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Gene Action and Combining Ability Studies in Quality Protein Maize (QPM) (*Zea mays* L.) Genotypes *

P Shanthi, G Suresh Babu, J Suresh , E Satyanarayana and R Sai Kumar
Department of Genetics and Plant Breeding Allahabad Agriculture Institute – Deemed University, Allahabad - 211007

ABSTRACT

Forty-five QPM single cross hybrids along with 10 parents and two checks *viz*., DHM-105 and Shaktiman-2 were evaluated for combining ability at two locations (Hyderabad and Allahabad) and in two seasons (*Kharif* 2003 and *Kharif* 2004) for 26 different yield, quality and yield contributing quantitative characters. From this study it is inferred that, both additive and non-additive gene effects were present in the material under study. However, the ratio of additive and non-additive genetic variance revealed that there was preponderance of non-additive gene action in the expression of all the traits under study. Based on *per se* performance and combining ability studies, the parents P_3 and P_1were adjudged as best parents followed by P_{10} for possessing maximum number of favourable genes for grain yield and also yield contributing characters while parents P_4, P_7 and P_2 recorded highest favourable genes for protein, oil and tryptophan content. The cross combinations P_2 x P_6, P_4 x P_7 and P_5 x P_{10} exhibited highest magnitude of positive significant *sca* effects along with highest *per se* performance for yield, quality and yield contributing characters.

Key words : Combining ability, Diallel, Grain yield, Quality parameters, QPM, *Zea mays* L.

Maize (*Zea mays* L.) is an excellent source of carbohydrates, protein and good quality oil. It is more complete in nutrients in comparison to other cereals nevertheless all cereals including maize tend to be low in two essential amino acids *viz.,* lysine and tryptophan [Olson R.A and Fray K.J. 1987]. Quality Protein Maize (QPM) is the one type of maize which is rich in lysine and tryptophan in its endosperm protein compared to normal maize [CIMMYT, 2000].

Concerted and continuous research work over more than 30 years made at CIMMYT, Mexico for the improvement of protein and oil content without affecting grain yield in maize was a successful story by utilizing opaque-2 gene and hard endosperm modifier genes which lead to the release of number of QPM parental lines and hybrids across the globe.

Further in India research efforts are being conducted at Directorate of Maize Research, I.A.R.I., New Delhi and also at Agricultural Research Station, Amberpet, Hyderabad in collaboration with CIMMYT, Mexico to screen and identify nutritionally superior genotypes with semi soft to hard endosperm corn coupled with high yield.

In this direction, the present investigation was carried out which aims at identification of superior parents with high general combining ability effects and hybrids possessing high specific combining ability effects along with high *per se* values for yield, yield components and quality parameters in QPM genotypes.

MATERIAL AND METHODS

Ten genetically diverse inbred lines of maize (P_1 to P_{10}) *viz*., BHOML 32, BQPML 29, BQPML 106, BHOML 45, BQPML 38, BQPML 66, BHOML 131, BHOML 39, BHOML 68 and BQPML 42 were crossed in diallele mating design excluding reciprocals during *rabi* 2002-2003 at ARS, Amberpet, Hyderabad, A.P. to produce 45 experimental single cross hybrids for this study. The 45 F_1's, ten parents along with two standard checks *viz.,* DHM 105- Normal maize hybrid (Better yielding check) and Shaktiman 2 – (QPM hybrid) were raised in Complete Randomized Block Design, replicated thrice. The experiments were conducted during *kharif* 2003 and *kharif* 2004 at two locations *viz.,* Agricultural Research Station (Maize), Amberpet, Hyderabad, A.P., (Location-1) and College Experimental Farm, Allahabad Agricultural Institute-Deemed University, Naine, Allahabad, U.P., (Location-2). Each genotype was planted in a single row of 5m length with a row to row and plant to plant spacing of 75 cm and 20 cm respectively. The field was uniformly fertilized with recommended dose of 120 kg Nitrogen, 60 kg P_2O_5 and 40 kg K_2O per hectare. Nitrogen was applied in three split doses (1/3basal + 1/3 at knee height stage + 1/3 at tasseling stage) and other two in total quantity were applied in basal application. Usual recommended cultural and plant protection practices as per the agronomical practices were adopted to maintain a good healthy crop.

The observations were recorded on 26 different yield, quality and yield contributing quantitative characters *viz.,* germination percentage, number of days taken for germination, seedling vigour index, total vegetative growth period, days to 50% tasselling, total anthers dehiscence period, days to 50% silking, total period of silk appearance, days to 50% silk drying, active pollination period, total grain filling period, total reproductive growth period, ratio of vegetative growth period to reproductive growth period, plant height at maturity (cm), ear height at maturity (cm), ear length (cm), ear girth (cm), number of seeds per cob, cob weight (g), 100-seed weight (g), grain yield per plot (kg), protein content (%), protein yield (kg / ha), oil content (%), oil yield (kg / ha), and tryptophan content (g / 16 g N). Five competitive plants were selected at random in each plot in each replication for all the genotypes in all the four environments excluding border plants for recording data except for days to 50 % tasseling, days to 50% silking, days to 50% silk drying, total vegetative growth period, total grain filling period, total reproductive growth period and grain yield which were recorded on whole plot basis. The combining ability analysis was carried out as per procedure given by Griffing method 2 and model 1 [Griffing. B. 1956a.] for all the 26 characters studied in QPM genotypes.

RESULTS AND DISCUSSION

In the present investigation, the combining ability analysis revealed significant mean squares due to general and specific combining ability effects indicating that both additive and non-additive gene actions involved in the inheritance of all the characters studied except for germination percentage. However, the ratio of additive and non-additive variance showed that, the non additive gene action played great role in the inheritance of all the traits under study (Table 1). Similar results were also reported by earlier workers [Bjarnason and Vasal, 1992; Joshi. *et al.,* 2002; Gautam, 2003; Ashish Srivastava *et al.,* 2003; Bhatnagar *et al.,* 2004]. Under these circumstances, for exploiting non-additive gene action and to improve these characters one has to resort to the breeding procedures, which lead to heterozygous end products such as recurrent selection and reciprocal recurrent selection.

The final selection of parents is mostly influenced by results on grain yield and other contributing characters, which have direct bearing on yield [Venkatesh, *et al*., 2001]. The general picture of combining ability of parents over all the characters is useful to decide the combining ability status of parents [Venkatesh *et al.,*2001]. Among the ten parental lines, P_3, P_1, P_{10}, P_8 and P_6 are the good combiners for grain yield, other yield contributing characters and growth parameters as evidenced by their positive and highly significant *gca* effects along with higher *per se* performance (Table 2 &3). The parental lines P_3 and P_1 can be given the status of good general combiners and genetically worthy parents, followed by P_{10} as they contributed maximum favourable genes for yield and yield components and were good combiners for maximum number of characters studied *i.e*., for 17 characters out of 26 characters studied. Hence, these high yielding parents with good attributes for different yield components may be inter crossed to pool the genes in desirable direction to improve the yield potential. Many researchers [Gautam, 2003; Prasad *et al.,* 1988; Venugopal *et al.,* 2002; Narasimha Reddy, 2003; Kabdal *et al.,*2003 and Suresh, 2004] also suggested that, grain yield in maize can be improved by improving the component characters. Whereas three parents *viz.,* P_4, P_2 and P_7 are found to be good general combiners with significant *gca* effects along with higher *per se* values for protein, oil and tryptophan content. Hence, these three parents can be better utilized for the simultaneous improvement of protein, oil and tryptophan content and also as a donor parents for these characters.

Table 1. Analysis of variance for combining ability for phenological, yield and quality parameters over two locations (Hyderabad and Allahabad) and two seasons (*Kharif* 2003 and *Kharif* 2004).

Source	df	GP	NDTG	SVI	TVGP	DT	TADP	DS	TPSA	DSD	APP	TGFP	TRGP	RVGP & RGP
GCA	9	0.276	0.331**	757549.720**	16.654**	18.062**	2.399**	19.77**	1.77**	5.243**	1.64**	32.422**	54.256**	0.037**
SCA	45	0.346	1.330**	346230.601**	4.813**	8.532**	1.913**	8.27**	1.52**	4.809**	1.20*	45.414**	65.046**	0.998**
Error	108	0.171	0.023	2095.802	0.606	0.610	0.0505	1.005	0.022	0.803	0.014	0.645	0.741	0.018
σ^2 gca		0.014	0.002	175.677	0.051	0.051	0.0044	0.084	0.002	0.067	0.0012	0.0539	0.062	0.00008
σ^2 sca		0.162	0.039	1987.463	0.578	0.578	0.0482	0.953	0.021	0.761	0.0139	0.612	0.702	0.0012
σ^2 gca / σ^2 sca		0.086	0.0945	0.088	0.088	0.088	0.0912	0.088	0.098	0.088	0.086	0.088	0.088	0.066

Source	df	PH	EH	EL	EG	NSPC	CW	100-SW	PC	PY	OC	OY	TC	GY
GCA	9	183.757**	44.608**	3.645**	3.028**	5152.928**	1638.761**	39.91**	1.19**	70247.64**	0.55**	31574.87**	0.0190**	1.2093**
SCA	45	864.640**	231.137**	9.559**	4.953**	17107.406**	2589.301*	16.72**	0.46**	90333.74**	0.31**	39898.72**	0.0172**	0.9798**
Error	108	9.025	2.401	0.288	0.235	308.601	52.921	0.977	0.083	603.154	0.044	311.012	0.00068	0.00085
σ^2 gca		0.756	0.201	0.024	0.019	25.943	4.436	0.0821	0.007	50.558	0.0037	26.070	0.000068	0.00008
σ^2 sca		8.559	2.276	0.273	0.223	292.648	50.185	0.927	0.0795	571.975	0.0417	294.935	0.00078	0.00089
σ^2 gca / σ^2 sca		0.088	0.088	0.088	0.086	0.088	0.088	0.088	0.088	0.088	0.0890	0.088	0.0871	0.090

Note:- GP - Germi-nation (%), NDTG - No.of days taken for germination, SVI - Seedling vigour index, TVGP - Total vegetative growth period, DT - Days to 50% tasseling, TADP - Total anthers dehescence period, DS - Days to 50% silking, TPSA - Total period of silk appearance, DSD - Days to 50% silk drying, APP - Active pollination period, TGFP - Total grain filling period, TRGP - Total reproductive growth period, RVGP & RGP - Ratio of vegetative growth period and reproductive growth period, PH - Plant height (cm), EH - Ear height (cm), EL - Ear length (cm), EG - Ear girth (cm), NSPC - No.of seeds per cob, CW - Cob weight (g), 100-SW - 100 seed weight (g), PC - Protein content (%) PY - Protein yield (kg / ha), OC - Oil content (%), OY - Oil yield (kg / ha), TC - Tryptophan content (g / 16 g N), GY - Grain yield per plot (kg)

Out of 45 single crosses evaluated, 27 crosses exhibited significant *sca* effect for grain yield. But, based on *sca* effects and highest *per se* performance eleven best specific combination for high yield were identified *viz.*, P_4 x P_7, P_3 x P_9, P_2 x P_6, P_5 x P_{10}, P_1 x P_8, P_3 x P_8, P_3 x P_6, P_1 x P_5, P_3 x P_5, P_1 x P_{10} and P_3 x P_{10}, which were having high grain yield *i.e.,* more than 4.00 kg grain yield per plot (Table-2 & 4). Among these hybrids except P_4 x P_7 were the combinations of either both the parents as good combiners or one of the parents as good combiner. However, this single cross (P_4 x P_7) can be effectively used in a recurrent selection programme that favours specific combining ability. The cross combinations P_1 x P_8, P_3 x P_8, P_3 x P_6, P_1 x P_{10} and P_3 x P_{10} are derivatives of high x high combiners and selection in these crosses may throw useful transgressive segregants for high grain yield in the future generations. Yield improvement can be sought from these crosses by pedigree or simple selection procedure. The other hybrids *viz.,* P_4 x P_7, P_5 x P_{10}, P_2 x P_6, P_3 x P_5, P_3 x P_9 and P_1 x P_5 can be exploited by production of single cross hybrids in realizing their high yield potential. Further, amongst these high yielding single crosses, the three cross combinations *viz.,* P_4 x P_7, P_2 x P_6 and P_5 x P_{10} were found as good specific combiners for high grain yield and other yield contributing characters along with quality parameters *i.e.,* protein, oil and tryptophan content. Hence, it is suggested that, these three hybrids (*viz.,* P_4 x P_7, P_2 x P_6 and P_5 x P_{10}) can be better exploited as QPM hybrids for commercial cultivation across the wide

Table 2. Mean Performance of 10 Quality Protein Maize Parental inbred lines and their 11 best single crosses over two locations (Hyderabad and Allahabad) and two seasons (*Kharif* 2003 and *Kharif* 2004)

PARENT	GP	NDTG	SVI	TVGP	DT	TADP	DS	TPSA	DSD	APP	TGFP	TRGP	RVGP & RGP
P1	97.65	8.67	4259.58	53.00	61.67	3.57	63.58	3.42	68.58	3.39	29.75	33.42	1.59
P2	97.44	7.73	4933.92	50.61	58.33	2.80	59.33	2.42	64.42	2.31	25.25	27.17	1.87
P3	98.25	9.75	4535.33	50.58	60.33	4.49	61.67	3.20	65.92	3.19	31.75	35.42	1.43
P4	98.65	8.75	5263.75	48.17	56.92	2.46	58.00	1.97	62.92	1.93	21.75	23.92	2.02
P5	98.53	9.49	4665.50	50.09	59.58	3.17	60.33	3.15	64.25	3.02	30.08	34.75	1.44
P6	98.38	9.75	4795.83	49.92	59.67	3.03	60.67	2.74	65.92	2.73	27.42	30.42	1.64
P7	97.67	8.67	5197.58	48.50	57.17	2.63	59.00	2.25	64.92	2.22	22.75	25.42	1.91
P8	98.47	8.65	5134.33	48.77	57.42	2.88	58.67	2.65	65.92	2.59	25.75	28.58	1.71
P9	98.77	7.69	4998.83	50.31	58.00	2.69	60.00	2.48	65.00	2.30	24.42	27.08	1.86
P10	98.61	9.73	3935.33	53.72	63.42	3.73	66.00	3.55	70.58	3.56	32.75	40.08	1.34
Mean	98.24	8.89	4771.998	50.37	59.25	3.15	60.73	2.78	65.84	2.72	27.17	30.63	1.68
Cross combination	GP	NDTG	SVI	TVGP	DT	TADP	DS	TPSA	DSD	APP	TGFP	TRGP	RVGP & RGP
P1 x P5	98.42	6.32	5735.17	48.10	54.42	7.20	55.67	6.02	61.92	5.69	47.75	54.92	0.88
P1 x P8	97.80	6.54	5131.25	50.96	57.50	6.93	58.92	5.70	62.58	5.76	46.75	54.58	0.93
P1 x P10	98.47	6.56	4662.67	3.02	59.58	6.97	60.00	6.28	63.33	6.13	44.42	51.25	1.03
P2 x P6	97.94	7.50	5597.17	47.67	55.17	6.77	57.33	7.00	64.83	6.06	48.75	55.92	0.85
P3 x P5	98.27	7.07	5130.58	50.93	58.00	6.30	59.58	6.22	64.58	6.04	48.08	54.83	0.93
P3 X P6	97.77	5.32	6195.83	46.60	51.92	6.70	54.58	6.38	59.92	5.76	45.42	52.33	0.90
P3 x P8	97.87	6.19	5671.50	48.89	55.08	6.42	55.92	6.05	61.25	5.39	45.42	52.08	0.94
P3 x P9	98.23	6.17	5679.83	48.58	54.75	6.57	56.58	5.92	60.58	5.56	43.75	50.75	0.96
P3 x P10	98.30	6.46	4475.83	53.88	60.33	7.13	63.58	6.45	61.58	5.75	46.75	53.75	1.00
P4 x P7	97.72	6.78	6404.33	43.73	50.50	7.27	52.25	5.58	62.50	5.46	45.92	52.92	0.83
P5 x P10	97.88	6.21	5134.50	51.54	57.75	6.53	59.25	6.55	61.17	5.87	45.92	52.75	0.98
Mean of 45 single cross hybrids	98.27	6.44	5700.79	48.17	54.61	5.19	56.45	4.56	62.13	4.36	40.04	45.04	1.09
Checks	GP	NDTG	SVI	TVGP	DT	TADP	DS	TPSA	DSD	APP	TGFP	TRGP	RVGP & RGP
DHM 105	97.80	5.46	6003.34	47.54	53.00	4.20	54.25	3.48	61.83	3.91	35.33	39.42	1.21
Shaktiman-2	97.93	5.57	6083.50	46.52	52.09	3.97	54.84	3.25	60.83	3.54	34.50	38.25	1.22

Table 2. Contd…………

PARENT	PH	EH	EL	EG	NSPC	CW	100-SW	PC	PY	OC	OY	TC	GY
P1	87.92	87.92	14.35	11.51	255.25	74.25	30.80	9.59	547.73	6.20	354.17	0.60	2.14
P2	96.25	96.25	11.68	11.01	201.58	47.42	25.82	11.93	442.86	7.88	292.10	0.88	1.39
P3	79.00	79.00	14.85	11.84	265.42	85.33	32.44	8.73	545.20	5.87	366.69	0.61	2.34
P4	87.25	87.25	10.18	9.67	173.42	42.67	23.76	11.97	428.43	8.06	288.42	0.94	1.34
P5	100.25	100.25	13.78	11.71	235.58	69.33	29.08	9.84	556.65	6.51	368.31	0.71	2.12
P6	95.83	95.83	11.68	11.51	229.58	51.33	27.36	11.25	477.60	7.28	308.64	0.80	1.59
P7	95.92	95.92	11.18	10.84	202.92	44.00	24.30	11.59	465.81	7.58	304.62	0.85	1.51
P8	100.17	100.17	11.35	11.67	213.42	50.67	26.41	11.00	481.61	6.83	298.59	0.77	1.64
P9	92.25	92.25	12.42	11.17	196.92	44.92	25.48	11.29	468.76	7.42	308.07	0.80	1.56
P10	84.25	84.25	11.85	13.44	270.42	81.67	30.42	8.93	514.41	6.07	349.16	0.61	2.16
Mean	91.91	91.91	12.33	11.44	224.45	59.16	27.59	10.61	492.91	6.97	323.88	0.76	1.78

Cross combination	PH	EH	EL	EG	NSPC	CW	100-SW	PC	PY	OC	OY	TC	GY
P1 x P5	173.92	92.67	22.18	17.87	641.08	225.00	36.04	11.03	1277.84	7.36	851.87	0.74	4.34
P1 x P8	167.83	81.33	20.52	17.87	550.92	211.58	32.83	10.38	1307.08	6.92	871.80	0.66	4.72
P1 x P10	169.92	91.33	21.52	17.20	563.42	199.83	35.25	10.98	1259.84	7.53	863.95	0.75	4.31
P2 x P6	164.25	98.33	21.18	18.37	567.92	195.75	36.35	12.05	1340.72	8.13	903.70	0.84	4.17
P3 x P5	160.92	74.33	21.18	18.53	571.92	200.25	34.26	11.67	1356.44	7.64	888.38	0.81	4.36
P3 X P6	175.25	78.67	19.68	17.84	579.08	202.00	36.18	10.63	1315.79	7.11	879.26	0.70	4.64
P3 x P8	168.08	87.33	20.35	17.17	580.58	215.00	34.27	10.80	1344.97	7.18	894.49	0.71	4.67
P3 x P9	179.42	80.67	19.85	17.34	530.58	206.42	31.52	10.49	1312.42	7.00	876.19	0.68	4.69
P3 x P10	181.42	78.67	20.35	17.67	579.25	192.67	34.99	11.49	1347.31	7.58	889.20	0.77	4.40
P4 x P7	164.92	95.92	22.18	17.01	639.75	207.92	32.30	12.03	1345.62	8.07	902.99	0.91	4.19
P5 x P10	166.58	92.67	20.18	18.20	560.75	194.42	34.61	11.71	1384.01	7.76	917.54	0.81	4.43
Mean of 45 single cross hybrids	147.39	75.58	18.32	15.68	487.83	145.24	27.87	11.21	953.87	7.21	614.28	0.76	3.22

Checks	PH	EH	EL	EG	NSPC	CW	100-SW	PC	PY	OC	OY	TC	GY
DHM 105	149.75	82.33	17.18	14.53	459.25	122.75	27.11	8.82	668.44	3.98	301.07	0.40	2.84
Shaktiman-2	124.50	77.00	15.18	13.20	362.75	84.75	25.32	10.38	718.39	5.30	366.22	0.72	2.59

Note:- GP - Germi-nation (%), NDTG - No.of days taken for germination, SVI - Seedling vigour index, TVGP - Total vegetative growth period, DT - Days to 50% tasseling, TADP - Total anthers dehescence period, DS - Days to 50% silking, TPSA - Total period of silk appearance, DSD - Days to 50% silk drying, APP - Active pollination period, TGFP - Total grain filling period, TRGP - Total reproductive growth period, RVGP & RGP - Ratio of vegetative growth period and reproductive growth period. PH - Plant height (cm), EH - Ear height (cm), EL - Ear length (cm), EG - Ear girth (cm), NSPC - No.of seeds per cob, CW - Cob weight (g), 100-SW - 100 seed weight (g), PC - Protein content (%) PY - Protein yield (kg / ha), OC - Oil content (%), OY - Oil yield (kg / ha), TC - Tryptophan content (g / 16 g N), GY - Grain yield per plot (kg)

Table 3. Mean GCA Effects of 10 Quality Protein Maize Parental inbred lines over two locations (Hyderabad and Allahabad) and two seasons (*Kharif* 2003 and *Kharif* 2004).

Parent	GP	NDTG	SVI	TVGP	DT	TADP	DS	TPSA	DSD	APP	TGFP	TRGP	RVGP & RGP
P1	0.00	0.06	-136.08**	0.56**	0.62**	0.71**	0.53*	0.38**	0.88**	0.53**	1.78**	2.40**	-0.07**
P2	0.03	0.13**	71.80**	-0.41	-0.29	0.04	-0.29	-0.07	0.82**	-0.10**	0.35	-0.02	-0.01
P3	-0.15*	0.15**	-101.4**	0.54**	0.70**	0.58**	0.78**	0.51**	0.24	0.50**	2.60**	3.12**	-0.08**
P4	-0.03	0.08**	349.68**	-1.83**	-1.76**	-0.55**	-1.71**	-0.53**	-0.63**	-0.42**	-1.87**	-2.56**	0.06**
P5	-0.07	0.06	-113.35**	0.55*	0.61**	-0.06	0.47	0.10*	-0.73**	0.06*	0.32	0.43	-0.01
P6	-0.14	-0.06	129.00**	-0.59**	-0.65**	-0.11	-0.66*	0.13**	-0.46	0.03	0.13	0.13	-0.02**
P7	-0.02	-0.19**	237.86**	-0.98**	-1.16**	-0.59**	-0.87**	-0.63**	-0.75**	-0.62**	-2.55**	-3.24**	0.10**
P8	0.02	-0.24**	54.39**	-0.08	-0.30	-0.21**	-0.54*	0.08	-0.15	-0.02	-0.20	-0.11	0.00
P9	0.11	-0.09**	71.06**	-0.34	-0.43*	-0.24**	-0.68**	-0.30**	-0.05	-0.25**	-1.68**	-2.07**	0.06**
P10	0.25**	0.10*	-562.95**	2.56**	2.66**	0.43**	2.97**	0.34**	0.83**	0.29**	1.13**	1.92**	-0.02**
SE (gi)	0.12	0.04	8.59	0.23	0.22	0.07	0.29	0.04	0.26	0.04	0.23	0.25	0.01
SE (gi-gj)	0.17	0.06	12.8	0.34	0.34	0.1	0.43	0.06	0.39	0.05	0.34	0.37	0.02
Parent	PH	EH	EL	EG	NSPC	CW	100-SW	PC	PY	OC	OY	TC	GY
P1	6.54**	1.13	0.80**	0.42**	20.62**	14.01**	2.14**	-0.56**	88.35**	-0.44**	52.35**	-0.08**	0.44**
P2	0.44	1.87**	-0.03	0.11	-16.45**	-1.65	0.40	0.23**	-31.36**	0.14**	-21.99**	0.01**	-0.16**
P3	4.48**	-0.37	0.55**	0.62**	24.13**	21.26**	2.74**	-0.43**	133.4**	-0.22**	93.78**	-0.05**	0.54**
P4	-2.84**	-0.43	-0.99**	-0.89**	-33.88**	-17.04**	-2.27**	0.30**	-97.06**	0.21**	-64.76**	0.06**	-0.37**
P5	-0.74	2.35**	0.46**	0.13	5.30	5.02**	0.40	0.02	9.54	0.06	9.74*	0.00	0.01*
P6	-4.40	-3.00**	-0.17	-0.03	-2.91	-1.10	0.64**	0.19*	26.11**	0.11*	17.92**	0.02**	0.03**
P7	-2.23**	-1.76**	-0.38**	-0.78**	-22.58**	-13.40**	-2.22**	0.41**	-101.21**	0.28**	-64.94**	0.04**	-0.44**
P8	2.85**	-0.20	-0.02	0.02	8.77	-2.02	-1.27**	-0.05	9.16	-0.11*	1.34	-0.01**	0.05**
P9	-5.57**	-1.40**	-0.55**	-0.12	-9.61	-8.11**	-1.91**	0.12	-67.41**	0.06	-47.32**	0.01**	-0.23**
P10	1.47	-0.19	0.35*	0.53**	26.60**	3.01	1.32**	-0.23**	30.49**	-0.09	23.87**	-0.03**	0.14**
SE (gi)	0.87	0.44	0.16	0.14	5.05	2.1	0.29	0.09	5.95	0.12	4.02	1.68	0.02
SE (gi-gj)	1.29	0.66	0.23	0.21	7.53	3.14	0.43	0.12	8.87	0.18	5.99	2.51	0.02

Note:- GP - Germi-nation (%), NDTG - No.of days taken for germination, SVI - Seedling vigour index, TVGP - Total vegetative growth period, DT - Days to 50% tasseling, TADP - Total anthers dehescence period, DS - Days to 50% silking, TPSA - Total period of silk appearance, DSD - Days to 50% silk drying, APP - Active pollination period, TGFP - Total grain filling period, TRGP - Total reproductive growth period, RVGP & RGP - Ratio of vegetative growth period and reproductive growth period, PH - Plant height (cm), EH - Ear height (cm), EL - Ear length (cm), EG - Ear girth (cm), NSPC - No.of seeds per cob, CW - Cob weight (g), 100-SW - 100 seed weight (g), PC - Protein content (%) PY - Protein yield (kg / ha), OC - Oil content (%), OY - Oil yield (kg / ha), TC - Tryptophan content (g / 16 g N), GY - Grain yield per plot (kg)

Table 4. Mean SCA Effects of 11 best QPM single crosses over two locations (Hyderabad and Allahabad) and two seasons (*Kharif* 2003 and *Kharif* 2004).

Cross combination	GP	NDTG	SVI	TVGP	DT	TADP	DS	TPSA	DSD	APP	TGFP	TRGP	RVGP &RGP
P1 x P5	0.24	-0.68**	452.68**	-1.58*	-2.26**	1.73**	-2.55**	1.31**	-1.05	1.04**	7.95**	9.68**	-0.24**
P1 x P8	-0.48	-0.17	-318.97**	1.91*	1.74*	1.61**	1.71	1.01**	-0.95	1.18**	7.47**	9.88**	-0.20**
P1 x P10	-0.04	-0.48**	-170.22**	1.33	0.85	1.01**	-0.71	1.33**	-1.18	1.25**	3.81**	4.52**	-0.08*
P2 x P6	-0.21	0.54**	-135.55**	0.09	0.64	2.02**	1.06	2.71**	1.67*	2.07**	10.57**	13.39**	-0.32**
P3 x P5	0.23	-0.02	-186.59**	1.27	1.25	0.96**	1.11	1.38**	2.26**	1.42**	7.47**	8.87**	-0.17**
P3 X P6	-0.20	-1.66**	636.32**	-1.92**	-3.59**	1.40**	-2.76**	1.51**	-2.67**	1.17**	4.99**	6.67**	-0.19**
P3 x P8	-0.26	-0.61**	186.60**	-0.15	-0.76	1.23**	-1.55	1.23**	-1.65*	0.84**	5.32**	6.66**	-0.18**
P3 x P9	0.01	-0.78**	178.27**	-0.19	-0.98	1.41**	-0.75	1.47**	-2.42**	1.24**	5.13**	7.29**	-0.21**
P3 x P10	-0.06	-0.68**	-391.73**	2.20**	1.52*	1.30**	2.61**	1.36**	-2.29**	0.91**	5.32**	6.30**	-0.09**
P4 x P7	-0.50*	0.00	284.89**	-2.05**	-2.04**	3.59**	-2.40**	2.51**	1.08	2.42**	12.63**	16.30**	-0.52**
P5 x P10	-0.56*	-0.83**	278.88**	-0.14	-0.97	1.35**	-1.41	1.89**	-1.74**	1.46**	6.77**	7.99**	-0.18**
SE (S_{ij})	0.39	0.14	28.89	0.76	0.76	0.22	0.98	0.14	0.87	0.12	0.78	0.84	0.03
SE (S_{ij} - S_{ik})	0.58	0.21	42.46	1.11	1.12	0.32	1.43	0.21	1.28	0.17	1.14	1.23	0.05

Cross combination	PH	EH	EL	EG	NSPC	CW	100-SW	PC	PY	OC	OY	TC	GY
P1 x P5	30.81**	16.66**	3.70**	2.41**	175.23**	76.38**	5.67**	0.46	309.91**	0.56**	228.30**	0.05**	0.95**
P1 x P8	21.14**	7.88**	2.50**	2.52**	81.59**	70.00**	4.13**	-0.12	339.52**	0.31*	256.63**	-0.02	1.28**
P1 x P10	24.60**	17.87**	3.14**	1.35**	76.26**	53.23**	3.96**	0.66	270.95**	0.88**	226.24**	0.09**	0.78**
P2 x P6	30.91**	28.94**	4.15**	3.39**	147.33**	68.91**	7.49**	0.53*	475.92**	0.71**	346.30**	0.05**	1.35**
P3 x P5	19.88**	1.83	2.95**	2.88**	102.55**	44.38**	3.30**	0.97**	343.45**	0.63**	223.38**	0.09**	0.86**
P3 X P6	37.88**	11.51**	2.08**	2.35**	117.92**	52.25**	4.97**	-0.23	286.23**	0.04	206.09**	-0.03	1.12**
P3 x P8	23.46**	17.38**	2.59**	1.63**	107.74**	66.17**	4.96**	0.17	332.36**	0.35*	237.89**	0.00	1.13**
P3 x P9	43.22**	11.91**	2.62**	1.94**	76.12**	63.69*	2.87**	-0.30	376.37**	0.00	268.26**	-0.05**	1.43**
P3 x P10	38.17**	8.70**	2.22**	1.62**	88.57**	38.81**	3.10**	1.04**	313.37**	0.72**	210.06**	0.09**	0.78**
P4 x P7	32.69**	27.58**	6.32**	3.77**	256.27**	108.77**	8.97**	0.23	673.83**	0.42**	471.21**	0.06**	2.05**
P5 x P10	28.56**	19.98**	2.15**	2.63**	88.91**	56.80**	5.07**	0.81**	473.94**	0.63**	322.44**	0.07**	1.34**
SE (S_{ij})	2.91	1.48	0.52	0.47	16.99	7.07	0.96	0.28	23.85	0.20	16.96	0.02	0.03
SE (S_{ij} - S_{ik})	4.28	2.18	0.77	0.69	24.98	10.40	1.42	0.41	35.06	0.30	24.93	0.04	0.04

Note:- GP - Germi-nation (%), NDTG - No.of days taken for germination, SVI - Seedling vigour index, TVGP - Total vegetative growth period, DT - Days to 50% tasseling, TADP - Total anthers dehescence period, DS - Days to 50% silking, TPSA - Total period of silk appearance, DSD - Days to 50% silk drying, APP - Active pollination period, TGFP - Total grain filling period, TRGP - Total reproductive growth period, RVGP & RGP - Ratio of vegetative growth period and reproductive growth period, PH - Plant height (cm), EH - Ear height (cm), EL - Ear length (cm), EG - Ear girth (cm), NSPC - No.of seeds per cob, CW - Cob weight (g), 100-SW - 100 seed weight (g), PC - Protein content (%) PY - Protein yield (kg / ha), OC - Oil content (%), OY - Oil yield (kg / ha), TC - Tryptophan content (g / 16 g N), GY - Grain yield per plot (kg) environments through heterosis breeding and also exploited for the derivation of QPM inbred lines in segregating generations.

In conclusion, from the present investigation it could be inferred that the parents P_3 and P_1 were adjudged as best parents followed by P_{10} for grain yield, other yield contributing and growth parameters, while parents P_4, P_7 and P_2 for protein, oil and tryptophan content and the three crosses namely., P_4 x P_7, P_2 x P_6 and P_5 x P_{10} were found as good specific combiners for high grain yield and other yield contributing characters along with quality parameters *i.e.,* protein, oil and tryptophan content.

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