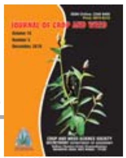
Journal of Crop and Weed, 16(1): 38-50 (2020)

ISSN- O : 2349 9400 ; P : 0974 6315



http://cwssbckv.org
www.cropandweed.com

Heterosis studies for yield and physical quality traits in hybrid rice (*Oryza sativa* L.)

S. BEGUM, V. RAM REDDY, B. SRINIVAS AND CH. ARUNAKUMARI
Agricultural College, Jagtial
Jayashankar Telangana State Agricultural University, Hyderabad

Received : 08.11.2019 ; Revised : 13.04.2020 ; Accepted : 20.05.2020

DOI: https://doi.org/10.22271/09746315.2020.v16.i1.1270

ABSTRACT

Forty-two hybrids of rice were developed by crossing six CMS lines and seven testers in line x tester mating design for estimation of heterosis for yield and physical quality traits. The data was collected on days to 50 per cent flowering, plant height (cm), panicle length (cm), number of productive tillers per plant, number of grains per panicle, spikelet fertility percentage (%),1000-grain weight (g), grain yield per plant (g), hulling percentage, milling percentage, head rice recovery percentage, kernel length (mm), kernel breadth (mm), kernel L/B ratio, paddy length (mm), paddy breadth (mm) and paddy L/B ratio.The analysis of variance (line x tester) revealed significant differences among genotypes for all the characters studied. The hybrids JMS 19A X JR 80, JMS 19A X JBR 6, JMS 19A X JR 83, JMS 19A X JR 67 and CMS 64A X JMBR 44 recorded high grain yield per plant and had higher percentage of relative heterosis, heterobeltiosis and standard heterosis for majority of the traits. Testing of these hybrids in multilocation trials across different states of the country may result in the identification of better hybrids in the near future for commercial exploitation.

Keywords : CMS lines, heterosis, line x tester, physical quality traits, rice, yield

Rice (*Oryza sativa* L.) is one of the most important cereal crops worldwide. More than half of the world's population, particularly in developing countries depends on rice for calories and protein. Rice and agriculture are still fundamental to the economic development of most of the Asian countries. In Asia, rice plays a central role in politics, society and culture, directly or indirectly employs more people than any other sector. Farmers need to achieve good yields without harming the environment so that they can make a good living while providing the rice-consuming people with a high-quality, affordable staple food. Underpinning this, a strong rice research sector can help to reduce costs, improve productivity and ensure environmental sustainability. Hybrid rice technology appears to be the most feasible and readily adaptable to increase the yieldlevel in rice. Extensive research work is going on throughout India and abroad on different aspects of hybrid rice. Several pioneer hybrids have shown ayield advantage of around 20% over current three- line hybrids on a commercial scale and the success of hybrid rice program depends upon the magnitude of heterosis which also helps in the identification of potential cross combinations to be used in the conventional breeding program to create a wide array of variability in the segregating generations (Krishna Veni and Sobha Rani, 2003). Rigorous efforts are needed to identify high yielding hybrids which are expensive and involves a large number of hybrid combinations in multi environmental trails, thereforethis study would be of considerable advantage as it aims to predict the yield performance of rice hybrids on the basis of mean performance, relative heterosis, heterobeltiosis and standard heterosis in order to include only the promising heterotic hybrids in subsequent evaluation trails before extensive field trails are taken up.

MATERIALS AND METHODS

Heterosis studies were carried out for forty-two hybrids obtained by crossing six CMS lines *viz.*, CMS 64A, JMS 11A, JMS 19A, CMS 52A, JMS 21A and JMS 20Aand seven restorer lines *viz.*, JR 83, JR 85, JR 80, JMBR 44, JMBR 31, JR 67 and JBR 6 by adopting Line × Tester mating design given by Kempthorne(1957). Thirteen parents and their forty two hybrids along with two checks *viz.*, US 312 and HRI 174 were evaluated in randomized block design with a spacing of 20 ×15 cm at Regional Agricultural Research Station (RARS), Polasa, Jagtial during *Kharif* 2017. All the recommended practices were followed to raise and maintain a healthy crop. Observations were recorded for days to 50 per cent flowering, plant height (cm), panicle length (cm), number of productive tillers plant^{-1}, number of grains panicle^{-1}, spikelet fertility percentage (%),1000- grain weight (g), grain yield plant^{-1} (g), hulling percentage, milling percentage, head rice recovery percentage, kernel length(mm), kernel breadth(mm), kernel L/B ratio, paddy length (mm), paddy breadth (mm) and paddy L/B ratio. Data obtained was subjected to analysis of variance and heterosis, heterobeltiosis, standard heterosis over high yielding checks were computed as given by Liang *et al.* (1971) and expressed in percentage as follows:

Heterosis over mid parent: Relative heterosis was expressed as per cent increase or decrease observed in the F_1 over the mid-parent as per the following formula.

Email : sameenabegum477@gmail.com

$$Heterosis(\%) = \frac{\overline{MP}-\overline{F}_1}{\overline{MP}}\,x100$$

where, $\overline{MP}$ = Mean of mid parents and $\overline{F}_1$ Mean of F_1

Heterosis over better parent: Heterobeltiosis was expressed as per cent increase or decrease observed in F_1 over the better parent as per the formula.

$$Heterobeltiosis\%(h2) = \frac{\overline{BP}-\overline{F}_1}{\overline{BP}}\,x100$$

where, $\overline{BP}$ = Mean of better parents and $\overline{F}_1$ Mean of F_1

$$\text{Standard Heterosis }\%(h3) = \frac{\overline{F}_1 - \text{Mean of check}}{\text{Mean of check}}\,x100$$

RESULTS AND DISCUSSION

Analysis of variance revealed significant differences for all treatments. It indicates that there is sufficient diversity among the genotypes. So, further heterotic studies were carried out.

The exploitation of heterosis can enhance yield from 30 to 40 per cent and can also enrich the domesticated crops with the most important traits of qualitative and quantitative nature.In the present study heterosis over mid parent (relative heterosis), over better parent (heterobeltiosis) and over the standard check (standard heterosis) was estimated in 42 hybrids for seventeen charactersto search out the best combination of parents giving a high degree of useful heterosis and characterization of parents for their prospects for future use in breeding programs. For plant height and days to 50% flowering negative heterosis is desirable but for rest of the characters positive heterosis is desirable. A large number of hybrids had significantly desired heterosis over the mid parent, better parent as well as checks for various traits and could be isolated for further evaluation at different locations and seasons (Table 1). Early maturing hybrids are desirable as they produce more yields per day and fit in multiple cropping systems. For days to 50 % flowering, maximum negative standard heterosis of 26.73 % (over HRI 174) and -21.28 % (over US 312) was observed in the hybrids CMS 64AX JR85, JMS 11 A X JR 85, JMS 19A X JR 85, CMS 52 A X JR 85 and JMS 20A X JR 85. Maximum negative heterosis was registered by hybrid CMS 64A X JR 85over better parent (-19.57 %)and JMS 19A X JR 85 overmid parent (-12.68 %). Similar findings have also been reported by Sahu*et al.* (2017), Chuwang Hijam and Singh (2019) and Gowayed Salah *et al.* (2020) indicating the possibility of exploiting heterosis for earliness.

Dwarf plant stature is desirable to develop semi-dwarf high yielding varieties which will be lodging resistant and fertilizer responsive. The maximum significant negative standard heterosis for plant height was manifested by JMS 20A X JR 85*viz.*, -24.56 % over HRI 174 and -25.56 % over US 312. The hybrid JMS 21A X JR 83 recorded maximum negative heterotic effect over better parent (-18.49%) and JMS 20A X JR 85 recorded maximum relative heterosis of -11.54 %. ChuwangHijam and Singh (2019) and Gowayed Salah *et al.* (2020)also emphasized the importance of negative significant heterosis for plant height to develop dwarf plant types.

A hybrid with longer panicle length is desirable since the spikelets attached to primary and secondary branch would increase proportionately with the enhancement of panicle length. In the present study, CMS 64A X JR 80 exhibited positive and significant heterobeltiosis (17.06 %) and relative heterosis (21.15 %). CMS 52A X JMBR 44 showed high standard heterosis to the extent of 19.48 % over HRI 174 and 12.32 % over US 312 for panicle length. The results are in conformity with the findings of Satheesh Kumar *et al.* (2016),Thorat *et al.* (2017) and Gokulakrishnan (2018).

The number of productive tillers per plant is known to directly contribute towards grain yield. In the case of productive tillers per plant, hybrid CMS 64A X JR 83 recorded the highest heterosis over standard checks HRI 174 (50.00 %) and US 312 (41.18 %), better parent (33.33 %) and mid parent (37.14 %).Satheesh Kumar *et al.* (2016),Thorat *et al.* (2017), ChuwangHijam and Singh (2019)reported highly significant and positive heterotic effects with respect to tiller number per plant which is in accordance with the present results.

The quantitative trait of 1000- grain weight is determined by both grain size and grain filling rate, which is characterized by the three dimensions of grain length, width and height (Xie *et al.*, 2015). Grain weight is mainly governed by genetic factors, whereas grain filling rate is affected by external environmentalconditions.Li *et al.* (2019) reported thatthe1000- grain weight influences yield greatly in rice. In this study maximum, significant positive heterotic effect for 1000- grain weight over better parent 15.64 % and mid parent 27.72 % was recorded in JMS 11A X JR 83. Hybrid JMS 11A X JR 80 recorded the highest standard heterosis of 13.42 % (over HRI 174) and 30.21 % (over US 312). The results are in akin to the findings of Samrath Bedi and Deepak Sharma (2016) and Gokulakrishnan (2018).

The number of grains per panicle is mainly determined by the panicle architecture, including panicle length and the number and length of primary, secondary and higher -order branches (Kovi *et al.*, 2011). To further increase yield and to break the yield stagnation breeding efforts have to be directed to expand the yield sink capacity, which is the maximum size of sink organs to

Table 1:Estimates of heterosisover standard checks (SH), better parent (BPH) and mid parent (MPH) for different yield and physical quality traits in rice.

S. No.	Crosses	Days to 50% flowering				Plant height (cm)				Panicle length (cm)			
		SH		BPH	MPH	SH		BPH	MPH	SH		BPH	MPH
		HRI 174	US 312			HRI 174	US 312			HRI 174	US 312		
1	CMS 64A X JR 83	-8.42*	-1.6 0	-2.63*	-1.07	0.76	-0.58	2.57	15.36*	8.99*	2.46	16.40*	20.00*
2	CMS 64A X JR 85	-26.73*	-21.28*	-19.57*	-10.84*	-15.73*	-16.85*	1.62	5.75*	1.12	-4.93	14.41*	14.65*
3	CMS 64A X JR 80	-8.91*	-2.13*	-10.68*	-5.64*	3.36*	1.99	-4.36*	12.03*	10.49*	3.87	17.06*	21.15*
4	CMS 64A X JMBR 44	-9.90*	-3.19*	-1.09	-0.82	1.51	0.17	-7.08*	9.33*	9.36*	2.82	-0.68	10.40*
5	CMS 64A X JMBR 31	-13.37*	-6.91*	-4.89*	-0.85	-11.86*	-13.03*	1.95	8.21*	-3.37	-9.15*	6.17	7.95*
6	CMS 64A X JR 67	-13.86*	-7.45*	-5.43*	-4.92*	193	0.58	15.87*	23.99*	7.49	1.06	14.80*	18.35*
7	CMS 64A X JBR 6	-10.89*	-4.26*	-7.22*	-4.76*	-5.55*	-6.80*	-3.44	8.40*	1.50	-4.58	14.83*	15.07*
8	JMS 11A X JR 83	-10.40*	-3.72*	-4.74*	-0.82	2.27	0.91	4.11*	10.19*	5.62	-0.70	8.46*	10.59*
9	JMS 11A X JR 85	-26.73*	-21.28*	-15.43*	-8.36*	-17.24*	-18.34*	-5.29*	-2.81	-5.62	-11.27*	-3.08	1.61
10	JMS 11A X JR 80	-6.44*	0.53	-8.25*	-0.79	5.13*	3.73*	-2.72	7.57*	7.49	1.06	10.38*	12.11*
11	JMS 11A X JMBR 44	-11.39*	-4.79*	-2.19*	0.00	5.55*	4.15*	-3.39*	7.36*	-4.49	-10.21*	-13.27*	-7.94*
12	JMS 11A X JMBR 31	-13.86*	-7.45*	-0.57	1.16	-7.40*	-8.63*	5.97*	6.53*	2.62	-3.52	5.38	8.95*
13	JMS 11A X JR 67	-9.90*	-3.19*	0.00	1.96*	-14.13*	-15.27*	-2.39	-2.06	-0.37	-6.34	2.31	4.31*
14	JMS 11A X JBR 6	-10.40*	-3.72*	-6.70*	-1.90*	-3.11	-4.40*	-0.95	4.63*	1.87	-4.23	4.62	9.68*
15	JMS 19A X JR 83	-9.90*	-3.19*	-4.71*	-4.46*	-4.04*	-5.31*	-2.31	9.13*	3.37	-2.82	10.40*	11.52*
16	JMS 19A X JR 85	-26.73*	-21.28*	-22.51*	-12.68*	-20.77*	-21.83*	-4.46*	-1.31	-3.37	-9.15*	5.31	7.28
17	JMS 19A X JR 80	-9.90*	-3.19*	-11.65*	-8.31*	0.42	-0.91	-7.08*	8.15*	4.87	-1.41	11.11*	12.68*
18	JMS 19A X JMBR 44	-10.89*	-4.26*	-5.76*	-3.74*	-1.68	-2.99	-10.01*	5.22*	7.87	1.41	-2.04	6.86
19	JMS 19A X JMBR 31	-12.38*	-5.85*	-7.33*	-1.67	-5.13*	-6.39*	9.73*	15.63*	1.12	-4.93	10.20*	10.66*
20	JMS 19A X JR 67	-10.89*	-4.26*	-5.76*	-3.49*	-9.59*	-10.79*	2.77	9.19*	4.12	-2.11	11.20*	12.32*
21	JMS 19A X JBR 6	-7.92*	-1.06	-4.12*	-3.38*	-5.63*	-6.89*	-3.53*	7.57*	0.75	-5.28	9.80*	11.85*
22	CMS 52A X JR 83	-6.93*	0.00	-1.05	7.74*	1.93	0.58	3.77*	15.10*	3.75	-2.46	9.92*	10.36*
23	CMS 52A X JR 85	-26.73*	-21.28*	-6.92*	-3.58*	-7.99*	-9.21*	10.95*	13.72*	-2.62	-8.45*	3.17	6.56
24	CMS 52A X JR 80	-22.77*	-17.02*	-24.27*	-14.52*	2.52	1.16	-5.14*	9.67*	7.49	1.06	13.89*	13.89*
25	CMS 52A X JMBR 44	-14.36*	-7.98*	-5.46*	1.17	-7.74*	-8.96*	-15.55*	-1.92	19.48*	12.32*	8.50*	16.85*
26	CMS 52A X JMBR 31	-15.84*	-9.57*	0.59	3.66*	-7.32*	-8.55*	7.20*	12.11*	9.74*	3.17	16.27*	18.38*
27	CMS 52A X JR 67	-9.90*	-3.19*	0.00	6.74*	-5.63*	-6.89*	7.27*	13.10*	7.12	0.7	13.49*	13.94*
28	CMS 52A X JBR 6	-10.89*	-4.26*	-7.22*	1.98*	-0.67	-1.99	1.55	12.42*	7.49	1.06	13.89*	17.62*
29	JMS 21A X JR 83	-18.32*	-12.23*	-13.16*	-4.62*	-19.93*	-21.00*	-18.49*	-6.21*	-2.25	-8.10*	4.40	5.88
30	JMS 21A X JR 85	-9.90*	-3.19*	16.67*	19.74**	-19.47*	-20.54*	-0.89*	3.63	-10.49*	-15.85*	-1.65	-0.21
31	JMS 21A X JR 80	-15.84*	-9.57*	-17.48*	-6.08*	-0.67	-1.99	-8.09	10.01*	-7.87	-13.38*	-2.38	-0.61
32	JMS 21A X JMBR 44	-7.92*	-1.06	1.64	9.73*	-3.11	-4.40*	-11.32*	6.62*	-0.37	-6.34	-9.52*	-0.93
33	JMS 21A X JMBR 31	-7.92*	-1.06	10.06*	14.46*	-14.72*	-15.85*	-1.36	7.30*	4.12	-2.11	14.40*	14.40*
34	JMS 21A X JR 67	-15.84*	-9.57*	-6.59*	0.59	-11.02*	-12.20*	1.15	10.90*	-1.87	-7.75*	4.80	6.29
35	JMS 21A X JBR 6	-7.92*	-1.06	-4.12*	6.29*	-11.35*	-12.53*	-9.37*	4.10*	-2.62	-8.45*	7.00	8.56*
36	JMS 20A X JR 83	-9.90*	-3.19*	-4.21*	0.28	-5.05*	-6.31*	-3.34	2.17	2.62	-3.52	9.60*	13.69*
37	JMS 20A X JR 85	-26.73*	-21.28*	-14.45*	-7.79*	-24.56*	-25.56*	-13.92*	-11.5*	-11.99*	-17.25*	-0.42	0.43*
38	JMS 20A X JR 80	-14.85*	-8.51*	-16.50*	-9.23*	0.25	-1.08	-7.24*	2.45	-0.37	-6.34	5.56	9.92*
39	JMS 20A X JMBR 44	-10.40*	-3.72*	-1.09	1.69	-1.6	-2.90	-9.93*	-0.04	4.68	-1.58	-4.93	6.27
40	JMS 20A X JMBR 31	-7.92*	-1.06	7.51*	8.77*	-12.45*	-13.61*	-0.10	0.58	-2.25	-8.10*	7.41	9.89*
41	JMS 20A X JR 67	-9.90*	-3.19*	0.00	2.54*	-10.93*	-12.12*	1.24	1.44	-5.99	-11.62*	0.40	4.15
42	JMS 20A X JBR 6	-13.86*	-7.45*	-10.31*	-5.18*	-1.51	-2.82	0.69	6.21*	3.37	-2.82	16.95*	17.95*

*Significant at p= 0.05, ** Significant at p= 0.01

contd.

contd. table 1

S.No	Crosses	No. of productive tillers per plant				1000- grain weight (g)				No. of grains per Panicle			
		SH		BPH	MPH	SH		BPH	MPH	SH		BPH	MPH
		HRI 174	US 312			HRI 174	US 312			HRI 174	US 312		
1	CMS 64A X JR 83	50.00*	41.18*	33.33*	37.14*	5.31	20.89*	12.71*	20.50*	-14.56	-16.18	2.84	6.68
2	CMS 64A X JR 85	6.25	0.00	-10.53	-5.56	-11.21*	1.93	9.13*	9.45*	-26.55*	-27.94*	-13.38	-9.60
3	CMS 64A X JR 80	18.75	11.76	11.76	11.76	6.30	22.04*	0.52	13.63*	24.84	22.48	61.94*	67.05*
4	CMS 64A X JMBR 44	31.25	23.53	23.53	27.27*	-2.54	11.88*	-8.97*	3.45	6.42	4.41	22.11	29.60*
5	CMS 64A X JMBR 31	6.25	0.00	-5.56	-2.86	4.67	20.16*	0.02	12.54*	-16.49	-18.07	8.33	22.07
6	CMS 64A X JR 67	0.00	-5.88	-5.88	-5.88	-15.90*	-3.45	-2.44	0.38	5.57	3.57	36.94*	47.83*
7	CMS 64A X JBR 6	6.25	0.00	0.00	6.25	-11.88*	1.17	8.32*	10.76*	-10.28	-11.97	-9.50	1.82
8	JMS 11A X JR 83	37.50*	29.41*	4.76	12.82	8.05*	24.04*	15.64*	27.72*	-22.27	-23.74	-6.44	2.98
9	JMS 11A X JR 85	-18.75	-23.53	-38.10*	-35.00*	-9.16*	4.29	12.30*	15.98*	-41.76*	-42.86*	-31.31*	-23.70
10	JMS 11A X JR 80	6.25	0.00	-19.05	-10.53	13.42*	30.21*	7.26*	24.98*	-9.85	-11.55	24.56	28.55
11	JMS 11A X JMBR 44	-6.25	-11.76	-28.57*	-18.92	6.06	21.76*	-0.93	16.03*	-10.49	-12.18	2.70	15.47
12	JMS 11A X JMBR 31	12.50	5.88	-14.29	-7.69	7.98*	23.97*	3.19	19.71*	-31.26*	-32.56*	1.26	7.72
13	JMS 11A X JR 67	12.50	5.88	-14.29	-5.26	1.79	16.86*	18.09*	25.70*	4.71	2.73	54.26*	56.73*
14	JMS 11A X JBR 6	6.25	0.00	-19.05	-5.56	-9.29*	4.14	16.63*	18.16*	-18.63	-20.17	-17.93	-2.56
15	JMS 19A X JR 83	18.75	11.76	5.56	15.15	-2.52	11.91*	4.33	22.44*	-3.43	-5.25	-6.24	3.80
16	JMS 19A X JR 85	-6.25	-11.76	-21.05	-11.76	-10.22*	3.07	10.99*	22.42*	1.07	-0.84	-1.87	7.64
17	JMS 19A X JR 80	12.50	5.88	5.88	12.50	6.35	22.09*	0.56	23.99*	15.63	13.45	12.27	31.87*
18	JMS 19A X JMBR 44	18.75	11.76	18.75	22.58	-7.19*	6.55	-13.30*	7.40*	16.06	13.87	12.68	22.07
19	JMS 19A X JMBR 31	25.00	17.65	11.11	21.21	-5.17	8.86*	-9.38*	11.28*	-2.36	-4.20	-5.20	20.00
20	JMS 19A X JR 67	12.50	5.88	5.88	12.50	-15.26*	-2.72	-1.69	11.51*	15.42	13.24	12.06	36.80*
21	JMS 19A X JBR 6	0.00	-5.88	6.67	6.67	-17.38*	-5.15	6.23	15.10*	50.32*	47.48*	45.95*	48.73*
22	CMS 52A X JR 83	37.50*	29.41*	22.22	22.22*	10.64*	27.01*	15.36*	16.87*	-35.76*	-36.97*	-22.68	-5.81
23	CMS 52A X JR 85	12.50	5.88	-5.26	-2.70	-0.46	14.27*	3.78	12.60*	-57.17	-57.98	-49.49	-37.98*
24	CMS 52A X JR 80	0.00	-5.88	-11.11	-8.57	10.44*	26.78*	4.43	9.53*	-2.57	-4.41	34.62	55.03*
25	CMS 52A X JMBR 44	6.25	0.00	-5.56	0.00	9.35*	25.54*	2.15	7.76*	-4.07	-5.88	10.07	36.59*
26	CMS 52A X JMBR 31	37.50*	29.41	22.22	22.22*	8.05*	24.04*	3.25	7.75*	-9.42	-11.13	51.61*	60.23*
27	CMS 52A X JR 67	6.25	0.00	-5.56	-2.86	1.68	16.73*	6.02	11.67*	-19.27	-20.80	22.80	35.61
28	CMS 52A X JBR 6	18.75	11.76	5.56	15.15	-9.38*	4.04	-5.51	4.35	6.42	4.41	7.34	39.61*
29	JMS 21A X JR 83	-31.25*	-35.29*	-38.89*	-29.03*	-2.85	11.53*	3.98	5.94	-28.48*	-29.83*	-13.92	-4.71
30	JMS 21A X JR 85	31.25*	23.53	10.53	31.25*	-16.98*	-4.70	-7.72*	-2.82	-8.99	-10.71	7.32	19.89
31	JMS 21A X JR 80	6.25	0.00	0.00	13.13	5.53	21.15*	-0.21	7.84*	8.78	6.72	50.30*	56.07*
32	JMS 21A X JMBR 44	12.50	5.88	12.50	24.14	5.31	20.89*	-1.63	6.90*	-5.57	-7.35	8.35	22.50
33	JMS 21A X JMBR 31	-6.25	-11.76	-16.67	-3.23	1.42	16.43*	-3.09	4.23	-28.69*	-30.04*	6.39	12.50
34	JMS 21A X JR 67	0.00	-5.88	-5.88	6.67	-0.04	14.75*	11.11*	13.48*	2.36	0.42	52.72*	54.19*
35	JMS 21A X JBR 6	0.00	-5.88	6.67	14.29	-13.27*	-0.43	-3.59	3.41	-6.85	-8.61	-6.05	12.11
36	JMS 20A X JR 83	43.75*	35.29*	27.78*	31.43*	-14.29*	-1.60	-8.26*	13.09*	-42.18*	-43.28*	-35.56*	-33.09*
37	JMS 20A X JR 85	-18.75	-23.53	-31.58*	-27.78*	-18.62*	-6.58	0.60	17.05*	12.42	10.29	25.30	28.83*
38	JMS 20A X JR 80	6.25	0.00	0.00	0.00	-2.85	11.53*	-8.13*	1854*	13.49	11.34	26.49	40.03*
39	JMS 20A X JMBR 44	12.50	5.88	5.88	9.09	7.59*	23.51*	0.50	30.24*	-1.93	-3.78	9.31	10.90
40	JMS 20A X JMBR 31	6.25	0.00	-5.56	-2.86	-17.62*	-5.43	-21.28*	1.20	13.92	11.76	26.97	52.44*
41	JMS 20A X JR 67	12.50	5.88	5.88	5.88	-28.31*	-17.69*	-16.83*	-0.67	-2.78	-4.62	8.35	25.07
42	JMS 20A X JBR 6	6.25	0.00	0.00	6.25	-23.82*	-12.54*	-2.05	12.09*	-2.36	-4.20	-1.51	3.40

**Significant at p= 0.05, ** Significant at p= 0.01*

contd.

contd. table 1

S. No	Crosses	Spikelet fertility (%)				Grain yield per plant (g)				Hulling (%)			
		SH		BPH	MPH	SH		BPH	MPH	SH		BPH	MPH
		HRI 174	US 312			HRI 174	US 312			HRI 174	US 312		
1	CMS 64A X JR 83	-0.51	2.03	-6.28	-0.77	79.83*	67.19*	32.10*	58.52*	2.59*	1.05*	-1.89*	3.46*
2	CMS 64A X JR 85	2.49	5.11	-13.37	-3.62	47.90*	37.50*	25.71*	41.94*	376*	2.20*	-0.77*	0.92*
3	CMS 64A X JR 80	-15.02	-12.85	-20.60*	-15.61	66.39*	54.69*	83.33*	86.79*	4.07*	2.51*	-0.47	2.35*
4	CMS 64A X JMBR 44	-0.07	2.48	-7.21	-1.09	80.67*	67.97*	85.34*	91.96*	1.11*	-0.41	-3.31*	-2.33*
5	CMS 64A X JMBR 31	4.10	6.76	-4.76	2.23	44.54*	34.38*	39.84*	48.92*	0.22*	-1.29*	-4.16*	-1.62*
6	CMS 64A X JR 67	-7.11	-4.73	-18.98*	-11.11	10.92*	3.13	9.09	15.28	3.15*	1.59*	-1.36*	0.25
7	CMS 64A X JBR 6	-2.86	-0.38	-5.56	-1.49	71.85*	59.77*	51.48*	68.31*	1.21*	-0.31	-3.21*	-1.16*
8	JMS 11A X JR 83	13.33	16.23	6.76	16.27	23.53*	14.84	-9.26	8.49	4.94*	3.36*	4.88*	8.29*
9	JMS 11A X JR 85	5.86	8.56	-10.53	2.23	-17.65	-23.44	-30.00	-21.29	2.93*	1.38*	1.83*	2.35*
10	JMS 11A X JR 80	-12.75	-10.52	-18.48	-10.89	47.06*	36.72*	60.55*	64.32*	2.47*	0.93*	2.41*	3.05*
11	JMS 11A X JMBR 44	-17.07	-14.95	-22.99*	-15.59	-0.84	-7.81	1.72	4.89	2.59*	1.05*	0.12	1.31*
12	JMS 11A X JMBR 31	-25.13*	-23.22*	-31.50*	-24.41*	5.04	-2.34	1.63	7.76	1.17*	-0.35	1.11*	1.57*
13	JMS 11A X JR 67	3.08	5.71	-10.10	1.33	36.13*	26.56	33.88*	40.87*	4.13*	2.57*	2.89*	3.48*
14	JMS 11A X JBR 6	14.21	17.13	11.04	19.19*	34.45*	25.00	18.52	31.15*	2.59*	1.05*	2.34*	2.44*
15	JMS 19A X JR 83	23.37*	26.52*	14.09	15.15	99.16*	85.16*	46.30*	78.20*	-3.80*	-5.25*	0.95*	1.77*
16	JMS 19A X JR 85	21.17*	24.27*	2.41	7.02	29.41*	20.31	10.00	26.23*	4.82*	3.24*	3.71*	6.76*
17	JMS 19A X JR 80	12.53	15.40	4.07	4.60	145.38*	128.13*	180.77*	180.77*	2.34*	0.80*	3.58*	5.45*
18	JMS 19A X JMBR 44	13.55	16.45	5.01	5.23	17.65	9.38	20.69	27.27*	2.84*	1.29*	0.36	4.00*
19	JMS 19A X JMBR 31	-3.59	-1.13	-11.80	-11.32	15.13	7.03	11.38	20.70	0.83*	-0.69	1.68*	3.70*
20	JMS 19A X JR 67	22.64*	25.77*	6.96	10.10	83.19*	70.31*	80.17*	93.78*	3.73*	2.17*	2.49*	5.57*
21	JMS 19A X JBR 6	20.22*	23.29*	11.18	13.96	108.40*	93.75*	83.70*	107.53*	2.90*	1.35*	2.65*	5.25*
22	CMS 52A X JR 83	1.90	4.51	-4.00	6.30	67.23*	55.47*	22.84*	50.19*	1.54*	0.01	0.52	4.27*
23	CMS 52A X JR 85	21.32*	24.42*	2.54	19.01*	0.84	-6.25	-14.29	-1.23	2.71*	1.17*	1.62*	1.65*
24	CMS 52A X JR 80	-7.25	-4.88	-13.35	-3.69	28.57*	19.53	47.12*	47.83*	2.90*	1.36*	1.87*	3.00*
25	CMS 52A X JMBR 44	2.20	4.81	-5.10	5.76	23.53	14.84	26.72*	34.25*	1.97*	0.43	-0.49	0.22
26	CMS 52A X JMBR 31	3.96	6.61	-4.89	6.69	77.31*	64.84*	71.54*	86.73*	0.78*	-0.74*	-0.23	0.69*
27	CMS 52A X JR 67	5.79	8.49	-7.73	5.67	17.65	9.38	15.70	25.00	3.63*	2.08*	2.40*	2.50*
28	CMS 52A X JBR 6	-4.10	-1.65	-6.77	1.79	57.14*	46.09*	38.52*	57.14*	1.51*	-0.01	0.50	0.88*
29	JMS 21A X JR 83	10.33	13.15	3.93	7.04	5.88	-1.56	-22.22*	0.40	2.56*	1.02*	9.40*	13.83*
30	JMS 21A X JR 85	9.16	11.95	-7.74	0.00	32.77*	23.44	12.86	37.99*	2.28*	0.74*	1.19*	9.08*
31	JMS 21A X JR 80	4.25	6.91	-2.60	0.71	4.20	-3.13	19.23	28.50	2.90*	1.35*	4.14*	11.08*
32	JMS 21A X JMBR 44	14.58	17.51	6.39	10.34	29.41*	20.31	32.76*	50.24*	1.99*	0.46	-0.46	7.97*
33	JMS 21A X JMBR 31	18.17	21.19*	8.11	12.92	35.29*	25.78	30.89*	51.89*	2.34*	0.80*	3.21*	10.27*
34	JMS 21A X JR 67	21.25*	24.34*	5.75	12.97	30.25*	21.09	28.10*	47.62*	3.83*	2.26*	2.59*	10.65*
35	JMS 21A X JBR 6	25.93*	29.15*	22.44*	24.16*	25.21	16.41	10.37	33.04	2.37*	0.83*	2.13*	9.67*
36	JMS 20A X JR 83	20.22*	23.29*	12.40	12.82	19.33	10.94	-12.35	1.07	1.48*	-0.04	5.20*	6.70*
37	JMS 20A X JR 85	26.37*	29.60*	6.81	12.20	-7.56	-14.06	-21.43	-15.06	0.06	-1.45	-1.01*	1.30*
38	JMS 20A X JR 80	3.44	6.09	-3.35	-3.32	19.33	10.94	19.33	27.35*	1.32*	-0.2	2.55*	3.77*
39	JMS 20A X JMBR 44	9.30	12.1	1.50	1.84	12.82	4.88	12.82	14.26	2.65*	1.11*	0.18	3.20*
40	JMS 20A X JMBR 31	11.58	14.43	2.08	3.18	23.53	14.84	19.51	21.49	-6.90*	-8.30*	-6.11*	-4.82*
41	JMS 20A X JR 67	-1.98	0.53	14.50	-11.54	32.35*	23.05	30.17*	31.25*	2.62*	1.08*	1.40*	3.83*
42	JMS 20A X JBR 6	11.50	14.35	4.25	6.28	39.50*	29.69*	22.96	30.71*	0.98*	-0.54	0.74*	2.67*

**Significant at p= 0.05, ** Significant at p= 0.01*

contd.

contd. table 1

S.No.	Crosses	Milling (%)				Head rice recovery (%)				Kernel length (mm)			
		SH		BPH	MPH	SH		BPH	MPH	SH		BPH	MPH
		HRI 174	US 312			HRI 174	US 312			HRI 174	US 312		
1	CMS 64A X JR 83	8.30*	6.01*	-3.39*	1.25	-15.88*	-19.58*	-19.57*	-17.98*	-1.71	-4.17*	-1.71	0.00
2	CMS 64A X JR 85	1.41	-0.73	-9.54*	-7.12*	-15.88*	-19.58*	-19.57*	-17.98*	-5.13*	-7.50*	-12.60*	-9.02*
3	CMS 64A X JR 80	5.28*	3.06*	-6.08*	-3.62*	-1.36	-5.70*	-14.20*	-8.45*	5.13*	2.50*	0.00	2.50*
4	CMS 64A X JMBR 44	-1.09	-3.18*	-13.64*	-12.72*	-26.61*	-29.83*	-28.35*	-27.68*	3.42*	0.83	-7.63*	-2.42*
5	CMS 64A X JMBR 31	0.85	-1.28	-10.04*	-4.90*	-18.22*	-21.82*	-18.65*	-17.99*	2.56	0.00	2.56	6.19*
6	CMS 64A X JR 67	-0.54	-2.64*	-11.28*	-6.65*	-13.98*	-17.77*	-24.53*	-19.80*	-3.42*	-5.83*	-3.42*	-3.42*
7	CMS 64A X JBR 6	4.52*	2.31*	-6.76*	-1.67*	-5.00*	-9.18*	-5.51*	0.68	1.71	-0.83	1.71	4.39*
8	JMS 11A X JR 83	4.41*	2.20*	1.17	1.84*	-9.82*	-13.78*	-13.78*	-4.52*	3.42*	0.83	3.42*	5.22*
9	JMS 11A X JR 85	-16.07	-17.85*	-21.03*	-19.87*	-22.37*	-25.78*	-25.78*	-17.80*	6.84*	4.17*	-1.57	2.46*
10	JMS 11A X JR 80	4.06*	1.86	-2.18*	-0.69	2.34	-2.16	-10.98*	2.71*	17.09*	14.17*	11.38*	14.17*
11	JMS 11A X JMBR 44	3.60*	1.42	-9.54*	-4.83*	0.75	-3.68*	-1.64	7.91*	15.38*	12.50*	3.05*	8.87*
12	JMS 11A X JMBR 31	-1.15	-3.23*	-4.21*	-2.69*	9.95*	5.11*	11.16*	20.02*	10.26*	7.50*	10.26*	14.16*
13	JMS 11A X JR 67	14.18*	11.77*	10.64*	11.83*	21.40*	16.06*	6.52*	22.46*	-3.42*	-5.83*	-3.42*	-3.42*
14	JMS 11A X JBR 6	1.96*	-0.19	-1.20	0.12	10.34*	5.49*	25.13*	27.95*	-1.71	-4.17*	-1.71	0.88
15	JMS 19A X JR 83	-5.45*	-7.45*	-7.15*	-6.74*	-11.28*	-15.18*	-15.17*	-13.38*	11.97*	9.17*	15.93*	16.96*
16	JMS 19A X JR 85	8.62*	6.32*	2.21*	4.84*	-1.18	-5.53*	-5.52*	-3.52*	-3.42*	-5.83*	-11.02*	-5.04*
17	JMS 19A X JR 80	6.17*	3.92*	-0.20	2.42*	13.88*	8.87*	-0.94	5.82*	5.13*	2.50*	0.00	5.13*
18	JMS 19A X JMBR 44	9.08*	6.78*	-4.76*	1.25	8.15*	3.40*	5.59*	6.72*	0.00	-2.50	-10.69*	-3.31*
19	JMS 19A X JMBR 31	7.04*	4.78*	6.05*	6.56*	6.80*	2.10*	6.52*	7.24*	1.71	-0.83	7.21*	8.18*
20	JMS 19A X JR 67	7.83*	5.55*	6.77*	6.80*	11.64*	6.73*	-2.04	4.23*	4.27*	1.67	4.27*	7.02*
21	JMS 19A X JBR 6	4.90*	2.68*	3.93*	4.16*	-4.57*	-8.77*	-4.82	1.28	-1.71	-4.17*	3.60*	3.60*
22	CMS 52A X JR 83	1.75	-0.40	-4.98*	-2.60*	6.35*	1.67	1.68	4.75*	10.26*	7.50*	14.16*	17.81*
23	CMS 52A X JR 85	0.07	-2.04	-6.54*	-6.19*	-13.89*	-17.68*	-17.67*	-15.19*	8.55*	5.83*	0.00	9.01*
24	CMS 52A X JR 80	0.88	-1.25	-5.79*	-5.48*	-18.41*	-22.00*	-29.03*	-23.54*	18.80*	15.83*	13.01*	21.40*
25	CMS 52A X JMBR 44	-5.73*	-7.72*	-17.69*	-14.93*	-22.46*	-25.87*	-24.30*	-22.80*	8.55*	5.83*	-3.05*	7.17*
26	CMS 52A X JMBR 31	1.91	-0.24	-4.83*	-1.56	-17.23*	-20.87*	-16.32	-16.13*	10.26*	7.50*	18.35*	20.00*
27	CMS 52A X JR 67	1.57	-0.58	-5.15*	-2.38*	-16.87*	-20.52*	-27.06*	-21.73*	13.68*	10.83*	13.68*	19.28*
28	CMS 52A X JBR 6	-2.95*	-5.00*	-9.37*	-6.49*	-27.41*	-30.60*	-26.27*	-22.21*	1.71	-0.83	7.21*	9.68*
29	JMS 21A X JR 83	-0.19	-2.30*	-1.99*	8.53*	-15.34*	-19.06*	-19.05*	-2.03	3.42*	0.83	7.08*	9.01*
30	JMS 21A X JR 85	4.16*	1.96*	-1.99*	10.59*	-0.19	-4.58*	-4.57*	15.49*	-3.42*	-5.83*	-11.02*	-4.24*
31	JMS 21A X JR 80	1.82	-0.33	-4.28*	8.05*	-15.70*	-19.40*	-26.67*	-7.97*	4.27*	1.67	-0.81	5.17*
32	JMS 21A X JMBR 44	-2.37*	-4.43*	-14.75*	-0.69	-15.43*	-19.14*	-17.43*	-0.90	8.55*	5.83*	-3.05*	5.83*
33	JMS 21A X JMBR 31	1.91	-0.24	1.93	11.94*	-7.35*	-11.42*	-6.33*	10.85*	6.84*	4.17*	14.68*	14.68*
34	JMS 21A X JR 67	-1.57	-3.65*	-2.54*	7.51*	-13.26*	-17.08*	-23.89*	-4.80*	0.00	-2.50	0.00	3.54*
35	JMS 21A X JBR 6	-3.93*	-5.96*	-4.39*	5.24*	-12.93*	-16.76*	-1.26	11.32*	-10.26*	-12.50*	-5.41*	-4.55*
36	JMS 20A X JR 83	3.29*	1.11	0.75	1.09	-13.33*	-17.14*	-17.13*	-9.82*	-5.13	-7.50	-1.77	5.71*
37	JMS 20A X JR 85	3.73*	1.54	-2.39*	-0.64	0.85	-3.59*	-3.58*	4.92*	0.00	-2.50*	-7.87*	4.46*
38	JMS 20A X JR 80	2.13*	-0.03	-3.99*	-2.22*	3.96*	-0.61	-9.57*	2.63*	1.71	-0.83	-3.25*	8.18*
39	JMS 20A X JMBR 44	6.03*	3.79*	-7.42*	-2.30*	-1.81	-6.13*	-4.14*	3.32*	10.26*	7.50*	-1.53	13.16*
40	JMS 20A X JMBR 31	-5.81*	-7.80*	-8.13*	-6.97*	-13.62*	-17.42*	-12.67*	-7.39*	-8.55*	-10.83*	-1.83	3.88*
41	JMS 20A X JR 67	1.04	-1.09	-1.45	-0.71	4.91*	0.30	-7.94*	4.08*	-6.84*	-9.17*	-6.84*	1.87
42	JMS 20A X JBR 6	0.88	-1.25	-1.60	0.61	-3.80*	-8.03*	9.10*	9.44*	1.71	-0.83	7.21*	14.42*

**Significant at p= 0.05, ** Significant at p= 0.01*

contd.

contd. table 1

S.No	Crosses	Kernel breadth (mm)				Kernel L/B ratio				Paddy length (mm)			
		SH		BPH	MPH	SH		BPH	MPH	SH		BPH	MPH
		HRI 174	US 312			HRI 174	US 312			HRI 174	US 312		
1	CMS 64A X JR 83	-12.2*	-14.29*	-2.70	2.86	12.08	11.89	-9.86	-3.40	6.63	12.87*	-3.98	1.58
2	CMS 64A X JR 85	-14.63*	-16.67*	6.06	6.06	11.21	11.01	-17.53*	-14.19*	8.84*	15.20*	-1.99	1.55
3	CMS 64A X JR 80	-19.51*	-21.43*	-8.33	-4.35	30.65*	30.42*	5.07	7.11	6.63	12.87*	-3.98	4.32
4	CMS 64A X JMBR 44	-12.20*	-14.29*	-5.26	1.41	18.04*	17.83*	-5.07	-3.65	-5.52	0.00	-14.93*	-12.76*
5	CMS 64A X JMBR 31	-9.76	-11.90*	0.00	5.71	13.66*	13.46*	-8.59	-0.46	1.1	7.02	-8.96*	-6.15
6	CMS 64A X JR 67	-7.32	-9.52	8.57	11.76*	4.55	4.37	-15.92*	-13.42*	6.63	12.87*	-3.98	4.32
7	CMS 64A X JBR 6	-14.63*	-16.67*	2.94	4.48	20.14*	19.93*	-3.38	0.51	0.00	5.85	-9.95*	-1.63
8	JMS 11A X JR 83	-19.51*	-21.43*	-10.81	-2.94	29.60*	29.37*	-2.12	7.95	3.31	9.36*	-7.88*	-2.09
9	JMS 11A X JR 85	-9.76	-11.90*	12.12	15.62*	18.39*	18.18*	-12.21*	-11.40*	-16.57*	-11.70*	-25.62*	-22.56*
10	JMS 11A X JR 80	-4.88	-7.14	8.33	16.42*	23.12*	22.90*	-7.01	-2.29	8.84*	15.20*	-2.96	5.91
11	JMS 11A X JMBR 44	0.00	-2.38	7.89	18.84*	15.41*	15.21*	-12.83*	-8.79	14.36*	21.05*	1.97	5.08
12	JMS 11A X JMBR 31	-7.32	-9.52	2.70	11.76*	18.91*	18.71*	-10.19*	0.59	2.21	8.19	-8.87*	-5.61
13	JMS 11A X JR 67	-9.76	-11.90*	5.71	12.12*	7.71	7.52	-18.65*	-13.68*	3.31	9.36*	-7.88*	0.54
14	JMS 11A X JBR 6	-9.76	-11.90*	8.82	13.85*	8.93	8.74	-17.72*	-11.84*	-3.31	2.34	-13.79*	-5.41
15	JMS 19A X JR 83	-4.88	-7.14	541	5.41	17.69*	17.48*	9.27	10.53	-11.05*	-5.85	-15.26*	-12.74*
16	JMS 19A X JR 85	-4.88	-7.14	5.41	11.43*	1.58	1.40	-24.68*	-15.39*	-6.63	-1.17	-11.05*	-10.34*
17	JMS 19A X JR 80	-4.88	2.38	16.22*	17.81*	0.18	0.00	-16.25*	-10.90*	-8.84*	-3.51	-13.16*	-8.08*
18	JMS 19A X JMBR 44	-9.76	-11.90*	-2.63	-1.33	10.86	10.66	-8.13	-1.86	-8.29*	-2.92	-13.09*	-12.86*
19	JMS 19A X JMBR 31	9.76	7.14	21.62*	21.62*	-7.36	-7.52	-11.98	-11.46*	-14.36*	-9.36*	-18.42*	-18.21*
20	JMS 19A X JR 67	4.88	2.38	16.22*	19.44*	-0.53	-0.70	-15.10*	-10.55*	-13.26*	-8.19	-17.37*	-12.53*
21	JMS 19A X JBR 6	-9.76	-11.90*	0.00	4.23	8.93	8.74	-5.04	-0.96	-9.78*	-4.50	-14.05*	-8.52*
22	CMS 52A X JR 83	0.00	-2.38	10.81	10.81*	10.33	10.14	2.44	6.06	-9.94*	-4.68	-8.94*	-6.59
23	CMS 52A X JR 85	-9.76	-11.90*	0.00	5.71	20.49*	20.28*	-10.65*	2.46	-6.63	-1.17	-9.63*	-5.32
24	CMS 52A X JR 80	-9.76	-11.90*	0.00	1.37	31.70*	31.47*	10.10	19.75*	12.15*	18.71*	19.41*	19.76*
25	CMS 52A X JMBR 44	-4.88	-7.14	2.63	4.00	14.19*	13.99*	-5.37	3.33	9.94*	16.37*	4.19	10.25*
26	CMS 52A X JMBR 31	-2.44	-4.76	8.11	8.11	13.31*	13.11*	8.92	10.88	3.87	9.94*	-0.53	4.74
27	CMS 52A X JR 67	-7.32	-9.52	2.70	5.56	22.94*	22.73*	4.93	13.04*	4.42	10.53*	11.18*	11.50*
28	CMS 52A X JBR 6	-4.88	-7.14	5.41	9.86	7.01	6.82	-6.72	-0.49	-23.20*	-18.71*	-18.24*	-17.51*
29	JMS 21A X JR 83	0.00	-2.38	7.89	9.33	3.50	3.32	-3.90	-0.51	-4.42	1.17	-3.35	2.98
30	JMS 21A X JR 85	-7.32	-9.52	0.00	7.04	4.38	4.20	-22.60*	-11.24*	-9.39*	-4.09	-12.30*	-4.65
31	JMS 21A X JR 80	0.00	-2.38	7.89	10.81*	4.20	4.02	-12.88*	-5.25	-4.42	1.17	2.37	6.13
32	JMS 21A X JMBR 44	-2.44	-4.76	5.26	5.26	11.21	11.01	-7.84	0.63	3.31	9.36*	-2.09	7.47*
33	JMS 21A X JMBR 31	-9.76	-11.90*	-2.63	-1.33	18.39*	18.18*	13.80*	15.85*	-7.73	-2.34	-11.64*	-3.47
34	JMS 21A X JR 67	-7.32	-9.52	0.00	4.11	7.88	7.69	-7.92	-0.81	-1.10	4.68	5.92	9.82*
35	JMS 21A X JBR 6	-7.32	-9.52	0.00	5.56	-2.98	-3.51	-15.42*	-9.77	-6.63	-1.17	1.20	4.32
36	JMS 20A X JR 83	0.00	-2.38	10.81	20.59*	-5.08	-5.24	-13.56	-12.72*	-9.94*	-4.68	-8.94*	-6.86
37	JMS 20A X JR 85	-9.76	-11.90*	12.12	15.62*	10.86	10.66	-17.79*	-9.38*	-9.94*	-4.68	-12.83*	-8.94
38	JMS 20A X JR 80	-2.44	-4.76	11.11	19.40*	4.20	4.02	-12.88*	-9.16	-7.73	-2.34	-2.34	-1.76
39	JMS 20A X JMBR 44	-9.76	-11.90*	-2.63	7.25	22.24*	22.03*	1.31	6.08	1.1	7.02	-4.19	1.10
40	JMS 20A X JMBR 31	0.00	-2.38	10.81	20.59*	-8.58	-8.74	-16.75*	-14.50*	-8.84*	-3.51	-12.70*	-8.33*
41	JMS 20A X JR 67	-14.60*	-16.67*	0.00	6.06	9.28	9.09	-6.73	-3.7	-11.05*	-5.85	-5.85	-5.29
42	JMS 20A X JBR 6	-4.88	-7.14	14.71*	20.00*	7.01	6.82	-6.72	-4.68	-15.47*	-10.53*	-10.53*	-9.47*

*Significant at p= 0.05, ** Significant at p= 0.01

contd.

contd. table 1

S.No.	Crosses	Paddy breadth (mm)				Paddy L/B ratio			
		SH		BPH	MPH	SH		BPH	MPH
		HRI 174	US 312			HRI 174	US 312		
1	CMS 64A X JR 83	-12.77*	-25.45*	-8.89*	-7.87*	22.34*	51.45*	5.37	10.24*
2	CMS 64A X JR 85	-12.77*	-25.45*	-8.89*	-4.65	24.94*	54.66*	5.37	6.47
3	CMS 64A X JR 80	-4.26	-18.18*	-4.26	-2.17	11.43*	37.94*	-4.03	6.32
4	CMS 64A X JMBR 44	-12.77*	-25.45*	-16.33*	-12.77*	8.44	34.24*	-6.60	-0.24
5	CMS 64A X JMBR 31	-4.26	-18.18*	-18.18*	-10.00*	5.71	30.87*	-8.95*	2.97
6	CMS 64A X JR 67	4.26	-10.91*	8.89*	8.89*	2.34	26.69*	-11.86*	-4.25
7	CMS 64A X JBR 6	-4.26	-18.18*	0.00	2.27	4.55	29.42*	-9.96*	-3.65
8	JMS 11A X JR 83	0.00	-14.55*	6.82*	10.59*	3.38	27.97*	-19.68*	-11.85*
9	JMS 11A X JR 85	-12.77*	-25.45*	0.00	0.00	-4.29	18.49*	-25.63*	-22.58*
10	JMS 11A X JR 80	8.51*	-7.27*	8.51*	15.91*	0.39	24.28*	-22.00*	-9.64*
11	JMS 11A X JMBR 44	-4.26	-18.18*	-8.16*	0.00	19.61*	48.07*	-7.06	4.01
12	JMS 11A X JMBR 31	4.26	-10.91*	-10.91*	2.08	-1.95	21.38*	-23.81*	-10.01*
13	JMS 11A X JR 67	8.51*	-7.27*	13.33*	18.60*	-4.68	18.01*	-25.93*	-15.78*
14	JMS 11A X JBR 6	-4.26	-18.18*	4.65	7.14*	1.04	25.08*	-21.49*	-11.99*
15	JMS 19A X JR 83	-8.51*	-21.82*	-2.27	0.00	-2.60	20.58*	-17.13*	-12.79*
16	JMS 19A X JR 85	-8.51*	-21.82*	2.38	3.61	2.21	26.53*	-13.80*	-13.42*
17	JMS 19A X JR 80	4.26	-10.91*	4.26	10.11*	-12.47	8.36	-25.52*	-17.05*
18	JMS 19A X JMBR 44	2.13	-12.73*	-2.04	5.49	-10.13	11.25	-23.54*	-17.86*
19	JMS 19A X JMBR 31	-12.77*	-25.45*	-25.45*	-15.46*	-1.69	21.70*	-16.35*	-4.90
20	JMS 19A X JR 67	8.51*	-7.27*	13.33*	17.24*	-20.00*	-0.96	-31.93*	-25.65*
21	JMS 19A X JBR 6	8.51*	-7.27*	18.60*	20.00*	-16.88	2.89	-29.28*	-23.90*
22	CMS 52A X JR 83	4.26	-10.91*	11.36*	12.64*	-13.51*	7.07	-18.28*	-17.16*
23	CMS 52A X JR 85	-4.26	-18.18*	4.65	7.14*	-2.34	20.90*	-17.63*	-11.84*
24	CMS 52A X JR 80	-8.51	-21.82*	-8.51*	-4.44	22.73*	51.93*	-19.17*	24.92*
25	CMS 52A X JMBR 44	0.00	-14.55*	-4.08	2.17	10.00	36.17*	6.81	7.69
26	CMS 52A X JMBR 31	-4.26	-18.18*	-18.18*	-8.16*	8.57	34.41*	5.42	12.97*
27	CMS 52A X JR 67	4.26	-10.91*	8.89*	11.36*	0.26	24.12*	-2.65	-0.06
28	CMS 52A X JBR 6	-2.13	-16.36*	6.98*	6.98*	-21.43*	-2.73	-23.71*	-22.93*
29	JMS 21A X JR 83	-4.26	-18.18*	0.00	1.12	-0.13	23.63*	-5.64	1.65
30	JMS 21A X JR 85	0.00	-14.55*	4.44	9.30*	-9.09	12.54	-23.33*	-13.10*
31	JMS 21A X JR 80	4.26	-10.91*	4.26	6.52*	-8.18	13.67*	-1.81	-0.28
32	JMS 21A X JMBR 44	8.51*	-7.27*	4.08	8.51*	-4.68	18.01*	-5.90	-0.68
33	JMS 21A X JMBR 31	-4.26	-18.18*	-18.18*	-10.00*	-3.64	19.29*	6.30	7.15
34	JMS 21A X JR 67	4.26	-10.91*	8.89*	8.89*	-5.06	17.52*	-2.79	0.83
35	JMS 21A X JBR 6	2.13	-12.73*	6.67*	9.09*	-8.57	13.18*	-9.40	-4.54
36	JMS 20A X JR 83	-4.26	-18.18*	-8.16*	-3.23	-5.84	16.56*	-11.04*	-4.16
37	JMS 20A X JR 85	-4.26	-18.18*	-8.16	0.00	-5.84	16.56*	-20.59*	-9.99*
38	JMS 20A X JR 80	8.51*	-7.27*	4.08	6.25*	-14.94*	5.31	-9.03	-7.62
39	JMS 20A X JMBR 44	4.26	-10.91*	0.00	0.00	-2.99	20.10*	-4.23	1.08
40	JMS 20A X JMBR 31	-4.26	-18.18*	-18.18*	-13.46*	-4.68	18.01*	5.16	5.99
41	JMS 20A X JR 67	-8.51*	-21.82*	-12.24*	-8.51*	-2.73	20.42*	-0.40	3.31
42	JMS 20A X JBR 6	-4.26	-18.18*	-8.16*	-2.17	-11.69*	9.32	-12.48*	-7.80

**Significant at p= 0.05, ** Significant at p= 0.01*

Table 2: **Estimates of heterosisover standard checks (SH), better parent (BPH) and mid parent (MPH) in top five hybrids for different yield and physical quality traits in rice.**

Sl. No.	Character / Cross	Standard heterosis		Heterobeltiosis	Relative heterosis
		Over HRI 174	Over US 312		
1	Days to 50 per cent flowering				
	CMS 64A X JR 85	-26.73*	-21.28*	-19.57*	-10.84*
	JMS 11A X JR 85	-26.73*	-21.28*	-15.43*	-8.36*
	JMS 19A X JR 85	-26.73*	-21.28*	-22.51*	-12.68*
	CMS 52A X JR 85	-26.73*	-21.28*	-6.92*	-3.58*
	JMS 20A X JR 85	-26.73*	-21.28*	-14.45*	-7.79*
2	Plant height (cm)				
	JMS 20A X JR 85	-24.56*	-25.56*	-13.92*	-11.54*
	JMS 19A X JR 85	-20.77*	-21.83*	-4.46	-1.31
	JMS 21A X JR 83	-19.93*	-21.00*	-18.49*	-6.21*
	JMS 21A X JR 85	-19.74*	-20.54*	-2.89*	3.63
	JMS 11A X JR 85	-17.24*	-18.34*	-4.46*	-2.81
3	Panicle length (cm)				
	CMS 52A X JMBR 44	19.48*	12.32*	8.50*	16.85*
	CMS 64A X JR 80	10.49*	3.87	17.06*	21.15*
	CMS 52A X JMBR 31	9.74*	3.17	16.27*	18.38*
	CMS 64A X JMBR 44	9.36*	2.82	-0.68	10.40*
	CMS 64A X JR 83	8.99*	2.46	16.40*	20.00*
4	Number of productive tillers per plant				
	CMS 64A JR 83	50.00*	41.18*	33.33*	37.14*
	JMS 20A X JR 83	43.75*	35.29*	27.78*	31.43*
	JMS 11A X JR 83	37.50*	29.41*	4.76	12.82
	CMS 52A X JR 83	37.50*	29.41*	22.22	22.22*
	CMS 52A X JMBR 31	37.50*	29.41*	22.22	22.22*
5	1000- grain weight (g)				
	JMS 11A X JR 80	13.42*	30.21*	7.26*	24.98*
	CMS 52A X JR 83	10.64*	27.01*	15.36*	16.87*
	CMS 52A X JR 80	10.64*	26.78*	4.43	9.53*
	CMS 52A X JMBR 44	9.35*	25.54*	2.15	7.76*
	JMS 11A X JR 83	8.05*	24.04*	15.64*	27.72*
6	Number of grains per panicle				
	JMS 19A X JBR 6	50.32*	47.48*	45.95*	48.73*
	CMS 64A X JR 80	24.84*	22.48*	61.94*	67.05*
	JMS 19A X JMBR 44	16.06	13.87	12.68	22.07*
	JMS 19A X JR 80	15.63	13.45	12.27	31.87*
	JMS 19A X JR 67	15.42	13.24	12.06	36.80*
7	Spikelet fertility (%)				
	JMS 20A X JR 85	26.37*	29.60*	6.81	12.20
	JMS 21A X JBR 6	25.93*	29.15*	22.44*	24.16*
	JMS 19A X JR 83	23.37*	26.52*	14.09	15.15
	JMS 19A X JR 67	22.64*	25.77*	6.96	10.10
	CMS 52A X JR 85	21.32*	24.42*	2.54	19.01*
8	Grain yield per plant (g)				
	JMS 19A X JR 80	145.38*	128.13*	180.77*	180.77*
	JMS 19A X JBR 6	108.40*	93.75*	83.70*	107.53*
	JMS 19A X JR 83	99.16*	85.16*	46.30*	78.20*
	JMS 19A X JR 67	83.19*	70.31*	80.17*	93.78*
	CMS 64A X JMBR 44	80.67*	67.97*	85.34*	-1.09
9	Hulling percentage (%)				
	JMS 11A X JR 83	4.94*	3.36*	4.88*	8.29*
	JMS 19A X JR 85	4.82*	3.24*	3.71*	6.76*
	JMS 11A X JR 67	4.13*	2.57*	2.89*	3.48*
	CMS 64A X JR 80	4.07*	2.51*	-0.47	2.35*
	JMS 21A X JR 67	3.83*	2.26*	2.59*	10.65*

Contd.

Contd. table 2

Sl. No.	Character / Cross	Standard heterosis		Heterobeltiosis	Relative heterosis
		Over HRI 174	**Over US 312**		
10	Milling percentage (%)				
	JMS 11A X JR 67	14.18*	11.77*	10.64*	11.83*
	JMS 19A X JMBR 44	9.08*	6.78*	-4.76*	1.25
	JMS 19A X JR 85	8.62*	6.32*	2.21*	4.84*
	CMS 64A X JR 83	8.30*	6.01*	-3.39*	1.25
	JMS 19A X JR 67	7.83*	5.55*	6.77*	6.80*
11	Head rice recovery (%)				
	JMS 11A X JR 67	21.40*	16.06*	6.52*	22.46*
	JMS 19A X JR 80	13.88*	8.87*	-0.94	5.82*
	JMS 19A X JR 67	11.64*	6.73*	-2.04	4.23*
	JMS 11A X JBR 6	10.34*	5.49*	25.13*	27.95*
	JMS 11A X JMBR 31	9.95*	5.11*	11.16*	20.02*
12	Kernel length (mm)				
	CMS 52A X JR 80	18.80*	15.83*	13.01*	21.40*
	JMS 11A X JR 80	17.09*	14.17*	11.38*	14.17*
	JMS 11A X JMBR 44	15.38*	12.50*	3.65*	8.87*
	CMS 52A X JR 67	13.68*	10.83*	13.68*	19.28*
	JMS 19A X JR 83	11.97*	9.17*	15.93*	16.96*
13	Kernel breadth (mm)				
	JMS 19A X JMBR 31	9.76	7.14	21.62*	21.62*
	JMS 19A X JR 67	4.88	2.38	16.22*	19.44*
	JMS 11A X JMBR 44	0.00	-2.38	7.89	18.84*
	CMS 52A X JR 83	0.00	-2.38	10.81	10.81*
	JMS 21A X JR 80	0.00	-2.38	7.89	10.81*
14	Kernel L/B ratio				
	CMS 52A X JR 80	31.70*	31.47*	10.10	19.75*
	CMS 64A X JR 80	30.65*	30.42*	5.07	7.11
	JMS 11A X JR 83	29.60*	29.37*	3.42*	7.95
	JMS 11A X JR 80	23.12*	22.90*	11.38*	-2.29
	CMS 52A X JR 67	22.90*	22.73*	13.68*	13.04*
15	Paddy length (mm)				
	JMS 11A X JMBR 44	14.36*	21.05*	1.97	5.08
	CMS 52A X JR 80	12.15*	18.71*	19.41*	19.76*
	CMS 52A X JMBR 44	9.94*	16.37*	4.19	10.25*
	CMS 64A X JR 85	8.84*	15.20*	-1.99	1.55
	JMS 11A X JR 80	8.84*	15.20*	-2.96	5.91
16	Paddy breadth (mm)				
	JMS 11A X JR 80	8.51*	-7.27*	8.51*	15.91*
	JMS 11A X JR 67	8.51*	-7.27*	13.33*	18.60*
	JMS 19A X JR 67	8.51*	-7.27*	13.33*	17.24*
	JMS 19A X JBR 6	8.51*	-7.27*	18.60*	20.00*
	JMS 21A X JMBR 44	8.51*	-7.27*	4.08	8.51*
17	Paddy L/B ratio				
	CMS 64A X JR 85	24.94*	54.66*	5.37	6.47
	CMS 52A X JR 80	22.73*	51.93*	-19.17*	24.92*
	CMS 64A X JR 83	22.34*	51.45*	5.37	10.24*
	JMS 11A X JMBR 44	19.61*	48.07*	-7.06	4.01
	CMS 64A X JR 80	11.43*	37.94*	-4.03	6.32

*Note : *Significant at p= 0.05, ** Significant at p= 0.01*

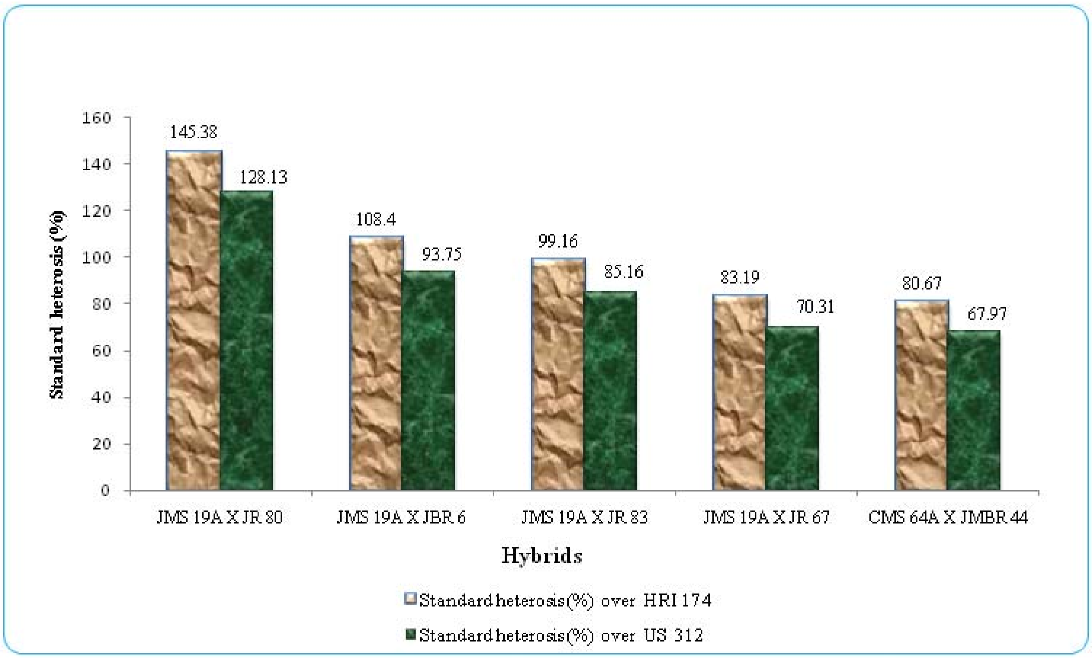
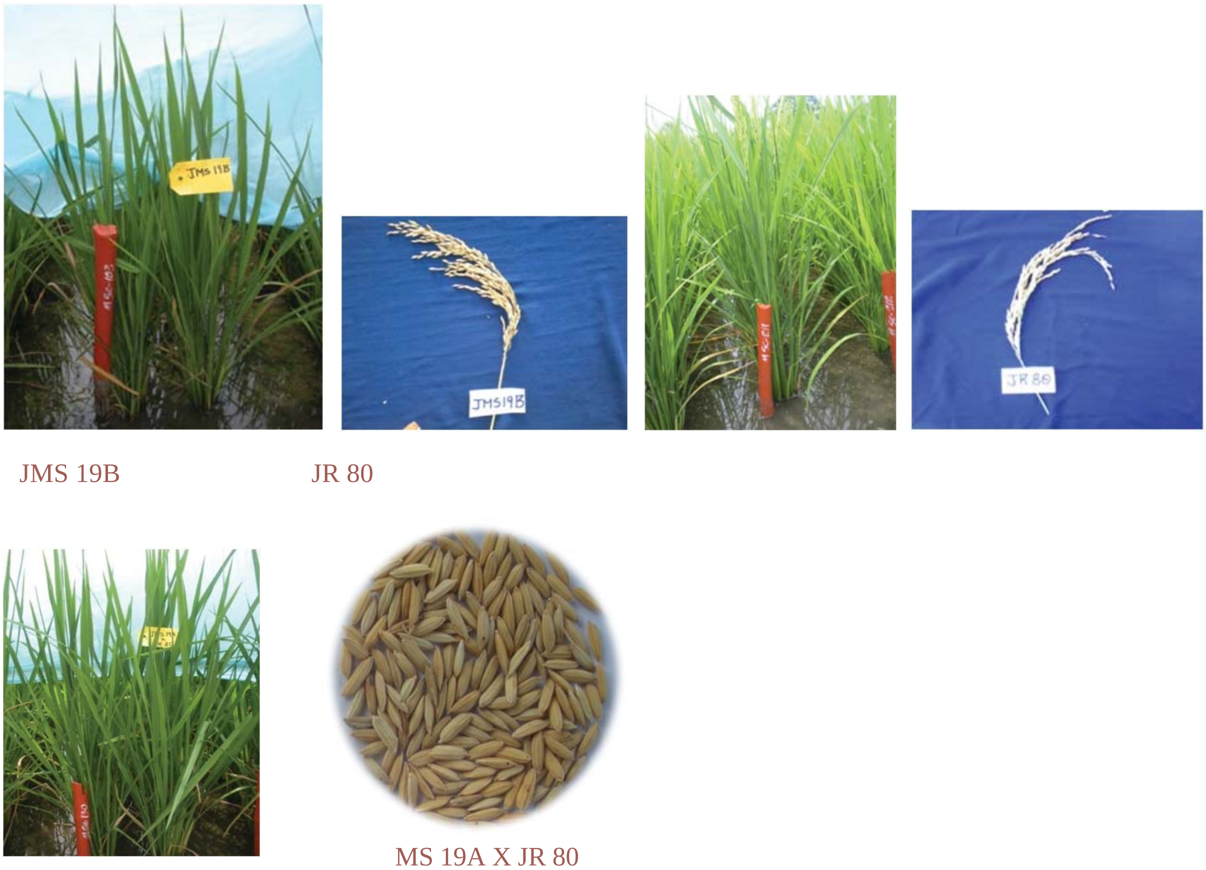


Fig. 1 : Top five hybrids identified based on standard heterosispercentage over checks HRI 174 and US 312 in the present investigation



JMS 19B JR 80

MS 19A X JR 80

Fig. 2 : Most promising experimental hybrid (JMS 19A X JR 80) and its parents identified in the present investigation based on overall performance.

be harvested, by increasing the number of grains per panicle. Hybrid JMS 19A X JBR 6 showed significant positive heterosis for number of grains per panicle over HRI 174 (50.32 %) and US 312 (47.48 %), whereas hybrid CMS 64A X JR 80 recorded high significant positive heterosis over better parent (61.94 %) and mid parent (67.05 %).A similar kind of heterotic pattern was observed by Rahimi *et al*. (2010) and Rama Krishna Prasad *et al*. (2019) who reported high heterotic effects for the number of grains per panicle.

Spikelet fertility percentage determines the reproducing ability of the cross and many hybrids recorded significant positive standard heterosis.The highest significant heterosis was recorded by the cross JMS 20A X JR 85 over checks HRI 174 (26.37 %) and US 312 (29.60 %). Maximum positive significant heterotic effects over better parent 22.44 % and mid parent 24.16 % was exhibited by the cross JMS 21A X JBR 6. Similar results have also been reported by Ranjith Raja Ram *et al.*(2019) and Gowayed Salah *et al.* (2020).

Grain yield per plant

Grain yield per plant is a multiplicative product of several basic components of yield. The improvement of yield by the exploitation of hybrid vigour in one or two characters may not reflect the direct increase of yield. However, increased grain yield is certainly the result of heterotic effect of a combination of characters.In the above crosses the superiority of hybrids in grain yield was through panicle length, number of grains per panicle, spikelet fertility and 1000- grain weight. The major reason for the high degree of heterosis was due to genetic divergence in the parents, though the predominance of dominant gene action was operating in the inheritance of the traits, as explained by Virmani *et al*. (1982).

Among 42 hybrids tested, 26 hybrids over HRI 174 and 15 hybrids over US 312 recorded significant positive standard heterosis for grain yield per plant (Table 1). The highest standard heterosis of 145.38 % was recorded in JMS 19A X JR 80 followed by JMS 19A X JBR 6 (108.40 %) and JMS 19A X JR 67 (83.19 %) over HRI 174 and by JMS 19A X JR 80 (128.13 %) followed by JMS 19A X JBR 6 (112.42 %) and JMS 19A X JR 67 (86.72 %) over US 312. Further, the hybrid JMS 19A X JR 80 exhibited the highest heterobeltiosis and relative heterosis of 180.77 % for grain yield per plant and identified as the best hybrid (Fig. 2).

Significant positive heterosis for grain yield per (g) have been reported by many researchers, some of them are Rama Krishna Prasad *et al.* (2019), ChuwangHijam and Singh (2019), Ranjith Raja Ram *et al.* (2019) and Gowayed Salah *et al.* (2020)

Physical quality traits

Hulling, milling and head rice recovery are the most important physical characters from the commercial point of view as it decides the amount of produce to be marketed.The highest standard heterosisof 4.94 % (over HRI 174) and 3.36 % (over US 312) and heterobeltiosis of 4.88 % were exploited in JMS 11A X JR 83 for hulling percentage.

The degree of milling is a measure of the per cent bran removed from the brown rice kernel. Milling degree affects milling recovery and influences consumer acceptance. Apart from the amount of white rice recovered, milling degree influences the colour and also the cooking behaviour of rice. The hybrid JMS 11A X JR 67registered significant positive standard heterosis, heterobeltiosis and relative heterosis for milling percentage.

“Head rice” or head rice percentage is the weight of head grain or whole kernels in the rice lot. Head rice normally includes broken kernels that are 75-80 per cent of the whole kernel. High head rice yield is one of the most important criteria for measuring milled rice quality.Hybrid JMS 11A X JBR 6 recorded high heterobeltiosis (25.13 %) and relative heterosis(27.95 %) for head rice recovery in a positive direction. The highest standard heterosis was observed in the cross JMS 11A X JR 67 over HRI 174 (21.40 %) and US 312 (16.06 %) for head rice recovery percentage.Satheesh Kumar *et al*. (2016) and Gonya Nayak *et al*. (2017), and ShamaParveen and Singh (2019) also reported significant positive heterosis for hulling percentage, milling percentage and head rice recovery in their studies.

Paddy length, paddy breadth, paddy L/B ratio, kernel length, kernel breadth and kernel L/B ratio are the important physical grain quality characters that determine the consumer’s preference of rice grain. Hybrid CMS 52A X JR 80 exhibited high positive standard heterosis, heterobeltiosis and relative heterosis for kernel length.For kernel breadth, high positive standard heterosis, heterobeltiosis and relative heterosis were recorded by JMS 19A X JMBR 31.The maximum heterobeltosis and relative heterosis of 19.41 and 19.76 per cent were manifested by CMS 52A X JR 80 for paddy length. The hybrid JMS 11A X JMBR 44 recorded maximum positive heterotic effect over HRI 174 (14.36 %) and US 312 (21.05 %) for paddy length.Out of 42 hybrids, five hybrids recorded significantly positive standard heterosis over HRI 174 (8.51%) and negative heterosis over US 312 (-7.27 %) for paddy breath, whereasthe hybrid JMS 19A X JBR 6 recorded highest heterobeltiosis and relative heterosis for this trait.

Grain size and shape (length-width ratio) is a varietal property. Long slender grains normally have greater breakage than short, bold grains and consequently have a lower milled rice recovery and higher value for L/B is desirable. For kernel L/B ratio maximum heterobeltiosis and relative heterosis of 13.68 and 13.04 per cent was registered in CMS 52A X JR 67. The hybrid CMS 52A X JR 80 recorded the highest significant and positive heterosis of 31.70 per cent (over HRI 174) and 31.47 per cent (over US 312) for this trait. For paddy L/B ratio hybrid CMS 64A X JR 85 recorded highest standardheterosis over HRI 174 (24.94 %) and US 312 (54.66 %), whereas hybrid CMS 52A X JR 80 recorded highest heterobeltiosis (19.17 %) and relative heterosis (24.92 %). These results are in accordance with findings of Satheesh Kumar *et al*. (2016) and Gonya Nayak *et al.* (2017), Shama Parveen and P.K. Singh (2019) and Ranjith Raja Ram *et al*. (2019).

In general, considerable heterosis, heterobeltiosis and standard heterosis observed for grain yield per plant and other associated characters suggested the presence of large genetic diversity among the testers, lines and crosses and also the unidirectional distribution of allelic constitution contributing towards desirable heterosis in the present material. The negative heterosis expressed by a number of crosses for characters such as days to 50 per cent flowering and plant height suggested that hybrids were superior to the parents for these traits and heterotic effects were in the desired direction. The crosses exhibiting good heterotic expression in F_1 may be further studied to isolate superior transgressivesegregants in later generations. The standard heterosis, heterobeltiosis and relative heterosis for the top five crosses for each trait are presented in table 2 and fig. 1.

A perusal of the top heterotic crosses revealed that none of the crosses was consistently superior for all the traits. Out of 42 crosses the hybrids JMS 19A X JR 80, JMS 19A X JBR 6, JMS 19A X JR 83, JMS 19A X JR 67 and CMS 64A X JMBR 44 were very promising and can be considered as elite crosses.Therefore, these hybrids are of considerable practical importance which was proved to be superior over popular commercial hybrid US 312 and HRI 174. Hybrids had significantly desired heterosis over the mid parent, better parent as well as checks for various traits and could be isolated for further evaluation at different locations and seasons.

REFERENCES

ChuwangHijam and Singh, N. B. 2019.Heterosis for grain yield and its important components in aromatic rice (*Oryzasativa* L.). *IJASR.*,**9**: 75-80.

Gokulakrishnan, J. 2018. Heterosis for yield and yield attributed traits in rice (*Oryza sativa* L.). *Hort. Biotec. Res.*,**4**: 26-29.

GonyaNayak, P., Sreedhar, M., SurenderRaju, Ch. and Vanisree, S. 2017. Heterosis and gene action studies involving aromatic lines for grain quality traits in rice. *IJLSCI.*,**4**: 517- 28.

Gowayed Salah, M.H., Abd El-MoneimDiaa., MetwaliEhab, M.R. and El-Malky Mohamed, M. Combining ability and heterosis studies for some economic traits in rice (*Oryzasativa* L.). *Res. J. Biotec*., 2020, **15**: 101-11.

Kempthorne, O. 1957.*An Introduction to Genetic Statistics*. John Wiley and Sons Inc., New York.

Krishna Veni, B. and Shobha Rani, N. 2003.Heterosis for yield and yield attributes in aromatic rice. *Madras Agric. J*., **90**: 10-12.

Kovi, M. R., Bai, X. F., Mao, D. H. and Xing, Y. Z. 2011.Impact of seasonal changes on spikelets per panicle, panicle length and plant height in rice (*Oryzasativa* L.).*Euphytica.*,**179**: 319-31. doi: 10.1007/s10681-0100332-7

Li, R., Li, M., Ashraf, U., Liu, S. and Zhang, J. 2019. Exploring the relationships between yield and yield-related traits for rice varieties released in China from 1978 to 2017. *Front. Pl. Sci.*,**10**:543. doi: 10.3389/fpls.2019.00543

Liang, G.H., Reddy, C.R. and Dayton, A.D. 1971. Heterosis, inbreeding depression and heritability estimates in a systematic series of grain sorghum genotypes. *CROP SCI.*, **12**: 400-11.

Rahimi, M., Rabiei, B.H., Samizadeh.and KafiGhasemi, A. 2010. Combining ability and heterosis in rice (*Oryzasativa*L.) cultivars. *JAST.*,**12**: 223-31.

Rama Krishna Prasad, K., Suneetha, Y. and Srinivas, T. 2019. Studies on heterosis and combining ability in rice (*Oryzasativa* L.).*International J. Agric. Sci*.,**15**: 60-66.

Ranjith Raja Ram, S., Anju, R. and Saravanan, K.R. 2019. Heterosis analysis for yield and yield component traits in rice (*Oryzasativa* L.).*J. Pharmacognosy and Phytochemistry*, **2**: 488-91.

Sahu, P.K., Deepak Singh., Satyapal.,Khute, I.K. and Sao, F.C. 2017. Heterotic expressions evaluation for grain yield and quality traits in cytoplasmic male sterility based rice hybrids. *Genetics.*,**9**: 257-62.

Samrath Bedi and Deepak Sharma. 2016. Heterosis studies in hybrid rice (*Oryzasativa*L.). *Int. J. Forestry and Crop Improve.*,**7**: 105-08.

Satheesh Kumar, P., Saravanan, K. and Sabesan, T. 2016. Studies on heterobeltiosis and standard heterosis for yield and yield component traits in rice (*Oryzasativa* L.) grown in irrigated saline low land of Tamilnadu, India. *Plant Archives.*,**16**: 642-46.

Shama Parveen and Singh, P.K. 2019. Exploitation of heterosis for quality traits in rice (*Oryzasativa* L.) using CMS system under upland conditions.*Int. J. Curr. Microbiol.App.Sci.*,**8**: 126-34

Thorat, B.S., Kunkerkar, R.L. and Bagkar, T.A. 2017. Studies on heterosis for yield and its contributing traits in hybrid rice (*Oryzasativa* L.). *International J. Chem. Stud*.,**5**: 07-12.

Virmani, S.S., Chaudhary, R.C. and Khush, G.S. 1982. Heterosis breeding in rice (*Oryzasativa* L.).*Theor. Appl. Genet*., **63**: 373-80.

Xie, Q., Mayes, S. and Sparkes, D. L. 2015. Carpel size, grain filling, and morphology determine individual grain weight in wheat. *J. Exp. Bot.***66**: 6715-30. doi:10.1093/jxb/erv378