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Combining ability and heterosis studies for grain yield and its components in rice (O*ryza sativa* L)

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Abstract
An experiment was carried out to study combining ability and heterosis in rice with a set of 32 hybrids along with their parents (B and R lines) and standard checks *viz*., RNR 15048 and PA 6444 were evaluated for grain yield and yield attributing traits. The mean performance of the F_1s for most of the traits recorded higher than that of parents except for milling per cent. The analysis of variance exhibited significant differences among parents, lines and hybrids for most of the traits studied. Degree of dominance was recorded greater than unity for all the traits except for plant height (0.56), panicle length (0.97), panicle weight (0.90), 1000 grain weight (0.77), number of grains per panicle (0.75), spikelet fertility (0.85), kernel length (0.91), and kernel breadth (0.96). GCA variances were lower than SCA variances for most of the traits. The analysis revealed the predominance of non-additive gene action for most of the traits under study. Among the CMS lines studied, JMS 14A was rated as good general combiner in the desired direction for several traits including yield. Among the testers, RNR 26059, RNR 26072, RNR 26074 and PAU 2K10-23-451-2-37-34-0-3 were performed as good general combiners. 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 23A × RP 5898-54-21-9-4-2-2, JMS 20A × Pusa 1701-10-5-8 and CMS 64A × RNR 26059 were exhibited high SCA effects for grain yield per plant. Thirteen hybrids were recorded positive significant standard heterosis over variety (RNR 15048), whereas six hybrids were recorded positive significant heterosis over the hybrid check (PA 6444). Overall data revealed that JMS 14A × RNR 26083, CMS 64A × PAU 2K10-23-451-2-37-34-0-3, CMS 23A × RNR26072 and JMS 14A × RNR 26084 were identified as potential hybrids for most of the traits based on their *sca* and heterosis estimates. These combinations could be used for the exploitation of heterosis in a hybrid breeding program.

Keywords: combining ability, heterosis, gene action, rice hybrids

Introduction

Rice is known as "grain of life" because it is the most important basic food in the world and nearly 2 billion people depend on it for more than 80% of their calories. It is not only basic need but also occupies major cereal consumption in the human diet and provides 21 % of global human per capita energy and 15% of per capita protein. Besides being the chief source of carbohydrate and protein in Asia (Veeresha *et al*., 2015) [16]. Despite the significant increase in rice production and productivity witnessed in the last five decades, a significant proportion of rice production is lost every year (Kreye *et al.*, 2009) [5]. But we are in the need to increase production to meet this growing population (Kumar *et al*., 2014) [7]. Hybrid rice technology is practically feasible technology to increase future rice production. Hybrid rice includes three-line and two-line hybrid rice that is developed via cytoplasmic male sterility and photo/thermo sensitive male sterility respectively given by Yuan and Peng (2005) [18]. The first approach is called a three-line system involving CMS line, a maintainer line and restorer line. The second approach is called a two-line system involving environmentally sensitive male sterility (Sheeba *et al*., 2009) [14]. Success in the development of hybrids depends primarily on the selection of appropriate parental lines. In the process, it is essential to understand the nature of gene action and to estimate the general combining ability of promising CMS lines and restorers and specific combining ability of the hybrids developed for quantitative characters of economic importance. The promising hybrids yielded 20-30% (Lin and Yuan, 1980) and 15-20% (Yuan, 1998) higher than the best hybrids and conventional rice varieties, respectively.The exploitation of heterosis in rice has been considered as an important tool for breeding the present yield barriers. The study on the magnitude of heterosis is the most important prerequisite for undertaking any heterosis breeding program (Saravanan *et al*., 2004). The magnitude of heterosis depends on the degree of genetic distinctiveness of the parental lines used while both positive and negative heterosis is useful for crop improvement, depending on the objectives of the breeding.

Breeding strategies based on the selection of hybrids require an expected level of heterosis as well as the specific combining ability (Satheesh kumar *et al*., 2016) [12, 15]. In the present investigation, an attempt was made to study the combining ability and magnitude of heterosis for grain yield and important yield attributes in 32 rice hybrids.

Material and Methods

The experiment was conducted at Rice Research Center of Agricultural Research Institute, Hyderabad, Telangana, India, during *Kharif*, 2019. Experimental material consisting of 32 F_1 hybrids obtained by line × tester mating generated by crossing 4 elite CMS lines and 8 testers (Table 1). These F_1s along with 8 pollen parents (testers), 4 maintainer lines of CMS 23A, CMS 64A, JMS 14A and JMS 20 A (lines) and 2 checks were grown in a single row of 3 m length with 2 replications in RBD with the spacing of 20 × 15 cm. All recommended agronomical practices were followed to raise the ideal crop stand.

Observations were recorded on five 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 a whole plot basis, whereas number of grains per panicle, 1000 grain weight (g), kernel length (mm), kernel breadth (mm), kernel length breadth ratio, hulling per cent, milling per cent and head rice recovery (%) were recorded on a random sample taken in each plot and per day productivity is calculated by dividing grain yield in hectare with days to maturity. The character means of each replication was subjected for analysis of variance (Panse and Sukhatme, 1967), Combining ability analysis and the testing of significance of different genotypes was based on the procedure given by Kempthorne (1957) [4]. and also estimated the heterosis over the better parent, standard variety and standard hybrid (Fonseca and Patterson, 1968) [2]. Computer software Windostat version 9.1 has been used for the analysis of data.

Results and Discussion

The *per se* performance of the hybrids for most of the traits was higher than that of parents. Among the thirty-two hybrids, none of the hybrids was superior for all the traits studied. The hybrids JMS 14A × JGL 26083, CMS 23A × RNR 26072, CMS 64A × RNR 26059, JMS 14A × RNR 26084 and CMS 64A × PAU 2K10-23-451-2-37-34-0-3 had recorded better *perse* performance for most of the yield attributing traits. In general, six hybrids were superior and seven hybrids are on par with hybrid check PA 6444 for grain yield per plant.

The results showed that all the traits for parent, cross and parent vs hybrids were found highly significant except number of filled grains per panicle, kernel length and hulling per cent for parent vs hybrids (Table 2). Mean sum of squares for crosses was partitioned into lines, testers and line x tester components. In the case of lines, significant variances were observed for all the traits except number of productive tillers, spikelet fertility, grain yield per plant and per day productivity. In testers, significant variances were observed for all traits except the per day productivity. In lines × testers, significant variances were observed for the thirteen characters studied *viz.*, days to 50% flowering, plant height, number of productive tillers, panicle length, panicle weight, 1000 grain weight, number of grains per panicle, kernel length, kernel breadth, kernel length breadth ratio hulling per cent, milling per cent and per day productivity. Parents × hybrids showed significant variance for thirteen characters indicating the superiority of hybrids and the presence of heterosis for almost all the traits studied. These results emphasized the importance of combining ability studies 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 all the traits except for plant height (0.56), panicle length (0.97), panicle weight (0.90), 1000 grain weight (0.77), number of grains per panicle (0.75), spikelet fertility (0.85), kernel length (0.91), and kernel breadth (0.96) (Table 3). SCA variances were higher than GCA variances for most of the characters, which indicated the predominance of non-additive gene action. The traits *viz.*, days to 50 per cent flowering (0.85), number of productive tillers per plant (0.48), kernel length breadth ratio (0.59), hulling per cent (0.10), milling per cent (0.06), head rice recovery % (0.19) and grain yield per plant (0.51) shown non-additive gene action, while plant height (3.08), panicle length (1.05), panicle weight (1.22), 1000 grain weight (1.67), number of grains per panicle (1.74), spikelet fertility (1.35), kernel length (1.20), and kernel breadth (1.06) exhibited additive gene action.

The *gca* effect was significant and positive for JMS 14A (3.39) among lines and RNR 26059 (2.93), RNR 26072 (1.64) RNR 26074 (1.71) and PAU 2K10-23-451-2-37-34-0-3 among testers for grain yield per plant. The *gca* effects revealed that among the lines JMS 14A had significant *gca* effects in the desired direction for important traits *viz.*, grain yield per plant, number of grains per panicle, spikelet fertility and head rice recovery % (Table 4). Among the testers, RNR 26059, RNR 26072, RNR 26074 and PAU 2K10-23-451-2-37-34-0-3 were good general combiners for the traits *viz.*, grain yield per plant, 1000 grain weight, panicle length and head rice recovery. It was observed in certain instances that the lines and testers with good mean performance have not been good general combiners and vice versa, thus the association between mean performance and GCA effects was evident in the present study indicated the effectiveness of choice of parents based on mean performance alone was not appropriate for predicting the combining ability of the parents.

The *sca* effects revealed that among thirty-two hybrids, JMS 14A × RNR 26083 (10.02) recorded highest significant positive *sca* effect for grain yield per plant followed by CMS 23A × RNR 26072 (6.42), CMS 64A × PAU 2K10-23-451-2-37-34-0-3 (6.34), JMS 14A × RNR 26084 (4.00), CMS 23A × RP 5898-54-21-9-4-2-2 (3.81) JMS 20A × Pusa 1701-10-5-8 (2.97) and CMS 64A × RNR 26059 (2.42) and were considered as desirable (Table 5). Six hybrids exhibited significant and negative *sca* effects for days to flowering and CMS 64A × RNR 26072 (-16.95), JMS 14A × RNR 26074 (-10.70), CMS 23A × RNR 26083 (-10.57), JMS20A × RNR 26059 (-8.14), JMS 20A × Pusa 1701-10-5-8 (-6.76) and CMS 23A × PAU 2K10-23-451-2-37-34-0-3 (-4.35) were considered to be highly desirable for earliness. Seven hybrids *viz.*, CMS 23A × RNR 26072 (11.74), CMS 64A × PAU 2K10-23-451-2-37-34-0-3 (3.38), JMS 20A × RNR 26072 (3.20), JMS 14A × RNR 26084 (3.00), JMS 14A × Pusa 1701-10-5-8 (2.86), CMS 64A RNR 26074 (2.57) and CMS 64A × RNR 26084 (2.50) recorded significant positive *sca* effects for spikelet fertility (%). Five hybrids *viz.*, CMS 23A × RNR 26072 (3.20), JMS 20A × RNR 26072 (2.16), CMS 64A × PAU 2K10-23-451-2-37-34-0-3 (1.66), JMS 14A × RNR 26083 (1.49) and JMS 14A × RNR 26084 (1.47) were having bold grains and recorded significant positive *sca* effects. Two lines *viz.*, JMS 20A (-1.41) and JMS 14A (-0.56), two testers Pusa 1701-10-5-8 (-2.87) and PAU 2K10-23-451-2-37-34-0-3 (-2.65) and five hybrids *viz*., CMS 64A × RNR 26072 (-5.17), CMS 23A × PAU 2K10-23-451-2-37-34-0-3 (-1.97), JMS 20A × RNR 26059 (-1.55), CMS 23A × RNR 26083 (-1.53), and JMS 20A × RNR 26084 (-1.34) were fine grain type and recorded significant negative *gca* and *sca* effects, respectively. The fourteen hybrids for head rice recovery exhibited significant and positive *sca* effect and identified as desirable. CMS 23A × RNR 26072 was found to be good specific combiner for traits *viz.*, grain yield per plant, number of productive tillers per plant, panicle weight, 1000 grain weight, number of filled grains per plant, spikelet fertility, kernel length, kernel length breadth ratio, single plant yield and per day productivity. Similarly the hybrids JMS 14A × RNR 26083, CMS 64A × PAU 2K10-23-451-2-37-34-0-3, JMS 14A × RNR 26084, CMS 23A × RP 5898-54-21-9-4-2-2, JMS 20A × Pusa 1701-10-5-8 and CMS 64A × RNR 26059 were found to be good specific combiner for grain yield and yield attributing traits. Heterosis studies showed that the heterobeltiosis over better parent ranged from -29.03 to 55.80 % for grain yield (Table 6). Ten hybrids showed significant positive heterosis for this trait. Highest significant positive heterobeltiosis was recorded by JMS 14A × RNR 26083, CMS 23A × RNR 26072, JMS 14A × RNR 26084, JMS 14A × RNR 26059, and CMS 64A × PAU 2K10-23-451-2-37-34-0-3. For standard heterosis, over variety (RNR 15048) thirteen hybrids were recorded positive significant heterosis. Highest significant positive heterosis was recorded for JMS 14A × RNR 26083 followed by JMS 14A × RNR 26059, CMS 23A × RNR 26072, JMS 14A × RNR 26084, CMS 64A × PAU 2K10-23-451-2-37-34-0-3, CMS 64A × RNR 26059 and JMS 20A × RNR 26074. Five hybrids were recorded positive significant heterosis *viz.*, JMS 14A × RNR 26083, CMS 23A × RNR 26072, JMS 14A × RNR 26084, JMS 14A × RNR 26059 and CMS 64A × PAU 2K10-23-451-2-37-34-0-3 over the standard hybrid check (PA 6444). Among these, JMS 14A × RNR 26083, JMS 14A × RNR 26059, CMS 23A × RNR 26072, JMS 14A × RNR 26084, and CMS 64A × PAU 2K10-23-451-2-37-34-0-3 were identified as potential hybrids for most of the traits studied based on their *per se* 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 findings are consistent with those of Saravanan *et al.* (2008) [11], Kumar *et al*. (2012) [6], Singh *et al*. (2013), Sharma *et al*. (2013), Pratap *et al.* (2013), Bhati *et al*. (2015), Satheesh kumar *et al*. (2016) [12, 15], Yogita *et al.* (2016) and Galal Bakr Anis *et al*. (2017).

Table 1: Details of experimental material used for study

S. No	Genotype	Source
	Lines	
1.	RNR 26059	RRC,ARI, Hyderabad
2.	RNR 26072	RRC,ARI, Hyderabad
3.	RNR 26074	RRC,ARI, Hyderabad
4.	RNR 26083	RRC,ARI, Hyderabad
5.	RNR 26084	RRC,ARI, Hyderabad
6.	Pusa 1701-10-5-8	IIRR, Hyderabad
7.	PAU 2K10-23-451-2-37-34-0-3	IIRR, Hyderabad
8.	RP 5898-54-21-9-4-2-2	IIRR, Hyderabad
	Testers	
1.	CMS 23B	IRRI, Philippines
2.	CMS 64B	IRRI, Philippines
4.	JMS 14B	RARS, Jagital
4.	JMS 20B	RARS, Jagital

Table 2: Analysis of variance for different characters in rice

Source of variation	DF	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
Replications	1	1.63	1.73	1.65	1.67	0.08	0.34	545.01 *	19.48 **	0.09	0.001	0.01	0.11	0.96	5.32	1.90	2.25
Treatments	43	180.16 **	482.31 **	3.13 **	14.67 **	1.65 **	17.58 **	5375.05 **	48.02 **	0.79 **	0.05 **	0.18 **	35.96 **	44.47 **	55.93 **	37.23**	315.16 **
Parents	11	175.67 **	790.05 **	1.60 *	15.94 **	1.90 **	27.37 **	6065.76 **	5.75 *	1.18 **	0.12 **	0.20 **	12.36 **	22.30 **	30.82 **	9.15 **	115.44 **
Lines	3	79.00**	350.11**	0.63	17.71**	0.74**	44.67**	8446.12**	2.65	0.44*	0.26**	0.30**	6.55**	11.89**	34.29**	3.77	32.07
Testers	7	63.56**	796.52**	1.75*	9.68**	1.85**	15.83**	4453.85**	6.99*	1.05**	0.07**	0.13*	10.95**	27.76**	33.73**	12.77**	62.09
Line × Tester	1	1250.52**	206.56**	3.44*	54.40**	5.73**	56.29**	10208.33**	6.37	4.34**	0.05**	0.34*	39.71**	15.33**	0.06	0.016	738.99**
Parents × hybrids	1	1405.64 **	1200.96 **	19.57 **	71.42 **	2.55 **	36.12 **	75.00	181.82 **	0.02	0.05 **	0.24 *	1.05	11.57 **	23.62 **	62.58 **	957.70 **
Hybrids	31	142.22 **	349.93 **	3.14 **	12.39 **	1.53 **	13.51 **	5300.93 **	58.70 **	0.68 **	0.03 **	0.17 **	45.45 **	53.40 **	65.88 **	46.37 **	365.30 **
Error	43	6.84	11.24	0.66	1.01	0.10	0.84	101.66	2.58	0.10	0.007	0.05	2.22	1.53	1.36	2.37	36.99

*Significant at P=0.05 level **Significant at P=0.01 level, X1=Days to 50% 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 SV= source of variation DF=degrees of freedom

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

Character	**Source of variation**			**Degree of Dominance (σ^2sca/ σ^2gca)$^{1/2}$**	**Nature of gene action**
	σ^2gca	**σ^2sca**	**σ^2gca/ σ^2sca**		
Days to 50% flowering	38.09	44.78	0.85	1.08	Non-Additive
Plant height (cm)	131.09	42.49	3.08	0.56	Additive
Number of productive tillers per plant	0.60	1.24	0.48	1.43	Non-Additive
Panicle length (cm)	3.33	3.17	1.05	0.97	Additive
Panicle weight (g)	0.41	0.34	1.22	0.90	Additive
1000 grain weight (g)	4.87	2.90	1.671	0.77	Additive
Number of grains per panicle	1916.68	1698.63	1.74	0.75	Additive
Spikelet fertility (%)	24.05	17.76	1.35	0.85	Additive
Kernel length (mm)	0.18	0.15	1.20	0.91	Additive
Kernel breadth (mm)	0.009	0.009	1.06	0.96	Additive
Kernel length breadth ratio	0.026	0.043	0.59	1.3	Non-Additive
Hulling percent	2.84	26.64	0.10	3.06	Non-Additive
Milling percent	2.29	33.56	0.068	3.82	Non-Additive
Head Rice Recovery (%)	6.83	35.55	0.19	2.28	Non-Additive
Grain yield per plant (g)	10.29	19.95	0.51	1.39	Non-Additive
Per day productivity	74.76	136.71	0.54	1.35	Non-Additive

σ^2: variances; gca: general combining ability; sca: specific combining ability.

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**
LINES													
CMS 23A	-1.54 *	-8.31 **	0.17	-1.19 **	-0.31 **	2.07 **	-28.71 **	-5.68 **	-0.07	0.08	-0.45	-1.57 **	-6.42 **
CMS 64A	1.20	2.59 **	-0.87 **	0.72 **	0.007	-0.09	1.53	-0.02	0.79 *	0.04	-1.19 **	-1.48 **	0.01
JMS 14A	4.57 **	5.82 **	-0.04	0.93 **	0.39 **	-0.56 *	35.65 **	2.72 **	-0.77 *	-0.11	1.28 **	3.39 **	7.17 **
JMS 20A	-4.23 **	-0.09	0.73 **	-0.46	-0.09	-1.41 **	-8.46 **	2.98 **	0.04	-0.01	0.36	-0.34	-0.76
TESTERS													
RNR 26059	-1.35	13.01 **	0.12	1.98 **	1.13 **	1.21 **	41.96 **	4.53 **	-2.82 **	-2.26 **	-2.85 **	2.93 **	11.86 **
RNR 26072	-5.98 **	-2.32	-0.05	1.66 **	-0.45 **	0.007	-44.96 **	-0.92	1.67 **	1.86 **	1.93 **	1.64 **	10.23 **
RNR 26074	0.89	6.16 **	0.63 *	0.28	-0.39 **	1.02 **	-9.28 *	-1.58 **	-0.07	-0.44	-0.92 *	1.71 **	-1.72
RNR 26083	10.89 **	11.49 **	-0.52	1.09 **	0.19	1.11 **	8.96 *	0.03	0.79	1.48 **	2.79 **	-0.61	-6.32 **
RNR 26084	-3.60 **	3.95 **	-0.03	0.08	-0.34 **	0.74 *	-28.78 **	0.43	-0.95	-0.26	-0.69	-0.94	1.19
Pusa 1701-10-5-8	-4.23 **	-21.58 **	-0.31	-3.67 **	-1.05 **	-2.87 **	-34.96 **	-0.07	2.03 **	0.40	0.93 *	-2.34 **	-7.74 **
PAU 2K10-23-451-2-37-34-0-3	-1.35	-5.22 **	0.57	-0.51	0.33 **	1.43 **	2.34	-2.46 **	2.04 **	2.36 **	3.62 **	1.32 *	0.48
RP 5898-54-21-9-4-2-2	4.76 **	-5.48 **	-0.39	-0.92 *	0.58 **	-2.65 **	64.59 **	0.048	-2.70 **	-3.13 **	-4.81 **	-3.68 **	-7.98 **

*Significant at P=0.05 level **Significant at P=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 grains per panicle**	**Spikelet fertility (%)**	**Hulling percent**	**Milling percent**	**Head rice recovery %**	**Grain yield per plant (g)**	**Per day productivity(kg/ha/day)**
CMS 23A × RNR 26059	2.17	2.36	1.32 *	1.46 *	0.14	1.04	19.21 *	-3.23 **	4.70**	5.66**	3.71**	-0.003	3.74
CMS 23A × RNR26072	8.79 **	-2.39	1.23 *	0.51	1.02 **	3.20 **	13.59	11.74 **	-1.79	-0.45	0.07	6.42**	14.87**
CMS 23A × RNR 26074	0.42	-6.18 *	0.84	1.49 *	-0.07	-0.16	-25.03 **	-1.56	3.95**	5.12**	5.99**	-0.36	-7.47
CMS 23A × RNR 26083	-10.57 **	-7.81 **	-0.12	-0.72	-0.30	-1.53 *	-18.28 *	2.02	-2.42*	-3.08**	-3.78**	-5.66**	-1.97
CMS 23A × RNR 26084	2.92	-4.37	0.88	-0.40	-0.25	-1.03	-9.53	-1.61	-0.17	3.66**	2.20*	-3.65**	-9.11*

CMS 23A × Pusa 1701-10-5-8	3.04	-1.23	-2.38 **	0.90	0.35	0.26	4.09	-4.91 **	-6.15**	-10.50**	-10.92**	0.36	-2.99
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	-4.32 *	8.00 **	-0.71	-0.35	0.41	-1.97 **	39.84 **	-3.00 *	0.82	0.04	1.38	-0.92	2.72
CMS 23A × RP 5898-54-21-9-4-2-2	-2.45	11.61 **	-1.05	-2.89 **	-1.29 **	0.19	-23.90 **	0.56	1.07	-0.45	1.32	3.81**	0.21
CMS 64A × RNR 26059	6.92 **	1.45	-0.32	-1.54 *	-0.12	1.09	-7.03	1.83	0.32	-2.29*	-4.89**	2.42*	5.87
CMS 64A × RNR26072	-16.95 **	5.04 *	-1.79 **	-0.19	-0.58 *	-5.17 **	1.84	-6.62 **	-4.67**	-4.92**	-5.18**	1.32	13.35**
CMS 64A × RNR 26074	2.67	5.30 *	-0.13	-2.02 **	-0.20	1.04	-11.28	2.57 *	1.57	2.38*	1.67	1.27	4.88
CMS 64A × RNR 26083	2.17	-8.12 **	-0.37	-0.03	0.76 **	0.13	34.46 **	-3.37 **	3.20**	1.95*	3.95**	-4.95**	-21.38**
CMS 64A × RNR 26084	-0.82	-0.78	-0.66	-2.72 **	0.42	0.90	28.71 **	2.50 *	-4.04**	-7.29**	-7.55**	1.36	-6.81
CMS 64A × Pusa 1701-10-5-8	1.79	7.55 **	1.05	3.44 **	-0.15	-0.67	-13.65	0.93	1.47	3.53**	5.81**	-3.75**	-3.58
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	1.92	-2.85	1.70 **	0.62	-0.15	1.66 *	-26.90 **	3.38 **	-1.54	1.07	3.62**	6.34**	17.41**
CMS 64A × RP 5898-54-21-9-4-2-2	2.29	-7.59 **	0.54	2.44 **	0.02	1.01	-6.15	-1.23	3.70**	5.57**	2.56**	-4.03**	-9.75*
JMS 14A × RNR 26059	-0.95	-4.07	-0.65	0.46	-0.09	-0.57	-51.65 **	0.06	-4.60**	-3.13**	-1.87*	1.03	-1.02
JMS 14A × RNR26072	1.17	-4.13	-0.37	-0.81	-0.04	-0.19	-24.78 **	-8.32 **	2.39*	1.74	2.34**	-5.51**	-10.28*
JMS 14A × RNR 26074	-10.70 **	-3.32	1.08	-0.53	0.07	-0.89	38.59 **	-0.85	-9.35**	-9.95**	-10.29**	-2.61*	0.55
JMS 14A × RNR 26083	7.29 **	13.55 **	0.79	2.35 **	0.34	1.49 *	39.34 **	0.93	-0.22	0.61	1.48	10.02**	19.63**
JMS 14A × RNR 26084	-2.70	1.84	-0.49	1.96 **	-0.60 *	1.47 *	-5.40	3.00 *	0.02	-0.13	0.96	4.00**	14.72**
JMS 14A × Pusa 1701-10-5-8	1.92	4.33	-0.62	-3.47 **	-0.17	0.01	-36.28 **	2.86 *	0.96	1.87*	0.84	0.41	-2.71
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	1.54	-4.33	0.14	0.46	0.44	-0.65	24.96 **	1.56	2.52*	1.74	-1.06	-6.74**	-18.77**
JMS 14A × RP 5898-54-21-9-4-2-2	2.42	-3.87	0.11	-0.42	0.04	-0.66	15.21 *	0.76	8.27**	7.24**	7.59**	-0.59	-2.10
JMS 20A × RNR 26059	-8.14 **	0.24	-0.33	-0.38	0.07	-1.55 *	39.46 **	1.34	-0.42	-0.23	3.04**	-3.45**	-8.59
JMS 20A × RNR26072	6.98 **	1.48	0.94	0.49	-0.39	2.16 **	9.34	3.20 **	4.07**	3.63**	2.76**	-2.23*	-17.94**
JMS 20A × RNR 26074	7.60 **	4.19	-1.79 **	1.06	0.20	0.009	-2.28	-0.15	3.82**	2.44**	2.62**	1.70	2.03
JMS 20A × RNR 26083	1.10	2.38	-0.28	-1.59 *	-0.80 **	-0.09	-55.53 **	0.42	-0.54	0.51	-1.65	0.59	3.72
JMS 20A × RNR 26084	0.60	3.30	0.27	1.16	0.43	-1.34 *	-13.78	-3.89 **	4.20**	3.76**	4.38**	-1.71	1.19
JMS 20A × Pusa 1701-10-5-8	-6.76 **	-10.65 **	1.94 **	-0.87	-0.02	0.40	45.84 **	1.11	3.72**	5.09**	4.26**	2.97*	9.29*
JMS 20A × PAU 2K10-23-	0.85	-0.81	-1.13	-0.73	-0.71 **	0.96	-37.90 **	-1.94	-1.79	-2.86	-3.93**	1.31	-1.36

451-2-37-34-0-3												
JMS 20A × RP 5898-54-21-9-4-2-2	-2.26	-0.15	0.38	0.87	1.23 **	-0.53	14.84 *	-0.09	-13.04**	12.36**	-11.48**	0.81	11.64

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

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	-13.43 **	-13.02 **	-5.56 *	-17.55 **	9.21 **	12.12**	-0.42	17.68 *	2.16
CMS 23A × RNR26072	-10.75 **	-11.16 **	-3.54	-22.95 **	-9.12**	-6.69 *	-2.73	14.95	-0.22
CMS 23A × RNR 26074	-10.90 **	-12.56 **	-5.05	0.1	-4.83	-2.29	-0.25	17.87 *	2.33
CMS 23A × RNR 26083	-12.68 **	-13.49 **	-6.06 *	2.76	-1.46	1.17	-23.35 **	-3.18	-15.95 *
CMS 23A × RNR 26084	-19.65 **	-14.42 **	-7.07 *	-13.84**	-5.2	-2.67	-5.46	11.72	-3.02
CMS 23A × Pusa 1701-10-5-8	-10.73 **	-14.88 **	-7.58 **	0.49	-25.62 **	-23.63 **	-35.29 **	-23.54 **	-33.62 **
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	-15.94 **	-19.07 **	-12.12 **	3.88	-2.28	0.33	-13.87	1.79	-11.64
CMS 23A × RP 5898-54-21-9-4-2-2	-20.17 **	-11.63 **	-4.04	12.01 **	0.77	3.46	-25.10 **	-11.12	-22.84 **
CMS 64A × RNR 26059	-6.48 *	-6.05 *	2.02	-10.67 **	18.32 **	21.48 **	-20.43 **	-9.14	-21.12 **
CMS 64A × RNR26072	-32.24 **	-32.56 **	-26.77 **	-8.77 **	7.61*	10.48 **	-34.78 **	-25.52 **	-35.34 **
CMS 64A × RNR 26074	-6.16 *	-7.91 **	0.00	16.65 **	15.59 **	18.67 **	-14.35	-2.18	-15.09 *
CMS 64A × RNR 26083	1.88	0.93	9.60 **	9.20 **	8.20*	11.09 **	-33.57 **	-16.09	-27.16 **
CMS 64A × RNR 26084	-20.52 **	-15.35 **	-8.08 **	-1.82	8.02*	10.90 **	-24.78 **	-14.10	-25.43 **
CMS 64A × Pusa 1701-10-5-8	-9.27 **	-13.49 **	-6.06 *	-6.81 *	-7.66 *	-5.19	-12.17	0.30	-12.93
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	-7.25 **	-10.70 **	-3.03	-1.33	-2.23	0.37	1.09	15.44	0.22
CMS 64A × RP 5898-54-21-9-4-2-2	-13.87 **	-4.65	3.54	-5.93	-6.79 *	-4.31	-20.50 **	-5.66	-18.10 *
JMS 14A × RNR 26059	-10.65 **	-10.23 **	-2.53	-12.25 **	16.23 **	19.33 **	-23.26 **	-4.17	-16.81 *
JMS 14A × RNR26072	-12.15 **	-12.56 **	-5.05	-13.37 **	2.19	4.91	-22.47 **	-3.18	-15.95 *
JMS 14A × RNR 26074	-15.64 **	-17.21 **	-10.10 **	16.40 **	10.67 **	13.62 **	-5.37	18.17 *	2.59
JMS 14A × RNR 26083	9.86 **	8.84 **	18.18 **	36.50 **	30.90 **	34.39 **	-17.85 **	3.77	-9.91
JMS 14A × RNR 26084	-19.21 **	-13.95 **	-6.57 *	3.02	13.35 **	16.38 **	-23.26 **	-4.17	-16.81 *
JMS 14A × Pusa 1701-10-5-8	-5.85 *	-10.23 **	-2.53	12.93 **	-7.66 *	-5.19	-26.44 **	-8.14	-20.26 **
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	-4.35	-7.91 **	0.00	5.62	-0.64	2.01	-13.32 *	8.24	-6.03
JMS 14A × RP 5898-54-21-9-4-2-2	-10.92 **	-1.40	7.07 *	10.64**	-0.46	2.2	-21.27 **	-1.69	-14.66 *
JMS 20A × RNR 26059	-25.46 **	-25.12 **	-18.69 **	-13.35 **	14.77 **	17.83 **	-5.29	6.75	-7.33
JMS 20A × RNR26072	-14.95 **	-15.35 **	-8.08 **	-13.60 **	1.91	4.63	4.87	17.68 *	2.16
JMS 20A × RNR 26074	-6.64 *	-8.37 **	-0.51	17.93 **	12.12**	15.11 **	-13.27	-2.68	-15.52 *
JMS 20A × RNR 26083	-4.23	-5.12 *	3.03	20.27 **	15.33 **	18.41 **	-20.20 **	0.79	-12.50
JMS 20A × RNR 26084	-24.02 **	-19.07 **	-12.12 **	-0.66	9.30 **	12.21 **	-0.88	11.22	-3.45
JMS 20A × Pusa 1701-10-5-8	-22.93 **	-26.51 **	-20.20 **	-11.06 **	-26.71 **	-24.75 **	11.50	25.12 **	8.62
JMS 20A × PAU 2K10-23-451-2-37-34-0-3	-13.53 **	-16.74 **	-9.60 **	3.29	-2.83	-0.23	-7.96	3.28	-10.34
JMS 20A × RP 5898-54-21-9-4-2-2	-22.27 **	-13.95 **	-6.57 *	8.41*	-2.46	0.14	-8.37	8.74	-5.60

*Significant at P=0.05 level **Significant at P=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	7.39	17.47 **	22.21 **	7.29	-10.62	-1.03	18.01 **	5.31	78.82 **
CMS 23A × RNR26072	-3.51	12.24 **	16.77 **	-6.98	-22.51 **	-14.19*	17.97 **	9.64*	86.16**
CMS 23A × RNR 26074	2.65	10.61 *	15.07 **	-11.91	-40.13**	-33.71 **	11.00*	-0.95	68.20 **
CMS 23A × RNR 26083	-1.91	4.9	9.13*	-33.11 **	-34.06 **	-26.98 **	0.19	-6.71	58.41 **
CMS 23A × RNR 26084	-1.96	2.04	6.16	-17.94*	-42.16**	-35.95 **	-1.65	-6.17	59.33 **
CMS 23A × Pusa 1701-10-5-8	5.87	-7.96	-4.25	15.45	-43.93 **	-37.91 **	-6.53	-16.59 **	41.63 **
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	-6.68	-0.2	3.82	10.28	-19.48 **	-10.83	1.75	-7.27	57.45 **
CMS 23A × RP 5898-54-21-9-4-2-2	-8.70	-12.24 **	-8.7	-0.3	-44.10**	-38.10**	-5.8	-15.94 **	42.74 **
CMS 64A × RNR 26059	3.30	13.00 **	17.56 **	8.3	-9.78	-0.09	10.92*	-4.21	62.65 **
CMS 64A × RNR26072	0.70	17.14**	21.87 **	-33.20 **	-44.35 **	-38.38 **	-33.12**	-37.84 **	5.54
CMS 64A × RNR 26074	-3.77	4.08	8.28	-7.2	-36.93 **	-30.16**	9.44	-5.25	60.89 **
CMS 64A × RNR 26083	6.79	15.51 **	20.17**	-9.24	-10.54	-0.93	-2.22	-8.96 *	54.59 **
CMS 64A × RNR 26084	-7.17	0.41	4.46	5.86	-25.38 **	-17.37 **	-2.69	-7.16	57.65 **
CMS 64A × Pusa 1701-10-5-8	1.89	10.20*	14.65 **	-17.15*	-47.05 **	-41.36 **	-19.60 **	-30.57 **	17.89*
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	3.21	11.63 **	16.14**	4.5	-23.69 **	-15.50*	9.04	-0.63	68.73 **
CMS 64A × RP 5898-54-21-9-4-2-2	8.49	17.35 **	22.08 **	30.87 **	-16.36 **	-7.38	-9.67	-21.99 **	32.45 **

JMS 14A × RNR 26059	11.57	22.04 **	26.96 **	16.80*	-2.7	7.75	2.22	-13.85 **	46.29 **
JMS 14A × RNR26072	-0.70	15.51 **	20.17**	-14.37*	-28.67 **	-21.01 **	-11.29*	-17.56 **	39.98 **
JMS 14A × RNR 26074	3.03	11.02*	15.50 **	9.43	-25.63 **	-17.65 **	-3.12	-16.12**	42.43 **
JMS 14A × RNR 26083	17.94	26.12**	31.21 **	-9.84	-11.13*	-1.59	2.1	-4.93	61.43 **
JMS 14A × RNR 26084	15.69	20.41 **	25.27 **	-9.57	-36.26 **	-29.41 ’*	-2.22	-6.71	58.41 **
JMS 14A × Pusa 1701-10-5-8	-8.56	-17.14**	-13.80 **	-7.02	-40.81 **	-34.45 **	-0.89	-29.58 **	19.57 **
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	4.58	11.84 **	16.35 **	27.25 **	-7.08	2.89	-4.72	-13.17**	47.44 **
JMS 14A × RP 5898-54-21-9-4-2-2	10.83	6.53	10.83*	41.99 **	-9.61	0.09	15.09*	-31.65 **	16.06*
JMS 20A × RNR 26059	3.17	12.86 **	17.41 **	10.32	-8.09	1.77	-7.59	-22.11 **	32.26 **
JMS 20A × RNR26072	-1.05	15.10**	19.75 **	-31.17**	-42.66 **	-36.51 **	-3.97	-10.76*	51.53 **
JMS 20A × RNR 26074	3.79	11.84 **	16.35 **	0.5	-31.70 **	-24.37 **	-2.86	-15.89 **	42.81 **
JMS 20A × RNR 26083	-2.48	4.29	8.49	-37.90 **	-38.79 **	-32.21 **	-9.74 *	-15.96 **	42.70 **
JMS 20A × RNR 26084	7.06	11.43 **	15.92 **	3.71	-26.90 **	-19.05 **	-19.58 **	-23.28 **	30.28 **
JMS 20A × Pusa 1701-10-5-8	0.94	-12.24 **	-8.7	13.01	-46.54 **	-40.80 **	-3.8	-31.65 **	16.06*
JMS 20A × PAU 2K10-23-451-2-37-34-0-3	-5.34	1.22	5.31	-10.62	-34.74 **	-27.73 **	-0.99	-9.77 *	53.21 **
JMS 20A × RP 5898-54-21-9-4-2-2	10.40	6.12	10.40*	82.41 **	2.28	13.26*	9.55	-34.94 **	10.47

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

Table 6: contd

Cross	Number of filled grains per panicle			Spikelet fertility (%)			Hulling per cent		
	HB	SHH	SHV	HB	SHH	SHV	HB	SHH	SHV
CMS 23A × RNR 26059	32.80 **	-9.94 *	-41.84 **	-7.97 **	-8.27 **	-7.12**	3.22	1.32	-3.14
CMS 23A × RNR26072	-33.14**	49.89 **	-67.64 **	2.51	2.27	3.55	0.54	-1.32	-5.66 **
CMS 23A × RNR 26074	-10.32	-51.19**	-68.48 **	-12.91 **	-13.19**	-12.10**	5.91 **	3.95	-0.63
CMS 23A × RNR 26083	48.70 **	40.39 **	-61.51 **	-9.78 **	-7.43 **	-6.27 **	-3.29	-3.29	-7.55 **
CMS 23A × RNR 26084	-15.5	-52.92 **	-69.60 **	-10.72 **	-11.01 **	-9.89 **	-2.63	-2.63	-6.92 **
CMS 23A × Pusa 1701-10-5-8	-8.98	49.68 **	-67.50 **	-14.96 **	-15.23 **	-14.17**	4.82*	-6.58 **	-10.69 **
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	29.79 **	-18.14**	-47.14 **	-15.48 **	-15.75 **	-14.70 **	3.5	2.63	-1.89
CMS 23A × RP 5898-54-21-9-4-2-2	28.33 **	-18.79 **	-47.56 **	-11.96 **	-9.03 **	-7.89 **	4.55*	-3.29	-7.55 **
CMS 64A × RNR 26059	-17.79 **	-8.21	-40.73 **	3.54	3.6	4.90*	-3.29	-3.29	-7.55 **
CMS 64A × RNR26072	47.97 **	41.90 **	-62.48 **	-11.84**	-11.79 **	-10.69 **	-3.95	-3.95	-8.18**
CMS 64A × RNR 26074	-39.26 **	-32.18**	-56.21 **	-2.41	-2.36	-1.13	1.97	1.97	-2.52
CMS 64A × RNR 26083	-17.84**	-4.54	-38.35 **	-9.50 **	-7.15**	-5.98 **	5.26*	5.26*	0.63
CMS 64A × RNR 26084	-31.33 **	-23.33 **	-50.49 **	-0.25	-0.19	1.06	-6.58 **	-6.58 **	-10.69 **
CMS 64A × Pusa 1701-10-5-8	-50.10**	44.28 **	-64.02 **	-2.55	-2.49	-1.27	4.61*	4.61 *	0
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	40.81 **	-33.91 **	-57.32 **	-2.48	-2.42	-1.2	0.66	0.66	-3.77
CMS 64A × RP 5898-54-21-9-4-2-2	-8.70 *	1.94	-34.17**	-7.83 **	-4.76 *	-3.56	0	1.32	-3.14
JMS 14A × RNR 26059	-19.20 **	-12.74 **	-43.65 **	2.41	4.68*	5.99 **	-14.10**	-11.84 **	-15.72 **
JMS 14A × RNR26072	43.20 **	-38.66 **	-60.39 **	-12.58 **	-10.64 **	-9.52 **	0.64	3.29	-1.26
JMS 14A × RNR 26074	-3.6	4.1	-32.78 **	-5.21 **	-3.11	-1.9	-16.67 **	-14.47 **	-18.24 **
JMS 14A × RNR 26083	-3.35	12.31 **	-27.48 **	-1.89	0.66	1.92	-3.85	-1.32	-5.66 **
JMS 14A × RNR 26084	-29.00 **	-23.33 **	-50.49 **	1.16	3.4	4.69*	-5.77 **	-3.29	-7.55 **
JMS 14A × Pusa 1701-10-5-8	43.80 **	-39.31 **	-60.81 **	0.45	2.68	3.97*	-0.74	1.87	-2.61
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	4.4	3.24	-33.33 **	-3.54	-1.41	-0.17	1.28	3.95	-0.63
JMS 14A × RP 5898-54-21-9-4-2-2	16.60 **	25.92 **	-18.69 **	-2.75	0.49	1.75	2.56	5.26*	0.63
JMS 20A × RNR 26059	34.59 **	7.56	-30.54 **	4.42*	6.38 **	7.72 **	-8.28 **	-5.26 *	-9.43 **
JMS 20A × RNR26072	-28.65 **	42.98 **	-63.18**	0.51	2.4	3.69*	3.18	6.58 **	1.89
JMS 20A × RNR 26074	-15.68 **	-32.61 **	-56.49 **	-3.85 *	-2.05	-0.82	0.64	3.95	-0.63
JMS 20A × RNR 26083	-55.02 **	47.73 **	-66.25 **	-2.16	0.39	1.65	-3.82	-0.66	-5.03 *
JMS 20A × RNR 26084	-32.43 **	46.00 **	-65.13**	-5.71 **	-3.94 *	-2.73	0	3.29	-1.26
JMS 20A × Pusa 1701-10-5-8	-3.51	-22.89 **	-50.21 **	-0.83	1.03	2.3	3.18	6.58 **	1.89
JMS 20A × PAU 2K10-23-451-2-37-34-0-3	-28.65 **	42.98 **	-63.18**	-6.75 **	-5.00 **	-3.81 *	-3.82	-0.66	-5.03 *
JMS 20A × RP 5898-54-21-9-4-2-2	33.51 **	6.7	-31.10**	-3.38	-0.17	1.09	-24.20 **	-21.71 **	-25.16**

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

Table 6: contd.

Cross	Milling per cent			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	6.28 **	-3.42	-4.73 **	-0.59	-4.88 *	-11.72 **	2.41	0.57	15.91 *	19.44*	7.23	14.71
CMS 23A × RNR26072	3.26	-6.16**	-7.43 **	1.26	-3.1	-10.07 **	40.26 **	18.86 **	36.98 **	33.28 **	19.65*	27.99 **
CMS 23A × RNR 26074	4.79*	-1.67	-3	4.90*	1.64	-5.67 **	8.86	-5.07	9.4	-16.71	-25.23 **	-20.01 *

CMS 23A × RNR 26083	-4.38*	-10.27 **	-11.49 **	-3.6	-7.75 **	-14.39 **	-18.55 **	-32.45 **	-22.15**	-15.39	-24.05 **	-18.75*
CMS 23A × RNR 26084	1.44	-3.42	-4.73 **	0.45	-3.88 *	-10.79 **	-20.69 **	-26.39 **	-15.17*	-14.84	-23.55 **	-18.22*
CMS 23A × Pusa 1701-10-5-8	-14.07 **	-21.92 **	-22.97 **	-18.18**	-21.71 **	-27.34 **	0	-17.01 **	-4.36	-18.94*	-27.23 **	-22.16*
CMS 23A × PAU 2K10-23-451-2-37-34-0-3	2.05	-4.79 **	-6.08 **	-0.83	1.55	-5.76 **	-10.86	-8.46	5.5	-1.79		-2.65
CMS 23A × RP 5898-54-21-9-4-2-2	-13.61 **	-13.01 **	-14.19**	-16.79 **	-11.63 **	-17.99 **	2.41	-9.45	4.36	-14.63	-23.36 **	-18.02*
CMS 64A × RNR 26059	-7.41 **	-14.38 **	-15.54**	-20.61 **	-19.38 **	-25.18**	11.63*	9.63	26.34 **	27.25 **	18.44*	26.70 **
CMS 64A × RNR26072	-5.19**	-12.33 **	-13.51 **	-13.74 **	-12.40 **	-18.71 **	14.90*	0.91	16.30*	35.46 **	26.08 **	34.88 **
CMS 64A × RNR 26074	0.73	-5.48 **	-6.76 **	-7.63 **	-6.20 **	-12.95 **	15.13*	1.11	16.53*	6.75	-0.64	6.29
CMS 64A × RNR 26083	2.92	-3.42	-4.73 **	1.53	3.1	-4.32*	-19.80 **	-29.56 **	-18.82 **	-36.64 **	-41.03 **	-36.91 **
CMS 64A × RNR 26084	-14.39 **	-18.49 **	-19.59 **	-21.37 **	-20.16**	-25.90 **	-0.95	-8.07	5.95	-5.59	-12.13	-6
CMS 64A × Pusa 1701-10-5-8	5.19**	-2.74	-4.05*	1.53	3.1	-4.32*	-21.94 **	-31.44 **	-20.99 **	-13.61	-19.59*	-13.99
CMS 64A × PAU 2K10-23-451-2-37-34-0-3	3.52	-3.42	-4.73 **	1.45	3.88*	-3.60 *	14.84 **	17.93 **	35.91 **	27.48 **	18.65*	26.92 **
CMS 64A × RP 5898-54-21-9-4-2-2	-5.44 **	-4.79 **	-6.08 **	-16.06 **	-10.85 **	-17.27 **	-29.03 **	-37.25 **	-27.69 **	-22.62 *	-27.98 **	-22.96 *
JMS 14A × RNR 26059	-12.77 **	-15.75 **	-16.89 **	-11.54 **	-10.85 **	-17.27 **	24.32 **	22.09 **	40.70 **	19.33*	18.78*	27.07 **
JMS 14A × RNR26072	0	-3.42	-4.73 **	2.31	3.1	-4.32*	3.25	-6.15	8.16	5.01	4.53	11.82
JMS 14A × RNR 26074	-19.86 **	-22.60 **	-23.65 **	-21.54 **	-20.93 **	-26.62 **	15.13*	4.64	20.60 **	3.54	3.07	10.26
JMS 14A × RNR 26083	-2.13	-5.48 **	-6.76 **	2.31	3.1	-4.32*	55.80 **	41.61 **	63.20 **	22.56 **	22.00 **	30.51 **
JMS 14A × RNR 26084	-5.67 **	-8.90 **	-10.14**	-3.85 *	-3.1	-10.07 **	28.07 **	18.86 **	36.98 **	25.99 **	25.42 **	34.16**
JMS 14A × Pusa 1701-10-5-8	-1.89	-5.25 **	-6.53 **	-1.54	-0.78	-7.91 **	11.1	0.99	16.38*	-8.67	-9.08	-2.74
JMS 14A × PAU 2K10-23-451-2-37-34-0-3	0.71	-2.74	-4.05*	-1.91	0.44	-6.78 **	-13.84*	-11.53*	1.96	-18.96*	-19.33*	-13.7
JMS 14A × RP 5898-54-21-9-4-2-2	-3.4	-2.74	-4.05*	-5.11**	0.78	-6.47 **	1.81	-7.46	6.65	-8.17	-8.59	-2.22
JMS 20A × RNR 26059	-9.79 **	-11.64 **	-12.84 **	8.85 **	-4.65 *	-11.51 **	-5.7	-7.39	6.74	-2.25	-1.52	5.35
JMS 20A × RNR26072	1.4	-0.68	-2.03	7.32 **	2.33	-5.04 **	-2.46	-7.76	6.3	-16.51 *	-15.89	-10.02
JMS 20A × RNR 26074	-3.5	-5.48 **	-6.76 **	0.8	-2.33	-9.35 **	12.89*	6.76	23.04 **	-6.09	-5.38	1.22
JMS 20A × RNR 26083	-3.5	-5.48 **	-6.76 **	3.21	-3.19	-10.15**	-0.15	-5.58	8.82	-9.87	-9.2	-2.86
JMS 20A × RNR 26084	-1.4	-3.42	-4.73 **	5.69 **	0.78	-6.47 **	-10.14	-15.02*	-2.07	-3.4	-2.67	4.12
JMS 20A × Pusa 1701-10-5-8	1.4	-0.68	-2.03	8.13**	3.1	-4.32*	2.33	-3.23	11.53	-4.48	-3.76	2.95
JMS 20A × PAU 2K10-23-451-2-37-34-0-3	-6.99 **	-8.90 **	-10.14**	-7.64 **	-5.43 **	-12.23 **	1.24	3.96	19.81 **	-7.63	-6.94	-0.45
JMS 20A × RP 5898-54-21-9-4-2-2	-29.93 **	-29.45 **	-30.41 **	-34.31 **	-30.23 **	-35.25 **	-10.94	-15.78 **	-2.93	-1.75	-1.01	5.9

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

Table 7: Top ranking hybrids based on 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	40.02	49.14 **	31.58 **	9.36 **
2	JMS 14A × RNR 26084	34.97	28.72 **	13.56 **	5.66**
3	CMS 64A × PAU 2K10-23-451-2-37-34-0-3	34.54	27.72 **	12.68 **	7.06 **
4	CMS 23A × RNR26072	34.28	27.51 **	12.50 **	3.23 **

Conclusion

The present investigation of 32 cross combinations, none of the hybrids are recorded as superior performance for all the traits. However, different cross combinations were found to be superior to various traits. This study concluded that the *gca* effects exhibited among the lines JMS 14A and the testers, RNR 26059, RNR 26072, RNR 26074 and PAU 2K10-23-451-2-37-34-0-3 had significant *gca* effects in the desired direction for most of the traits including grain yield. The degree of dominance was more than unity for all the traits except for plant height, panicle length, panicle weight, 1000 grain weight, number of grains per panicle, spikelet fertility, kernel length, and kernel breadth. SCA variances were higher than GCA variances for most of the characters, which indicated the predominance of non-additive gene action. Among 32 F_1s, top-ranking hybrids *viz*., JMS 14A × RNR 26083, CMS 64A × PAU 2K10-23-451-2-37-34-0-3, CMS 23A × RNR26072 and JMS 14A × RNR 26084 were identified as good specific combiners and *per se* performance in the present study for yield and its components which is ideal for the exploitation of heterosis breeding.

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