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Heterosis Studies for Yield and Yield Attributing Characters in Maize (*Zea mays* L.)

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ABSTRACT: The study of heterosis among maize germplasm is very essential to maximize the effectiveness of cultivars selection. Diallel analysis using 6inbred lines was carried out with a view to estimating heterosis in maize. Significant heterosis for grain yield traits was observed in most of the hybrids. Higher magnitude of heterosis against all yield and quality traits were not expressed in a single hybrid combination which varied from the cross to cross due to the diverse genetic background of their parents. An examination of mean values for different characters revealed that CML-482 and IT-INA-011-2 were the high yielding parents and were also good for various yield attributing traits. In general, the parents showing superior performance give superior hybrids and a higher magnitude of heterosis in hybrid combination. The considerable magnitude of heterosis and heterobeltiosis was observed for all the characters. The higher significant and positive standard heterosis for kernel yield per plant and some of its yield contributing traits were recorded in the cross, CML-482 × IT-INA-011-2. The *per se* performance of hybrids was, in general, related to the heterotic response in the majority of characters. This indicated that the selection of crosses on the basis of *per se* performance or heterotic response would be equally important.

Keywords: Heterosis, Heterobeltiosis, Diallel, Maize, yield, yield components.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important economic cereal crops of the world. It was domesticated over the past ten thousand years from the grass teosinte in Central America. Maize is also considered as a staple food in many developing countries. Maize grain is gaining popularity and huge demand in our country due to nutritionally important and can be grown in all seasons. Generally, maize use as dual purposes both grain and forage. It has variable uses as food for humans, live stocks and poultry. There is no other cereal on the earth, which has such enormous potential as maize, so it called as 'Queen of Cereals'.

In this era of population increase and starvation and malnutrition in human maize is efficient crop to solve both this problems. For that, development of Hybrids with good nutritive value such as amylose and protein and with high yielding performance is necessary.

With the introduction of hybrids in maize, the inclinations of acreage and production have been increasing due to its high yield potential. In India, it is grown round the year in an area of 9.86 million hectares with a production of 26.26 million tonnes and 2664 kg/ha productivity, whereas, in Gujarat, it covers an area of 4.5 lakh hectares with a total production of 0.80 million tonnes with 1780 kg/ha productivity (Anonymous, 2017). Generally, maize is grown in all the districts of Gujrat but Panchmahal, Dahod, Vadodara, Mahisagar and Kheda are major maize producing districts. Among several methods, the diallel technique elaborated by Griffing (1956) is a useful methodology for evaluating parents and crosses for combing ability and also for the understanding nature of gene action. The diallel analysis is widely used in both self and cross-pollinated species to understand the nature of gene action involved in the expression of quantitative traits. It provides a sensitive approach to large-scale studies of quantitative characters. Thus, the diallel mating design provides useful genetic information to breeders, to help them to devise appropriate breeding and selection strategies.

MATERIALS AND METHODS

The experimental plant material consisted of six inbred lines *viz.*, GYL-2, CML-482, CM-500, IT-INA-011-2, GYL-9 and GYL-5. They were crossed in half diallel fashion during *rabi* 2019 to obtain 15 F_1s. All these hybrids along with their parents and standard check GAYMH-3 were observed in a randomized block design with three replications at College farm, College of Agriculture, Navsari Agricultural University, Bharuch. Each entry was planted in a single row consisting of 10 plants in each row with a spacing of 60 × 20 cm. The standard agronomical practices were followed to raise the experimental crop. Biometrical observations were recorded for 17 yield and yield attributing traits *viz.*, Days to 50 % tasselling, Days to 50% silking, plant height (cm), days to maturity, cob weight (gm), cob length (cm), cob diameter (cm), kernel rows per cob, cob per plant, kernels per row, kernels per cob, shelling percentage, moisture percentage, 100 kernels weight (gm), kernels yield per plant (g), protein content, and amylose content. comprising 15 hybrids and 6 parents and 1 standard check. The mean values were utilized for calculating the heterosis as per cent increase or decrease of F_1s over better parent (heterobeltiosis) and over the standard check (standard heterosis).

RESULT AND DISCUSSION

The analysis of variance (Table 1) for experimental design revealed that the mean square due to genotypes, parents, hybrids and parents Vs hybrids were significant for all the traits indicating a sufficient amount of genetic variability present in the material used.

The heterobeltiosis ranged from -10.45 % (CM-500 × GYL-9) to -1.56% (GYL-2 × GYL-9) for days to maturity. A total of 13 crosses exhibited significant and desirable (negative) heterobeltiosis. The highest desirable (negative) heterobeltiosis was recorded in the cross -10.45 % (CM-500 × GYL-9) followed by -6.55 % (GYL-2 × IT-INA-011-2). The standard heterosis ranged from -5.97 % (GYL-9 × GYL-5) to 6.55 % (CML-482 × CM-500) days to maturity. Seven crosses exhibited significant and desirable standard heterosis. The highest desirable (negative) standard heterosis was recorded in the cross -5.97 % (GYL-2 × GYL-9) followed by -4.10 % (GYL2 × IT-INA-011-2) and -4.10% (CM-500 × GYL-9). The results were concordance with Saidaiah *et al*. (2008); Avinashe *et al.* (2013); Kumar *et al.* (2014); Kulselan *et al.* (2017); Pole *et al*. (2018); Kumar *et al.* (2019).

For the plant height, the heterobeltiosis ranged from -5.54 % (GYL-2 × CML-482) to 30.98% (CML-482 × CM-500) for plant height. A total of 12 crosses exhibited significant and desirable (positive) heterobeltiosis. The highest desirable (positive) heterobeltiosis was recorded in the cross 30.98 % (CM-500 × GYL-5) followed by 17.64 % (CM-500 × IT-INA-011-2) and 15.41% (GYL-2 × IT-INA-011-2). The standard heterosis ranged from 3.73 % (GYL-2 × GYL-5) to 34.12 % (CML-482 × CM-500) for plant height. All crosses exhibited significant and desirable standard heterosis. The highest desirable (positive) standard heterosis was recorded in the cross 34.12 % (CML-482 × CM-500) followed by 29.23% (CML-482 × GYL-9) and 22.37% (CML-482 × IT-INA-011-2). These results were in concordance Saidaiah *et al*. (2008); Avinashe *et al.* (2013); Singh *et al.* (2012); Kumar *et al.* (2013); and Patel *et al.* (2019).

Out of 15 hybrids, three hybrids registered significant and desirable (positive) heterobeltiosis, whereas 1 hybrid registered significant and desirable (positive) standard heterosis for cobs per plant. The value for heterobeltiosis was ranged from -38.71% (CML-482 × CM-500) to 36.36% (CM-500 × GYL-9). The standard heterosis spectrum of varied from -41.94% (IT-INA-011-2 × GYL-5) to 6.13% (GYL-2 × CML-482) in hybrids. The highest significant and desirable (positive) heterobeltiosis was recorded in the cross at 36.36% (CM-500× GYL-9) followed by 31.82% (CM-500 × GYL-5) and 22.73% (GYL-2 × CM-500). The highest significant and desirable (positive) standard heterosis was recorded at 6.13% in the cross (GYL-2× CML-482). These results were similar to Singh *et al.* (2012); Bekele and Rao (2013); Pole *et al*. (2018) and Patel *et al.* (2019).

Out of 15 hybrids, thirteen hybrids registered significant and desirable (positive) heterobeltiosis, whereas 11 hybrids registered significant and desirable (positive) standard heterosis for kernels per cob. The spectrum of variation for heterobeltiosis ranged from -18.28% (GYL-9 × GYL-5) to 50.38% (GYL-2 × CM-500). The standard heterosis spectrum of variation ranged from -18.71% (GYL-9 × GYL-5) to 30.47% (CML-482 × GYL-5) in hybrids. The highest significant and desirable (positive) heterobeltiosis was recorded in the cross 50.38% (GYL-2× CM-500) followed by 44.08% (IT-INA-011-2 × GYL-9) and 41.19% (CM-500 × GYL-9). The highest significant and desirable (positive) standard heterosis was recorded 30.47% in the cross (CML-482 × GYL-5) followed by 22.22% (GYL-2 × CM-500) and 16.41% in (IT-INA-011-2 × GYL-9). These results were similar to Singh *et al.* (2019); Pole *et al*. (2018); Patel *et al*. (2019).

Out of 15 hybrids, four hybrids registered significant and desirable (positive) heterobeltiosis, whereas only one hybrid registered significant and desirable (positive) standard heterosis for 100 kernels weight. The heterobeltiosis was ranged from -12.64% (CM-500 × GYL-9) to 15.68% (GYL-2 × IT-INA-011-2). The standard heterosis value for the range were from -11.59% (GYL-9 × GYL-5) to 12.77% (CML-482 × CM-500) in hybrids. The highest significant and desirable (positive) heterobeltiosis was recorded in the cross GYL-2 × IT-INA-011-2 (15.68%) followed by GYL-2 × GYL-9 (14.11%) and (GYL-2 ×GYL-5) (12.69%). The highest significant and desirable (positive) standard heterosis was recorded 12.77% in the cross (CML-482× CM-500). These results were in confirmity with Bajaj *et al.* (2007); Saidaiah *et al*. (2008); Shete *et al.* (2011); Raghu *et al*. (2012); Kumar *et al.* (2013); Singh *et al.* (2012); Rajesh *et al.* (2014) and Pole *et al*. (2018); Sandesh *et al.* (2018); Kumar *et al*. (2019).

Out of 15 hybrids, 9 hybrids registered significant and desirable (positive) heterobeltiosis, whereas only 1 hybrid registered significant and desirable (positive) standard heterosis for kernels yield per plant.The heterobeltiosis was ranged from -26.04 (GYL-2 × CML-482) to 19.36% (GYL-2 × GYL-9). The highest significant and desirable (positive) heterobeltiosis was recorded in the cross 19.36% (GYL-2 × GYL-9) followed by 18.41% (CM-500 × GYL-9) and 15.39 (CML-482 × IT-INA-011-2). The standard heterosis was ranged from -48.93% (GYL-2 × GYL-5) to 2.98% (CML-482 × IT-INA-011-2). The highest significant and desirable (positive) standard heterosis was recorded in the cross 2.98% (CML-482 × IT-INA-011-2). These results are in concordance with Saidaiah *et al.* (2008); Premlatha and Kalamani (2010); Shete *et al.* (2011); Raghu *et al.* (2012); Kumar *et al.* (2013); Singh *et al.* (2012); Rajesh *et al.* (2014); Pole *et al.* (2018); Sandesh *et al.* (2018); Sharma *et al.* (2021); Kumar *et al.* (2019).

Table 1: Analysis of variance (mean squares) for experimental design for various characters in maize.

Sr. No	Source of Variations	DF	Days to 50 % tasseling	Days to 50 % Silking	Days to maturity	Plant height	Cob diameter	Cob length	Cob weight	Kernel rows per cob	Kernels Per row
1.	Replicates	2	7.73	4.33	0.59	225.23	0.02	1.0	135.11	0.86	14.69
2.	Genotypes	20	19.18**	18.84**	24.36**	1206.91**	3.71**	9.52**	1409.98**	6.40**	23.87**
3.	Parents	5	18.35**	18.62**	48.19**	1333.75**	4.12**	7.06**	1738.93**	4.048**	15.78**
4.	Hybrids	14	25.76**	23.62**	26.99**	1046.85**	2.15**	9.17**	1484.23**	6.01**	22.455**
5.	Parents vs Hybrids	1	53.74**	49.17**	46.41**	7444.85**	25.75**	36.40**	2976.21**	39.02**	128.30**
6.	Error	40	1.80	1.48	1.74	225.84	0.21	0.59	119.48	0.56	3.21

Contin. Table 1...

Sr. No.	Source of Variations	DF	Kernels per cob	Cobs per plant	Shelling percentage	Moisture percentage	100 kernels weight	Kernel yield per plant	Protein content	Amylose content
1.	Replicates	2	4487.34	0.14	22.9	0.06	4.34	81.8	0.08	0.08
2.	Genotypes	20	17674.62**	0.32**	36.61**	6.10**	32.12**	10060.89**	2.08**	293.67**
3.	Parents	5	11613.83**	0.33**	63.56**	3.80**	51.31**	13284.38**	0.42*	417.99**
4.	Parents vs Hybrids	1	14681.79**	0.33**	68.61**	7.58**	21.30**	8889.87**	2.66**	341.25**
5.	Hybrids	14	140701.34**	0.18*	107.30**	2.40*	109.21**	14574.59**	3.54**	149.46**
6.	Error	40	1647.30	0.03	5.57	0.56	3	436.31	0.12	0.19

Table 2: Estimation of heterobeltiosis and standard heterosis for different character in maize.

Sr. No.	Crosses	Days to 50 % tasseling		Days to 50 % Silking		Plant height		Days to maturity		Cob diameter		Cob length	
		H%	SH%	H%	SH%	H%	SH%	H%	SH%	H%	SH%	H%	SH%
1	GYL-2 × CML-482	-3.75	6.21**	-9.04**	-1.83	-5.54**	16.02**	-1.88	-2.61*	0.52	5.96*	0.62	5.49
2	GYL-2 × CM-500	-11.11**	4.83*	-6.56**	4.27*	9.34**	4.60**	-5.57**	1.12	14.94*	9.30*	20.87**	15.64*
3	GYL-2 × IT-INA-011-2	-7.14**	-1.38	-8.72**	-4.27*	15.41**	10.40**	-6.55**	-4.10**	5.80	-7.97*	5.21	0.65
4	GYL-2 × GYL-9	-8.33**	-1.38	0.00	1.22	8.88**	9.81**	-1.56	-5.97**	14.72*	1.47	6.04	1.45
5	GYL-2 × GYL-5	-5.92**	-1.38	-3.01	-1.83	8.43**	3.73**	-4.03**	-2.24	10.95*	0.78	-0.52	-3.20
6	CML-482 × CM-500	-3.51	13.79**	-6.01**	4.88*	9.20**	34.12**	-4.18**	2.61**	0.39	5.82*	3.33	8.33*
7	CML-482 × IT-INA-011-2	-3.13	6.90**	-6.78**	0.61	-0.36	22.37**	-4.36**	-1.87	-1.35	3.99	-6.80*	-2.29
8	CML-482 × GYL-9	-6.25**	3.45	-0.56	7.32**	5.22**	29.23**	-2.63*	-3.36**	-6.65*	-1.60	-8.43*	-4.00
9	CML-482 × GYL-5	-6.88**	2.76	-4.52*	3.05	-4.89**	16.82**	-3.66**	-1.87	0.30	5.73*	-5.20	-0.62
10	CM-500 × IT-INA-011-2	-6.43**	10.34**	-3.28	7.93**	17.64**	10.36**	-4.53**	2.24	0.10	-4.81	9.89*	1.05
11	CM-500 × GYL-9	-6.43**	10.34**	-7.65**	3.05	3.35**	4.23**	-10.45**	-4.10**	4.92	-0.23	23.01**	13.13*
12	CM-500 × GYL-5	-9.36**	6.90**	-8.74**	1.83	30.98**	16.10**	-6.27**	0.37	10.70*	5.27*	15.02*	11.93*
13	IT-INA-011-2 × GYL-9	-2.56	4.83*	-6.40**	-1.83	5.07**	5.96**	-5.82**	-3.36**	15.39*	2.06	27.91**	10.98*
14	IT-INA-011-2 × GYL-5	-7.79**	-2.07	-8.72**	-4.27*	15.00**	7.88**	-5.09**	-2.61*	13.82*	3.39	-5.38	-7.93*
15	GYL-9 × GYL-5	-7.05**	0.00	-7.83**	-6.71**	3.03**	3.91**	-3.30**	-1.49	-1.97	-10.95*	-16.89**	-19.13**
16	S.E. (d) ±	1.094	1.094	0.994	0.994	12.270	12.270	1.076	1.076	0.373	0.373	0.628	0.628

Conti. Table 2

Sr. No.	Crosses	Cob weight		Kernel rows Per cob		Kernels Per row		Kernels percob		Cobs per plant		Shelling percentage	
		H%	SH%	H%	SH%	H%	SH%	H%	SH%	H%	SH%	H%	SH%
1.	GYL-2 × CML-482	-15.79**	-17.20**	3.54	0.00	1.95	13.52**	7.03**	13.50**	-16.13*	6.13*	-1.83	0.94
2.	GYL-2 × CM-500	4.57**	-19.70**	28.00**	9.40*	17.35**	11.66**	50.38**	22.22**	22.73*	-12.90	6.32**	-4.72**
3.	GYL-2 × IT-INA-011-2	-11.41**	-17.03**	2.00	-12.82*	16.59**	10.22**	18.81**	-4.01**	9.26	-4.84	-1.46	-4.25**
4.	GYL-2 × GYL-9	-10.96**	-14.52**	17.35*	-1.71	18.98**	11.25**	39.52**	9.25**	10.00	-29.03*	2.44	-0.94
5.	GYL-2 × GYL-5	2.39**	-21.37**	1.27	2.14	1.46	0.52	2.99**	2.45**	5.00	-32.26*	-0.46	2.36
6.	CML-482 × CM-500	-1.53**	-3.17**	3.54	0.00	0.09	11.46**	4.98**	11.33**	-38.71*	-38.71*	-3.67	-0.94
7.	CML-482 × IT-INA-011-2	2.38**	0.67	4.42	0.85	-11.03**	-0.93	-5.91**	-0.21	3.23	3.23	-3.21	-0.47
8.	CML-482 × GYL-9	5.09**	3.34**	9.73*	5.98	-2.87	8.15	8.08**	14.62**	-9.68	-9.68	-5.50**	-2.83
9.	CML-482 × GYL-5	-11.54**	-13.02**	17.80*	18.80*	-1.30	9.91**	23.03**	30.47**	-29.03*	-29.03*	7.34**	10.38**
10.	CM-500 × IT-INA-011-2	13.55**	6.34**	12.00*	-4.27	5.64	0.52	18.18**	-3.95**	-25.93*	-35.48*	0.00	-2.83
11.	CM-500 × GYL-9	-10.26**	-13.86**	23.00**	5.13	14.10**	8.57	41.19**	14.75**	36.36*	-3.23	1.46	-1.89
12.	CM-500 × GYL-5	38.72**	1.67**	-10.17*	-9.40*	19.58**	18.47**	7.63**	7.07**	31.82*	-6.45	1.38	4.25**
13.	IT-INA-011-2 × GYL-9	5.91**	1.67**	15.00*	-1.71	25.66**	18.78**	44.08**	16.41**	11.11	-3.23	2.43	-0.47
14.	IT-INA-011-2 × GYL-5	12.83**	5.68**	5.08	5.98	-1.46	-2.37	4.28**	3.74**	-33.33*	-41.94*	0.46	3.30
15.	GYL-9 × GYL-5	-4.17**	-8.01**	-11.86*	-11.11*	-7.50	-8.36	-18.28**	-18.71**	-10.00	-41.94*	-2.29	0.47
16.	S.E. (d) ±	8.925	8.925	0.613	0.613	1.462	1.462	33.139	33.139	0.151	0.151	1.927	1.927

Conti. Table 2

Sr. No.	Crosses	Moisture percentage		100 kernels weight		Kernel yield per plant		Protein content		Amylose content	
		H%	SH%	H%	SH%	H%	SH%	H%	SH%	H%	SH%
1.	GYL-2 × CML-482	-14.05*	-7.13	-4.89	-4.89	-26.04**	-34.00**	-10.75*	-21.94*	-5.92*	9.96*
2.	GYL-2 × CM-500	-2.11	-4.14	1.92	5.89	11.28**	-33.27**	-2.61	-15.10*	-25.83**	-31.73**
3.	GYL-2 × IT-INA-011-2	5.47	15.17*	15.68**	2.26	-15.20**	-39.97**	-11.88*	-23.93*	-66.89**	-57.17**
4.	GYL-2 × GYL-9	-0.89	1.84	14.11**	-6.25	19.36**	-39.30**	-8.25*	-20.80*	7.40*	-1.14
5.	GYL-2 × GYL-5	4.42	3.22	12.69**	-10.69**	2.12**	-48.93**	0.64	-9.97*	30.20**	19.84**
6.	CML-482 × CM-500	-4.47	3.22	8.54**	12.77**	-12.20**	-21.64**	4.23	-8.83*	-6.18*	9.66**
7.	CML-482 × IT-INA-011-2	-5.47	3.22	3.53	3.53	15.39**	2.98**	-13.03*	-23.93*	-3.41*	24.93**
8.	CML-482 × GYL-9	-24.47**	-18.39*	-7.07	-7.07	-21.94**	-30.34**	-12.38*	-23.36*	-8.28**	7.21*
9.	CML-482 × GYL-5	-10.64*	-3.45	-6.97	-6.97	-4.93**	-15.15**	0.64	-9.97*	-8.23**	7.27*
10.	CM-500 × IT-INA-011-2	-1.26	7.82	-4.97	-1.27	7.23**	-24.09**	-1.96	-14.53*	3.10*	33.36**
11.	CM-500 × GYL-9	-12.08*	-9.66*	-12.64**	-9.24**	18.41**	-28.99**	-14.71*	-25.64**	18.81**	-18.72**
12.	CM-500 × GYL-5	-15.58*	-16.55*	-7.41	-3.80	14.90**	-31.09**	7.96*	-3.42	63.57**	21.03**
13.	IT-INA-011-2 × GYL-9	5.89	15.63*	2.97	-8.97**	3.85**	-26.48**	-8.33*	-24.79*	-47.93**	-32.65**
14.	IT-INA-011-2 × GYL-5	-15.37*	-7.59	3.38	-8.61**	-15.26**	-40.01**	-21.97*	-30.20**	-41.68**	-24.57**
15.	GYL-9 × GYL-5	-18.12*	-15.86*	7.61	-11.59**	3.11**	-47.57**	-17.20*	-25.93**	3.70*	-23.27**
16.	S.E. (d) ±	0.609	0.609	1.414	1.414	17.055	17.055	0.286	0.286	0.358	0.358

Table 3: Best heterotic cross and its performance for kernel yield per plant and related parameters in maize.

Best crosses (P_1 x P_2)	Heterobeltiosis (%)	Standard heterosis (%)	Significant standard heterosis in other traits in the desired direction
CML-482 x IT-INA-011-2	15.39	2.98	Days to 50% tasseling, plant height, amylose content.

CONCLUSIONS

The high, significant and positive standard heterosis for Kernel yield per plant and some of its component traits were recorded in the crosse, CML-482 × IT-INA-011-2 Such crosses could be exploited for heterosis breeding programme in maize.

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Conflicts of Interest. None.

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