The Bioscan 11(2):1043-1047,2016(Supplement on Genetics and Plant Breeding) www.thebioscan.com
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES

GENE ACTION AND COMBINING ABILITY ANALYSIS FOR YIELD AND ITS COMPONENT TRAITS IN MAIZE (*ZEA MAYS* L.)

I. SWARNALATHA DEVI*, K. PARIMALA AND K. SRAVANTHI
Seed Research and Technology Centre, PJTSAU, Rajendranagar - 500 030, Hyderabad, INDIA
e-mail: sld_66@yahoo.co.in

KEYWORDS
Maize
Gene action
GCA effect
SCA effect
Heterosis

Received on :
21.12.2015

Accepted on :
05.05.2016

***Corresponding author**

ABSTRACT
A study was carried out involving seven lines and three testers crossed in line x tester design to produce 21 crosses to know the nature of gene action and to estimate the magnitude of heterosis in maize. The ratio of GCA / SCA was less than unity for all the characters studied indicating the predominance of non-additive gene action. The line BML-7 for grain yield per plant, ear length and number of kernels per row; CM-210 for grain yield per plant and number of kernel rows per ear; the tester Y-3 for ear girth, number of kernels per row and grain yield per plant identified as promising general combiners due to having positive significant *gca* effect. The cross BML-7 x Y-3recorded significant *sca* effect for number of kernel rows per ear. The crosses, CM-202 x Y-14, CM-210 x Y-14, BML-7 x Y-18 and CM-105 x Y-18 were found to be good specific combiners for grain yield per plant. The hybrids BML-7 x Y-18 and CM 210 x Y-14 were found to be promising cross combinations which exhibited high *sca* effects, heterobeltiosis and standard heterosis for grain yield per plant. These hybrid combinations could be utilized for exploitation of hybrid vigour.

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in the world after rice and wheat. It plays a significant role in human and livestock nutrition. Hybrid cultivars have played a vital role in increasing acreage and productivity of maize. The single cross maize hybrids have become popular among Indian farmers due to their high yield potential and excellent uniformity. Information on heterotic patterns and combing ability among maize germplasm is necessary in maximizing the effectiveness of hybrid development (Beck *et al*., 1990). Success of hybrid development depends on selection of parents for hybridization and type of gene action involved in controlling of yield traits. Combining ability analysis provides such information so as to frame the breeding programme effectively (Dwivedi and Pandey, 2012). The hybrid breeding is imperative to select the cross combinations with high degree of SCA as well as parents with high GCA. In maize, extent of heterosis and combining ability for yield and its component traits were studied by Rokadia and Kaushik (2008), Kanagarasu (2010) and Farhan Ali *et al*., (2012). The studies on heterosis can provide the basis for the exploitation of valuable hybrid combinations in the future breeding programmes and their commercial utilization (Rajeev Kumar *et al*., 2013). Exploitation of hybrid vigour is another possibility for increasing grain yield (Ulaganathan *et al*., 2015). Therefore the present investigation was undertaken to know the nature of gene action controlling the traits under study and to identify heterotic cross combinations for grain yield and its component traits.

MATERIALS AND METHODS

In the present study seven inbreds were used as lines *viz*., BML-7, CM-105, CM-115, CM-202, CM-206, CM-208 and CM-210 and three inbreds were used as testers *viz*., Y3, Y14 and Y18. Crosses were made between lines and testers in Line x Tester mating design during *kharif*, 2013. The resulting 21 F_1s and their parents were sown with a spacing of 60 cm between rows and 30 cm between plants during *rabi*, 2013 at Seed Research and Technology Centre, Rajendranagar, Hyderabad. The experiment was laid out in a randomized block design with three replications. Each entry consisted of two rows of *5* m long and one plant per hill was maintained. Observations were recorded for nine quantitative traits *viz*., days to 50% tasselling, days to 50% silking, days to maturity, plant height (cm), ear length (cm), ear girth (cm), number of kernel rows per ear, number of kernels per row and grain yield per plant (g). Five randomly selected plants from each entry per replication were used for recording observations.

The data recorded on the material generated as per Line x Tester design were subjected to analysis of variance as per the Line x Tester model given by Singh and Chaudhary (1979).The mean data were subjected to combining ability analysis using Line x Tester design as suggested by Kempthorne (1957) to estimate the general and specific combining ability.The magnitude of heterosis in hybrids was calculated using the following formula:

Heterobeltiosis

Heterobeltiosis was expressed as per cent increase or decrease observed in F_1 over the better parent as per the formula of Liang *et al*. (1971).

$$\text{Heterobeltiosis (\%)} = \frac{\overline{F_1}\ \ \overline{BP}}{\overline{BP}}\ \ 100$$

Where,

$\overline{BP}$ = Mean of better parent

$\bar{F}_1$ = Mean performance of F_1 hybrid

Standard heterosis

Standard heterosis was expressed as per cent increase or decrease observed in F_1 over standard checks.

$$\text{Standard heterosis (\%)} = \frac{\bar{F}_1 \quad \text{Mean of check}}{\text{Mean of check}} \quad 100$$

Where,

$\bar{F}_1$ = Mean performance of F_1 hybrid

RESULTS AND DISCUSSION

The analysis of variance for combining ability revealed that variance due to crosses was significant for the traits studied (Table 1). The interaction between lines x testers was significant for all the characters studied indicating the importance of additive components of genetic variance in the inheritance of these traits. The ratio of GCA/SCA was less than unity for all the traits indicated the predominance of non-additive gene action which is favourable for heterosis breeding. Kanagarasu *et al*. (2010) and Praveen Kumar *et al*. (2014) also found similar findings in their studies for grain yield and its components. Dar *et al*. (2015) also found the role of non-additive gene action in controlling the traits *viz*., plant height, number of kernel rows per ear, number of kernels per row and grain yield per plant.

GCA effects

Estimates of *gca* effects revealed that the line CM-105 exhibited significant negative *gca* effect for days to 50 % tasseling, days to 50 % silking and days to maturity indicating that it was good general combiner for earliness (Table 3). Positive *gca* effect for ear length and ear girth was recorded in BML-7 and CM-115 respectively. The line CM-210 was found to be good general combiner for number of kernel rows per ear and the line BML-7 for number of kernels per row. Highly significant positive *gca* effect was observed in the lines BML-7 and CM-210 for grain yield per plant. Singh *et al*. (2012) also identified inbreds with good general combining ability for ear length, number of kernels per row and earliness. Among the testers studied, Y-3 was found to be promising general combiner for ear girth, number of kernels per row and grain yield per plant. Result indicated that this tester possess higher proportion of favourable genes for these traits. The tester, Y-14 was found to have desirable *gca* effect for days to 50 % tasselling and days to 50 % silking. Alam *et al*. (2008) and Khalil *et al*. (2010) reported higher positive GCA effects for number of kernels per ear and grain yield per plant in their findings. Kanagarasu *et al*. (2010) found good *gca* parents for grain yield, earliness, ear length, number of kernels per row and ear girth. Thus, the inbred lines which exhibited good general combining ability for atleast one trait can be used as donor parents for the accumulation of favourable genes.

SCA effects

Among the 21 crosses evaluated , the crosses, BML-7 x Y18, CM-105 x Y18, CM-202 x Y14 and CM-210 x Y14 involving high x low, medium x low, low x medium and high x medium interaction of GCA of the parents expressed significant positive *sca* effects for grain yield per plant (Table 4). The crosses, BML-7 x Y3 and CM-206 x Y-18 registered as promising specific combiner for number of kernel rows per ear and number of kernels per row respectively. Dar *et al*., (2015) observed highly significant positive *sca* effect for number of kernel rows per ear and grain yield per plant. Eight crosses showed negative significant *sca* effect for days to 50 % tasselling and days to 50 % silking among which, CM-115 x Y-14, CM-208 x Y-3, and CM-210 x Y-18 recorded highest significant negative *sca* effect. The crosses CM-210 x Y-18 (-4.69) and CM-115 x Y-14 (-4.28) involving medium x medium and high x low interaction of GCA of the parents showed highest significant negative *sca* effect for days to maturity indicating that they were good specific combiners for earliness. Among the hybrids studied, four hybrids

Table 1: Analysis of variance for line x tester analysis for grain yield and its components in maize

Source	DF	Days to 50 % tasselling	Days to 50 % silking	Days to maturity	Plant height	Ear length	Ear girth	No. of kernel rows/ear	No. of kernels /row	Grain yield /plant
Replications	2	2.33	3.61	5.33	50.57	0.98	0.49	0.90	13.30	66.72
Crosses	20	44.56 **	45.78 **	34.71 **	1531.53 **	6.83 *	2.87 **	3.12 *	22.86 **	708.66 **
Lines Effect	6	13.66	13.51	41.43	2342.36	3.96	0.89	2.10	20.39	700.05
Testers Effect	2	34.42	25.33	39.00	1231.63	2.92	7.07	2.28	54.74	530.40
Lines x Testers Eff.	12	61.71 **	65.33 **	30.64 **	1176.11**	8.92 **	3.16 **	3.77 **	18.78 *	742.68 **
Error	40	1.75	2.31	3.16	94.23	2.95	1.17	1.33	7.80	82.92
Total	62	15.58	16.38	13.41	556.47	4.14	1.70	1.89	12.83	284.25

* significant at 5 % level ., ** significant at 1 % level

Table 2: Magnitude of *gca* and *sca* variance for grain yield and its contributing characters in maize

Source	Days to 50 % tasselling	Days to 50 % silking	Days to maturity	Plant height	Ear length	Ear girth	No. of kernel rows/ear	No. of kernels /row	Grain yield/ plant
ó^{2}g	1.30	1.28	3.94	223.08	0.33	0.08	0.20	1.94	66.67
ó^{2}s	35.26	37.33	17.51	672.08	5.09	1.80	2.15	10.73	424.39
ó^{2}g : ó^{2}s	0.037	0.034	0.22	0.33	0.07	0.04	0.09	0.18	0.15

Table 3: General combining ability (*gca*) effects of lines and testers for yield and its components in maize

Parents	Days to 50 % tasselling	Days to 50 % silking	Days to maturity	Plant height	Ear length	Ear girth	No. of kernel rows / ear	No. of kernels / row	Grain yield / plant
Lines									
BML-7	1.00*	0.69	-0.74	8.78**	0.95	-0.17	0.22	1.74	13.81**
CM-105	-1.55**	-1.85**	-3.07**	23.81**	-0.49	-0.30	0.35	-0.92	-4.74
CM-115	0.33	0.81	-1.52*	7.96*	-0.55	0.57	0.03	-1.41	-7.62*
CM-202	0.00	0.03	2.58**	-12.66**	-0.25	-0.09	-0.60	-2.06*	-7.69*
CM-206	0.00	0.47	-0.19	-26.09**	0.23	0.24	-0.63	1.68	1.16
CM-208	1.77**	1.36*	2.92**	-3.26	0.77	-0.28	-0.03	0.21	-5.25
CM-210	-1.55**	-1.52**	0.03	1.46	-0.66	0.04	0.67	0.76	10.34**
Testers									
Y 3	0.66**	0.09	-1.42**	-1.08	0.23	0.60*	0.38	1.85*	5.06*
Y14	-1.47**	-1.14**	1.28**	8.14**	0.19	-0.05	-0.19	-1.11	-0.07
Y 18	0.81**	1.04**	0.14	-7.05**	-0.43	-0.55*	-0.19	-0.74	-4.98*

* significant at 5 % level ., ** significant at 1 % level

Table 4: Specific combining ability (*sca*) effects of crosses for yield and its components in maize

Crosses	Days to 50 % tasselling	Days to 50 % silking	Days to maturity	Plant height	Ear length	Ear girth	No. of kernel rows / ear	No. of kernels / row	Grain yield / plant
BML-7 x Y3	-2.33**	-2.31*	-3.34**	-4.87	2.02*	-0.50	-1.04	1.03	6.83
BML-7 x Y14	3.81**	4.25**	2.60*	25.95**	-0.47	-0.34	-1.14	0.49	-21.75**
BML-7 x Y18	-1.47	-1.93*	0.74	-21.07**	-1.54	0.85	2.19**	-1.53	14.92**
CM-105 x Y3	-0.11	0.57	0.31	6.90	-1.38	-0.57	-0.50	-2.13	-11.50*
CM-105 x Y14	-1.96*	-2.19*	-2.06	4.03	0.51	0.98	-0.43	0.66	-1.50
CM-105 x Y18	2.07**	1.61	1.74	-10.93*	0.87	-0.41	0.93	1.46	13.01*
CM-115 x Y3	8.33**	8.23**	3.42**	13.27*	1.03	1.51*	0.35	1.35	3.09
CM-115 x Y14	-6.52**	-7.52**	-4.28**	-9.88	-1.06	-1.52*	0.38	0.38	-9.65
CM-115 x Y18	-1.81 *	-0.71	0.85	-3.38	0.03	0.01	-0.73	-1.74	6.55
CM-202 x Y3	-1.00	0.98	-3.01**	-4.88	0.33	-1.41*	0.45	0.67	-12.78*
CM-202 x Y14	1.81*	1.25	1.60	4.07	-0.23	0.97	0.52	2.06	19.11**
CM-202 x Y18	-0.81	-0.27	1.41	0.81	-0.10	0.44	-0.97	-2.73	-6.33
CM-206 x Y3	0.33	-0.09	1.42	4.26	0.77	1.01	-0.18	-2.40	-4.41
CM-206 x Y14	0.81	2.47**	1.04	-9.23	-0.78	-0.42	0.458	-1.11	-2.44
CM-206 x Y18	-1.18*	-2.38**	-2.47*	4.96	0.00	-0.59	-0.277	3.52*	6.86
CM-208 x Y3	-4.11**	-4.31**	-1.68	-9.98	-1.46	-0.16	1.086	2.22	10.40
CM-208 x Y14	-2.30**	-2.07*	-0.73	17.54**	3.06**	-0.13	-0.876	0.02	0.34
CM-208 x Y18	6.41**	6.39**	2.41*	-7.55	-1.60	0.29	-0.210	-2.24	-10.74*
CM-210 x Y3	-1.11	-1.09	2.87*	-4.68	-1.32	0.11	-0.158	-0.75	8.37
CM-210 x Y14	4.36**	3.81**	1.82	-32.48**	-1.02	0.47	1.080	-2.52	15.90**
CM-210 x Y18	-3.25**	-2.71**	-4.69**	37.17**	2.34*	-0.59	-0.922	3.27	-24.27**

* significant at 5 % level ., ** significant at 1 % level

recorded the significant positive *sca* effect for plant height and these hybrid combinations were found to be best for tallness. In case of ear length, the hybrid CM-210 x Y-18 (3.06) was found to be best specific combiner followed by CM-210 x Y-18 (2.34) and BML-7 x Y-3 (2.02) which exhibited significant positive *sca* effect. These results are in conformity with the earlier reports of Kanagarasu *et al*. (2010) and Singh *et al*. (2012) for grain yield and some of other component characters.

Heterosis

Estimates of heterosis for grain yield and its component traits in maize were presented in Table 5. Heterosis in negative direction is desirable for days to 50% tasseling, days to 50% silking and days to maturity. The range of heterosis for days to 50% tasseling and days to 50% silking varied from -11.27 % (BML-7 x Y3) to 15.87 % (CM 115 x Y 3) and -11.27 % (CM-115 x Y-14) to 14.36 % (CM-208 x Y-18) over better parent respectively. The cross CM-115 x Y-14 registered highly significant negative heterosis for days to 50% tasseling and days to 50% silking. Among the 21 crosses studied, five crosses over better parent and six crosses over standard check exhibited significant negative heterosis for days to maturity. Negative heterosis for these three characters indicates the possibilities for breeding of maize for earliness and results were in conformity with earlier reports of Appunu *et al*. (2007), Saidaiah *et al*. (2008), Avinash *et al*. (2013) and Rajesh *et al*. (2014). The cross CM 208 x Y-14 exhibited the highly significant positive heterosis for ear length over better parent and standard check. For ear girth only one cross, CM 115 x Y-3 recorded the positive significant heterosis over standard check. None of the cross was found to have positive significant heterosis over better parent and standard check for number of kernel rows per ear. The cross CM 206 x Y-18 (18.57) recorded the highly positive significant heterobeltiosis for number of kernels per row followed by BML 7 x Y-3 (16.84). Significant positive

Table 5: Estimates of heterobeltiosis (HB) and standard heterosis (SH) for yield and its component traits in maize

Crosses	Days to 50 % tasselling		Days to 50 % silking		Days to maturity		Plant height	
	HB	SH	HB	SH	HB	SH	HB	SH
BML-7 x Y3	-11.27 **	-4.06 *	-9.91 **	-5.66 **	-9.77 **	-5.99 **	8.51	-13.95 **
BML-7 x Y14	-5.63 **	2.03	-2.7	1.89	-2.3	1.8	39.27 **	5.5
BML-7 x Y18	-9.86 **	-2.54	-8.11 **	-3.77 *	-4.89 **	-0.9	-13.88 **	-24.71 **
CM-105 x Y3	2.73	-4.57 **	2.03	-5.19 **	-5.64 **	-4.79 **	24.92 **	-0.94
CM-105 x Y14	-3.83 *	-10.66 **	-4.06 *	-10.85 **	-2.15	-4.49 **	56.24 **	2.15
CM-105 x Y18	6.56 **	-1.02	5.08 **	-2.36	0.31	-2.1	0.09	-12.49 **
CM-115 x Y3	15.87 **	11.17 **	13.73 **	9.43 **	-1.48	-0.6	19.12 **	-5.53
CM-115 x Y14	-11.11 **	-14.72 **	-11.27 **	-14.62 **	-1.25	-5.09 **	34.13 **	-12.30 **
CM-115 x Y18	0.0	-4.06 *	1.96	-1.89	1.23	-1.5	-4.52	-16.52 **
CM-202 x Y3	-0.52	-3.55 *	-0.49	-4.72 **	-5.80 **	-2.69	-4.63	-24.37 **
CM-202 x Y14	0.52	-2.54	0.99	-3.3	0.58	3.89 **	29.18 **	-15.54 **
CM-202 x Y18	0.0	-3.05	1.97	-2.36	-0.58	2.69	-13.64 **	-24.50 **
CM-206 x Y3	1.04	-1.52	0.98	-2.83	-2.08	-1.2	-7.24	-26.44 **
CM-206 x Y14	-1.56	-4.06 *	2.94	-0.94	1.2	0.9	9.33	-28.52 **
CM-206 x Y18	-1.04	-3.55 *	-0.98	-4.72 **	-3.00 *	-3.29 *	-18.79 **	-29.00 **
CM-208 x Y3	-1.59	-5.58 **	-2.97	-7.55 **	-2.08	-1.2	-2.0	-22.29 **
CM-208 x Y14	-2.12	-6.09 **	-1.49	-6.13 **	5.57 **	2.1	46.16 **	-4.43
CM-208 x Y18	15.34 **	10.66 **	14.36 **	8.96 **	6.77 **	3.89 **	-13.07 **	-24.00 **
CM-210 x Y3	2.78	-6.09 **	2.6	-7.08 **	-0.59	0.3	4.14	-17.41 **
CM-210 x Y14	12.07 **	-1.02	10.64 **	-1.89	5.92 **	1.8	12.52 *	-26.43 **
CM-210 x Y18	2.87	-9.14 **	3.72	-8.02 **	-2.46	-5.09 **	14.40 **	0.02

* significant at 5 % level ., ** significant at 1 % level

Table 5: Cont......

Crosses	Ear length		Ear girth		No. of kernel rows / ear		No. of kernels / row		Grain yield / plant	
	HB	SH	HB	SH	HB	SH	HB	SH	HB	SH
BML-7 x Y3	-1.56	22.09 **	-7.47	-5.95	-8.33	-8.33	16.84 *	11.17	27.50 **	8.77
BML-7 x Y14	8.84	7.36	-2.21	-9.03	-12.5	-12.5	9.47	0.97	11.20 *	-11.00 *
BML-7 x Y18	-7.2	-2.52	1.75	-4.72	4	8.33	3.13	-3.88	20.86 **	7.62
CM-105 x Y3	-24.37 **	-6.2	-8.69	-7.19	-4.17	-4.17	-1.02	-5.83	2.15	-12.85 **
CM-105 x Y14	18.68 *	4.65	9.36	-1.64	1.14	-7.29	1.58	-6.31	12.45 *	-10.00 *
CM-105 x Y18	-1.85	3.1	-7.46	-13.35 *	-2.8	1.25	4.17	-2.91	7.39	-4.38
CM-115 x Y3	-13.28 *	7.56	9.29	11.09 *	-0.83	-0.83	8.16	2.91	10.2	-5.98
CM-115 x Y14	7.91	-4.84	-1.83	-11.70 *	0.0	-4.17	-0.84	-8.54	4.37	-16.46 **
CM-115 x Y18	-6.83	-2.13	1.1	-5.34	-14.74 *	-11.19	-7.4	-13.69	1.25	-9.84 *
CM-202 x Y3	-15.16 *	5.23	-12.53 *	-11.09 *	-4.17	-4.17	4.08	-0.97	-0.76	-15.33 **
CM-202 x Y14	15.38	1.74	10.73	-0.41	0.68	-7.29	2.42	-5.53	25.38 **	0.35
CM-202 x Y18	-5.9	-1.16	-0.44	-6.78	-20.00**	-16.67*	-12.5	-18.45 *	-7.28	-17.44 **
CM-206 x Y3	-10.78	10.66	4.24	5.95	-8.33	-8.33	6.12	0.97	11.08 *	-5.23
CM-206 x Y14	14.95	1.36	3.42	-6.98	0.45	-7.92	4.21	-3.88	16.08 **	-7.09
CM-206 x Y18	-2.58	2.33	-5.04	-11.09 *	-16.00 *	-12.5	18.75 *	10.68	7.24	-4.51
CM-208 x Y3	-18.75 **	0.78	-6.06	-4.52	3.33	3.33	15.82 *	10.19	16.85 **	-0.31
CM-208 x Y14	43.96 **	26.94 **	1.83	-8.42	-4.55	-12.5	3.16	-4.85	13.42 *	-9.22 *
CM-208 x Y18	-8.49	-3.88	-2.63	-8.83	-12	-8.33	-3.85	-10.39	-8.58	-18.59 **
CM-210 x Y3	-24.84 **	-6.78	-2.42	-0.82	0.0	0.0	8.37	3.11	26.17 **	7.64
CM-210 x Y14	5.16	-5.23	3.49	-2.67	8.7	4.17	-3.16	-10.68	36.24 **	9.04 *
CM-210 x Y18	5.35	10.66	-6.77	-12.32 *	-12.0	-8.33	15.1	7.28	-7.22	-17.38 **

* significant at 5 % level .,** significant at 1 % level

heterobeltiosis was observed in 11 crosses for grain yield per plant. The cross CM 210 x Y- 14 exhibited the maximum heterobeltiosis (36.24) and standard heterosis (9.04) for grain yield per plant. The heterotic behaviour and magnitude of heterosis in the superior experimental hybrids revealed that heterosis for grain yield may be because of the fact that at least one parent involved in these crosses had desirable and significant *gca* effect.

REFERENCES

Alam, A. K. M. M., Ahmed, S., Begum, M. and Sultan, M. K. 2008. Heterosis and combining ability for grain yield and its contributing characters in maize. *Bangladesh J. Agril. Res.* **33(3):** 375-379.

Appunu, C., Satyanarayana, E. and Nageswar Rao, T. 2007. Heterosis for grain yield and its components in maize (*Zea mays* L.). *J. Research ANGRAU.* **70(3):** 257-263.

Avinash, H. A., Samidha, S., Jaiwar Girase, V. K., Shamal, A. Rawool and Khanorkar, S. M. 2013. Heterosis studies for yield and yield component characters in maize (*Zea mays* L.). *J. Soils and Crops.* **23(1):** 123-129.

Beck, D. L., Vasal, S. K. and Carossa, J. 1990. Heterosis and combining ability of CIMMYT's tropical early and intermediate maturity maize (*Zea mays* L.) germplasm. *Maydica.* **35:** 279-285.

Dar, Z. A., Lone, A. A., Alaie, B. A., Gowhar Ali, Asima Gazal. and Abidi, I. 2015. Estimation of combining ability involving quality protein maize (QPM) inbreds under temperate conditions. *The Bioscan*. **10(2):** 863-867.

Dwivedi, D. K. and Pandey, M. P. 2012. Gene action and heterosis for yield and associated traits in indica and tropical japonica crosses of rice (*Oryza sativa* L.) involving wide compatibility genes. *Int. J. Plant Breed. Genet.* **6(3):** 140-150.

Farhan, A., Irfan, Ahmed, S., Hidayatur, R., Mohammad, N., Durrishahwar, Muhammad Yasir Khan, Ihteram, U. and Jianbing, Y. 2012. Heterosis for yield and agronomic attributes in diverse maize germplasm. *Australian J. Crop Science*. **6(3):** 455-462.

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

Kempthorne, O. 1957. An introduction to genetic studies. *J. Wiley and Sons Inc.*, New York.

Khalil, I. A., Rahman, H., Saeed, N., Khan, N. U., Durrishawar Nawaz, I., Ali, F., Sajjad, M. and Saeed, M. 2010. Combining ability analysis in maize single cross hybrids for grain yield: A graphical analysis. *Sarhad J. Agric*. **26(3):** 373-379.

Liang, G. H., Reddy, C. R. and Dayton, A. D. 1971. Heterosis, inbreeding depression and heritability estimates in a systematic series of grain sorghum genotypes. *Crop Science.* **12:** 409-411.

Praveen Kumar, G., Narsimha Reddy, V., Sudheer Kumar, S. and Venkateshwara Rao, P. 2014. Combining ability studies in newly developed inbred lines in maize (*Zea mays* L.). *Int. J. Plant, Animal and Env. Sci.* **4(4):** 229-234.

Rajeev, K., Shahi, J. P. and Srivastava, K. 2013. Estimation of heterosis in field corn and sweet corn at marketable stage. *The Bioscan*. **8(4):** 1165-1170.

Rajesh, V., Sudheer Kumar, S., Narsimha Reddy, V. and Sivasankar, A. 2014. Heterosis studies for grain yield and its component traits in single cross hybrids of maize (*Zea mays* L.). *Int. J. of Plant, Animal and Envl. Sci*. **4(1):** 304-306.

Rokadia, P. and Kaushik, S. K. 2008. Exploitation of combing ability for heterosis in maize (*Zea mays* L.): In: Pixely, K and S.H. Zhang (ed). Proc.9th Asian Rey, Maize workshop. Beijing, China, September 5-9, pp. 89-91.

Saidaiah, P., Satyanarayana, E. and Sudheerkumar, S. 2008. Heterosis for yield and yield component characters in maize (*Zea mays* L.). *Agril. Sci. Digest.* **28(3):** 201-208.

Singh, P. K., Singh, A. K., Shahi, J. P. and Ranjan, R. 2012. Combining ability and heterosis in quality protein maize. *The Bioscan*. **7(2):** 337-340.

Singh, R. K. and Chaudhary, B. D. 1979. Line × tester analysis: Biometrical methods in quantitative genetics. *Kalyani Publishers, New Delhi, India.*

Ulaganathan, V., Vinoth, R., Baghyalakshmi, K., Suvarna Rani Chimili and Gurusamy, A. 2015. Standard heterosis for grain yield and other agronomic characters in maize (*Zea mays* L.) under normal and moisture stress conditions. *The Bioscan*.**10(3):** 1251-1253.