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Combining Ability for Yield, Yield Attributes and Protein Content in Maize (*Zea mays* L.)

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ABSTRACT

Combining ability studies were conducted using 10 parents and their 45 hybrids obtained from a half-diallel mating for eleven grain yield and yield components over two locations (Hyderabad and Palem) and two seasons (*kharif,* 2002 and *rabi,* 2002-03). The studies revealed significant *GCA* and *SCA* effects for all the traits. The parental lines P_{8-} and P_9 were early and contributed maximum favourable genes for maturity characters. P_8 and P_9 for plant height and ear height, P_1, P_3 and P_8 for ear length, P_2 and P_8 for ear girth were the good general combiners. Considering the two locations and two seasons, P_2 and P_8 contributed more useful genes for number of kernel rows per ear and number of kernels per row. Parents P_1, P_2, P_8 and P_{10} for grain yield and P_4, P_5 and P_6 for protein content turned out to be good general combiners. Among the crosses, P1 X P8, P2 X P5, P2 X P8, P2 X P9, P4 X P6, P4 X P7, P5 x P7 and P6 x P7 were the best specific crosses for grain yield and four crosses *viz*., P3 X P5, P3 X P9, P4 X P9 and P4 x P10 turned out to be good specific combiners for protein content.

Key words : Combining ability, Locations and seasons, Maize, Protein content, Yield.

Maize (*Zea mays* L.) is one of the most important cereal crops in the world next to rice and wheat. It occupies a prominent position in global agriculture. Maize owes its importance to the grain (seed) meant for human consumption, poultry feed, live stock feed and green fodder to animals. To establish a sound basis for any breeding programme aimed at achieving higher yield, breeders must have information on the nature of combining ability of parents, their behaviour and performance in hybrid combination. Such knowledge of combining ability is essential for selection of suitable parents for hybridization and identification of promising hybrids for the development of improved varieties. General combining ability (*gca*) as defined by Sprague and Tatum (1942) is the average performance of a genotype in hybrid combination while specific combining ability (*sca*) as those cases in which certain combinations perform relatively better or worse than would be expected on the basis of the average performance. Falconer (1989) observed that *gca* is directly related to the breeding value of the parent and is associated with additive genetic effects, while *sca* is associated with non-additive such as dominance, epistatic and genotype x environment interaction effects.

Estimate of combining ability using diallel-mating design has been widely used to provide information on the performance of parental lines and facilitate in determination of the type of gene action controlling particular character, which ultimately helps the breeder to formulate suitable breeding programme in exploiting heterosis for higher yields. Keeping in view the above, the present experiment was conducted to investigate on combining ability of parents and crosses and development of single cross hybrids for dent and flint type.

MATERIAL AND METHODS

The experimental material comprised of ten promising elite genotypes *viz.,* P_1, P_3, P_5, P_7 and P_9 lines are of flint grain type and the remaining five lines P_2, P_4, P_6, P_8 and P_{10} are of dent grain type and 45 single crosses obtained by diallel mating of parental lines without reciprocals. The details of parental lines are given below:

Reciprocal crosses were avoided presuming absence of cytoplasmic influence in the experiemental material. The single crosses, along with parents and two checks were evaluated during *kharif,* 2002 and *rabi,* 2002-03 at Hyderabad and

Palem in Complete Randomized Block Design with three replications. The plot size of each entry was a single row of five metre length, with a spacing of 75 cm and 20 cm between inter row and intra rows respectively. Initially two to three seeds per hill were sown and after germination, the population was thinned out to a single seedling per hill. Border rows were planted to eliminate the border effect. Usual recommended package of practices and cultural practices were adopted to maintain a good crop. The data were recorded on days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, 100 kernel weight, grain yield per plot and protein content. In the present investigation the combining ability analysis was worked out according to method-II, model-I (Fixed effects model) given by Griffing (1956).

RESULTS AND DISCUSSION

The analysis of variance of Randomized Complete Block Design (RCBD) with respect to eleven characters studied during *kharif* and *rabi* seasons at Hyderabad and Palem (Table 1) revealed that the mean sum of squares of genotypes at two locations *viz.,* Hyderabad and Palem and two seasons (*kharif* and *rabi*) were found to be significant for yield and yield contributing characters. The pooled analysis of variance for all the eleven quantitative characters over 2 locations *viz.,* Hyderabad and Palem during 2 seasons *viz., kharif,* 2002 and *rabi* 2002-03 (Table 2) revealed significant differences among the genotypes for all the traits, which indicates the existence of sufficient variation in the material. Sundararajan and Kumar (2011) reported existence of variability for proceeding for hybridization. Combining ability analysis revealed importance of non-additive gene action for most of the traits. Hence, recurrent selection was suggested to improve these characters (Alam *et al.*, 2008). The mean sum of squares for replications was found to be non-significant for all the traits studied. The mean sum of squares for seasons was found to be significant for all the characters barring number of kernel rows per ear and protein content, while for locations significant difference was found for all the characters except for days to 50 per cent tasselling, number of kernel rows per ear and protein content.

The interaction effects *i.e.,* seasons x locations were found to be significant for days to 50 per cent tasseling, plant height, ear height, ear girth, number of kernels per row and grain yield. The seasons x genotypes interaction was found to be significant in respect of all the characters except days to 50 per cent silking, number of kernel rows per ear and protein content. The interaction between locations x genotypes was found to be significant for all the traits barring protein content. While seasons x locations x genotypes interaction was found to be significant in respect of plant height, ear height, ear girth, number of kernels per row, 100 kernel weight and grain yield.

General combining ability is the pre breeding value of a parental line. The parental lines, P_8 and P_9 (Table 3) were early flowering and turned out to be good general combiners for days to 50 per cent tasselling, days to 50 per cent silking and contributed maximum favourable genes for earliness at two locations and in two seasons. Thus, they can be used as potential donors for inducing

S. No.	Parent	Pedigree	Grain colour and texture
P_1	HOL P11	HOL P11 – 2-3-1-1-1-1	Orange Yellow, flint
P_2	BQL 74	BQL 74 – 1-2-1-3-1-1	Yellow dent
P_3	BQL 83	BQL 83 – 1-1-1-1-2-1	Orange Yellow, flint
P_4	QPM 47	QPM 47 – 3-1-1-2-1-1	Yellow dent
P_5	BQL 102	BQL 102 – 2-1-1-1-1-1	Orange Yellow, flint
P_6	DMR 332	DMR 332 – 1-2-1-1-x-1-1	Yellow dent
P_7	BQL 68	BQL 68 – 1-2-1-1-1-1	Orange Yellow, flint
P_8	DMR 201	DMR 201 – 1-3-1-x-1-1-1	Yellow dent
P_9	Shakti 21	Shakti 21 – 1-1-1-3-1-1	Orange Yellow, flint
P_{10}	BQL 97	BQL 97 – 1-2-1-1-1-1	Yellow dent

Table 1. Analysis of variance from RBD for grain yield and yield components in maize.

Source of variation	d.f.	Mean sum of squares for										
		Days of 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels row / ear	No. of kernels / row	100 kernel weight (g)	Grain yield / plot (kg)	Protein content (%)
Kharif 2002, Rajendranagar												
Replications	2	1.174	1.176	2.261	2.623	0.153	0.090	1.472	0.288	0.122	0.0001	0.806
Genotypes	54	12.692**	12.186**	2008.486**	387.717**	14.592**	4.981**	4.468**	98.741**	49.347**	1.561**	2.187**
Error	108	1.867	1.718	2.791	3.285	0.986	0.109	0.991	2.031	0.714	0.057	0.824
CV (%)		2.290	2.118	1.291	3.503	6.202	2.341	6.793	3.882	3.024	10.943	7.967
Kharif 2002, Palem												
Replications	2	0.030	0.254	5.825	0.290	0.187	0.343	1.024	0.074	0.132	0.002	0.001
Genotypes	54	15.555**	14.345**	1614.023**	495.306**	14.093**	2.458**	4.187**	115.478**	50.307**	1.279**	2.224**
Error	108	1.277	2.045	5.966	5.105	0.368	0.238	0.431	1.220	1.616	0.010	0.078
CV (%)		1.884	2.305	2.031	3.775	4.268	3.883	4.515	3.339	4.861	3.384	3.979
Rabi 2002-03, Rajendranagar												
Replications	2	5.258	0.439	8.000	1.826	0.731	0.685	0.293	15.296	0.691	0.001	0.043
Genotypes	54	12.186**	11.818**	1845.722**	392.983.**	12.997**	6.130**	4.468**	94.596**	57.989**	1.234**	2.198**
Error	108	2.810	4.825	8.944	7.299	0.273	0.260	1.772	5.068	0.791	0.012	0.019
CV (%)		2.491	3.154	2.130	3.911	2.938	3.217	9.084	5.540	2.685	1.655	3.075
Rabi 2002-03, Palem												
Replications	2	5.883	0.157	0.645	22.254	0.006	0.243	1.164	8.798	1.857	1.279	0.051
Genotypes	54	9.339**	8.468**	1806.722**	479.555**	13.714**	3.182**	4.097**	80.084**	66.767**	1.316**	2.158**
Error	108	1.928	1.275	6.840	7.865	0.183	0.211	2.497	3.244	0.905	0.497	0.026
CV (%)		2.068	1.628	1.931	4.124	2.670	3.142	10.890	4.795	3.031	1.942	2.050

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

Table 2. Pooled analysis of variance for grain yield and yield components involving 55 genotypes, 2 seasons and 2 locations in maize

Source of variation	d.f.	Mean sum of squares for										
		Days of 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels row / ear	No. of kernels / row	100 kernel weight (g)	Grain yield / plot (kg)	Protein content (%)
Replications	2	0.320	0.265	16.172	6.220	0.067	0.530	0.825	13.745	2.600	0.024	0.037
Seasons	1	8990.992**	9378.956**	28197.775**	26157.701**	526.461**	598.622**	0.068	2910.618**	4464.630**	97.193**	0.059
Locations	1	1.319	1.210	8211.157**	2236.634**	513.637**	322.246**	2.541	1846.666**	516.266**	18.557**	0.001
Genotypes	54	40.390**	37.384**	6704.660**	1336.118**	51.514**	12.255**	14.119**	328.611**	168.056**	4.534**	8.761**
Seasons x Locations	1	10.704*	7.128	696.867**	3730.104**	0.156	3.898**	0.076	12.242*	-0.678	3.117**	0.016
Seasons x Genotypes	54	3.327**	3.229	41.917**	104.243**	0.759**	0.576**	0.370	19.710**	25.790**	0.338**	0.002
Locations x Genotypes	54	3.358**	3.483*	477.842**	229.948**	2.529**	3.490**	2.361**	24.746**	17.708**	0.311**	0.001
Seasons x Locations x Genotypes	54	2.696	2.719	50.156**	85.251**	0.594	0.431**	0.370	15.828**	12.855**	0.208**	0.002
Error	438	1.998	2.440	6.099	5.903	0.451	0.205	1.376	2.900	0.993	0.065	0.237

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

Table 2. Pooled analysis of variance for grain yield and yield components involving 55 genotypes, 2 seasons and 2 locations in maize

Source of variation	d.f.	Mean sum of squares for										
		Days of 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels row / ear	No. of kernels / row	100 kernel weight (g)	Grain yield / plot (kg)	Protein content (%)
Kharif 2002, Rajendranagar												
gca	9	6.922**	6.107**	148.240**	93.277**	0.828**	1.933**	1.274**	10.144**	19.072**	0.324**	0.734**
sca	45	3.691**	3.652**	773.745**	136.431**	5.671**	1.605**	1.532**	37.467**	15.924**	0.559**	0.728**
Error	108	0.622	0.572	0.930	1.095	0.328	0.036	0.330	0.677	0.238	0.019	0.274
Kharif 2002, Palem												
gca	9	5.814**	5.166**	90.607**	20.496**	0.635**	0.740**	1.742**	9.537**	21.752**	0.249**	0.737**
sca	45	5.059**	4.704**	627.488**	194.023**	5.510**	0.835**	1.326**	44.282**	15.772**	0.462**	0.742**
Error	108	0.4257	0.681	1.988	1.702	0.123	0.079	0.143	0.407	0.538	0.003	0.026
Rabi 2002-03, Rajendranagar												
gca	9	5.051**	5.648**	138.070**	24.181**	0.541**	1.766**	1.274**	30.296**	18.250**	0.194**	0.725**
sca	45	3.864**	3.597**	710.674**	152.357**	5.090**	2.099**	1.532**	31.779**	19.545**	0.454**	0.734**
Error	108	0.936	1.608	2.981	2.433**	0.091	0.086	0.590	1.689	0.263	0.004	0.006
Rabi 2002-03, Palem												
gca	9	5.337**	4.477**	77.088**	22.092**	0.643**	1.262**	2.207**	5.922**	28.313**	0.161**	0.711**
sca	45	2.668**	2.491**	707.270**	187.403**	5.356**	1.020**	1.197**	30.849**	21.043**	0.494**	0.721**
Error	108	0.642	0.425	2.280	2.621	0.061	0.070	0.783	1.081	0.301	0.061	0.008

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

Table 4. Estimation of general combining ability effects of parents for grain yield and yield components

Entry No.	Days of 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels row / ear	No. of kernels / row	100 kernel weight (g)	Grain yield / plot (kg)	Protein content (%)
***Kharif* 2002, Hyderabad**											
P_1	-1.2667**	-1.2333**	3.9167**	-0.7500**	0.3267*	0.2750**	-0.4333**	-1.0667**	2.2593**	0.0550	-0.1320
P_2	0.6500**	0.6000**	-0.2500	-0.0833	0.2433	0.6250**	0.4000*	2.0167**	-1.1032**	0.1344**	-0.2770
P_3	0.6500**	0.6000**	3.91467**	4.6667*	0.1933	-0.1083**	0.0667	0.0167	0.6477**	0.0885*	0.1913
P_4	-0.3500**	-0.2333	0.5833**	-0.7500**	-0.0400	-0.0833	-0.4333**	-0.7333**	0.7457**	-0.2138**	0.2247
P_5	1.3167**	1.2667**	0.1667	-4.5000**	0.1233	-0.5000**	0.2667	-0.0667	-0.2107	-0.0939*	0.2805
P_6	0.3167	0.2667	-3.1667**	1.2500**	-0.3400*	-0.1250*	0.2333	0.1833	-1.9290**	-0.1739**	0.3555*
P_7	-0.1000	-0.1500	0.5833*	0.0833	0.0651	0.4333**	0.4000*	-0.4833*	0.9532**	-0.1144**	-0.1120
P_8	-0.7667**	-0.6500**	-5.2500**	-3.6667**	0.2683	0.3583**	0.2333	1.0167**	1.1777**	0.3167**	-0.3570*
P_9	-0.4333*	-0.4000	-4.8333**	0.3333	-0.4567**	-0.4500**	-0.2667	-0.7333**	-0.1098	-0.0902*	-0.0195
P_{10}	-0.0167	-0.0667	4.3333**	3.4167**	-0.0067	-0.4250**	0.0667	-0.1500	0.9668**	0.0915	-0.1545
SE(gi)	0.0521	0.0480	0.0780	0.0917	0.0275	0.0030	0.0276	0.0567	0.0199	0.0016	0.0230
SE (gi-gi)	0.1159	0.1067	0.1733	0.2039	0.0612	0.0067	0.0654	0.1261	0.0434	0.0035	0.0512
***Kharif* 2002, Palem**											
P_1	-1.333**	-1.1778**	-0.2333	1.4333**	0.2317*	-0.0017	-0.5056**	-1.4167**	1.8550**	0.0428**	-0.1383**
P_2	0.5000**	0.5167*	-6.4833**	-2.6500**	0.1400	0.0817	0.4944**	1.6667**	-0.978***	0.1328**	-0.2880**
P_3	0.5000**	0.4333	2.9333**	1.0167**	0.0817	-0.0433	-0.1722	0.4167*	0.1050	-0.0255	0.2178**
P_4	0.0000	-0.1778	-0.2333	-1.2333**	-0.1433	0.2650**	-0.5056**	-0.0833	-1.0367**	-0.1813**	0.2248**
P_5	1.0000**	0.9056**	0.2667	0.1833	0.2150*	-0.4100**	-0.1444	0.0833	-0.1200	-0.0272**	0.2531**
P_6	0.2500	0.4056	-0.9000*	-0.5667	-0.2350*	-0.2183**	0.1611	-0.5000**	-1.5533**	-0.2147**	0.3601**
P_7	0.2500	0.2944	0.0167	0.4333	-0.0933	0.2400**	0.4944**	-0.5833**	-1.9367**	-0.0663**	-0.1224**
P_8	-0.917**	-0.9278**	-0.7333	-0.7333*	0.3067**	0.2817**	0.3278**	1.0000**	1.0550**	0.2653**	-0.3486**
P_9	-0.333	-0.2611	1.8500**	0.6000	-0.1017	-0.3267**	-0.3111**	0.1667	1.0467**	0.0403*	-0.0077
P_{10}	0.0833	-0.0111	3.5167**	1.5167**	-0.4017**	0.1317	0.1611	-0.7500**	1.5633**	0.0787**	-0.1508**
SE(gi)	0.0356	0.0571	0.1666	0.1426	0.0103	0.0066	0.0120	0.0341	0.0451	0.0002	0.0022
SE (gi-gi)	0.0793	0.1269	0.3703	0.3170	0.0229	0.0147	0.0268	0.0758	0.1003	0.0063	0.0049

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

Table 4. Estimation of general combining ability effects of parents for grain yield and yield components.

Entry No.	Days of 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels row / ear	No. of kernels / row	100 kernel weight (g)	Grain yield / plot (kg)	Protein content (%)
***Rabi* 2002-03, Hyderabad**											
P_1	-05167	-0.5833	2.8167**	1.2667**	-0.1317	-0.2283**	-0.4333*	-0.5000	1.9417**	0.0493**	-0.1423**
P_2	0.5667*	0.7500*	0.3167	-0.0667	0.1100	0.6133**	0.4000*	3.5000*	-0.2417	-0.0632**	-0.2865**
P_3	0.7333**	0.6667	3.6500**	0.7667	0.1767*	0.1883*	0.0667	1.5000*	0.7000**	0.0385*	0.1877**
P_4	-0.1000	-0.2500	0.6500	0.1000	0.0933	0.0467	-0.4333*	-1.2500**	0.4833**	-0.0823**	0.2218**
P_5	1.0667**	1.0833**	-0.1000	-0.7333	-0.0650	-0.4867**	-0.2667	0.1667	-0.7250**	-0.1057**	0.2785**
P_6	0.1500	0.2500	-4.9333**	-1.9000**	-0.1567	-0.0700	0.2333	-0.2500	-2.3500**	-0.1815**	0.3552**
P_7	-0.1833	0.0000	-0.0167*	0.1000	-0.2900**	0.3800**	0.4000*	-1.6667**	-1.3500**	-0.0898**	-0.1065**
P_8	-0.9333**	-1.0000**	-4.2667**	-1.4833**	0.4017**	0.3717**	0.2333	0.8333*	0.2583	0.1202**	-0.3465**
P_9	-0.7667**	-0.7500*	-2.6833**	-0.9833*	-0.2317**	-0.3700**	-0.2667	-0.9167*	0.2083	0.0702**	-0.0123
P_{10}	-0.0167	-0.1667	5.5667**	2.9333**	0.0933	-0.4450**	0.0667	-1.4167**	1.0750**	0.2443**	-0.1490**
SE(gi)	0.0785	0.1348	0.2499	0.2039	0.0076	0.0072	0.0495	0.1416	0.2211	0.0003	0.0005
SE (gi-gi)	0.1744	0.2996	0.5533	0.4532	0.0169	0.0161	0.1100	0.3147	0.0491	0.0007	0.0011
***Rabi* 2002-03, Palem**											
P_1	-1.2000**	-1.2333**	-3.6000**	-1.9167**	0.2233**	-0.0733	-0.4667	-0.1833	-2.4333**	0.1733*	-0.1302**
P_2	0.5500*	0.6000**	-4.4333**	-2.3333**	0.2233**	0.0683	0.5333*	0.6500*	0.1417	0.1942*	-0.2793**
P_3	0.7167**	0.6000**	2.1500**	1.1667**	0.3400**	-0.1067	-0.1333	0.4833	0.9750**	0.1975*	0.1807**
P_4	-0.1167	0.1000	2.4000**	1.0833*	-0.4017**	0.3350**	-0.6333*	0.5667*	0.0583	-0.1333	0.2190**
P_5	1.0500**	0.7667**	2.9000**	1.7500**	0.0483	-0.4650**	0.0333	0.7333*	-0.1167	-0.0083	0.2773**
P_6	-0.1167	-0.0667	-1.1833**	-0.2500	-0.1517*	-0.2067**	0.0333	-0.1000	-0.9167**	-0.1583	0.3540**
P_7	-0.4500*	-0.3167	1.2333*	1.0833*	-0.0767	0.0933	0.3667	-0.1833	-0.1500	-0.1467	-0.1068**
P_8	-0.5333*	-0.5667**	-1.0167*	-0.2500	0.0067	0.4683**	0.7000**	-1.6000**	-3.5333**	0.1792*	-0.3510**
P_9	0.3000	0.2667	-0.0167	0.3333	0.0567	-0.4567**	-0.1333	0.1500	0.1250	-0.1500	-0.0193
P_{10}	-0.2000	-0.1500	1.5667**	-0.6667	-0.2633**	0.3433**	-0.3000	-0.5167	0.9833**	-0.1475	-0.1443**
SE(gi)	0.0538	0.0356	0.1911	0.2197	0.0051	0.0058	0.0657	0.0906	0.0252	0.0051	0.0007
SE (gi-gi)	0.1197	0.0791	0.4247	0.4883	0.0113	0.0131	0.1460	0.2014	0.0561	0.0111	0.0016

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

Table 5. Estimates of specific combining ability effects of the crosses for grain yield and yield components.

a) *Kharif* 2002, Hyderabad

	Days of 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels row / ear	No. of kernels / row	100 kernel weight (g)	Grain yield / plot (kg)	Protein content (%)
P_1 x P_2	0.9621	0.7424	11.9697**	24.1061**	1.2136*	-0.8182**	-0.6212	7.3409**	-2.9042**	0.1039	-0.0759
P_1 x P_3	0.9621	0.7424	22.8030**	4.3561**	1.6636**	0.8152**	-0.2879	-0.6591	3.6350**	0.2295	-0.5742
P_1 x P_4	1.9621**	1.5758*	11.1364**	-5.2273**	-0.5030	0.4902**	0.2121	-1.9091*	-7.2617**	-0.7978**	0.4124
P_1 x P_5	0.2955	0.0758	-13.4470**	-6.4773**	1.5803**	0.4068*	0.0455	0.4242	-4.9867**	-0.4478**	0.0266
P_1 x P_6	1.2955	1.0758	34.8864**	2.7727**	1.5970**	-0.1682	1.5455**	2.1742**	4.3117**	1.0725**	-0.5184
P_1 x P_7	-3.2879**	-3.5076**	-3.8636**	3.9394**	-1.4780**	-0.2265	-0.6212	1.8409*	-6.0642**	-0.5469**	0.4591
P_1 x P_8	-5.6212**	-5.0076**	21.9697**	2.6894**	1.7886**	-0.5515**	1.5455**	7.3409**	0.8150	1.557**	-0.3059
P_1 x P_9	-5.9545**	-6.2576**	-3.4470**	-6.3106**	2.0136**	-0.1432	0.0455	0.0909	4.2325**	0.3929**	-0.3834
P_1 x P_{10}	1.6288*	1.4091*	32.3864**	0.6061	1.4636**	0.5318**	1.7121**	-1.4924*	2.1558**	0.4719**	-0.1984
P_2 x P_3	-0.9545	-1.0909	11.9697**	-1.3106	0.8470	-0.3348	0.8788	2.2576**	-1.1325*	0.2294	-0.2792
P_2 x P_4	0.0455	-0.2576	20.3030**	19.1061**	0.9803	0.5402**	1.3788**	-3.9924**	-1.5992**	-0.2726*	0.7774
P_2 x P_5	-1.6212*	-1.7576*	35.7197**	22.8561**	2.2636**	1.0568**	1.2121*	5.3409**	3.4258**	1.1831**	-0.3184
P_2 x P_6	-0.6212	-0.7576	-0.9470	-12.8939**	2.1803**	0.1818	0.7121	4.0909**	-6.3058**	-0.4076**	0.1666
P_2 x P_7	-0.2045	-0.3409	10.3030**	-1.7273	1.3053*	-0.8765**	0.5455	3.7576**	-5.0917**	-0.5817**	0.7041
P_2 x P_8	2.4621**	2.1591**	21.1364**	2.0227*	1.8720**	0.3985*	-1.2879*	3.2576**	2.5875**	0.7522**	-0.3609
P_2 x P_9	0.1288	-0.0909	10.7197**	6.0227**	1.4970**	1.0068**	1.2121*	3.0076**	8.5050**	1.5731**	-0.7384
P_2 x P_{10}	-0.2879	-0.4242	-3.4470**	-15.0606**	0.8470	0.5818**	-1.1212*	0.4242	-1.5817**	-0.3683**	1.0466*
P_3 x P_4	0.0455	-0.2576	-3.8636**	-0.6439	2.1303**	1.1735**	1.7121**	5.0076**	2.2300**	1.0637**	-0.7009
P_3 x P_5	-1.6212*	-1.7576*	1.5530	-1.8939*	-0.9864	-0.0098	-0.4545	0.3409	-1.2350**	-0.1910	1.2933**
P_3 x P_6	-0.6212	-0.7576	24.8864**	17.3561**	0.7303	0.3152	-0.9545	2.0909**	-0.3267	-0.0463	0.4183
P_3 x P_7	1.7955*	1.6591*	21.1364**	3.5227**	1.1553*	0.2568	-1.1212*	3.7576**	-2.7425**	-0.1918	0.9458
P_3 x P_8	0.4621	0.1591	1.9697*	-2.7273**	1.1220*	-0.1682	1.0455*	7.2576**	-0.9233*	0.7424**	0.3708
P_3 x P_9	2.1288**	1.9091**	16.5530**	8.2727**	1.1470*	0.2402	-0.4545	2.0076**	-2.2258**	-0.2106	1.7333**
P_3 x P_{10}	-0.2879	-0.4242	17.3864**	5.1894**	-0.0030	1.5152**	1.2121*	-2.5758**	3.0675**	0.3630**	-0.6517
P_4 x P_5	-0.6212	-0.9242	-10.1136**	-16.4773*	0.4470	0.0652	0.0455	4.0909**	0.2683	0.3551**	0.0799
P_4 x P_6	0.3788	0.0758	8.2197**	-12.2273**	1.1636*	-0.4098*	-0.4545	5.8409**	-2.9733**	0.0014	0.7949
P_4 x P_7	0.7955	0.4924	4.4697**	-1.0606	2.3886**	0.1318	-0.6212	4.5076**	9.6608**	1.3416**	-0.9776*
P_4 x P_8	-1.5379*	-1.0076	10.3030**	2.6894**	-0.1447	-0.8932**	-0.4545	4.0076**	-0.1300	0.1345	-0.2026
P_4 x P_7	-1.8712*	1.2576	29.8864**	8.6894**	0.0803	1.0152**	0.0455	0.7576	-3.7525**	-0.3523**	1.9099**
P_4 x P_{10}	-1.2879	-1.5909*	30.7197**	25.6061**	1.3303*	1.7902**	1.7121**	-1.8258*	-3.4492**	-0.1950	1.5949**
P_5 x P_6	0.7121	0.5758	8.6364**	11.5227**	-0.6530	0.7068**	1.3788**	3.1742**	-6.2383**	-0.2346	1.1691*
P_5 x P_7	-0.8712	-1.0076	14.8864**	2.6894**	2.4720**	1.1485**	1.2121*	-3.1591**	4.6158**	0.5163**	-0.6134
P_5 x P_8	-0.2045	-0.5076	20.7197**	6.4394**	-0.3614	-0.1765	1.3788**	-5.6591**	-1.6850**	-0.4405**	0.3816
P_5 x P_9	-0.5379	-0.7576	5.3030**	-7.5606**	0.4636	0.6318**	-0.1212	3.0909**	-0.2475	0.1668	-0.0059
P_5 x P_{10}	-0.9545	-1.0909	16.1364**	4.3561**	2.3136**	1.4068**	-0.4545	7.5076**	-0.9642*	0.4110**	-0.3209
P_6 x P_7	2.1288**	1.9924**	13.2197**	11.9394**	0.5886	0.7735**	0.7121	-0.4091	6.3042**	0.8956**	-0.9984*
P_6 x P_8	0.7955	0.4924	19.0530**	5.6894**	1.1553*	0.7485**	-1.1212*	1.0909	0.0033	-0.1798	0.5666
P_6 x P_9	0.4621	0.2424	-26.3636**	-8.3106**	0.3803	1.0568**	-0.6212	1.8409*	-1.3592**	-0.1323	0.2891
P_6 x P_{10}	0.0455	-0.0909	-15.5303**	-11.3939**	-0.4697	0.5318**	1.0455*	2.2576**	-1.5558**	0.2497	-1.2759**
P_7 x P_8	1.2121	0.9091	15.3030**	6.8561**	2.1803**	-0.4098*	-1.2879*	6.7576**	-5.1325**	-0.3700**	0.5841
P_7 x P_9	0.8788	0.6591	9.8864**	-7.1439**	-0.1947	-0.5015**	-0.7879	0.5076	-0.3150	-0.1231	0.2766
P_7 x P_{10}	0.4621	0.3258	-4.2803**	-15.2273**	-0.6447	-0.3265	0.8788	5.9242**	-0.7117	0.6765**	-0.1984
P_8 x P_9	1.5455*	1.1591	-4.2803**	-8.3939**	0.5720	1.1735**	1.3788**	3.0076**	2.0142**	0.7369**	-0.5184
P_8 x P_{10}	1.1288	0.8258	-18.4470**	-6.4773	0.9220	1.5485**	1.0455*	0.4242	2.0175**	0.4895**	-0.1734
P_9 x P_{10}	0.7955	0.5758	21.1364**	19.5227**	0.2470	0.9568**	-0.4545	4.1742**	-3.5350**	-0.1783	-0.0509
SE (S_{ij})	0.5906	0.5433	0.8824	1.0383	0.3119	0.0345	0.3133	0.6422	0.2257	0.6181	0.2606
SE (S_{ij} - S_{ik})	1.2754	1.1739	2.2436	2.2436	0.6739	0.0746	0.6770	1.3876	0.4877	0.0320	0.5632

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

Table 5. Estimates of specific combining ability effects of the crosses for grain yield and yield components.

b) *Kharif* 2002, Palem

	Days of 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels row / ear	No. of kernels / row	100 kernel weight (g)	Grain yield / plot (kg)	Protein content (%)
P_1 x P_2	1.8333**	1.6490*	11.4621**	8.0530**	1.8992**	-0.6455*	-0.5404	6.6591**	-2.0258**	0.0902	-0.1137
P_1 x P_3	1.8333**	0.7323	17.0455**	10.3864**	2.2576**	0.4795	0.1263	-2.0909**	5.8909**	0.2985**	-0.5595**
P_1 x P_4	1.3333*	2.3434**	0.2121	-2.3636*	-1.0174**	-0.5288*	0.4596	-1.5909**	-6.9674**	-0.7157**	0.4036**
P_1 x P_5	1.3333*	1.2601	-0.2879	0.2197	1.2242**	0.3462	0.0985	2.2424**	-4.8841**	-0.3248**	-0.0048
P_1 x P_6	1.0833	0.7601	30.8788**	16.9697**	1.2742**	-0.3455	-0.2071	3.8258**	3.6492**	0.5777**	-0.4617**
P_1 x P_7	-2.9167**	-2.1288**	-5.0379**	-3.0303*	-0.3674	0.1962	-0.5404	2.9091**	-5.7674**	0.3893**	0.4508**
P_1 x P_8	-6.7500**	-6.9066**	5.7121**	8.1364**	1.2326**	1.1545**	1.6263**	5.3258**	2.3409**	0.9677**	-0.2531
P_1 x P_9	-7.3333**	-6.5732**	33.1288**	11.8030**	1.6409**	-0.7371**	0.2652	-1.8409**	4.1492**	0.1627**	-0.4139**
P_1 x P_{10}	0.2500	0.1768	-3.5379**	-0.1136	1.2409**	0.2045	1.7929**	-0.9242	3.3326**	0.4943**	-0.2009
P_2 x P_3	-2.0000**	-0.9621	18.2955**	12.4697**	0.5492	-0.3038	1.1263**	3.8258**	-2.9758**	0.1385**	-0.2698
P_2 x P_4	-1.5000*	-1.3510	16.4621**	11.7197**	0.7742*	0.5879*	1.4596**	-0.6742	0.3659	0.1743**	0.7533**
P_2 x P_5	-2.5000**	-2.4343**	5.9621**	-2.6970*	2.1159**	0.7629**	1.0985**	5.1591**	5.5492**	1.3152**	-0.4384**
P_2 x P_6	-0.7500	-0.9343	7.1288**	2.0530	1.7659**	0.5712*	0.7929*	4.7424**	-5.2174**	-0.1623**	0.1380
P_2 x P_7	0.2500	-0.4899	6.2121**	3.0530*	1.2242**	1.1129**	-1.5404**	4.8258**	-7.3341**	-0.5407**	0.6905**
P_2 x P_8	1.4167*	1.3990	1.9621	-1.7803	2.0242**	-0.6288*	0.62963	4.2424**	3.0742**	0.8177**	-0.3134*
P_2 x P_9	0.8333	-0.2677	4.3788**	4.8864**	1.6326**	0.1795	-0.7348*	3.0758**	6.8826**	0.8127**	-0.6875**
P_2 x P_{10}	0.4167	-0.5177	2.7121*	1.9697	1.0326**	-0.1788	0.7929*	0.9924	-1.5341*	0.0743	1.1488**
P_3 x P_4	-0.5000	-0.2677	-2.9545*	-0.9470	2.1326**	0.2129	0.1263	6.5758**	1.8826**	0.7027**	-0.7459**
P_3 x P_5	-2.5000**	-1.3510	11.5455**	6.6364**	-0.5258	-0.0121	-0.2348	1.4091*	-2.6341**	-0.1365*	1.3191**
P_3 x P_6	-1.7500**	-1.8510*	7.7121**	4.3864**	-0.0758	0.1962	-0.5404	1.9924**	-1.1008	0.0160	0.4722**
P_3 x P_7	0.2500	-0.4066	1.7955	-0.6136	0.6826*	0.1379	1.1263**	2.0758**	-2.0174**	0.0477	0.9647**
P_3 x P_8	1.4167*	0.4823	22.5455**	11.5530**	-0.4174	-0.8038**	-0.7071*	5.4924**	-0.9091	0.1760**	0.3874**
P_3 x P_9	0.8333	0.8157	13.9621**	9.2197**	0.0909	0.7045**	-0.0682	1.3258*	0.6992	0.1910**	1.7499**
P_3 x P_{10}	0.4167	0.5657	22.2955**	11.3030**	0.0909	0.3462	-0.5404	-2.7576**	2.4826**	-0.0473	-0.6470**
P_4 x P_5	0.0000	-0.7399	-0.2879	-0.1136	0.8992**	-0.1205	0.0985	4.9091**	0.2076	0.3993**	0.1422
P_4 x P_6	1.7500**	1.7601*	10.8788**	7.6364**	2.2492**	1.6879**	-0.2071	6.4924**	-0.2591	0.3118**	0.8752**
P_4 x P_7	0.7500	-0.1288	12.9621**	5.6364**	1.0076**	-0.7705**	-0.5404	5.5758**	9.8242**	1.2235**	-1.0023**
P_4 x P_8	-0.0833	0.0934	9.7121**	4.8030**	0.6076	-0.1121	-0.3737	5.924**	-1.1674	0.1818**	-0.2562
P_4 x P_7	-2.6667**	-3.5732**	23.1288**	13.4697**	0.9159**	0.7962**	0.2652	0.8258	-2.1591**	-0.1132*	1.9130**
P_4 x P_{10}	-3.0833**	-2.8232**	29.4621**	15.5530**	0.3159	0.4379	1.7929**	-2.2576**	-3.5758**	-0.2215**	1.6161**
P_5 x P_6	-0.2500	-0.3232	9.3788**	3.2197**	1.9909**	1.2629**	1.4318**	5.3258**	-5.4758**	0.0527	1.0969**
P_5 x P_7	-0.2500	-0.2121	19.4621**	11.2197**	1.9492**	1.8045**	1.0985**	-2.5909**	3.9076**	0.2843**	-0.6206**
P_5 x P_8	-0.0833	-0.9899	20.2121**	11.3864**	-1.6508**	-0.4371	1.2652**	-4.1742**	-18841**	-0.3173**	0.4155**
P_5 x P_9	-0.6667	-0.6566	2.6288*	1.0530	-0.1424	0.1712	0.2374	1.6591**	-1.7758**	-0.0323	0.0147
P_5 x P_{10}	-1.0833	-0.9066	10.9621**	4.1364**	2.4576**	-0.2871	-0.5682	6.5758**	-3.1924**	0.1193*	-0.3323*
P_6 x P_7	0.5000	0.2879	20.6288**	11.9697**	2.4992**	0.7129**	0.7929*	-1.0076	5.5409**	0.5368**	-1.0176**
P_6 x P_8	0.6667	0.5101	21.3788**	16.1364**	0.9992**	0.3712	-1.0404**	-2.5909**	1.9492**	-0.1948**	0.5286**
P_6 x P_9	1.0833	0.8434	-26.2045**	-15.1970**	-0.7924*	0.1795	-0.4015	-1.7576**	-2.1424**	-0.3298**	0.2577
P_6 x P_{10}	0.6667	0.5934	-14.8712**	-9.1136**	-0.3924	-0.3788	1.1263**	7.1591**	-2.8591**	0.5018**	-1.2492**
P_7 x P_8	1.6667**	1.6212*	15.4621**	6.1364**	1.9576**	-1.0871**	-1.3737**	-3.5076**	-3.8674**	-0.9432**	0.5811**
P_7 x P_9	2.0833**	1.9545*	7.8788**	2.8030*	-0.5341	-0.8788**	-0.7348*	5.3258**	-0.9591	0.0718	0.3402*
P_7 x P_{10}	0.6667	0.7045	1.2121	4.8864**	-0.3341	-1.1371**	0.7929*	8.2424**	-0.7758	0.6535**	-0.2167
P_8 x P_9	1.2500*	1.1768	-1.3712	3.9697**	-0.1341	0.7795**	1.4318**	3.7424**	0.7492	0.6802**	-0.4837**
P_8 x P_{10}	0.8333	0.9268	-8.0379**	-2.9470*	1.0659**	1.0212**	0.9596**	5.6591**	2.2326**	0.9818**	-0.2006
P_9 x P_{10}	1.2500*	1.2601	24.3788**	10.7197**	1.3742**	1.6295**	-0.4015	0.4924	-3.5591**	-0.3332**	-0.1214
SE (S_{ij})	0.4037	0.6464	1.8856	1.6139	0.1166	0.0752	0.1364	0.3859	0.5108	0.0032	0.0249
SE (S_{ij} - S_{ik})	0.8723	1.3968	4.0743	3.4873	0.2519	0.1626	0.2948	0.8338	1.1038	0.0069	0.6539

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

Table 5. Estimates of specific combining ability effects of the crosses for grain yield and yield components.

a) Rabi 2002, Hyderabad

	Days of 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels row / ear	No. of kernels / row	100 kernel weight (g)	Grain yield / plot (kg)	Protein content (%)
P_1 x P_2	2.6591**	2.1970	11.4848**	507273**	1.1417**	0.0477	-0.6212	6.3636**	-4.7182**	-0.2533**	-0.0810
P_1 x P_3	2.4924**	2.2803	18.1515**	8.8939**	1.1750**	0.1727	-0.2879	-3.6364**	4.2402**	0.5251**	-0.5952**
P_1 x P_4	2.3258**	2.1970	6.1515**	2.5606	-0.6417*	0.4144	0.2121	-0.8864	-6.5432**	-0.5241**	0.4307**
P_1 x P_5	1.1591	1.8636	-8.0985**	-1.6061	0.3167	1.5477**	0.0455	-0.3030	-4.2348**	-0.2108**	-0.0060
P_1 x P_6	2.0758*	1.6970	31.7348**	14.5606**	1.0083**	0.8311**	1.5455*	2.1136	5.3902**	0.3951**	-0.5027**
P_1 x P_7	-3.5909**	-3.0530**	-7.1818**	-5.4394**	-0.3583	0.2811	-0.6212	3.5303**	-4.6098**	-0.1766**	0.4590**
P_1 x P_8	-5.8409**	-5.0530**	26.0682**	10.1439**	1.9500**	-0.5106	1.5455*	8.0303**	2.8818**	0.9534**	-0.2910**
P_1 x P_9	-6.0076**	-6.3030**	-0.5152	-1.3561	1.8833**	0.7311**	0.0455	0.7803	4.8318**	0.3934**	-0.3752**
P_1 x P_{10}	1.2424	1.1136	34.2348**	19.7273**	1.7583**	1.3061**	1.7121*	1.2803	4.1652**	0.9692**	-0.1885*
P_2 x P_3	-0.5909	-0.0530	15.6515**	9.2273**	1.2333**	-0.4689	0.8788	2.3636*	-3.0765**	-0.0024	-0.2910**
P_2 x P_4	0.2424	-0.1364	23.6515**	8.8939**	1.0167**	0.6727*	1.3788	-2.8864*	-3.3598**	-0.0416	0.7848**
P_2 x P_5	-1.9242*	-1.4697	39.4015**	13.7273**	2.1750**	1.3061**	1.2121	5.6970**	3.9485**	0.5717**	-0.3118**
P_2 x P_6	-0.0076	-0.6364	-0.7652	0.8939	1.7667**	0.0894	0.7121	5.1136**	-5.4265**	-0.4224**	0.1415
P_2 x P_7	0.3258	0.6136	0.3182	1.8939	0.7000*	-0.4606	0.5455	6.5303**	-4.3265**	-0.1841**	0.7432**
P_2 x P_8	1.0758	0.6136	18.5682**	9.4773**	1.0083**	0.6477*	-1.2879	4.0303**	5.2652**	0.3859**	-0.3468**
P_2 x P_9	-0.0909	-0.6364	4.9848**	1.9773	1.7417**	1.3894**	1.2121	5.7803**	9.0152**	1.2359**	-0.7310**
P_2 x P_{10}	-0.8409	-0.2197	-1.2652	0.0606	1.0167**	0.9644**	-1.1212	2.2803	7.3485**	0.5717**	1.0457**
P_3 x P_4	0.0758	-0.0530	2.3182	3.0606*	1.4500**	0.8977**	1.7121*	6.1136**	1.8985**	0.9167**	-0.6993**
P_3 x P_5	-1.0909	-0.3864	-8.9318**	-5.1061**	-0.8917**	0.1311	-0.4545	4.6970**	1.1068*	-0.0299	1.3040**
P_3 x P_6	-0.1742	-0.5530	25.9015**	7.0606**	-0.7000*	0.3144	-0.9545	3.1136**	0.6318	-0.2641**	0.4173**
P_3 x P_7	2.1591*	2.6970*	21.9848**	7.0606**	1.6333**	0.0644	-1.1212	6.5303**	-2.2682**	-0.3758**	0.9490**
P_3 x P_8	0.9091	0.6970	3.2348*	2.6439	1.1417**	-0.1273	1.0455	7.0303**	1.0235*	0.5842**	0.3690**
P_3 x P_9	0.7424	0.4470	15.6515**	6.1439**	1.3750**	0.0144	-0.4545	-1.2197	-3.7265**	-0.3558**	1.7548**
P_3 x P_{10}	-1.0076	-1.1364	11.4015**	6.2273**	0.4500	1.4894**	1.2121	-3.7197**	3.2068**	0.3501**	-0.6585**
P_4 x P_5	-1.2576	-1.4697	-10.9318**	-3.4394*	0.6917*	-0.4273	0.0455	-0.5530	1.3235**	0.2809**	0.0498
P_4 x P_6	-0.3409	0.3636	8.9015**	4.7273**	1.2833**	-0.8439**	-0.4545	1.8636	-3.1515**	-0.1533**	0.7932**
P_4 x P_7	-2.0076*	-1.3864	-0.0152	-0.2727	2.4167*	-0.2939	-0.6212	-5.7197**	10.2485**	0.3351**	-1.0052**
P_4 x P_8	-1.2576	-1.3864	8.2348**	4.3106**	-0.2750	-0.9856**	-0.4545	5.7803**	0.5401	0.1751**	-0.2052**
P_4 x P_7	-0.4242	-0.6364	29.6515**	13.8106**	-0.1417	0.6561*	0.0455	4.5303**	5.4902**	0.6551**	1.9207**
P_4 x P_{10}	0.8258	0.7803	25.4015**	10.8939**	1.5333**	1.6311**	1.7121*	2.0303	-4.4765**	0.0609	1.5973**
P_5 x P_6	-1.5076	-1.9697	4.6515**	2.5606	-0.5583*	0.9894**	1.3788	-1.5530	-4.9432**	-0.2199**	1.1765**
P_5 x P_7	-1.1742	-0.7197	12.7348**	4.5606**	2.4750**	1.3394**	1.2121	0.8636	6.2568**	1.3284**	-0.6118**
P_5 x P_8	-0.4242	-0.7197	18.9848**	6.1439**	-0.1167	-0.7523**	1.3788	1.3636	-3.3515**	-0.0916	0.3882**
P_5 x P_9	-0.5909	-0.9697	7.4015**	4.6439**	0.8167**	-0.0106	-0.1212	1.1136	-3.3015**	-0.2416**	0.0040
P_5 x P_{10}	-0.3409	-0.5530	19.1515**	9.7273**	2.1917**	1.4644**	-0.4545	0.6136	-3.4682**	-0.4158**	-0.2993**
P_6 x P_7	1.7424	1.1136	15.5682**	9.7273**	0.6667*	1.1227*	0.7121	1.2803	1.0818*	1.0342**	-0.9985**
P_6 x P_8	1.4924	2.1136	18.8182**	10.3106**	0.2750	0.9311**	-1.1212	-0.2197	1.9735**	0.2042**	0.5615**
P_6 x P_9	0.3258	0.8636	-27.7652**	-14.1894**	1.9083**	0.8727**	-0.6212	0.5303	-0.9765*	-0.1658**	0.2873**
P_6 x P_{10}	-0.4242	-0.7197	-16.0152**	-7.1061**	-0.5167	0.9477**	1.0455	2.0303	-1.7432**	0.2401**	-1.2760**
P_7 x P_8	0.8258	0.3636	14.9015**	9.3106**	2.4083**	-0.3189	-1.2879	0.1970	-3.7265**	-0.5074**	0.5832**
P_7 x P_9	0.6591	1.1136	13.3182**	7.8106**	-2.2583**	-0.3773	-0.7879	0.9470	-0.9765*	-0.2374**	0.2890**
P_7 x P_{10}	0.9091	0.5303	-4.9318**	-2.1061	-2.2833**	-0.3023	0.8788	0.4470	-0.8432	0.0984	-0.1943**
P_8 x P_9	1.4091	1.1136	-8.4318**	-4.6061**	0.3500	1.1311**	1.3788	-1.5530	2.4152**	0.6626**	-0.5310**
P_8 x P_{10}	0.6591	1.5303	-16.6818**	-9.5227**	1.0250**	1.2061**	1.0455	-2.0530	3.8485**	0.4084**	-0.1743*
P_9 x P_{10}	1.4924	1.2803	21.7348**	9.9773**	0.3583	1.2477**	-0.4545	0.6970	-4.3015**	0.2084**	-0.0885
SE (S_{ij})	0.8881	1.5252	2.8273	2.3074	0.0862	0.0824	0.5602	1.6021	0.2502	0.0039	0.0059
SE (S_{ij} - S_{ik})	1.9189	3.2956	6.1091	4.9857	0.1864	0.1780	1.2105	3.4618	0.5406	0.0085	0.0129

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

Table 5. Estimates of specific combining ability effects of the crosses for grain yield and yield components.

b) *Rabi* 2002, Palem

	Days of 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels row / ear	No. of kernels / row	100 kernel weight (g)	Grain yield / plot (kg)	Protein content (%)
P_1 x P_2	1.5227*	1.2879*	7.6515**	4.2500**	1.8152**	-0.5205*	-0.5758	6.9697**	-3.8568**	-0.0166	0.0943
P_1 x P_3	1.3561	1.2879*	17.0682**	9.7500**	1.6985**	-0.1455	0.0909	-0.8636	5.309**	0.4501*	-0.5943**
P_1 x P_4	1.1894	1.7879	-1.1818	-3.1667*	-0.1598	-0.3871	0.5909	-0.9470	1.1265*	0.1409	0.4373**
P_1 x P_5	0.0227	0.1212	0.3182	-0.8333	1.4902**	0.4129	-0.0758	0.8864	-2.6985**	0.2759	0.0190
P_1 x P_6	-3.8106**	-4.0455**	30.4015**	14.167**	1.1902**	-0.0455	-0.0758	3.7197**	4.3015**	0.7859**	-0.5477**
P_1 x P_7	-4.4773**	-3.7955**	-3.0152*	-0.1667	0.0152	0.4545	-0.4091	4.8030**	-6.3651**	0.3458	0.4832**
P_1 x P_8	-4.3939**	-4.5455**	6.2348**	3.167*	-0.1682	1.1795**	1.2576	1.2197	4.7182**	0.5284*	-0.2727**
P_1 x P_9	0.7727	0.6212	35.2348**	15.5833**	1.7818**	-0.7955**	0.0909	-0.5303	6.0599**	0.5876*	-0.3643**
P_1 x P_{10}	1.2727	1.0379	3.6515**	1.5833	1.3068**	0.2045	2.2576**	-0.8636	2.5015**	0.7451**	-0.1793*
P_2 x P_3	-1.3939	-1.5455*	15.9015**	11.1667**	1.2985**	-0.3871	1.0909	1.3030	-2.3985**	0.1292	-0.2852**
P_2 x P_4	0.5606	-0.0455	19.6515**	8.2500**	-1.0598**	0.2712	1.5909	1.2197	-1.3818**	0.3601	0.8065**
P_2 x P_5	-0.7273	-0.7121	13.1515**	4.5833**	1.9902**	0.8712**	0.9242	1.0530	3.1932**	0.7951**	-0.2918**
P_2 x P_6	0.4394	0.1212	15.2348**	7.5833**	1.8902**	0.7129**	0.9242	2.8864**	-5.3068**	-0.1949	0.1715*
P_2 x P_7	0.7727	0.3712	7.8182**	4.2500**	1.9152**	1.3129**	-1.4091	1.9697*	1.3265**	0.0834	0.7523**
P_2 x P_8	0.8561	1.6212**	0.0682	0.5833	2.0318**	-0.6621**	0.2576	3.3864**	6.7099**	0.8076**	-0.3235**
P_2 x P_9	-0.9773	-1.2121*	11.0682**	4.0000**	1.7818**	-0.0371	-0.9091	1.6364	7.0515**	0.7567**	-0.7752**
P_2 x P_{10}	-1.4773*	-0.7955	2.4848	-4.0000**	1.3068**	-0.0371	1.2576	3.3030**	-2.4068**	0.3742	1.0098**
P_3 x P_4	-1.7273*	-2.0455**	-2.9318*	-7.2500**	2.1235**	0.2462	0.2576	1.3864	1.6849**	0.4167	-0.7135**
P_3 x P_5	-0.8939	-0.7121	9.5682**	6.0833**	-0.2265	0.1462	-0.4091	1.2197	-1.5401**	-0.0883	1.2682**
P_3 x P_6	0.2727	0.1212	13.6515**	7.0833**	0.7735**	0.3879	0.4091	2.0530*	-1.1401*	-0.0083	0.3915**
P_3 x P_7	0.6061	0.3712	4.2348**	0.7500	0.6985**	0.3879	1.2576	2.1364*	-2.1068*	0.3801	0.9223**
P_3 x P_8	0.6894	0.6212	23.4848**	10.0833**	0.1152	-0.6871**	-1.0758	3.5530**	4.2765**	0.1742	0.3465**
P_3 x P_9	-0.1439	-0.2121	7.4848**	5.5000**	0.0652	0.7379**	0.2424	1.8030	0.5182	0.1134	1.7848**
P_3 x P_{10}	0.3561	1.2045*	20.9015**	13.5000**	-0.1098	0.1379	-0.0758	2.4697**	0.659	0.3409	-0.6102**
P_4 x P_5	-1.0606	-1.2121*	9.3182**	6.1667**	1.3152**	-0.1955	0.0909	10.1364**	-1.3235**	0.0626	0.0198
P_4 x P_6	1.1061	1.6212**	15.4015**	7.1667**	1.4152**	-0.2538	0.0909	2.9697**	7.4765**	1.1826**	0.7732**
P_4 x P_7	0.4394	-0.1288	13.9848**	7.8333**	1.7402**	-0.5538*	-0.2424	2.0530*	5.7099**	0.8909**	-0.9660**
P_4 x P_8	-0.4773	0.1212	8.2348**	7.1667**	1.3568**	1.8712**	0.5758	2.4697**	1.0932*	-0.1449	-0.1918*
P_4 x P_7	-2.3106**	-2.7121**	22.2348**	13.5833**	1.3068**	0.7962**	0.2576	1.7197	-2.5651**	0.0058	1.9065**
P_4 x P_{10}	-0.8106	-0.2955	25.6515**	12.5833**	0.8318**	0.1962	0.4242	2.3864*	-5.4235**	0.2183	1.6115**
P_5 x P_6	-0.0606	-0.0455	7.9015**	3.5000*	2.1652**	1.3462**	1.4242	2.8030**	-6.3485**	-0.1624	1.1348**
P_5 x P_7	0.2727	0.2045	20.4848**	10.1667**	1.2902**	0.0462**	1.0909	-1.1136	1.8849**	0.5259*	-0.6043**
P_5 x P_8	-0.6439	-0.5455	22.7348**	12.5000**	-1.9932**	-0.8288**	0.7576	0.3030	2.2682**	0.1201	0.3798**
P_5 x P_9	-1.4773*	-0.3788	8.7348**	3.9167**	-0.4432	0.1962	1.5909	1.5530	-1.2901*	0.4792*	0.0182
P_5 x P_{10}	0.9773	-0.9621	10.1515**	6.9167**	2.0818**	-0.2038	-0.2424	3.2197**	-3.2485**	-0.1233	-0.2668**
P_6 x P_7	0.4394	0.0379	17.5682**	9.1667**	1.0902**	0.9879**	-0.9091	0.7197	1.7849**	-0.1559	0.9810**
P_6 x P_8	1.5227*	1.2879*	16.8182**	9.5000**	-0.5932**	1.0129**	0.7576	2.1364*	4.0682**	0.4501*	0.5232**
P_6 x P_9	1.6894*	1.4545*	25.1818**	-11.0833**	-0.0432	0.5379*	-0.4091	0.3864	-2.4901**	-0.2708	0.2815**
P_6 x P_{10}	0.1894	-0.1288	-5.7652**	-0.0833	-0.6182**	-0.4621	-0.2424	3.0530**	-3.4485**	-0.1133	-1.2635**
P_7 x P_8	0.8561	0.5379	14.4015**	8.1667**	2.3318**	-0.8871**	0.4242	1.2197	-1.1985*	-0.2516	0.5640**
P_7 x P_9	1.0227	1.7045**	13.4015**	6.5833**	-0.9182**	-1.1621**	-0.7424	7.4697**	-1.0568*	0.0676	0.2523**
P_7 x P_{10}	0.5227	0.1212	6.8182**	5.5833**	-0.1932	-1.1621**	-0.5758	3.1364**	-1.6151**	0.1051	-0.2227**
P_8 x P_9	1.1061	0.9545	5.6515**	3.9167**	0.0985	0.8629**	0.9242	2.8864**	2.0265**	0.3617	-0.5235**
P_8 x P_{10}	0.6061	0.3712	-0.9318	-2.0833	1.5235**	1.2629**	1.0909	1.5530	5.4682**	6.6892**	-0.1985*
P_9 x P_{10}	-0.2273	-0.4621	-1.9318	-0.6667	1.0735**	1.6879**	-0.0758	0.8030	-2.3901**	-0.1116	-0.1102
SE (S_{ij})	0.6095	0.4029	2.1622	2.4861	0.0580	0.0667	0.7433	1.0255	0.2860	0.0586	0.0082
SE (S_{ij} - S_{ik})	1.3170	0.8707	4.6719	5.3719	0.1253	0.1441	1.6060	2.2160	0.6180	0.1268	0.01787

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

earliness. The crosses, P_1 x P_7, P_1 x P_8 and P_1 x P_9 were the best specific combiners (Table 4) at two locations and in two seasons with significant negative *sca* effects for earliness. The above crosses possessed one of the parent involved as good combiner and gene action is primarily non-additive, which can be improved through suitable population improvement in addition to utilizing them in heterosis breeding (Abdel *et al.,* 2009).

In respect of plant height, P_3 and P_{10} parents were found to be taller at two locations and in two seasons. These parents possessed significant *gca* effects and recorded as good general combiners. The study of specific combining ability effects revealed significant and desirable effects of P_1 x P_6, P_4 x P_9 x P_4 x P_{10} and P_9 x P_{10}. For ear height, P_3, and P_{10} possessed higher mean values and were good general combiners. Thus these parents can be used in breeding programmes aimed at improving the ear height. These findings are similar to that of Lilian *et al.* (2011). The best specific crosses were P_1 x P_6, P_4 x P_9 x P_4 x P_{10} and P_9 x P_{10}.

For ear length, higher *gca* effects were observed in P_1, P_3 and P_8 which contributed maximum favourable genes and they can be used as donors for increasing ear length. The cross combinations, P_1 x P_3, P_3 x P_4 x P_4, P_2 x P_5, P_2 x P_8, P_5 x P_{10} and P_7 x P_8 were the best specific crosses and consistent over two locations and two seasons. In respect of ear girth, P_2, and P_8 had higher *per se* performance and turned out to be good combiners at two locations and in two seasons. The parent P_8 contributed maximum favourable genes for ear girth at two locations and in two seasons. Among the crosses, P_5 x P_7 was the best specific cross at two locations, P_8 x P_9 and P_8 x P_{10} were the best at Hyderabad and P_5 x P_{10} and P_4 x P_8 were the best at Palem.

For number of kernel rows per ear and number of kernels per row P_2 and P_8 were found to be good general combiners. Among the crosses, P_1 x P_8, P_3 x P_4 x P_3 x P_8, P_4 x P_{10} and P_8 x P_9 were the best specific crosses. P_1, P_3, P_8 and P_{10} were good general combiners for 100 kernel weight. These parental lines can be used in a series of multiple crosses to combine gene and gene complexes into a gene pool. Many crosses exhibited significant *sca* effects, but the crosses, P_1 x P_6, P_1 x P_3, P_2 x P_9, P_2 x P_{10}, P_4 x P_7 and P_8 x P_{10} were the best specific combiners. Camilo *et al.* (2008) and Abdel *et al.* (2009) also suggested that grain yield in maize can be improved by improving component characters *viz.,* ear girth, number of kernel rows per ear and 100 kernel weight.

Grain yield is a complex character among the ten parental lines, P_1, P_2, P_8 and P_{10} registered higher grain yield and are the good combiners as evidenced by their significant *gca* effects. The good combiners can also be intercrossed to develop high yielding composites. The best specific crosses combinations for high yield are P_1 x P_8, P_2 x P_5, P_2 x P_8, P_2 x P_9, P_4 x P_6, P_4 x P_7, P_5 x P_7. Selection in these crosses may throw useful transgressive segregates for high yield in the future generations. Yield improvement can be sought from these crosses by employing recurrent selection procedures. Aliu *et al.* (2008) and Premlatha and Kalamani (2010) advocated production of superior single crosses with lines having good combining ability. In the present study, the above hybrids have parents with good combining ability and greater progress can be achieved in the production of synthetics.

The protein content of maize has nutritional value and it was demonstrated that protein per cent can be increased by breeding. In the present investigation it was to note that P_4, P_5 and P_6 parents possessed higher protein per cent and contributed maximum favourable genes for protein per cent. Among the crosses, P_4 x P_9, P_4 x P_{10}, P_3 x P_9 and P_3 x P_5 were the best specific combinations. The results are in consonance with the findings of Ikramullah *et al.* (2011).

However, the final selection of parents is mostly influenced by results of grain yield and other characters, which have direct bearing on yield (Sundararajan and Senthil Kumar, 2011). Ojo *et al. (*2007) suggested that the general picture of the combining ability of parents over all the characters is useful to decide the combining ability status of parents. Considering the two locations and two seasons for the yield and yield contributing characters, P_2, P_3 and P_8 can be given the status of good general combiners and genetically worthy parents as they contributed maximum favourable genes for yield and yield components. 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. The best specific crosses combinations for high yield (P_1 x P_8, P_2 x P_5, P_2 x P_8, P_2 x P_9, P_4 x P_6, P_4 x P_7 and P_5 x P_7) are identified and after thorough multilocational trials these could be recommended for commercial cultivation. Further, selection in these crosses may throw useful transgressive segregates for high yield in the future generations.

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