar). 43 (1/2/3): 153-157.

[10] Mohammad, H.H, Maqsadollah Easmaeilof, Rajab Choukan and Valiollah Rameeh. 2012. Combining ability analysis of days to silking, plant height, yield components and kernel yield in maize breeding lines. *African* Journal of Agricultural Research. 7 (36): 5153-5159.

[11] Ram Reddy, V., Seshagiri Rao, A and Sudarshan, M.R. 2011. Heterosis and combining ability for grain yield and its components in maize (*Zea mays* L.). Journal of Research. ANGRAU. 39 (3): 6-15.

[12] Sunil Kumar, B., Prakash, M., Sathyanarayanan, G.and Padmavathi, S. 2012. Studies on combining ability and hetrosis through line × tester analysis in maize (*Zea mays* L.). Crop Research, Hisar. 43 (1, 2 & 3): 153-157.

[13] Venugopal, M., Ansari, N.A and Rao, N.V. 2002. Combining ability studies in maize (*Zea mays* L.). Annals of Agricultural Research. 23: 92-95.