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MID-PARENT, BETTER-PARENT AND STANDARD HETEROSIS OF EXPERIMENTAL CROSSES IN MAIZE

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Abstract: The estimates of *gca* effects of parents help in identifying superior parents to be utilized for production of heterotic hybrids. The objective of this study was to estimate the general combining ability of early generation inbred lines (L1 to L6), specific combining ability and heterosis of 24 crosses developed using these lines and four testers *viz*., CM 111, CML 451, CML 472 and CML 02450. The crosses were evaluated during Rabi 2017-18 using randomized complete block design with two replications. The observations were recorded for days to 50% pollen shed and silking, cob weight, shelling per cent, 100-grain weight and grain yield. The variance due to lines was non-significant for grain yield and variance due to testers was significant for shelling per cent and 100-grain weight, whereas variance due to l × t interaction was significant for days to 50 per cent pollen shed, cob weight, shelling per cent and grain yield. The *gca* effects of lines indicated that, no single line was a good combiner for all traits studied. However, the line, L2 exhibited significant *gca* effects for cob weight and grain yield indicating that this is a good general combiner which can be utilized in development of heterotic hybrids. The cross involving L2 as female parent exhibited higher *sca* effect for most traits and figured top ranking hybrid among the test crosses. The cross L2 × CML 472 recorded significant superior average heterosis, heterobeltiosis and standard heterosis for grain yield.

Keywords: Maize, combining ability, *gca, sca*, line × tester design

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal in India after wheat and rice. Currently it is cultivated over 11.87 lakh ha with 32.23 lakh tonnes production having average productivity of 2830 kg ha^{-1} (Directors report, IIMR, 2016). Maize contributes Rs. 100 billion to the agricultural GDP at current prices apart from the providing employment to nearly 100 million man-days at the farm and downstream agricultural and industrial sectors (Dar *et al*., 2016 and Debnath *et al*., 2016). In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material to the industry for production of starch, oil, protein, alcoholic beverages, food sweeteners and more recently bio-fuel (Ethanol). Being a potential crop in India, maize occupies an important place as a source of human food (25%), animal feed (12%), poultry feed (49%), industrial products mainly as starch (12%) and 1% each in brewery and seed (Dar *et al*., 2016).

In addition to being an economically important crop, this species is widely used for genetic studies, thus contributing for an understanding of many questions of a genetic nature with the great economic importance of maize; genetic breeding in this crop is very intense and mostly targeted at increasing grain yield. A frequent method used in maize breeding

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is to obtain inbred lines that are later crossed in order to develop different types of hybrids, which exhibit high heterosis when the inbred lines are complementary and also have high uniformity.

Heterosis and combining ability is prerequisite in development of good and economically viable hybrids in maize. Information on the heterotic patterns and combining ability among maize germplasm is essential in maximizing the effectiveness of hybrid development (Beck *et al.,* 1990). Combining ability analysis is one of the powerful tools in identification of good combiners that could be utilized in crosses to exploit heterosis. It also helps to understand the genetic architecture of various traits that enable the breeder to design effective breeding plan for future improvement of the existing materials. Thus, the present study was undertaken to estimate combining ability of new inbred lines and to explore suitable heterotic hybrid combinations.

MATERIAL AND METHODS

The experimental material used in the present study consisted of six early generation inbred lines (L1 to L6) and four testers *viz*., CM 111, CML 451, CML 472 and CML 02450. Twenty four crosses were generated by crossing 6 lines with 4 testers in line × tester fashion during *Kharif* 2017 at AICRP on Maize, MARS, Dharwad. All the 24 hybrids along with parents and a check hybrid, 900M Gold were grown in randomized block design with two replications during *Rabi* 2017-18. Each entry was raised in two rows of 4m length with 60 cm spacing between rows. Two seeds per hill were dibbled by following 20 cm spacing between the hills and later thinned to single seedling per hill. At pre-flowering stage, plant count was recorded in each entry from entire two rows in both the replications, followed by days to 50 % pollen shed and days to 50 % silk. At the time of harvesting, cob weight per plot and grain moisture (%) were recorded immediately after the harvest and five cobs in each test entry was sampled from replication I and II for post harvest observations. Further, shelling per cent was calculated using grain weight (g) and pith weight (g) data of all five cobs. The hundred seeds in each entry were randomly counted from the shelled kernels and weighed to get the 100-grain weight. The grain yield was calculated using cob weight, grain moisture (%) and shelling per cent. The general and specific combining ability effects of the parents were assessed using software Windostat Version 9.2 as given by line × tester analysis (Kempthorne, 1957).

RESULTS AND DISCUSSION

The estimates of analysis of variance for combining ability for yield and yield component traits are presented in Table 1. The mean sum of squares due to lines were not significant for all the seven characters studied indicating the presence of less variability between the inbred lines, whereas the mean sum of squares due to testers were highly significant for characters like shelling per cent and 100-grain weight, justifying a considerable amount of variation among testers. However, line × tester interaction were highly significant for the characters *viz*., days to 50 per cent pollen shed, cob weight per plot, shelling per cent and grain yield, suggesting the contribution of *sca* effects towards variation among the crosses.

The estimates of general combining ability (*gca*) effects are presented in Table 2. The *gca* effects of lines indicated that, no single line among the six was good combiner for all the seven traits. However, the line L2 exhibited significant positive *gca* effects for two important traits, cob weight (0.60) and grain yield (9.04) indicating that this is a good general combiner which can be utilized in development of heterotic hybrids. The parental lines which showed significant positive *gca* effect in the studies of Kallu *et al*. (2001), Uddin *et al*. (2006) and Raghu *et al*. (2011) were good general combiners for grain yield per plot and proved as an useful index for combining ability. Among lines L3 and L4 exhibited significant *gca* effects for days to 50 per cent pollen shed in desirable direction indicating that these are good general combiners and they can be utilized in development of early maturity hybrids. Among four testers, none recorded significant positive *gca* effect for grain yield, however the tester CML 472 exhibited positive significant *gca* effects for

Table 1: Analysis of variance for combining ability for yield and yield component traits in maize

Characters	*d.f*	*Days to 50% pollen shed*	*Days to 50% silk*	*Cob weight / plot (Kg)*	*Moisture %*	*Shelling %*	*100-grain weight (g)*	*Grain yield (Qtl/ha)*
Lines	5	2.08	1.37	0.99	23.32	31.83	13.28	205.41
Testers	3	1.36	0.74	0.95	18.96	76.18 *	101.02 **	314.9
Line x Tester	15	1.69 **	1.09	1.80 **	14.03	16.27 *	8.49	451.23 **
Error	23	0.25	1.08	0.52	14.32	6.17	8.11	125.81

Table 2: General combining ability (gca) estimates of lines and testers for grain yield in maize

Lines	*Days to 50% pollen shed*	*Days to 50% silk*	*Cob weight /plot (Kg)*	*Moisture %*	*Shelling %*	*100-grain weight (g)*	*Grain yield (Qtl/ha)*
L 1	0.58 **	0.10	-0.32	-2.73	-1.43	-0.04	-4.84
L 2	0.08	0.35	0.60 *	-0.61	-1.43	-1.29	9.04 *
L 3	-0.79 **	-0.52	0.20	2.49	1.43	0.70	2.63
L 4	-0.41 *	-0.52	0.00	0.14	-2.31 *	1.20	-1.60
L 5	0.33	0.22	-0.25	0.00	2.68 **	1.20	-2.51
L 6	0.20	0.35	-0.24	0.70	1.06	-1.79	-2.70
CD @ 5 %	0.37	0.76	0.53	2.76	1.81	2.08	8.20
Testers							
CML 451	-0.20	0.27	0.15	-0.51	-0.06	1.54	2.61
CML 472	0.45 **	0.10	0.30	0.71	0.85	3.04 **	5.51
CML 02450	-0.29	-0.31	-0.30	-1.50	-3.39 **	-1.04	-6.12
CM 111	0.04	-0.06	-0.15	1.30	2.60 **	-3.54 **	-2.00
CD @ 5 %	0.30	0.62	0.43	2.26	1.48	1.70	6.69

Table 3: Specific combining ability (sca) estimates of single cross hybrids for grain yield in maize

Crosses	*Days to 50% pollen shed*	*Days to 50% silk*	*Cob weight / plot (Kg)*	*Moisture %*	*Shelling %*	*100-grain weight (g)*	*Grain yield (Qtl/ha)*
L1 x CML 451	1.33 **	1.47	-0.24	1.18	1.68	-1.79	-2.90
L1 x CML 472	0.16	0.14	0.43	2.39	-2.22	1.20	3.52
L1 x CML 02450	-1.08 **	-0.93	-0.56	-5.18	0.52	-1.20	-6.33
L1 x CM 111	-0.41	-0.68	0.37	1.60	0.02	1.79	5.71
L2 x CML 451	-1.16 **	-0.27	0.14	-1.13	-1.31	0.45	1.81
L2 x CML 472	-0.83 *	-0.60	1.14 *	-0.66	2.27	0.45	18.85 *
L2 x CML 02450	0.91 *	0.31	-0.98	1.85	-3.47	-2.95	-17.07 *
L2 x CM 111	1.08 **	0.56	-0.30	-0.05	2.52	2.04	-3.60
L3 x CML 451	1.20 **	0.10	0.29	-1.09	-0.68	0.95	4.44
L3 x CML 472	0.04	0.27	0.17	-0.97	4.89 *	-0.54	5.43
L3 x CML 02450	-0.70	-0.31	-0.62	-0.01	-2.35	-1.95	-9.80
L3 x CM 111	-0.54	-0.06	0.15	2.08	-1.85	1.54	-0.07
L4 x CML 451	-1.16 **	-0.89	0.05	3.05	-0.43	0.45	-1.19
L4 x CML 472	0.66	0.77	0.11	-1.97	1.14	-1.04	3.08
L4 x CML 02450	-0.08	-0.31	-0.32	-1.96	0.39	1.54	-3.32
L4 x CM 111	0.58	0.43	0.15	0.88	-1.10	-0.95	1.43
L5 x CML 451	0.08	-0.64	-0.35	-0.05	-0.93	0.95	-5.0
L5 x CML 472	-0.08	-0.47	0.33	-1.39	-0.35	0.45	5.50
L5 x CML 02450	0.16	0.93	0.99	2.62	2.39	2.54	14.89
L5 x CM 111	-0.16	0.18	-0.97	-1.18	-1.10	-3.95	-15.37
L6 x CML 451	-0.29	0.22	0.09	-1.95	1.68	-1.04	2.86
L6 x CML 472	0.04	-0.10	-2.21 **	2.61	-5.72 **	-0.54	-36.41 **
L6 x CML 02450	0.79 *	0.31	1.51 **	2.67	2.52	2.04	21.64 *
L6 x CM 111	-0.54	-0.43	0.60	-3.33	1.52	-0.45	11.90
CD @ 5 %	0.74	1.52	1.06	5.53	3.63	4.16	16.40

Table 4: Per cent standard heterosis for grain yield and its contributing characters

Hybrids	*Days to 50% pollen seed*	*Days to 50% silking*	*Cob weight/ plot (kg)*	*Moisture %*	*Shelling %*	*100-grain weight (g)*	*Grain yield (Qtl/ha)*
L1 × CML 451	8.09 **	7.19 **	-26.16	-10.64	-3.11	-8.62	-26.66
L1 × CML 472	7.35 **	5.04 **	-2.03	1.49	-6.83 *	6.9	-9.52
L1 × CML 02450	4.41 **	2.88	-49.13 *	-47.03 *	-8.70 **	-15.52	-49.04 *
L1 × CM 111	5.88 **	3.60 *	-17.44	0.5	-1.86	-13.79	-19.3
L2 × CML 451	3.68 **	5.04 **	11.92	-11.63	-6.83 *	-5.17	7.54
L2 × CML 472	5.15 **	4.32 **	45.35 *	-3.22	-1.24	0.01	44.20 *
L2 × CML 02450	6.62 **	5.04 **	-34.59	-1.73	-13.66 **	-25.86 *	-43.25 *
L2 × CM 111	7.35 **	5.76 **	-10.47	2.72	1.24	-17.24	-10.9
L3 × CML 451	5.88 **	4.32 **	4.65	3.96	-2.48	3.45	0.59
L3 × CML 472	5.15 **	4.32 **	5.52	10.64	5.59	3.45	7.73
L3 × CML 02450	2.94 **	2.88	-35.76	4.46	-8.70 **	-15.52	-41.69
L3 × CM 111	3.68 **	3.60 *	-8.72	28.71	-0.62	-12.07	-16.21
L4 × CML 451	2.94 **	2.88	-7.85	12.87	-6.83 *	3.45	-17.58
L4 × CML 472	6.62 **	5.04 **	-2.03	-5.94	-3.73	3.45	-4.38
L4 × CML 02450	4.41 **	2.88	-32.56	-16.83	-9.94 **	-1.72	-37.56
L4 × CM 111	5.88 **	4.32 **	-14.24	11.14	-4.35	-18.97	-21.23
L5 × CML 451	5.88 **	4.32 **	-27.33	-3.22	-1.24	5.17	-26.29
L5 × CML 472	6.62 **	4.32 **	-2.91	-3.71	0.62	8.62	-1.59
L5 × CML 02450	5.88 **	5.76 **	-1.74	5.2	-1.24	1.72	-5.73
L5 × CM 111	5.88 **	5.04 **	-54.65 *	0.25	1.86	-29.31 **	-53.79 *
L6 × CML 451	5.15 **	5.76 **	-13.95	-9.16	0.01	-12.07	-12.13
L6 × CML 472	6.62 **	5.04 **	-76.74 **	19.55	-8.07 *	-5.17	-79.01 **
L6 × CML 02450	6.62 **	5.04 **	13.66	8.91	-3.11	-10.34	6.31
L6 × CM 111	5.15 **	4.32 **	-8.43	-6.93	3.11	-27.59 **	- 4.01

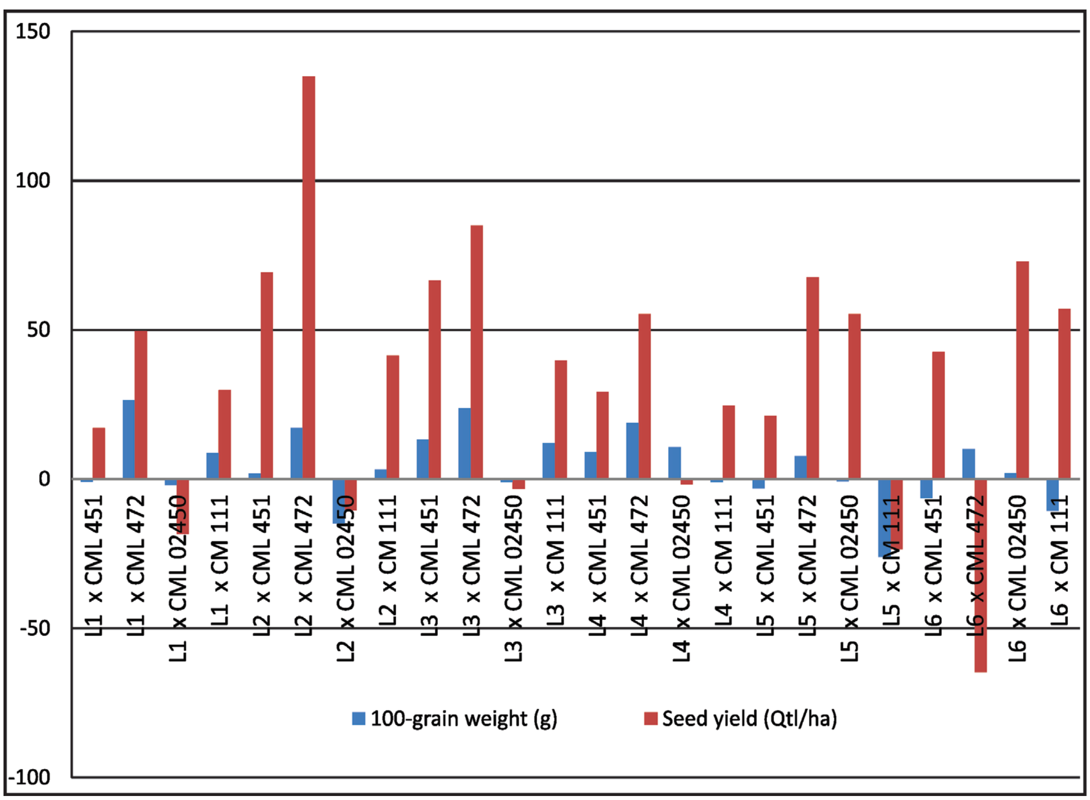

Figure 1: Percent mid-parent heterosis for 100-grain weight and grain yield

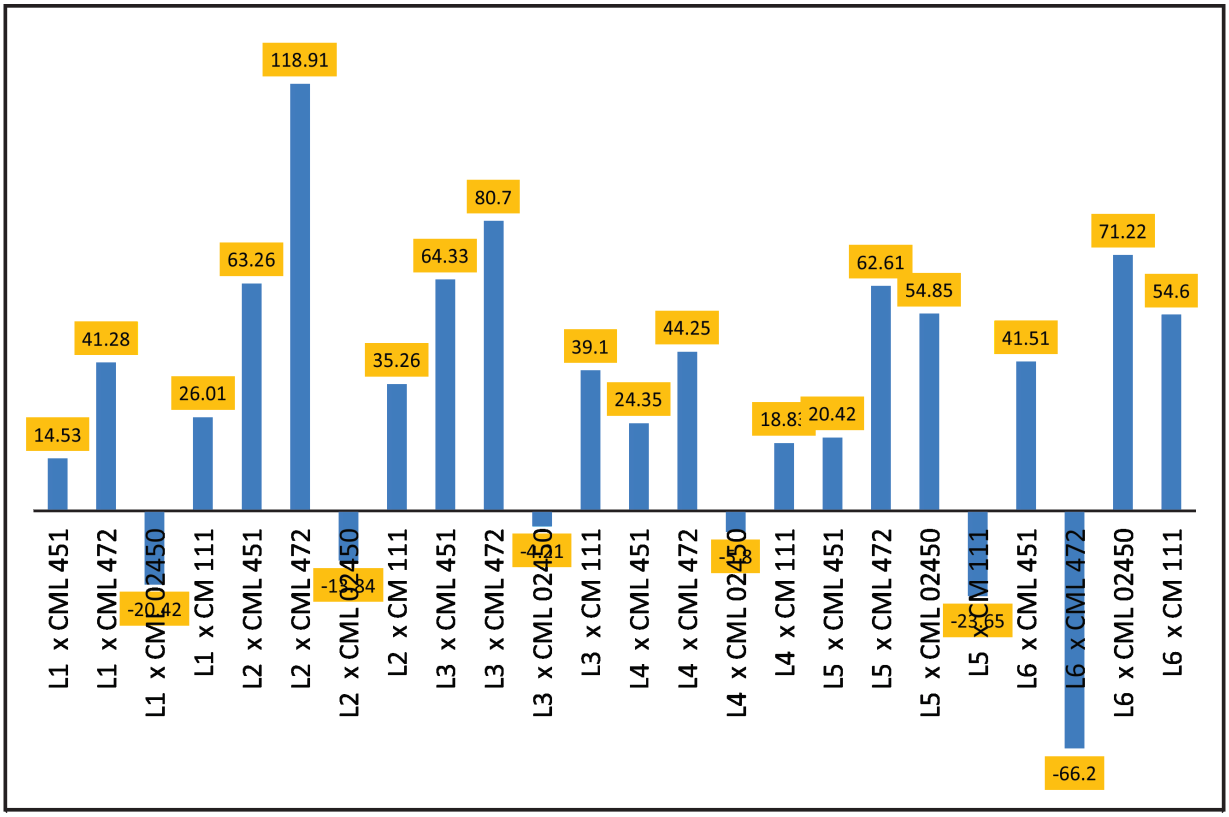

Figure 2: Percent better-parent heterosis for grain yield in maize

days to 50 per cent pollen shed and 100-grain weight. The above results were in accordance with findings of the combining ability studies of Singh *et al.* (1995) and Hussain *et al.* (2003).

The line L5 (2.68), tester CM 111 (2.60) for shelling per cent and the tester CML 472 for 100-seed weight (3.04) exhibited significant positive *gca* effects indicating that they are good combiners for the respective traits. The *sca* effects of the crosses for yield and its attributing traits are presented in Table 3. Significant negative *sca* effects was observed in four crosses for days to 50 per cent pollen shed *viz.*, L2 × CML 472 (-0.83), L2 × CML 451 (-1.16), L4 × CML 451 (-1.16) and L1 × CML 02450 (-1.08). In the study conducted by Singh *et al.* (2012) recorded negative *sca* effects for the hybrids. Significant positive *sca* effects was observed in two crosses for cob weight per plot and one cross for shelling percentage. Significant positive *sca* represents dominance and epistatic component of variation. The significant positive *sca* effects were noticed in two hybrids *viz.*, L6 × CML 02450 (21.64) and L2 × CML 472 (18.85) for grain yield. Considering the *sca* effects of the hybrids, both these two hybrids were good specific combiners for important traits *viz.*, days to 50 % pollen shed, cob weight per plot and grain yield.

A good amount of variation was observed for heterosis for the traits studied in the crosses. The mid-parent heterosis ranged from 1.85 to 26.53 per cent and 17.11 to 134.94 per cent for 100-grain weight and grain yield, respectively (Figure 1). The cross L1 x CML 472 manifested highest significant superior average heterosis for 100-grain weight and the cross L2 x CML 472 recorded significant superior grain yield followed by the cross L3 x CML 472 (84.95%). The heterobeltiosis ranged from 14.53 to 118.91 per cent (Figure 2). The experimental cross L2 x CML 472 exhibited highest significantly superior better-parent heterosis followed by L3 x CML 472 (80.70%). The per cent standard heterosis expressed by the F_1 hybrids over the commercial hybrid check for yield and different yield contributing characters are presented in Table 4. Only one cross L2 × CML 472 showed significantly positive heterosis for cob weight per plot (45.35 %) and yield (44.20 %) among all the hybrids over the commercial check 900M

Gold. Such similar results were opined Talekar et al. (2011), Vinaykumar et al. (2011), Talekar et al. (2012) in sweet sorghum for grain yield, Panda *et al.* (2017), Varalakshmi and Wali (2017), Anilkumar *et al*. (2018) and Gazala *et al.* (2017) in maize for cob weight and grain yield. The realization of less number of hybrids with significant positive *sca* effects and the good heterosis could be due to the presence of less variability among the inbred lines.

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