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Identification of heterotic hybrids in rice (*Oryza sativa* L.)

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Abstract
The present study was carried out to investigate the extent of standard heterosis and to identify promising hybrids with high magnitude of heterosis for yield and yield contributing traits. 32 hybrids were developed involving 8 males and 4 females through line x tester mating design. In present investigation, efforts were made to know the nature and magnitude of heterosis in the form of standard heterosis for grain yield per plant and its component traits. Heterosis for grain yield plant^{-1} was manifested due to the significant and positive heterosis for its components *viz.*, number of productive tillers plant^{-1}, panicle length (cm), panicle weight (g), spikelet fertility (%), 1000 grain weight (g). The top three heterotic combinations identified for grain yield plant^{-1} were CMS 64A x WGL 14, CMS 59A x JGL 11118 and CMS 23A x IET 26264.

Keywords: Identification, heterotic hybrids, *Oryza sativa* L

Introduction
Rice (*Oryza sativa* L.) is the most important staple food crop for more than 60 per cent of the global population and forms the cheapest source of food energy and protein. In many countries, rice accounts for more than 70 per cent of human caloric intake and 20-25 per cent of agricultural income. It occupies more than 23 per cent of gross cropped area in India (44.2 Million Hectares) which is the largest in the world among all the rice growing countries. Annual production of rice in India is around 111.32 Mt with an average productivity of 2404 kg ha^{-1} (Indiastat, 2017) [2]. The productivity has become stagnated over past two decades with the existing inbred varieties. With the ever-growing population, there is a dire need to increase the rice productivity to obtain global food security. In plant breeding programme, exploitation of heterosis is vital and considered to be one of the greatest outstanding achievements. The F_1 hybrids can be exploited commercially and/or can be used for selection of promising recombinants in the subsequent generations to release the best variety through the attained homozygosity. To know the potentiality of hybrids, the magnitude and direction of heterosis are important (Singh *et al*., 1995) [11]. The magnitude of heterosis depends on the degree of genetic distinctiveness of the parental lines and their combining ability. Both positive and negative heterosis is useful for crop improvement, depending on objectives of the breeding.

Material and Methods
Experimental material for the present investigation comprised of four WA based cytoplasmic male sterile (CMS) lines and eight proven restorer lines which were crossed in line x tester mating design (Kempthorne, 1957) [3] to obtain 32 hybrids during *rabi*, 2016-17. These 32 hybrids along with four checks (2 varietal checks MTU 1001 & JGL 11470 and 2 hybrid checks US 312 and HRI 174) were evaluated in Randomized Block Design with two replications at Rice Research Centre, Agricultural Research Institute, PJTSAU, Hyderabad during *Kharif* 2017. Each genotype was planted in two rows of two meter length with a spacing of 20 x 15 cm. All the necessary recommended package of practices was followed to raise good crop. The data was recorded from average of five randomly selected plants from each replication for quantitative characters *viz.*, plant height, panicle length, number of productive tillers per plant, panicle weight, spikelet fertility (%) and grain yield per plant. However, days to 50 % flowering was recorded on whole plot basis and a random sample in each plot was used to record 1000 grain weight, hulling per cent, milling per cent, head rice recovery, kernel length, kernel breadth, kernel length- breadth ratio. To estimate the significant differences among hybrids and checks, the mean value of each character was subjected to Analysis of Variance.

Results and Discussion

The analysis of variance revealed that no significant differences were recorded for replications for all the traits. Further, the variability was partitioned into lines, testers and lines × testers. The lines were found significant for certain characters *viz.*, days to 50 per cent flowering, plant height, no. of productive tillers, panicle weight, 1000 grain weight, kernel breadth and length-breadth ratio whereas. Ramesh *et al*., (2017) [8] reported significance of the characters viz., plant height, grain length and grain breadth. The testers were significant for 1000 grain weight whereas Ramesh *et al*., (2017) [8] reported significance of all the characters except 1000 grain weight and grain length-breadth ratio; while the interaction between lines and testers were significant for all the traits except kernel breadth whereas Ramesh *et al*., (2017) [8] reported significance for all the characters. In present investigation, efforts were made to know the nature and magnitude of heterosis and in the form standard heterosis over all the checks for grain yield per plant and its component traits in 32 rice hybrids. However, data of Standard heterosis over best checks, MTU 1001 and US 312 only is discussed hereunder.

Earliness is being a desirable trait and helps to develop early hybrid. All hybrids recorded significant standard heterosis over standard checks in desired direction and two crosses CMS 23A x JGL 11118 and CMS23A x JGL 18047 were earliest and significantly different from checks which can be used for developing early maturing hybrids as observed by Saidaiah *et al.* (2012) [10] and Kumari Priyanka *et al.* (2014) [6] for other parents. For plant height, the heterosis ranged from -18.45 (CMS 23A x IET 26274) to 30.70 (CMS 23A x RNR 11450). Out of 32 hybrids, cross CMS 23A x IET 26274 showed significant negative estimate of relative heterosis over varietal check (-15.14) and over hybrid check (-24.24) and this cross can be used for breeding dwarf hybrid.

The crosses *viz*., CMS 64A x RNR 26060, JMS 13A x RNR 26060, CMS 23A x WGL 14 and CMS 59A x WGL 14 showed significant high standard heterosis over both the checks for panicle length and these cross combinations can be utilized for development of hybrids having longer panicle. Hybrids are generally characterized by having longer panicles, indicating their efficiency in partitioning assimilates into reproductive parts. This is one of the important attributes for higher yields in hybrids. Number of productive tillers per plant is known to directly contribute towards grain yield and can be exploited. More the number of productive tillers more will be the yield and vice versa. The standard heterosis over MTU 1001 ranged from -33.33 (CMS 64A x RNR 26060) to 19.30 (CMS 64A x WGL 14) and five hybrids showed significant positive standard heterosis. The range of standard heterosis over hybrid check US 312 varied from -23.73 (CMS 23A x RNR 26060) to 35.59 (CMS 64A x RNR 26060).

Panicle weight is positively associated with grain yield and is known to contribute grain yield *via* more number of filled grains. The standard heterosis over varietal check ranged from -32.16 (CMS 23 A x RNR 26060) to 29.82 (JMS 13A x RDR 1140) and four hybrids exhibited significant positive heterosis. Similarly, standard heterosis over hybrid check ranged from -25.69 (CMS 23 A x RNR 26060) to 42.20 (JMS 13A x RDR 1140) and eight hybrids recorded significant positive standard heterosis.

Significant positive standard heterosis for panicle weight was observed earlier by Krishna *et al*. (2011) [4], Dorosti and Monajjem (2014) [1] and Rukmini *et al.*, (2014) [9] for other variety. Test weight of a genotype serves as an indicator to the end product *i.e.*, grain yield. Cross, JMS 13A x IET 26264 (55.28) showed highest significant positive standard heterosis over the hybrid check, US 312 followed by CMS 64A x JGL 18047 (46.86) and CMS 64A x RNR 26060 (44.69).

Crosses, CMS 64A x WGL 14, CMS 59A x WGL 14, CMS 23A x IET 26264, CMS 59A x RNR 11450, CMS 64A x RNR 11450, JMS 13A x IET 26274 and CMS 59A x JGL 11118 showed significant positive estimates of standard heterosis over the hybrid check, US 312 for grain yield per plant indicate that these crosses may be utilized in developing high yield potential hybrids.

In rice, grain physical quality parameters like hulling per cent, milling per cent, head rice recovery (%), kernel length, kernel breadth and L/B ratio were also highly influence the performance of hybrids. The cross, CMS 59A x RNR 26060 exhibited the positive heterosis, heterobeltiosis and standard heterosis over varietal check MTU 1001 and hybrid check US 312 for hulling per cent, milling per cent, head rice recovery (%) and kernel length (Krishna *et al*. 2016) [4].

Slender grain type is most preferred. So, negative significant heterosis, heterobeltiosis and standard heterosis is desirable. For kernel breadth, significant high negative heterosis and negative heterobeltiosis with highest negative significant standard heterosis over varietal check MTU 1001 (-32.57) and hybrid check US 312 (-29.74) was JMS 13A x RNR 11450 (Panwar and Mashiat Ali, 2010) [7].

Table 1: Analysis of variance for 14 different characters of 32 hybrids, parents and standard checks in rice

Source of Variation	Replicates	Treatments	Parents	Lines	Testers	L x T	Crosses	Lines	Testers	L x T	Parents vs Crosses	Error	Total
Degrees of freedom	1	43	11	7	3	1	31	7	3	21	1	43	87
Days to 50% flowering	2.91	93.00**	59.01	90.29	3.46	6.75	72.72**	156.14*	79.64	43.93**	1095.38	1.05	46.52
Plant height	2.32	344.27**	259.38	368.02	66.83	76.51	382.38**	998.52**	310.48	187.28**	96.78	7.68	173.98
Panicle length	0.45	10.80**	6.75	8.98	3.03	2.25	11.11**	15.35	1.52	11.07**	45.62	1.04	5.85
No. of productive tillers per plant	0.27	7.02**	7.31	6.79	8.95	6.02	7.06**	14.61**	2.68	5.17**	2.82	1.76	4.34
Panicle weight	0.01	0.29**	0.15	0.09	0.23	0.37	0.29**	0.73**	0.04	0.18**	1.81	0.03	0.16
Spikelet fertility (%)	2.42	76.76**	46.41	52.42	31.75	48.3	79.68**	92.82	32.15	82.09**	320.11	1.09	38.51
1000-grain weight (g)	0.03	18.17**	22	25.76	19.97	1.75	17.37**	37.35**	34.83*	8.21**	0.91	0.87	9.41
Hulling	2.53	10.77**	3.87	1.6	10.14	0.9	13.48**	22.89	6.26	11.38**	2.77	1.87	6.28
Milling	0.33	12.30**	11.73	2.1	32.64	16.4	12.85**	22.14	6.67	10.63**	1.79	4.33	8.23
Head rice recovery	2.54	15.68**	7.49	2.19	5.61	50.25	16.98**	15.3	2.89	19.56**	65.46	4.88	10.19
Kernel length (mm)	0	0.53**	0.59	0.66	0.61	0.04	0.48**	0.6	0.73	0.41**	1.41	0.07	0.3
Kernel breadth	0	0.03**	0.04	0.05	0.01	0.15	0.03**	0.08**	0.02	0.01	0.12	0.01	0.02
L/B ratio	0.01	0.19**	0.28	0.33	0.11	0.41	0.13**	0.24*	0.07	0.10*	1.13	0.04	0.11
Grain yield per plant (g)	4.18	169.33**	44.42	53.24	21.22	52.25	178.03**	279.89	95.83	155.82**	1273.67	10.94	89.15

** Significant at 1% level of significance; * Significant at 5 % level of significance

Table 2: Estimates of standard heterosis (over varietal check MTU 1001 and hybrid check US 312) for Days to 50 % flowering, Plant height (cm), Panicle length (cm), Number of productive tillers/plant and Panicle weight (g)

	Days to 50 % flowering		Plant height (cm)		Panicle length (cm)		Number of productive tillers/plant		Panicle weight (g)	
	MTU 1001	US 312	MTU 1001	US 312	MTU 1001	US 312	MTU1001	US 312	MTU 1001	US 312
CMS 23A x RNR 26060	-10.58**	-19.14**	11.24**	-0.7	6.19	4.04	-21.05*	-23.73*	-32.16**	-25.69**
CMS 59A x RNR 26060	-7.41**	-16.27**	19.27**	6.47**	20.21**	17.78**	-29.82**	32.20**	-9.88	-1.28
CMS 64A x RNR 26060	-7.94**	-16.75**	24.31**	10.97**	27.22**	24.65**	-33.33**	35.59**	-9.72	-1.1
JMS 13A x RNR 26060	-5.29**	-14.35**	3.62	-7.49**	21.65**	19.19**	-7.02	-10.17	4.69	14.68*
CMS 23A x WGL 14	2.12	-7.66**	-5.05	-15.23**	3.09	1.01	-8.77	-11.86	-5.86	3.12
CMS 59A x WGL 14	0.53	-9.09**	11.93**	-0.08	5.15	3.03	-1.75	-5.08	-2.01	7.34
CMS 64A x WGL 14	3.17**	-6.70**	0.46	-10.32**	7.22	5.05	19.30*	15.25	13.57*	24.40*
JMS 13A x WGL 14	-14.81**	-22.97**	-10.32**	-19.94**	9.28*	7.07	-8.77	-11.86	0.17	9.72
CMS 23A x JGL 18047	-17.46**	-25.36**	-5.50*	-15.64**	12.37**	10.1	-14.04	-16.95	-6.03	2.94
CMS 59A x JGL 18047	-14.29**	-22.49**	-1.38	-11.96**	9.28*	7.07	-19.30*	-22.03*	-8.71	0
CMS 64A x JGL 18047	-14.29**	-22.49**	-6.65*	-16.67**	1.03	-1.01	-26.32**	28.81**	-14.24*	-6.06
JMS 13A x JGL 18047	-12.70**	-21.05**	-4.17	-14.46**	16.49**	14.14**	-12.28	-15.25	-15.24*	-7.16
CMS 23A x JGL 11118	-20.11**	-27.75**	-12.84**	-22.19*	3.09	1.01	-26.32**	28.81**	-20.94**	-13.39
CMS 59A x JGL 11118	-11.11**	-19.62**	16.28**	3.81	26.80**	24.24**	-19.30*	-22.03*	-14.24*	-6.06
CMS 64A x JGL 11118	-15.87**	-23.92**	8.94**	-2.74	19.59**	17.17**	-8.77	-11.86	0	9.54
JMS 13A x JGL 11118	-6.88**	-15.79**	2.98	-8.07**	8.25	6.06	-12.28	-15.25	-10.22	-1.65
CMS 23A x RDR 1140	-12.17**	-20.57**	8.67**	-2.99	17.53**	15.15**	-8.77	-11.86	11.73	22.39**
CMS 59A x RDR 1140	-8.47**	-17.22**	-2.98	-13.39**	1.03	-1.01	-17.54	-20.34*	26.97**	39.08**
CMS 64A x RDR 1140	-12.70**	-21.05**	-5.50*	-15.64**	-1.03	-3.03	-12.28	-15.25	4.19	14.13*
JMS 13A x RDR 1140	-9.52**	-18.18**	11.70**	-0.29	3.09	1.01	-12.28	-15.25	29.82**	42.20**
CMS 23A x RNR 11450	-13.23**	-21.53**	25.00**	11.59**	23.30**	20.81**	14.04	10.17	16.58*	27.71**
CMS 59A x RNR 11450	-1.06	-10.53**	14.22**	1.97	5.57	3.43	15.79	11.86	-8.04	0.73

CMS 64A x RNR 11450	-3.17**	-12.44**	22.02**	8.93**	4.33	2.22	3.51	0	-2.35	6.97
JMS 13A x RNR 11450	0.53	-9.09**	15.60**	3.19	21.86**	19.39**	-17.54	-20.34*	-2.01	7.34
CMS 23A x IET 26264	-6.35**	-15.31**	26.61**	13.02**	23.51**	21.01**	4.21	0.68	0	9.54
CMS 59A x IET 26264	-1.06	-10.53**	29.36**	15.48**	26.60**	24.04**	-12.28	-15.25	-0.34	9.17
CMS 64A x IET 26264	-3.17**	-12.44**	29.36**	15.48**	26.60**	24.04**	-8.77	-11.86	-0.34	9.17
JMS 13A x IET 26264	-2.12	-11.48**	3.94	-7.21**	-5.57	-7.47	2.46	-1.02	-4.19	4.65
CMS 23A x IET 26274	-14.29**	-22.49**	-15.14**	-24.24**	7.22	5.05	-15.79	-18.64*	5.19	15.23*
CMS 59A x IET 26274	-13.76**	-22.01**	8.26**	-3.36	4.12	2.02	-31.58**	33.90**	-15.91*	-7.89
CMS 64A x IET 26274	-1.06	-10.53**	-2.98	-13.39**	5.15	3.03	5.26	1.69	-8.71	0
JMS 13A x IET 26274	-1.06	-10.53**	-2.75	-8.27**	1.03	-1.01	-14.04	-16.95	-8.21	0.55

Table 2: Estimates of standard heterosis (over varietal check MTU 1001 and hybrid check US 312) for Spikelet fertility (%), 1000 grain weight (g), Hulling per cent, Milling per cent and Head rice recovery (HRR) %

	Spikelet fertility (%)		1000 grain weight (g)		Hulling per cent		Milling per cent		Head rice recovery (HRR) %	
	MTU 1001	**US 312**	**MTU 1001**	**US 312**	**MTU1001**	**US 312**	**MTU 1001**	**US 312**	**MTU 1001**	**US 312**
CMS 23A x RNR 26060	4.92**	10.30**	-16.38**	30.25**	-2.03	-0.48	-2.39	-1.79	-2.63	-8.20*
CMS 59A x RNR 26060	3.42*	8.72	-10.44**	39.51**	-0.96	0.61	0.6	1.21	6.21	0.13
CMS 64A x RNR 26060	8.12**	13.66*	-7.11	44.69**	-1.67	-0.11	0.45	1.06	1.35	-4.46
JMS 13A x RNR 26060	14.24**	20.10**	-18.43**	27.05**	-1.25	0.32	-0.12	0.48	-2.55	-8.13*
CMS 23A x WGL 14	2.57*	7.83**	-21.49**	22.29**	-0.91	0.66	0.14	0.75	4.75	-1.25
CMS 59A x WGL 14	9.90**	15.53**	-11.54**	37.79**	-0.32	1.26	0.81	1.42	1.99	-3.84
CMS 64A x WGL 14	2.36	7.61**	-11.54**	37.79**	-14.20**	-12.84**	-10.25**	-9.71**	-15.68**	-20.51**
JMS 13A x WGL 14	-7.44**	-2.69*	-39.79**	-6.21	-4.81**	-3.3	-4.06	-3.48	-4.41	-9.88**
CMS 23A x JGL 18047	-9.20**	-4.54**	-17.27**	28.86**	1.47	3.08	-0.03	0.58	-3.28	-8.81*
CMS 59A x JGL 18047	6.13**	11.57**	-11.13**	38.42**	-0.65	0.93	-0.7	-0.09	-4.01	-9.50**
CMS 64A x JGL 18047	-4.66**	0.23	-5.71	46.86**	-3.11	-1.58	-0.63	-0.02	-0.36	-6.06
JMS 13A x JGL 18047	-5.89**	-1.07	-23.78**	18.73**	-2.08	-0.52	-1.8	-1.21	-8.06*	-13.32**
CMS 23A x JGL 11118	-2.41	2.6	-19.54**	25.33**	-1.34	0.22	-0.45	0.16	-1.23	-6.89*
CMS 59A x JGL 11118	-9.85**	-5.23**	-29.89**	9.2	1.19	2.8	0.69	1.3	-4.15	-9.64**
CMS 64A x JGL 11118	7.05**	12.54**	-29.76**	9.41	1.55	3.16	2.36	2.99	6.53	0.44
JMS 13A x JGL 11118	-5.75**	-0.92	-40.85**	-7.87	4.64*	6.30**	7.28*	7.93*	1.02	-4.76
CMS 23A x RDR 1140	-6.99**	-2.22	-3.58	-7.87	-2.12	-0.57	-4.32	-3.74	-9.52*	-14.70**
CMS 59A x RDR 1140	-3.90**	1.03	-11.66**	37.61**	-1.08	0.49	-0.12	0.48	-2.3	-7.90*
CMS 64A x RDR 1140	-10.45**	-5.86**	-29.29**	10.13	1.93	3.54*	1.51	2.13	-1.13	-6.79
JMS 13A x RDR 1140	3.01*	8.30**	-27.18**	13.42*	0.29	1.88	2.25	2.87	3.94	-2.01
CMS 23A x RNR 11450	2.21	7.46**	-33.20**	4.04	1.96	3.58*	8.36**	9.01**	2.68	-3.2
CMS 59A x RNR 11450	-5.45**	-0.6	-22.81**	20.24**	0.51	2.1	1.75	2.36	-1.28	-6.93*
CMS 64A x RNR 11450	7.29**	12.79**	-18.61**	26.78**	1.22	2.82	3.54	4.17	4.43	-1.55
JMS 13A x RNR 11450	-21.06**	-17.01**	-41.53**	-8.93	1.54	3.15	4.12	4.75	-1.29	-6.94*
CMS 23A x IET 26264	-7.03**	-2.26	-15.39**	31.79**	-0.92	0.65	1.89	2.51	0.78	-4.99
CMS 59A x IET 26264	-2.4	2.61	-9.58*	40.83**	0.41	2	0.24	0.85	-0.92	-6.6
CMS 64A x IET 26264	-2.4	2.61	-9.58*	40.83**	0.41	2	0.24	0.85	-0.92	-6.6
JMS 13A x IET 26264	8.69**	14.26**	-0.31	55.28**	-0.25	1.33	1.85	2.47	-0.36	-6.06
CMS 23A x IET 26274	-8.26**	-3.56*	-23.35**	19.39**	-4.25*	-2.73	-5.44	-4.87	-3.03	-8.58*
CMS 59A x IET 26274	-0.36	4.75**	-26.72**	14.14*	1.28	2.89	4.07	4.7	5.48	-0.56
CMS 64A x IET 26274	0.86	6.03**	-29.43**	9.92	2.52	4.15*	4.79	5.42	2.89	-3
JMS 13A x IET 26274	5.30**	10.70**	-40.35**	-7.09	3.08	4.72*	5.48	6.12	3.7	-2.24

Table 2: Estimates of standard heterosis (over varietal check MTU 1001 and hybrid check US 312) for Kernel length (mm), Kernel breadth (mm), Kernel Length-breadth ratio (L/B) and Grain yield per plant (g)

	Kernel length (mm)		**Kernel breadth (mm)**		**Kernel Length-breadth ratio (L/B)**		**Grain yield per plant (g)**	
	MTU 1001	**US 312**	**MTU 1001**	**US 312**	**MTU 1001**	**US 312**	**MTU 1001**	**US 312**
CMS 23A x RNR 26060	5.49	13.46**	-22.99 **	-19.76 **	36.96 **	41.57 **	-42.95**	-52.72**
CMS 59A x RNR 26060	-0.14	7.4	-20.50 **	-17.17 **	25.91 **	30.15 **	-15.08	-29.62**
CMS 64A x RNR 26060	3.89	11.74**	-20.31 **	-16.97 **	30.43 **	34.83 **	-8.36	-24.05*
JMS 13A x RNR 26060	-3.2	4.11	-20.11 **	-16.77 **	21.01 **	25.09 **	9.84	-8.97
CMS 23A x WGL 14	0.07	7.63	-19.73 **	-16.37 **	24.64 **	28.84 **	27.87*	5.98
CMS 59A x WGL 14	1.25	8.90 *	-22.22 **	-18.96 **	29.89 **	34.27 **	86.89**	54.89**
CMS 64A x WGL 14	-5.15	2.02	-25.29 **	-22.16 **	26.63 **	30.90 **	57.38**	30.43**
JMS 13A x WGL 14	0.7	8.30 *	-27.01 **	-23.95 **	37.68 **	42.32 **	-40.49**	-50.68**
CMS 23A x JGL 18047	-2.57	4.79	-23.75 **	-20.56 **	27.90 **	32.21 **	36.72**	13.32
CMS 59A x JGL 18047	-7.3	-0.3	-25.10 **	-21.96 **	23.55 **	27.72 **	19.67	-0.82
CMS 64A x JGL 18047	-6.95	0.07	-23.75 **	-20.56 **	22.28 **	26.40 **	12.46	-6.79
JMS 13A x JGL 18047	-3.41	3.89	-21.65 **	-18.36 **	23.01 **	27.15 **	-1.31	-18.21
CMS 23A x JGL 11118	-2.5	4.86	-22.03 **	-18.76 **	25.00 **	29.21 **	4.16	-13.67
CMS 59A x JGL 11118	-11.96 **	-5.31	-21.07 **	-17.76 **	11.23	14.98 *	45.08**	20.24*
CMS 64A x JGL 11118	-2.99	4.34	-28.35 **	-25.35 **	34.96 **	39.51 **	21.64	0.82
JMS 13A x JGL 11118	-11.40 **	-4.71	-24.52 **	-21.36 **	16.85 *	20.79 **	6.56	-11.68
CMS 23A x RDR 1140	-8.21 *	-1.27	-25.86 **	-22.75 **	23.55 **	27.72 **	0.41	-16.78
CMS 59A x RDR 1140	-2.71	4.64	-25.67 **	-22.55 **	30.62 **	35.02 **	-0.1	-17.2
CMS 64A x RDR 1140	-17.80 **	11.59**	-25.67 **	-22.55 **	10.87	14.61	35.57**	12.36
JMS 13A x RDR 1140	-3.89	3.37	-25.48 **	-22.36 **	28.80 **	33.15 **	12.54	-6.73
CMS 23A x RNR 11450	-12.66 **	-6.06	-27.78 **	-24.75 **	20.83 **	24.91 **	36.07**	12.77
CMS 59A x RNR 11450	-0.14	7.4	-24.14 **	-20.96 **	31.34 **	35.77 **	50.33**	24.59*
CMS 64A x RNR 11450	-2.5	4.86	-27.20 **	-24.15 **	33.88 **	38.39 **	47.54**	22.28*
JMS 13A x RNR 11450	-24.06 **	18.32**	-32.57 **	-29.74 **	12.5	16.29 *	6.39	-11.82
CMS 23A x IET 26264	-12.31 **	-5.68	-12.26 **	-8.58	-0.18	3.18	76.89*	46.60**
CMS 59A x IET 26264	-1.18	6.28	-16.09 **	-12.57 **	17.57 *	21.54 **	35.57**	12.36
CMS 64A x IET 26264	-1.18	6.28	-16.09 **	-12.57 **	17.57 *	21.54 **	35.57**	12.36
JMS 13A x IET 26264	-12.45 **	-5.83	-17.43 **	-13.97 **	6.16	9.74	39.34**	15.49
CMS 23A x IET 26274	2.71	10.47 *	-22.80 **	-19.56 **	32.61 **	37.08 **	-19.34	-33.15**
CMS 59A x IET 26274	1.25	8.90 *	-25.29 **	-22.16 **	35.14 **	39.70 **	-31.15**	-42.93**
CMS 64A x IET 26274	-6.05	1.05	-28.54 **	-25.55 **	31.16 **	35.58 **	16.72	-3.26
JMS 13A x IET 26274	-17.25 **	10.99**	-31.23 **	-28.34 **	20.11 **	24.16 **	45.90**	20.92*

Conclusion

The above results concluded that out of 32 hybrids three hybrids showed desirable performance for certain yield related characters when compared over standard checks. In practical breeding programme, standard heterosis would alone be taken into consideration rather than mid and better parent heterosis for selection of hybrids. Hybrid CMS 64A x WGL 14 showed early in maturity, dwarf stature and finer grain type and also showed significant positive standard heterosis (over hybrid check, US 312) for panicle weight, spikelet fertility (%) and 1000 grain weight. Hybrid CMS 59A x JGL 11118 showed significant negative standard heterosis (over US 312 and MTU 1001) for days to 50 % flowering and grain breadth and significant positive standard heterosis (over US 312 and MTU 1001) for panicle length and number of productive tillers per plant (over MTU 1001). Hybrid CMS 23A x IET 26264 recorded significant negative standard heterosis (over US 312 and MTU 1001) for days to 50 % flowering and grain breadth. This hybrid also showed significant positive standard heterosis for panicle length and number of productive tillers per plant over US 312 and MTU 1001. So, these crosses can be utilized for the development of hybrids with the excellent grain physical quality parameters.

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