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Exploration of combining ability for yield and morpholo-physical traits in hybrid rice (*Oryza sativa* L.)

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Abstract
Combining ability in rice was studied with a set of 4 line and 10 testers and their 40 hybrids. The magnitudes of GCA variances were higher than SCA variance for all the characters which indicated the additive gene action was predominant in the expression of traits. The estimation of GCA effects for parents revealed that females, APMS 6A & males OM6162 & CBO5-501 were good general combiners for yield & yield attributing characters. The best specific cross combinations obtained through poor X good & Poor average combining parents respectively for grain yield per plant.

Keywords: Cropping systems, economic status, agronomic management, soil quality, yield

Introduction
Rice is most loved cereal of Asia, Feeds the majority of the world's population. To cope up with the ever increasing demand for rice it should be met with quantum jumping production in fixed cultivable area. This is a daunting task, in view of plateauing trend observed in yield potential of high yielding varieties and decreasing and declining nature resource base (Gopikannan & Ganesh, 2013) [5]. Breeding strategies for developing hybrids with high yield potential and better quality require the expected level of heterosis and combining ability. In plant breeding for high yield crop plants, the breeders of an face with the problem of selecting parents and crosses (Faiz, *et al.,* 2006) [3]. The successful development of rice hybrids by utilizing the cytoplasm genetic male sterile lines and economically viable seed production technology (Sreeramchandra *et al.,* 2000). Combining ability is a powerful tool in identifying the best combiners that may be used in crosses either to exploit heterosis or accumulate fixable genes and obtain desirable segregates. Evaluation of inbred lines is the prerequisite for any hybrids program. Combining ability analysis evaluation tools to estimate the combining ability variance and effects for selecting the desirable parents and crosses for exploitation of heterosis. Combining ability variance is usually used for the estimation of genetic control of a specific trait (Islam,2009). The analysis of the parents and crosses provide information on the two components of variance *viz.*, additive genetic & dominance variance which are important to decide upon the parents and crosses to be followed to select desirable hybrids. In this method of selection GCA measures additive gene effects and SCA, non- additive gene effects including dominance & epistasis (Upadhyay and Jaiswal, 2015) [18].
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, tiller/plant, productive tiller/plant, panicle length, number of filled spikelet/panicle, number of unfilled spikelet/plant, spikelet fertility %, pollen fertility %, hundred seed weight, grain yield/plant, harvest index & quality character like hulling %, milling % & head rice recovery %.

Material and Method
The present investigation was carried out at the Research farm, Department of Genetics and Plant breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur(Chhattisgarh) in Kharif 2011 & Kharif 2012. The breeding material comprised of three CMS lines *viz.*, IR58025A, APMS 6A, PUSA 6A and six testers *viz.*, IC577036, OM6162, CB05-501, CHANDRAHASNI, CT18154-5-1-4-2-2-N and BALILLA through LXT design. The generated 18 crosses along with their parents were grown in randomized complete block design during kharif 2012 with two replication. Twenty-one day old seedlings were transplanted in a single row of 1 m length.

The single seedling hill^{-1} was planted with the spacing of 15X15 cm. All the recommended agronomic package of practices was followed. In each entry, five plants were randomly selected from each replication and biometrical observations were recorded for days to 50% flowering, plant height(cm), tiller/plant, productive tiller/plant, panicle length (cm), number of filled spikelet/panicle, number of unfilled spikelet/plant, spikelet fertility %, pollen fertility %, hundred seed weight, grain yield/plant, harvest index, hulling %, milling % & head rice recovery %. Following the standard evaluation system for rice (IRRI, 1988). The mean data were subjected to ANOVA and combining ability studies using the Line X tester Analysis (Kempthorne, 1957) [9].

Result and Discusion

The analysis of variance for combining ability of all the traits under study is presented in the tab.1, which showed that variances due to treatments, hybrids and line X tester were highly significant for all the characters. The variance due to parents was also found highly significant for almost all the characters except for panicle length and head rice recovery %. The variance due to parents *vs* hybrids were non significant only for panicle length, hundred seed weight and hulling %. The result revealed sufficient variability present in the material under study. These results coincide with the finding of Jayasudha & Sharma (2009) [7], Rahimi (2010) [13] & Shrikrishna Latha *et al.,* 2013 [10]. 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 traits except plant height. Suggesting the significance of dominance and epistatic gene action for controlling these traits (Table 2) except plant height. Preponderance of dominance and epistatic gene action for grain yield and its components was also reported earlier by Sarawgi *et al.,* (1991) [15], Munhot *et al.,* (2000) [11], Rita & Motiramani (2005) [14], Venkatesan *et al.,*(2007) [19], Dalvi & Patel (2009) [2], Bagheri and Jelodar (2010) [8], Saidaiah *et al.,*(2010) & Ghosh *et al.,*(2013) [4]. The results revealed that none of the parents showed significant GCA effects simultaneously in the desired direction for all the traits studied (Tab.3). However, to determine the appropriate parents for subsequent hybrid rice development, variation in GCA effects was estimated among lines and testers for all traits. Negative GCA effects were desirable for days to 50 % flowering, Plant height & number of unfilled spikelet/panicle while in other traits positive GCA effects were desirable. Character wise estimation of GCA effects of lines (Tab.3) revealed the line APMS 6A to be a good combiner of grain yield and several contributing characters *viz.,* tillers/Plant, Productive tillers/Plant, No. of filled spikelet/Panicle, hundred seed weight and harvest index. The line PUSA 6A was good combiner for days to 50% flowering, Plant height and hulling %. The tester CBO5-501 was good general combiner for grain yield plant^{-1}. The result revealed that none of the parents showed significant GCA effects simultaneously in the desired direction for all the traits studied (Tab.3). However, to determine the appropriate parent for subsequent hybrid rice development, variation in GCA effects was estimated among lines and testers for all traits. Negative GCA effects were desirable for days to 50 % flowering, plant height & no. of unfilled spikelet/Panicle while in other traits positive GCA effects were desirable. Character wise estimation of GCA effects of lines (Tab.3) revealed the line APMS 6A to be a good combiner of grain yield and several contributing characters *viz.,* Plant height, tiller/plant, productive tiller/plant, no. of filled spikelet/panicle, no. of unfilled spikelet/panicle, spikelet fertility %, pollen fertility %, milling % & head rice recovery %. IR58025A to be a good combiner for panicle length, hundred seed wt., grain yield/ panicle & harvest index. The line PUSA 6A was good combiner for days to 50% flowering, Plant height & hulling %. Among testers, OM6162 & CBO5-501 were adjudged as a good general combiners, as they showed significantly favourable GCA effects for tiller/plant, productive tiller/ plant, no. of filled spikelet/panicle, spikelet fertility%, Pollen fertility % & grain yield/plant. The GCA effect is considered as intrinsic genetic value of the parent for a trait which is due to additive gene effects and it is fixable (Simmonds, 1989) [16]. Singh & Singh (1985) [17] suggested that parents with high GCA would produce transgressive segregants in F_2 or later generations. Hence, the lines & testers with GCA effects may be utilized in hybridization programme to improve the grain yield traits through transgressive breeding. The present findings had also been reported earlier by Rita & Motiramani (2005) [14], Venkatesan *et al.* (2007) [19], Dalvi & Patel (2009) [2], Jayasudha & Sharma (2009) [7], Bagheri & Jelodar (2010) [8] & Srikrishna latha *et al.,* (2013) [10].

The crosses APMS 6A X OM6162, APMS 6A X CBO5-501, PUSA 6A X CBO5-501, PUSA 6A X CHANDRAHASNI, IR58025A X OM6162, IR58025A X CBO5-501 & APMS 6A X CHANDRAHASNI were recorded as good specific combiners for grain yield/plant(tab. 4). These crosses were also recorded as good specific combiners for important yield attributes *viz.*,IR58025A X OM6162 for plant height, tiller/plant, productive tiller/plant, panicle length, harvest index; IR58025A X CBO5-501 for plant height, tiller/plant, productive tiller/plant & head rice recovery %; APMS 6A X OM6162 for days to 50% flowering, productive tiller/plant, panicle length, no. of filled spikelet/panicle, spikelet fertility%, pollen fertility %, hundred seed wt., milling % & head rice recovery; APMS 6A X CBO5-501 for days to 50% flowering, tiller/plant, productive tiller/plant, no. of filled spikelet/panicle, no. of unfilled spikelet/panicle, spikelet fertility%, pollen fertility %, hundred seed wt., APMS 6A X CHANDRAHASNI for plant height, no. of filled spikelet/panicle, no. of unfilled spikelet/panicle, spikelet fertility%, pollen fertility %, hundred seed wt.; PUSA 6A X CBO5-501 for days to 50% flowering, panicle length, no. of filled spikelet/panicle, no. of unfilled spikelet/panicle, spikelet fertility%, pollen fertility %, hundred seed wt., harvest index & hulling %. PUSA 6A X CHANDRAHASNI for plant height, panicle length & no. of unfilled Spikelet/panicle.

Table 1: Analysis of Variance for Line X Tester analysis

Source of variance	DF	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
Replication	1	0.15	0.34	1.90	3.63	1.00	322.82	263.89	1.27	0.80	0.00006	0.69	0.63	2.89	4.56	3.52
Treatment	26	24.01**	449.41**	26.78**	26.94**	7.62**	7479.67**	3525.33**	631.59**	619.90**	0.33**	1049.5**	138.158**	7.65**	18.99**	192.39**
Parents	8	377.69**	2334.62**	122.63**	184.82**	21.55	34190.92**	7448.89**	709.76**	747.14**	3.04**	5216.16**	1401.38**	25.86**	145.66**	231.27
Hybrids	17	213.04**	9301.48**	556.51**	475.50**	175.14**	15604.81**	54069.95**	11302.78**	11147.95**	5.44**	20662.3**	2166.78**	169.04**	307.32**	4063.93**
Parents *vs* Hybvrids	1	33.44**	48.47**	17.16**	40.00**	1.40	4276.00**	30139.55**	4408.73**	4227.26**	0.009	1407.97**	23.66**	4.05	40.66**	706.87**
Lines	2	23.85**	3109.02**	44.00**	31.23**	81.21**	3301.76**	6564.15**	580.96**	550.00**	0.38**	868.28**	188.63**	3.65	20.84	224.14*
Testers	5	79.64**	5609.12**	104.44**	104.84**	26.62**	73484.10**	19156.24**	4232.63**	4334.54**	2.03**	9549.80**	199.18**	16.57	13.87	681.08**
Line X Tester	10	109.56**	583.35**	408.08**	339.44**	67.31**	79218.92**	28349.57**	6489.20**	6258.41**	3.06**	10244.13**	1178.99**	148.83**	272.61**	3158.63**
Error	26	17.67	48.22	43.98	33.27	28.97	1793.79	2201.59	133.67	120.33	0.48	11.57	15.34	27.69	97.07	365.68

*&** Significant at p=0.05 & 0.01 respectively.

X_1 Days to 50% flowering, X_2 Plant Height(cm), X_3 Tiller per plant, X_4 Productive tiller per plant, X_5 Panicle length(cm),X_6 No. of filled Spikelet/panicle, X_7 No. of unfilled spikelet/ panicle, X_8 Spikelet fertility%, X_9 Pollen fertility%, X_{10} Hundred seed wt., X_{11} Grain yield/plant, X_{12} Harvest Index, X_{13} Hulling %, X_{14} Milling %, X_{15} Head rice recovery%.

Table 2: General combining ability and Specific combining ability variance

S.No.	Characters	GCA Variance	SCA variance	GCA/SCA ratio
1.	Days to 50% flowering	0.34	5.11	0.06
2.	Plant height(cm)	142.21	27.90	5.10
3.	Tillers/plant	-2.16	20.16	0.11
4.	Productive tillers/plant	-1.74	16.74	0.11
5.	Panicle length(cm)	1.81	3.17	0.58
6.	No. of filled spikelet/panicle	28.00	3944.12	0.0071
7.	No. of unfilled spikelet/panicle	80.20	1382.25	0.06
8.	Spikelet fertility %	-8.94	321.85	0.03
9.	Pollen fertility %	-6.10	310.87	0.02
10.	Hundred seed weight (g)	-0.009	0.15	0.0006
11.	Grain yield/plant	16.41	511.99	0.04
12.	Harvest index	-12.32	88.70	0.14
13.	Hulling %	-1.37	6.93	0.20
14.	Milling %	-2.30	11.85	0.20
15.	Head rice recovery %	-21.31	148.02	0.15

Table 3: Estimates of general combining ability (GCA) effects

Source of variance	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
Line	0.15	0.34	1.90	3.63	1.00	322.82	263.89	1.27	0.80	0.00006	0.69	0.63	2.89	4.56	3.52
IR58025A	24.01**	449.41**	26.78**	26.94**	7.62**	7479.67**	3525.33**	631.59**	619.90**	0.33**	1049.5**	138.158**	7.65**	18.99**	192.39**
APMS 6A	377.69**	2334.62**	122.63**	184.82**	21.55	34190.92**	7448.89**	709.76**	747.14**	3.04**	5216.16**	1401.38**	25.86**	145.66**	231.27
PUSA 6A	213.04**	9301.48**	556.51**	475.50**	175.14**	15604.81**	54069.95**	11302.78**	11147.95**	5.44**	20662.3**	2166.78**	169.04**	307.32**	4063.93**
Parents *vs* Hybvrids	33.44**	48.47**	17.16**	40.00**	1.40	4276.00**	30139.55**	4408.73**	4227.26**	0.009	1407.97**	23.66**	4.05	40.66**	706.87**
Lines	23.85**	3109.02**	44.00**	31.23**	81.21**	3301.76**	6564.15**	580.96**	550.00**	0.38**	868.28**	188.63**	3.65	20.84	224.14*
Testers	79.64**	5609.12**	104.44**	104.84**	26.62**	73484.10**	19156.24**	4232.63**	4334.54**	2.03**	9549.80**	199.18**	16.57	13.87	681.08**
Line X Tester	109.56**	583.35**	408.08**	339.44**	67.31**	79218.92**	28349.57**	6489.20**	6258.41**	3.06**	10244.13**	1178.99**	148.83**	272.61**	3158.63**
Error	17.67	48.22	43.98	33.27	28.97	1793.79	2201.59	133.67	120.33	0.48	11.57	15.34	27.69	97.07	365.68

*&** Significant at p=0.05 & 0.01 respectively

X_1 Days to 50% flowering, X_2 Plant Height(cm), X_3 Tiller per plant, X_4 Productive tiller per plant, X_5 Panicle length(cm), X_6 No. of filled Spikelet/panicle, X_7 No. of unfilled spikelet/ panicle, X_8 Spikelet fertility%, X_9 Pollen fertility%, X_{10} Hundred seed wt., X_{11} Grain yield/plant, X_{12} Harvest Index, X_{13} Hulling %, X_{14} Milling %, X_{15} Head rice recovery%.

Table 4: Estimation of specific combining ability (SCA) effects

Hybrids	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
IR58025A															
IC577036	-1.30 **	4.46 **	-2.85 **	-2.86 **	0.00	67.79 **	-45.50 *8	23.14 **	22.65**	0.04	0.40	2.11 **	2.82 **	-0.86	-1.73
OM6162	-0.62	-2.73 **	0.91*	1.39 **	1.28 **	-51.80 **	40.21 **	18.64 **	18.86 **	0.01	6.86 **	11.51 **	-1.13 *	-2.13 **	-8.22 **
CBO5-501	1.92**	-1.73 **	1.94 **	0.67 *	-1.28 **	-16.00 **	5.30	-4.50 **	-3.79 **	-0.03	6.46 **	-13.62 **	-1.69 **	2.98 **	9.95 **
CHANDRAHASNI	1.36**	1.43 *	-1.10 **	-1.35 **	-0.47	-47.29 **	17.43 **	-8.48 **	-6.85 **	-0.19 **	-8.37 **	7.91 **	1.74 **	-0.70	-3.46
CT18154-5-1-4-2-2-N	1.26**	-4.36 **	-2.87 **	-2.79 **	-2.18 **	-67.83 **	-54.13 **	-14.23 **	-13.53**	0.19 **	-24.28 **	-8.19 **	0.58	-1.30	-2.55
BALILLA	0.46	-9.01 **	-7.71 **	-6.79 **	-1.94 **	-47.53 **	12.88 **	-6.43 **	-6.98 **	0.05	-35.89 **	2.49 **	-2.49 **	-3.10 **	-2.27
SE_m^+	0.37	0.69	0.32	0.30	0.27	2.50	3.61	0.99	0.87	0.06	0.29	0.31	0.44	0.81	1.92
APMS 6A															
IC577036	0.16	1.73*	0.06	-0.04	1.78 **	16.36 **	-15.10 **	5.61 **	5.88 **	-0.04	-0.53	1.38 **	1.24 **	-0.07	1.24
OM6162	-1.82**	7.59**	-2.87 **	8.14 **	2.42 **	88.82 **	24.71 **	14.91 **	13.83 **	0.15 *	44.26 **	-10.40 **	0.74	3.80 **	5.72 **
CBO5-501	-1.42**	2.64**	2.81 **	2.83 **	0.40	51.47 **	-9.60 *	8.62 **	7.65 **	-0.15 *	24.81 **	6.81 **	-1.82 **	1.37	1.30 **
CHANDRAHASNI	0.69	-4.01**	-0.17	-0.22	-1.17 **	50.01 **	-14.19 **	11.07 **	9.49 **	-0.08	7.94 **	-0.61	-1.00 *	-0.31	-5.42 **
CT18154-5-1-4-2-2-N	-0.44	-3.15**	-1.20 **	-1.29 **	-0.54	-40.68 **	13.92 **	-9.46 **	-9.27 **	0.55 **	-7.45 **	-3.89 **	-3.24 **	-3.81 **	-4.09 *
BALILLA	-0.25	7.15**	1.37 **	1.50 **	1.71 **	-9.33 **	0.27	-1.61	-0.22	-0.47 **	-0.49	4.51 **	4.24 **	4.12 **	9.50 **
SE_m^+	0.37	0.69	0.32	0.30	0.27	2.50	3.61	0.99	0.87	0.06	0.29	0.31	0.44	0.81	1.92
PUSA 6A															
IC577036	-2.53 **	-1.41	3.66 **	3.18 **	-1.52 **	- 69. 11 **	67.11 **	-29. 66 **	-29.9 2 **	0.19 **	-10.29 **	-11.32 **	-2.51 **	4.28 **	18.14 **
OM6162	4.32 **	2.05 **	-3.72 **	-3.78 **	-0.10	45.44 **	-30. 31 **	22.99 **	22.84 **	-0.72 **	-0.18 **	6.50 **	1.43 **	1.42	8.00 **
CBO5-501	-1.79 **	-0.65	0.06	0.60	1.62 **	23.67 **	-12. 98 **	6.68 **	7.08 **	0.53 **	10.47 **	4.82 **	1.08 *	-5.70 **	-26.15 **
CHANDRAHASNI	1.61 **	-2.21 **	0.40	0.48	1.39 **	-17. 76 **	-9.73 **	-1.68	-1.25	0.07	10.85 **	0.53	-2.30 **	-2.34 **	-8.78 **
CT18154-5-1-4-2-2-N	-2.70 **	0.60	-1.93 **	-1.68 **	-0.87 **	26.05 **	5.61	4.44 **	4.99 **	-0.15 *	-5.50 **	4.47 **	1.01 **	2.01 *	1.12
BALILLA	1.08 **	1.60 *	1.53 **	1.20 **	-0.52 **	-8.28 **	4.13	-2.76 **	-3.74 **	0.08	-5.35 **	-5.00 **	0.68	0.32	7.66 **
SE_m^+	0.37	0.69	0.32	0.30	0.27	2.50	3.61	0.99	0.87	0.06	0.29	0.31	0.44	0.81	1.92

*&** Significant at p=0.05 & 0.01 respectively

X_1 Days to 50% flowering, X_2 Plant Height(cm), X_3 Tiller per plant, X_4 Productive tiller per plant, X_5 Panicle length(cm), X_6 No. of filled Spikelet/panicle, X_7 No. of unfilled spikelet/ panicle, X_8 Spikelet fertility%, X_9 Pollen fertility%, X_{10} Hundred seed wt., X_{11} Grain yield/plant, X_{12} Harvest Index, X_{13} Hulling %, X_{14} Milling %, X_{15} Head rice recovery%.

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