INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES
IJPAES
Volume-4, Issue-2, April-June-2014 ISSN 2231-4490

Coden : IJPAES www.ijpaes.com

Received: 21st Dec-2013 *Revised: 23rd Jan-2014* *Accepted: 26th Jan-2014*

Research article

COMBINING ABILITY AND GENE ACTION FOR MORPHOLOGICAL PARAMETERS IN QUALITY PROTEIN MAIZE (*Zea Mays* L.)

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ABSTRACT: Combining ability analysis was done using 45 F1 hybrids and their parents obtained from a diallel mating design for six morphological parameters. Both general and specific combining ability variances were highly significant for almost all the characters except anthesis-silking interval. Based on GCA effects the parents , P_4 - TQPM 34-1 and P_3- QPM 46-3 were early and contributed maximum favourable genes for maturity characters and P_3- QPM 46-3 and P_{10}-QPM 89E- were good general combiners for plant height and ear height while the crosses Viz., P_1 X P_9 and P_4 X P_9 for earliness and P_4 X P_6 and P_3 X P_6 for plant height and ear height are the best specific combiners, involving either both the parents or one of the parents as good general combiners. Hence, these crosses could be advanced further for isolation of transgressive segregants and also to develop good inbred lines. These crosses exhibited 15-20 % yield superiority over the best hybrid check.
Key words: Diallel, gca, sca, morphological parameters, Quality Protein Maize**.**

INTRODUCTION

Maize (*Zea mays* L.) has worldwide significance as food, feed and as a good source of starch, protein, fat, oil, sucrose in addition to some of the important vitamins and minerals. Genetic variability for most traits in maize is incredibly high and amenable to enhancements. Maize breeding programs mostly involve hybridization, evaluation and selection of desirable genotype(s). Combining ability has a prime importance in plant breeding as it provides information not only for the selection of desirable parents but also regarding the nature and magnitude of gene action. Diallel analysis [5] is widely used to determine combining ability, heterotic responses and patterns in maize populations; [2, 6]. It is useful to partition the total variation into GCA of the parents and SCA of the crosses. GCA is an average performance of a parent in a series of crosses and SCA designates those in which certain specific cross combinations perform relatively better or worse than would be expected on the basis of average performance of lines involved in a series of cross combinations. The GCA includes additive variance and additive × additive epistasis, while SCA is responsible for non-additive genetic variances. The comparison of GCA and SCA variance components provides an estimate of the predominance of additive or non-additive gene effects. Additive component of genetic variance is fixable through normal selection procedures, whereas, non-additive component is not fixable and its presence for controlling traits necessitates exploitation of hybrid vigour through heterosis breeding. The studies on gene action for various morphological parameters would be helpful in formulating suitable breeding methodology for the development of high yielding quality protein maize hybrids. Therefore, in the present investigation efforts were made by selecting ten elite QPM inbreds known for their good agronomic characters from the germplasm developed at Agricultural Research Station (Maize), Amberpet, Hyderabad, India to study the combining ability and gene action for various morphological parameters and to identify the parents with high GCA and single crosses with high SCA for morphological parameters.

MATERIALS AND METHODS

Ten promising elite QPM genotypes *viz.*, P_1-TQPM 178-1, P_2-PK (C103ae x B 73ae) B-3-6, P_3- QPM 46-3, P_4-TQPM 34-1, P_5-QPM 10-2, P_6-TQPM 42-1, P_7-TQPM 80-1, P_8-DMR 274-1, P_9-QPM 35-1 and P_{10}-QPM 89E-1 were mated in diallel fashion without reciprocals to obtain single crosses during *Kharif*, 2002.

The resultant 45 crosses along with ten parental lines and two standard checks *viz.*, Madhuri and Shaktiman-2 were evaluated at Rajendranagar and Palem during *kharif* and *rabi*, 2003 in Randomized Complete Block Design (RBD) with three replications. The plot size for each entry was a single row of five-meter length, with a spacing of 75 cm and 20 cm between rows and plants, respectively. Recommended cultural practices were adopted to maintain a healthy crop. Data were recorded on six morphological parameters *viz*., days to 50% flowering, days to 50% silking, anthesis-silking interval, days to maturity, plant height and ear height. The data on plant height and ear height were recorded on five randomly selected competitive plants in each plot, while the data on days to 50 per cent tasseling, days to 50 per cent silking, anthesis silking interval and days to maturity were recorded on plot basis. Days to 50 per cent tasseling and Days to 50 per cent silking were recorded by counting the number of days taken from the date of sowing to the date on which 50 per cent plants shed pollen and 50 per cent plants with silk emergence respectively. Anthesis - silking interval (days) was estimated as the number of days taken from days to 50 per cent tasseling to days to 50 per cent silking. Days to maturity was recorded as the number of days from the date of sowing to the date w the cobs in 50 per cent plants turned to brown. Plant height at maturity was measured from the base of the plant to tip of the tassel. Ear height measurement was taken from the base of the plant to the node of attachment of the upper most ear.

Data recorded on parents and their F_1s were subjected to combining ability analysis following the procedure proposed by Griffing (1956a)-Experimental Method-II and Model-I (Fixed effects) with the assumption that there were no reciprocal differences.

RESULTS AND DISCUSSION

The hybrids in general were high yielding, when compared to parents. Combining ability analysis revealed the importance of both additive and non-additive gene action in governing most of the characters but non-additive gene action was found to be predominant. Hence, recurrent selection was suggested to improve these characters.

The analysis of variance revealed significant differences among the genotypes for all the characters studied indicating the existence of sufficient variability in the material studied. The combining ability analysis revealed significant mean squares due to general and specific combining ability indicating that both additive and non-additive gene actions were important in the inheritance of all these characters except anthesis - silking interval. The relative importance of additive and non-additive gene action was reported by [8, 9]. They also reported the predominance of SCA for plant height and ear height (Table 1). The estimates of components of variance, σ^2 *gca* and σ^2 *sca* indicated the preponderance of non-additive gene action for the characters studied. The findings are in consonance with earlier reports for days to 50 per cent tasseling [12]; days to 50 per cent silking [7, 10, 13] , days to maturity and plant height [10, 13]; ear height [1, 10]; anthesis silking interval [3, 4].

The parental lines P_4 and P_3 possessed low mean values and were found to be good general combiners for days to 50 % tasseling, silking and maturity and thus, these parents contributed maximum favourable genes for earliness at all the four locations (Table 2). Hence they can be used as potential donors for earliness. The crosses P_1 X P_9, P_2X P_5 and P_4 X P_9 were the best specific combiners with significant negative *sca* effects for earliness (Table 3). Though these crosses were not having good general combiners in their parentage except P_4 and were the resultant of non-additive gene action, which can be improved through suitable population improvement in addition to utilising them in heterosis breeding.

Table 1: Analysis of variance for combining ability for morphological parameters in QPM at two locations over two seasons (Contd.)

Source of variation	df	Mean Sum of Squares											
		Days to 50 % tasseling				Days to 50 % silking				Anthesis-silking interval			
		Rajendranagar		Palem		Rajendranagar		Palem		Rajendranagar		Palem	
		Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
GCA	9	14.18**	24.90**	11.56**	11.93**	12.47**	26.70**	12.64**	10.97**	0.13NS	0.44NS	0.21NS	0.77**
SCA	45	10.99**	14.76**	10.38**	16.67**	11.15**	14.59**	9.86**	16.72**	0.08NS	0.38NS	0.38NS	0.20NS
ERROR	108	0.15	1.05	1.04	1.46	0.22	1.23	1.13	1.20	0.08	0.30	0.31	0.18
σ2gca		0.0127	0.0882	0.0874	0.1222	0.0188	0.1035	0.0949	0.1012	0.0070	0.0253	0.0264	0.0152
σ2sca		0.1438	0.9977	0.9891	1.3820	0.2122	1.1713	1.0734	1.1448	0.0794	0.2867	0.2984	0.1717
σ2gca/sca		0.0880	0.0880	0.0830	0.0884	0.0880	0.0880	0.0884	0.0883	0.0880	0.0880	0.0885	0.0885

* - Significant at 5 % level ** - Significant at 1 % level NS – Non significant

Analysis of variance for combining ability for morphological parameters in QPM at two locations over two seasons

Source of variation	df	Mean Sum of Squares											
		Days to maturity				Plant height				Ear height			
		Rajendranagar		Palem		Rajendranagar		Palem		Rajendranagar		Palem	
		Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
GCA	9	13.79**	21.57**	18.09**	11.42**	1218.58**	488.17**	602.61**	473.98**	254.11**	260.35**	253.42**	215.10**
SCA	45	9.98**	13.25**	11.38**	15.56**	461.90**	588.24**	512.67**	563.70**	188.27**	196.81**	133.19**	129.24**
ERROR	108	0.65	1.52	1.77	2.90	6.72	30.69	5.78	6.71	0.60	3.48	6.13	4.35
σ2gca		0.0548	0.1271	0.1484	0.2439	0.0505	2.5726	0.4850	0.5627	0.0505	0.2922	0.5139	0.3649
σ2sca		0.6198	1.4382	1.6789	2.7589	0.5718	29.1041	5.4864	6.3659	0.5718	3.3054	5.8137	4.1280
σ2gca/sca		0.0884	0.0880	0.0884	0.0884	0.0880	0.0880	0.0884	0.0883	0.0880	0.0884	0.0884	0.8830

* - Significant at 5 % level ** - Significant at 1 % level NS – Non significant

Table 2: Estimates of GCA effects of ten parents for morphological parameters in QPM at two locations over two seasons (Contd.)

Parents	Days to 50 % tasseling				Days to 50 % silking				Anthesis-silking interval			
	Rajendranagar		Palem		Rajendranagar		Palem		Rajendranagar		Palem	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
P_1	-0.33**	-1.15**	-0.33	-0.22	-0.16	-1.17**	-0.35	-0.19	0.17*	-0.02	-0.02	0.02
P_2	-0.30**	-0.40	-0.32	-0.30	-0.22	-0.50	-0.52	-0.11	0.08	-0.10	0.07	0.19
P_3	-0.52**	-0.73**	-0.17	0.03	-0.44**	-0.50	-0.27	-0.19	0.08	0.23	-0.10	-0.23
P_4	-2.38**	-2.65**	-2.08**	-2.22**	-2.27**	-3.00**	-2.18**	-2.36**	0.11	-0.35*	-0.10	-0.14
P_5	0.76**	1.27**	0.17	-0.13	0.70**	1.08**	-0.02	-0.11	-0.06	-0.18	-0.18	0.02
P_6	1.06**	2.18**	1.00**	-0.22	0.92**	2.17**	1.15**	0.14	-0.14	-0.02	0.15	0.36**
P_7	-0.19	-0.23	0.08	1.45**	-0.19	0.00	0.15	1.22**	0.00	0.23	0.07	-0.23
P_8	0.95**	0.18	1.42**	0.78*	0.87**	0.42	1.57**	0.72*	-0.08	0.23	0.15	-0.06
P_9	1.31**	1.77**	0.83**	1.03**	1.26**	1.75**	0.65*	0.69*	-0.06	-0.02	-0.18	-0.34**
P_{10}	-0.36**	-0.23	-0.33	-0.22	-0.47**	-0.25	-0.18	0.19	-0.11	-0.02	0.15	0.41**
SE(gi)	0.113	0.30	0.29	0.34	0.15	0.32	0.28	0.32	0.00	0.17	0.17	0.14
SE(gi-gj)	0.17	0.44	0.44	0.52	0.20	0.48	0.46	0.46	0.14	0.22	0.28	0.17

* - Significant at 5 % level ** - Significant at 1 % level NS – Non significant

Estimates of GCA effects of ten parents for morphological parameters in QPM at two locations over two seasons

Parents	Days to maturity				Plant height				Ear height			
	Rajendranagar		Palem		Rajendranagar		Palem		Rajendranagar		Palem	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
P_1	-0.17	-1.08**	-0.25	-0.60	4.89**	-0.76	-2.75**	-4.51**	-0.18	-0.93	4.05**	3.16**
P_2	-0.26	-0.42	-0.83*	-0.27	5.19**	-6.34**	-2.51**	-0.55	0.43*	-1.41**	1.01	0.98
P_3	-0.59**	-0.67*	-0.42	-0.10	19.53**	12.61**	9.62**	8.07**	11.18**	10.98**	5.76**	5.52**
P_4	-2.12**	-2.67**	-2.50**	-2.27**	9.81**	-0.87	1.29	0.50	3.15**	4.15**	-4.12**	-3.77**
P_5	1.13**	1.17**	-0.08	-0.10	-6.33**	0.77	-3.48**	-0.45	-3.91**	-4.77**	-0.93	-1.09
P_6	1.05**	1.75**	1.17**	0.23	-15.33**	-8.45**	-6.00**	-4.60**	-4.82**	-4.82**	-4.80**	-4.13**
P_7	-0.78**	0.25	0.42	1.23**	-3.44**	-7.12**	-5.07**	-5.47**	-3.10**	-2.85**	-4.24**	-4.25**
P_8	1.16**	0.08	1.92**	0.73	-7.44**	1.02	7.13**	5.71**	0.12	-0.13	0.99	1.31*
P_9	0.97**	1.67**	1.00**	0.90	-0.31	4.99**	-9.54**	-8.97**	-0.16	0.34	-5.06**	-4.57**
P_{10}	-0.39	-0.08	-0.42	0.23	-6.56**	4.13**	11.32**	10.26**	-2.71**	-0.57	7.35**	6.85**
SE(gi)	0.22	0.36	0.38	0.48	0.22	1.60	0.69	0.74	0.22	0.53	0.72	0.60
SE(gi-gj)	0.35	0.53	0.57	0.73	0.00	2.39	1.03	0.50	0.33	0.80	1.06	0.90

* - Significant at 5 % level ** - Significant at 1 % level NS – Non significant

In respect of plant height and ear height P_3, P_4 and P_{10} parents were found to be taller at all the locations but only P_3 and P_{10} possessed significant *gca* effects (Table 2). An examination of *sca* effects of the crosses at all the locations indicated that P_4 X P_6 and P_3 X P_6 in addition to P_2 X P_3 were best specific crosses for ear height (Table 3). These crosses were not having good general combiners in their parentage and were the resultant of non-additive gene action. The relative importance of non-additive gene action for plant height was also reported earlier by Vasal, [13] and Singh and Singh [11]. The flowering data indicated that P_4 and P_3 parents were early and contributed maximum favourable genes for maturity characters. It was also found that P_3 and P_{10} were good general combiners for plant height and ear height. They were also good combiners for most of the other characters and hence can be given the status of good general combiners. Among the crosses P_1 X P_9 and P_4 X P_9 were early and possessed significant *sca* effects for earliness. The cross combinations P_4 X P_6 and P_3 X P_6 were the best specific crosses for plant height and ear height involving both the parents or one of the parents as good general combiners (Table 4). Hence these crosses could be advanced further for the isolation of transgressive segregants and also to develop good inbred lines. These crosses exhibited 15-20 % yield superiority over the best hybrid check. Lines with higher GCA effects can be used more effectively in the development of synthetic variety whereas SCA effects could help in the selection of parental material for hybridization, when high yielding specific combinations are desired.

Table 3: Estimates of *sca* effects of 45 crosses for morphological parameters in QPM at two locations over two seasons (Contd..)

Cross	Days to 50 % tasseling				Days to 50 % silking				Anthesis-silking interval			
	Rajendranagar		Palem		Rajendranagar		Palem		Rajendranagar		Palem	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
P_1 X P_2	-1.28**	-0.80	-0.81	0.73	-1.16**	-0.06	-0.24	1.09	0.11	0.73	0.57	0.36
P_1 X P_3	-1.05**	-0.46	-0.23	-1.60	-1.27**	-1.06	-0.49	-1.82	-0.22	-0.60	-0.27	-0.22
P_1 X P_4	2.81**	4.45**	3.69**	2.65*	2.56**	3.44**	3.42**	2.34*	-0.25	-1.02*	-0.27	-0.31
P_1 X P_5	-1.66**	-1.46	-3.56**	-4.43**	-1.74**	-1.64	-2.74**	-3.91**	-0.08	-0.18	0.82	0.53
P_1 X P_6	-0.64	3.62**	-0.39	1.65	-0.30	3.27**	-0.91	2.84**	0.34	-0.35	-0.52	1.19**
P_1 X P_7	-0.72*	-3.96**	0.52	-1.02	-0.86*	-3.56**	1.09	-1.24	-0.14	0.40	0.57	-0.22
P_1 X P_8	2.81**	-3.38**	1.19	3.65**	2.42**	-2.98**	0.67	3.26**	-0.39	0.40	-0.52	-0.39
P_1 X P_9	-6.22**	-6.96**	-5.23**	-5.60**	-6.30**	-7.31**	-5.41**	-5.71**	-0.08	-0.35	-0.18	-0.11
P_1 X P_{10}	-2.22**	-2.96**	-3.06**	-3.35**	-2.24**	-3.31**	-2.58**	-3.21**	-0.03	-0.35	0.48	0.14
P_2 X P_3	-5.41**	-6.21**	-4.98**	-6.52**	-5.55**	-6.73**	-4.33**	-6.91**	-0.14	-0.52	0.65	-0.39
P_2 X P_4	-2.55**	-2.30*	-1.06	-2.27*	-2.38**	-2.23*	-1.41	-1.74	0.17	0.07	-0.35	0.53
P_2 X P_5	-5.03**	-5.21**	-5.31**	-7.35**	-5.36**	-5.31**	-5.58**	-6.99**	-0.33	-0.10	-0.27	0.36
P_2 X P_6	2.34**	0.87	2.86**	5.73**	1.76**	1.61	2.26*	5.76**	-0.58*	0.73	-0.60	0.03
P_2 X P_7	2.25**	2.29*	2.77**	3.07**	2.53**	2.77**	2.26*	2.68**	0.28	0.48	-0.52	-0.39
P_2 X P_8	-4.89**	-4.13**	-3.56**	-3.27**	-5.19**	-4.64**	-3.16**	-3.82**	-0.30	-0.52	0.40	-0.56
P_2 X P_9	2.09**	2.29*	1.02	-0.52	2.76**	2.02*	0.76	-0.80	0.67*	-0.27	-0.27	-0.28
P_2 X P_{10}	5.09**	6.29**	6.19**	6.73**	5.48**	6.02**	5.59**	6.70**	0.39	-0.27	-0.60	-0.03
P_3 X P_4	5.34**	7.04**	5.52**	7.40**	4.84**	6.77**	4.34**	7.34**	-0.50	-0.27	-1.18*	-0.06
P_3 X P_5	2.20**	3.12**	3.27**	5.32**	2.87**	3.69**	3.17**	6.09**	0.67*	0.57	-0.10	0.78*
P_3 X P_6	-1.11**	-0.80	-0.56	0.40	-1.36**	0.61	-0.99	-0.16	-0.25	1.40**	-0.43	-0.56
P_3 X P_7	-2.19**	-3.38**	-2.64**	-4.27**	-2.24**	-3.23**	-2.99**	-4.24**	-0.05	0.15	-0.35	0.03

* - Significant at 5 % level ** - Significant at 1 % level NS – Non significant

Estimates of *sca* effects of 45 crosses for morphological parameters in QPM at two locations over two seasons

	Days to maturity				Plant height				Ear height			
	Rajendranagar		Palem		Rajendranagar		Palem		Rajendranagar		Palem	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
$P_1 X P_2$	-1.55*	0.41	-0.64	1.85	10.58**	23.42**	26.33**	25.67**	19.37**	18.81**	10.46**	10.85**
$P_1 X P_3$	0.45	-1.34	-2.06	-1.32	-14.08**	6.14	0.24	1.75	10.62**	10.08**	3.05	3.32
$P_1 X P_4$	2.98**	2.66*	4.02**	2.85	-20.03**	-45.38**	12.90**	14.42**	-28.02**	-25.08**	5.09*	1.80
$P_1 X P_5$	-1.27	-2.17	-2.39	-3.32*	-0.56	-53.69**	11.03**	10.27**	-10.96**	-10.50**	5.87*	6.13**
$P_1 X P_6$	-0.52	3.24**	0.36	1.35	19.78**	-6.47	14.45**	9.72**	-6.04**	-8.11**	7.24**	8.06**
$P_1 X P_7$	0.98	-3.26**	2.11	-1.65	8.56**	4.20	22.79**	24.39**	-4.10**	-4.75**	11.65**	12.48**
$P_1 X P_8$	3.04**	-2.09	0.61	2.85	-18.11**	16.39**	12.66**	9.11**	1.01	-2.47	10.41**	9.53**
$P_1 X P_9$	-6.44**	-6.67**	-5.48**	-5.32**	24.08**	22.76**	-12.74**	-11.42**	13.96**	17.39**	-8.93**	-9.40**
$P_1 X P_{10}$	-4.41**	-2.92**	-2.06	-3.65*	10.67**	26.95**	10.79**	6.86**	13.51**	8.64**	6.26**	6.08**
$P_2 X P_3$	-5.13**	-6.01**	-5.48**	-5.65**	43.94**	16.39**	4.90*	2.89	3.68**	6.89**	0.62	0.59
$P_2 X P_4$	-1.60*	-3.01**	-0.39	-1.48	-16.00**	27.87**	30.76**	30.66**	6.71**	6.72**	17.74**	16.98**
$P_2 X P_5$	-6.85**	-4.84**	-6.81**	-6.65**	-0.53	-0.11	10.79**	24.41**	4.10**	4.97**	8.38**	8.30**
$P_2 X P_6$	1.23	1.58	2.94*	6.02**	-10.86**	-10.55*	-24.49**	-27.54**	-16.99**	-16.97**	-10.52**	-11.87**
$P_2 X P_7$	3.40**	2.08	1.69	2.02	6.92**	-12.22*	14.42**	13.13**	2.96**	-0.61	9.99**	10.46**
$P_2 X P_8$	-5.21**	-3.76**	-3.81**	-3.48*	-3.42	19.64**	-0.31	-1.55	13.07**	15.67**	0.42	1.10
$P_2 X P_9$	2.31**	1.66	1.11	-1.65	10.44**	18.67**	-43.48**	-45.18**	0.68	-3.81*	-20.49**	-19.22**
$P_2 X P_{10}$	5.67**	6.41**	5.52**	6.02**	19.03**	-7.13	21.62**	20.70**	6.90**	6.44**	12.30**	12.56**
$P_3 X P_4$	2.73**	6.24**	4.19**	6.35**	-1.00	-25.41**	6.77**	7.64**	1.96**	-4.00*	2.09	0.44
$P_3 X P_5$	1.48*	4.41**	2.77*	6.18**	6.14*	7.95	19.00**	15.79**	-6.65**	-8.42**	-1.41	-0.33
$P_3 X P_6$	-2.44**	-0.17	-1.48	-0.15	4.14	-16.16**	48.82**	47.14**	-6.40**	-2.36	23.63**	22.60**
$P_3 X P_7$	-0.94	-3.67**	-2.73*	-4.15**	1.58	10.84*	-1.77	1.32	12.54**	10.33**	-6.79**	-5.07**
$P_3 X P_8$	1.45	3.49**	4.77**	4.35**	16.58**	-28.97**	7.63**	8.63**	-1.02	-2.72	12.97**	13.57**
$P_3 X P_9$	3.65**	0.91	2.69*	-0.82	19.78**	-11.27*	10.53**	11.31**	8.60**	7.81**	16.00**	16.14**
$P_3 X P_{10}$	-1.66*	-2.34*	-2.89*	-3.15*	15.03**	4.92	-6.37**	-11.02**	6.15**	-1.28	-2.38	-1.97
$P_4 X P_5$	-0.33	-0.59	1.86	1.35	43.53**	24.42**	-37.37**	-46.44**	17.04**	11.42**	-5.39*	-4.95*
$P_4 X P_6$	1.09	-3.17**	-0.39	-0.98	-12.81**	56.98**	3.65	1.41	27.29**	28.81**	-8.92**	-1.72
$P_4 X P_7$	-1.08	1.33	-2.64*	-2.98	18.97**	25.98**	-0.31	0.38	0.23	-3.50*	-1.78	-2.39
$P_4 X P_8$	-1.35	-1.51	-3.14*	-0.48	26.97**	24.17**	-15.54**	-10.00**	16.68**	18.11**	-7.41**	-7.15**
$P_4 X P_9$	-4.16**	-4.09**	-6.23**	-1.65	-13.17**	-13.80**	4.29	5.97*	11.62**	11.97**	5.17*	4.33*
$P_4 X P_{10}$	1.20	-0.34	0.19	-5.98**	15.42**	-24.94**	3.99	5.55*	-0.15	13.89**	-0.64	-0.99
$P_5 X P_6$	1.17	-0.01	3.19**	-3.15*	24.67**	17.01**	8.88**	37.26**	21.35**	11.72**	1.35	0.41
$P_5 X P_7$	-3.33**	-5.51**	-3.06*	2.85	-12.89**	47.01**	11.93**	7.73**	13.29**	19.42**	8.79**	10.33**
$P_5 X P_8$	3.06**	2.66*	0.44	-5.65**	-2.89	14.20**	2.22	1.15	-0.60	12.03**	-9.37**	-9.02**
$P_5 X P_9$	0.92	3.08**	4.36**	1.18	-41.36**	11.23*	14.13**	10.02**	-0.65	0.22	11.02**	11.25**
$P_5 X P_{10}$	1.62*	1.83	0.77	6.85**	-28.11**	0.42	-7.07**	-14.60**	-13.77**	-12.19**	3.14	3.53
$P_6 X P_7$	-3.24**	-2.09	-2.31	0.52	17.11**	3.23	29.98**	27.38**	-7.46**	-4.19*	7.37**	5.77**
$P_6 X P_8$	0.81	0.08	1.19	-3.98*	-10.22**	-4.91	-12.69**	-20.50**	4.98**	3.75*	7.23**	7.01**
$P_6 X P_9$	-0.99	3.49**	3.11*	1.85	-34.36**	-9.55	-45.32**	-45.73**	-10.40**	-11.39**	-19.11**	-17.22**
$P_6 X P_{10}$	-1.63*	-3.76**	-2.48*	-2.48	-4.78*	-9.36	11.28**	11.65**	-12.18**	-13.47**	0.61	0.47
$P_7 X P_8$	2.65**	1.58	2.94*	1.02	-14.44**	-36.58**	-11.78**	-14.83**	2.93**	1.78	-12.39**	-11.67**

* - Significant at 5 % level ** - Significant at 1 % level NS – Non significant

Table 4: *Per se* performance, *gca* and *sca* effects of superior crosses for morphological parameters in QPM at two locations over two seasons

Character	Cross	*Per se* performance of F_1	*Per se* performance of parents		*sca* effect	*gca* effects	
			Parent 1	Parent 2		Parent 1	Parent 2
Days to 50% Tasseling	$P_2 X P_3$	54.58	62.92	59.42	-5.41**	-0.30**	-0.52**
	$P_4 X P_9$	55.42	57.92	65.67	-4.46**	-2.65**	1.77**
	$P_2 X P_5$	55.50	62.92	62.92	-5.21**	-0.40	1.27**
Days to 50% Silking	$P_2 X P_3$	56.92	65.50	62.08	-5.55**	-0.22	-0.44**
	$P_2 X P_5$	57.75	65.50	65.00	-5.36**	-0.22	0.70**
	$P_1 X P_9$	57.92	67.00	67.67	-6.30**	-0.16	1.26**
Anthesis silking interval	$P_1 X P_4$	1.75	2.50	2.17	-0.25**	0.17*	0.11
	$P_3 X P_4$	1.83	2.67	2.17	-0.50*	0.08	0.11
	$P_5 X P_8$	2.00	2.08	3.33	-0.16*	-0.06	-0.08
Days to maturity	$P_2 X P_3$	89.25	97.58	95.50	-6.01**	-0.42	-0.67*
	$P_2 X P_5$	89.50	97.58	97.25	-4.84**	-0.42	1.17**
	$P_1 X P_9$	90.33	98.50	100.25	-6.67**	-1.08**	1.67**
Plant height	$P_2 X P_3$	192.39	134.38	159.90	3.68**	0.43*	11.18**
	$P_3 X P_5$	186.26	159.90	142.27	-6.65**	7.18**	-3.91**
	$P_3 X P_6$	188.80	159.90	135.74	-6.40**	11.18**	-4.82**
Ear height	$P_3 X P_9$	88.72	69.44	75.33	2.09**	5.76**	-5.06**
	$P_1 X P_2$	87.22	59.48	53.94	10.46**	4.05**	1.01
	$P_3 X P_8$	85.23	69.44	67.45	12.97**	5.76**	0.99

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