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COMBINING ABILITY AND HETEROSIS IN QUALITY PROTEIN MAIZE

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ABSTRACT
A half diallel set of eight newly developed white kernel colour quality protein maize inbred lines were utilized to evaluate combining ability and heterosis for yield and its components characters. Analysis of variance revealed significant differences among the parents and experimental hybrids for all the characters except ear diameter. Combining ability analysis revealed that estimate of specific combining ability (SCA) variances were higher than general combining ability (GCA) variances for all the traits under study, indicating predominance of non-additive gene action of these traits. The parents HUZQPM 3-2, HUZQPM 6-2 and HUZQPM 5 were identified as good combiners for yield and its related traits. The best experimental hybrids, on the basis of *per se* performance, SCA effect and standard heterosis for grain yield per plant and two to five of its component was HUZQPM 1-1 X HUZQPM 3-2 followed by HUZQPM 1-1 X HUZQPM 5 that yielded 51.28 and 33.16 per cent more grain yield, respectively over best commercial check hybrid HQPM 1. Result suggested that these crosses may be exploited for commercial cultivation in North East Plane Zone (NEPZ) of maize growing areas after testing over the location.

INTRODUCTION

Being a great yield potential, maize attained the leading position among cereals in terms of production and productivity. Maize is the most preferred energy source due to its high energy, low fibre, better palatability, presence of pigments and essential fatty acids. However, the normal maize contains high *zein* fraction, which is practically devoid of lysine and low in tryptophan (Prasanna *et al*., 2001). A genetic approach to improve the nutritional quality of maize protein yielded the quality protein maize which contains *opaque-2*, a single gene mutation that alter the protein composition of the endosperm protein and nearly double the essential amino acid concentrations and yielded 10 % more grains than traditional maize varieties (Akande and Lamidi, 2006). The single cross quality protein maize hybrids have become popular among Indian farmers due to their high yield potential and excellent uniformity.

The hybrid breeding is imperative to select the cross combinations with high degree of SCA as well as parents with high GCA. Combining ability is a powerful tool in identifying the best combiners for hybridization especially, when a large number of advance inbred lines are available and most promising once are to be selected on the basis of their ability to give superior quality protein maize hybrids. General and specific combining ability are due to genes which are largely additive and dominance or epistatic effects respectively (Spraque and Tatum, 1942). Information on heterotic patterns and combining ability among maize germplasm is essential in maximizing the effectiveness of hybrid development (Beck *et al*., 1990). Development of commercial maize hybrid usually requires a good knowledge of combining ability of the breeding materials to be used. The success in commercial production of hybrid maize depends up on the availability of productive diverse quality protein maize inbred lines and clear knowledge of gene action for specific traits. Therefore, the present investigation was undertaken to study the combining ability and estimate the extent of heterosis for grain yield and yield contributing traits.

MATERIALS AND METHODS

Eight newly developed white kernel inbred lines of QPM *viz*. HUZQPM 1-1, HUZQPM 1-2, HUZQPM 2, HUZQPM 3-2, HUZQPM 4-2, HUZQPM 5, HUZQPM 6-1 and HUZQPM 6-2 were utilized to produce twenty eight F_1 hybrids using a half diallel crossing system during *rabi* 2007-08. The 28 hybrids along with their parents and check hybrid (HQPM 1) were raised in randomized block designs with three replications during *kharif* 2008 at Institutional Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Each entry was planted in a plot consisting of two rows of 5 m length with a spacing of 60 cm x 20 cm apart. Observations were recorded on plot basis for days to 50 % pollen shedding, days to 50 % silking and days to 50 % dry husk where as plant height (cm), cob height (cm), ear length (cm), ear diameter (cm), number of kernel rows per ear, number of kernels per row, 1000-grain weight (g), grain yield per plant were recorded on twenty competitive randomly selected plants in each replication. The mean data were subjected to combining analysis using model-I and method-II as suggested by Griffing (1956) as well as for estimation of per cent heterosis over standard check (Hayes *et al*., 1955).

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant difference for all the characters studied (Table 1). The mean square due to parents differed significantly indicating the parents involved in the study were diverse for all the characters except ear diameter, and significant differences were also observed among the crosses for all the characters. The variance due to parents *vs* crosses differs significantly indicating the presence of high heterosis response in the material studied. The variance due to general and specific combining ability were highly significant for all the characters under study, indicated that the influence of both additive and non-additive effects in the expression of these characters. The influence of both types of gene effects were also observed by Singh and Kumar (2008); Verma and Narayan (2008) and Amiruzzaman *et al.* (2011) in QPM maize. Combining ability analysis revealed that estimate of specific combining ability (SCA) variances were higher than general combining ability (GCA) variances for all the characters under study, suggesting predominance of non-additive gene action for these traits. These results are in agreement with earlier reports of Pavan *et al.* (2011) for number of kernels per row, number of kernels per ear, 100-grain weight and grain yield per plant, and Amiruzzaman *et al.* (2011) for quantitative and qualitative traits like kernel yield per plant, number of kernel per ear, 1000-kernel weight, lysine and tryptophan content.

GCA effects

The estimate of GCA effects showed that the parents HUZQPM 3-2, HUZQPM 6-2 and HUZQPM 5 were good combiners for yield and yield attributing traits like ear length, number of kernels per row and 1000-kernel weight (Table 2). Result indicated that the parents possess high frequency of favourable genes for these traits. The parent HUZQPM 3-2 was significantly negative for days to 50% tasseling, days to 50% silking and cob height. The estimates of GCA effects showed that the parent HUZQPM 3-2 was the best combiner of 1000-kernel weight, number of kernels per row and ear length, cob height and also for earliness. Thus, the inbred lines which exhibited good general combining ability for at least one trait can be used as donor parents for the accumulation of favourable genes. These findings are in accordance with Alam *et al.* (2008) and Khalil *et al.* (2010). They reported that higher positive GCA effects for number of grains per ear, 1000-kernel weight and grain yield per plant.

SCA effect

Specific combining ability effects of some crosses showed positive significant performance for many traits under study (Table 2). Among the crosses, HUZQPM 1-1 X HUZQPM 3-2 possessed significant SCA effect for grain yield per plant, ear length, number of rows per ear, number of kernels per row and 1000-grain weight exhibited best specific combiner for these traits, followed by HUZQPM 1-1 X HUZQPM 5 for grain yield per plant and two to five of its component traits. Days to 50% tasseling and days to 50% silking, two crosses namely HUZQPM 1-1 X HUZQPM 3-2 and HUZQPM 1-1 X HUZQPM 5 involving low x high and low x low interaction of GCA of the parents showed significant and negative SCA effects. Therefore, in the diallel analysis, one must select hybrids of high specific combining ability in which one of the parental lines presents high general combining ability. Similarly, Aguir *et al.* (2003) showed the positive significant SCA effect for the traits like plant height, ear height, number of ears per plant and grain yield per plant in the cross L-08-05F X L-38-05D, and Amiruzzaman *et al.* (2011) for kernel yield, yield components and qualitative traits like lysine and tryptophan content in the crosses CML 171 X CML 192 and CML 172 X CML 193.

Heterosis

The standard heterosis expressed by some crosses for different traits is presented in Table 2. The expression and magnitude of heterosis however, varied for different traits in the same cross and even for same traits among the crosses. The two experimental hybrids namely, HUZQPM 1-1 X HUZQPM 3-2 and HUZQPM 1-1 X HUZQPM 5 were identified as superior hybrids and they yielded 51.28 and 33.16 per cent more grain yield, respectively, over best commercial check hybrid HQPM 1. The high heterosis for yield per plant and its major components 1000-kernel weight, number of kernels per row, number of rows per ear, ear diameter and ear length were observed either due to good GCA of parents or due to high SCA effect of the respective crosses.

Table 1: Analysis of variance for eleven quantitative characters in quality protein maize

Source of variation	d.f.	Mean Sum of Squares Days to 50% tassel	Days to 50% silking	Days to 50% brown husk	Plant height (cm)	Cob height (cm)	Ear length (cm)	Ear diameter (cm)	No. of rows per ear	No. of kernels per ear	1000-kernel weight (g)	Yield per plant (g)
Replication	2	8.44	3.78	1.37	3.17	6.25	35.73	7.92	7.12	1.49	894.73	36.5
Genotype	35	72.04**	92.17**	5.00	775.1**	399.94**	84711.96**	8.39**	571.64**	13.88**	39.95**	80.11**
Parents	7	97.78**	124.5**	78.73**	810.13**	368.47**	751.95**	0.42	433.97**	24.63**	161.89**	19.89**
Crosses	28	41.95**	44.28**	100.84**	756.99**	375.65**	92495.58**	10.68**	611.82**	11.23**	460.27**	70.45**
Parents *vs* Crosses	1	704.38**	1155.87**	51.11**	1018.57**	1276.00**	1464.42**	2.19	449.55**	10.18	161.85**	62.33**
Error	70	0.41	0.43	0.52	10.36	0.70	1.37	2.61	2.04	43.71	16.12	0.82
σ^2GCA	-	2.88	3.45	3.66	34.88	14.43	147.94	15661.74	102.71	0.93	0.097	5.33
σ^2SCA	-	22.29	29.22	29.77	222.77	129.67	632.58	120233.55	2099.68	3.00	0.177	17.47

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

Table 2: Elite three specific combination for grain yield and its component traits in quality protein maize

Character	Parents	GCA effect	Cross	SCA effect	Cross	Heterosis
Days to 50 % tassel	HUZQPM 2	-2.09**	HUZQPM 5 X HUZQPM 6-1	-6.93**	HUZQPM 3-2 X HUZQPM 5	-12.33**
	HUZQPM 3-2	-2.03**	HUZQPM 1-1 X HUZQPM 3-2	-6.49**	HUZQPM 3-2 X HUZQPM 6-2	-10.00**
	HUZQPM 6-1	-1.23**	HUZQPM 4-2 X HUZQPM 6-2	-6.43**	HUZQPM 4-2 X HUZQPM 6-2	-9.18**
Days to 50 % silking	HUZQPM 2	-2.16**	HUZQPM 4-2 X HUZQPM 6-2	-6.66**	HUZQPM 3-2 X HUZQPM 6-2	-8.71**
	HUZQPM 3-2	-2.12**	HUZQPM 5 X HUZQPM 6-1	-6.32**	HUZQPM 1-1 X HUZQPM 3-2	-8.70**
	HUZQPM 6-1	-0.79**	HUZQPM 1-1 X HUZQPM 3-2	-6.12**	HUZQPM 4-2 X HUZQPM 6-2	-7.40**
Days to 50 % brown husk	HUZQPM 6-1	-2.10**	HUZQPM 1-1 X HUZQPM 1-2	-8.17**	HUZQPM 3-2 X HUZQPM 6-2	-10.48**
	HUZQPM 1-1	-1.60**	HUZQPM 4-2 X HUZQPM 6-1	-7.10**	HUZQPM 1-1 X HUZQPM 1-2	-9.52**
	HUZQPM 2	-0.87**	HUZQPM 2 X HUZQPM 3-2	-5.33**	HUZQPM 5 X HUZQPM 6-1	-6.38*
Plant height (cm)	HUZQPM 1-1	-8.77**	HUZQPM 4-2 X HUZQPM 5	-40.80**	HUZQPM 4-2 X HUZQPM 5	-35.43**
	HUZQPM 1-2	-4.83	HUZQPM 6-1 X HUZQPM 6-2	-15.50**	HUZQPM 1-1 X HUZQPM 1-2	-26.11**
	HUZQPM 5	-4.70	HUZQPM 1-1 X HUZQPM 1-2	-12.77**	HUZQPM 1-1 X HUZQPM 4-2	-19.43**
Cob height (cm)	HUZQPM 1-2	-5.50**	HUZQPM 4-2 X HUZQPM 5	-12.75**	HUZQPM 1-1 X HUZQPM 1-2	-36.46**
	HUZQPM 1-1	-4.07**	HUZQPM 2 X HUZQPM 3-2	-11.82**	HUZQPM 1-2 X HUZQPM 3-2	-22.62**
	HUZQPM 3-2	-0.50**	HUZQPM 1-2 X HUZQPM 3-2	-10.88**	HUZQPM 2 X HUZQPM 3-2	-14.92**
Ear length (cm)	HUZQPM 6-2	1.09**	HUZQPM 1-1 X HUZQPM 2	2.61**	HUZQPM 1-1 X HUZQPM 2	7.14**
	HUZQPM 1-2	0.79**	HUZQPM 1-1 X HUZQPM 3-2	2.39**	HUZQPM 2 X HUZQPM 5	5.84*
	HUZQPM 3-2	0.73**	HUZQPM 6-1 X HUZQPM 6-2	2.05**	HUZQPM 4-2 X HUZQPM 6-2	3.92
Ear diameter (cm)	HUZQPM 2	0.90**	HUZQPM 2 X HUZQPM 3-2	2.83**	HUZQPM 2 X HUZQPM 4-2	10.24**
	HUZQPM 3-2	0.77**	HUZQPM 1-1 X HUZQPM 5	0.86	HUZQPM 2 X HUZQPM 5	10.23**
	HUZQPM 6-1	0.38	HUZQPM 1-2 X HUZQPM 6-2	0.57	HUZQPM 1-1 X HUZQPM 2	6.98
No. of rows per ear	HUZQPM 2	2.97**	HUZQPM 1-1 X HUZQPM 3-2	7.89**	HUZQPM 3-2 X HUZQPM 4-2	45.38**
	HUZQPM 1-1	1.67**	HUZQPM 1-1 X HUZQPM 2	6.83**	HUZQPM 4-2 X HUZQPM 6-1	40.92**
	HUZQPM 6-1	0.90**	HUZQPM 1-1 X HUZQPM 6-2	4.29	HUZQPM 3-2 X HUZQPM 5	40.62**
No. of kernels per row	HUZQPM 2	43.71**	HUZQPM 1-1 X HUZQPM 3-2	14.21**	HUZQPM 1-2 X HUZQPM 2	12.21**
	HUZQPM 3-2	15.91**	HUZQPM 1-1 X HUZQPM 2	14.09**	HUZQPM 1-1 X HUZQPM 2	11.22**
	HUZQPM 6-1	13.18*	HUZQPM 1-1 X HUZQPM 5	9.41**	HUZQPM 4-2 X HUZQPM 6-1	8.58*
1000-kernel weight (g)	HUZQPM 2	16.12**	HUZQPM 1-1 X HUZQPM 5	74.35**	HUZQPM 2 X HUZQPM 4-2	27.93**
	HUZQPM 6-1	13.98**	HUZQPM 1-1 X HUZQPM 6-1	69.41**	HUZQPM 4-2 X HUZQPM 6-1	21.72**
	HUZQPM 3-2	11.72**	HUZQPM 1-1 X HUZQPM 3-2	54.05**	HUZQPM 3-2 X HUZQPM 6-2	18.98**
Yield per plant (g)	HUZQPM 3-2	15.63**	HUZQPM 1-1 X HUZQPM 3-2	71.57**	HUZQPM 1-1 X HUZQPM 3-2	51.28**
	HUZQPM 6-2	15.44**	HUZQPM 1-1 X HUZQPM 5	45.20**	HUZQPM 1-1 X HUZQPM 5	33.16**
	HUZQPM 5	5.84**	HUZQPM 2 X HUZQPM 4-2	22.78**	HUZQPM 2 X HUZQPM 4-2	17.98

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

Parihar *et al*. (2012) observed maximum economic heterosis in all the environments for grain yield per plant in the crosses P9 X P12 and P4 X P 12. On the other hand, lowest heterosis over the best check was observed in the cross HUZQPM 1-1 X HUZQPM 6-1 due to non additive gene effect for grain yield per plant. The significant negative heterosis was observed in cross HUZQPM 3-2 X HUZQPM 6-2 for days to 50% tasseling, days to 50% silking and days to 50% brown husk. Alam *et al*. (2008) and Singh *et al*. (2011) observed similar result for grains per ear; days to 50% tasseling and days to 50% silking in quality protein maize, respectively. The heterotic behaviour and magnitude of heterosis in the superior experimental hybrids revealed that heterosis for grain yield may be because of the fact that at least one parent involved in these crosses had desirable and significant gca effect. Result suggesting besides genetic diversity gca effect should also taken in to account for heterosis breeding. Thus, it can be concluded from the present results that the parental lines HUZQPM 3-2, HUZQPM 6-2 and HUZQPM 5 would be the desirable lines as donor to get high yield. The two crosses HUZQPM 1-1 X HUZQPM 3-2 and HUZQPM 1-1 X HUZQPM 5 were identified as outstanding for grain yield and its component traits due to possessing high SCA effect and high heterosis for grain yield per plant. Therefore, these hybrids and their parents may further utilize in future QPM hybrid breeding programme.

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