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Combining ability and heterosis studies for selecting elite parents and hybrids in rice (*Oryza sativa* l.)

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Abstract

Thirty-two hybrids along with their parents (B and R lines) and standard checks *viz*., RNR 15048 and PA 6444 were evaluated for grain yield and related traits to study combining ability and heterosis in rice. The mean performance of the hybrids for most of the characters was higher than that of parents except for milling percent. The analysis of variance revealed significant differences among parents, lines and hybrids for most of the characters studied. Degree of dominance was more than unity for all the traits except for plant height (0.53), panicle length (0.83), panicle weight (0.94),1000 grain weight (0.83), number of grains per panicle (0.73) and spikelet fertility (0.79). SCA variances were higher than GCA variances for most of the characters, which indicated the predominance of non-additive gene action. The *gca* effects revealed that among the lines JMS 14B had significant *gca* effects in desired direction for several traits including yield. Among the testers, RNR 26059and RNR 26072 were found to be good general combiner for the traits *viz.,* days to 50 percent flowering, panicle length, head rice recovery, per day productivity and grain yield per plant. Among thirty two hybrids, JMS 14A × RNR 26083, CMS 64A × PAU 2K10-23-451-2-37-34-0-3,CMS 23A × RNR26072, JMS 14A × RNR 26084,CMS 64A × RNR 26059 and JMS 20A × RP 5898-54-21-9-4-2-2 were found good specific combiners based on grain yield per plant. Six hybrids recorded positive significant standard heterosis over variety (RNR 15048), whereas two hybrids recorded positive significant heterosis over hybrid check (PA 6444). Overall data revealed that JMS 14A × RNR 26083 and CMS 64A × RNR26059 were identified as potential hybrids with respect to all characters based on their *sca* and heterosis estimates.

Key Words: Combining ability, heterosis, gene action, rice hybrids

Introduction

Rice is one of the most important food crops in the world, especially in Asian countries. It is estimated that by 2035, global demand for rice will increase to 852 million tons, however, records have shown that annual growth in yield was close to 1% only in the past decade (Khush, 2013). But there is dire need to increase production to meet the growing population (Kumar *et al*., 2014). Theoretically, rice still has great yield potential to be tapped and there are many ways to raise rice yield, such as molecular breeding, new plant type and hybrid rice technology. However, hybrid rice technology offers the most effective solution to enhance yield on suitable land for rice cultivation. The economical way to increase productivity is to develop hybrid varieties based on the fruitful experience gained in China (Galal Bakr Anis *et al*., 2017). The success story of hybrid rice technology in China (Lin and Yuan, 1980) as leading producer of hybrid rice in the world (Swaminathan, 2006) and some other countries along with India has been witnessed as an important and readily adoptable genetic option to increase the rice production and offers a viable solution to meet the ever increasing food challenge in different countries (Rai, 2009; Sanghera and Wani, 2008; Virmani *et al.,* 2003). Exploitation of heterosis for yield increase in rice through hybrid varieties becomes a practical option and is considered as an important breeding tool to overcome the present yield barriers. This seems to be more effective, as commercial rice hybrid has been reported to exhibit 38 % more yield in comparison with best commercial variety (Singh *et al*., 2013). The study on the magnitude of heterosis is the most important prerequisite for undertaking any heterosis breeding program (Saravanan *et al*., 2008).

For generating promising hybrids, the first step is selection of desirable parents. The contribution of parents in a cross and combining ability of parents in crosses can be assessed by biometrical methods through combining ability studies. Line × Tester analysis devised by Kempthorne (1957) is one of the effective mating designs followed to estimate gca and sca which enables the effective screening of parental lines. Combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis (Sarker*et al*., 2002). 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 the breeder an insight into nature and relative magnitude of fixable and non-fixable genetic variances *i.e.* due to dominance or epistatic components (Pratap *et al*., 2013). Keeping this in view, the present investigation was formulated to study the combining ability and magnitude of heterosis for grain yield and important yield attributes in rice.

Materials and Methods

The present investigation was conducted at Regional Agricultural Research Station, Warangal, Telangana, India, during *Kharif*, 2019. Four stable Wild Abortive cytoplasm based CMS lines and eight restorer lines were utilized in the present study (**Table 1**). Crosses

Table 1. Details of experimental material used for study

S. No	Genotype	Features
	Lines	
1.	RNR 26059	Mid late duration, Long-Slender, Resistance to BLB
2.	RNR 26072	Medium duration, Long-Slender, Resistance to BLB
3.	RNR 26074	Medium duration, Long-Slender, Resistance to BLB
4.	RNR 26083	Medium duration, Long-Slender, Resistance to BLB
5.	RNR 26084	Mid late duration, Long-Slender, Resistance to BLB
6.	Pusa 1701-10-5-8	Medium duration, Long-Slender, Resistance to BLB
7.	PAU 2K10-23-451-2-37-34-0-3	Mid late duration, Long-Slender, Resistance to BLB
8.	RP 5898-54-21-9-4-2-2	Late duration, Short-Slender, Resistance to BLB
	Testers	
1.	CMS 23B	Early duration, Long-Bold, Susceptible to BLB
2.	CMS 64B	Medium duration, Long-Slender, Susceptible to BLB
4.	JMS 14B	Medium duration, Short-Slender, Susceptible to BLB
4.	JMS 20B	Mid-early duration, Short-Slender, Susceptible to BLB

were made between these CMS lines and restorers in Line X Tester mating design during *rabi* 2018-19 at Rice Research Centre, ARI, Rajendranagar, Hyderabad and obtained 32 hybrids. These hybrids along with eight pollen parents (testers), four maintainers of corresponding CMS lines and two checks were grown in single row of 3 m length by adopting a spacing of 20 × 15 cm in RBD design with 2 replications. Recommended agronomic practices were followed to raise a good crop.

Observations were recorded on 5 randomly selected plants for estimation of different traits *viz.*, plant height (cm), number of productive tillers per plant, panicle length (cm), panicle weight (g), spikelet fertility (%) and grain yield per plant(g). However, days to 50% flowering was recorded on whole plot basis, whereas number of grains per panicle, 1000 grain weight (g), kernel length (mm), kernel breadth (mm), kernel length breadth ratio, hulling percent, milling percent and head rice recovery (%) were recorded on a random sample taken in each plot and per day productivity was calculated by dividing grain yield in hectare with days to maturity. The character means of each replication was subjected to analysis of variance (Panse and Sukhatme, 1967). Combining ability analysis and the testing of significance of different genotypes was estimated based on the procedure given by Kempthorne (1957) and also recorded the heterosis over the better parent, standard variety and standard hybrid (Fonseca and Patterson, 1968). Computer software Windostat version 9.1 was used for analysis of data.

Results and Discussion

The analysis of variance revealed significant differences for all the characters studied for hybrids (**Table 2**). The variance due to hybrid was partitioned into variance due to lines, testers and lines × testers for all the characters. The variance due to lines was significant for all the characters except panicle weight, number of filled grains per panicle and kernel length. Variance due to testers was significant for all traits studied. The variance due to lines × testers were significant for the five characters *viz.,* days to 50% flowering, plant height, 1000 grain weight, number of grains per panicle and spikelet fertility. Parents × hybrids showed significant variance for six characters *viz.,* plant height, panicle length, panicle weight, 1000 grain weight, number of grains per panicle and kernel length indicating superiority of hybrids and presence of heterosis for these traits studied.These results emphasized the importance of combining ability studies indicating the variability in the material and there is a good scope for identifying promising parents and hybrid combinations for improving yield through its components.

In the present investigation, the degree of dominance was more than unity for the traits *viz.,* days to 50 percent flowering (1.05), number of productive tillers per plant (1.59), kernel breadth (1.05), kernel length breath ratio (1.32), hulling percent (2.08), milling percent (1.70), head rice recovery (1.57), grain yield per plant (1.25) and per day productivity (1.35) indicating predominance of non-additive gene action, while plant height (0.53), panicle length (0.83), panicle weight (0.94), 1000 grain weight (0.83), number of grains per panicle (0.73) and spikelet fertility (0.79) exhibited additive gene action (**Table 3**). SCA variances were higher than GCA variances for most of the characters, indicating the predominance of non-additive gene action. The importance of additive as well as non-additive gene effects with predominance of non-additive gene effects in inheritance of grain yield and yield components of rice were in agreement with earlier findings of Saleem *et al*. (2010), Saidaiah *et al.* (2010), Rashid *et al*. (2007), Saravanan *et al.* (2006) and Vanaja *et al.* (2003).

The *gca* effects revealed that among the lines JMS 14B had significant *gca* effects in desired direction for important traits *viz.,* grain yield per plant (3.95), number of grains per panicle (28.15), spikelet fertility (3.54) and panicle weight (0.35) (**Table 4**). Among the testers, RNR 26059 and RNR 26072 were good

Table 2. Analysis of variance for yield and yield components in rice

Source of variation	DF	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
Replications	1	7.10	88.76**	0.03	0.30	0.14	1.70	441.01	3.93	0.02	0.00	0.02	2.00	1.69	0.86	1.24	0.20
Treatments	43	205.24**	468.07**	3.87**	17.80**	2.58**	20.16**	3140.38**	61.57**	0.83**	0.04**	0.20**	28.67**	25.99**	43.26**	41.92**	308.88**
Parents	11	129.07**	771.59**	1.33**	24.42**	2.61**	32.26**	3256.58**	10.93**	1.27**	0.12**	0.25**	11.34**	13.86**	62.59**	7.55	38.38
Lines	3	2348.26**	1025.53**	27.83**	146.62**	0.40	19.47**	218.93	312.32**	0.02	0.13**	0.53**	10.06*	6.45*	41.12**	22.28*	1284.72**
Testers	7	163.14**	342.38**	4.00**	11.29**	2.65**	15.88**	3193.38**	71.45**	0.70**	0.01**	0.17**	35.42**	30.92**	36.47**	54.75*	373.38**
Line × Tester	1	418.39*	408.15**	5.92	2.70	1.57	39.14*	7179.04**	337.36**	1.04	0.03	0.14	22.79	35.30	46.0	127.31	465.95
Parents × hybrids	1	194.01	1111.56**	3.27	33.93**	6.98**	28.77*	6921.07**	46.13	1.37*	0.02	0.29	31.90	28.55	37.67	46.16	507.87
Hybrids	31	116.39**	76.59**	3.97**	4.97**	1.36**	8.27**	1381.44**	41.89**	0.42**	0.01**	0.13**	38.40**	31.09**	34.72**	47.24**	315.32**
Error	43	5.21	4.43	0.44	0.98	0.11	0.54	133.29	2.27	0.02	0.00	0.02	2.41	1.17	1.68	3.92	45.91

*Significant at P=0.05 level **Significant at P=0.01 level

X1 =Days to50%flowering, X2=Plant height (cm), X3=No of productive tillers, X4=Panicle length (cm), X5=Panicle weight (g), X6=1000 grain weight (g), X7=No. of grains per panicle, X8=Spikelet fertility (%), X9=Kernel length (mm), X10 =Kernel breadth (mm), X11 =Kernel length breadth ratio, X12 =Hulling percent, X13=Milling percent, X14 =Head rice recovery, X15 = grain yield per plant (g) X16 =Per day Productivity DF = degrees of freedom

Table 3: Estimates of general and specific combining ability variances and proportionate gene action for different traits in rice

Character	Source of variation			Degree of Dominance $(\sigma^2sca/\sigma^2gca)^{1/2}$	Nature of gene action
	σ^2gca	σ^2sca	σ^2gca/σ^2sca		
Days to 50% flowering	50.164	55.586	0.902	1.053	Non additive
Plant height (cm)	125.904	36.08	3.49	0.535	Additive
Number of productive tillers per plant	0.692	1.762	0.393	1.596	Non additive
Panicle length (cm)	2.89	1.997	1.447	0.831	Additive
Panicle weight (g)	0.695	0.625	1.112	0.948	Additive
1000 grain weight (g)	5.569	3.861	1.442	0.833	Additive
Number of grains per panicle	1152.794	624.078	1.847	0.736	Additive
Spikelet fertility (%)	31.58	19.811	1.594	0.792	Additive
Kernel length (mm)	0.197	0.199	0.989	1.005	Non Additive
Kernel breadth (mm)	0.004	0.004	0.907	1.050	Non Additive
Kernel length breadth ratio	0.033	0.057	0.573	1.321	Non additive
Hulling percent	4.156	17.994	0.231	2.081	Non additive
Milling percent	5.126	14.962	0.343	1.708	Non additive
Head Rice Recovery (%)	6.692	16.518	0.405	1.571	Non additive
Grain yield per plant (g)	13.803	21.664	0.637	1.253	Non additive
Per day productivity (kg/ha/day)	73.499	134.705	0.546	1.354	Non additive

general combiners for the traits *viz*., panicle length, grain yield per plant and head rice recovery. For per day productivity the testers *viz.,* RNR 26059 (10.01), RNR 26072 (8.54) and RNR 26074 (7.35) were found to be good general combiners. The testers, RNR 26059 (1.65), RNR 26083 (1.41), RNR 26084 (1.24) and PAU 2K10-23-451-2-37-34-0-3 (1.92) were found good general combiners for 1000 grain weight. It was observed in certain instances that the lines and testers with good *perse* performance were not good general combiners and *vice versa*, thus the association between *perse* performance and GCA effects evident in the present study indicated that the effectiveness of choice of parents based on *perse* performance alone was not appropriate for predicting the combining ability of the parents. Similar findings were reported by Manjunath *et al.,* 2019.

The *sca* effects revealed that among thirty two hybrids, JMS 14A × RNR 26083 (10.00) recorded highest significant positive *sca* effect for grain yield per plant followed by CMS 23A × RNR 26072 (7.72), CMS 64A ×PAU 2K10-23-451-2-37-34-0-3 (6.75), JMS 14A × RNR 26084 (4.51), CMS 64A × RNR 26059 (4.36) and JMS 20A × RP 5898-54-21-9-4-2-2(4.02) and were considered as desirable (**Table 5**). Six hybrids *viz*., CMS 64A × RNR 26072 (-17.01), JMS 14A × RNR 26074 (-11.20), CMS 23A × RNR 26083 (-11.57), JMS 14 A × RNR 26084 (-7.95), JMS20A × RNR 26059 (-6.20) and CMS 23A × PAU 2K10-23-451-2-37-34-0-3 (-5.95) recording significant and negative *sca* effects for days to flowering were considered to be highly desirable for earliness.

Six hybrids *viz*., CMS 23A × RNR 26072 (9.06), CMS 64A × PAU 2K10-23-451-2-37-34-0-3 (5.47), JMS

Table 4. Estimates of general combining ability effects in lines and testers for yield and yield contributing characters in rice

Parents	Days to 50% flowering	Plant height (cm)	Number of productive tillers per plant	Panicle length (cm)	Panicle weight (g)	1000 grain weight (g)	Number of grains per panicle	Spikelet fertility (%)	Hulling percent	Milling percent	Head rice recovery %	Grain yield per plant (g)	Per day productivity (kg/ha/day)
LINES													
CMS 23A	4.672 **	-5.798 **	0.006	-0.342	-0.32 **	1.749 **	-23.313 **	-6.689 **	0.432	0.251	1.325 **	-2.576 **	-3.277
CMS 64A	5.766 **	0.371	-0.731 **	0.337	0.156	0.209	-2.375	0.860 *	1.437 **	2.001 **	1.524 **	-0.108	-4.202 *
JMS 14A	2.828 **	6.459 **	-0.034	0.375	0.359 **	0.099	28.125 **	3.542 **	-0.562	-1.040 **	-0.932 **	3.952 **	7.677 **
JMS 20A	-3.922 **	-1.032	0.759 **	-0.369	-0.185 *	-2.056 **	-2.438	2.286 **	-1.307 **	-1.213 **	-1.918 **	-1.268 *	-0.197
TESTERS													
RNR 26059	-1.859 *	11.171 **	-0.521 *	2.068 **	1.875 **	1.654 **	34.875 **	4.942 **	0.494	0.064	1.369 **	4.153 **	10.012 **
RNR 26072	-5.734 **	-3.733 **	0.012	2.147 **	-1.019 **	-0.830 **	-31.250 **	0.465	1.526 **	1.064 **	1.693 **	2.085 **	8.547 **
RNR 26074	-1.609	2.002 *	0.448	0.518	-0.402 **	-0.027	-11.750 **	-3.672 **	-2.552 **	-1.753 **	-1.238 *	-0.502	7.357 **
RNR 26083	8.766 **	16.162 **	-0.809 **	2.043 **	0.519 **	1.414 **	-1.500	-0.271	1.994 **	1.328 **	1.818 **	0.008	-6.478 *
RNR 26084	-1.859 *	5.946 **	0.041	0.056	-0.220	1.242 **	-13.125 **	0.054	0.938	0.939 *	0.568	-0.392	-2.468
Pusa 1701-10-5-8	-4.109 **	-22.091 **	-0.321	-2.969 **	-0.969 **	-2.743 **	-32.500 **	-0.292	0.486	1.106 **	-0.306	-3.683 **	-5.220 *
PAU 2K10-23-451-2-37-34-0-3	0.641	-4.204 **	1.271 **	-2.132 **	0.351 **	1.929 **	5.625	-1.431 *	0.744	1.189 **	0.818	0.475	0.154
RP 5898-54-21-9-4-2-2	5.766 **	-5.254 **	-0.121	-1.732 **	-0.136	-2.640 **	49.625 **	0.204	-3.631 **	-3.936 **	-4.722 **	-2.145 **	-11.902 **

* Significant at 0.05 % level, **Significant at 0.01 % level

Table 5. Estimates of specific combining ability effects in crosses for yield and yield contributing characters in rice

Hybrids	Days to 50% flowering	Plant height (cm)	Number of productive tillers per plant	Panicle length (cm)	Panicle weight (g)	1000 grain weight (g)	Number of filled grains per panicle	Spikelet fertility (%)	Hulling percent	Milling percent	Head rice recov-ery %	Grain yield per plant (g)	Per day produc-tivity(kg/ha/day)
CMS 23A × RNR 26059	0.04	4.09 **	-0.05	1.19	-0.31	0.40	13.18	-1.47	-1.55	-0.50	0.55	1.58	1.59
CMS 23A × RNR26072	9.42 **	3.25 *	1.20 *	1.47 *	1.03 **	2.86 **	31.31 **	9.06 **	1.41	0.49	1.17	7.72 **	14.32 **
CMS 23A × RNR 26074	-1.20	-11.98 **	1.55 **	-2.65 **	-0.78 **	-0.89	-5.68	1.57	-0.01	1.31	1.60	-2.81	1.34
CMS 23A × RNR 26083	-11.57 **	-0.29	-0.51	-0.48	-0.97 **	-0.78	-24.43 **	0.79	-0.55	-0.76	-0.95	-3.22 *	-5.18
CMS 23A × RNR 26084	10.54 **	-3.97 *	1.13 *	-1.44 *	-0.24	0.50	-5.81	-3.10 **	-0.001	-0.87	-0.70	-2.80	-11.34 *
CMS 23A ×Pusa 1701-10-5-8	2.79	1.11	-1.55 **	2.03 **	1.26 **	-0.26	-7.43	-4.53 **	-1.54	-2.04 *	-3.82 **	0.68	-9.35
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	-5.95 **	2.77	-1.29 *	-0.80	1.14 **	-2.24 **	23.93 **	-1.23	-1.80	-2.12 **	-3.45 **	-0.64	5.14
CMS 23A × RP 5898-54-21-9-4-2-2	-4.07 *	5.02 **	-0.45	0.69	-1.14 **	0.42	-25.06 **	-1.07	4.06 **	4.49 **	5.59 **	-0.49	3.49
CMS 64A × RNR 26059	0.60	1.92	-0.31	0.41	0.13	0.85	-14.75	1.66	1.93	0.74	-1.55	4.36 **	8.77
CMS 64A × RNR26072	-17.01 **	-1.36	-1.45 **	-2.01 **	0.11	-6.34 **	-7.12	-6.30 **	-3.59 **	-1.75 *	-1.52	0.42	13.02 *
CMS 64A × RNR 26074	7.85 **	-1.40	-1.18 *	0.36	0.33	2.14 **	-2.62	1.33	2.48 *	1.06	1.40	2.81	-4.51
CMS 64A × RNR 26083	3.48 *	-3.16 *	-0.03	1.93 **	-0.29	-0.38	23.62 **	-4.67 **	-2.06	-1.51	-2.14 *	-8.36 **	-18.04 **
CMS 64A × RNR 26084	-4.89 **	-1.14	-0.28	0.02	0.11	1.81 **	9.25	2.66 *	-2.00	-1.62 *	-0.39	-2.29	-3.99
CMS 64A × Pusa 1701-10-5-8	2.35	11.39 **	-0.61	0.25	-0.84 **	0.08	-13.37	-0.94	-1.01	-1.29	-1.52	-0.66	-3.71
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	4.10 *	-0.99	3.10 **	-0.68	0.24	1.43 *	-14.50	5.47 **	2.68 *	1.62 *	1.35	6.75 **	15.10 **
CMS 64A × RP 5898-54-21-9-4-2-2	3.48 *	-5.24 **	0.78	-0.28	0.19	0.39	19.50 *	0.78	1.56	2.74 **	4.39 **	-3.03 *	-6.64
JMS 14A × RNR 26059	5.54 **	-3.35 *	-0.01	1.57 *	0.87 **	-1.15 *	-26.75 **	-0.34	-0.56	-0.71	0.75	-0.81	-1.12
JMS 14A × RNR26072	4.92 **	-4.45 **	-0.55	-0.20	-1.02 **	0.72	-33.62 **	-8.33 **	-0.96	-0.71	-1.56	-3.51 *	-14.52 **
JMS 14A × RNR 26074	-11.20 **	5.01 **	1.21 *	1.42	-0.01	-1.25 *	23.37 **	0.17	-8.51 **	-7.89 **	-8.13 **	-2.49	0.04
JMS 14A × RNR 26083	6.92 **	4.45 **	1.77 **	-1.00	0.83 **	2.08 **	42.12 **	-0.62	1.93	2.52 **	2.80 **	10.00 **	20.84 **
JMS 14A × RNR 26084	-7.95 **	-0.63	-1.67 **	-0.11	-0.22	-0.68	1.25	4.61 **	0.99	1.41	2.05 *	4.51 **	19.03 **
JMS 14A ×Pusa 1701-10-5-8	-3.70 *	1.70	0.78	-1.23	-0.77 **	-0.02	-12.87	4.33 **	-0.62	-0.08	0.93	-1.99	-0.58
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	4.04 *	-2.48	-1.10 *	-0.22	-0.18	0.41	17.50 *	0.65	1.18	1.16	1.80	-5.20 **	-19.39 **
JMS 14A × RP 5898-54-21-9-4-2-2	1.42	-0.23	-0.41	-0.22	0.51 *	-0.10	-11.00	-0.47	6.56 **	4.29 **	1.34	-0.49	-4.28
JMS 20A × RNR 26059	-6.20 **	-2.66	0.39	-3.18 **	-0.69 **	-0.10	28.31 **	0.15	0.18	0.46	0.24	-5.13 **	-9.24
JMS 20A × RNR26072	2.67	2.57	0.79	0.74	-0.13	2.76 **	9.43	5.56 **	3.15 **	1.96 *	1.91 *	-4.63 **	-12.81 *
JMS 20A × RNR 26074	4.54 **	8.37 **	-1.57 **	0.86	0.46	0.003	-15.06	-3.08 **	6.04 **	5.51 **	5.12 **	2.49	3.13
JMS 20A × RNR 26083	1.17	-0.99	-1.22 *	-0.45	0.42	-0.91	-41.31 **	4.51 **	0.68	-0.24	0.29	1.58	2.38
JMS 20A × RNR 26084	2.29	5.75 **	0.82	1.53 *	0.35	-1.64 **	-4.68	-4.17 **	1.01	1.08	-0.95	0.59	-3.69
JMS 20A ×Pusa 1701-10-5-8	-1.45	-14.20 **	1.39 **	-1.04	0.35	0.20	33.68 **	1.14	3.19 **	3.42 **	4.41 **	1.97	13.65 **
JMS 20A × PAU 2K10-23-451-2-37-34-0-3	-2.20	0.70	-0.70	1.71 *	-1.20 **	0.40	-26.93 **	-4.89 **	-2.06	-0.66	0.29	-0.90	-0.85
JMS 20A × RP 5898-54-21-9-4-2-2	-0.82	0.45	0.09	-0.18	0.43	-0.70	16.56	0.76	-12.1**	-11.5**	-11.32**	4.0**	7.43

* Significant at 0.05% level, **Significant at 0.01% level

20A × RNR 26072 (5.56), JMS 14A × RNR 26084 (4.61), JMS 14A × Pusa 1701-10-5-8 (4.33) and CMS 64A × RNR 26084 (2.66) showed significant positive *sca* effects for spikelet fertility (%), an important parameter to be considered for hybrids. Six hybrids *viz*., CMS 23A × RNR 26072 (2.86), JMS 20A × RNR 26072 (2.76), CMS 64A × RNR 26074 (2.14), JMS 14A × RNR 26083 (2.08), CMS 64A × RNR 26074 (1.81) and CMS 64A × PAU 2K10-23-451-2-37-34-0-3 (1.43) having bold grains recorded significant positive *sca* effects for 1000-grain weight. JMS 20A (-2.05) line. three testers *viz.,* Pusa 1701-10-5-8 (-2.74), PAU 2K10-23-451-2-37-34-0-3 (-2.64) and RNR 26072 (-0.83) along with five hybrids *viz*., CMS 64A × RNR 26072 (-6.34), CMS 23A × PAU 2K10-23-451-2-37-34-0-3 (-2.24.), JMS 20A × RNR 26084 (-1.64), JMS 14A × RNR 26074 (-1.25), JMS 14A × RNR 26059 (-1.15) were fine grain type and recorded significant negative *gca* or *sca* effects for 1000-grain weight.

The *sca* effect was significant and positive for seven hybrids for head rice recovery and identified as desirable. Considering various parameters, six hybrids *viz*., JMS 14A × RNR 26083, CMS 64A × RNR 26059, CMS 64A × PAU 2K10-23-451-2-37-34-0-3, JMS 14A × RNR 26084, JMS 20A × RP 5898-54-21-9-4-2-2 and CMS 23A × RNR 26072 were found to be good specific combiners for grain yield and yield attributing traits. Heterosis studies showed that the heterobeltiosis over better parent ranged from -33.61 to 47.10% for grain yield (**Table 6**). Six hybrids showed significant positive heterosis for this trait. Highest significant positive heterobeltiosis was recorded by JMS 14A × RNR 26083 followed by CMS 23A × RNR 26072, CMS 64A × RNR 26059, JMS 14A × RNR 26084, JMS 14A × RNR 26059and CMS 64A × PAU 2K10-23-451-2-37-34-0-3.

For grain yield per plant, six hybrids exhibited positive significant standard heterosis over variety (RNR 15048). Highest significant positive heterosis was recorded in JMS 14A × RNR 26083 followed by CMS 64A × RNR 26059, JMS 14A × RNR 26084, JMS 14A × RNR 26059, CMS 23A × RNR 26072 and CMS 64A × PAU 2K10-23-451-2-37-34-0-3. Two hybrids *viz*., JMS 14A × RNR 26083 and CMS 64A × RNR 26059 showed positive significant heterosis over standard hybrid check (PA 6444). Among these, JMS 14A × RNR 26083 and CMS 64A × RNR 26059 were identified as potential hybrids with respect to characters *viz.,* panicle length, panicle weight, grain yield per plant and per day productivity based on their *perse* performance and heterosis estimates. Marked variation in the expression of heterobeltiosis and standard heterosis for yield and yield components was observed for all cross combinations. These finding are in consonance with those of Saravanan *et al*. (2008), Kumar *et al*. (2012), Singh *et al*. (2013), Sharma *et al*. (2013), Pratap *et al.* (2013), Bhati *et al*. (2015), Satheesh kumar *et al*. (2016), Yogita *et al.* (2016), Galal Bakr Anis *etal*. (2017) and Manjunath *et al.* (2019).

Table 6. Heterobeltiosis and standard heterosis of hybrids for yield and yield contributing traits in rice

Cross	Days to 50 % flowering			Plant height (cm)			Number of productive tillers per plant		
	HB	SHH	SHV	HB	SHH	SHV	HB	SHH	SHV
CMS 23A × RNR 26059	-21.72 **	-22.77 **	-13.50 **	-16.38 **	10.31 **	19.13**	-19.84 **	-5.71	-18.85 **
CMS 23A × RNR26072	-14.81 **	-17.86 **	-8.00 **	-13.23 **	-3.81	3.87	-5.30	11.38	-4.14
CMS 23A × RNR 26074	-16.99 **	-23.66 **	-14.50 **	-13.30 **	-12.33 **	-5.33 *	1.01	18.81 **	2.25
CMS 23A × RNR 26083	-21.56 **	-23.66 **	-14.50 **	5.64 **	10.85 **	19.71 **	-27.78 **	-12.86	-25.00 **
CMS 23A × RNR 26084	-14.16**	-13.39 **	-3	-8.58 **	-1.61	6.25 **	-5.67	10.95	-4.51
CMS 23A × Pusa 1701-10-5-8	-14.29 **	-22.32 **	-13.00 **	9.58 **	-22.20 **	-15.98 **	-30.36 **	-18.10 **	-29.51 **
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	-24.55 **	-25.89 **	-17.00 **	4.94*	-4.66 *	2.95	-15.38 **	-0.48	-14.34 *
CMS 23A × RP 5898-54-21-9-4-2-2	-21.40 **	-19.64 **	-10.00 **	13.64**	-3.59	4.12	-19.84 **	-5.71	-18.85 **
CMS 64A × RNR 26059	-11.76 **	-12.95 **	-2.5	-13.66 **	13.90 **	23.00 **	-27.05 **	-15.24 *	-27.05 **
CMS 64A × RNR26072	-29.63 **	-32.14**	-24.00 **	-11.97 **	-2.42	5.38*	-31.97 **	-20.95 **	-31.97 **
CMS 64A × RNR 26074	0	-6.25 **	5.00*	1.55	2.69	10.90 **	-26.23 **	-14.29 *	-26.23 **
CMS 64A × RNR 26083	1.83	-0.89	11.00 **	8.46 **	13.81 **	22.91 **	-29.76 **	-15.24 *	-27.05 **
CMS 64A × RNR 26084	-18.58 **	-17.86 **	-8.00 **	-1.08	6.46 **	14.96 **	-22.13 **	-9.52	-22.13 **
CMS 64A × Pusa 1701-10-5-8	-7.62 **	-13.39 **	-3	-3.37	-7.44 **	-0.05	-27.87 **	-16.19 *	-27.87 **
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	-5.91 **	-7.59 **	3.5	1.78	-2.51	5.28*	15.74 **	34.48 **	15.74 **
CMS 64A × RP 5898-54-21-9-4-2-2	-5.68 **	-3.57	8.00 **	-3.18	-7.26 **	0.15	-14.75 *	-0.95	-14.75 *
JMS 14A × RNR 26059	-9.95 **	-11.16**	-0.5	-13.12**	14.62 **	23.78 **	-23.26 **	-5.71	-18.85 **
JMS 14A × RNR26072	-12.04 **	-15.18**	-5.00 *	-9.55 **	0.27	8.28 **	-23.26 **	-5.71	-18.85 **
JMS 14A × RNR 26074	-19.42 **	-25.89 **	-17.00 **	12.64**	13.90 **	23.00 **	-6.20	15.24 *	-0.82
JMS 14A × RNR 26083	2.29	-0.45	11.50 **	20.17**	26.10**	36.17**	-11.63 *	8.57	-6.56
JMS 14A × RNR 26084	-23.89 **	-23.21 **	-14.00 **	4.42*	12.38 **	21.36 **	-31.78 **	-16.19 *	-27.87 **
JMS 14A × Pusa 1701-10-5-8	-13.30 **	-21.43 **	-12.00 **	6.87 **	-10.67 **	-3.54	-15.50 **	3.81	-10.66
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	-8.64 **	-10.27 **	0.5	11.85 **	1.61	9.73 **	-17.83 **	0.95	-13.11 *
JMS 14A × RP 5898-54-21-9-4-2-2	-10.04 **	-8.04 **	3	21.04 **	2.69	10.90 **	-23.26 **	-5.71	-18.85 **
JMS 20A × RNR 26059	-26.70 **	-27.68 **	-19.00 **	-17.74 **	8.52 **	17.19**	-4.48	5.71	-9.02
JMS 20A × RNR26072	-20.37 **	-23.21 **	-14.00 **	-9.92 **	-0.15	7.83 **	4.70	14.67 *	-1.31
JMS 20A × RNR 26074	-10.68 **	-17.86 **	-8.00 **	8.98 **	10.20 **	19.01 **	-16.53 **	-3.81	-17.21 **
JMS 20A × RNR 26083	-9.17**	-11.61 **	-1	9.12**	14.50 **	23.65 **	-27.39 **	-12.38	-24.59 **
JMS 20A × RNR 26084	-20.80 **	-20.09 **	-10.50 **	3.5	11.39 **	20.29 **	3.86	15.24 *	-0.82
JMS 20A × Pusa 1701-10-5-8	-17.73 **	-25.45 **	-16.50 **	-20.83 **	-31.66 **	-26.20 **	6.96	17.14 *	0.82
JMS 20A × PAU 2K10-23-451-2-37-34-0-3	-20.45 **	-21.88 **	-12.50 **	7.60 **	-2.24	5.57*	2.61	12.38	-3.28
JMS 20A × RP 5898-54-21-9-4-2-2	-17.90 **	-16.07 **	-6.00 *	11.90 **	-3.41	4.31 *	-6.67	6.67	-8.20

* Significant at 0.05% level, **Significant at 0.01% level

Table 6. contd..

Cross	Panicle length (cm)			Panicle weight (g)			1000 gram weight (g)		
	HB	SHH	SHV	HB	SHH	SHV	HB	SHH	SHV
CMS 23A × RNR 26059	5.92	16.48 **	31.60 **	3.85	3.24	0.96	14.09 **	1.05	78.50 **
CMS 23A × RNR26072	-1.71	17.87 **	33.18**	-26.55 **	-27.06 **	-28.67 **	9.50*	0.92	78.27 **
CMS 23A × RNR 26074	11.61*	-4.21	8.23	-12.95	-50.59 **	-51.68 **	-3.53	-12.02 **	55.41 **
CMS 23A × RNR 26083	7.09	9.96*	24.24 **	-44.01 **	-36.27 **	-37.68 **	-2.98	-5.21	67.44 **
CMS 23A × RNR 26084	-4.98	-1.34	11.47*	-30.50 **	-36.57 **	-37.97 **	0.13	-0.31	76.10 **
CMS 23A × Pusa 1701-10-5-8	27.80 **	0.38	13.42 **	59.36 **	-21.57 **	-23.30 **	-10.97 **	-21.15**	39.29 **
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	-9.36 *	-7.28	4.76	16.99*	1.96	-0.29	0.36	-9.37 **	60.09 **
CMS 23A × RP 5898-54-21-9-4-2-2	13.48 **	0	12.99 **	-26.07 *	-52.45 **	-53.50 **	-7.07	-17.69 **	45.40 **
CMS 64A × RNR 26059	5.57	16.09 **	31.17**	22.19**	21.47 **	18.79 **	13.76 **	-3.72	70.07 **
CMS 64A × RNR26072	-10.70 **	7.09	21.00 **	-35.14**	-35.59 **	-37.01 **	-41.52 **	-46.10**	-4.8
CMS 64A × RNR 26074	22.13**	9.96*	24.24 **	10.47	-19.31 **	-21.09 **	3.7	-5.43	67.05 **
CMS 64A × RNR 26083	18.66 **	21.84 **	37.66 **	-23.94 **	-13.43*	-15.34*	-8.09 *	-10.20 **	58.62 **
CMS 64A × RNR 26084	2.95	6.9	20.78 **	-12.35	-20.00 **	-21.76 **	-0.88	-1.31	74.32 **
CMS 64A × Pusa 1701-10-5-8	6.81	-3.83	8.66	-36.24 **	-53.43 **	-54.46 **	-12.67 **	-26.36 **	30.09 **
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	-6.37	-4.21	8.23	7.54	-6.27	-8.34	10.74 **	0	76.64 **
CMS 64A × RP 5898-54-21-9-4-2-2	9.79*	-1.15	11.69*	14.09	-16.67*	-18.50 **	-10.54*	-24.56 **	33.26 **
JMS 14A × RNR 26059	9.76 **	20.69 **	36.36 **	40.73 **	39.90 **	36.82 **	2.79	-13.00 **	53.67 **
JMS 14A × RNR26072	-4.79	14.18**	29.00 **	-53.60 **	-53.92 **	-54.94 **	-8.50 *	-15.67 **	48.96 **
JMS 14A × RNR 26074	26.81 **	14.18**	29.00 **	-1.49	-22.16**	-23.87 **	-13.15**	-20.80 **	39.91 **
JMS 14A × RNR 26083	7.84*	10.73 **	25.11 **	-1.03	12.65	10.16	2.49	0.13	76.88 **
JMS 14A × RNR 26084	2.58	6.51	20.35 **	-15.15*	-22.55 **	-24.26 **	-12.36 **	-12.74 **	54.14**
JMS 14A × Pusa 1701-10-5-8	0.64	-9.39 *	2.38	-34.37 **	-48.14**	-49.28 **	10.70*	-27.32 **	28.38 **
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	-4.49	-2.3	10.39*	2.59	-10.59	-12.56	5.26	-4.95	67.90 **
JMS 14A × RP 5898-54-21-9-4-2-2	10.21 *	-0.77	12.12**	18.24*	-6.57	-8.63	27.64 **	-27.21 **	28.58 **
JMS 20A × RNR 26059	-9.41 *	-0.38	12.55 **	-0.79	-1.37	-3.55	-2.95	-17.86 **	45.09 **
JMS 20A × RNR26072	-4.15	14.94 **	29.87 **	-46.79 **	-47.16**	-48.32 **	-9.05 *	-16.18**	48.07 **
JMS 20A × RNR 26074	27.23 **	9.20*	23.38 **	35.06 **	-23.33 **	-25.02 **	-17.47 **	-24.74 **	32.95 **
JMS 20A × RNR 26083	7.09	9.96*	24.24 **	-17.48 **	-6.08	-8.15	-20.64 **	-22.46 **	36.97 **
JMS 20A × RNR 26084	5.9	9.96*	24.24 **	-14.5	-21.96 **	-23.68 **	-26.08 **	-26.40 **	30.01 **
JMS 20A × Pusa 1701-10-5-8	7.94	-11.49 **	0	19.85	-36.67 **	-38.06 **	-2.1	-35.73 **	13.53*
JMS 20A × PAU 2K10-23-451-2-37-34-0-3	0	2.3	15.58 **	-32.73 **	-41.37 **	-42.67 **	-5.21	-14.40 **	51.20 **
JMS 20A × RP 5898-54-21-9-4-2-2	9.57*	-3.45	9.09*	26.22 *	-18.82 **	-20.61 **	6.49	-39.27 **	7.27

* Significant at 0.05% level, **Significant at 0.01% level

Table 6. contd..

Cross	Number of filled grains per panicle			Spikelet fertility (%)			Hulling percent		
	HB	SHH	SHV	HB	SHH	SHV	HB	SHH	SHV
CMS 23A × RNR 26059	21.12**	-5.34	-40.09 **	-9.50 **	-6.50 **	-8.09 **	1.86	-1.28	4.35*
CMS 23A × RNR26072	-7.26	-28.64 **	-54.84 **	-2.99	0.23	-1.48	7.15**	3.85	0.62
CMS 23A × RNR 26074	-14.24	-37.14**	-60.22 **	-15.47 **	-12.67 **	-14.16**	-0.13	-3.21	-6.21 **
CMS 23A × RNR 26083	-50.41 **	41.26 **	-62.83 **	-12.66 **	-9.77 **	-11.31 **	1.92	1.92	-1.24
CMS 23A × RNR 26084	-12.93	-37.86 **	-60.68 **	-16.50 **	-13.73 **	-15.20 **	2.6	1.28	-1.86
CMS 23A × Pusa 1701-10-5-8	-27.21 **	48.06 **	-67.13**	-18.41 **	-15.71 **	-17.14**	1.86	-1.28	4.35*
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	16.12*	-14.32*	-45.78 **	-16.08 **	-13.31 **	-14.78 **	-1.74	-1.28	4.35*
CMS 23A × RP 5898-54-21-9-4-2-2	13.2	-16.75 **	-47.31 **	-16.87 **	-11.31 **	-12.82 **	0.64	0.64	-2.48
CMS 64A × RNR 26059	-18.97 **	-8.74	-42.24 **	3.35	5.37 **	3.57*	3.16	4.49*	1.24
CMS 64A × RNR26072	44.18**	-37.14**	-60.22 **	-10.97 **	-8.44 **	-10.00 **	-2.53	-1.28	4.35*
CMS 64A × RNR 26074	-33.84 **	-25.49 **	-52.84 **	-6.24 **	-4.57 *	-6.19**	0	1.28	-1.86
CMS 64A × RNR 26083	-22.13**	-7.77	-41.63 **	-9.63 **	-7.46 **	-9.04 **	0	1.28	-1.86
CMS 64A × RNR 26084	-29.31 **	-20.39 **	-49.62 **	-0.26	1.05	-0.67	-1.27	0	-3.11
CMS 64A × Pusa 1701-10-5-8	47.41 **	40.78 **	-62.52 **	-5.16**	-3.34	-4.99 **	-0.58	0.69	-2.43
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	-31.47 **	-22.82 **	-51.15**	1.19	2.51	0.77	4.43*	5.77 **	2.48
CMS 64A × RP 5898-54-21-9-4-2-2	2.16	15.05*	-27.19**	-7.08 **	-0.87	-2.56	-2.53	-1.28	4.35*
JMS 14A × RNR 26059	-14.32 **	0.24	-36.56 **	4.08*	6.11**	4.30*	-3.75	-1.28	4.35*
JMS 14A × RNR26072	44.61 **	-35.19**	-58.99 **	-10.27 **	-7.72 **	-9.29 **	-2.97	-0.48	-3.57
JMS 14A × RNR 26074	-12.86*	1.94	-35.48 **	-4.58 **	-2.87	-4.53 **	-17.50 **	-15.38 **	-18.01 **
JMS 14A × RNR 26083	-2.05	16.02 **	-26.57 **	-2.34	0.01	-1.69	1.25	3.85	0.62
JMS 14A × RNR 26084	-22.61 **	-9.47	-42.70 **	5.82 **	6.19**	4.38*	-1.25	1.28	-1.86
JMS 14A × Pusa 1701-10-5-8	-36.51 **	-25.73 **	-53.00 **	3.51*	5.49 **	3.70*	-3.84	-1.38	4.44*
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	-8.09	7.52	-31.95 **	-0.2	0.14	-1.56	-1.25	1.28	-1.86
JMS 14A × RP 5898-54-21-9-4-2-2	-1.66	15.05*	-27.19**	-5.61 **	0.7	-1.01	0	2.56	-0.62
JMS 20A × RNR 26059	35.88 **	12.14*	-29.03 **	1.26	5.27 **	3.47*	-3.14	-1.28	4.35*
JMS 20A × RNR26072	-14.12*	-29.13**	-55.15**	2.26	6.31 **	4.50*	1.89	3.85	0.62
JMS 20A × RNR 26074	-17.06*	-31.55 **	-56.68 **	-11.39 **	-7.88 **	-9.45 **	0.4	2.33	-0.85
JMS 20A × RNR 26083	48.77 **	-39.32 **	-61.60 **	0.35	4.32*	2.55	-0.63	1.28	-1.86
JMS 20A × RNR 26084	-11.76	-27.18**	-53.92 **	-8.58 **	-4.96 **	-6.58 **	-1.54	0.35	-2.76
JMS 20A × Pusa 1701-10-5-8	-0.59	-17.96 **	-48.08 **	-3.27	0.56	-1.15	0.63	2.56	-0.62
JMS 20A × PAU 2K10-23-451-2-37-34-0-3	-13.82	-28.88 **	-54.99 **	-10.93 **	-7.40 **	-8.98 **	-5.66 **	-3.85	-6.83 **
JMS 20A × RP 5898-54-21-9-4-2-2	37.65 **	13.59*	-28.11 **	-5.62 **	0.69	-1.03	-23.90 **	-22.44 **	-24.84 **

* Significant at 0.05% level, **Significant at 0.01% level

Table 6. contd.

Cross	Milling percent			Head rice recovery (%)			Grain yield per plant (g)			Per day Productivity (kg/ha/day)		
	HB	SHH	SHV	HB	SHH	SHV	HB	SHH	SHV	HB	SHH	SHV
CMS 23A × RNR 26059	3.22	-7.33 **	-7.33 **	6.12**	0.09	-4.23*	12.5	-3.74	8.67	22.04 *	14.86	16.64
CMS 23A × RNR26072	6.19**	-4.67 **	-4.67 **	4.65*	1.5	-2.88	27.16**	9.17	23.24 **	41.71 **	31.16**	33.18**
CMS 23A × RNR 26074	-0.71	-7.33 **	-7.33 **	0.78	-2.26	-6.47 **	-15.96*	-32.49 **	-23.78 **	19.55	10.65	12.36
CMS 23A × RNR 26083	0.71	-6.00 **	-6.00 **	4.43*	-1.5	-5.76 **	-11.91	-32.15**	-23.41 **	-14.04	-18.81	-17.56
CMS 23A × RNR 26084	-0.71	-6.67 **	-6.67 **	2.84	-3.01	-7.19**	-19.47*	-32.11 **	-23.35 **	-15.65	-21.93*	-20.72 *
CMS 23A × Pusa 1701-10-5-8	2.47	-8.00 **	-8.00 **	-3.54	-9.02 **	-12.95 **	-11	-31.46 **	-22.62 **	-16.84	-23.03 *	-21.85*
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	-2.27	-8.00 **	-8.00 **	-10.20 **	-6.77 **	-10.79 **	-10.55	-22.49 **	-12.5	14.24	5.73	7.36
CMS 23A × RP 5898-54-21-9-4-2-2	1.44	-6.00 **	-6.00 **	3.97	-1.5	-5.76 **	-15.75*	-30.33 **	-21.35 **	-7.19	-14.1	-12.78
CMS 64A × RNR 26059	3.57*	-3.33 *	-3.33 *	-5.63 **	-2.79	-6.99 **	26.28 **	12.90*	27.45 **	30.28 **	23.92 *	25.83 *
CMS 64A × RNR26072	1.43	-5.33 **	-5.33 **	-5.11*	-2.26	-6.47 **	4.97	-6.15	5.95	34.52 **	27.95 **	29.92 **
CMS 64A × RNR 26074	1.43	-5.33 **	-5.33 **	-5.11*	-2.26	-6.47 **	4.28	-6.77	5.25	6.03	0.85	2.4
CMS 64A × RNR 26083	2.14	-4.67 **	-4.67 **	-5.84 **	-3.01	-7.19**	-33.61 **	-40.64 **	-32.99 **	-35.61 **	-38.76 **	-37.81 **
CMS 64A × RNR 26084	0.71	-5.33 **	-5.33 **	-5.11*	-2.26	-6.47 **	-13.48	-22.65 **	-12.68	-8.14	-12.63	-11.28
CMS 64A × Pusa 1701-10-5-8	2.14	-4.67 **	-4.67 **	-8.02 **	-5.26 *	-9.35 **	-19.38 **	-27.92 **	-18.62*	-11.9	-16.2	-14.91
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	5.52 **	-0.67	-0.67	-2.96	0.75	-3.6	21.72 **	8.82	22.85 **	24.92 *	18.81	20.65 *
CMS 64A × RP 5898-54-21-9-4-2-2	0.71	-6.00 **	-6.00 **	-5.84 **	-3.01	-7.19**	-22.30 **	-30.54 **	-21.58 **	-26.53 *	-30.12**	-29.04 **
JMS 14A × RNR 26059	-6.21 **	-9.33 **	-9.33 **	12.17**	-3.01	-7.19**	23.22 **	9.34	23.44 **	30.73 **	26.77 *	28.73 **

Table 6. contd.

Cross	Milling percent			Head rice recovery (%)			Grain yield per plant (g)			Per day Productivity (kg/ha/day)		
	HB	SHH	SHV	HB	SHH	SHV	HB	SHH	SHV	HB	SHH	SHV
JMS 14A × RNR2 6072	-4.83 **	-8.00 **	-8.00 **	-3.1	-6.02 **	-10.07 **	6.19	-5.77	6.38	8.54	5.26	6.89
JMS 14A × RNR 26074	-18.62 **	-21.33 **	-21.33 **	-17.83 **	-20.30 **	-23.74 **	0.59	-10.74	0.77	28.51 **	24.63 *	26.55 *
JMS 14A × RNR 26083	0	-3.33 *	-3.33 *	7.20 **	0.75	-3.6	47.10**	30.54 **	47.37 **	38.91 **	34.71 **	36.78 **
JMS 14A × RNR 26084	-2.07	-5.33 **	-5.33 **	4	-2.26	-6.47 **	26.03 **	11.83	26.25 **	42.20 **	37.90 **	40.02 **
JMS 14A × Pusa 1701-10-5-8	-3.90 *	-7.11 **	-7.11 **	0.8	-5.26 *	-9.35 **	-9.01	-19.26 **	-8.85	8.81	5.52	7.15
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	-2.07	-5.33 **	-5.33 **	-5.86 **	-2.26	-6.47 **	-5.61	-16.24*	-5.44	-11.24	-13.92	-12.59
JMS 14A × RP 5898-54-21-9-4-2-2	-4.83 **	-8.00 **	-8.00 **	-6.35 **	-11.28 **	-15.11 **	1.84	-9.63	2.02	-6.69	-9.51	-8.11
JMS 20A × RNR 26059	-4.83 **	-8.00 **	-8.00 **	9.57 **	-5.26 *	-9.35 **	-9.67	-20.91 **	-10.71	3.19	3.64	5.24
JMS 20A × RNR26072	-1.38	-4.67 **	-4.67 **	0.78	-2.26	-6.47 **	-15.36*	-25.89 **	-16.33*	-4.07	-3.65	-2.17
JMS 20A × RNR 26074	-0.37	-3.69 *	-3.69 *	1.2	-1.84	-6.08 **	1.09	-11.48	-0.07	17.19	17.7	19.52
JMS 20A × RNR 26083	-4.06*	-7.26 **	-7.26 **	1.6	-4.51 *	-8.63 **	-0.36	-12.75	-1.5	-3.82	-3.4	-1.91
JMS 20A × RNR 26084	-2.76	-6.00 **	-6.00 **	-2.4	-8.27 **	-12.23 **	-5.4	-17.16*	-6.48	-6.8	-6.4	-4.95
JMS 20A × Pusa 1701-10-5-8	0.69	-2.67	-2.67	4.80*	-1.5	-5.76 **	-12.32	-23.22 **	-13.32	14.24	14.73	16.5
JMS 20A × PAU 2K10-23-451-2-37-34-0-3	-4.83 **	-8.00 **	-8.00 **	-9.48 **	-6.02 **	-10.07 **	-7.68	-19.16**	-8.74	1.07	1.51	3.07
JMS 20A × RP 5898-54-21-9-4-2-2	-26.90 **	-29.33 **	-29.33 **	-28.03 **	-31.82 **	-34.76 **	0.69	-11.83	-0.47	-4.35	-3.94	-2.45

* Significant at 0.05% level, **Significant at 0.01% level ; HB = Heterobeltiosis; SHH = Standard Heterosis over hybrid (PA 6444); SHV = Standard Heterosis over variety(RNR 15048).

Table 7: Top ranking hybrids based on mean, heterosis over varietal and hybrid check and *sca* effect.

S. No.	Hybrids	Grain yield/ plant (g)	Heterosis over varietal check (%)	Heterosis over hybrid check (%)	*sca* Effect
1	JMS 14A × RNR 26083	41.15	47.37 **	30.54 **	10.00 **
2	CMS 64A × RNR26059	35.59	27.45 **	12.90*	4.36 **

Conclusions

Present investigation showed that superior performance for all the characters was not expressed in any single hybrid combination. However, different cross combinations were found to be superior for various characters. The *gca* effects revealed that among the lines JMS 14A and among the testers, RNR 26059 and RNR 26072 had significant *gca* effects in the desired direction for several traits including grain yield. Hence, these lines and testers could be considered as potential donors in improving grain yield per plant and associated components in future breeding programme.The degree of dominance was more than unity for the traits *viz.*, days to 50 percent flowering (1.05), number of productive tillers per plant (1.59), kernel length (1.00), kernel breadth (1.05), kernel length breath ratio (1.32), hulling percent (2.08), milling percent (1.70), head rice recovery (1.57), grain yield per plant (1.25) and per day productivity (1.35) indicating predominance of non-additive gene action, while plant height (0.53), panicle length (0.83), panicle weight (0.94), 1000 grain weight (0.83), number of grains per panicle (0.73) and spikelet fertility (0.79) exhibited additive gene action. Among 32 hybrids, JMS 14A × RNR 26083 and CMS 64A × RNR 26059 (**Table 7**) were identified as promising hybrids based on *per se* grain yield per plant, heterosis and specific combining ability which would be further tested in bigger plot for advancement.

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