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Combining ability and heterosis for yield and its related traits in rice hybrids

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ABSTRACT

Combining ability analysis and heterosis for yield and its attributing traits was carried out in rice through line x tester analysis of 30 hybrids developed by crossing three females with ten male lines during wet season 2010 at Mandya, Karnatak. The hybrids along with parents and a standard check KRH-2 grown in a RCBD with two replications were evaluated for grain yield and yield contributing traits during dry season 2011. The estimates of gca effects indicated that, among females, KCMS 49A and among males Thanu are good general combiners for grain yield and most of the traits studied. High sca effects were observed in the crosses, KCMS 47A × KMR 4, KCMS 48A × MSN 75 and KCMS 47A × MSN 98 and they were found to be the best combinations for grain yield and its traits. The crosses KCMS 47A× KMR 4 and KCMS 49A × MSN 93 exhibited high mean seed yield and high standard heterosis over standard check KRH-2.

Key words: *hybrid rice, yield, CMS, combining ability, heterosis*

Success of any plant breeding programme depends on the choice of appropriate genotypes as parents in the hybridization programme. Among different methods available, combining ability analysis is one of the effective approaches available for estimating the combining ability effects that help in selecting desirable parents and crosses for the exploitation of heterosis. To exploit maximum heterosis using male sterility system in hybrid breeding programme, knowledge on the combining ability of different male sterile and restorer lines is essential. From a practical point of view, standard heterosis is the most important of the two levels of heterosis because it is aimed at developing desirable hybrids superior to the existing high yielding commercial varieties. Significant heterosis and standard heterosis have been reported in rice by a number of workers such as Umakantha *et al*., (2002), Nadali (2010) and Tiwary *et al*., (2011) etc.Accordingly, the present investigation was undertaken to study combining ability for yield and its traits with a view to identify good combiners and also to identify high yielding non aromatic rice hybrids.

MATERIAL AND METHODS

The experimental material for this study comprised of three newly developed non-aromatic CMS lines {KCMS 47A, KCMS 48A and KCMS 49A having WA type of cytoplasm} and ten testers (Thanu, KMR-3, KMR-4, KMR-12, MSN-36, MSN-75, MSN-91, MSN-93, MSN-98 and MSN-99) by validating SSR tightly linked to fertility restoration. These were crossed in 3 line × 10 tester fashion during wet season 2010 to produce thirty F_1 hybrids by adopting clipping method of crossing. These F_1 hybrids, parents along with standard check variety KRH-2 were evaluated during 2011 in RCBD with two replications. The hybrids and their parents and checks were transplanted one seedling hill^{-1} with a spacing of 15 cm × 15 cm. All the recommended package of practices were followed to ensure good crop growth and development. Five competitive plants were randomly selected to record the observations on grain yield and yield contributing characters viz., days to 50% flowering, plant height, No. of tillers, plant^{-1}, No. of Panicles plant^{-1}, Panicle length (cm), Yield plant^{-1}, 1000 grain weight and L/B ratio. The mean values of these five plants were used for combining ability analysis as suggested by Kemtphorne (1957). The variances for general combining ability (gca) and specific combining ability (sca) were tested against their respective error variances derived from ANOVA reduced to mean level. Significance test for gca and sca effects were performed using t-test. The aroma of the new hybrids was tested using standard KOH test using IR58025A (highly aromatic) as check. The per cent increase or decrease of F_1 hybrids over mid parent and standard check was calculated to estimate heterotic effects of yield and its related traits.

The overall *gca* status of parents was calculated based on the methods of Arunachalam and Bandyopadyay (1979) with slight modification as suggested by Mohan Rao (2001).

RESULTS AND DISCUSSION

Analysis of variance revealed presence of significant difference among the genotypes studied. Mean squares of parents and crosses were significantly different for all the traits indicated that they are suitable for genetic studies. The mean squares due to females (lines) and males (testers) were significant most of the traits studied. The variance due to hybrids differed significantly for all the characters. Mean sum of squares due to lines x testers interaction were highly significant for all the characters indicating that the lines differed significantly from testers in respect of all the characters studied. The variance due to hybrids differed significantly for all the characters except no. of tillers plant^{-1}. Thus, suggesting the importance of heterosis breeding for improvement of these traits. The analysis of variance for combining ability revealed that the estimates of sca variances were predominant for all the characters studied as revealed by the ratio of gca and sca variances. This indicates predominance of non-additive gene action in respect of all the traits studied. These results are in agreement with earlier findings of Jagadeesan and Ganesan (2006), Rahimi *et al*. (2010), Saravanan *et al.* (2006), Anandkumar *et al.* (2004).

Among the CMS lines, KCMS 49A was the best general combiner as it showed highly significant *gca* effects for all the traits in desirable (positive) direction except for days to 50 % flowering, Plant height and no. of tillers plant^{-1}. Among the testers, Thanu was found superior general combiner for no. of panicles plant^{-1}, and yield plant^{-1} (Table 1). For Panicle length KMR-4 was found to be superior. Testers KMR-12 and MSN-36 were found good general combiners for spikelet fertility and no. of spikelets panicle^{-1}, respectively. The tester MSN-91 was good general combiner for L/B ratio. It was evident from the results that the lines KCMS 48A and KCMS 49A had high (H) overall *gca* status. Among the testers, Thanu, KMR-3, KMR-4, KMR-12, MSN-36, MSN-93 and MSN-98 posses high (H) overall *gca* status (Table 2). Similar results were reported by Swamy *et al*. (2003) and Saidaiah *et al*., (2010).

The estimate of *sca* effects with their respective standard error for each character in thirty cross combinations were presented in Table 2. None of the crosses exhibited high *sca* effects for all the characters studied. The majority of the crosses showed significant *sca* effects, which involved atleast one parent having high *gca* effects. Only six out of forty crosses, showed positively significant *sca* effects for grain yield plant^{-1} of which highest being KCMS 49A × MSN 75. This hybrid also had highly significant s*ca* values for panicle length, spikelet fertility and yield hectare^{-1} in positive direction. The hybrid KCMS 48A × MSN 75 exhibited highest positive significant *sca* for spikelet fertility and 1000 grain weight. For yield plant^{-1}, the cross KCMS 47A × KMR 4 was found superior. Another hybrid KCMS 47A × MSN 98 was found superior for earliness as it exhibited lowest negative *sca* for days to 50% flowering. This cross also exhibited superior L/B ratio. For panicle weight, hybrid KCMS 48A×MSN 36 was found superior. The hybrids KCMS 49A × KMR 12 and KCMS 49A × MSN 75 were found good specific combiners for no. of spikelets panicle^{-1} and plant height respectively. These results are in corroboration with the earlier findings of Jagadeeasan and Ganesan (2006) and Saidaiah *et al*. (2010). Seventeen out of thirty hybrids studied exhibited high (H) overall *gca* status and thirteen crosses exhibited low (L) overall *gca* status as estimated by the method suggested by Arunachalam and Bandyopadyay (1979) with slight modification as suggested by Mohan Rao (2001). All the twenty crosses with high overall *sca* effects have parents with all types of combination of *gca* effect viz., H x H, H x L and L x L. These results are in agreement with the earlier

Table.1 Estimates of general combining ability effects of lines and testers for yield and yield contributing character

	Days to 50% flowering	Plant height (cm)	No. of tillers plant^{-1}	No. of panicles plant^{-1}	Panicle length (cm)	Spikelet fertility (%)	No. of spikelets panicle^{-1}	Yield plant^{-1} (g)	1000 grain weight (g)	L/B ratio	overall gca status
Lines											
KCMS 47A	-1.48	0.03	0.37	-0.44 **	1.49	1.70 **	-6.77	-3.15 **	-0.65 **	-0.26 **	L
KCMS 48A	0.46	0.37	0.09	-0.27 **	1.36	1.15 **	-14.03 **	-1.74 *	-0.06	-0.01	H
KCMS 49A	1.02	-0.40	-0.46	0.71 **	-2.85 *	-2.85 **	20.80 **	4.89 **	0.71 **	0.27 **	H
SEm±	1.084	0.5241	0.6101	0.0489	1.2294	0.0824	4.8169	0.6912	0.0475	0.0358	
Testers											
Thanu	5.64 **	-0.05	0.04	0.69 **	6.51 **	1.97 **	43.89 **	5.72 **	-0.85 **	0.08	H
KMR-3	-2.69	2.06 *	1.76	0.03	9.19 **	-4.53 **	-36.02 **	3.56 **	2.90 **	-0.08	H
KMR-4	-1.08	0.34	0.93	0.02	10.90 **	0.63 **	-29.93 **	3.33 *	0.77 **	0.13 *	H
KMR-12	7.92 **	0.67	0.98	0.32 **	-2.06	4.97 **	21.85 *	-2.28	-0.17	-0.05	H
MSN-36	5.26 *	-0.61	0.37	0.37 **	1.50	0.47 **	45.39 **	5.06 **	-0.82 **	-0.13	H
MSN-75	-8.69 **	-1.77	-1.41	-1.30 **	-45.68 **	1.13 **	-37.82 **	-18.74 **	-0.33 **	-0.49 **	L
MSN-91	6.64 **	-0.39	-0.63	-0.04	10.60 **	4.80 **	-3.11	0.40	-1.34 **	0.34 **	L
MSN-93	4.26 *	-1.33	-1.30	0.24 *	2.10	0.97 **	14.79	4.72 **	0.49 **	0.20 **	H
MSN-98	-7.97 **	1.45	-0.24	0.24 *	4.08	-3.53 **	-1.65	1.21	0.93 **	-0.11	H
MSN-99	-9.30 **	-0.36	-0.52	-0.58 **	2.87	-6.87 **	-17.38	-2.99 *	-1.57 **	0.10	L
SEm±	1.9792	0.9568	1.1139	0.0892	2.2446	0.1504	8.7944	1.262	0.0868	0.0653	

*Significance at 0.05, ** Significance at 0.01

reports of Mohan Rao (2001), Saidaiah *et al*. (2010). The proportional contribution of lines, testers and their interactions to total variances showed that testers played an important role toward difficult traits, indicating influence of testers on these traits. The smaller contribution of interactions of the line x tester than testers, indicating higher estimates of variances due to general combining ability. Nadali (2010) observed higher estimates of gca variances due to testers in rice. Contribution of interactions of line x tester was higher than lines for all the traits except for spikelet fertility and L/B ratio indicating higher estimates of gca variances for interaction.

In the present study among the lines KCMS 49A and among the testers Thanu was the good general combiner for yield and its majority of the traits since they had high positive *gca* effects for yield and majority of yield attributing characters. These best combiners could be utilized in hybrid development breeding programme. The crosses KCMS 47A × KMR 4, KCMS 48A × MSN 75 and KCMS 47A × MSN 98 were identified as most promising for yield based on *sca* effects. Hence these could be used for the exploitation of heterosis for yield and related characters.

Heterosis was computed as increase or decrease in F_1 value over mid parent and over best commercial variety (standard heterosis). The relative magnitude of heterosis was expressed as heterosis over mid parent and standard checks for yield and other characters (Table. 3). Significant heterosis for days to 50 % flowering in negative direction over mid parent (-15.99%) and over the check KRH-2 (-5.38%) was recorded by the hybrid KCMS 49A × MSN 99 (-16.43%). For plant height the cross KCMS 47A × MSN 98 showed significant mid parent heterosis (-15.35%) followed by the hybrid KCMS 47A × MSN 99 (-11.43%) while none of the hybrids showed significant negative heterosis over the check KRH-2. Earlier workers including Umakantha *et al*. (2002), Nadali (2010), Saidaiah *et al.*, (2010), Tiwary *et al*., (2011) also noticed significant negative heterosis for early flowering and plant height. With respect to no. of tillers plant^{-1} the hybrid KCMS 48A × KMR 4 recorded maximum heterosis over mid parent (30.86%) while none of the crosses showed positive significant heterosis over the check for this trait. For no. of panicles plant^{-1} the cross KCMS 48A × KMR 4 showed highest significant mid parent heterosis (44.44%) followed by

Table 2. Estimates of specific combining ability effects in crosses for yield and yield contributing characters

	Days to 50% flowering	Plant height (cm)	No. of tillers plant^{-1}	No. of panicles plant^{-1}	Panicle length (cm)	Spikelet fertility (%)	No. of spikelets panicle^{-1}	Yield plant^{-1} (g)	1000 grain weight (g)	L/B ratio	overall sca status
KCMS 47A×Thanu	-1.24	0.30	0.63	-0.05	4.99	-0.87 **	-8.43	2.59	0.22	-0.17	H
KCMS 47A× KMR 3	0.42	0.53	1.07	0.03	1.07	-2.37 **	-3.63	-0.55	0.86 **	0.09	H
KCMS 47A× KMR 4	4.14	-1.58	-1.93	0.52 **	0.58	1.47 **	21.74	7.13 **	-0.66 **	-0.03	H
KCMS 47A × KMR 12	5.31	1.75	1.18	-0.16	-2.47	3.13 **	-4.20	-6.25 **	-0.49 **	-0.02	L
KCMS 47A × MSN 36	-5.02	0.36	-0.21	0.08	-5.37	-0.37	7.37	2.68	-0.18	-0.14	H
KCMS 47A × MSN 75	-0.24	0.03	0.07	-0.44 **	0.16	-3.03 **	-21.43	-2.06	0.71 **	-0.02	L
KCMS 47A × MSN 91	2.26	0.97	0.63	0.26	-0.37	1.30 **	22.97	3.16	0.40 *	0.19	H
KCMS 47A × MSN 93	4.81	-0.25	-0.70	0.02	2.38	-0.87 **	-18.73	-7.48 **	-0.31 *	-0.14	L
KCMS 47A × MSN 98	-9.30 *	-1.20	0.24	-0.26	-4.81	2.63 **	10.90	0.71	0.26	0.34 **	L
KCMS 47A × MSN 99	-1.14	-0.89	-0.98	-0.02	3.82	-1.03 **	-6.56	0.06	-0.80 **	-0.11	L
KCMS 48A × Thanu	2.66	-0.71	-0.26	0.26	-3.29	-0.32	9.93	-0.60	-0.24	-0.06	L
KCMS 48A × KMR 3	4.65	-1.98	-1.48	0.49 **	-3.51	1.18 **	11.93	3.24	-0.17	0.13	H
KCMS 48A × KMR 4	-0.62	2.90	2.86	0.00	-3.16	-2.48 **	2.54	0.89	0.27	-0.22	H
KCMS 48A × KMR 12	-5.79	-1.93	-2.03	0.01	8.13 *	-1.32 **	-30.54	2.21	-0.04	-0.06	H
KCMS 48A × MSN 36	-0.29	-0.49	-0.25	0.05	9.78 *	1.18 **	-0.98	-3.04	-0.46 **	-0.15	L
KCMS 48A × MSN 75	-3.68	4.01 *	3.86	-0.68 **	-2.68	5.52 **	19.33	-4.35	1.03 **	0.32 **	H
KCMS 48A × MSN 91	1.16	-2.87	-2.59	-0.14	1.57	0.85 **	-31.08	-2.90	-0.34 *	-0.05	L
KCMS 48A × MSN 93	-2.29	-1.09	-0.26	-0.24	-4.76	-1.32 **	25.73	2.82	-0.36 *	-0.11	H
KCMS 48A × MSN 98	1.43	-0.68	-1.48	0.07	3.76	-2.82 **	-20.14	-1.72	-0.25	-0.16	L
KCMS 48A × MSN 99	2.77	2.84	1.63	0.18	-5.86	-0.48	13.29	3.46	0.56 **	0.36 **	H
KCMS 49A × Thanu	-1.41	0.42	-0.37	-0.21	-1.70	1.18 **	-1.50	-1.99	0.03	0.23	L
KCMS 49A × KMR 3	-5.08	1.46	0.41	-0.52 **	2.44	1.18 **	-8.30	-2.69	-0.69 **	-0.21	L
KCMS 49A × KMR 4	-3.52	-1.32	-0.93	-0.52 **	2.57	1.02 **	-24.28	-8.03 **	0.39 *	0.24 *	L
KCMS 49A × KMR 12	0.48	0.18	0.85	0.15	-5.66	-1.82 **	34.74 *	4.04	0.53 **	0.08	H
KCMS 49A × MSN 36	5.31	0.13	0.46	-0.13	-4.41	-0.82 **	-6.39	0.36	0.64 **	0.29 *	H
KCMS 49A × MSN 75	3.92	-4.04 *	-3.93	1.11 **	2.51	-2.48 **	2.10	6.42 **	-1.74 **	-0.30 *	H
KCMS 49A × MSN 91	-3.41	1.90	1.96	-0.12	-1.21	-2.15 **	8.11	-0.27	-0.06	-0.14	H
KCMS 49A × MSN 93	-2.52	1.35	0.96	0.21	2.38	2.18 **	-6.99	4.67 *	0.67 **	0.25 *	H
KCMS 49A × MSN 98	7.87 *	1.88	1.24	0.19	1.05	0.18	9.24	1.01	-0.01	-0.18	H
KCMS 49A × MSN 99	-1.63	-1.95	-0.65	-0.16	2.03	1.52 **	-6.73	-3.51	0.24	-0.26 *	L
SEm±	3.428	1.6573	1.9293	0.1545	3.8878	0.2604	15.2323	2.1859	0.1503	0.1131	

*Significance at 0.05, ** Significance at 0.01

KCMS 47A × KMR 3 (37.77%), for this trait also none of the hybrids have recorded positive significant heterosis over KRH-2. Maximum mid parent heterosis for panicle length was exhibited by the hybrid KCMS 49A × MSN 98 (14.26%) followed by the hybrid KCMS 49A × KMR 12 (14.08%) while no positively significant standard heterosis was recorded for this trait also. Joshi (2000), Umakantha *et al*., (2002), Nadali (2010) and Tiwary *et al*. (2011) reported similar results in their respective studies. For Spikelet fertility out of thirty hybrids studied no one exhibited significant positive mid parent heterosis and standard heterosis over the check.

The hybrid KCMS 49A × KMR 12 recorded highest heterosis over mid parent (64.20%), over the check KRH-2 (39.86%) for no. of spikelets panicle^{-1}.

Seed yield is a complex trait and it is the multiplicative end product of several yield components. Many hybrids showed positive significant heterosis for this trait. For yield plant^{-1} the range of mid parent heterosis was recorded from -37.41% (KCMS 48A × MSN 75) to 118.88% (KCMS 47A × KMR 4). However only one hybrid *viz.*, KCMS 49A × MSN 93 manifested significant positive heterosis over the check KRH-2 (16.31%). Joshi (2000), Umakantha *et al*., (2002),

Table 3. Heterosis (%) of new hybrids for yield and various yield related traits

Crosses	Days to 50% flowering		Plant height (cm)		No. of tillers plant^{-1}		No. of panicles plant^{-1}		Panicle length (cm)	
	MP Heterosis	SH over KRH-2	MP Heterosis	SH over KRH-2	MP Heterosis	SH over KRH-2	MP Heterosis	SH over KRH-2	MP Heterosis	SH over KRH-2
KCMS 47A × Thanu	-0.50	6.45 **	5.19	10.95 **	11.35	-0.95	29.90 *	6.38	4.79	-10.72 **
KCMS 47A × KMR 3	-9.90 **	-2.15 **	-3.88	4.69	21.89 *	12.52	37.77 **	20.17	2.62	-8.87 **
KCMS 47A× KMR 4	1.01 **	7.53 **	9.36 **	9.70 *	-1.54	-9.58	11.79	-4.28	7.93 **	-5.66 *
KCMS 47A × KMR 12	6.53 **	13.98 **	14.67 **	19.25 **	13.19	11.57	28.99 *	15.92	6.72 *	-5.73 *
KCMS 47A × MSN 36	-3.45 **	5.38 **	-1.51	7.04	-5.22	-3.84	14.77	3.16	6.18 *	-7.58 **
KCMS 47A × MSN 75	-7.02 **	3.23 **	-7.43 *	-1.57	-6.16	-12.46	7.95	-6.41	-11.18 **	-20.89 **
KCMS 47A × MSN 91	0.48	11.83 **	6.13	15.18 **	-1.86	0.98	6.67	2.11	5.62 *	-5.14
KCMS 47A × MSN 93	0.51	5.38 **	9.27 **	15.34 **	-7.09	-11.54	-0.59	-10.66	7.60 **	-6.84 *
KCMS 47A × MSN 98	-2.02 **	4.30 **	-15.35 **	-9.39 *	8.98	-0.95	15.65	2.11	0.33	-11.09 **
KCMS 47A × MSN 99	-14.08 **	-3.23 **	-11.43 **	-2.98	-10.49	-9.61	-1.14	-7.47	0.87	-12.20 **
KCMS 48A × Thanu	-1.98 **	6.45 **	12.56 **	16.43 **	8.80	-4.79	20.02	-1.08	12.50 **	-5.18
KCMS 48A × KMR 3	-8.29 **	1.08 *	3.37	10.48 *	10.08	0.03	16.36	2.11	9.86 **	-3.44
KCMS 48A × KMR 4	-4.98 **	2.69 **	8.92 *	7.04	30.86 **	18.29	44.44 **	24.44	9.62 **	-5.18
KCMS 48A × KMR 12	0.00	8.60 **	8.52 *	10.64 *	-4.95	-7.67	3.53	-6.41	9.94 **	-3.88
KCMS 48A × MSN 36	-3.88 **	6.45 **	6.24	13.30 **	-6.74	-6.72	11.77	1.05	5.15	-9.43 **
KCMS 48A × MSN 75	-0.72 *	11.83 **	-6.98 *	-2.98	22.53 *	12.52	32.94 **	15.95	1.05	-10.91 **
KCMS 48A × MSN 91	-1.90 **	10.75 **	8.89 **	15.96 **	-20.38 *	-19.22	-17.12	-20.23	3.53	-7.95 **
KCMS 48A × MSN 93	-2.02 **	4.30 **	6.73 *	10.48 *	-8.71	-14.40	0.00	-9.60	11.97 **	-4.07
KCMS 48A × MSN 98	-9.45 **	-2.15 **	-2.39	2.50	16.32	4.04	0.59	-10.66	6.22 *	-6.84 *
KCMS 48A × MSN 99	-15.29 **	-3.23 **	-4.65	2.51	14.43	13.91	14.14	7.43	1.93	-12.20 **
KCMS 49A × Thanu	-3.02 **	3.76 **	6.63 *	13.15 **	12.99	-2.74	17.86	-5.36	13.66 **	0.11
KCMS 49A × KMR 3	-10.89 **	-3.23 **	-7.00 *	1.88	29.03 **	15.41	29.20 *	10.63	5.69 *	-3.11
KCMS 49A × KMR 4	-4.04 **	2.15 **	3.87	4.85	0.54	-10.56	15.17	-3.22	12.59 **	1.66
KCMS 49A × KMR 12	-3.02 **	3.76 **	11.89 **	17.06 **	4.52	0.03	22.90	8.49	14.08 **	4.07
KCMS 49A × MSN 36	-8.37 **	0.00	8.95 **	19.09 **	-6.35	-7.67	15.65	2.11	13.05 **	1.66
KCMS 49A × MSN 75	-10.90 **	-1.08 *	-2.12	4.69	-31.93 **	-38.46 **	-26.28 *	-37.27 **	0.50	-7.58 **
KCMS 49A × MSN 91	-7.25 **	3.23 **	2.79	12.21 **	3.84	3.87	11.86	5.30	-1.10	-8.32 **
KCMS 49A × MSN 93	-1.03 **	3.76 **	4.35	10.80 **	3.11	-4.79	7.21	-5.36	12.19 **	0.37
KCMS 49A × MSN 98	-9.09 **	-3.23 **	1.31	9.08 *	29.85 **	14.28	18.99	3.16	14.26 **	4.55
KCMS 49A × MSN 99	-15.99 **	-5.38 **	-10.23 **	-1.09	-16.66	-18.23	-2.90	-10.66	7.50 **	-3.33

Crosses	Spikelet fertility (%)		No. of spikelets panicle^{-1}		Yield per plant (g)		1000 grain weight(g)		L/B ratio	
	MP Heterosis	SH over KRH-2	MP	SH	MP	SH	MP	SH	MP	SH
KCMS 47A × Thanu	13.72	4.32	41.60 **	16.94	75.09 **	-4.54	-5.23 **	-21.30 **	-12.19 **	-13.53 **
KCMS 47A × KMR 3	12.15	2.90	-4.25	-18.40 *	61.98 **	-16.66 *	4.79 **	-1.96 *	2.30	-11.18 *
KCMS 47A× KMR 4	10.79	4.31	32.33 **	-3.60	118.88 **	0.39	-10.98 **	-18.02 **	-1.71	-8.82 *
KCMS 47A × KMR 12	-2.66	-14.00	30.30 **	8.56	0.21	-43.06 **	-9.58 **	-21.39 **	-13.90 **	-12.94 **
KCMS 47A × MSN 36	-4.52	-13.24	16.91 *	25.08 **	40.27 **	-5.85	-6.09 **	-22.89 **	-14.32 **	-17.65 **
KCMS 47A × MSN 75	-54.82 **	-60.83 **	-8.34	-27.62 **	-27.95	-71.14 **	1.93	-16.83 **	-25.88 **	-23.53 **
KCMS 47A × MSN 91	11.28	2.87	30.15 **	9.60	92.40 **	-15.40 *	-4.48 **	-22.65 **	-6.93 *	1.18
KCMS 47A × MSN 93	14.59	-3.70	23.14 *	-1.60	35.93 **	-29.87 **	-5.42 **	-17.74 **	-13.07 **	-10.00 *
KCMS 47A × MSN 98	4.60	-9.65	16.66	4.61	46.01 **	-19.17 **	-5.07 **	-13.28 **	-1.30	-5.88
KCMS 47A × MSN 99	11.23	-1.17	-1.09	-11.01	45.62 **	-30.26 **	-19.60 **	-28.95 **	-13.89 **	-11.41 **
KCMS 48A × Thanu	1.03	-5.28	47.29 **	22.16 *	59.36 **	-8.63	0.15	-20.71 **	0.31	-5.29
KCMS 48A × KMR 3	4.02	-2.47	-0.08	-14.49	75.45 **	-4.78	7.20 **	-3.86 **	15.28 **	-4.59
KCMS 48A × KMR 4	3.88	-0.11	14.69	-16.05	83.48 **	-10.67	0.56	-11.28 **	4.11	-7.65
KCMS 48A × KMR 12	8.42	-2.02	10.85	-7.25	33.29 **	-20.50 **	0.17	-16.79 **	-5.45	-8.24
KCMS 48A × MSN 36	11.90	3.93	9.69	17.74	20.48 *	-15.73 *	0.30	-21.52 **	-4.79	-12.35 **
KCMS 48A × MSN 75	-59.67 **	-64.22 **	11.12	-11.86	-37.41 **	-73.16 **	12.13 **	-12.84 **	-8.84 *	-9.65 *
KCMS 48A × MSN 91	11.11	4.95	-4.51	-19.25 *	58.05 **	-26.05 **	-0.51	-23.29 **	-3.32	1.18
KCMS 48A × MSN 93	2.26	-12.00	44.42 **	15.91	78.10 **	-3.09	1.84	-15.36 **	-3.02	-3.53

Table 3....contd...

Crosses	Spikelet fertility (%)		No. of spikelets panicle^{-1}		Yield per plant (g)		1000 grain weight(g)		L/B ratio	
	MP Heterosis	SH over KRH-2	MP	SH	MP	SH	MP	SH	MP	SH
KCMS 48A × MSN 98	13.12	-0.01	-3.82	-13.41	34.90 **	-21.52 **	-0.47	-12.93 **	-3.61	-12.00 **
KCMS 48A × MSN 99	-3.57	-12.38	5.09	-5.08	59.20 **	-19.26 **	-5.72 **	-20.33 **	6.55	5.29
KCMS 49A × Thanu	-10.32	-8.28	57.70 **	33.18 **	67.02 **	3.36	10.03 **	-16.17 **	22.67 **	8.24
KCMS 49A × KMR 3	-2.71	-0.49	6.08	-7.62	64.61 **	-3.18	12.11 **	-2.80 **	22.89 **	-5.88
KCMS 49A × KMR 4	-2.92	1.62	17.42	-12.28	57.97 **	-15.91 *	8.61 **	-7.42 **	33.14 **	9.88 *
KCMS 49A × KMR 12	-21.73 **	-22.60 **	64.20 **	39.86 **	54.01 **	-1.14	11.20 **	-10.95 **	12.10 **	1.88
KCMS 49A × MSN 36	-18.24 **	-17.11 *	20.88 **	31.58 **	43.96 **	7.24	15.19 **	-13.31 **	21.92 **	4.71
KCMS 49A × MSN 75	-62.05 **	-63.10 **	19.30	-3.58	40.54 **	-33.36 **	4.79 **	-21.68 **	-11.39 **	-17.65 **
KCMS 49A × MSN 91	-5.85	-3.05	34.28 **	15.58	85.32 **	-4.86	9.67 **	-18.70 **	7.53 *	5.88
KCMS 49A × MSN 93	-3.41	-8.66	42.96 **	16.89	97.26 **	16.31 *	15.53 **	-7.42 **	19.55 **	11.53 **
KCMS 49A × MSN 98	-4.98	-7.92	27.61 **	16.80	59.28 **	-0.09	8.32 **	-8.48 **	10.57 *	-5.88
KCMS 49A × MSN 99	-7.60	-8.17	10.95	1.88	44.71 **	-20.03 **	0.08	-18.42 **	5.14	-2.59

*Significance at 0.05, ** Significance at 0.01

Nadali (2010) and Tiwary *et al*. (2011) in their respective studies have reported different levels of heterosis for seed yield plant^{-1}. The hybrid KCMS 49A × MSN 36 showed highest mid parent heterosis (15.19%) for 1000 grain weight. No hybrids out of thirty hybrids showed positively significant heterosis over the check KRH-2. Joshi (2000) and Tiwary *et al*., (2011) reported significant heterosis for test weight. For L/B ratio the cross KCMS 49A × KMR 4 showed highest mid parent heterosis of 33.14%. Another hybrid KCMS 49A × MSN 93 recorded significant heterosis (11.53%) over the check. All the thirty hybrids studied were non aromatic compared to check KRH-2 which is slightly aromatic hybrid.

The present study resulted in identification of promising non- aromatic rice hybrids *viz.*, KCMS 47A× KMR 4 and KCMS 49A × MSN 93 based on high mean seed yield and high heterosis over standard check KRH-2. Hence these hybrids could be considered for commercial cultivation.

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