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Combining Ability Studies for Development of New Hybrids in Rice over Environments

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Abstract

Combining ability study on grain yield and its components from line x tester analysis over the locations of five well adapted CMS lines and twenty three testers of different eco-geographic origin revealed higher *SCA* variance than *GCA* variance for all the traits indicating the prevalence of non-additive gene action. The lines APMS 6A, PUSA 5A and CRMS 32A and testers 1096, 1005, IBL-57 and SC5 9-3 were the good general combiners for yield and its majority of the traits. IBL-57 was the only good general combiner among the male parents for earliness, dwarfness and grain yield per plant. The hybrids APMS 6A x SC5 9-3, APMS 6A x 1005 and APMS 6A x GQ 25 were identified as potential one for yield and desired traits based on *sca* effects.

Keywords: Hybrid rice, CMS lines, Combining ability, Gene action

1. Introduction

The development and use of hybrid rice varieties on commercial scale utilizing CMS – fertility restoration system has proved to be one of the mile stones in the history of rice improvement. The hybrid rice technology now in operation, aims at yield increment through higher exploitable heterosis levels. With increasing interest in exploitation of heterosis in rice, there is an urgent need to subject various CMS lines and restorer lines for combining ability tests. The knowledge of combining ability is useful to assess nicking ability in self pollinated crops and at the same time elucidate the nature and magnitude of gene actions involved. It provides to the breeders an insight in to nature and relative magnitude of fixable and non-fixable genetic variances. Therefore, the present investigation was carried out to estimate combining ability effects for yield and its components involving CMS lines and restorer lines in rice.

2. Material and Methods

The material for the present study comprised 115 F_1s of rice generated involving five CMS lines (viz., IR 58025A, IR 79156A, APMS 6A, PUSA 5A and CRMS 32A) and 23 diverse elite restorer lines as testers through Line x Tester design during *rabi*, 2006-07. The resultant 115 F_1s and 28 parents were grown in randomized complete block design with two replications during *kharif*, 2007 at three different locations viz., Directorate of

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Rice Research, Hyderabad (Southern Telangana Agro-climatic zone), Regional Agricultural Research Station, Warangal (Central Telangana Agro-climatic zone) and Regional Agricultural Research Station, Jagtial (Northern Telangana Agro-climatic zone. Thirty days old seedlings were transplanted with one seedling per hill adopting 20 x 15 cm spacing and each entry was planted in two rows of 1.8 m length. All the recommended agronomic practices were followed. In each entry, five plants were selected randomly from each replication and biometrical observations were recorded for plant height, flag leaf length, flag leaf width, productive tillers per plant, panicle length, panicle weight, filled grains per panicle, spikelet fertility %, 1000 grain weight, grain yield per plant and productivity per day. Days to 50% flowering was recorded on plot basis. The mean data over the three locations were analyzed for combining ability following the standard method of Kempthorne (1957).

3. Results and Discussion

The pooled analysis of variance for combining ability over three locations revealed that the variance due to parents, parents vs. crosses and crosses were highly significant (Table 1) for all the characters studied. The variance due to lines was significant for all the characters except days to fifty per cent flowering, plant height and 1000 grain weight, whereas for testers, plant height, flag leaf length, productive tillers per plant, panicle length, filled grains per panicle and 1000 grain weight were found significant. Interaction effects of (Parents vs. crosses) x locations, parents x locations and crosses x locations were significant for all the characters, except flag leaf width in case of (parents vs. crosses) x locations interaction. Further partitioning of crosses x locations indicated that the interaction of lines x locations showed significant differences for productive tillers per plant, flag leaf length and flag leaf width, while testers x locations was significant only for filled grains per panicle. The interaction due to lines x testers and lines x testers x locations were significant for all the traits indicating that combining ability contributed heavily in the expression of these traits and provided importance of dominance or non additive variances for all the traits. The comparative estimates of variances due to *GCA* and *SCA* revealed the importance of *SCA* variance. The *SCA* variances were higher than *GCA* variances for all the traits suggesting the significant role of non additive gene action Predominance of non additive gene action for grain yield and its components was also reported by other workers (Satyanarayana *et al.*(2000), Rita and Motiramani (2005) ; Singh *et al.* (2005) ; Venkatesan *et al.* (2007) and Dalvi and Patel (2009))

The estimates of *gca* effects (Table 2) showed that parents with high *gca* effects differed for various traits. Among the lines APMS 6A had favourable genes for grain yield and other traits including flag leaf length, flag leaf width, productive tiller per plant, panicle weight, filled grains per panicle, spikelet fertility % and productivity per day. The line PUSA 5A was the best combiner for grain yield, dwarfness, 1000 seed weight and productivity per day. However CRMS 32A contributed positive alleles for grain yield, dwarfness, panicle length, panicle weight, filled grains per panicle and productivity per day. Among the testers, 1096 possessed the desirable genes for grain yield, productive tillers per plant, panicle length, panicle weight, filled grains per panicle, and productivity per day, whereas 1005 for grain yield, dwarfness, flag leaf length, flag leaf width, panicle weight, filled grains per panicle and productivity per day. Some other good general combiners that had also contributed positive genes for various characters were; IBL-57 for grain yield, earliness of flowering, dwarfness, flag leaf length, productive tillers per plant, filled grains per panicle and productivity per day; SC5 9-3 for grain yield, flag leaf length, flag leaf width, productive tillers per plant, filled grains per panicle and spikelet fertility % and 124 for grain yield, panicle length, panicle weight, filled grains per panicle, spikelet fertility % and productivity per day.

Crosses with desirable *sca* effects for various traits along with mean performance and *gca* effects of parents involved in the crosses are listed in the table 3. The crosses APMS 6A X SC5 9-3, APMS 6A X 1005 and APMS 6A X GQ 25, PUSA 5A X IR 55 and PUSA 5A X IR 43 expressed significant *sca* effects as well as high *per se* performance for grain yield per plant and few other traits. However, CRMS 32A X IR 43 and PUSA 5A X IR 60 for plant height (dwarfness), IR 79156A X GQ-120 for flag leaf length, APMS 6A X 118 for flag leaf width, APMS 6A X SC 5 9-3 and APMS 6A X 118 for panicle weight, APMS 6A X 1005 for filled grains per panicle, APMS 6A X SC5 9-3 and APMS 6A X 1005 for grain yield per plant, PUSA 5A X KMR 3 for productivity per day had high mean performance and highly significant mean values. These desirable cross combinations involved high x high type of general combiners. Kalitha and Upadhaya (2000), Shivani *et al.* (2009) and Salgotra *et al.* (2009) also reported about interaction between positive and positive alleles in crosses involving high x high combiners which can be fixed in subsequent generations if no repulsion phase linkages are involved.

The desirable performance of combinations like high x low may be ascribed to the interaction between dominant alleles from good combiners and recessive alleles from poor combiners (Dubey, 1975). Such combinations were observed in the hybrids ; IR 58025AX BR 827-35 and IR 58025A X EPLT 109 for days to 50% flowering (earliness), IR 79156A X GQ 25 and IR 79156A X EPLT 109 for plant height (dwarfness), CRMS 32A X SC5

9-3, CRMS 32A X IBL-57 and IR 79156A x 1096 for flag leaf length, APMS 6A X 619-2 for flag leaf width, CRMS 32A X IR 43 for productive tillers per plant, IR 58025A XGQ 37-1, APMS 6A X GQ 120, IR 79156A X GQ 70 and IR 58025A X 517 for panicle length, IR 79156A X SG 27-77 for filled grains per panicle, APMS 6A X 611-1 for spikelet fertility %, PUSA 5A X 517, APMS 6A X IR 60 and APMS 6A X EPLT 109 for 1000 grain weight, APMS 6A X GQ 25, PUSA 5A X IR 43 and PUSA 5A XIR 55 for grain yield per plant and APMS 6A X GQ 25, PUSA 5A X IR 43, PUSA 5A X IR 55 and IR 79156A X IBL 57 for productivity per day. Peng and Virmani (1990) also reported the possibility of interaction between positive alleles from good combiner and negative alleles from poor combiner in high x low cross combination and suggested for the exploitation of F_1 generation, as their high yielding potential would be unfixable in succeeding generation.

Involvement of both the poor combiners also produced superior specific combining hybrids as evidenced from the combinations: PUSA 5A X IR 60, CRMS 32A X IR 43 and APMS 6A X 118 (days to 50% flowering (earliness), IR 79156A X GQ-120 (plant height (dwarfness)), CRMS 32 A X 118 (flag leaf length), PUSA 5A X GQ 37-1, CRMS 32A X 124 and CRMS 32A X IBL 57 (flag leaf width), PUSA 5A X 1096, IR 79156A X KMR 3, APMS 6A X SC 5 9-3 and APMS 6A X124 (productive tillers per plant), PUSA 5A X SC5 2-2-1(panicle length), IR 58025A X IR 60, IR 79156A X SG 27-77 and IR 79156A X GQ 37-1 (panicle weight), PUSA 5A X 619-2 and PUSA 5A X 611-1 (filled grains per panicle), PUSA 5A X 611-1, CRMS 32A X EPLT-109 and IR 58025A X IR 55 (spikelet fertility %) and APMS 6A X IBL 57 and CRMS 32A X IR 43 (1000 grain weight). Involvement of both the combiners with low *gca* has been attributed to over dominance and epistasis interaction, which has been suggested by Amrithadevarathinam (1983), Singh *et al.* (2005) and Dalvi and Patel (2009). In majority of the crosses, high *sca* was mainly either due to high x low or low x low combining parents, which further substantiate the operation of non-additive gene action (additive x dominance and dominance x dominance epistatic interaction).

Combining ability analysis revealed that 1096, 1005, IBL-57 and SC5 9-3 were the good general combiners for yield and its majority of the trait among the male lines, whereas APMS 6A, PUSA 5A and CRMS 32A were among female lines. APMS 6A x SC5 9-3, APMS 6A x 1005 and APMS 6A x GQ 25 were identified as most promising crosses for yield based on *sca* effects, better *per se* and both or one of the parents with high *gca* for yield per plant also, could be exploited profitably for yield in rice.

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Table 1a. Pooled analysis of variance for combining ability (L X T) for yield and yield components in rice

		Mean sum of squares					
Source of variation	d.f	Days to 50% flowering	Plant height	Flag leaf length	Flag leaf width	Productive tillers/plant	Panicle length
Locations	2	8166.540 **	6484.604 **	6451.716 **	6.618 **	86.747 **	202.405 **
Replications x Locations	2	4.938	29.056	0.375	0.134 **	0.175	0.379
Treatments	142	63.697 **	336.490 **	80.313 **	0.175 **	12.895 **	11.118 **
Parents	27	105.061 **	805.453 **	81.219 **	0.256 **	2.885 **	10.987 **
Parent vs. Crosses	1	42.894 **	1930.397 **	1593.886 **	0.203 **	1058.221 **	514.087 **
Crosses	114	54.083 **	211.438 **	66.821 **	0.155 **	6.097 **	6.737 **
Lines	4	39.357	394.483	245.108 **	0.870 **	10.618 *	19.280 **
Testers	22	71.607	372.022 **	109.044 **	0.189	13.195 **	10.127 *
Lines x Testers	88	50.371 **	162.972 **	48.162 **	0.114 **	4.116 **	5.319 **
Parents x Locations	54	33.297 **	92.719 **	40.486 **	0.095 **	2.260 **	3.337 **
(Parent vs. Crosses) x Locations	2	597.974 **	858.389 **	81.341 **	0.030	26.055 **	37.831 **
Crosses x Locations	228	54.380 **	87.636 **	42.938 **	0.079 **	4.269 **	2.818 **
Lines x Locations	8	42.079	130.372	200.827 **	0.289 **	10.170 *	1.735
Testers x Locations	44	65.061	91.173	47.957	0.090	4.533	2.515
Lines x Testers x Locations	176	52.269 **	84.809 **	34.506 **	0.067 **	3.935 **	2.943 **
Error	426	3.812	9.963	8.677	0.021	0.967	0.796
σ^2GCA		0.61	4.44	2	0.01	0.13	0.17
σ^2SCA		7.73	25.48	6.56	0.02	0.52	0.76
σ^2GCA/σ^2SCA		0.08	0.17	0.30	0.50	0.25	0.22

*: Significant at 5% level and **: Significant at 1% level

Table 1b. Pooled analysis of variance for combining ability (L X T) for yield and yield components in rice

Mean Sum of Squares							
Source of variation	d.f	Panicle weight	Filled grains per panicle	Spikelet fertility %	1000 grain weight	Grain yield per plant	Productivity per day
Locations	2	10.027 **	12805.560 **	4297.021 **	34.324 **	876.645 **	4823.378 **
Replications x Locations	2	0.268	160.089	0.282	0.221	1.522	12.162
Treatments	142	3.027 **	7583.527 **	119.148 **	25.561 **	160.233 **	714.219 **
Parents	27	1.932 **	6297.925 **	79.294 **	40.342 **	52.871 **	240.599 **
Parent vs. Crosses	1	98.811 **	100092.800 **	375.922 **	51.517 **	4458.350 **	20275.250 **
Crosses	114	2.446 **	7076.527 **	126.335 **	21.832 **	147.958 **	654.804 **
Lines	4	21.533 **	49802.710 **	312.097 *	21.425	503.279 **	1960.378 *
Testers	22	2.359	9377.320 **	165.686	54.209 **	156.382	711.171
Lines x Testers	88	1.600 **	4559.229 **	108.053 **	13.756 **	129.701 **	581.368 **
Parents x Locations	54	0.829 **	1856.914 **	60.818 **	9.070 **	30.227 **	139.273 **
(Parent vs. Cross) x Locations	2	3.983 **	13293.420 **	104.211 **	42.976 **	150.846 **	545.955 **
Crosses x Locations	228	0.935 **	2449.021 **	98.394 **	13.826 **	68.936 **	319.323 **
Lines x Locations	8	1.043	3146.987	190.423	17.752	82.201	357.870
Testers x Locations	44	1.131	2587.760 **	85.863	16.059	62.670	297.621
Lines x Testers x Locations	176	0.882 **	2382.610 **	97.344 **	13.089 **	69.899 **	322.996 **
Error	426	0.152	138.77	6.25	0.39	3.68	16.50
σ^2GCA		0.14	350.53	2.77	0.46	3.88	15.69
σ^2SCA		0.24	735.69	17.02	2.23	20.97	93.98
σ^2GCA/σ^2SCA		0.58	0.48	0.16	0.21	0.19	0.17

*: Significant at 5% level and **: Significant at 1% level

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Table 2. General combining ability (GCA) effects of parents in rice

	FLL	FLW	DFF	PHT	EBT	PL
LINES						
IR 58025A	-0.73 **	-0.043**	-0.78 **	1.00 **	-0.42**	0.26 **
IR79156A	1.26 **	-0.10 **	-0.08	1.68 **	-0.06	0.20 **
APMS 6A	1.54 **	0.12 **	0.63 **	0.57 *	0.33 **	-0.01
PUSA 5A	-1.51 **	0.00	-0.11	-2.63 **	0.02	-0.64 **
CRMS32A	-0.56 *	0.02	0.34 *	-0.61 *	0.14	0.20 **
SE (lines)	0.25	0.01	0.17	0.27	0.09	0.07
Testers						
1096	1.05	-0.08 **	-0.69	3.50 **	0.88 **	0.41 **
1005	1.12 *	0.12 **	0.84 *	-1.89 **	0.10	-0.43 **
619-2	-0.29	0.02	0.84 *	0.297	0.16	0.42 **
612-1	0.09	0.02	-1.56 **	3.80 **	0.92 **	0.89 **
611-1	2.77 **	0.04	-0.06	0.49	-0.55 **	0.28
GQ-25	-0.87	0.06 *	0.31	-1.192 *	0.18	-0.21
GQ-37-1	-0.82	0.05	-1.46 **	-0.847	0.96 **	-0.38 *
GQ-70	2.05 **	0.09 **	-2.19 **	-3.46 **	0.22	-0.23
GQ-120	1.86 **	-0.06 *	0.01	3.51 **	-0.03	0.41 *
KMR-3	-0.59	-0.15 **	-2.49 **	5.79 **	0.80 **	0.47 **
IBL-57	2.61 **	-0.04	-3.49 **	-2.277 **	0.59 **	-1.19 **
BR827-35	0.62	0.01	0.48	0.36	0.20	-0.14
EPLT-109	0.26	-0.02	-0.26	-5.985 **	-0.21	-1.03 **
SC_5 2-2-1	-1.04	0.07 **	1.51 **	-1.12	-0.13	0.18
SC_5 9-3	2.53 **	0.12 **	1.18 **	-0.89	0.12	0.13
SG27-77	1.94 **	-0.06 *	0.48	2.09 **	0.31	0.471 **
SG26-120	-0.41	-0.05	-1.43 **	6.13 **	0.33	0.59 **
118	-3.54 **	0.13 **	2.18 **	1.79 **	-0.04	0.08
124	0.02	0.02	1.28 **	4.79 **	-0.29	0.83 **
517	-0.20	-0.08 **	2.84 **	-0.63	-0.90 **	-0.51 **
IR 43	-3.06 **	-0.12**	1.48 **	-5.82 **	-1.21 **	-0.99 **
IR55	-2.26 **	-0.1 **	0.21	-3.68 **	-1.46 **	0.39 *
IR60	-3.83 **	-0.01	-0.03	-4.82 **	-0.95 **	-0.43 **
SE (testers)	0.54	0.03	0.36	0.58	0.18	0.16

Table 2 continued..,

	PWT	FG	SF%	1000 SW	GY	PDP
LINES						
IR 58025A	-0.37 **	-12.83**	-0.40	-0.17 **	-1.68 **	-3.23 **
IR79156A	-0.35 **	-17.59 **	1.35 **	0.31 **	-2.42 **	-4.84 **
APMS 6A	0.51 **	26.27 **	1.41 **	-0.28 **	1.45 **	2.69 **
PUSA 5A	-0.08 *	-9.56 **	-2.26 **	0.52 **	0.91 **	1.91 **
CRMS32A	0.30 **	13.71 **	-0.09	-0.38 **	1.73 **	3.48 **
SE (lines)	0.05	1.03	0.21	0.05	0.17	0.36
Testers						
1096	0.50 **	28.82 **	0.31	-0.65 **	1.35 **	3.00 **
1005	0.42 **	44.25 **	0.12	-2.20 **	1.34 **	2.23 **
619-2	0.07	-4.14	-0.12	0.55 **	-1.81 **	-4.06 **
612-1	0.14	-8.06 **	-2.97 **	1.37 **	0.15	0.98
611-1	-0.153 *	-21.38 **	-5.85 **	2.41 **	-2.69 **	-5.53 **
GQ-25	0.01	-3.36	-0.27	0.32 **	0.27	0.25
GQ-37-1	-0.40 **	-11.74 **	-1.93 **	-1.55 **	0.09	0.83
GQ-70	-0.26 **	16.66 **	1.62 **	-2.05 **	0.55	2.04 **
GQ-120	-0.23 **	-9.52 **	-0.15	-0.91 **	-0.99 **	-1.93 *
KMR-3	-0.06	-15.14 **	0.67	1.10 **	3.99 **	9.49 **
IBL-57	0.13	13.92 **	0.96 *	-1.55 **	1.89 **	5.03 **
BR827-35	0.20**	-12.71 **	-1.62 **	2.86 **	-1.002 **	-2.28 **
EPLT-109	-0.21 **	-17.04 **	-3.39 **	0.70**	-4.68 **	-9.89 **
SC_5 2-2-1	0.15 *	-5.90 **	-0.42	0.57 **	-1.25 **	-3.25 **
SC_5 9-3	0.37 **	9.37 **	0.96 *	0.30 **	1.00 **	1.37
SG27-77	0.11	14.46 **	2.71 **	-1.28 **	5.12 **	10.27 **
SG26-120	-0.01	2.10	3.54 **	-0.68 **	1.91 **	4.62 **
118	0.24 **	20.20 **	2.87 **	-0.42 **	0.75 *	0.81
124	0.15 *	7.03 **	2.73 **	-0.27 *	1.23 **	1.96 *
517	0.11	7.41 **	3.25 **	-0.07	0.79 *	0.23
IR 43	-0.48 **	-11.18 **	0.70	-0.51 **	-2.50 **	-5.33 **
IR55	-0.59 **	-32.34 **	-2.80 **	0.93 **	-3.17 **	-6.30 **
IR60	-0.20 **	-11.72 **	-0.92 *	0.12	-2.34**	-4.55 **
SE (testers)	0.11	2.20	0.45	0.11	0.36	0.76

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Table 3. Top five crosses with high sca effects, per se performance and *gca* effects of parents for grain yield and its components in rice

Character/ Cross	Mean per formance	*sca* effect	*gca* effect		*gca* status
			Female parent	Male parent	
Days to 50% flowering (earliness)					
PUSA 5A X IR 60	93.33	-6.40**	0.34**	1.48	L x L
CRMS 32A X IR 43	102.50	-6.62**	-0.11	-0.03	L x L
APMS 6A X 118	96.67	-6.23**	0.63**	2.18	L x L
IR 58025AX BR 827-35	94.50	-5.29**	-0.78**	0.48	H x L
IR 58025A X EPLT 109	93.83	-5.22**	-0.78**	-0.26	H x L
Plant height (dwarfnenss)					
IR 79156A X GQ 25	95.26	-11.74**	1.68**	-1.19**	L x H
IR 79156A X GQ-120	100.78	-10.92**	1.68**	3.51**	L x L
CRMS 32A X IR 43	102.67	-10.90**	-0.61**	-5.82**	H x H
PUSA 5A X IR 60	89.19	-9.87**	-2.63**	-4.82**	H x H
IR 79156A X EPLT 109	94.17	-8.04**	1.68**	-5.98**	L x H
Flag leaf length					
CRMS 32 A X SC5 9-3	46.48	5.97 **	-0.56**	2.53**	L x H
CRMS 32 A X IBL-57	46.22	5.63**	-0.56**	2.61**	L x H
IR 79156A X GQ-120	47.12	5.45**	1.26**	1.86**	H x H
IR 79156A x 1096	45.25	4.39**	1.26**	1.05	H x L
CRMS 32 A X 118	38.53	4.09**	-0.56**	-3.54**	L x L
Flag leaf width					
APMS 6A X 118	2.34	0.32**	0.12**	0.13**	H x H
APMS 6A X 619-2	2.20	0.28**	0.12**	0.02	H x L
PUSA 5A X GQ 37-1	2.10	0.26**	0.00	0.05	L x L
CRMS 32A X 124	2.07	0.25**	0.02	0.02	L x L
CRMS 32A X IBL 57	2.01	0.24**	0.02	-0.04	L x L
Productive tillers per plant					
PUSA 5A X 1096	14.80	2.01**	0.02	0.88**	L x L
IR 79156A XKMR 3	13.82	1.83**	-0.06	0.80**	L x L
APMS 6A XSC 5 9-3	13.40	1.70**	0.33	0.12	L x L
APMS 6A X124	12.84	1.55**	0.33	-0.29	L x L
CRMS 32A X IR 43	11.42	1.24**	0.14	-1.21**	L x H
Panicle length					
PUSA 5A X SC5 2-2-1	27.16	1.67**	-0.64**	0.18	L x L
IR 58025A XGQ 37-1	27.44	1.61**	0.26**	-0.38**	H x L
APMS 6A X GQ 120	27.94	1.60**	-0.01	0.41**	L x H
IR 79156A X GQ 70	27.41	1.49**	0.20**	-0.23	H x L
IR 58025A X517	26.58	1.43**	0.26**	-0.51**	H x L

Table 3. contd…

Character/ Cross	Mean performance	*sca* effect	*gca* effect		*gca* status
			Female parent	Male parent	
Panicle weight					
IR 58025A X IR 60	4.98	1.19**	-0.37**	-0.20**	L x L
APMS 6A X SC 5 9-3	6.35	1.10**	0.51**	0.37**	H x H
APMS 6A X 118	6.20	1.01**	0.51**	0.24**	H x H
IR 79156A X SG 27-77	5.10	0.98**	-0.35**	0.11	L x L
IR 79156A X GQ 37-1	4.52	0.91**	-0.35**	-0.40**	L x L
Filled grains per panicle					
PUSA 5A X 619-2	224.97	57.75**	-9.56**	-4.14	L x L
APMS 6A X 1005	307.00	55.57**	26.27**	44.25**	H x H
IR 79156A X SG 27-77	233.17	55.38**	-17.59**	14.46**	L x H
PUSA 5A X 611-1	203.53	53.56**	-9.56**	-21.38**	L x L
CRMS 32A X 517	254.90	52.87**	13.71**	7.41**	H x H
Spikelet fertility %					
PUSA 5A X 611-1	81.31	7.99**	-2.26**	-5.85**	L x L
CRMS 32A X EPLT-109	84.94	7.00**	-0.09	-3.39**	L x L
CRMS 32A XGQ 70	89.93	6.98**	-0.09	1.62**	L x H
APMS 6A X 611-1	82.94	5.95**	1.41**	-5.85**	H x L
IR 58025A X IR 55	84.15	5.93**	-0.40	-2.80**	L x L
1000 grain weight					
APMS 6A X IBL 57	22.78	3.13**	-0.28**	-1.55**	L x L
PUSA 5A X 517	25.03	3.09**	0.52**	-0.07**	H x L
APMS 6A X IR 60	23.67	2.35**	-0.28**	0.12**	L x H
APMS 6A X EPLT 109	24.21	2.31**	-0.28**	0.70**	L x H
CRMS 32A X IR 43	21.93	2.24**	-0.38**	-0.51**	L x L
Grain yield per plant					
APMS 6A X GQ 25	34.50	10.49**	1.45**	0.27	H x L
PUSA 5A X IR 43	34.59	10.08**	0.91**	-2.50**	H x L
PUSA 5A XIR 55	31.72	7.89**	0.91**	-3.17**	H x L
APMS 6A X SC5 9-3	36.17	7.63**	1.45**	1.00**	H x H
APMS 6A X 1005	36.44	7.56**	1.45**	1.34**	H x H
Productivity per day					
APMS 6A X GQ 25	79.32	22.03**	2.69**	0.25	H x L
PUSA 5A X IR 43	71.12	20.18**	1.91**	-5.33**	H x L
PUSA 5A X IR 55	66.69	16.73**	1.91**	-6.30**	H x L
IR 79156A X IBL 57	70.84	16.29**	-4.84**	5.03**	L x H
PUSA 5A X KMR 3	63.56	16.16**	1.91**	9.49**	H x H

H= High *gca* effect; L=Low *gca* effect