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DEVELOPMENT OF HIGH YIELDING RICE HYBRIDS THROUGH HETEROSIS AND COMBINING ABILITY ANALYSIS

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ABSTRACT

Heterosis and combining ability analysis in rice was conducted by utilising 65 hybrids along with parents and two checks The analysis of variance for combining ability revealed presence of considerable amount of variation among hybrids and parents. Significant gca effects were recorded for six male parents, JGL5614 (2.29**), JGL5868 (1.84**), JGL21800 (1.36**), JGL21820 (1.24**), JGL20649 (0.41**) and JGL21815 (0.40**) and three females CMS46A (2.05**), CMS23A (0.16**) and CMS14A (0.10*) were identified as good general combiners for grain yield. The ratio of gca and sca variance was less than unity for all the characters also indicated preponderance of non-additive genetic variance and suggested good prospects of the exploitation of variation through hybrid breeding.Three hybrids (CMS46A x JGL5614, CMS46A x JGL21819 and CMS46A x JGL21820) had significant positive heterosis over both the checks (24.87, 23.62; 24.87,23.62 and 19.29, 18.09 respectively) for grain yield. High yielding hybrids should be tested for their stability in multi-location trials for grain yield and fertility.

KEY WORDS
Hybrid rice
Heterosis
Lx T
GCA, SCA, high yield

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INTRODUCTION

Rice (*Oryza sativa* L.) is an important food crop grown and consumed world over. During 1960 - 1990 most of the Asian countries able to keep pace between population growth and food production due to the contributions of green revolution technologies. During recent decade, rice production started declining and there has been a plateauing effect of productivity and population growth in most of the Asian countries continues to be around 2% per year (Ravindra Babu and Chaitanya, 2015). In this context, there is immediate need for stepping up rice production significantly. Among the innovative genetic options available, hybrid rice technology is practically feasible and readily adoptable. However, commercial success of hybrid rice technology mainly depends on the extent of heterosis realized and the quality of rice.Under irrigated environment, it has contributed to 10 - 30 % yield advantage over conventional inbred (Virmani and Kumar,2004). Till today around 78 hybrids have been released in India using three line system (A, B and R line system). The government of India had set a target of expanding the cultivation of hybrid rice to 25% of the rice area by 2025 thereby contributing significantly towards national food security (Spielman *et al.*, 2013).

Identification of high yielding hybrids is possible when there is high heterosis for yield and its components. In order to exploit maximum heterosis using the CMS system in a hybrid programme, one must know the com-bining ability of different male sterile and restorer lines. The knowledge of combining ability allows the assessment of nicking ability among genotypes and understanding of the nature and magnitude of gene actions involved. Its role is important to decide parents, crosses and appropri-ate breeding procedures to be followed to select desirable segregants (Salgotra *et al.,* 2009). Line x Tester (Kempthorne, 1957) analysis is one of the most powerful tools for estimating the GCA of parents and se-lection of desirable parents and crosses with high SCA for the exploitation of heterosis (Tiwari *et al.,* 2011). In this perspective the present investigation was accomplished to identify high yielding hybrids and to assess the combining ability of five stable male sterile and 13 identified restorer lines for the exploitation of maximum heterosis in F_1 hybrids for yield and yield contributing traits.

MATERIALS AND METHODS

The present investigation was carried out at Rice Research Scheme, Regional Agricultural Research Station, Polasa, Jagtial, Karimnagar District, Telangana, India (18°50'20.24" N latitude, 78°56'54.20" E longitude and situated 249 m above mean sea level). The soil type of experimental plot comprised of inseptisol with a soil PH of 8.2.The average annual rain fall of the location is 849.7 mm and 90 percent of it is received between June to October (769.4 mm).The genetic material used in the study were from diverse backgrounds as they were developed at different research institutes. The experimental material comprised of 65 hybrids (produced during rabi 2013-14by making crosses following LxT design using 5 CMS lines and 13 restorers, Table 1), five maintainers of cytoplasmic male sterile lines (JMS1B, CMS11B, CMS14B, CMS23B and CMS46B), 13 known restorer lines used as testers (JGL17653-1, JGL17653-2, JGL18624,JGL18801, JGL20649, JGL21800, JGL21815, JGL21819, JGL21820, JGL21828, JGL21836, JGL5614 and JGL5868) and two standard checks (JGL18047 and MTU1010).

The experiment was laid out in randomized block design with two replications during 2014 wet season. The seed was raised on nursery beds and 25 days old seedlings were transplanted in main field under irrigated system. In each plot, the entry was planted in 4m^2 area by adopting row to row spacing of 15 cm and plant to plant spacing of 15cm. The experiment was conducted with recommended package of practices with need based plant protection measures. The data was recorded on five randomly selected plants per plot for effective bearing tillers per plant, plant height (cm), panicle length(cm) and number of grains per panicle. Spikelet fertility percentage was calculated as percent of number of filled grains to total spikelets in five plants. Incidence of gall midge was recorded as percent tillers affected with silver shoots (SES, IRRI, 2002) on 10 random plants and averaged. Genotypes having gall midge incidence percentage more than 5 were considered as susceptible. However, days to 50 % flowering, grain yield (t/ha) were recorded on whole plot basis, whereas random sample was taken after harvest for estimation of test weight (1000 grain weight in grams). Standard statistical procedures were followed for analysis of variance of combining ability, general combining ability (GCA) and specific combining ability (SCA) effects following Line x Tester design proposed by Kempthorne (1957). The magnitude of heterosis was calculated over mid parent, better parent and superiority over checks. These parameters were estimated using Windostat software version 8.0

RESULTS AND DISCUSSION

Analysis of variance revealed presence of significant amount of variation among the treatments, parents, testers and crosses for gall midge incidence, yield and yield component characters (Table 2). The analysis of line and tester effects showed highly significant differences for all the traits except gall midge incidence among lines and testers. Significant variation insinuated their suitability to combining ability studies. Further,Line x Tester effects were found significant for all the characters, except for panicle length, indicated that specific combining ability attributed heavily in the expression of these traits and provide the importance of dominance or non additive variances for all the traits. Several researchers have reported the predominance of dominant gene action for a majority of the yield traits in rice (Ashok, 2014 and Ishu Kumar Khute *et al*., 2015). In contrary, there was less variation observed for number of grains per panicle, spikelet fertility and grain yield among the lines. Similarly, Vikas sahu *et al.* 2013 observed variation for only one trait (grain weight per panicle) among lines in combining ability analysis. Significant mean square for parent *vs.* crosses for all nine traits studied revealed scope of exploiting heterosis for these traits. These results coincide with the earlier findings of Rahimi *et al*., 2010 and Latha *et al*., 2013 for all traits except for gall midge incidence.

The major role of non-additive gene effects in the manifestation of all the traits was confirmed by higher values of *sca* variance ($\acute{o}^2sca$) than for *gca* variance ($\acute{o}^2gca$) and the ratio of sca variance to gca variance ($\acute{o}^2gca/\acute{o}^2sca$) observed was less than one (Table2). These results suggest the feasibility of exploitation of non-additive genetic variation for traits through hybrid breeding. The importance of non-additive genes for expression of yield and its components have also been previously reported (Selvaraj *et al.,* 2011 and Bhatti *et al*., 2015). Investigation of *gca* effects revealed that among lines and testers presence of good general combiners for grain yield and the other

Table1: Pedigree information of genotypes used as lines, testers and checks.

Sl. No.	Genotype	Pedigree/Source material information	Classification	Graintype	GM incidence%	GM reaction
L1	JMS1A	JGL2933A	B line	ELS	4.8	R
L2	CMS11A	IR68902A	B line	LS	3.6	R
L3	CMS14A	IR69628A	B line	LS	9.9	S
L4	CMS23A	IR72081A	B line	LB	0.0	R
L5	CMS46A	IR80559A	B line	LS	12.1	S
T1	JGL17653-1	JGL3828 x OR1032-5-2	R line	LS	3.4	R
T2	JGL17653-2	JGL3828 x OR1032-5-2	R line	LS	0.0	R
T3	JGL18624	WGL32100 x NLR34452//WGL14377	R line	LS	4.3	R
T4	JGL18801	MTU1010 x JGL13595	R line	SS	2.5	R
T5	JGL20649	MTU1010 x JGL11118	R line	ELS	2.7	R
T6	JGL21800	MTU1010 x JGL11118	R line	MS	1.1	R
T7	JGL21815	JGL13595 x JGL11470	R line	LS	2.3	R
T8	JGL21819	JGL13595 x JGL11470	R line	SS	0.0	R
T9	JGL21820	JGL13595 x JGL11470	R line	SS	6.1	S
T10	JGL21828	JGL13595 x JGL11470	R line	MS	0.0	R
T11	JGL21836	JGL11118 x JGL11727	R line	SS	2.6	R
T12	JGL5614	JGL1798 x Betagamblin	R line	MS	2.4	R
T13	JGL5868	JGL245 x Gedonzipeton	R line	SB	0.0	R
C1	JGL18047	MTU1010 x JGL13595	Popular variety	LS	3.5	R
C2	MTU1010	Krishnaveni x IR64	Mega variety	LS	3.5	R

Table 2 : Analysis of variance for Line x Tester and combining ability for yield and yield component traits in rice

Source of variation	d.f.	GM%	DFF	EBT	PH	PL	NGP	SF%	TW	Grain Yield
Replications	1	4.6	9.4	1.4	20.2	2.2	410.66	14.8	4.4	0.02
Teatments	82	30.35**	60.02**	1.63**	158.69**	4.82**	5365.43**	296.14**	20.22**	9.61**
Parents	17	38.18**	121.42**	1.29**	223.18**	5.64**	11551.66**	83.20**	31.56**	3.61**
Lines	4	61.17**	72.65**	2.96**	220.82**	7.87**	1065.85	60.35	9.40**	0.92
Testers	12	18.75**	111.90**	0.73*	66.10**	3.57**	8872.08**	94.70**	35.32**	3.91**
Line vs Tester	1	179.39**	430.78**	1.42	2117.55**	21.60**	85649.85**	36.69	75.03**	10.75**
Lines vs crosses	1	14.79**	629.14**	2.21*	334.92**	50.18**	28186.45**	3666.95**	105.61**	38.87**
Crosses	64	28.5**	34.8**	1.7**	138.8**	3.9**	3365.6**	300.0**	15.8**	10.7**
Line effects	4	53	280.7**	4.07*	1269.6**	39.7**	7938.1**	645.6**	19.0**	53.3**
Tester effects	12	37.4	62.2**	3.2**	169.9**	2.7*	8009.7**	910.5**	34.2**	21.3**
Line x Tester effects	48	24.3**	7.4**	1.1**	36.7**	1.2	1823.6**	118.6**	11.0**	4.5**
Error	64	0.7	1.5	0.4	12	0.9	476.1	43.1	1.7	0.5
Variance of GCA		0.08	0.49	0.01	1.82	0.05	27.54	3.24	0.09	0.11
Variance of SCA		11.71	2.96	0.37	12.09	0.17	631.25	40.7	4.73	2.03
Variance of GCA/ Variance of SCA		0.01	0.16	0.03	0.15	0.28	0.04	0.08	0.02	0.05

* = significant at < 0.05 level and ** = significant at < 0.01 level of probability

Legend: GM% = Gall midge incidence%; DFF = days to 50% flowering; EBT = Effective bearing tillers per plant; PH = Plant height;PL = Panicle length; NGP = Number of grains per panicle; SF% = Spikelet fertility %; TW = Test weight

Table 3 : General combining ability (GCA) effect of different parents for yield and its components in rice.

Lines Genotype	GM%	DFF	EBT	PH	PL	NGP	SF%	TW	Yield
JMS1A	-0.95 **	-2.13**	0.20**	-0.09**	-0.25**	-15.82**	-3.85**	0.36*	-1.96**
CMS11A	-1.07**	-1.59**	0.53**	-6.18**	-1.34**	-11.90**	0.57	-0.18**	-0.34**
CMS14A	-0.43**	4.52**	-0.42**	10.64**	1.49**	11.91	-2.85**	-1.41**	0.10*
CMS23A	-0.002**	-3.17**	0.05	-6.33**	-0.95**	-8.86**	-2.28**	0.48**	0.16**
CMS46A	2.44**	2.37**	-0.36**	1.96*	1.05**	24.68	8.42*	0.75**	2.05**
Testers									
JGL17653-1	-0.04**	1.05*	0.60**	-7.12**	-0.92**	-42.23**	-15.32**	0.09	-0.87**
JGL17653-2	1.17**	1.15**	0.22*	-6.02**	-0.62**	-13.33**	-2.52**	-0.11**	-0.50**
JGL18624	1.35**	1.05*	0.16*	2.30	0.74**	-5.83**	-8.62**	1.09*	-0.95**
JGL18801	-2.40**	1.75**	-0.05**	5.04*	-0.26**	-16.53**	-15.02**	-1.81**	-2.97**
JGL20649	0.07	-4.85**	-0.55**	-1.00**	-0.34**	-7.93**	7.98	1.79**	0.41**
JGL21800	-1.82**	-2.05**	-0.28**	-3.28**	0.54*	25.97	15.28*	-0.11**	1.36**
JGL21815	-0.87**	-1.55**	0.28**	-0.86**	0.54*	-5.33**	6.08	2.29**	0.40**
JGL21819	-0.85**	-2.45**	-1.01**	-0.66**	-0.003**	28.07	6.28	-4.01**	-0.01**
JGL21820	2.40**	1.25**	-1.01**	6.70*	0.34	70.67	5.88	-2.41**	1.24**
JGL21828	-3.77**	1.15**	0.04	1.00	0.02	-27.83**	-10.32**	-0.41**	-1.11**
JGL21836	0.15	-2.85**	0.28**	-2.34**	-0.24**	-0.13**	4.38	0.19	-1.17**
JGL5614	2.88**	3.65**	0.50**	4.24	0.60*	-1.13**	3.18	2.09**	2.29**
JGL5868	1.71**	2.75**	0.81**	2.00	-0.36**	-4.43**	2.78	1.29**	1.84**

* = significant at < 0.05 level and ** = significant at < 0.01 level of probability

Legend: GM% = Gall midge incidence; DFF = days to 50% flowering; EBT = Effective bearing tillers per plant; PH = Plant height; PL = Panicle length; NGP = Number of grains per panicle; SF% = Spikelet fertility %; TW = Test weight

traits.Parentswithsignificant positive general combining ability (*gca*) effects for grain yield along with spikelet fertility are considered as good general combiners.

Significant positive gca effects for grain yield accentuate that six males (JGL5614, JGL5868, JGL21800, JGL21820, JGL20649 and JGL21815) and three females (CMS46A, CMS23A and CMS14A) are good general combiners (Table 3). Similarly, Sharma *et al.*, 2013 identified three restorers and one CMS line as good general combiners out of 14 male and three female parents. Hence, these good general combiners of males and females may be extensively used in future for hybrid rice breeding programme. JGL5614 and JGL5868 were the best general combiners among the restorers which govern significant positive gca effects for grain yield (2.29**, 1.84**), test weight (2.09**, 1.29**), effective bearing tillers (0.50**, 0.81**), days to 50% flowering (3.65**, 2.75**) and both of them were resistant to gall midge. Hence, these could extensively used for development of high yielding, long grain, gall midge resistant hybrids. Significant positive gca effects for grain yield and negative gca effects for test weight by JGL21800 (1.36**, -0.11**) and JGL21820 (1.24**, -2.41**) emphasizes their suitability for development of fine grain hybrids by using medium slender CMS lines.

JGL20649 and JGL21815 could be exploited for development of early maturity hybrids as they had significant negative gca effect for days to 50 % flowering and positive gca effect for grain yield (Table 3). Among the female parents, CMS46A was the best general combiner for grain yield (2.05**) along with high gca effects for all the traits except for effective bearing tillers(-0.36**). CMS23A had significant positive gca effect for grain yield and test weight and significant negative gca effect for days to 50 % flowering, plant height and gall midge incidence. Hence, this female line could be a best genetic source for early maturing, gall midge resistant hybrid development. There is a scope to develop high yielding medium maturity hybrids using best combiner CMS46A along with CMS14A as indicated by its significant positive gca effect for grain yield, panicle length and days to 50% flowering. Interestingly, two female parents (JMS1A and CMS11A) identified as short stature and early maturing were poor general combiners for grain yield.

Specific combining ability (SCA) helps in understanding the effect of non additive gene action for a trait. Non-additive gene action of a trait is an indicator for the selection of a hybrid combination. Among 65 crosses, 28 showed significant SCA effects for grain yield (Table 4). Out of 28 hybrids, significant positive SCA effects were expressed by 16 hybrids and 12 hybrids had significant negative SCA effects. The highest significant positive SCA effect was exhibited by the cross CMS14A x JGL21815 (2.162) followed by CMS23A x JGL17653-2 (2.051), CMS11A x JGL21820 (1.861), CMS14A x JGL21800 (1.852), CMS46A x JGL21819 (1.822), CMS46A x JGL21836 (1.632), CMS46A x JGL17653-1 (1.582), CMS14A x JGL21836 (1.532), JMS1A x JGL18624 (1.524), CMS11A x JGL21828 (1.411), CMS23A x JGL21828 (1.361), CMS14A x JGL5868 (1.322), CMS23A x JGL21820 (1.311), CMS11A x JGL18624 (1.301), CMS23A x JGL17653-1 (1.271) and JMS1A x JGL18801 (1.094) for grain yield. Similarly Thakare *et al.* 2013 found only five best hybrid combinations out of 45 hybrids tested. In promising specific combinations for grain yield it was observed that majority of the crosses were involved with presence of high/low gca effects combinations indicating additive x dominance type of geneinteractions for expression of trait. But very few crosses showing low/low general combiners showed high SCA effects, suggesting the epistatic gene action which maybe due to genetic diversity in the form of heterozygous loci. Also, very few crosses having high/high general combiners showed high SCA effects, which could be ascribed to predominance of additive x additive type of gene action. Thus, in majorityof the crosses, high SCA effects for grain yield were attributed to dominance and epistatic gene action and in only few cases attributed to additive interactions, whichwas also reported by Pradhan and Singh (2008) and Sharma *et al.* (2013).

Heterosis for grain yield along with its components is very important consideration in heterosis breeding. Yield is a complex character and ultimate aim of plant breeding. The magnitude of average heterosis and heterobeltosis(over better parent) ranged from -67.45 to 43.29 and -69.31 to 42.42 respectively (Table 5). While standard heterosis over the checks JGL18047 and MTU1010 ranged from -68.53 to 24.87and -68.84 to 23.62 respectively. Three hybrids (CMS46A x JGL5614, CMS46A x JGL21819 and CMS46A x JGL21820) had significant positive heterosis over both the checks. These three hybrids were developed using common female, CMAS46A, having good gca effects. Two hybrids (CMS14A x JGL21800 and CMS14A x JGL5868) exhibited significant positive heterosis over only one check, JGL18047. All promising hybrids were having combination of parents with positive gca effects except CMS46A x JGL21819. Similar findings were also reported by Mirarab *et al.* (2011), Malik and Singh (2013), Jain *et al.* (2014) and Ishu kumar khute *et al.* (2015). Manifestation of significant positive heterosis in the present genetic material bestows an opportunity for hybrid rice breeding.These five prospective hybrids could be tested in multi-location trials to know the stability of yield and fertility for commercial exploitation in future.

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