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Combining Ability Analysis for Yield and Earliness in Hybrid Rice (*Oryza sativa* L.)

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ABSTRACT
To study the gene action and selection of better parent for rice (*Oryza sativa* L.) hybrids can achieve only with combining ability analysis. This investigation aims to identify good general and specific combiners for selecting better parents and better cross combinations in rice crop for developing high yielding and short duration rice hybrids. Five restorers were crossed with four different Cytoplasmic Male Sterile (CMS) lines in 2009. The experimental material comprising of 29 entries including 20 crosses and nine parents was planted in LxT (Line X Tester) design in three replications in kharif 2010. Analysis for combining ability of sixteen characters revealed significant differences among the genotypes. The variance due to lines, testers and line x tester interaction were highly significant for all the traits. In the analysis of General Combining Ability (GCA), Jaya was found good general combiner for grain yield plant^{-1}, 100 grain weight, pollen fertility, kernel length, kernel breadth, kernel length after cooking, elongation ratio and alkali digestion value among lines and IR68897A was good general combiner for days to maturity among testers. In the analysis of Specific Combining Ability (SCA), cross IR67684A×Swetha was best for grain yield plant^{-1} and IR68897A×Sasyashree was best for 100 grain weight. IR80555A×Swetha was found best for the traits days to maturity, seeds panicle^{-1} and kernel breadth. These genotypes, CMS lines and crosses may be used in hybrid production in rice crop.

Key words: CMS, restoration, GCA, SCA, genotype

INTRODUCTION
The successful development of rice hybrids by utilizing the cytoplasmic genetic male sterility system and fertility restoration system mainly depends on the availability of stable male sterile lines and economically viable seed production technology (Sreeramachandra *et al.*, 2000). Concept of combining is an important method for selecting potential parents for hybridization and selecting crosses for further exploitation (Pradhan and Singh, 2008). In a hybridization programme, choice of parents is a basic requisite to obtain good hybrids. Combining ability is the capacity of an individual to transmit superior performance to its offspring. Combining ability analysis also elucidates the nature and magnitude of gene action involve in the expression of economically desirable traits (Sharma and Mani, 2008). At present, hybrid rice research is concentrated on conversion and identification of stable local CMS lines, effective restorers and superior combining heterotic hybrids (Lavanya, 2000). The analysis of the parents and crosses provide information on the two components of variance viz., additive genetic and dominance variance which are important to decide upon the parents and crosses to be selected for eventual success and also the appropriate

breeding procedure to be followed to select desirable hybrids (Kalita and Upadhya, 2000). In this method of selection GCA measures additive gene effects and SCA, non-additive gene effects including dominance and epistasis (Pradhan and Singh, 2008).

All the commercial rice hybrids are currently being based on cytoplasmic genetic male sterility system. This system is very stable, excessive dependence on a single source of cytoplasm, cumbersome process. But hybrid seed production and parental line development need the system yet today. Thus present study was an attempt to assess the good CMS lines, their restorer (male parent) and crosses for development of good hybrid based on different parameters like yield, maturity, plant height and quality characters like kernel length, kernel width, kernel length after cooking, elongation ratio and alkali digestion value.

MATERIALS AND METHODS

Experimental materials: Five rice genotypes were selected on the basis of their restoration behaviour (Upadhyay and Jaiswal, 2012) from twenty two rice genotypes in 2009. As the CMS lines from the local elite lines were still under process of conversion through repeated backcross, CMS lines developed from International Rice Research Institute (IRRI) were utilised to keep up the pace of hybrid rice development. This study was also based on CMS lines of IRRI origin. The parental lines were planted in a crossing block in kharif (wet season) 2009 at Agriculture Research Farm, Banaras Hindu University, Varanasi. Each pollinator was crossed with four different CMS lines to generate 20 crosses. The experimental material comprising of 29 entries including 20 crosses and nine parents was planted in LxT design in three replications in kharif (wet season) 2010.

Experiment: Seedlings were transplanted as single seedling hill^{-1} at a spacing of 20×15 (row to row and plant to plant) after 25 days of sowing. All the recommended cultural practices were adopted to raise a good crop. Data were recorded on 16 characters viz., days to 50% flowering, days to maturity, plant height, panicle plant^{-1}, seed panicle^{-1}, panicle length, grain yield plant^{-1}, 100 grain weight, spikelet fertility, pollen fertility, kernel length, kernel breadth, length breadth ratio, kernel length after cooking, elongation ratio, alkali digestion value. The mean values of 16 characters were used for combining ability analysis as suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

Analysis for combining ability of sixteen characters revealed significant differences among the genotypes (Table 1). The variance due to lines, testers and line x testers interaction were highly significant for all the traits. In the present study additive genetic variance was higher than non additive variance for the traits days to 50% flowering, days to maturity, plant height, 100 grain weight and alkali digestion value indicating the predominance of additive gene action (Table 1). Similar results were reported earlier for days to 50% flowering, plant height and 100 grain weight by Gnanasekaran *et al.* (2006). The traits pollen fertility, spikelet fertility, number of panicle plant^{-1}, panicle length, seed panicle^{-1}, yield plant^{-1}, kernel length, kernel breadth, length breadth ratio and kernel length after cooking were highly influenced by non-additive gene action as their additive: Non additive variance ratio was less than one. Similar results of non-additive gene action governing various traits were reported for panicle length, spikelet fertility and yield plant^{-1} by Gnanasekaran *et al.* (2006).

In the analysis of GCA, Jaya was found best general combiner for yield plant^{-1} (4.19), 100 grain weight (0.33), pollen fertility (2.61), kernel length (0.24), kernel breadth (0.10), kernel length after cooking (0.40), elongation ratio (0.02) and alkali digestion value (0.97) (Table 2). Jaya

Table 1: Analysis of variance for LxT for 16 characters in rice

Source of variations	DF	Days to 50% flowering	Days to maturity	Plant height	Panicle plant^{-1}	Panicle length	Grain panicle^{-1}	100 grain weight	Pollen fertility	Spikelet fertility	Grain yield plant^{-1}	Kernel length	Kernel breadth	L/B ratio	KLAC	ER	ALKD
		Mean sum of square															
Replication	2	1.11	14.21	1.43	18.08**	2.07**	12.81	0.01	14.68*	8.63*	48.99**	0.010	0.010	0.01	0.02	0.0001	0.07
Treatments	28	208.51**	236.05**	235.61**	22.14**	13.86**	3388.48**	0.18*	45.61**	9.79**	150.72**	0.35**	0.010	0.15**	0.66**	0.0035**	6.96**
Parents	8	346.00**	484.28**	283.19**	38.03**	15.17**	2721.11**	0.28**	22.42**	7.96**	89.47**	0.45**	0.010	0.19**	0.92**	0.0026**	12.98**
Parents (Testers)	3	101.66**	138.52**	71.91**	13.84**	23.92**	1816.58**	0.18**	19.41**	9.64*	54.37**	0.20**	0.010	0.06**	0.79**	0.0041**	7.83**
Parents (Lines)	4	274.93**	523.06**	283.60**	2.08*	9.84**	1673.76**	0.41**	8.25	5.77	28.44**	0.28**	0.010	0.13**	0.51**	0.0014	11.18**
Parents (L vs T)	1	1363.26**	1366.44**	915.41**	254.35**	10.23**	9624.13**	0.12**	88.16**	11.68*	438.89**	1.89**	0.000	0.79**	2.95**	0.0030	35.65**
Parents vs. Crosses	1	330.20**	0.44	1427.49**	87.37**	70.88**	11273.07**	0.07*	128.80**	7.94	1956.64**	0.82**	0.010	0.47**	0.72**	0.0016	1.23**
Crosses	19	144.21**	143.94**	152.84**	12.02**	10.30**	3254.50**	0.14**	51.00**	10.66**	81.46**	0.28**	0.020	0.12**	0.54**	0.0039**	4.73**
Lines effect	4	140.68	80.73**	453.45*	10.32	8.05	5998.02	0.57**	41.29	20.55	81.06	0.29	0.070*	0.18	0.89	0.0044	4.80*
Testers effect	3	416.46	680.86*	151.16	12.33	10.88	1650.10	0.01	68.08	3.62	107.56	0.41	0.010	0.07	0.65	0.0033	21.97**
Line *Tester Eff.	12	77.32**	30.77**	53.06**	12.51**	10.91**	2741.10**	0.03**	49.96**	9.12**	75.07**	0.24**	0.010**	0.10**	0.40**	0.0040	0.39**
Error	56	2.30	5.55	2.52	0.72	0.37	42.34	0.01	3.48	2.39	4.74	0.01	0.010	0.01	0.01	0.0008**	0.079
Total	86	69.41	80.80	78.38	8.10	4.80	1131.09	0.06	17.45	4.94	53.30	0.11	0.010	0.05	0.22	0.0017	2.32
σ2GCA		20.46	27.79	22.20	0.78	0.67	280.12	0.02	3.79	0.71	6.63	0.02	0.003	0.009	0.5	0.0044	0.98
σ2SCA		25.00	8.40	16.84	3.92	3.51	899.58	0.01	15.49	2.24	23.44	0.07	0.002	0.034	0.13	0.01	0.10
σ2A/σ2D		1.63	6.61	2.63	0.39	0.38	0.62	4.00	0.48	0.64	0.56	0.64	0.300	0.53	0.86	0.00	18.57

*,**Significant at 5 and 1% levels, L/B: Length/Breadth, KLAC: Kernel length after cooking, ER: Elongation ratio, ALKD: Alkali digestion value

Table 2: General Combining Ability (GCA) effect of different parents for different characters

Parents/ characters	Days to 50% flowering	Days to Maturity	Plant height	No. of panicle plant^{-1}	Penicle length	Grain panicle^{-1}	100 grain weight	Pollen fertility	Spikelet fertility	Grain yield plant^{-1}	Kernel length	Kernel breadth	L/B ratio	KLAC	Elongation ratio	ALKD
IR79156	-2.83**	0.18	3.37**	0.27	0.63**	6.17**	0.00	2.22**	-0.60	2.85**	0.18**	0.01	0.10**	0.17**	-0.02**	0.23**
IR68897	-2.63**	-5.28**	-0.14	-1.31**	-0.93**	-15.48**	0.02	-2.60**	-0.19	-3.39**	-0.16**	-0.04**	-0.02	-0.19**	0.00	0.56**
IR80555	-2.43**	-4.35**	-4.22**	0.27**	0.81**	2.55	0.01	1.15*	0.34	-0.68	0.10**	0.04**	-0.02	0.19**	0.00	-1.76**
IR67684	7.90**	9.45**	0.99*	0.78	-0.51**	6.77**	-0.02	-0.78	0.45	1.22*	-0.12**	-0.01	-0.06**	-0.17**	0.02*	0.97**
BPT5204	4.68**	4.03**	1.23*	-1.57**	-1.01**	-6.69**	-0.24**	-0.75	-0.59	-1.29*	-0.08**	-0.08**	0.12**	-0.07	0.01	-0.63**
SWETHA	1.18*	1.20	5.23**	0.35	1.10**	39.70**	-0.09**	0.77	-0.85	0.84	-0.04	0.06**	-0.17**	-0.04	0.00	-0.21*
JAYA	-2.98**	-1.63*	5.21**	0.38	0.06	-14.19**	0.33**	2.61**	-0.88	4.19**	0.24**	0.10**	-0.08**	0.40**	0.02*	0.97**
HUR5-2	-3.73**	-1.97**	-9.52**	-0.01	-0.54**	-9.41**	-0.13**	-2.40**	-1.24**	-2.10**	-0.17**	-0.05**	0.01	-0.36**	-0.02**	-0.39**
SASYASREE	0.85	-1.63*	-2.14**	0.85**	0.39*	-9.41**	-0.04**	-0.22	1.85***	-1.64*	0.06*	-0.03**	0.11**	0.06	0.00	0.26**

*Significant at 5 and 1% levels

Table 3: Specific Combining Ability (SCA) effect of different crosses for different characters

Parents/ characters	Days to 50% flowering	Days to maturity	Plant height	No. of panicle $plant^{-1}$	Penicle length	Grain $panicle^{-1}$	100 grain weight	Pollen fertility	Spikelet fertility	Grain yield $plant^{-1}$	Kernel length	Kernel breadth	L/B ratio	KLAC	Elongation ratio	ALKD
IR79156×BPT5204	3.75**	0.23	2.38**	2.68**	2.67**	13.45**	-0.01	3.92**	1.91***	5.87**	-0.12**	0.005	-0.09**	-0.11**	0.018*	0.06
IR79156×SWETHA	0.75	1.40*	-3.88**	-0.03	-0.02	-37.16**	0.03*	-2.11**	-1.42**	-4.57**	-0.14**	-0.03**	-0.02	-0.12**	0.019*	-0.19*
IR79156×JAYA	0.92*	1.57*	0.22	0.85**	0.84**	33.05**	0.11**	-4.49**	-0.99*	2.21**	-0.20**	0.05**	-0.23**	0.05	0.03**	0.33**
IR79156×HUR5-2	-4.67**	-2.43**	-2.80**	-2.10**	-2.09**	-2.39	0.03*	1.38**	-0.05	1.16*	-0.18**	-0.02*	-0.08**	-0.31**	-0.06	-0.13
IR79156×SASYASREE	6.75**	-0.77	4.08**	-1.40**	-1.40**	-6.95**	-0.16**	1.30*	0.551	-4.67**	0.63**	0.002	0.42**	0.49**	-0.06**	-0.08
IR68897×BPT5204	0.72	-0.97	2.20**	-2.63**	2.67**	10.08**	0.02	-2.06**	-3.38***	-3.93**	0.02	0.001	0.02	-0.09*	-0.01	0.28**
IR68897×SWETHA	6.55**	4.20**	-0.97*	0.12	-2.63	-35.51**	-0.01	0.49	-0.40	-5.10**	-0.20**	0.004	-0.13**	-0.21**	0.02**	-0.09
IR68897×JAYA	-4.95**	-2.97**	1.78**	0.98**	0.11**	21.69**	-0.13**	5.31**	2.24***	6.25**	0.32**	0.001	0.20**	0.47**	-0.02**	0.00
IR68897×HUR5-2	-3.53**	-3.97 **	1.75**	1.37**	0.97**	-19.74**	-0.01	-3.62**	0.22	1.81**	0.06**	0.007	0.03	0.04	-0.01	-0.08
IR68897×SASYASREE	1.22**	3.70**	-4.76**	0.17	1.36	23.48**	0.14**	-0.12	1.317	0.98	-0.20	0.003	-0.13**	-0.21**	0.02**	-0.12
IR80555×BPT5204	1.18**	1.10	-2.83**	0.79**	0.78**	-18.26**	0.09**	0.69	0.82*	1.37*	0.14**	-0.013	0.12**	0.25**	0.01	0.11
IR80555×SWETHA	-7.32**	-4.07**	4.78**	1.43**	1.43**	38.35**	0.07**	4.78**	2.32***	2.75**	0.22**	0.086**	-0.04*	0.41**	0.01*	0.44**
IR80555×JAYA	2.52**	1.10	-2.36**	-2.16**	-2.15**	-37.43**	-0.07**	1.52**	-1.42**	-5.71**	0.04	0.001	0.02	-0.02	-0.02**	-0.77**
IR80555×HUR5-2	5.93**	1.77**	1.34**	-1.99**	-1.99**	25.01**	-0.05**	-3.50**	-0.40	-2.53**	0.02	0.020*	-0.05*	-0.15**	-0.02**	0.02
IR80555×SASYASREE	-2.32**	0.10	-5.65**	1.93**	1.92**	-7.66**	-0.03*	-3.50**	-1.31**	4.11**	-0.41**	-0.093**	-0.06**	-0.48**	0.02**	0.21**
IR67684×BPT5204	1.85**	-0.37	-1.75**	-0.83**	-0.83**	-5.26**	-0.09**	-2.56**	0.64	-3.31**	-0.03	0.008	-0.05*	-0.05	-0.01*	-0.46**
IR67684×SWETHA	0.02	-1.53*	0.07	-1.53**	-1.52**	34.33**	-0.08**	-3.16**	-0.49	6.92**	0.11**	-0.050**	0.18**	-0.08*	-0.05**	-0.16*
IR67684×JAYA	1.52**	0.30	-4.36**	0.33	0.33	-17.31**	0.09**	-2.34**	0.16	-2.75**	-0.16**	-0.047**	0.01	-0.50**	0.01*	0.45**
IR67684×HUR5-2	2.27**	4.63**	-0.29	2.72**	2.72**	-2.88	0.04**	5.74**	0.23	-0.45	0.10**	-0.009	0.09**	0.42**	0.03**	0.19*
IR67684×SASYASREE	-5.65**	-3.03**	6.33**	-0.69**	-0.69**	-8.88**	0.05**	2.32**	-0.55	-0.42	-0.02	-0.98*	-0.23**	0.21**	0.02**	-0.02

*,**Significant at 5 and 1% levels

Table 4: Highest SCA scoring crosses for specific character

	Highest SCA performing crosses (ranking)		
Characters	1st	2nd	3rd
Days to 50% flowering	IR80555 A×Swetha	IR67684 A×Sasyasree	IR68897 A×Jaya
Days to maturity	IR80555 A×Swetha	IR68897 A×HUR 5-2	IR67684 A×Sasyasree
Plant height	IR80555 A×Sasyasree	IR68897 A×Sasyasree	IR67684 A×Jaya
No. of panicle per plant	IR67684 A×HUR 5-2	IR79156 A×BPT 5204	IR80555 A×Swetha
Main panicle length	IR67684 A× HUR 5-2	IR68897 A×BPT 5204	IR80555 A×Swetha
Grain per panicle	IR80555 A×Swetha	IR67684 A×Swetha	IR68897 A×BPT 5204
100 grain weight	IR68897 A×Sasyasree	IR79156 A×Jaya	IR80555 A×BPT5204
Pollen fertility	IR67684 A×HUR 5-2	IR68897A×Jaya	IR80555 A×Swetha
Spikelet fertility	IR68897 A×Jaya	IR80555 A×Swetha	IR79156 A×BPT 5204
Grain yield per plant	IR67684 A×Swetha	IR68897 A×Jaya	IR 79156 A×BPT 5204
Kernel length	IR79156 A×Sasyasree	IR68897 A×Jaya	IR80555 A×Swetha
Kernel breadth	IR67684 A×Sasyasree	IR80555 A×Swetha	IR79156 A×Jaya
Length breadth ratio	IR79156 A×Sasyasree	IR68897 A×Jaya	IR67684 A×Swetha
Kernel length after cooking	IR79156 A×Sasyasree	IR68897 A×Jaya	IR67684 A×HUR 5-2
Elongation ratio	IR79156 A×Jaya	IR68897 A×Swetha	IR68897 A×Jaya
Alkali digestion value	IR67684 A×Jaya	IR80555 A×Swetha	IR79156 A×Jaya

was a good general combiner for early flowering and maturity. Sharma and Mani (2008) reported similar results for days to flowering. HUR 5-2 was good general combiner for dwarf plant type and earliness as their GCA value is -9.52 for plant height and -3.73 for earliness. Here highest negative value is desirable. Similarly, Sashyashree was good general combiner for panicle plant^{-1} (0.85) and spikelet fertility (2.52) and Swetha was good for seeds panicle^{-1} (39.70) and panicle length (1.10). IR68897A was best general combiner for days to maturity (-5.28) as well as second best over lines and testers for 100 grain weight (0.02) (Table 2). IR67684A was the best general combiner for elongation ratio (0.02) and alkali digestion value (0.97). These are the important quality traits for rice. Remaining CMS lines showed variable performance for various characters. The promising parents identified in terms of grain yield and earliness were Jaya, Swetha, IR68897A and IR79156A. A number of parents although poor in GCA for grain yield, were observed to exhibit good GCA for other important traits (Table 2) and thus results were in accordance with Tyagi *et al.* (2008).

In the analysis of SCA, cross IR67684A×Swetha was best for grain yield plant^{-1} (6.92) (Table 3) and IR68897A×Sasyashree was best for 100 grain weight (0.14) (Table 3). Kumar *et al.* (2010) shows similar results for grain yield plant^{-1}. IR80555A×Swetha was found best for the traits days to maturity (-4.07), seeds panicle^{-1} (38.35) and kernel breadth (0.09) (Table 3). Cross IR79156A×Sasyashree was found best for kernel length (0.63). Cross IR68897×Jaya was best cross for spikelet fertility (4.92) (Table 3). Cross IR80555A×Sasyashree was best for plant height (-5.65) as it gave the highest negative SCA value which is desirable. IR67684×HUR 5-2 was best cross for the characters panicle plant^{-1} (2.72), panicle length (2.72) and kernel length (0.10).

Highest SCA for 100 grain weight was exhibited by cross IR68897A×Sasyashree which also exhibited desirable SCA for plant height. IR67684A×HUR 5-2, IR68897A×Swetha, IR 80555A× Swetha and IR68897A×Jaya were good specific combiner for earliness (Table 3). Crosses which recorded good SCA for high yield plant^{-1}, earliness and quality may be utilized for commercial production of hybrids.

CONCLUSION

The promising parents identified in terms of grain yield and earliness were Jaya, Swetha, IR68897A and IR79156A (Table 4) and may be utilised in hybrid rice seed production as parent. The perusal of different crosses revealed that the crosses IR67684A×Swetha, IR67684A×Sasyashree were good for hybrid production for grain yield, IR80555A×Swetha for earliness and IR79156A×Sasyashree for kernel length (Table 4) and may be utilised in future for good hybrid production in rice crop.

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