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Research Note

Study on heterosis and inbreeding depression in maize (*Zea mays* L.)

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Abstract
A study was undertaken to investigate the heterosis and inbreeding depression in 21 hybrids (F_1) and their F_{2s} produced by crossing seven maize inbreeds in all possible combinations, excluding reciprocal. . The crosses VL-1016556 × CML-171 and VL-1016556 × KL-153237 were identified as the best F_1s as they showed superiority for grain yield per plant over the check. The highest heterobeltiosis (Hb) was recorded by hybrids VL-1016556 × KL-153237 and VL-1016556 × CML-171 while hybrids VL-1016556 × KL-153237 and VL-1016556 × CML-171 exhibited the highest economic heterosis (Hc). Keeping the greater magnitude of heterosis, high mean performance and lesser inbreeding depression (less than 15%) into consideration, five crosses, namely, VL-1016556 × BHU-N5, VL-1016556 × CML-171, VL-1016556 × CML-161, CML-171 × BHU-N5 and VL-1016556 × BHU QPM-3 were identified as best hybrids.

Keywords: Heterosis, Inbreeding, Maize and Hybrids

Maize is India's third most significant grain crop, after rice and wheat. It accounts for 9% of the country's total food grain output. It is regarded as the "Queen of Cereals" or "Wonder Grain" because it is a versatile crop that may be used for food, feed and has industrial use. In the case of maize, there is much room for genetic improvement due to the abundance of variability in their germplasm (Om Prakash *et al*., 2019). Before designing genetic improvement techniques, it is necessary to understand various traits of interest (both qualitative and quantitative attributes) and their genetic regulation (Kumari *et al*., 2018). Increasing maize production requires the exploitation of heterosis. The reaction to heterosis is indicated as a difference in F_1 (cross) performance from either parent (better parent heterosis) or the average of the parental values (midparent heterosis). Maize breeders increasingly emphasise single-cross hybrids for increased grain yield, homogeneity, inexpensive hybrid seed production costs and the availability of superior and diversified inbred lines (Kumari *et al*., 2019 and Chavan *et al.,* 2022). When individuals that are closely connected by ancestry mate together, as opposed to random mating, inbreeding develops. Inbreeding produces a drop in the mean phenotypic value of features associated to reproductive capability or physiological efficiency, known as "inbreeding depression." The present research looked into the heterosis in F_1 over the standard check (SC) and inbreeding depression in F_2 segregating generation for yield and its associated features in maize.

During the Spring of 2020, the research was carried out at the Field Experimentation Centre of the Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (Allahabad) (U.P.). The experimental material included 50 genotypes of Quality Protein Maize (21 F_1 + 21 F_2 + 7 parents + 1 check) (**Table 1**) , grown in Randomized Block Design

Table 1. List of inbred lines used in present investigation and the hybrid combinations generated

S.No.	Notation	Genotype	S.No.	Notation	Genotype
1	P1	VL-1016556	15	P_2×P_4	CML-171 × BHU QPM-3
2	P2	CML-171	16	P_2×P_5	CML-171 × BHU-N6
3	P3	BHU-N5	17	P_2×P_6	CML-171 × CML-161
4	P4	BHU QPM-3	18	P_2×P_7	CML-171 × KL-153237
5	P5	BHU-N6	19	P_3×P_4	BHU-N5 × BHU QPM-3
6	P6	CML-161	20	P_3×P_5	BHU-N5 × BHU-N6
7	P7	KL-153237	21	P_3×P_6	BHU-N5 × CML-161
8	P_1×P_2	VL-1016556 × CML-171	22	P_3×P_7	BHU-N5 × KL-153237
9	P_1×P_3	VL-1016556 × BHU-N5	23	P_4×P_5	BHU QPM-3 × BHU-N6
10	P_1×P_4	VL-1016556 × BHUQPM-3	24	P_4×P_6	BHU QPM-3 × CML-161
11	P_1×P_5	VL-1016556 × BHU-N6	25	P_4×P_7	BHU QPM-3 × KL-153237
12	P_1×P_6	VL-1016556 × CML-161	26	P_5×P_6	BHU-N6 × CML-161
13	P_1×P_7	VL-1016556 × KL-153237	27	P_5×P_7	BHU-N6 × KL-153237
14	P_2×P_3	CML-171 × BHU-N5	28	P_6×P_7	CML-161 × KL-153237

(RBD) with three replications. Oservations were recorded on 16 traits namely Days to 50% tasseling, Days to 50% silking, Anthesis Silking Interval, Plant height (cm), Plant girth (cm) , Leaf area index, Chlorophyll content, Canopy Temperature Deficit, Cob height (cm) , Cob length (cm) , Cob girth (cm), Cob weight (g), Number of kernel rows per cob, Number of kernels per row, 100 seed weight(g), Grain yield per plant (g). . Analysis of Variance (ANOVA) was computed according to Panse and Sukhatme (1967). Heterosis over the standard check (SC) and heterobeltiosis was calculated as a percentage increase or decrease in in performance of a hybrid for a trait over the standard check variety and better parent in a desirable direction. Inbreeding depression is shown as a percentage difference in vigour between F_2 and F_1. It was calculated by using the formula $(F_1-F_2)/F_1 \times 100$.

The ANOVA for characters , presented in **Table 2**, indicated thatthe mean sum of squares due to treatments, parents, hybrids, and parent *vs* hybrids showed significant differences among the genotypes at 1% and 5% levels of significance for all the characters except for anthesis silking interval and canopy temperature deficit. This indicates the presence of significant variability among the parents, their crosses (F_1) and parents *vs* hybrids (F_1) for most of the characters studied. This suggests that the parental lines selected were quite variable and a considerable amount of variability existed among the hybrids. Similar results in maize have also been reported by Amiruzzaman *et al*. (2018) for different characters like plant height, grain yield per plant, and ear height, Kumari *et al*. (2018) for days to 50 per cent tasseling, days to 50 per cent silking, plant height, cob height, cob length, cob girth, 100-seed weight and grain yield per plant, Babagouda *et al*. (2017), Darshan and Marker (2019), Solomon *et al*. (2020) for days to 50% tasseling, days to 50% silking, the number of rows per cob, the number of kernels per row, 100-seed weight and grain yield per plant.

Character wise heterobeltiosis and standard heterosis, presented in **Table 3** Indicate that the estimates of significant heterobeltiosis (Hb) for grain yield per plant varied from 45.53 (VL-1016556 × CML-171) to 19.29% (BHU QPM-3 × BHU-N6). All the crosses exhibited positive significant heterobeltiosis for grain yield per plant in spring seasons. The estimates of significant economic heterosis (Hc) for grain yield per plant varied from 13.09 (VL-1016556 × CML-171) to 7.06% (CML-171 × BHU-N5). Five crosses exhibited positive significant economic heterosis for grain yield per plant in spring.

Heterobeltiosis (Hb) is an important parameter as it provides information about the presence of dominance and dominance x dominance type of gene actions in the expressions of various traits. Overall perusal of estimates of heterosis revealed that the cross VL-1016556 × CML-171 exhibited positive significant economic heterosis for grain yield and other yield attributing characters like 100 seed weight (test weight), and cob weight. Whereas, VL-1016556 × CML-171, VL-1016556 × BHU-N5 and VL-1016556 × KL-153237 exhibited positive significant economic heterosis for grain yield and other yield attributing characters like 100 seed weight (test weight), cob weight and the number of kernel rows per cob in spring. Similar findings were also reported in maize by Kumar and Babu (2019), Kumari *et al*. (2018), Darshan and Marker (2019) and Solomon *et al*. (2020). The cross CML-171 × BHU-N6 exhibited the highest negative significant economic heterosis for the traits, days to 50% tasselling and days to 50% silking in *spring*. These crosses can be exploited further in breeding programmes for developing

Table 2. ANOVA for different quantitative and qualitative parameters in QPM parents and hybrids (*spring*-2020)

S. No.	Characters	Mean Sum of Squares						
		Replications	Treatments	Parents	Hybrids	Parent Vs. Hybrids	Error	Total
	Degrees of Freedom	2	27	6	20	1	54	83
1.	Days to 50% tasseling	7.17	14.62**	1.30	18.26**	21.73	6.05	8.86
2.	Days to 50% silking	6.04	14.46**	1.41	18.30**	15.75	5.89	8.68
3.	Anthesis Silking Interval	0.37	0.22	0.16	0.22	0.67	0.37	0.32
4.	Plant height	878.93	1063.65**	1460.92**	345.63**	13040.36**	110.83	439.29
5.	Plant girth	0.07	1.84**	1.59**	1.91**	1.9**	0.24	0.76
6.	Leaf area index	1.51	0.72**	0.98**	0.59**	1.9**	0.00	0.27
7.	Chlorophyll content	162.20	53.61**	48.26**	25.59*	646.08**	13.49	30.12
8.	Canopy Temperature Deficit	0.07	0.29	0.150	0.21	2.74**	0.26	0.27
9.	Cob height	77.51	137.77**	75.10	88.49	1499.14**	65.40	89.23
10.	Cob length	0.29	5.44**	0.55	1.93**	104.92**	0.22	1.94
11.	Cob girth	2.69	2.073*	0.02	1.32**	29.46**	0.30	0.93
12.	Cob weight	31.03	300.96**	6.31	62.05**	6846.88**	10.02	105.17
13.	Number of kernel rows per cob	0.45	0.46**	0.24	0.33**	4.22**	0.11	0.23
14.	Number of kernels per row	1.07	5.95**	0.83	2.28**	110.01**	0.48	2.28
15.	100 seed weight	0.42	10.24**	1.79**	3.74**	191.01**	0.32	3.55
16.	Grain yield per plant	36.88	302.37**	6.35	54.22**	7041.42**	9.63	105.5

**Significant at 1% and *Significant at 5% level

early maturing varieties. Amiruzzaman *et al.* (2018), Mohammed *et al.* (2017), Matin *et al.* (2017), Kumari *et al.* (2019), Darshan and Marker (2019), Solomon *et al.* (2020) and Chavan *et al.* (2022) revealed the importance of non-additive gene action for this trait. The cross CML-171 × CML-161 recorded the highest negative significant economic heterosis for plant height in spring. It can be exploited further in breeding programmes for developing small and medium-stature varieties in maize crops. Amirruzzaman *et al.* (2018), Kumari *et al.* (2019), Aminu *et al.* (2017), Darshan and Marker (2019) and Solomon *et al.* (2020) reported similar results for these traits.

To study the extent of change in performance in F_2 generation, inbreeding depression was worked out and the results are presented in Table 2. The results revealed that maximum inbreeding depression for grain yield per plant was recorded in F_2 generation of the crosses VL-1016556 × BHU-N6; BHU-N5 × KL-153237 (23.18%) followed by CML-171 × KL-153237, BHU QPM-3 × KL-153237 (22.12%) and VL-1016556 × CML-161 (12.45%). Four crosses exhibited negative significant estimates of inbreeding depression in grain yield per plant. Apart from the eleven crosses which exhibited significant positive estimates of inbreeding depression and four crosses with negative significant estimates of inbreeding depression, all the remaining cross combinations recorded statistically non-significant values of inbreeding depression for grain yield per plant.

A close perusal of data on inbreeding depression for days to 50% tasseling suggested that it varied from -8.15% to -8.35%. The negative estimate for days to 50% tassel emergence gave an indication of late tasseling tendency of F_2 populations. Hallauer and Miranda (1988) also reported that inbreeding tends to increase the time of flowering in maize populations. Whereas for days to 50% silking, it ranged from -4.68% to -7.08%. None of the cross combinations recorded positive estimates of inbreeding depression for days to 50% tasseling and silking and this type of consequence of inbreeding may not attribute to the appearance of transgressive segregants in F_2 population.

The extent of significant inbreeding depression for plant height in spring across F_2 populations varied from -4.43 to -77.15%. Low inbreeding depression for plant height in a positive direction was a desirable attribute and F_2 populations derived from these crosses are supportive in the screening of transgressive segregants from F_2 population for reduced plant height. But in the present study, none of the F_2 populations recorded positive significant inbreeding depression in plant height. Unlike the results obtained from this study, positive estimates of low inbreeding depression were reported earlier by Das *et al.*(2017), Ejigu *et al.*(2017), Gazal *et al.* (2017), Krishnaji *et al.*(2018) and Manoj *et al.*(2018).

Considering the relevance of better fitness, negative estimates of inbreeding depression for days to 50%

Table 3. Heterobeltiosis (Hb), Economic heterosis (Hc) and Inbreeding depression in 21 maize crosses

S. No.	Genotypes		Days to 50% tasseling	Days to 50% silking	Anthesis Silking Interval	Plant height	Stem girth	Leaf area index	Chlorophyll content	Canopy Tempera-ture Deficit	Cob Height	Cob length	Cob Girth	Cob weight	No. Of Kernel rows/ cob	N0. Of kernels/ row	100 seed weight(g)	Grain yield per plant
1	VL-1016556 × CML-171	Hb	-1.55	-1.49	-14.29	37.85**	12.67	37.85**	-12.01*	-14	19.91	25.44**	21.97**	40.79**	5.71*	20.79**	12.32**	45.53**
		Hc	-8.17**	-8.76**	-33.33*	9.48	-4.23	9.48	3.36	-14	-1.76	14.84**	15.17**	11.61**	-3.65	10.26**	6.46**	13.09**
		ID	-2.32	-3.92	-13.77	-63.21 **	-4.22	-13.16	-7.25	-5.59	-10.99 **	-32.21	-8.72	-53.11 **	-65.26 **	-3.22	-13.61**	10.00**
2	VL-1016556 × BHU-N5	Hb	-5.15	-4.98	0	15.14**	-28.13**	15.14**	-17.37**	43.9	28.29	20.60**	29.18**	36.26**	6.32**	6.38**	18.44**	41.47**
		Hc	-11.54**	-11.98**	-22.22	4.55	-23.04	4.55	-8.93	18	-2.29	9.59**	21.98**	8.01**	-3.65	2.56	10.30**	8.96**
		ID	-6.21	-6.5	0	-13.01	-12.67 *	10.56	-2.67	-8.91	6.84 **	-10.56	7.59	-7.44	-11.92	-12.19 *	10.19	3.15*
3	VL-1016556 × BHU QPM-3	Hb	0.52	1.01	0	11.26*	-9.02	11.26*	-9.24	50	5.88	25.81**	23.93**	31.36**	2.75	17.65**	11.36**	38.28**
		Hc	-7.69**	-7.83**	-11.11	8.57	-6	8.57	0.94	20	-2.89	15.75**	17.03**	5.70*	-2.6	7.69**	3.71	8.78**
		ID	2.12	3.77	9	-43.21 **	51.75 **	-41.17 **	18.11 *	-21.42 **	14.79 **	-29.15	12.66	-30.33 **	-34.43 **	46.12 **	14.49 **	5.7*
4	VL-1016556 × BHU-N6	Hb	-2.59	-2.01	0	-15.12**	52.77**	-15.12**	-19.60**	55	39.57*	23.12**	17.19**	28.99**	6.32**	7.69**	16.96**	34.47**
		Hc	-9.62**	-10.14**	-22.22	-6.27	24.12**	-6.27	-2.48	24	17.74	11.87**	11.02*	2.25	-3.65	-1.28	8.93**	3.56
		ID	-5.03	-4.68 *	0	-15.07	9.31 *	19.2	12.54 *	-11.79	-3.15	-22.51	-5.35 *	-11.97	-17.23	9.85 *	-40.11**	23.18 **
5	VL-1016556 × CML-161	Hb	-2.62	-2.53	0	40.07**	16.22*	40.07**	-20.48**	-10	-11.94	23.37**	13.34**	36.92**	7.47**	14.64**	13.57**	42.25**
		Hc	-10.58	-11.06**	-22.22	6.17	20.58**	6.17	-12.36*	-10	-8.21	12.10**	7.03	8.54**	-2.6	6.41**	5.77**	9.56**
		ID	1.95	2.72	0	-8.23	-55.27 **	-17.72	-17.77 **	41.67 **	7.16 **	34.03	6.9	-5.94	-8.27	-59.67 **	-1.78	12.45**
6	VL-1016556 × KL-153237	Hb	11.34**	10.40**	0	11.72*	-10.27	11.72**	-4.02	5	25.85	19.10**	12.56**	29.17**	1.66	7.54**	20.50**	37.90**
		Hc	3.85	2.76	-22.22	5.1	-10.13	5.1	5.78	-16	12.27	8.22**	6028	2.39	-4.17	-1.28	12.23**	6.21
		ID	-8.23 *	-6.08 *	2.21	9.33	-7.66	-35.59 *	-12.69	-4.19	18.97 **	-4.92 *	18.19 *	13.63	11.37	-2.94	-18.95 **	-15.61*
7	CML-171 × BHU-N5	Hb	-3.09	-1.99	28.57	20.30**	-15.62*	20.30**	-10.29	-30	24.26	26.43**	8.91*	31.77**	5.71*	5.05*	15.94**	37.89**
		Hc	-9.62**	-9.22**	0	9.24	-9.65	9.24	5.37	-30	1.81	15.75**	1.83	4.29	-3.65	1.28	9.89**	7.16*
		ID	-3.91	-2.79	5.97	-67.13 **	10.98 *	20.34	-5.61	17.25 **	16.64 **	15.72	11.97	-57.42 **	-55.72 **	11.88 *	16.13**	8.03**
8	CML-171 × BHU QPM-3	Hb	-3.09	-2.49	0	6.26	3.79	6.26	-15.15**	-4	-2	14.39**	9.47*	24.52**	3.85	12.04**	5.94**	28.81**
		Hc	-9.62**	-9.68**	-11.11	3.69	7.23	3.69	-0.34	-4	-10.12	5.25	2.35	0.2	-1.56	2.56	0.41	1.32
		ID	-1.51	-5.91	-15.77	-75.11 **	-4.11	-15.17	-7.15	-5.59	-10.99 **	-22.1	-7.02	-44.31 **	-54.67 **	-3.28	-12.11	-13.31*
9	CML-171 × BHU-N6	Hb	-6.7	-6.47*	0	0.75	13.24	0.75	-23.59**	26	47.84**	14.46**	9.84*	25.46**	8.00**	6.29*	14.35**	33.69**
		Hc	-12.98**	-13.36**	-22.22	11.25*	-3.75	11.25*	-7.32	26	24.72	4.79	4.06	-0.7	-1.56	-2.56	8.38**	3.89
		ID	-7.11	-7.5	0	-15.01	-11.77 *	10.57	-1.77	-8.91	7.84 **	-12.05	6.19	-5.04	-10.27	-10.11 *	9.12	-3.13
10	CML-171 × CML-161	Hb	-1.55	-1.99	-14.29	47.92**	-8.88	47.92**	-12.12*	2	7.57	14.21**	10.30*	25.81**	3.43	14.64**	6.96**	30.91**
		Hc	-8.17**	-9.22**	-33.33*	17.47**	-5.47	17.47**	3.22	2	12.12	4.57	3.13	-0.42	-5.73**	6.41**	1.37	1.73
		ID	1.11	5.77	9	-45.11 **	51.75 **	-41.17**	18.11*	-11.41 **	14.79 **	-27.11	11.69	-32.13 **	-33.33 **	44.13 **	15.04 **	4.4*

Table 3.Continued...

S. No.	Genotypes		Days to 50% tasseling	Days to 50% silking	Anthesis Silking Interval	Plant height	Stem girth	Leaf area index	Chlorophyll content	Canopy Tempera-ture Deficit	Cob Height	Cob length	Cob Girth	Cob weight	No. Of Kernel rows/ cob	N0. Of kernels/ row	100 seed weight(g)	Grain yield per plant
11	CML-171 × KL-153237	Hb	2.06	1.98	14.29	10.8	-17.34**	10.8	-18.12**	22	35.37*	15.46**	17.50**	30.38**	3.31	11.73**	10.43**	34.68**
		Hc	-4.81	-5.07	-11.11	4.24	-17.20**	4.24	-3.83	22	20.77	5.71*	10.59*	3.2	-2.6	2.56	4.67*	4.66
		ID	-5.05	-4.78*	0	-15.07	9.51 *	19.1	11.54*	-11.79	-5.15	-20.55	-6.43 *	-10.27	-15.72	7.45 *	-42.03**	22.12 **
12	BHU-N5 × BHU QPM-3	Hb	-5.15	-4.98	-12.5	14.98**	-15.02*	14.98**	-13.04*	58.54	18.45	12.90**	14.07**	22.85**	-3.3	5.05*	18.33**	26.68**
		Hc	-11.54**	-11.98**	-22.22	12.19*	-9	12.19*	-3.29	30	8.63	3.88	6.66	-1.15	-8.33**	1.28	7.28**	-0.35
		ID	1.95	1.71	0	-8.15	-55.17**	-17.71	-17.77**	41.77 **	7.17 **	29.2	4.65	-6.14	-7.07	-56.77 **	-1.97	-12.33
13	BHU-N5 × BHU-N6	Hb	-5.15	-5.47	-14.29	-17.43**	1.8	-17.43**	-27.80**	21.95	-1.98	15.58**	9.54*	26.28**	3.45	5.05*	16.67**	31.66**
		Hc	-11.54**	-12.44**	-33.33*	-8.82	9	-8.82	-12.42*	0	-17.31	1.6	3.78	-2.4	-6.25**	1.28	4.81*	-0.54
		ID	-8.15*	-7.08*	1.11	9.55	-7.77	-55.59*	-11.79	-4.19	18.97 **	-4.94 *	19.21 *	11.96	13.31	-2.34	-19.05 **	-13.21*
14	BHU-N5 × CML-161	Hb	-3.61	-2.99	14.29	11.21	5.41	11.21	-14.01*	12	14.72	10.91**	2.72	24.25**	4.02	1.06	20.97**	32.20**
		Hc	-10.10**	-10.14**	-11.11	0.99	12.86	0.99	-7.05	12	19.57	-2.51	-3.96	-2.62	-5.73**	-2.56	9.34**	0.45
		ID	-5.91	-1.79	5.97	-77.15 **	10.98 *	10.54	-5.71	17.15 **	17.74 **	14.57	10.17	-54.22 **	-51.66 **	10.89 *	13.23	-7.23
15	BHU-N5 × KL-153237	Hb	-4.64	-4.46	14.29	5.54	0.15	5.54	-6.49	46.34	10.37	21.30**	5.59	22.87**	-0.55	6.38**	12.42**	26.67**
		Hc	-11.06**	-11.06**	-11.11	-0.71	7.23	-0.71	1.07	20	-1.53	6.62*	-0.62	-5.44	-6.25**	2.56	-0.55	-4.32
		ID	-1.51	-4.51	-1.497	-7.431 **	-4.31	-1.437	-7.35	-4.49	-11.69 **	-22.51	-5.35 *	-11.97	-17.23	9.85 *	-40.11**	23.18 **
16	BHU QPM-3 × BHU-N6	Hb	-4.66	-3.52	0	-0.2	18.57**	-0.2	-10.02*	27.5	8.27	18.11**	14.84**	16.65**	-7.69**	11.89**	15.45**	19.29**
		Hc	-11.54**	-11.52**	-11.11	10.21*	22.51**	10.21*	9.13	2	-0.7	8.68**	8.79	-6.14*	-12.50**	2.56	4.67*	-6.16
		ID	-7.31	-7.5	0	-1.401	-11.97 *	11.57	-1.97	-8.61	7.84 **	34.03	6.9	-5.94	-8.27	-59.67 **	-1.78	-12.45
17	BHU QPM-3 × CML-161	Hb	1.05	2.03	0	6.92	-9.66	6.92	-15.88**	20	3.71	7.44*	11.66*	17.46**	-0.55	9.12**	10.30**	21.26**
		Hc	-7.21*	-7.37**	-11.11	4.34	-6.27	4.34	-6.45	20	8.1	-1.14	4.06	-5.49	-5.73**	1.28	0	-4.61
		ID	1.31	4.97	9	-4.431 **	51.95 **	-41.37**	18.31*	-11.41 **	14.99 **	-27.11	11.69	-32.13 **	-33.33 **	44.13 **	15.04 **	4.4
18	BHU QPM-3 × KL-153237	Hb	-6.19	-5.94*	0	15.93**	3.16	15.93**	-11.78*	47.5	19.6	8.19*	11.88**	19.20**	2.75	7.54**	13.03**	25.22*
		Hc	-12.50**	-12.44**	-11.11	13.12*	6.59	13.12*	-1.88	18	9.7	-0.46	5.29	-4.09	-2.6	-1.28	2.47	-1.5
		ID	-4.05	-4.98*	0	-1.407	9.51 *	19.3	11.54*	-11.99	-0.435	-20.55	-6.43 *	-10.27	-15.72	7.45 *	-42.03**	22.12 **
19	BHU-N6 × CML-161	Hb	-3.11	-2.01	33.33	0.2	-1.91	0.2	-21.87**	-2	20.16	15.06**	9.71*	29.16**	4.6	10.50**	16.72**	34.98**
		Hc	-10.10**	-10.14**	-11.11	10.64*	1.77	10.64*	-5.24	-2	25.25	1.14	3.93	1.23	-5.21*	2.56	5.49**	2.56
		ID	1.65	1.91	0	-8.35	-5.437 **	-17.91	-17.97**	41.97 **	7.37 **	29.2	4.65	-6.14	-7.07	-56.77 **	-1.97	-12.33
20	BHU-N6 × KL-153237	Hb	-3.61	-3.47	14.29	-8.01	-4.49	-8.01	-21.71**	50	32.23	15.32**	4.9	26.21**	1.66	11.73**	9.48**	29.68**
		Hc	-10.10**	-10.14**	-11.11	1.58	-4.34	1.58	-5.04	8	17.96	1.37	-0.62	-2.45	-4.17	2.56	-1.65	-3.25
		ID	-8.35*	-7.08*	1.31	9.55	-7.97	-5.459*	-11.99	-4.39	18.67 **	-4.94 *	19.21 *	11.96	13.31	-2.34	-19.05 **	-13.21*
21	CML-161 × KL-153237	Hb	-3.09	-2.97	14.29	16.62**	-14.00*	16.62**	-13.64*	14	17.18	22.46**	14.80**	23.94**	4.97**	13.26**	3.8	28.46**
		Hc	-9.62**	-9.68**	-11.11	9.71	-10.77	9.71	-6.65	14	22.14	4.57	8.05	-2.86	-1.04	5.13*	-6.18**	-2.4
		ID	-4.61	-1.99	4.47	-47.35 **	11.68 *	11.54	-4.91	17.35 **	17.94 **	-12.05	6.19	-5.04	-10.27	-10.11 *	9.12	-3.13

Table 4. Hybrid combinations showing higher mean value and lesser inbreeding depression in F_2 generation for grain yield per plant

S. No.	Hybrid combination	Mean performance in F_2 (g)	Inbreeding depression
1	VL-1016556 × BHU-N5	77.39	3.15*
2	VL-1016556 × CML-171	77.16	10.00**
3	VL-1016556 × CML-161	75.73	12.45**
4	CML-171 × BHU-N5	75.59	8.03**
5	VL-1016556 × BHU QPM-3	75.47	5.7*

tasseling, days to 50% silking, plant height and positive estimates for all other traits could be regarded as undesirable (Ram *et al.,* 2017). The estimated significant values of inbreeding depression for stem girth, leaf area index, chlorophyll content, canopy temperature deficit, cob height, cob length, cob girth, cob weight, the number of kernels per cob, the number of kernels per row, 100 seed weight and grain yield per plant ranged between -55.27% to 59.95%, -5.46% to -55.59%, -17.97% to 18.31%, -21.42% to 41.97%, -10.99% to 18.97%, -4.92% to -4.94%, -5.35% to 19.21%, -57.42% to -30.33%, -65.26% to -33.33%, -59.67% to 46.12%, -13.6% to 16.33% and 4.4% to 23.18% respectively.

San-Vincente and Hallauer (1993) previously documented inbreeding depression for yield contributing variables such as cob girth, the number of kernel rows per cob, and the number of kernels per row. Eagles and Hardacre (1993), Sohu and Kapoor (1993), Pacheco *et al.* (2002), Maldonado and Miranda-Filho (2002), and Simon *et al.* (2004) have reported high inbreeding depression for yield.

Hybrids are regarded to have a high level of biological fitness in a particular setting. This fitness is often compromised by inbreeding. Crosses that can withstand this stress are useful for developing a heterotic group. An inbreeding-tolerant base population might be utilised to create inbred lines (extract inbred lines) and make effective and economical single-cross hybrids. In the current study, five crosses, namely VL-1016556 × BHU-N5, VL-1016556 × CML-171, VL-1016556 × CML-161, CML-171 × BHU-N5, and VL-1016556 × BHU QPM-3, demonstrated significant economic heterosis (Hc), higher mean performance in the F_2 generation, and lower inbreeding depression values (considering less than 15%) and can as a result, be used further in the maize improvement programs **(Table 4)**.

However, the cross combinations showing low heterosis coupled with high inbreeding depression could be utilized to develop superior inbred lines which could be further utilized to exploit in hybridization programmes.

Considering the increased amplitude of heterosis, high mean performance, and lower inbreeding depression (less than 15%), five crossings were recognised as the best hybrids: VL-1016556 × BHU-N5, VL-1016556 × CML-171, VL-1016556 × CML-161, CML-171 × BHU-N5, and VL-1016556 × BHU QPM-3. In the F_2 generation, these cross combinations show strong heterosis with low inbreeding depressions suggesting the role of non-additive gene action and that heterosis breeding could be a viable approach to exploit the same

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