COMBINING ABILITY AND HETEROSIS IN MAIZE (*Zea mays* L.) INBRED LINES

Abstract

The present study was framed to determine the combining ability and the extent of heterosis in maize using line × tester design at maize section, Bihar Agricultural University, Sabour, Bhagalpur. Crosses were made involving ten lines and three testers in Rabi, 2019-20 for the study. 30 Crosses along with 13 parents and 2 checks were evaluated in randomized block design with two replications during kharif, 2020. The hybrids DHM 117 and SHM 1 were used as checks. Data were recorded on 13 morphological traits. The contribution of lines is found to be greater than that of the testers for most of the characters studied. On the basis of GCA effects, the lines VL109476, VL109475, VL1010848, VL109479 andtester VP15295 were identified as good combiners for grain yield, whereas the line VL1017524 and the tester SML-1 were also identified as good combiner in terms of earliness. These can be used as parents in multiple hybridization programme. On the basis of SCA effects, the crossesVL109476 x V P15295, VL1010763 x VP15295, VL1018419 x VP15295 and VL109475 x SML-1were identified as good specific combiners for grain yield, whereas on the basis of standard heterosisVL109476 x V P15295, VL1010763 x VP15295, VL109475 x SML-1 and VL109479 x SML-1 were superior to the better check in grain yield. The identified hybrids may be tested on large scale multi-location trial and in farmers' field before commercial utilization.

Keywords: Combining ability, Heterosis, GCA, SCA,grain yield,cereal crop,Rice,biodiversity

Introduction

"Maize (*Zea mays* L.) is a high yielding cereal crop and has key importance in assuring food security to the teeming population (Saeed et al. 2000). It possesses somatic chromosome number of 20, a genome size of 2.3 gigabase and more than 32,000 genes (Schnable et al. 2009). It is a member of the grass family Poaceae, tribe Maydeae and one of the oldest cultivated crops" (Sleper and Poehlman 2006). The name maize is derived from a South American Indian Arawak-Carib word "Mahiz" and its centre of origin considered to be Central America (Mexico) (Watson and Dallwitz 1992). "Maize isgrown at latitudes ranging from the equator to approximately 50◦ North and South, and at altitudes ranging from sea level to over 3,000 meters elevation. This reflects its ability to adapt to a wide range of production environments, under temperatures ranging from extremely cold to very hot, under moisture regimes ranging from extremely wet to semi-arid" (Dowswell et al. 1996).

"In India, maize is the third most important cereal crop after Rice and Wheat, that provides food, feed, fodder, fuel and also serves as a source of basic raw material for a number of industrial products *viz*., starch, oil, protein, alcoholic beverages, food sweeteners, cosmetics and bio-fuel etc.It is cultivated in nearly 201 m ha with a production of 1162 m tonnes and productivity of 5754.7 kg/ha all over the world, having wider diversity of soil, climate, biodiversity and management practices" (FAOSTAT 2021)."India ranks 4th in terms of global maize acreage and 6th in productionwith 31.51 million tonnes and area of 9.9

million hectares in 2020-21, whereas in kharif 2021-22, maize production was 21.24 million tonnes in an area of 8.15 million hectares" (agricoop.nic). "United States of America (USA) is the largest producer of maize contributing 30 per cent of the global production and is regarded as the driver of the US economy. In this context developing high yielding late maturity hybrids which can compete with rice with full productive potentiality and profitability are required. Maize in the tropics is continually exposed to different forms of stresses and variations within the seasons. This may be partly due to global climatic changes, partly due to displacement of maize to more difficult production environments by high value crops, and partly due to declining soil organic matter reducing soil fertility and water holding capacity. Research efforts in the public sector institution has achieved limited success in developing high yielding early maturing hybrids. Choice of germplasm is essential for successful development of high yielding genotypes through suitable breeding programs. Genetic relationship among different genotypes is one of the important parameter which provides essential information regarding choice of germplasm to develop new genotypes from breeding populations" (Spraque and Tatum, 1942).

"The hybrid breeding is vital to select the cross combinations with high degree of SCA as well as parents with high GCA. Combining ability is an important tool in identifying the best combiners for hybridization especially, when more numbers of advance inbred lines are available and most promising are to be selected on the basis of their ability to give superior hybrids. GCA &SCA are due to genes which shows additive and dominance or epistatic effects respectively" (Spraque and Tatum, 1942). Information on heterotic patterns and combining ability among maize germplasm is basic in improving the effectiveness of hybrid development. Development of commercial maize hybrid generally requires a good knowledge of combining ability of the breeding materials to be used.The result of commercial production of hybrid maize depends up on the availability of productive diverse inbred lines and clear knowledge of gene action for specific traits. Eventually, the present investigation was undertaken to study the combining ability and estimate the extent of heterosis.

Materials and Methods

"In Rabi, 2019-20 the experiment was planned in a line × tester mating pattern and 30 crosses were made. In Kharif, 2020 all 30 crosses along with their 13 parentsand 2checkswere grown in Randomized Block Design with two replications and were evaluated. After land preparation, sowing was done in July 2020. Seeds were sown by hand dibbling with two seeds per hill and afterwards thinned to one plant per hill after emergence to attain an optimum plant population density. Each entry was planted in plot consisting of two rows of 5m length and plot size of 6.0 m^2. Observations were recorded on plot basis for days to 50 per cent tasseling, days to 50 per cent silking, anthesis – silking interval, days to 75 per cent brown husk, plant height, ear height, cob length, cob girth, number of rows per cob, number of grains per row, test weight, shelling percentage and grain yield at 15% moisture from five randomly selected plants from each plot.

Table 1. Details of lines, testers and checks

S. No.	Code	Name	Source
1	L_1	VL1016537	CIMMYT, Hyderabad
2	L_2	VL109476	CIMMYT, Hyderabad
3	L_3	VL1010763	CIMMYT, Hyderabad
4	L_4	VL1018419	CIMMYT, Hyderabad
5	L_5	VL109475	CIMMYT, Hyderabad
6	L_6	VL1017055	CIMMYT, Hyderabad
7	L_7	VL109353	CIMMYT, Hyderabad
8	L_8	VL1010848	CIMMYT, Hyderabad
9	L_9	VL109479	CIMMYT, Hyderabad
10	L_{10}	VL1017524	CIMMYT, Hyderabad
11	T_1	VL1016498	CIMMYT, Hyderabad
12	T_2	VP15295	CIMMYT, Hyderabad
13	T_3	SML-1	BAU, Sabour
14	C_1	DHM 117	ANGRAU, Hyderabad
15	C_2	SHM 1	BAU, Sabour

Results and Discussion

The analysis of variance displays highly significant differencefor all the characters studied (Table 2). With the exception of the Anthesis-Silking interval, the mean square due to parents varied greatly, showing that the parents included in the study were heterogeneous. Additionally, there were considerable differences identified among the crosses for every character. There is a considerable difference in the variance attributed to parents compared to crosses, suggesting that the material under study has a high heterosis response. With the exception of the Anthesis-Silking interval, all of the characters under research had highly significant variance due to general and particular combining abilities, suggesting the involvement of both additive and non-additive influences on character expression. In maize, Singh and Kumar (2008), Verma and Narayan (2008), and Amiruzzaman et al. (2011) also noted the significance of both types of gene effects. Combining ability analysis revealed that degreeof specific combining ability (SCA) variances were higher thangeneral combining ability (GCA) variances for all the charactersunder study except Anthesis – Silking interval, suggesting predominance of non-additive geneaction for these characters.

GCA effect

The GCA effects were found to be having both significant positive and significant negative values for various traits studied (Table 3). The high GCA effect observed were attributed to additive effect and additive × additive gene effect.General combining ability is a good indicator of inbred line performance at hybrid combinations. Parents with high GCA always produce hybrids with high estimate of SCA. However, on the contrary good general combining parents does not always show high SCA effects in their hybrid combination. Kumar and Babu (2016) and Gowharet al. (2009) reported that, the crosses with high SCA effects were found to show result due to all possible parental GCA combinations.The lines VL109476 (464.817), VL109475 (748.317), VL1010848 (541.483) and VL109479 (1424.650) were identified as good combiners for grain yield at 15 % moisture. The line VL1017524 was also found to show good GCA effects for days to 50 per cent tasseling, days to 50 % silking, plant height and ear height. But the line VL109475 showed poor combining ability effects for days to 50 % tasseling and days to 50 % silking. Among the testers, the tester VP15295 (313.517) was identified as good combiner for grain yield at 15 % moisture, cob length, number of grains per row, test weight and shelling percentage, while SML-1is showing good GCA effects for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk, cob length and also shelling percentage. These observations were in agreement with the works ofElmyhun et al. (2020), Mogesse et al. (2020),Onejeme et al. (2020).

Table 2. Mean sum of square for quantitative traits in maize (*Zea mays* L.)

Sources	D.f	Mean Sum of Squares (MSS)					
		Days to 50 per cent tasseling (Day)	Days to 50 per cent silking (Day)	Anthesis-silking interval (Day)	Days to 75 per cent brown husk (Day)	Plant height (cm)	Ear height (cm)
Replicates	1	0.94186	1.674	0.186	0.570	1243.360	0.047
Treatments	42	18.81783	18.462***	0.882	10.220*	1337.957***	306.107***
Parents	12	20.05128	18.635***	1.667**	19.571***	1188.782***	352.878***
Parents Vs crosses	1	233.25012	197.847***	1.290	36.076*	26742.470***	5634.467***
Crosses	29	10.91322	12.205***	0.543	5.460	523.667***	103.017
Lines	9	13.09074	17.807**	0.896	8.444***	866.743**	227.128***
Testers	2	68.11667	60.117***	0.217	28.717***	1579.650**	160.117*
Line × tester	18	3.46852	4.080	0.402	1.383	234.798	34.617
Error	42	4.27519	3.960	0.615	5.260	130.837	70.737

*** Significant at 0.1% level ** Significant at 1% level * Significant at 5% level

Contd.

Table 2A. Mean sum of square for quantitative traits in maize (*Zea mays* L.)

Sources	D.f	Mean Sum of Squares (MSS)						
		Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of grains per row	Test weight (g)	Shelling percentage (%)	Grain yield at 15 % moisture (Kg/ha)
Replicates	1	13.442	0.158	2.279	0.890	143.267	17.759	622710.800
Treatments	42	14.247***	0.519***	2.401**	41.316***	3026.800***	49.841***	3308530.000*
Parents	12	9.947***	0.482***	1.205	11.154***	415.282***	36.057***	199571.600*
Parents Vs crosses	1	302.060***	10.026***	15.976***	1024.277***	66440.270**	958.321***	86662500.000**
Crosses	29	6.102**	0.207***	2.428**	19.902***	1920.756***	24.217***	1720721.000***
Lines	9	11.949**	0.186	3.822	34.078*	3247.807	27.771	3539063.000**
Testers	2	8.690	0.373	1.800	30.383	1220.517	103.679**	2065211.000
Line × tester	18	2.891	0.199***	1.800	11.650***	1335.035***	13.611*	773273.800***
Error	42	2.578	0.058	1.041	2.472	37.625	7.261	76723.670

Table 3. Estimates of GCA effects

Parent	Days to 50 per cent tasseling (Day)	Days to 50 per cent silking (Day)	Anthesis-silking interval (Day)	Days to 75 per cent brown husk (Day)	Plant height (cm)	Ear height (cm)
L_1	0.983	1.200	0.233	-0.500	2.117	0.017
L_2	-1.017	-1.133	-0.100	-1.667	6.283	5.850
L_3	0.150	0.200	0.067	-0.333	3.783	0.017
L_4	0.650	0.367	-0.267	0.500	9.617*	-0.817
L_5	2.150*	2.033*	-0.267	-0.667	5.950	5.850
L_6	-0.017	0.367	0.400	1.167	-3.717	4.183
L_7	0.317	0.867	0.567	0.667	-0.383	2.517
L_8	-0.017	-0.133	-0.100	0.500	3.783	-0.317
L_9	0.317	0.533	0.233	2.000*	5.117	-1.650
L_{10}	-3.517***	-4.300***	-0.767*	-1.667	-32.5***	-15.6***
T_1	-0.5	-0.517	0.083	-0.667	-7.1**	-2.9
T_2	2.0***	1.933***	-0.117	1.383*	9.9***	2.7
T_3	-1.483**	-1.417**	0.033	-0.717	-2.800	0.183
C.D. at 95% (Line)	1.726	1.662	0.655	1.915	9.551	7.022
C.D. at 95% (Tester)	0.946	0.910	0.359	1.049	5.231	3.846

*** Significant at 0.1% level ** Significant at 1% level * Significant at 5% level

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Table 3A. Estimates of GCA effects of parents

Parent	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of grains per row	Test weight (g)	Shelling percentage (%)	Grain yield at 15 % moisture (Kg/ha)
L_1	1.264	-0.136	-1.067*	0.396	-30.867***	-3.942**	-784.850***
L_2	1.154	0.206*	-0.067	1.513*	11.467***	1.190	464.817***
L_3	-0.130	-0.007	-0.400	0.612	-0.367	1.373	-38.350
L_4	0.442	-0.179	-0.733	2.438***	-25.700***	1.285	-353.183**
L_5	0.060	-0.012	0.267	-0.438	42.133***	-2.387*	748.317***
L_6	-0.835	0.013	0.267	-1.604*	-15.867***	1.345	-514.850***
L_7	-1.503*	0.231*	-0.733	0.229	-20.200***	0.845	-525.683***
L_8	1.195	0.225*	1.267**	-0.771	15.633***	1.108	541.483***
L_9	1.302	-0.062	1.267**	3.063***	20.967***	1.977	1424.650***
L_{10}	-2.950**	-0.279**	-0.067	-5.438***	2.800	-2.795*	-962.350***
T_1	-0.407	-0.056	-0.300	-0.538	-9.017***	0.904	-328.633***
T_2	0.761*	-0.099	0.000	1.410***	4.283**	-2.590***	313.517***
T_3	-0.354	0.156**	0.300	-0.873*	4.733**	1.686**	15.117
C.D. at 95 % (Line)	1.341	0.201	0.852	1.313	5.122	2.250	231.276
C.D. at 95 % (Tester)	0.734	0.110	0.467	0.719	2.805	1.232	126.675

*** Significant at 0.1% level ** Significant at 1% level * Significant at 5% level

SCA effect

The SCA effect was also found to be having both significant positive and significant negative values for various traits studied (Table 4). The crosses VL109476 x V P15295 (502.483), VL1010763 x VP15295 (521.650), VL1018419 x VP15295 (470.483), VL109475 x SML-1 (747.383), VL109353 x SML-1 (651.383) and VL1010848 x VL1016498were identified as good specific combiners for grain yield at 15% moisture and none of the crosses were identified as good specific combiners for earliness. These observations were in agreement with the works ofElmyhun et al. (2020),Mogesse et al. (2020), Nandan et al. (2020), Onejeme et al. (2020), Darshan and Marker (2019), Dar et al. (2018) andKumar et al. (2015).

Table 4. Estimates of SCA effects of crosses

Crosses	Days to 50 per cent tasseling (Day)	Days to 50 per cent silking (Day)	Anthesis-silking interval (Day)	Days to 75 per cent brown husk (Day)	Plant height (cm)	Ear height (cm)
$L_1 \times T_1$	-0.583	-0.150	0.417	1.000	-17.017 *	-5.417
$L_1 \times T_2$	0.267	0.400	0.117	-1.050	5.883	1.433
$L_1 \times T_3$	0.317	-0.250	-0.533	0.050	11.133	3.983
$L_2 \times T_1$	-0.583	-0.817	-0.250	-0.333	-1.183	1.250
$L_2 \times T_2$	0.767	1.233	0.450	0.617	-0.783	0.600
$L_2 \times T_3$	-0.183	-0.417	-0.200	-0.283	1.967	-1.850
$L_3 \times T_1$	-1.250	-1.150	0.083	-0.667	-1.183	-5.417
$L_3 \times T_2$	1.100	1.400	0.283	-0.217	-0.783	1.433
$L_3 \times T_3$	0.150	-0.250	-0.367	0.883	1.967	3.983
$L_4 \times T_1$	-0.750	-0.817	-0.083	-0.500	0.483	2.917
$L_4 \times T_2$	1.100	1.233	0.117	0.450	8.383	-0.233
$L_4 \times T_3$	-0.350	-0.417	-0.033	0.050	-8.867	-2.683
$L_5 \times T_1$	1.750	2.017	0.417	0.167	13.150	-3.750
$L_5 \times T_2$	-0.400	-0.933	-0.383	0.617	-2.950	8.100
$L_5 \times T_3$	-1.350	-1.083	-0.033	-0.783	-10.200	-4.350
$L_6 \times T_1$	0.917	0.683	-0.250	0.833	8.817	2.917
$L_6 \times T_2$	-0.733	-0.267	0.450	-0.717	6.717	-2.733
$L_6 \times T_3$	-0.183	-0.417	-0.200	-0.117	-15.533	-0.183
$L_7 \times T_1$	0.583	0.183	-0.417	0.333	-7.017	4.583
$L_7 \times T_2$	-0.067	0.233	0.283	-1.217	-4.117	-3.567
$L_7 \times T_3$	-0.517	-0.417	0.133	0.883	11.133	-1.017
$L_8 \times T_1$	1.417	1.183	-0.250	0.000	-6.183	-1.083
$L_8 \times T_2$	-0.233	-0.267	-0.050	-0.050	9.217	-0.733
$L_8 \times T_3$	-1.183	-0.917	0.300	0.050	-3.033	1.817
$L_9 \times T_1$	0.583	0.517	-0.083	-1.000	-0.017	1.250
$L_9 \times T_2$	-1.067	-1.433	-0.383	1.450	-3.117	0.600
$L_9 \times T_3$	0.483	0.917	0.467	-0.450	3.133	-1.850
$L_{10} \times T_1$	-2.083	-1.650	0.417	0.167	10.150	2.750
$L_{10} \times T_2$	-0.733	-1.600	-0.883	0.117	-18.450 *	-4.900
$L_{10} \times T_3$	2.817	3.250 *	0.467	-0.283	8.300	2.150
C.D at 95%	2.990	2.878	1.134	3.317	16.542	12.163

Contd.

Table 4A. Estimates of SCA effects of crosses

Crosses	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of grains per row	Test weight (g)	Shelling percentage (%)	Grain yield at 15% moisture (Kg/ha)
$L_1 \times T_1$	-1.695	-0.022	-0.033	-4.296 ***	4.017	0.658	-476.700 *
$L_1 \times T_2$	1.948	0.351 *	-0.333	2.757 *	-4.283	-5.123 *	141.150
$L_1 \times T_3$	-0.253	-0.329	0.367	1.539	0.267	4.466 *	335.550
$L_2 \times T_1$	-1.335	-0.409 *	-1.033	-0.412	-12.317 **	1.626	-674.367 **
$L_2 \times T_2$	1.033	-0.011	-0.333	0.340	27.383 ***	-1.245	502.483 *
$L_2 \times T_3$	0.302	0.419 *	1.367	0.072	-15.067 **	-0.381	171.883
$L_3 \times T_1$	-0.196	-0.220	-0.700	-1.013	-10.983 *	0.058	-541.200 **
$L_3 \times T_2$	0.356	-0.062	0.000	3.190 **	-1.783	0.822	521.650 *
$L_3 \times T_3$	-0.160	0.283	0.700	-2.178	12.767 **	-0.879	19.550
$L_4 \times T_1$	0.762	0.216	0.633	3.663 **	-30.150 ***	0.851	58.133
$L_4 \times T_2$	-0.461	-0.091	0.333	-1.660	31.550 ***	-1.425	470.483 *
$L_4 \times T_3$	-0.301	-0.126	-0.967	-2.003	-1.400	0.574	-528.617 *
$L_5 \times T_1$	-1.496	-0.255	0.633	0.538	-29.983 ***	-0.882	-288.367
$L_5 \times T_2$	-0.504	-0.052	-0.667	-1.410	0.717	0.817	-459.017 *
$L_5 \times T_3$	2.000	0.308	0.033	0.873	29.267 ***	0.066	747.383 ***
$L_6 \times T_1$	0.699	-0.015	-1.367	-1.296	31.017 ***	-0.604	-41.200
$L_6 \times T_2$	-0.009	0.293	1.333	2.757 *	-25.283 ***	2.115	343.150
$L_6 \times T_3$	-0.690	-0.277	0.033	-1.461	-5.733	-1.511	-301.950
$L_7 \times T_1$	-0.178	-0.214	0.633	-0.129	-4.150	1.446	76.133
$L_7 \times T_2$	-0.505	-0.131	-0.667	-2.577 *	-7.450	-4.005 *	-727.517 ***
$L_7 \times T_3$	0.683	0.344	0.033	2.706 *	11.600 *	2.559	651.383 **
$L_8 \times T_1$	1.184	0.248	0.633	0.871	45.017 ***	-0.692	1223.967 ***
$L_8 \times T_2$	-0.834	-0.119	-0.667	-0.077	-9.283 *	2.447	-393.183
$L_8 \times T_3$	-0.350	-0.129	0.033	-0.794	-35.733 ***	-1.754	-830.783 ***
$L_9 \times T_1$	0.547	0.255	-0.367	0.538	22.683 ***	-1.516	339.300
$L_9 \times T_2$	-0.191	0.043	0.333	-0.910	-4.117	2.648	-50.850
$L_9 \times T_3$	-0.357	-0.297	0.033	0.373	-18.567 ***	-1.133	-288.450
$L_{10} \times T_1$	1.709	0.416 *	0.967	1.538	-15.150 **	-0.944	324.300
$L_{10} \times T_2$	-0.834	-0.221	0.667	-2.410 *	-7.450	2.950	-348.350
$L_{10} \times T_3$	-0.875	-0.196	-1.633 *	0.873	22.600 ***	-2.006	24.050
C.D@95%	2.322	0.348	1.476	2.274	8.871	3.897	400.582

*** Significant at 0.1% level ** Significant at 1% level * Significant at 5% level

Table 5. Magnitude of heterosis for grain yield at 15 % moisture (Kg ha^{-1})

Crosses	Heterosis (%) over			
	RH	BP	Check1	Check2
$L_1 \times T_1$	27.75	22.39	-49.64**	-50.78**
$L_1 \times T_2$	65.13 **	45.36 **	-21.36**	-23.15
$L_1 \times T_3$	120.53 **	85.44 **	-23.69**	-25.43*
$L_2 \times T_1$	97.16 **	96.25 **	-26.03**	-27.71
$L_2 \times T_2$	151.07 **	112.20 **	14.78**	12.17**
$L_2 \times T_3$	107.89 **	109.59 **	0.67**	-1.62
$L_3 \times T_1$	55.29 **	40.07 **	-34.33**	-35.83***
$L_3 \times T_2$	105.85 **	92.12 **	3.92**	1.55**
$L_3 \times T_3$	129.44 **	83.37 **	-14.04**	-16.00
$L_4 \times T_1$	92.22 **	91.16 **	-27.96	-29.60
$L_4 \times T_2$	109.51 **	76.93 **	-4.28	-6.43*
$L_4 \times T_3$	103.88 **	78.66 **	-33.41*	-34.93
$L_5 \times T_1$	159.52 **	136.11 **	-11.01	-13.04*
$L_5 \times T_2$	134.33 **	84.07 **	-0.42**	-2.69
$L_5 \times T_3$	107.01 **	88.30 **	19.95**	17.21***
$L_6 \times T_1$	87.27 **	75.62 **	-33.81	-35.32
$L_6 \times T_2$	104.90 **	64.95 **	-10.77*	-12.80
$L_6 \times T_3$	122.94 **	106.22 **	-31.95	-33.50
$L_7 \times T_1$	91.09 **	81.96 **	-31.41	-32.98
$L_7 \times T_2$	47.32 **	20.08	-35.05*	-36.53
$L_7 \times T_3$	187.11 **	161.69 **	-10.79	-12.82
$L_8 \times T_1$	225.27 **	113.84 **	18.25*	15.51**
$L_8 \times T_2$	116.31 **	78.22 **	-3.59	-5.78
$L_8 \times T_3$	153.25 **	127.99 **	-20.10	-21.92
$L_9 \times T_1$	224.38 **	103.75 **	18.24**	15.55**
$L_9 \times T_2$	177.46 **	129.06 **	25.02*	22.15*
$L_9 \times T_3$	253.64 **	117.65 **	11.87**	9.375*
$L_{10} \times T_1$	89.62 **	70.74 **	-35.65	-37.72
$L_{10} \times T_2$	51.09 **	17.69	-36.33*	-37.51*
$L_{10} \times T_3$	124.35 **	116.43 **	-34.67***	-36.23

*** Significant at 0.1% level ** Significant at 1% level * Significant at 5% level

*RH- Relative heterosis

*BP-Better Parent

Estimates of heterosis

Negative and significant heterosis is desirable for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent brown husk, anthesis- silking interval,plant height and ear height as it implies that these crosses may mature earlier.

In Maize shorter plants are taken in to consideration over taller types, so significant negative heterosis is considered desirable for plant height for the development of shorter hybrids that could avoid lodging.

Positive and significant heterosis for cob length, cob girth, number of grains per row, number of rows per cob, test weight, shelling % and grain yield at 15% moisture is desired. In the present study several crosses were showing desirable significant heterosis for these traits. On the basis of standard heterosisVL109476 x V P15295, VL1010763 x VP15295, VL109475 x SML-1 and VL109479 x SML-1 were superior to the better check in grain yield. The identified hybrids may be tested on large scale multi-location trial and in farmers' field before commercial utilization.

These finding also agree with, Ali et al. (2014), Shushay (2014), Amiruzzaman et al. (2010), Sumalini and Rani (2010), Singhal et al. (2006), Mohanraj and Gopalan (2005), Reddy and Ahuja (2004), Sinha *etal*. (2004), Dubey *etal*. (2001), Iqbal et al. (2001), Pandey and Kumar (2001), Pradhan (1999) and Sinha and Mishra (1977) who also reported positive and significant heterosis for yield and related traits.

Conclusion

The good general combiner for yield lines L_2, L_5, L_8 and L_9 and tester T_2 observed in the study, may be used in hybridization programmes for greater yield.The best cross combinations for greater yield $L_2 \times T_2$, $L_3 \times T_2$, $L_4 \times T_2$, $L_5 \times T_3$, $L_7 \times T_3$ and $L_8 \times T_1$ in the study, may be forwarded for multi-location testing and Front Line Demonstration (FLD), and then promising crosses may be released as hybrid.As a future breeding strategy, improvement of the traits showing preponderance of non-additive gene action could be achieved by recurrent selection, or by way of inter-mating the most desirable segregants, followed by selection or the use of multiple crosses or biparental mating.

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