Elucidating the Heterosis for Yield and Quality Parameters in Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author NRG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author AD managed the analyses of the study. Authors SK, KC and TK managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

A set of thirty-nine hybrids of maize were developed to estimate heterosis. These hybrids were evaluated along with their respective parents and three standard checks namely, Pratap Hybrid Maize-3(PHM-3), PMH-3 and PM-9, were evaluated during *Kharif* 2017 for 14 characters at instructional farm Rajasthan College of Agriculture, Udaipur, Rajasthan. The mean sum of squares for hybrids, inbred lines and testers, was significant for all the traits except for days to 75 per cent brown husk of inbred lines. A perusal of estimates of economic heterosis for grain yield per plant revealed that five hybrids $L_7 \times T_2$ (14.47%), $L_3 \times T_3$ (11.19%), $L_6 \times T_2$ (10.44%), $L_6 \times T_1$ (9.93%), and $L_9 \times T_3$ (9.88%) depicted positive significant economic heterosis for grain yield per plant over the best check Pratap Hybrid Maize-3. Hybrid ($L_6 \times T_2$) also exhibited significant positive economic heterosis for oil content. These crosses will be considered for finding transgressive segregants in segregating generation to develop a maize variety with quality improvement.

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1. INTRODUCTION

In India, maize is third most important cereal crop after rice and wheat that provides food, feed, fodder and serves as a source of raw material for developing thousands of industrial products viz., starch, protein oil, alcoholic beverages, food sweeteners, pharma, cosmetics, and bio-fuel., etc. The commercial maize varieties usually contain 9-12% protein which is enough to meet the physiological need of the human body [1].

The concept of heterosis is practically exploited to develop hybrid varieties. Heterosis may be defined as the increase in size, vigor, fertility, and overall productivity of a hybrid plant, over the mid parent value (average performance of the two parents) and over the performance of best parent. It is occurred when two inbred lines of out bred species are crossed, as much as when crosses are made between pure lines [2]. The magnitude of heterosis provides information an extent of genetic diversity of parents used in developing superior F_1 hybrids. The high magnitude of heterosis in an early generation will help in selecting inbred lines with high yield potential so that these can be focused in subsequent generations The increased vigour of F_1 over the mid parent, better parent and best commercial variety is designated as relative heterosis, heterobeltiosis and standard heterosis, respectively. All these are important to analyze and identify superior hybrids. Mid-parent heterosis and better-parent heterosis are important parameters as they provide information about the presence of dominance and over dominance type of gene action in the expression of various characters. The magnitude of heterosis depends on the relative performance of parental inbred lines and the corresponding hybrids crosses. The heterosis has been extensively used in maize by several workers like [3,4 and 5] and continue to be applied in quantitative genetic studies. The present investigation was therefore undertaken to determine the extent of relative heterosis, heterobeltiosis and standard heterosis in maize to identify maize hybrids that express high heterosis.

2. MATERIALS AND METHODS

The experimental material generated using thirteen inbred lines crossed with three testers (Table 1) to generate 39 experimental hybrids during Rabi 2016-17. These 39 F_1 experimental hybrids along with 16 parents and three checks *viz.*, Pratap Hybrid Maize-3(PHM-3), PMH-3 and PM-9 were evaluated in a randomized complete block design with three replications with a single row plot of four-meter length, maintaining crop geometry of 60 x 25 cm. The experimental material was planted at Instructional farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, India during Kharif, 2017. The observations were recorded on randomly selected five competitive plants of each entry in each replication for grain yield, starch, oil and protein content. The starch content was estimated by using anthrone reagent method [6], while oil was estimated by using Soxhlet method developed by [7] and protein content was estimated by using [8] method and the value of nitrogen content was multiplied by a factor of 6.25 and averaged and their mean values were subjected to various statistical analyses. Computation of relative heterosis, heterobeltiosis and economic heterosis for all characters was carried out as per procedure suggested by [9,10 and 11] respectively.

3. RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences among the genotypes, parental inbred lines and experimental hybrids for all the traits, whereas parental inbred lines vs experimental hybrids also exhibited highly significant differences for all the traits except for oil content (Table 2).

The estimates of relative heterosis for grain yield per plant revealed that out of 39 hybrids, thirty hybrids depicted positive significant relative heterosis for this trait with the magnitude ranging from 28.33 (L_{10} x T_3) to 91.72 per cent (L_7 x T_2) (Table 3). Twenty seven hybrids exhibited positive significant heterobeltiosis ranging from 26.46 (L_{10} x T) to 82.22 per cent (L_7 x T_2). Five hybrids depicted positive significant economic heterosis for grain yield varied from 9.88 (L_9 x T_3) to 14.67 (L_7 x T_2) over the best check Pratap Hybrid Maize-3. The maximum positive significant economic heterosis was depicted by hybrid $L_7 \times T_2$ followed by hybrid $L_2 \times T_3$ and $L_3 \times T_3$ for grain yield per plant. These findings are in accordance with [12,13,14,15,3,16,17,5,18 and 19].

Table 1. List of Inbred lines, tester and checks used in in present study

S.No.	Inbred Lines (Symbol/Code)	Stage of level of inbred line	Origin
Details of Parents			
1.	L1 (EI-2817)	S_5	MPUAT , Udaipur
2.	L2 (EI-2823)	S_5	MPUAT , Udaipur
3.	L3 (EI-2826)	S_5	MPUAT , Udaipur
4.	L4 (EI-2835)	S_5	MPUAT , Udaipur
5.	L5 (EI-2838)	S_5	MPUAT , Udaipur
6.	L6 (EI-2840)	S_5	MPUAT , Udaipur
7.	L7 (EI-2843)	S_5	MPUAT , Udaipur
8.	L8 (EI-2845)	S_5	MPUAT , Udaipur
9.	L9 (EI-2851)	S_5	MPUAT , Udaipur
10.	L10 (EI-2857)	S_5	MPUAT , Udaipur
11.	L11 (EI-2858)	S_5	MPUAT , Udaipur
12.	L12 (EI-2862)	S_5	MPUAT , Udaipur
13.	L13 (EI-2865)	S_5	MPUAT , Udaipur
14.	T1 (EI-1104-1)	S_6	MPUAT , Udaipur
15.	T2 (EI-1175-3)	S_6	MPUAT , Udaipur
16.	T3 (EI-1110-2)	S_6	MPUAT , Udaipur
Details of Checks			
1.	C1	Pratap Hybrid Maize-3(PHM-3)	MPUAT , Udaipur
2.	C2	PMH-3	PAU, Ludhiana
3.	C3	PM-9	MPUAT , Udaipur

Where, PAU- Punjab Agricultural University,
MPUAT-Maharana Pratap University of Agriculture and Technology

Twelve experimental hybrids exhibited positive significant relative heterosis for oil content with the magnitude ranged from 6.50 (L_9 x T_3) to 29.79 percent (L_4 x T_3). Seven hybrids showed significant positive heterobeltiosis for oil content and its ranged from 4.05 (L_6 x T_1) to 16.53 percent (L_4 x T_3). Six hybrids exhibited positive significant economic heterosis with magnitude ranged from 3.98 (L_6 x T_1) to 12.72 percent (L_4 x T_3) over the best check Pratap Hybrid Maize-3. The maximum positive significant economic heterosis for oil content L_2 x T_3 followed by hybrid L_7x T_1 and hybrid L_4 x T_2 [17,18 and 19] also reported similar findings.

For starch content, six hybrids exhibited significant relative heterosis in positive direction with the range varied from 4.70 (L_3 x T_3) to 8.33 percent (L_7 x T_1). In case of heterobeltiosis, four

hybrids exhibited positive significant heterobeltiosis with magnitude ranged from 4.76 (L_6 x T_1) to 7.93 percent (L_7 x T_1). The result is in general agreement with the findings of [20,3 and 16]

Out of 39 hybrids, twenty hybrids exhibited positive significant relative heterosis for protein content with the magnitude range from 4.95 (L_{13} x T_2, L_5 x T_3) to 22.40 per cent (L_{12} x T_3) (Table 4) .Fourteen hybrids exhibited positive significant heterobeltiosis for this trait with the magnitude ranged from 6.49 (L_8 x T_1) to 21.17 per cent (L_{12} x T_2). Similar results are obtained in the studies of [21,22,23,24,25,20,3 and 16]. From the above result, L_7 x T_2 for grain yield per plant and hybrid L_4 xT_3 oil content exhibited significant high relative heterosis, heterobeltiosis and standard heterosis.

Table 2. Analysis of variance for grain yield and quality traits in maize

Source of variation	Df	Mean Squares			
		Grain yield/ plant	Oil content	Starch content	Protein content
Replications	2	122.30	0.04	5.45	0.05
Genotypes	57	2386.08	1.52	10.46	1.57**
Parents	15	263.14**	1.31**	7.12**	1.36**
Hybrids	38	1916.14**	1.69**	12.68**	1.71**
Parent v/s Hybrids	1	54347.79**	0.35**	0.02	0.85**
Error	114	131.88	0.01	3.51	0.06

*, ** Significant at 5 % and 1 % level of significance, respectively

Table 3. Extent of heterosis for grain yield per plant and oil content

SN.	Crosses	Grain yield per plant			Oil content		
		RH	HB	EH	RH	HB	EH
1.	L1 x T1	-23.07*	-	-	14.05**	-	-
2.	L2 x T1	-16.84	-	-	-1.14	-	-
3.	L3 x T1	46.82**	41.90**	-	3.10	-	-
4.	L4 x T1	59.89**	39.96**	-	-9.36**	-	-
5.	L5 x T1	87.05**	64.60**	8.40	2.64	1.00	0.92
6.	L6 x T1	73.10**	66.93**	9.93**	10.08**	4.05*	3.98*
7.	L7 x T1	54.31**	43.47**	-	19.07**	9.25**	9.17**
8.	L8 x T1	66.43**	44.44**	-	8.23**	-	-
9.	L9 x T1	18.50	8.46	-	-35.73**	-	-
10.	L10 x T1	33.54**	26.46**	-	-5.67**	-	-
11.	L11 x T1	33.76**	31.37**	-	-32.20**	-	-
12.	L12 x T1	62.04**	52.84**	0.65	19.39**	-	-
13.	L13 x T1	15.17	2.51	-	-24.50**	-	-
14.	L1 x T2	75.67**	72.12**	8.13	29.94**	8.58**	3.48
15.	L2 x T2	4.83	2.28	-	-17.43**	-	-
16.	L3 x T2	36.88**	35.38**	-	-3.32	-	-
17.	L4 x T2	60.99**	43.85**	-	-15.68**	-	-
18.	L5 x T2	43.59**	28.99*	-	-26.57**	-	-
19.	L6 x T2	78.15**	75.81**	10.44**	16.62**	12.75**	7.46**
20.	L7 x T2	91.72**	82.22**	14.47**	-4.97**	-	-
21.	L8 x T2	36.99**	21.33	-	-0.96	-	-
22.	L9 x T2	45.35**	35.94**	-	-37.77**	-	-
23.	L10 x T2	-10.40	-	-	-0.33	-	-
24.	L11 x T2	60.20**	53.78**	5.02	10.04**	3.36	-
25.	L12 x T2	75.95**	69.73**	6.62	-11.66**	-	-
26.	L13 x T2	11.03	0.92	-	-22.95**	-	-
27.	L14 x T2	51.21**	50.25**	-	15.88**	-	-
28.	L2 x T3	74.83**	72.79**	5.62	-19.78**	-	-
29.	L3 x T3	81.52**	80.95**	11.19**	26.36**	8.67**	5.12**
30.	L4 x T3	65.00**	49.30**	-	29.79**	16.53**	12.72**
31.	L5 x T3	91.79**	74.50**	6.56	1.76	1.76	-
32.	L6 x T3	76.93**	76.78**	8.13	-29.58**	-	-
33.	L7 x T3	1.32	-	-	8.56**	1.10	-
34.	L8 x T3	34.92**	20.99	-	-5.19*	-	-
35.	L9 x T3	89.86**	79.95**	9.88**	6.50**	4.76*	4.76*
36.	L10 x T3	28.23**	17.27	-	-2.66	-	-
37.	L11 x T3	68.89**	59.96**	9.23	-29.89**	-	-
38.	L12 x T3	59.67**	56.16**	-	-20.07**	-	-
39.	L13 x T3	-1.72	-	-	-2.24	-	-

*,** Significant at 5 % and 1 % level of significance, respectively

Table 4. Extent of heterosis for starch content and protein content

SN.	Crosses	Starch content			Protein content		
		RH	HB	EH	RH	HB	EH
1.	L1 x T1	0.89	0.86	-	6.39**	2.23	-
2.	L2 x T1	-0.12	-	-	1.50	-	-
3.	L3 x T1	-1.31	-	-	5.43*	1.00	-
4.	L4 x T1	-2.49	-	-	-10.89**	-	-
5.	L5 x T1	1.87	1.82	-	-11.43**	-	-
6.	L6 x T1	6.17**	4.76*	-	16.78**	16.66**	-
7.	L7 x T1	8.33**	7.93**	1.65	-9.49**	-	-
8.	L8 x T1	-3.23	-	-	1.35	1.01	-
9.	L9 x T1	-5.19*	-	-	8.64**	6.49**	-
10.	L10 x T1	-5.63**	-	-	0.89	-	-

SN.	Crosses	Starch content			Protein content		
		RH	HB	EH	RH	HB	EH
11.	L11 x T1	-8.67**	-	-	5.47**	-	-
12.	L12 x T1	-2.79	-	-	12.71**	10.78**	-
13.	L13 x T1	0.10	0.01	-	6.08**	1.70	-
14.	L1 x T2	3.87	3.45	-	2.78	-	-
15.	L2 x T2	4.18*	3.20	-	1.91	-	-
16.	L3 x T2	-2.04	-	-	13.12**	6.16**	-
17.	L4 x T2	0.21	-	-	-5.19*	-	-
18.	L5 x T2	0.00	-	-	16.31**	12.54**	-
19.	L6 x T2	7.58**	5.70*	0.42	19.32**	16.90**	-
20.	L7 x T2	-0.02	-	-	-9.08**	-	-
21.	L8 x T2	-2.00	-	-	-1.92	-	-
22.	L9 x T2	-4.66*	-	-	-14.14**	-	-
23.	L10 x T2	-3.27	-	-	13.29**	13.07**	-
24.	L11 x T2	1.53	0.97	-	3.76	-	-
25.	L12 x T2	3.34	2.22	-	21.70**	21.17**	-
26.	L13 x T2	2.25	1.71	-	4.95*	-	-
27.	L1 x T3	0.87	0.50	-	-5.84**	-	-
28.	L2 x T3	0.25	0.08	-	-5.03*	-	-
29.	L3 x T3	4.70*	4.08	-	11.77**	7.59**	-
30.	L4 x T3	-3.90	-	-	7.02**	0.45	-
31.	L5 x T3	1.71	1.31	-	4.95*	4.25	-
32.	L6 x T3	6.50**	5.44*	-	20.32**	19.60**	0.67
33.	L7 x T3	1.46	1.43	-	-18.75**	-	-
34.	L8 x T3	-0.75	-	-	3.33	2.47	-
35.	L9 x T3	2.95	2.46	-	12.03**	10.36**	-
36.	L10 x T3	-1.14	-	-	15.12**	11.91**	-
37.	L11 x T3	1.79	0.45	-	11.87**	4.50*	1.31
38.	L12 x T3	-0.18	-	-	22.40**	19.72**	0.77
39.	L13 x T3	-0.76	-	-	-1.78	-	-

*,** Significant at 5 % and 1 % level of significance, respectively

4. CONCLUSION

This article may be useful for scholars and researchers who want to work in maize and develop high yielding varieties. The Crosses integration of population improvement with inbreed line development may be provided new superior lines for single cross hybrids breeding and other option for hybrid development. The superior hybrids for various traits like grain yield, oil content, and protein content can be exploited further in breeding programs for improvement various quantitative and qualitative characters.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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