

Original Research Article

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Estimation of Heterosis through Diallel Crosses in Maize (*Zea mays* L.) for Grain Yield and Protein Content

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ABSTRACT

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The experiment comprised of twenty one maize hybrids generated from a 7 X 7 diallel cross, along with their parents and two standard check hybrids (Gujarat Maize 3 and HQPM 1). The analysis of variance revealed that all the characters studied exhibited highly significant genotypic differences. This indicated that experimental material under study had sufficient genetic diversity for different traits among females, males, hybrids and checks. As per the *per se* performance, for grain yield cross GWL 24 x CML 490 (196.23) having the highest value, while for protein content cross CML 264 x GWL 27 (12.75) were the best. The heterotic hybrid GWL 24 x CML 490 followed by cross CML 264 x GWL 22 registered significant heterosis in desired direction for grain yield. Whereas, the cross CML 264 x GWL 27 followed by CML 186 x GWL 28 registered significant and positive relative heterosis, heterobeltiosis and standard heterosis for protein content. The hybrids GWL 24 x CML 490, CML 264 x GWL 22 and CML 264 x GWL 27 showed high *per se* performance and higher heterotic effects which could be used to exploit commercially as single cross hybrid or synthetic/composite cultivars.

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crop after rice and wheat, contributing to agriculture economy in various ways finding its utility as a source of food for human being as well as a feed for animals and poultry across the world. It is a crop being commercially exploited extensively fetches the name “queen of cereals”. Maize is staple food of Asian people and is also utilized in starch, oil, food and feed industries. Maize grain contains about 10 per cent protein, 4 per cent oil, 70 per cent starch and 2.7 per cent crude fibre. In India, about 55 per cent of

maize produced is used for food purposes, about 14 per cent as livestock feed, 18 per cent as poultry feed, 12 per cent in wet milling industry (for starch and oil production) and 1 per cent as seed.

The recent trend is to go for single cross hybrid than for double crosses as the single cross hybrid show higher uniformity and heterosis than the double cross hybrid and three-way cross hybrid. Therefore a study was envisaged with an objective to identify superior maize hybrids exhibiting high heterosis for yield and yield contributing characters.

Materials and Methods

The experimental material comprised of seven white grained parental inbred lines and their 21 single cross hybrids developed by diallel mating scheme without reciprocals (Griffing method-II; Griffing, 1956) crosses and two checks, Gujarat Maize 3 and HQPM 1. The seed of 21 hybrids were produced during 2012 by hand pollination at Anand Agricultural University, Anand. The inbred lines were maintained by sibbing.

The crosses, parental inbred lines and checks were sown in Randomized Complete Block Design with three replications consisted of two rows of each treatment of 5 m length with inter and intra row spacing of 60 cm and 20 cm, respectively.

The cultivation practices followed as per the recommendations to raise normal crop for optimum yield potential expression. The observations were recorded on randomly selected five plants per treatment in each replication for the thirteen characters *viz.* days to 50 % tasselling, days to 50 % silking, plant height (cm), ear height (cm), days to 75 % dry husk, ear length (cob length, cm), ear girth (cm), number of grain rows per ear, number of grains per row, 100-kernel weight (g), grain yield (g), shelling percentage and protein content (%) as per standard methods laid by Indian Institute of Maize Research, ICAR, New Delhi.

Analysis of variance technique suggested by Panse and Sukhatme (1967) was followed to test the differences among the genotypes for all the characters. Heterotic effects were estimated in terms of three parameters relative heterosis (RH) suggested by Turner (1953); heterobeltiosis (HB) suggested by Fonseca and Patterson (1968) and standard heterosis (SH) suggested by Meredith and Bridge (1972).

Results and Discussion

The study involving seven parental lines with white kernels resulted that all the characters studied exhibited significant genotypic differences among the test entries. This indicated that experimental material under study had sufficient genetic diversity for all the traits among parents, hybrids and checks, showing existence of heterosis (Table 1). The mean performance of hybrids were found promising than parents for grain yield and most of other characters except days to 75% dry husk and kernel weight, which revealed that hybrids largely exceeded for the expression of the characters and possibility for higher heterotic effects (Table 2).

Relative heterosis, heterobeltiosis and standard heterosis 1 and standard heterosis 2 ranged from -32.52 to 72.61, -37.16 to 71.28, -42.51 to 37.28 and -39.92 to 43.47 per cent for grain yield, respectively (Table 3). The crosses, GWL 24x CML 490 and CML 264 x GWL 22 showed positive and highly significant result for relative heterosis, heterobeltiosis and standard heterosis over both the checks; whereas the cross GWL 24x GWL 28 gave the positive and significant relative heterosis, standard heterosis over both the checks for grain yield.

The cross GWL 24 x CML 490 also showed significant and positive heterosis for the characters ear length, ear girth, number of grain rows per ear, number of grains per row and shelling percentage; whereas the hybrid CML 264 x GWL 22 also showed significant heterosis in the desirable direction for the characters days to 50 % silking, ear height, number of grains per row and 100-kernel weight. These results were in conformity with the findings of the earlier workers Patel (2007), Pajic *et al.*, (2008), Amiruzzaman *et al.*, (2010), Avinash (2011) and Gosai *et al.*, (2014).

Table.1 Analysis of variance (Mean squares) for various characters

Source	d.f.	Mean squares												
		DT	DS	PH	EH	DDH	EL	EG	GRE	NGR	KW	GY	SP	PC
Replications	2	0.43	0.27	97.14	0.10	0.13	1.01	0.12	0.84	4.93	3.61	109.97	5.47	0.03
Genotypes	27	47.18**	45.54**	876.85**	174.49**	34.37**	10.087**	3.09**	3.56**	51.58**	42.55**	1670.67**	49.75**	4.14**
Parents	6	41.15**	9.30**	1029.08**	69.74**	12.74**	5.59**	2.16**	2.57*	15.52*	12.44**	588.10**	10.25*	1.18**
Hybrids	20	46.87**	50.19**	345.13**	145.21**	36.47**	10.45**	2.378*	2.38**	52.08**	46.98**	1999.09**	64.96**	5.21**
Between Checks	1	48.16**	32.66**	181.50*	486.00**	32.66**	3.08*	1.21	0.80	96.00**	88.16**	57.04	16.83	4.82**
Parents vs Hybrids	1	96.57**	64.00**	9956.57**	406.34**	12.00*	20.91**	18.78*	30.45**	157.14**	2.48	2493.38**	0.17	0.001
Checks vs Hybrids	1	58.28**	192.03**	1012.55**	664.78**	130.93**	18.94**	13.35*	14.10**	71.12**	131.36**	1679.21**	62.88**	3.85**
Error	58	2.68	2.48	38.63	10.96	2.36	0.66	0.47	0.86	5.41	2.15	124.83	4.22	0.06

*, ** Significant at 5% and 1% levels, respectively.

Table.2 Mean performance of the genotypes for various characters

Individuals	DT	DS	PH	EH	DDH	EL	EG	GRE	NGR	KW	GY	SP	PC
Parental mean	57.71	64.25	134.09	66.56	107.23	14.20	14.44	15.38	25.23	24.00	109.76	74.58	10.30
Hybrids mean	55.23	63.47	159.23	71.64	108.11	15.35	15.54	16.77	28.39	23.60	122.34	74.68	10.31
General mean	56.03	64.25	154.57	71.2	108.23	15.21	15.18	16.34	27.90	24.02	120.57	74.88	10.25

d.f. = degree of freedom DT = Days to 50 % tasselling DS = Days to 50 % silking PH = Plant height EH = Ear height DDH = Days to 75 % dry husk EL = Ear length EG = Ear girth GRE = Number of grain rows per ear NGR = Number of grains per row KW = 100-kernal weight GY = Grain yield SP = Shelling percentage PC = Protein content

Table.3 Estimates of relative heterosis (RH), heterobeltilosis (HB) and standard heterosis (SH) of top three crosses for yield and its attributes for various characters

Cross	RH (%)	Cross	HB (%)	Cross	SH 1 (%)	Cross	SH 2 (%)
Days to 50 % tasselling							
CML 264 x GWL 24	-16.18**	CML 264 x GWL 24	-14.20**	CML 264 x GWL 24	-13.17**	CML 264 x GWL 24	-21.19**
GWL 22 x CML 490	-14.91**	GWL 22 x GWL 24	-13.37**	GWL 22 x GWL 24	-10.77**	GWL 22 x GWL 24	-19.02**
GWL 22 x GWL 24	-14.61**	GWL 24 x GWL 27	-11.29**	GWL 22 x CML 490	-7.78**	GWL 22 x CML 490	-16.30**
CML 186 x CML 264	9.59**	CML 186 x CML 264	14.93**	GWL 27 x GWL 28	14.37**	GWL 27 x GWL 28	3.80**
Days to 50 % silking							
GWL 22 x GWL 24	-16.19**	GWL 22 x GWL 24	-14.65**	GWL 22 x GWL 24	-19.30**	GWL 22 x GWL 24	-24.53**
CML 264 x GWL 24	-11.73**	CML 264 x GWL 24	-10.82**	CML 264 x GWL 24	-14.35**	CML 264 x GWL 24	-19.90**
GWL 24 x CML 490	-11.33**	GWL 24 x GWL 27	-9.13**	CML 264 x GWL 22	-13.36**	CML 264 x GWL 22	-18.98**
GWL 27 x GWL 28	4.83**	GWL 28 x CML 490	7.14**	GWL 28 x CML 490	3.96**	GWL 28 x CML 490	-2.77**
Plant height							
CML 264 x GWL 24	43.29**	GWL 24 x GWL 27	44.28**	GWL 24 x GWL 28	13.45**	CML 264 x GWL 27	3.18**
GWL 24 x GWL 27	39.62**	CML 264 x GWL 24	43.69**	GWL 24 x GWL 27	-3.17**	GWL 24 x GWL 27	3.18*
GWL 27 x GWL 28	33.33**	CML 264 x GWL 28	38.09**	GWL 27 x GWL 28	-3.92**	GWL 27 x GWL 28	2.39*
CML 186 x GWL 24	0.35	CML 186 x CML 490	8.85**	GWL 22 x GWL 24	-25.98**	GWL 22 x GWL 24	-21.11**
Ear height							
CML 264 x GWL 24	25.25**	GWL 22 x GWL 28	24.73**	CML 264 x GWL 24	-11.63**	CML 264 x GWL 24	9.95**
GWL 22 x GWL 28	25.06**	CML 264 x GWL 22	20.10**	CML 186 x GWL 27	-12.36**	CML 186 x GWL 27	9.04**
CML 264 x GWL 22	23.70**	GWL 27 x GWL 28	17.41**	GWL 22 x GWL 28	-13.81**	GWL 22 x GWL 28	7.23**
CML 186 x CML 264	-17.04**	CML 186 x CML 264	-24.18**	CML 186 x CML 264	-40.72**	CML 186 x CML 264	-26.24**
Days to 75 % dry husk							
GWL 24 x GWL 28	8.10**	GWL 24 x GWL 28	9.32**	GWL 28 x CML 490	3.01**	GWL 28 x CML 490	-1.15**
GWL 27 x GWL 28	7.21**	GWL 27 x GWL 28	7.54**	GWL 27 x GWL 28	3.01**	GWL 27 x GWL 28	-1.15**
GWL 28 x CML 490	6.21**	GWL 28 x CML 490	7.54**	GWL 24 x GWL 28	2.40**	GWL 24 x GWL 28	-1.73**
CML 264 x CML 490	-3.84**	CML 264 x CML 490	-3.69**	GWL 22 x GWL 24	-7.83**	GWL 22 x GWL 24	-11.56**

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Cross	RH (%)	Cross	HB (%)	Cross	SH 1 (%)	Cross	SH 2 (%)
Ear length							
GWL 24 x CML 490	43.02**	GWL 24 x CML 490	30.34**	GWL 24 x CML 490	23.23**	GWL 24 x CML 490	13.38**
CML 186 x CML 264	32.31**	CML 186 x CML 264	30.02**	CML 186 x CML 264	13.73**	CML 186 x CML 264	4.64**
GWL 24 x GWL 28	23.54**	GWL 24 x GWL 28	21.29**	CML 186 x GWL 22	3.63**	CML 186 x GWL 22	-4.64**
CML 264 x CML 490	-16.70**	CML 264 x CML 490	-21.15**	CML 264 x CML 490	-25.45**	CML 264 x CML 490	-31.41**
Ear girth							
GWL 24 x CML 490	18.72**	GWL 24 x CML 490	11.50**	GWL 24 x CML 490	16.39**	GWL 24 x CML 490	24.13**
CML 186 x CML 264	16.30**	CML 186 x CML 264	11.28**	CML 186 x CML 264	16.16**	CML 186 x CML 264	23.89**
CML 264 x GWL 27	14.38**	CML 186 x CML 490	11.13**	CML 264 x GWL 27	15.70**	CML 264 x GWL 27	23.39**
GWL 22 x GWL 24	-4.98**	GWL 22 x GWL 24	-6.80**	CML 186 x GWL 24	-2.30	GWL 28 x CML 490	0.98
Number of grain rows per ear							
GWL 24 x CML 490	23.11**	GWL 27 x CML 490	20.27**	GWL 24 x CML 490	18.88**	GWL 24 x CML 490	24.74**
GWL 27 x CML 490	21.67**	GWL 24 x CML 490	16.38**	GWL 22 x GWL 28	18.45**	GWL 22 x GWL 28	24.32**
GWL 22 x GWL 28	15.96**	GWL 27 x GWL 28	11.89**	GWL 24 x GWL 28	13.73**	GWL 24 x GWL 28	19.36**
CML 186 x GWL 24	-5.80**	CML 186 x GWL 24	-7.96**	CML 186 x GWL 24	-6.00**	CML 186 x GWL 24	-1.35
Number of grains per row							
GWL 24 x CML 490	55.69**	GWL 24 x CML 490	53.75**	GWL 24 x CML 490	46.42**	GWL 24 x CML 490	13.88**
CML 264 x GWL 22	34.22**	CML 264 x GWL 22	31.57**	CML 264 x GWL 22	19.04**	CML 264 x GWL 22	-7.40**
GWL 24 x GWL 28	32.41**	GWL 24 x GWL 28	23.07**	CML 186 x GWL 22	16.66**	CML 186 x GWL 22	-9.25**
CML 186 x CML 490	-11.37**	CML 186 x CML 490	-14.94**	CML 264 x GWL 24	-14.28**	CML 264 x GWL 24	-33.33**
100-kernel weight							
CML 264 x GWL 28	41.00**	CML 264 x GWL 28	36.11**	CML 264 x GWL 28	-1.03	CML 264 x GWL 28	32.43**
CML 264 x GWL 24	25.35**	CML 264 x GWL 24	23.61**	CML 264 x GWL 24	-8.24**	CML 264 x GWL 24	20.27**
CML 264 x GWL 22	20.00**	CML 264 x GWL 22	19.17**	CML 264 x GWL 22	-10.30**	CML 264 x GWL 22	17.56**
GWL 28 x CML 490	-26.53**	GWL 28 x CML 490	-32.50**	GWL 28 x CML 490	-44.32**	GWL 28 x CML 490	-27.02**

Contd.....

Cross	RH (%)	Cross	HB (%)	Cross	SH 1 (%)	Cross	SH 2 (%)
Grain yield							
GWL 24 x CML 490	72.61**	GWL 24 x CML 490	71.28**	GWL 24 x CML 490	37.28**	GWL 24 x CML 490	43.47**
CML 264 x GWL 22	42.23**	CML 264 x GWL 22	36.69**	CML 264 x GWL 22	12.44**	CML 264 x GWL 22	17.51**
GWL 24 x GWL 28	40.74**	GWL 27 x GWL 28	34.98**	GWL 24 x GWL 28	2.27	GWL 24 x GWL 28	6.88**
CML 186 x GWL 24	-32.52**	CML 186 x GWL 24	-37.16**	CML 186 x GWL 24	-42.51**	CML 186 x GWL 24	-39.92**
Shelling percentage							
CML 186 x GWL 28	11.15**	CML 186 x GWL 28	8.06**	CML 186 x GWL 28	8.95**	CML 186 x GWL 28	4.37**
GWL 24 x CML 490	8.41**	GWL 24 x CML 490	7.67**	GWL 24 x CML 490	5.85**	GWL 24 x CML 490	1.40*
CML 264 x GWL 28	6.78**	CML 264 x GWL 28	5.16**	CML 186 x CML 264	3.53**	CML 186 x CML 264	-0.81
GWL 27 x CML 490	-13.66**	GWL 27 x CML 490	-14.32**	GWL 27 x CML 490	-14.46**	GWL 27 x CML 490	-18.06**
Protein content							
CML 186 x GWL 28	23.21**	CML 264 x GWL 27	20.23**	CML 264 x GWL 27	48.64**	CML 264 x GWL 27	22.94**
CML 186 x CML 490	22.94**	CML 186 x CML 490	17.19**	GWL 22 x GWL 24	46.38**	GWL 22 x GWL 24	21.07**
CML 264 x GWL 27	22.90**	CML 186 x GWL 28	14.31**	CML 186 x GWL 28	41.76**	CML 186 x GWL 28	17.25**
CML 264 x GWL 28	-22.99**	CML 264 x GWL 28	-24.78**	CML 264 x GWL 28	-6.72**	CML 264 x GWL 28	-22.87**

*, ** Significant at 5% and 1% levels, respectively

In each character, the 4th cross showed lowest heterosis

RH = Relative Heterosis, HB = Heterobeltiosis, SH = Standard Heterosis, SH 1 = GM 3, SH 2 = HQPM 1

For the character protein content, relative heterosis, heterobeltiosis and standard heterosis 1 and standard heterosis 2 ranged from -22.99 to 23.21, -24.78 to 20.23, -6.72 to 48.64 and -22.87 to 22.94 per cent for protein content, respectively (Table 3). The crosses, CML 264 x GWL 27 and CML 186 x GWL 28 recorded positive and highly significant result for relative heterosis, heterobeltiosis and standard heterosis over both the checks; whereas the cross CML 186x CML 490 observed positive and significant relative heterosis and heterobeltiosis for protein content. The cross CML186xGWL 28 also showed highly significant and positive heterosis for shelling percentage. Hence, the hybrid could be further evaluated in heterosis breeding programme and simultaneously could be advanced in segregating generations to obtain desirable segregants for the development of superior genotypes for improvement of grain yield and protein content. Based on over all study, the parental lines CML 264, CML 490 and GWL 28 yielded better heterotic hybrids for grain yield and protein content. Hence, these parents could be exploited to improve grain yield potential or to improve the quantity of the protein and used in future breeding programme for development of superior genotypes for commercial cultivation.

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