SHORT COMMUNICATION

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Gene action for yield and grain quality traits in rice (*Oryza sativa* L.)

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ABSTRACT

Combining ability analysis was carried out with nine parents and 18 F_{1s} for yield and quality traits in rice. Predominance of non additive gene action was observed for flag leaf length, days to 50% flowering, number of effective tillers, flag leaf width, yield per plant, alkali spreading value, water uptake and volume expansion ratio, while rest of the characters were controlled by additive gene action. Kavya among the lines found to be good general combiner for days to 50 % flowering, filled seeds per panicle, yield per plant, milling recovery, head rice recovery followed by CN 1448-5-2-5-5-MLD6. Among the testers CR 3005-230-5-50 was identified as good general combiner as they could contribute alleles with positive effect for improving the important quantitative and qualitative traits. The crosses Kavya x JGL 19618, Kavya x CR 3005- 230-5-50, Kavya x CN 1448-5-2-5-5- MLD6, MTU 1075 x CR 3005-230-5-50, HKR 08-62 x CR 3005 -230-5-50 and Swarna x CR 3005-230-5-50 were identified as most promising for yield and quality traits.

Key words: *Combining ability, yield, quality traits, rice, line x tester*

Rice is the staple food of more than half of the world's population. To meet the demand of increasing population and to maintain self sufficiency the present production level needs to be increased up to 120 million tons by 2020. Improvement in rice grain quality has become an important breeding objective as many countries have achieved rice self sufficiency (Juliano and Duff, 1991). The combining ability of the parents in terms of quality traits should be good so as to get varieties with desirable quality attributes for consumer preference. The importance of rice grain quality is now instrumental and has become a valuable tool for the acceptance of varieties to be released. In the present study an attempt was made to assess the combining ability for yield, grain quality and other related traits.

Six elite lines with good plant type with agronomical features and quality traits *i.e.*, were crossed with three testers in Line x Tester mating design during *Rabi* 2013 at Regional Agricultural Research Station, Warangal. The resultant 18 F_1S along with 9 parents were evaluated during *Kharif*, 2014 in randomized block design with 3 replications. Observations were recorded on 10 plants selected randomly from each cross for all metric traits, plant height (cm), effective tillers per plant, panicle length (cm), flag leaf length(cm), flag leaf width (cm), filled seeds per panicle, test weight (g), yield per plant (g) whereas, days to 50 % flowering was computed on plot basis. The F_1 produce was used for quality analysis for hulling percentage, milling percentage, head rice recovery (%), kernel length (mm), kernel width (mm), length/breadth ratio, kernel length after cooking (mm), kernel elongation ratio, alkali spreading value, volume expansion ratio and water uptake. The combing ability analysis for L x T design was performed as per method suggested by Kempthorne (1957).

The variance due to sca was higher than gca (Table 1) for days to 50% flowering, effective tillers, flag leaf length, flag leaf width, yield per plant, alkali spreading value, water uptake, volume expansion ratio suggesting significant role of non additive gene action like dominance, epitasis and other interaction effects in the expression of these characters. The results are in agreement with the findings of Rukmini Devi et al.

Table 1. GCA and SCA variance for yield and yield components in rice (*Oriza sativa*.L.).

Source of Variation	Days to 50% flowering	Effective tillers	Plant height(cm)	Panicle length(cm)	Flag leaf length(cm)	Flag leaf width(cm)	Filled seeds /Panicle	Test weight(g)	Yield/Plant (g)
σ^2GCA (Lines)	23.5	916.9	35.8	5.05**	22.71*	0.02**	1078.5*	12.69**	31.48
σ^2GCA (Testers)	2.16	1003.1	485.5**	1.56**	12.73	-0.001	3550.2**	1.23	24.05
σ^2GCA	9.23*	974.3*	335.6**	2.73**	16.05**	0.0074**	2726.3**	5.05**	26.5
σ^2SCA	22.85**	1531.7**	36.9**	0.19	17.49**	0.008	850.9**	1.77**	129.4**
σ^2GCA/ σ^2 SCA	0.41	0.64	1.45	14.70	0.91	0.973	3.20	2.85	0.20

* and ** significant at 5% and 1% level respectively

(2014) and Roy and Senapathi (2012) for effective tillers and yield per plant and Chandra Mohan Singh and Suresh babu (2012) for flag leaf width and flag leaf length. The variance due to gca was higher than sca for plant height, panicle length, filled seeds per panicle, test weight, hulling percentage, milling percentage, head rice recovery, kernel length, kernel width, length / breadth ratio, kernel length after cooking and kernel breadth after cooking. The results are in agreement with Monhot et al. (2000) for plant height, panicle length ,filled grains per panicle, kernel length, length / breadth ratio, kernel breadth after cooking and Rukmini Devi et al. (2014) for plant height, panicle length, filled grain per panicle, kernel width, length / breadth ratio, kernel length after cooking, kernel breadth after cooking suggesting major role of additive gene action in the expression of the characters .

General combining ability effects of parents revealed that among six lines Kavya (7.150**) followed by CN 1774-303-313-19-8-8 and MTU1075 exhibited significant positive gca effect for grain yield per plant (Table 2), while Swarna and BPT 5204 showed negative significant value. Whereas, HKR 08-62 showed non significant positive value for the same. For head rice recovery, Kavya, BPT5204, MTU1075 and HKR.08-62 showed high positive gca value, while Swarna and CN1774-303-313-19-8-8 showed negative significant values. MTU1075 and BPT5204 showed significant gca effect for kernel elongation ratio. Among the lines Kavya for days to 50% flowering, plant height and kernel breadth after cooking, BPT 5204 for plant height and kernel breadth after cooking exhibited the desired significantly negative gca value in desired direction and may be utilized in the crossing program as one of the parent for improvement of characters.

Among the testers, CR 3005-230-5-50 exhibited significant positive gca effect for yield per plant, while CN 1448 -5-2-5-5-MLD6 showed negative significant gca effect and JGL 19618 showed non significant positive gca. The tester CR 3005-230-5-50 showed significantly positive gca values for other yield and quality traits like panicle length, filled seeds per panicle , milling percentage, head rice recovery, kernel length, kernel width after cooking in desired direction. Among

Table 2. Estimates of general combining ability effects for yield and yield components in rice (*Oryza sativa* L.).

Source of Variation	Days to 50% flowering	Effective tillers	Plant height(cm)	Panicle length (cm)	Flag leaf length(cm)	Flag leaf width(cm)	Filled seeds / Panicle	Test weight (g)	Yield/ Plant (g)
Lines									
Kavya	-4.722 **	-29.639 **	-1.278 **	-0.369 ***	7.533 *	0.282 **	33.972 **	-0.342	7.150 **
MTU1075	0.444	-28.306 **	-0.278 **	-1.536 ***	0.250	0.010	16.972*	-2.475 **	2.983 *
BPT5204	1.278	33.528	-9.611 **	-2.536 ***	-1.983	-0.081	1.306	-4.408 **	-8.733 **
CN1774-303-313-19-8-8	-3.222 **	-1.639 **	7.722**	3.947 **	3.433**	0.052	-4.694	4.692 **	2.250**
HKR08-62	-2.722 **	-16.139 **	5.722**	1.264	-3.167 **	-0.215 **	-62.361 **	3.825 **	0.650
Swarna	8.944 **	42.194	-2.278 **	-0.769 ***	-6.067 **	-0.048	14.806 *	-1.292 **	-4.300 **
SE ±	**0.9426**	**7.2507**	**1.5956**	**0.5342**	**1.0802**	**0.0709**	**6.0246**	**0.3123**	**0.7547**
Testers									
CR3005-230-5-50	-0.889	32.028**	25.306 **	1.456 **	4.208 **	-0.040	64.806**	0.075	4.717 **
JGL19618	-0.972	0.111	-10.111 **	-0.386 ***	-1.942 **	0.054	-11.944 **	-1.167 **	0.408
CN1448-5-2-5-5-MLD6	1.861*	-32.139 **	-15.194 **	-1.069 ***	-2.267 **	-0.015	-52.861 **	1.092 **	-5.125 **
SE ±	**0.6665**	**5.1270**	**1.1282**	**0.3777**	**0.7638**	**0.0501**	**4.2600**	**0.2209**	**0.5337**

* and ** significant at 5% and 1% level respectively.

Table 1. GCA and SCA variance for quality traits in rice (*Oriza sativa* L.).

Source of Variation	Hulling percentage	Milling percentage	Head rice recovery (%)	Kernel length (mm)	Kernel width (mm)	L/ B ratio	Kernel length after cooking (mm)	Kernel breadth after cooking (mm)	Kernel elongation ratio	Alkali spreading value	Volume expansion ratio	Water uptake
σ^2GCA (Lines)	0.66	31.8**	37.63**	0.168**	0.012	0.0307	0.259**	0.055**	0.0009	0.1124	0.0111	88.62
σ^2GCA (Testers)	0.18	5.63	13.54**	0.020	0.0138	0.0533	0.141**	0.0109*	0.0022**	-0.0049	-0.0032	139.62
σ^2GCA	0.34*	14.39**	21.57**	0.070**	0.0133**	0.0457**	0.181**	0.0255**	0.0017*	0.034	0.0016	122.62
σ^2SCA	-0.20	6.91	10.79**	0.052**	0.0102**	0.0425**	0.053**	-0.005	0.0022*	0.237	0.0066	-168.94
σ^2GCA/ σ^2 SCA	1.67	2.08	1.99	1.35	1.30	1.07	3.38	5.1	0.77	0.144	0.242	0.72

* and ** significant at 5% and 1% level respectively

Table 2. Estimates of general combining ability effects for quality traits in rice (*Oryza sativa* L.).

Source of Variation	Hulling%	Milling%	HRR(%)	KL(mm)	KW(mm)	L/ B ratio	KLAC(mm)	KBAC(mm)	KER	ASV	VER	WU
Lines												
Kavya	1.092	3.069*	4.447 **	-0.147 ***	0.006 *	-0.120 ***	-0.250 ***	-0.186 ***	-0.019 ***	-0.361 ***	0.047	-5.667 ***
MTU1075	-0.258	1.736	2.764**	-0.297 ***	-0.078 ***	-0.005 ***	-0.033 ***	-0.069 ***	0.065 ***	0.639 **	-0.069 ***	11.833
BPT5204	1.058	2.686*	3.714 **	-0.381 ***	-0.161 ***	0.009 *	-0.567 ***	-0.269 ***	0.003 *	0.306	-0.136 ***	-22.167 ***
CN1774-303-313 -19-8-8	-0.425	-11.747 **	-12.103 **	0.186 ***	0.172 ***	-0.141 ***	0.017	0.397 ***	-0.042 ***	-0.028 ***	0.081 *	17.667
HKR08-62	0.208	2.603	1.914*	0.753 ***	0.056 ***	0.342 ***	0.967 ***	0.147 ***	0.001	-0.528 ***	0.247 ***	12.333
Swarna	-1.675 *	1.653	-0.736 **	-0.114 ***	0.006 *	-0.085 ***	-0.133 ***	-0.019 ***	-0.009 ***	-0.028 ***	-0.169 ***	-14.000 ***
SE ±	**0.6512**	**1.2421**	**0.8606**	**0.0743**	**0.0267**	**0.0324**	**0.0900**	**0.0615**	**0.0206**	**0.2646**	**0.1153**	**13.2709**
Testers												
CR3005-230-5-50	-0.717 *	2.911**	4.214 **	-0.131 ***	0.131 ***	-0.267 ***	-0.400 ***	0.131 ***	-0.056 ***	-0.194 ***	-0.053 ***	-10.750 ***
JGL19618	0.250	-1.714	-1.336 **	-0.039 ***	-0.103 ***	0.149 ***	0.042 **	-0.061 ***	0.025 ***	0.056	0.064 **	17.250
CN1448-5-2-5-5-MLD6	0.467	-1.197	-2.878 **	0.169 ***	-0.028 ***	0.119 ***	0.358 ***	-0.069 ***	0.031 ***	0.139	-0.011 ***	-6.500 ***
SE ±	**0.4605**	**0.8763**	**0.6085**	**0.0525**	**0.0189**	**0.0229**	**0.637**	**0.0435**	**0.0146**	**0.1871**	**0.0815**	**9.3840**

HRR- Head rice recovery, KL-kernel length, KW-kernel width, KLAC-kernel length after cooking, KBAC-kernel breadth after cooking, KER-kernel elongation ratio, ASV-alkali spreading value, VER-volume expansion ratio, WU-water uptake, * and ** significant at 5% and 1% level respectively.

the testers CR 3005-230-5-50 can be judged as a potential parent for most of the important yield components and quality traits.

Eight crosses exhibited significantly positive sca value for grain yield per plant (Table 3). The cross BPT 5204 x CR 3005-230-5-50 recorded significant positive sca effects for yield per plant, length /breadth ratio, kernel length after cooking and Kavya x CN 1448-5-2-5-5-MLD6 for flag leaf length, filled grain per panicle and test weight. If grain yield per plant and length/breadth ratio are assumed to be most important yield and quality characters, BPT 5204 x CR 3005-230-5-50 seems to promising for yield per plant, length / breadth ratio. HKR 08-62 x CN 1448-5-2-5-5-MLD6 showed significant positive sca for length / breadth ratio and negative significant sca for days to 50% flowering and kernel width in desired direction.

For yield, MTU1075 x CR 3005-230-5-50, Kavya x JGL 19618 and Kavya x CN 1448-5-2-5-5, while for quality traits and yield BPT 5204 x CR 3005-230-5-50, HKR 08-62 x CN1448-5-2-5-5-MLD6 were found to be superior crosses. For quality, MTU 1075 x CR 3005-230-5-50 recorded significant sca effect for milling recovery, head rice recovery, filled seeds per panicle and days to 50% flowering and plant height in desired direction.

The desirable combinations involved high x low, high x high, low x high type of general combiners and such combinations were observed in hybrids , MTU1075 x CR 3005-230-5-50 (H x L) for plant height, HKR 08-62 x CN 1448-5-2-5-5- MLD 6 (H x L) for filled grains per panicle and test weight, BPT 5204 x CR-3005-230-5-50 (H x L) for length / breadth ratio, HKR-08-62 x CN1448-5-2-5-5- MLD6 (L x H) for kernel width, HKR 08-62 x CN 1448-5-2-5-5-MLD6 (L x H) for effective tillers and CN1774-303-313-19-8-8 x CR 3005-230-5-50 (L x H) for milling percentage and head rice recovery. Involvement of both poor combiners (L x L) also produced superior specific combining hybrids as evaded from the combination BPT 5204 x JGL 19618 (L x L) for effective tillers, and filled grains per panicle, Kavya x CN 1448-5-2-5-5- MLD6 for test weight, BPT 5204 x CR 3005-230-5-50 for kernel length after cooking, Swarna x JGL 19618 for head rice recovery. Similar views also expressed by Roy and Senapathi (2012).

Table 3. Estimates of specific combining ability effects for yield and yield components in rice (*Oryza sativa* L.).

Source of Variation	Days to 50% flowering	Effective tillers	Plant height(cm)	Panicle length (cm)	Flag leaf length(cm)	Flag leaf width(cm)	Filled seeds /Panicle	Test weight (g)	Yield/Plant (g)
Kavya x CR3005-230-5-50	-2.111	17.972	3.361	0.111	-6.25**	-0.074	-41.472**	-0.742	-11.867**
Kavya x JGL19618	1.972	11.389	-4.722	-0.697	-1.375	0.122	12.778	-1.050	7.792**
Kavya x CN1448-5-2-5-5-MLD6	0.139	-29.361*	1.361	0.586	7.900**	-0.049	28.694*	1.795**	4.075**
MTU1075 x CR3005-230-5-50	-5.778**	-10.861	-1.639	1.478	6.458**	0.048	20.528	0.392	11.300**
MTU1075 x JGL19618	4.806**	-4.944	0.778	-0.981	0.692	-0.071	-9.222	0.583	-1.592
MTU1075 x x CN1448-5-2-5-5-MLD6	0..972	15.806	0.861	-0.497	-5.767**	0.023	-11.306	-0.975	-9.708**
BPT5204 x CR3005-230-5-50	4.889**	-43.694**	4.694	-0.572	-1.608	-0.010	-20.806	0.125	9.017**
BPT5204 x JGL19618	-3.528*	60.222**	0.111	0.519	0.992	-0.054	41.444**	0.667	-5.525**
BPT5204 x CN1448-5-2-5-5-MLD6	-1.361	-16.528	-4.806	0.053	0.617	0.065	-20.639	-0.792	-3.492**
CN1774-303-313-19-8-8 x CR3005-230-5-50	-5.611**	-33.028*	-9.139**	-1.356	0.075	0.006	30.694**	0.825	-19.317**
CN1774-303-313-19-8-8 x JGL19618	0.972	-5.611	3.278	0.686	-1.025	0.012	-7.556	-1.933**	6.892**
CN1774-303-313-19-8-8 x CN1448-5-2-5-5-MLD6	4.639*	38.639**	5.861*	0.669	0.950	-0.019	-23.139*	0.108	12.425**
HKR08-62 x CR3005-230-5-50	7.889**	61.472**	-1.639	0.178	-0.225	0.123	19.361	-1.458*	3.353*
HKR08-62 x JGL19618	-3.028	-35.111*	-5.222	-0.531	0.125	-0.071	-36.389**	0.883	-6.908**
HKR08-62 x CN1448-5-2-5-5-MLD6	-4.861**	-26.361	6.861*	0.353	0.100	-0.052	17.028	0.575	3.375*
Swarna x CR3005-230-5-50	0.722	8.139	4.361	0.161	1.825	-0.094	-8.306	0.858	7.333**
Swarna x JGL19618	-1.194	-25.944	5.778	1.003	1.975	0.062	-1.056	0.850	-0.658**
Swarna x CN1448-5-2-5-5-MLD6	0.472	17.806	-10.139**	-1.164	3.800	0.031	9.361	-1.708**	-6.675
SE ±	**1.6326**	**12.558**	**2.7636**	**0.9252**	**1.8710**	**0.1228**	**10.4249**	**0.5410**	**1.3072**

* and ** significant at 5% and 1% level respectively

Table 3. Estimates of specific combining ability effects for quality traits in rice (*Oryza sativa* L.).

Source of Variation	Hulling%	Milling%	HRR(%)	KL(mm)	KW(mm)	L/ B ratio	KLAC (mm)	KBAC (mm)	KER	ASR	VER	WU
Kavya x CR3005-230-5-50	-1.467	-1.411	-2.047	-0.036	-0.147**	0.199**	-0.017	-0.047	0.009	0.361	-0.297	-5.583
Kavya x JGL19618	0.067	1.964	1.553	-0.228	-0.014	-0.117	-0.158	-0.006	0.019	-0.889	-0.014	-8.083
Kavya x CN1448-5-2-5-5-MLD6	0.400	-0.553	0.494	0.264	0.161**	-0.082	0.175	0.053	-0.028	0.528	0.311	13.667
MTU1075 x CR3005-230-5-50	1.133	-1.978	-2.114	0.164	0.036	-0.026	0.067	-0.114	-0.034	-0.639	0.169	7.417
MTU1075 x JGL19618	-0.433	1.797	1.836	-0.178	-0.081	0.143*	0.025	0.078	0.055	0.611	0.103	-20.583
MTU1075 x x CN1448-5-2-5-5-MLD6	-0.700	0.181	0.278	0.014	0.044	-0.117	-0.092	0.036	-0.021	0.028	-0.272	13.167
BPT5204 x CR3005-230-5-50	0.167	-0.978	0.436	0.197	0.031	0.141*	0.350*	-0.114	0.003	0.194	-0.064	-13.583
BPT5204 x JGL19618	-0.600	1.847	-0.764	0.156	0..003	0.090	-0.192	-0.022	-0.038	-0.056	-0.131	23.417
BPT5204 x CN1448-5-2-5-5-MLD6	0.433	-0.869	0.328	-0.353*	0.028	-0.230*	-0.158	0.136	0.035	-0.139	0.194	-9.833
CN1774-303-313-19-8-8 x CR3005-230-5-50	1.000	6.606**	4.353**	-0.119	0.086	-0.134*	-0.483**	0.069	-0.057	0.028	0.169	-3.417
CN1774-303-313-19-8-8 x JGL19618	-0.217	-6.819**	-5.747**	-0.111	0.019	-0.145*	0.175	-0.039	0.052	0.778	-0.147	11.083
CN1774-303-313-19-8-8 x CN1448-5-2-5-5-MLD6	-0.783	0.214	1.394	0.231	-0.106*	0.280	0.308	-0.031	0.005	-0.806	-0.022	-7.667
HKR08-62 x CR3005-230-5-50	0.117	-1.594	-2.564	-0.286	0.003	-0.148*	-0.083	0.119	0.054	0.528	0.003	29.417
HKR08-62 x JGL19618	-0.200	0.081	-0.364	0.172	0.136**	-0.134*	0.275	-0.039	0.004	-0.222	0.036	-11.083
HKR08-62 x CN1448-5-2-5-5-MLD6	0.083	1.514	2.928	0.114	-0.139**	0.281**	-0.192	-0.081	-0.058	-0.306	-0.039	-18.333
Swarna x CR3005-230-5-50	-1.950	-0.644	1.936	0.081	0.053	-0.031	0.167	0.086	0.024	-0.472	0.019	-14.250
Swarna x JGL19618	1.383	1.131	3.486*	0.189	0.064	0.163**	-0.125	0.028	-0.091*	-0.222	0.153	5.250
Swarna x CN1448-5-2-5-5-MLD6	0.567	-0.486	-5.422**	-0.269	0.011	-0.132*	-0.042	-0.114	0.067	0.694	-0.172	9.000
SE ±	**1.1279**	**2.1514**	**1.4905**	**0.1286**	**0.0463**	**0.0561**	**0.1560**	**0.1065**	**0.0357**	**0.4584**	**0.1997**	**22.9858**

HRR- Head rice recovery, KL-kernel length, KW-kernel width, KLAC-kernel length after cooking, KBAC-kernel breadth after cooking, KER-kernel elongation ratio, ASV-alkali spreading value, VER-volume expansion ratio, WU-water uptake, * and ** significant at 5% and 1% level respectively.

The sca value is a useful index to determine the usefulness of a particular cross combination for exploitation of heterosis (Peng and Virmani, 1990). Among the crosses which exhibited high sca values and pre se performance for grain yield per plant were Kavya x JGL 19618 , Kavya x CN 1448-5-2-5-5-MLD6 which also showed high sca values for other yield contributing characters like day to 50% flowering , plant height, filled seeds per panicle and test weight.

The cross showing high sca effects involving parents with good combining ability would be exploited for hybrid development. Crosses with high sca effects and involving high x high combiners indicate additive x additive type of interaction, where as cross between high x low gca parents indicate additive x dominance type of interaction. The results of the present investigation showed that no cross was good for all the characters but some crosses showed good sca effects for number of characters.

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