HETEROSIS STUDIES IN SINGLE CROSS HYBRIDS OF MAIZE (*Zea mays* L.) FOR YIELD AND YIELD CONTRIBUTING TRAITS

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ABSTRACT

In the present investigation twenty eight hybrids developed through crossing eight inbred lines in a half diallel fashion were evaluated along with their eight parents to determine the extent of heterosis for yield and yield components. Five crosses out of 28 exhibited highly significant standard heterosis for grain yield per plant. Higher heterosis for yield was realized through heterosis for individual yield components or additive or synergistic effects of the component characters viz., number of kernels per row and 100-seed weight etc. The hybrids viz., CM 149 x BML 6, CM 149 x BML 15 and CM 148 x BML 15, which exhibited highly significant standard heterosis for grain yield per plant had also displayed high per se performance for yield and other yield contributing traits. These crosses could offer the best possibilities for further exploitation.

Key Words : *Heterosis, heterobeltiosis, yield, single cross hybrid, maize.*

Maize is the most important food crop in the world and it occupies a prominent position in global agriculture after wheat and rice. Maize is gaining popularity at a fast rate due to its increasing demand particularly as livestock feed besides being used as food for human and also as an industrial raw material. Therefore, there is a dire need to increase the maize production and productivity through the development of new hybrids to meet the increasing demands. In maize, the scope of exploitation of hybrid vigour will depend on the direction and magnitude of heterosis. Hence, heterosis is a valuable tool to determine superior hybrid combinations, for use in hybrid breeding programmes. Therefore, heterotic studies can prove the basis for the exploitation of valuable hybrid combinations in the future breeding programme and their commercial exploitation. While selection of superior hybrids, a breeder must consider not only the per se performance of the hybrid but also the predictors of single cross hybrid value (or) heterosis between the parental inbred lines, which will increase the efficiency of hybrid breeding programme (1). Hence, the present investigation was under taken to assess the nature and magnitude of heterosis for yield and yield contributing traits between the recycled inbred lines aimed for grain yield improvement.

MATERIALS AND METHODS

The experimental material comprised eight inbred lines of maize viz., CM 209, CM 132, CM 133, CM 148, CM 149, BML 6, BML 7 and BML 15, which were mated in a half diallel fashion to generate twenty eight cross combinations during kharif, 2010 at Sri Venkateswara Agricutural College farm, Tirupati. These eight parents and twenty eight cross combinations were sown in RBD with three replications during rabi, 2011. Each entry was planted in a single row plot of 4 m length and the row-to-row and plant to plant distance was maintained at 75 and 20 cm, respectively. Standard plant protection measures were adopted to minimize the effect of insect pests and diseases. The data were recorded on randomly selected five competitive plants on plant height, cob length, cob girth, number of kernel rows per ear, number of kernels per row, 100-seed weight and grain yield per plant. However, the data for the traits viz., days to 50 per cent tasseling, days to 50 per cent silking, anthesis-silking interval and days to 50 per cent maturity were recorded an per plot basis. The data were subjected to preliminary analysis of variance (2) and the heterosis effects were estimated by following the method suggested by (3).

RESULTS AND DISCUSSION

Results of preliminary analysis of variance (Table-1) revealed highly significant differences among the genotypes for all the characters studied. The estimates of heterosis for grain yield per plant and its components were presented in Table-2.

Based on the heterosis studies the hybrids viz., CM 209 x CM 149 and CM 149 x BML 7 exhibited maximum significant negative heterobeltiosis for days

Table-1 : Analysis of variance for yield and yield components in maize.

S. No.	Characters	Source of Variation		
		Replications (df=2)	Genotypes (df=35)	Error (df=70)
1.	Days to 50 % tasseling	3.01	68.42**	1.65
2.	Days to 50% silking	4.39	62.87**	1.73
3.	Anthesis-silking interval	1.01	2.88**	0.53
5.	Days to 50% maturity	5.11	75.04**	2.63
6.	Plant height (cm)	395.00	1278.67**	67.61
7.	No. of kernel rows per ear	1.06	6.99**	0.47
8.	No. of kernels per row	21.93	98.04**	8.96
9.	Cob length (cm)	2.76	22.77**	1.53
10.	Cob girth (cm)	0.55	5.84**	0.39
11.	100 seed weight (g)	5.53	42.53**	2.69
12.	Yield per plant (g)	500.31	3884.18**	206.91

** Significant at 1% level.

to 50 per cent tasseling. Similarly, the hybrids CM 209 x BML 15 and CM 209 x BML 6 also exhibited maximum significant negative heterobeltiosis for days to 50 per cent silking, indicating earliness. For the trait anthesis-silking interval, highly significant negative heterobeltiosis was exhibited by CM 148 x CM 149 and CM 148 x BML 6. Eight and four hybrids registered significant negative and positive heterosis, respectively for this trait. Likewise, for the trait days to 50 per cent maturity, the hybrids CM 148 x BML 6 and CM 209 x CM 133 showed maximum heterobeltiosis in negative direction. For this trait twenty four hybrids showed significant negative heterosis. Heterosis in negative direction was considered to be desirable for tasseling, silking, anthesis-silking interval and maturity traits which aid in selection of high yielding genotypes coupled with earliness. Similar phenomenon of negative heterosis was reported for days to 50 per cent tasseling by (4), days to 50 per cent silking and anthesis-silking interval by (5) and for days to 50 per cent maturity by (6).

In maize tall types are preferred over dwarf types and hence, positive heterosis is considered to be desirable for plant height (7). The crosses which exhibited maximun percentage of heterobeltiosis besides high per se performance (Table-3) were CM 132 x CM 149 and BML 7 x BML 15. Further, fourteen hybrids exhibited significant positive heterobeltiosis for plant height, indicating that most of the hybrids showed tall stature. Positive heterosis for the cob features in addition to high per se performance is expected to yield better hybrids. For the trait, number of kernel rows per ear, the hybrids BML 6 x BML7 and CM 133 x BML 6 manifested highest percentage of positive heterobeltiosis in addition to high mean performance. Further, nine hybrids exhibited significant positive heterobeltiosis for this trait. This finding was in harmony with the findings of (8). Similarly, the other hybrids viz., CM 209 x CM 148 and CM 209 x BML 15 also exhibited maximum positive heterobeltiosis coupled with high per se performance for the trait number of kernels per row. Regarding, this trait twenty two hybrids were identified to show significant positive heterobeltiosis. Similar results of high heterosis for this trait were also repeated by (9). The estimates of heterosis for cob length revealed that the hybrids CM 132 x CM 148 and CM 149 x BML 6 exhibited highest percentage of heterobeltiosis besides high *per se* performance. Twenty three hybrids exhibited significant positive heterobeltiosis for cob length. Likewise, for both the traits viz., cob girth and 100-seed weight, the hybrids CM 149 x BML 6 and CM 148 x BML 6 exhibited highest heterobeltiosis and also high per se performance. Significant positive heterobeltiosis was exhibited by twenty five and twenty crosses for cob girth and 100-seed weight, respectively. Similar trend of significant positive heterosis was also observed for cob length by (10) and for cob girth and 100-seed weight by (11).

The perusal of estimates of heterosis for grain yield per plant revealed that the hybrids CM 148 x BML 15 and CM 148 x BML 6 exhibited maximum percentage of heterobeltiosis besides high per se performance. Further, out of 28 crosses twenty seven crosses were displayed highly significant positive heterosis over better parent for grain yield per plant. Moreover, in the present study, higher heterosis for yield was realized through heterosis for individual yield components or additive or synergistic effects of the component characters viz., number of kernels per row,

Table-2 : Percentage of heterosis over mid parent and better parent for yield and yield components in maize.

S. No.	Crosses	DT		DS		ASI		DM		PH		KRE	
		MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
1	CM 209 × CM 132	-10.34**	-12.08**	-11.27**	-13.3**	-30.00	-36.36*	-8.73**	-12.35**	18.67**	8.53	15.49**	5.67
2	CM 209 × CM 133	-8.91**	-10.24**	-8.57**	-9.43**	0.07	-11.11	-8.92**	-12.17**	20.88**	7.90	17.29**	8.50*
3	CM 209 × CM 148	-4.08**	-5.53**	-4.08**	-4.31**	-4.00	-25.00*	-4.01**	-4.47**	31.08**	22.69**	-1.17	-14.57**
4	CM 209 × CM 149	-8.62**	-12.06**	-8.54**	-12.5**	-6.67	-22.22	-5.36**	-6.54**	21.23**	13.64**	5.94	-6.07
5	CM 209 × BML 6	-13.82**	-19.30**	-11.96**	-17.02**	37.50	22.22	-5.63**	-9.88**	18.59**	3.28	14.29**	2.02
6	CM 209 × BML 7	-9.77**	-16.02**	-9.21**	-14.77**	6.67	-11.11	-3.95**	-8.41**	20.24**	2.99	-7.56*	-15.79**
7	CM 209 × BML 15	-11.11**	-17.60**	-11.41**	-17.15**	-20.00	-33.33	-7.18**	-11.11**	23.95**	6.93	2.15	-13.36**
8	CM 132 × CM 133	-6.31**	-6.76**	-5.12**	-6.42**	22.22	0.04	-4.28**	-4.71**	15.55**	12.51**	7.47*	6.19
9	CM 132 × CM 148	-6.00**	-9.18**	-7.73**	-9.63**	-33.33**	-43.75**	-5.23**	-9.41**	23.40**	6.30	20.52**	13.17**
10	CM 132 × CM 149	0.26	-5.31**	0.98	-5.50**	17.65	-9.09	-4.99**	-7.65**	36.19**	32.62**	1.52	-1.95
11	CM 132 × BML 6	-11.26**	-15.35**	-9.05**	-12.34**	44.44*	18.18	-0.88	-1.45	18.07**	11.86**	24.31**	20.98**
12	CM 132 × BML 7	-11.87**	-16.45**	-9.89**	-13.5**	41.18*	9.09	-1.90	-2.61*	17.51**	9.29*	10.78**	10.24*
13	CM 132 × BML 15	-10.45**	-15.45**	-10.72**	-14.64**	-17.65	-36.36*	-7.04**	-7.31**	20.54**	13.02**	3.98	-4.39
14	CM 133 × CM 148	-7.54**	-10.24**	-7.36**	-8.02**	-4.35	-31.25**	-5.10**	-8.90**	29.86**	9.39*	9.23*	1.43
15	CM 133 × CM 149	-2.83	-7.80**	0.04	-5.19**	84.62**	71.43**	-0.91	-3.26**	9.97*	4.35	11.22**	6.19
16	CM 133 × BML 6	-9.93**	-14.47**	-7.38**	-11.91**	71.43**	71.43**	-5.14**	-6.10**	7.04	4.06	27.72**	22.86**
17	CM 133 × BML 7	-5.96**	-11.26**	-5.57**	-10.55**	7.69	0.06	-3.23**	-4.35**	25.84**	20.05**	7.51*	5.71
18	CM 133 × BML 15	-6.39**	-12.02**	-6.87**	-12.13**	-23.08	-28.57	-3.68**	-4.39**	18.84**	14.31**	9.95*	0.02
19	CM 148 × CM 149	-6.63**	-8.81**	-8.77**	-12.92**	-45.45**	-62.5**	-1.11	-2.80*	24.88**	10.07	8.36*	5.24
20	CM 148 × BML 6	-10.69**	-17.54**	-9.46**	-14.47**	13.04	-18.75	-7.95**	-12.50**	20.90**	-0.46	13.37**	9.28*
21	CM 148 × BML 7	-4.72**	-12.55**	-4.04**	-9.7**	9.09	-25.00*	3.21**	-2.03	22.93**	-0.32	8.62*	2.46
22	CM 148 × BML 15	-3.76**	-12.02**	-6.25**	-12.13**	-54.55**	-68.75**	-0.92	-5.56**	35.27**	10.42*	15.91**	13.33**
23	CM 149 × BML 6	-8.74**	-17.54**	-7.76**	-16.6**	23.08	14.29	2.86**	-0.58	17.52**	8.58*	4.94	4.12
24	CM 149 × BML 7	-8.43**	-17.75**	-5.39**	-14.77**	100.00**	100.00**	-0.60	-4.06**	11.02**	0.76	5.58	2.46
25	CM 149 × BML 15	-6.47**	-16.31**	-5.83**	-15.48**	16.67	16.67	-4.68**	-7.60**	17.49**	7.46	16.8**	10.99*
26	BML 6 × BML 7	-6.32**	-6.93**	-3.81**	-4.22**	84.62**	71.43**	-2.76**	-2.90*	1.89	-0.08	26.95**	24.14**
27	BML 6 × BML 15	-8.89**	-9.87**	-8.86**	-9.62**	-7.69	-14.29	-5.25**	-5.52**	13.37**	12.12**	13.66**	7.22
28	BML 7 × BML 15	-5.17**	-5.58**	-5.88**	-6.28**	-33.33	-33.33	-1.02	-1.45	27.44**	26.35**	5.60	-2.46

Contd....

S. No.	Crosses	KR		CL		CG		100-SW		GYP	
		MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
1.	CM 209 × CM 132	48.08**	43.58**	24.49**	14.61	21.82**	18.09**	17.28**	0.12	129.24**	117.37**
2.	CM 209 × CM 133	23.36**	-2.89	20.94**	3.17	13.10**	10.21**	21.31**	11.22	92.39**	46.50**
3.	CM 209 × CM 148	68.88**	66.91**	40.98**	40.36**	12.42**	2.93	34.88**	26.67**	140.45**	105.68**
4.	CM 209 × CM 149	34.91**	20.28	23.39**	11.95	17.84**	14.67**	31.5**	14.53**	103.86**	79.47**
5.	CM 209 × BML 6	59.11**	51.13**	36.04**	20.98**	32.12**	24.21**	33.76**	24.07**	174.23**	161.05**
6.	CM 209 × BML 7	48.43**	37.31**	30.30**	12.66	16.93**	16.5**	29.08**	11.54*	121.22**	90.24**
07.	CM 209 × BML 15	70.54**	56.46**	35.01**	16.2*	21.04**	13.94**	34.29**	21.7**	201.43**	179.01**
8.	CM 132 × CM 133	36.92**	10.33	34.94**	24.10**	13.87**	7.66*	4.28	-3.62	75.84**	39.21**
09.	CM 132 × CM 148	71.28**	64.19**	56.40**	44.58**	19.34**	12.5**	14.61**	3.45	173.87**	124.19**
10.	CM 132 × CM 149	52.07**	39.44**	38.54**	36.34**	14.66**	14.21**	24.78**	21.89**	112.08**	96.01**
11.	CM 132 × BML 6	67.6**	64.08**	49.15**	43.59**	27.42**	23.44**	18.28**	8.06	165.98**	140.76**
12.	CM 132 × BML 7	53.13**	45.87**	43.39**	33.84**	20.35**	16.26**	19.67**	17.95**	134.34**	111.25**
13.	CM 132 × BML 15	60.57**	51.65**	43.49**	33.26**	17.05**	13.54**	33.76**	25.1**	200.28**	164.72**
14.	CM 133 × CM 148	31.83**	2.89	38.27**	18.39**	18.55**	6.03	38.43**	34.92**	123.88**	53.55**
15.	CM 133 × CM 149	11.32	-3.51	19.37**	11.42	9.05**	3.48	13.66**	7.40	42.69**	20.40
16.	CM 133 × BML 6	35.94**	11.36	21.51**	15.86*	24.65**	14.39**	19.60**	18.11**	96.67**	44.82**
17.	CM 133 × BML 7	39.83**	17.15*	29.75**	27.70**	16.96**	14.39**	21.73**	14.03**	89.08**	63.22**
18.	CM 133 × BML 15	44.68**	22.11**	35.04**	33.62**	17.93**	8.35*	20.84**	19.3**	122.93**	61.09**
19.	CM 148 × CM 149	51.00**	33.24**	36.81**	24.63**	22.70**	15.25**	34.46**	24.01**	158.45**	99.09**
20.	CM 148 × BML 6	72.27**	61.81**	50.39**	34.27**	29.14**	25.56**	42.82**	40.93**	258.58**	220.27**
21.	CM 148 × BML 7	53.72**	40.67**	48.73**	29.08**	22.66**	11.94**	36.51**	24.84**	131.62**	75.06**
22.	CM 148 × BML 15	86.93**	69.67**	54.75**	33.69**	28.10**	24.38**	32.96**	27.98**	301.61**	268.47**
23.	CM 149 × BML 6	55.42**	45.35**	43.50**	40.33**	37.08**	32.30**	50.9**	40.9**	217.43**	167.84**
24.	CM 149 × BML 7	32.55**	27.32*	26.96**	20.31**	17.90**	14.32**	24.19**	23.05**	90.4**	85.3**
25.	CM 149 × BML 15	62.21**	57.18**	40.66**	32.61**	29.41**	25.06**	31.31**	25.59**	206.38**	152.38**
26.	BML 6 × B ML 7	48.11**	44.04**	31.91**	27.73**	28.5**	20.39**	13.00**	4.62	134.43**	93.49**
27.	BML 6 × BML 15	66.36**	60.36**	39.91**	34.77**	24.55**	24.38**	32.10**	28.81**	217.9**	208.64**
28.	BML 7 × BML 15	66.36**	64.86**	35.07**	34.34**	19.02**	11.65**	14.55**	8.61	163.29**	112.32**

*, ** significant at 5 and 1 % level, respectively;

Note : DT: Days to 50 per cent Tasseling; DT: Days to 50 per cent Silking; ASI: Anthesis-Silking Interval; DM: Days to 50 per cent Maturity; PH: Plant Height, KRE: Number of Kernels per Row; KR: Number of Kernels per Row; CL: Cob length; CG: Cob Girth; 100-SW: 100-Seed Weight; GYP: Grain Yield Per Plant.

Table-3 : Best identified hybrids based on heterobeltiosis and per se performance for yield and yield components in maize

Sl. No.	Characters	Better parent heterosis (best hybrids)	Better parent heterosis (%)	*Per se* performance of the hybrid
1.	Days to 50 % tasseling	CM 209 x BML 6	-19.30**	61.33
		CM 149 x BML 7	-17.75**	63.33
2.	Days to 50% silking	CM 209 x BML 15	-17.75**	66.00
		CM 209 x BML6	-17.02**	65.00
3.	Anthesis-silking interval	CM 148 x BML 15	-68.75**	1.67
		CM 132 x CM 148	-43.75**	3.00
5.	Days to 50% maturity	CM 148 x BML 6	-12.50**	100.33
		CM 209 x CM 132	-12.35**	99.33
6.	Plant height (cm)	CM 132 x CM 149	32.62**	190.80
		BML 7 x BML 15	26.35**	211.33
7.	No. of kernel rows per ear	BML 6 x BML 7	24.14**	16.80
		CM 133 x BML 6	22.86**	17.20
8.	No. of kernels per row	CM 209 x BML 15	70.54**	34.73
		CM 209 x CM 148	68.31**	30.93
9.	Cob length (cm)	CM 132 x CM 148	44.56**	19.13
		CM 149 x BML 6	40.33**	20.07
10.	Cob girth (cm)	CM 149 x BML 6	32.30**	17.07
		CM 148 x BML 6	25.56**	19.20
11.	100 seed weight (g)	CM 148 x BML 6	40.93**	32.40
		CM 149 x BML 6	40.90**	37.34
12.	Yield per plant (g)	CM 148 x BML 15	268.47**	150.15
		CM 148 x BML 6	220.27**	138.58

**Significant at 1% level.

cob length, 100-seed weight, plant height and number of kernel rows per ear. Similarly, (12, 13) also reported greater heterosis for grain yield followed by varying degrees of heterosis for various yield components.

In case of hybrid breeding programme, the overall heterosis for various characters may be low, but high heterotic effect for economic yield measures the feasibility of commercial cultivation of hybrids. Hence, in this study, an attempt was made to compare the yield potentials of these 28 hybrids using DHM-111 (BML 6 x BML 15) as a standard check, which is also one among these twenty eight hybrids and released for commercial cultivation during 2010. The perusal of results (Table 4) revealed that five hybrids viz., CM 149 x BML 6 (26.21 %), CM 149 x BML 15 (18.92 %), CM 148 x BML 15 (12.42 %), CM 133 x BML 7 (11.86 %) and CM 133 x BML 15 (10.46 %) exhibited superior heterosis over the standard check DHM-111 for grain yield per plant besides high per se performance for yield. The parents involved in these five combinations also exhibited desirable significant gca effects (Table 3) for most of the traits. Interestingly, all the five hybrids also depicted significant and positive sca effects for grain yield per plant thereby indicating the importance of non-additive gene effects in the heterotic response of these hybrids. Further, critical analysis of the results depicted that the cross combinations viz., CM 149 x BML 6, CM 149 x BML 15 and CM 148 x BML 15, exhibiting high heterosis for yield and most of the yield related traits besides early tasseling, early silking and reduced anthesis-silking interval. Hence, these crosses might be considered as a source of superior segregants or could constitute a suitable base population in the breeding programmes of maize aimed at high yield in water stress conditions, as anthesis-silking interval has been correlated with drought tolerance mechanism in maize (14).

From the foregoing discussion, it can be concluded that, different hybrids exhibited different magnitude of heterosis for different traits. The main reason ascribed is diversified parents involved in cross combinations might have resulted in maximum exploitable level of heterosis. The perusal of results also revealed that all the hybrids in which the inbreds CM 148 and CM 209 were involved as female parents have exhibited highest heterosis in desired direction for most of the traits studied. These two parental inbred lines might be promising in future hybrid maize breeding programme. However, the best promising hybrids identified for further use in maize breeding programme were CM 149 x BML 6, CM 149 x BML 15, CM 148 x BML 15, CM 133 x BML 7 and CM 133 x BML 15. Hence, these promising hybrids could be exploited as commercial hybrids after testing over

Table-4 : Top five high yielding hybrids identified over standard check (DHM-111) for grain yield and its components in maize.

S. No.	Top Crosses	Per se performance for grain yield per plant (g)	Per cent of heterosis over standard check (BML 6 X BML15-DHM 111)	Heterobeltiosis % for grain yield per plant	gca effects of parents for grain yield per plant	sca effects of crosses for grain yield per plant	Useful and highly significant heterobeltiosis in desirable direction and high per se performance for component traits
1	CM 149 X BML 6	168.56	26.21**	167.84**	A x A (1.52 x 0.89)	51.37**	DT, DS, ASI,KR, CL, CG,100SW and GYP
2	CM 149 X BML 15	158.83	18.92**	152.36**	A x H (1.52 x 5.45*)	37.06**	DT, DS,DM, KR, CL, CG,100SW and GYP
3	CM 148 X BML 15	150.15	12.42*	268.47**	L x H (-7.59** x 5.45*)	37.50**	DT, DS, ASI, DM,KR,KRE, CL, CG,100SW and GYP
4	CM 133 X BML 7	149.4	11.86*	63.22**	H x A (9.16**X 2.58)	22.87**	DT, DS, DM,PH,CL, CG,100SW and GYP
5	CM 133 X BML 15	147.44	10.46*	61.09**	H x H (9.16** x 5.45*)	18.04*	DT, DS, DM, PH, KRE,CL,100SW and GYP
Standard check	DHM 111	133.55	-	-	-	-	-

*, ** significant at 5 and 1 % level, respectively;

Note : DT: Days to 50 per cent Tasseling; DT: Days to 50 per cent Silking; ASI: Anthesis-Silking Interval; DM: Days to 50 per cent Maturity; PH: Plant Height, KRE: Number of Kernels per Row; KR: Number of Kernels per Row; CL: Cob length; CG: Cob Girth; 100-SW: 100-Seed Weight; GYP: Grain Yield Per Plant.

different locations and seasons to confirm their superiority and stability.

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