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Study on Standard Heterosis for Yield, Quality and its Attributing Characters in Rice (*Oryza sativa* L.) Hybrids under Aerobic Cultivation

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Authors' contributions

"This work was carried out in collaboration between all authors. Authors PM and CSR designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors PS and SV managed the analyses of the study. Authors SNR and MSM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Field experiments were conducted for development and evaluation of aerobic rice hybrids during2015-16 to 2016-17 years. In the first experiment sufficient amount of variability was observed for grain yield per plant and its components among 125 genotypes evaluated in aerobic condition. Among these eight genotypes were the top ranking yield in aerobic conditions and good restorers tested by Test Cross Nursery and *Rf3, Rf4* fertility restorer gene screening. Than 32

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hybrids were produced involving 4 CMS lines (CMS23A, CMS59A, CMS64A and IR68897A) and 8 testers (SVHR-3005, NH-12-103R, KMP-128, MTU-1001, KMP-175, SV-315-081R, RNR-21280 and MTU-1075) and evaluated along with three checks (*viz.,* hybrid check, KRH-2, inbred checks, MTU-1010, MAS-946) under aerobic situation and carryout standard heterosis analysis, to identify best heterotic hybrids over local checks. CMS23A x SV-315-081R manifested high heterotic effects (>20%) for grain yield per plant over the standard checks, besides for important components. Few more CMS59A x KMP-175, CMS59A x RNR-21280, CMS23A x MTU-1001, IR-68897A x MTU-1075 and CMS23A x MTU-1075 were also identified as potential hybrids in view of higher amount of heterosis. For quality, CMS64A x RNR-21280 (hulling percentage, milling percentage, head rice recovery and kernel elongation ratio) and CMS23A x SV-315-081R (head rice recovery, kernel length, L/B ratio and Kernel length after cooking) were best heterotic hybrids. Two crosses *viz.,* CMS59A x SVHR-3005 and CMS64A x SVHR-3005 expressed negative heterosis for kernel breadth and positive heterosis for kernel L/B ratio which was desirable.

Keywords: Rice; aerobic; hybrids; heterosis; checks.

1. INTRODUCTION

"Aerobic rice" is a new concept of growing rice. It is a production system in which specially developed, high input response rice varieties with "aerobic adaptation" are grown in well-drained, non-puddled, and without ponded water. It holds promise for farmers in water-scarce irrigated environments or where water is too expensive to grow flooded lowland rice. To make aerobic rice more profitable, new varieties in the high yield potential and high input use efficiency and corresponding better management practices need to be developed.

This Telangana state rice is the principal food crop grown in 16.0 L.ha. under irrigation ecosystem with an average productivity of 3.24 t/ha. (milled rice). More than 50% of the water resources from wells, tanks and project canals are diverted for this crop at the cost of other crops and requirements. In addition to this, labour scarcity is becoming a major threat to rice cultivation and in coming 5-10 years total rice cultivation has to be mechanized. At this juncture, innovative technologies are required to use the water most economically without yield sacrifice. This system of rice cultivation would be more successful in the state, provided location specific high yield potential hybrids with acceptable cooking quality are developed and it is need of the day too.

In certain areas, where medium soils with good fertility are available farmers resorted to growing rice purely as aerobic crop especially with MTU-1010 and MTU-1001 varieties, due to labour and water scarcity. Seed is drilled in rows and maintained as irrigated dry crop throughout season avoiding puddling and transplanting and saving on labour cost up to Rs. 5000 – 5500 per hectare. Hence, there is lot of scope for aerobic rice in this state, provided potential inbred/hybrid varieties with good management practices are made available to the farmers.

Keeping in view of the above aspects, the present research was carried out in four steps to develop and identify heterotic hybrids suitable for aerobic conditions based on yield components. Data on quality parameters were also generated, as the success of hybrid rice technology largely depends on this aspect especially, milling recovery and cooking qualities.

2. MATERIALS AND METHODS

The present work was conducted to pick up the promising cultures in aerobic rice in the 1st step (evaluation of 125 genotypes under aerobic system –*Kharif, 2015*), to identify restorers and maintainers in the 2nd step (Test cross nursery and molecular screening to identify *Rf3, Rf4* fertility restorer genes –*Rabi, 2015/16*) and to study the standard heterosis for development of heterotic hybrids suitable for aerobic rice cultivation with the background of wild abortive (WA) cytoplasmic male sterile lines in the last step (*Kharif*-2016).

Based on the restorer/ maintainer reaction and spikelet fertility (%), seed of 32 hybrids (4 Lines x 8 testers) and 12 parents (Eight 'R' lines and Four 'B' lines of corresponding male sterile lines), were sown in sandy loam type of soil type under aerobic situation during *kharif*, 2016 along with 3checks at Rice Research Centre, Rajendranagar Hyderabad, Telangana state in India. In *Kharif 2016*, received 839.2mm rainfall,

Table 1. List of male sterile lines, effective restorers and checks used in the study

S. No.	Genotypes	Characters
		CMS Lines
1	CMS-23A	WA cytoplasm, LB & very early duration CMS
2	CMS-59A	WA cytoplasm, LS & mid early duration CMS
3	CMS-64A	WA cytoplasm, LS & mid early duration CMS
4	IR-68897A	WA cytoplasm, LS & early duration CMS
		Restorer lines
1	MTU-1001	MB, good plant type, wider adaptability
2	SV-315-081R	Early, MS grain type.
3	RNR-21280	Mid early
4	NH12-103R	Mid early
5	SVHR-3005	Mid early
6	KMP-175	MS, Water saving up to 60%, seed saving
7	MTU-1075	150 days duration, non-shattering, resistant to BPH
8	KMP-128	Drought resistant
		Checks
1	MTU-1010	Semi dwarf, medium tillering, LS, erect
2	KRH-2	Medium duration hybrid, LS grain

in 64 rainy days from June, 2016 to October, 2016 (crop duration) along with 6 irrigations were given through surface irrigation method during crop duration when cracks appeared in the soil. Recommended dose of fertilizer for hybrids at 150:50:40 kg NPK/ha was applied in aerobic cultivation. The list of male sterile lines, restorers and checks used in the study is given in Table 1.

Crossed seeds of hybrids were treated with Carbendazim solution (0.1%) and got them germinated in petridishes at Rice Research Centre, Rajendranagar Hyderabad, Telangana state in India. Sprouted seeds were sown under aerobic situation and irrigated immediately. The F_1 seeds of all 32 crosses of rice were directly sown in the field under moisture scarce aerobic situation during *Kharif,* 2016 season. The crop was grown under aerobic condition non-transplanted and directly sown. The field was kept at field capacity. Irrigation was given at 2cm depth twice a week at 4 days interval depending on weather condition. A total of 480-500mm of irrigation was provided.

A completely randomized block design with three replications was followed. Top dressing was given with urea and need based plant protection measures were undertaken for raising healthy seedlings. Each entry was planted in 2 rows of 4 m length with a spacing of 20 x 15 cm and all the recommended package of practices were followed to raise a healthy crop under aerobic system three to four hybrid seeds were dibbed initially and later thinned to one seedling per hill after establishment.

3. RESULTS AND DISCUSSION

3.1 Study of Means

Analysis of Variance revealed significant differences among the genotypes for yield and yield components *viz.*, days to 50 per cent flowering, plant height, number of productive tillers per plant, panicle length, total number of grains per panicle, number of filled grains per panicle, spikelet fertility, 1000 grain weight and grain yield per plant. Hence there was high amount of genetic variation (Table 2).

The mean data on grain quality parameters *viz.,* hulling (%), milling (%), head rice recovery (%), kernel length(L), kernel breadth (B), kernel L/B ratio and kernel length after cooking and kernel elongation ratio were collected and analyzed. Analysis of variance showed significant difference among the treatments (parents and crosses) for all the characters studied (Table 3). These results suggest that both parents and hybrids exhibited high amount of genetic variation for the yield and quality characters studied.

3.2 Study of Heterosis

Standard heterosis (diii) is the superior performance as desirable over the commercial varieties/hybrid check (MTU-1010, KRH-2 and MAS-946) respectively was estimated in 32 hybrids for nine characters (*viz.*, days to 50% flowering, plant height, number of productive tillers per plant, panicle length, total number of grains per panicle, number of filled grains per panicle, spikelet fertility (%), 1000 grain weight and grain yield per plant) are presented character-wise. The negative heterosis for days to 50% flowering and plant height indicates earliness and short stature respectively which are desirable, while for other characters positive heterotic values were considered as desirable. Heterosis breeding was also attempted in aerobic rice improvement programme. Heterosis is the increased growth vigour of hybrid over parents. This vigour will tends to decrease in F_2 generation onwards. So, F_1 are used as varieties, particularly known as hybrids. An experiment was undertaken to identify heterotic rice hybrids for aerobic condition based on yield and its attributing characters.

3.2.1 Yield and its attributting characters

Grain yield is a complex quantitative character controlled by many genes interacting with the environment and is the product of many factors called yield components. Selection of parents based on yield alone often misleading. Hence, the knowledge about relationship between yield and its contributing characters is needed for an efficient selection strategy for development of high yielding variety. For the trait grain yield per plant eight crosses exhibited significant positive standard heterosis over MTU-1010 and KRH-2 ranging from 15.73 (CMS64A x SV-315-081R) to 59.75 per cent (CMS23A x SV-315-081R). Only three hybrids showed significant positive standard heterosis over check MAS-946 i.e. CMS23A x SV-315-081R (35.29%), CMS59A x RNR-21280 (20.14%) and CMA59A x KMP-175 (16.99%) (Table 4). Both positive and negative heterosis over standard check reported by [1,2,3,4,5,6,7].

The hybrids CMS23A x SV-315-081R, CMS59A x RNR-21280 and CMA59A x KMP-175 registered highly significant positive standard heterosis over all three standard checks. Based on *per se* performance and positive SCAeffects six superior combinations for grain yield were identified, they are CMS23A x SV-315-081R, CMS59A x KMP-175, CMS59A x RNR-21280, CMS23A x MTU-1001, IR-68897A x MTU-1075, CMS23A x MTU-1075.

These hybrids also excellent in mean performance, SCA effects and heterosis for important yield deciding traits like number of productive tillers per plant, panicle length, number of filled grains per panicle and test weight (Table 4). This also indicated that these yield attributes played greater role in expression of high heterosis for grain yield per plant ultimately. [8] Also observed that the crosses involving lines with, IR68897A, CMS-23A and CMS-59A found to be superior for grain yield per plant. Hence these lines could be utilized for future breeding programmes. Promising hybrids which exhibited high mean, SCA effects and standard heterosis for grain yield.

In the comparison of GCA and SCA variances, the ratio of GCA to SCA variance in pooled analysis was less than unity indicating predominant role of non-additive gene action for all the characters studied except for days to 50% flowering, plant height. The predominance of non-additive gene action which includes both dominance and epistasis implied the feasibility of exploiting heterosis in rice. [9,10] Also were of opinion that much attention is required for the hybrids with significant positive SCA effects and high *per se* as non additive and epistatic gene effects would be made use in effective way.

3.2.2 Quality characters

Similarly with respect to the grain quality traits, efforts were made to estimate the nature and magnitude of heterosis in the form of standard heterosis for eight quality characters *viz.,* hulling (%), milling (%), head rice recovery (%), kernel length, kernel breadth, kernel L/B ratio, kernel length after cooking and kernel elongation ratio over varietal checks MTU-1010, BPT-5204 and hybrid check DRRH-3. The results were presented in the Table 4.

The cross CMS64A x RNR-21280 exhibited considerable amount of heterosis over standard checks for hulling percentage, milling percentage, head rice recovery and kernel elongation ratio. Significant standard heterosis was found in the hybrid, CMS23A x SV-315-081R for head rice recovery, kernel length, L/B ratio and Kernel length after cooking. The crosses CMS59A x SVHR-3005 and CMS64A x SVHR-3005 showed highly significant negative heterosis for kernel breadth and positive heterosis for kernel L/B ratio. Earlier researchers, [5,10,11] reported positive heterosis for kernel L/B ratio and [12,13,14] observed negative heterosis kernel breadth. These cross combinations could be utilized for exploitation of hybrid vigour for grain quality improvement in rice.

Table 2. Analysis of variance for yield and yield components

	DF	Days to 50% flowering	Plant Height (cm)	Panicle Length (cm)	Productive tillers	Total Grains/ Panicle	Filled Grains/ Panicle	Spikelet Fertility (%)	1000 Seed weight (gr)	Seed Yield (gr)
Replications	2	15.347	67.932 *	9.288 *	0.307	87.079	69.880	2.035	0.170	9.936
Treatments	46	411.422**	200.735 **	12.472 **	5.795 **	4028.251 **	2249.886 **	107.561 **	25.818 **	76.342**
Error	92	12.790	12.329	1.681	0.489	242.395	146.665	11.925	1.617	3.780
Total	140	143.805		5.335	2.229	1484.100	836.627	43.207	9.548	27.709

**Significant at 5%level, **Significant at 1%level*

Table 3. Analysis of variance for grain quality traits

	DF	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length	Kernel breadth	Kernel L/B ratio	Kernel length after cooking	Kernel elongation ratio
Replications	2	14.199**	14.581 **	8.178	0.003	0.000	0.003	0.057	0.002
Treatments	46	12.019 **	25.078 **	123.729 **	1.189 **	0.115 **	0.337 **	3.164 **	0.217 **
Error	92	1.538	2.402	6.547	0.032	0.005	0.019	0.060	0.006
Total	140	5.163	10.027	45.073	0.412	0.041	0.123	1.080	0.076

**Significant at 5%level, **Significant at 1%level*

Table 4. Mean and Standard heterosisof aerobic rice hybrids (Yield and its attributing traits)

Genotypes	Days to 50% flowering				Plant height (cm)				Panicle length (cm)				Productive tillers			
Crosses	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**
CMS23 X MTU-1001	101.00	10.99 **	0.66	0.00	84.13	8.42 *	-4.21	1.11	20.80	15.77 **	2.13	7.18	8.80	22..22**	26.92**	-5.38
CMS23 X SU-315-081R	110.00	20.88 **	9.63 **	8.91 **	96.87	24.83 **	10.3*	16.42 **	22.93	27.64 **	12.60 *	18.17 **	8.13	12.96	17.31*	-12.54 *
CMS23 X RNR-21280	75.33	-17.22 *	-24.92 *	-25.41 **	74.55	-3.93	-15.1*	-10.40 *	19.35	7.70	-4.99	-0.29	6.43	-10.65	-7.21	-30.82 **
CMS23 X NH12-103R	77.00	-15.38 *	-23.26*	-23.76 **	83.08	7.07	-5.40	-0.15	19.17	6.68	-5.89	-1.24	5.97	-17.13 *	-13.94	-35.84 **
CMS23 X SVHR-3005	78.00	-14.29 *	-22.26 *	-22.77 **	79.27	2.15	-9.75*	-4.74	18.40	2.41	-9.66	-5.19	9.33	29.63 **	34.62 **	0.36
CMS23 X KMP-175	84.00	-7.69 *	-16.28 *	-16.83 **	97.49	25.63 **	11.0*	17.16 **	20.98	16.75 **	3.00	8.09	8.03	11.57	15.87*	-13.62 *
CMS23 X MTU1075	90.00	-1.10	-10.30*	-10.89 **	91.40	17.78 **	4.07	9.85 **	19.60	9.09	-3.76	1.00	8.17	13.43	17.79*	-12.19 *
CMS23 X KMP-128	89.33	-1.83	-10.96*	-11.55 **	90.47	16.58 **	3.01	8.73 *	21.33	18.74 **	4.75	9.93	8.20	13.89	18.27 *	-11.83 *
CMS59A X MTU-1001	103.67	13.92 **	3.32	2.64	88.60	14.18 **	0.88	6.48	20.60	14.66 *	1.15	6.15	9.07	25.93 **	30.77 **	-2.51
CMS59A X SU-315-081R	92.00	1.10	-8.31 **	-8.91 **	89.92	15.88 **	2.38	8.07 *	20.38	13.41 *	0.05	5.00	7.20	0.00	3.85	-22.58 **
CMS59A X RNR-21280	74.67	-17.95 *	-25.58 *	-26.07 **	89.04	14.75 **	1.39	7.01 *	18.73	4.27	-8.02	-3.47	9.47	31.48 **	36.54 **	1.79
CMS59A X NH12-103R	74.67	-17.95 *	-25.58*	-26.07 **	90.37	16.45 **	2.89	8.61 *	21.38	19.02 **	4.99	10.19	6.67	-7.41	-3.85	-28.32 **
CMS59A X SVHR-3005	82.00	-9.89 **	-18.27*	-18.81 **	82.42	6.21	-6.16	-0.95	19.96	11.08	-2.01	2.83	6.30	-12.50	-9.13	-32.26 **
CMS59A X KMP-175	85.67	-5.86	-14.62*	-15.18 **	98.67	27.15 **	12.3*	18.58 **	22.80	26.90 **	11.95 *	17.49 **	8.57	18.98*	23.56*	-7.89
CMS59A X MTU-1075	102.00	12.09 **	1.66	0.99	97.47	25.60 **	10.9*	17.14 **	20.07	11.69	-1.47	3.40	8.07	12.04	16.35*	-13.26 *
CMS59A X KMP-128	101.33	11.36 **	1.00	0.33	93.98	21.10 **	7.00 *	12.94 **	24.18	34.56 **	18.71 **	24.58 **	6.73	-6.48	16.35*	-27.60 **

Genotypes	Days to 50% flowering				Plant height (cm)				Panicle length (cm)				Productive tillers			
Crosses	Mean	H-1	H-2	H-3	Mean	H-1	H-2	H-3	Mean	H-1	H-2	H-3	Mean	H-1	H-2	H-3
CMS64A X MTU-1001	106.33	16.85 **	5.98 *	5.28	83.13	7.13 *	-5.34	-0.09	19.67	9.46	-3.44	1.34	8.33	15.74*	-2.88	-10.39
CMS64A X SU-315-081R	98.33	8.06 *	-1.99	-2.64	86.40	11.34 **	-1.62	3.84	21.70	20.78 **	6.55	11.82 *	8.73	21.30*	25.96**	-6.09
CMS64A X RNR-21280	92.67	1.83	-7.64 *	-8.25 **	84.47	8.85 *	-3.83	1.51	18.64	3.75	-8.48	-3.95	8.60	19.44 *	24.04 **	-7.53
CMS64A X NH12-103R	84.33	-7.33 *	-15.95*	-16.50 **	84.47	8.85 *	-3.83	1.51	19.92	10.85	-2.21	2.63	7.23	0.46	4.33	-22.22 **
CMS64A X SVHR-3005	97.67	7.33 *	-2.66	-3.30	76.66	-1.22	-12.7*	-7.87 *	17.22	-4.14	-15.43 **	-11.25 *	7.23	0.46	4.33	-22.22 **
CMS64A X KMP-175	105.00	15.38 **	4.65	3.96	103.4	33.25 **	17.7*	24.27 **	23.87	32.84 **	17.18 **	22.98 **	7.53	4.63	8.65	-19.00 **
CMS64A X MTU-1075	109.33	20.15 **	8.97 **	8.25 **	92.14	18.74 **	4.91	10.74 **	20.98	16.79 **	3.03	8.12	8.03	11.57	15.87	-13.62 *
CMS64A X KMP-128	101.33	11.36 **	1.00	0.33	91.50	17.91 **	4.18	9.97 **	22.47	25.05 **	10.31	15.77 **	8.87	23.15 **	27.88 **	-4.66
IR68897A X MTU-1001	100.33	10.26 **	0.00	-0.66	83.18	7.20 *	-5.29	-0.03	17.96	-0.06	-11.83 *	-7.47	7.23	0.46	4.33	-22.22 **
IR68897A X SU-315-081R	84.33	-7.33 *	-15.95*	-16.50 **	83.13	7.13 *	-5.34	-0.09	19.98	11.19	-1.91	2.94	9.40	30.56 **	35.58 **	1.08
IR68897A X RNR-21280	77.67	-14.65 *	-22.59*	-23.10 **	81.72	5.30	-6.9*	-1.79	19.36	7.74	-4.96	-0.26	6.63	-7.87	-4.33	-28.67 **
IR68897A X NH12-103R	71.67	-21.25*	-28.57*	-29.04 **	73.74	-4.97	-16.1*	-11.38*	19.12	6.44	-6.10	-1.46	6.00	-16.67 *	-13.46	-35.48 **
IR68897A X SVHR-3005	72.33	-20.51 *	-27.91*	-28.38 **	72.00	-7.22 *	-18.0*	-13.47*	18.07	0.56	-11.29 *	-6.90	8.27	14.81	19.23 *	-11.11
IR68897A X KMP-175	88.67	-2.56	-11.63 *	-12.21 **	91.87	18.38 **	4.60	10.41 **	21.94	22.13 **	7.74	13.07 *	8.20	13.89	18.27 *	-11.83 *
IR68897A X MTU-1075	95.33	4.76	-4.98	-5.61	98.53	26.98 **	12.2*	18.42 **	22.85	27.18 **	12.19 *	17.74 **	11.5	60.65 **	66.83 **	24.37 **
IR68897A X KMP-128	101.67	11.72 **	1.33	0.66	90.20	16.24 **	2.70	8.40 *	20.10	11.87 *	-1.31	3.57	7.50	4.17	8.17	-19.35 **
Checks																
MTU-1010 (H-1)	91.00				77.60				17.97				7.20			
KRH-2 (H-2)	100.33				87.83				20.37				6.93			
MAS-946 (H-3)	101.00				83.21				19.41				9.63			
CV (%)	3.86				4.11				6.55				9.01			

Table 4 (Cont.): Mean and standad heterosis of aerobic rice hybrids (Yield and its attributing traits)

Genotypes	Filled grains/ panicle				Spikelet fertility (%)				1000 Seed weight (gr)				Seed yield (gr)			
Crosses	Mean	H-1	H-2	H-3	Mean	H-1	H-2	H-3	Mean	H-1	H-2	H-3	Mean	H-1	H-2	H-3
CMS23 X MTU-1001	119.50	24.91 *	-2.37	5.44	89.10	13.78 **	6.56	6.54	23.81	0.95	18.04 **	5.40	30.70	28.78 **	27.9*	9.06
CMS23 X SU-315-081R	141.33	47.74 **	15.47	24.71 *	85.09	8.66 *	1.77	1.75	22.66	-3.93	12.34 *	0.31	38.08	59.75 **	58.6*	35.29 **
CMS23 X RNR-21280	114.67	19.86	-6.32	1.18	83.39	6.49	-0.26	-0.29	19.22	-18.51 **	-4.71	-14.92 **	19.51	-18.18 **	-18.7*	-30.70 **
CMS23 X NH12-103R	105.33	10.1	-13.94	-7.06	89.70	14.55 **	7.28 *	7.25 *	22.65	-4.00	12.26 *	0.24	19.21	-19.44 **	-19.9*	-31.77 **
CMS23 X SVHR-3005	123.33	28.92*	0.76	8.82	80.79	3.17	-3.37	-3.40	20.46	-13.27 **	1.42	-9.44	23.51	-1.40	-2.07	-16.49 **
CMS23 X KMP-175	99.14	3.63	-19.00 *	-12.52	87.65	11.93 **	4.83	4.81	22.91	-2.87	13.58 *	1.42	26.46	11.00	10.25	-5.99
CMS23 X MTU1075	131.22	37.16*	7.21	15.78	81.90	4.59	-2.05	-2.07	21.02	-10.91 *	4.18	-6.98	29.36	23.17 **	22.3*	4.31
CMS23 X KMP-128	102.54	7.18	-16.23	-9.52	78.32	0.02	-6.32	-6.35	23.04	-2.33	14.21 *	1.98	23.47	-1.57	-2.24	-16.64 **
CMS59A X MTU-1001	94.62	-1.09	-22.69 *	-16.51	75.38	-3.73	-9.84*	-9.86*	21.62	-8.37	7.15	-4.32	18.12	-24.01 **	-24.5*	-35.64 **
CMS59A X SU-315-081R	141.15	47.55 *	15.32	24.55*	79.42	1.42	-5.01	-5.03	18.04	-23.54 **	-10.59	-20.17 **	17.67	-25.88 **	-26.3*	-37.23 **
CMS59A X RNR-21280	156.33	63.41 **	27.72*	37.94*	85.91	9.71 *	2.75	2.72	20.60	-12.66	2.13	-8.81	33.82	41.86 **	40.9*	20.14 **
CMS59A X NH12-103R	97.52	1.94	-20.33 *	-13.95	82.89	5.85	-0.86	-0.88	21.01	-10.94 *	4.15	-7.01	24.37	2.21	1.51	-13.44 *

Genotypes	Filled grains/ panicle				Spikelet fertility (%)				1000 Seed weight (gr)				Seed yield (gr)			
Crosses	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**
CMS59A X SVHR-3005	97.33	1.74	-20.48 *	-14.12	77.59	-0.92	-7.20*	-7.22*	22.49	-4.66	11.48 *	-0.46	19.98	-16.19 *	-16.7*	-29.02 **
CMS59A X KMP-175	124.07	29.69 *	1.36	9.47	90.80	15.95 **	8.60 *	8.57 *	20.12	-14.70 **	-0.25	-10.93 *	32.93	38.14 **	37.2*	16.99 **
CMS59A X MTU-1075	136.25	42.42 **	11.32	20.22 *	83.88	7.12	0.33	0.30	23.05	-2.30	14.24 **	2.01	27.76	16.43 *	15.6*	-1.40
CMS59A X KMP-128	151.44	58.30 **	23.73 *	33.63 **	80.43	2.71	-3.80	-3.83	21.76	-7.74	7.88	-3.67	24.74	3.76	3.06	-12.13 *
CMS64A X MTU-1001	124.04	29.66*	1.34	9.45	79.24	1.19	-5.23	-5.25	20.09	-14.84 **	-0.41	-11.08 *	16.84	-29.35 **	-29.8*	-40.17 **
CMS64A X SU-315-081R	168.73	76.38 **	37.85 **	48.88 **	85.04	8.59 *	1.71	1.68	18.27	-22.57 **	-9.45	-19.15 **	27.59	15.73 *	14.9 *	-1.99
CMS64A X RNR-21280	138.25	44.51 **	12.95	21.99 *	80.45	2.73	-3.78	-3.81	16.07	-31.86 **	-20.32 **	-28.86 **	19.14	-19.73 **	-20.2*	-32.02 **
CMS64A X NH12-103R	145.62	52.21 **	18.97 *	28.49 **	92.54	18.17 **	10.6*	10.6*	22.74	-3.60	12.72 *	0.65	19.84	-16.78 *	-17.3*	-29.52 **
CMS64A X SVHR-3005	86.33	-14.98	-29.47 *	-23.82 *	75.79	-3.21	-9.35*	-9.37*	14.45	-38.75 **	-28.37 **	-36.04 **	15.88	-33.39 **	-33.8*	-43.59 **
CMS64A X KMP-175	155.67	62.72**	27.18 **	37.35	75.39	-3.73	-9.84*	-9.86*	20.01	-15.18 **	-0.81	-11.43 *	22.08	-7.38	-8.01	-21.56 **
CMS64A X MTU-1075	188.00	96.52*	53.59 **	65.88 **	85.26	8.88 *	1.97	1.95	21.35	-9.50 *	5.83	-5.50	21.41	-10.19	-10.80	-23.94 **
CMS64A X KMP-128	139.47	45.78*	13.94	23.06 *	76.04	-2.89	-9.05*	-9.1*	21.62	-8.34	7.19	-4.29	21.53	-9.70	-10.32	-23.53 **
IR68897A X MTU-1001	118.00	23.34*	-3.6	4.11	75.38	-3.74	-9.85*	-9.87*	21.15	-10.33 *	4.86	-6.37	18.47	-22.54 **	-23.1*	-34.40 **
IR68897A X SU-315-081R	128.84	34.68*	5.26	13.69	86.26	10.15 **	3.17	3.14	20.13	-14.65 **	-0.20	-10.89 *	26.16	9.72	8.97	-7.08
IR68897A X RNR-21280	148.61	55.34 **	21.41 *	31.13 **	82.78	5.71	-0.99	-1.02	15.95	-32.39 **	-20.94 **	-29.40 **	18.31	-23.20 **	-23.7*	-34.96 **
IR68897A X NH12-103R	83.39	-12.84	-31.87 *	-26.42 *	82.02	4.74	-1.90	-1.93	20.99	-11.02 *	4.05	-7.10	16.58	-30.47 **	-30.9*	-41.11 **
IR68897A X SVHR-3005	177.67	85.72 **	45.16 **	56.77 **	75.12	-4.07	-10.2*	-10.2*	13.48	-42.87 **	-33.20 **	-40.35 **	18.21	-23.60 **	-24.1*	-35.30 *
IR68897A X KMP-175	147.47	54.15 **	20.48 *	30.12 **	83.57	6.72	-0.05	-0.07	20.45	-13.31 **	1.37	-9.49	25.19	5.68	4.96	-10.50
IR68897A X MTU-1075	163.92	71.34*	33.92*	44.63**	79.03	0.92	-5.48	-5.50	20.35	-13.72 **	0.89	-9.91 *	29.92	25.50 **	24.6*	6.29
IR68897A X KMP-128	102.07	6.69	-16.61	-9.94	79.73	1.82	-4.64	-4.66	13.20	-44.04 **	-34.57 **	-41.58 **	16.31	-31.57 **	-32.1*	-42.05
Checks																
MTU-1010 (H-1)	95.67				78.30				23.59				23.84			
KRH-2 (H-2)	122.40				83.61				20.17				24.00			
MAS-946 (H-3)	113.33				83.63				22.59				28.15			
CV (%)	9.50				4.26				6.35				8.56			

Table 5. Mean, Standard heterosis of aerobic rice hybrids (Quality characters)

Genotypes	Hulling (%)				Milling (%)				Head rice recovery (%)				Kernel length			
Crosses	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**
CMS23 X MTU-1001	79.99	3.00 *	4.05 **	4.32 **	70.24	4.56 *	7.80 **	1.80	53.71	-9.43 *	-7.46 *	-12.81 **	5.67	-3.13	10.09 **	-7.80 **
CMS23 X SU-315-081R	78.57	1.16	2.19	2.46	67.21	0.04	3.14	-2.60	60.34	1.74	3.96	-2.06	6.44	9.96 **	24.97 **	4.66
CMS23 X RNR-21280	79.70	2.62 *	3.67 **	3.94 **	69.86	3.99 *	7.21 **	1.25	54.48	-8.13 *	-6.13	-11.56 **	4.30	-26.58 **	-16.56*	-30.12 **
CMS23 X NH12-103R	80.38	3.50 **	4.56 **	4.83 **	70.80	5.39 **	8.66 **	2.61	53.99	-8.96 *	-6.98	-12.36 **	5.45	-7.00 **	5.69	-11.48 **
CMS23 X SVHR-3005	79.72	2.65 *	3.69 **	3.97 **	75.40	12.24 **	15.71 **	9.27 *	44.38	-25.16 **	-23.54 **	-27.96 **	5.44	-7.06 **	5.63	-11.54 **
CMS23 X KMP-175	79.40	2.24	3.28 *	3.55 **	69.47	3.41	6.61 **	0.68	42.51	-28.31 **	-26.75 **	-30.99 **	5.65	-3.59	9.57 **	-8.23 **
CMS23 X MTU1075	79.19	1.97	3.01 *	3.28 *	69.52	3.48 *	6.69 **	0.75	58.03	-2.14	-0.01	-5.80	5.53	-5.52 *	7.37 *	-10.08 **
CMS23 X KMP-128	79.22	2.00	3.04 *	3.32 *	70.13	4.40 *	7.63 **	1.64	46.49	-21.61 **	-19.91 **	-24.54 **	5.28	-9.90 **	2.39	-14.25 **

Genotypes	Hulling (%)				Milling (%)				Head rice recovery (%)				Kernel length			
Crosses	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**
CMS59A X MTU-1001	79.04	1.77	2.81 *	3.08 *	69.63	3.65 *	6.85 **	0.91	54.87	-7.48 *	-5.46	-10.93 **	5.52	-5.75 *	7.12 *	-10.29 **
CMS59A X SU-315-081R	78.25	0.76	1.79	2.06	67.20	0.03	3.13	-2.61	53.57	-9.66 **	-7.70 *	-13.04 **	4.93	-15.82 **	-4.33	-19.88 **
CMS59A X RNR-21280	78.10	0.57	1.59	1.86	68.90	2.57	5.74 **	-0.14	60.69	2.34	4.57	-1.48	4.58	-21.80 **	-11.13*	-25.57 **
CMS59A X NH12-103R	77.89	0.29	1.31	1.58	69.75	3.83 *	7.04 **	1.08	60.12	1.38	3.59	-2.40	6.47	10.42 **	25.49	5.09 *
CMS59A X SVHR-3005	81.76	5.28 **	6.35 **	6.63 **	65.56	-2.41	0.61	-4.99*	48.72	-17.85 **	-16.06 **	-20.91 **	5.43	-7.23 **	5.43	-11.70 **
CMS59A X KMP-175	77.73	0.08	1.10	1.37	70.40	4.79 **	8.03 **	2.02	39.28	-33.76 **	-32.32 **	-36.23 **	5.64	-3.76	9.38 **	-8.40 **
CMS59A X MTU-1075	77.73	0.09	1.11	1.38	68.44	1.88	5.03 **	-0.82	56.86	-4.12	-2.03	-7.70 *	6.79	15.99 **	31.82 **	10.40 **
CMS59A X KMP-128	78.99	1.71	2.74 *	3.02 *	68.06	1.31	4.45 *	-1.36	51.45	-13.24 **	-11.35 **	-16.48 **	5.78	-1.25	12.23 **	-6.01 *
CMS64A X MTU-1001	80.85	4.11 **	5.17 **	5.45 **	68.95	2.64	5.82 **	-0.07	63.60	7.25 *	9.59 *	3.25	5.42	-7.51 **	5.11	-11.97 **
CMS64A X SU-315-081R	80.58	3.76 **	4.81 **	5.09 **	71.63	6.63 **	9.93 **	3.81 *	52.97	-10.67 **	-8.73 *	-14.01 **	5.28	-9.85 **	2.46	-14.19 **
CMS64A X RNR-21280	81.29	4.67 **	5.74 **	6.02 **	73.11	8.83 **	12.19 **	5.95*	52.22	-11.94 **	-10.02 **	-15.23 **	4.59	-21.57 **	-10.87*	-25.35 **
CMS64A X NH12-103R	80.23	3.31 *	4.36 **	4.64 **	70.38	4.76 **	8.01 **	2.00	51.90	-12.49 **	-10.58 **	-15.76 **	6.61	12.86 **	28.27 **	7.42 **
CMS64A X SVHR-3005	76.27	-1.80	-0.80	-0.53	65.50	-2.50	0.52	-5.08*	54.37	-8.32 *	-6.33	-11.75 **	4.60	-21.51 **	-10.80*	-25.30 **
CMS64A X KMP-175	78.72	1.36	2.40	2.67 *	70.41	4.80 **	8.05 **	2.03	59.24	-0.11	2.07	-3.84	5.29	-9.73 **	2.59	-14.08 **
CMS64A X MTU-1075	80.72	3.93 **	4.99 **	5.27 **	69.02	2.74	5.92 **	0.03	57.99	-2.21	-0.09	-5.87	5.25	-10.36 **	1.88	-14.68 **
CMS64A X KMP-128	77.68	0.02	1.04	1.30	66.54	-0.95	2.12	-3.5*	56.30	-5.07	-3.00	-8.61 *	6.17	5.35 *	19.73 **	0.27
IR68897A X MTU-1001	79.73	2.67 *	3.71 **	3.99 **	70.32	4.67 **	7.91 **	1.91	66.72	12.51 **	14.96 **	8.31 *	4.17	-28.86 **	-19.15*	-32.29 **
IR68897A X SU-315-081R	80.80	4.04 **	5.10 **	5.38 **	71.52	6.47 **	9.76 **	3.65 *	50.46	-14.92 **	-13.07 **	-18.09 **	5.40	-7.74 **	4.85	-12.19 **
IR68897A X RNR-21280	80.49	3.64 **	4.69 **	4.97 **	72.15	7.40 **	10.73 **	4.56*	52.13	-12.10 **	-10.18 **	-15.38 **	5.04	-13.89 **	-2.13	-18.04 **
IR68897A X NH12-103R	79.37	2.20	3.24 *	3.52 **	68.50	1.97	5.13 **	-0.72	42.07	-29.05 **	-27.51 **	-31.70 **	6.28	7.17 **	21.80 **	2.00
IR68897A X SVHR-3005	78.71	1.35	2.38	2.65 *	69.58	3.58 *	6.78 **	0.84	58.65	-1.11	1.05	-4.80	4.55	-22.37 **	-11.77 *	-26.11 **
IR68897A X KMP-175	77.18	-0.62	0.39	0.66	66.90	-0.41	2.67	-3.04	60.01	1.20	3.40	-2.58	5.50	-6.15 *	6.66 *	-10.67 **
IR68897A X MTU-1075	79.19	1.97	3.00 *	3.28 *	70.03	4.25 *	7.47 **	1.49	62.38	5.19	7.48 *	1.26	5.69	-2.79	10.48 **	-7.48 **
IR68897A X KMP-128	73.59	-5.24 **	-4.28 **	-4.03 **	61.42	-8.57 **	-5.74 **	-10.9*	51.45	-13.24 **	-11.35 **	-16.48 **	5.20	-11.27 **	0.84	-15.55 **
Checks																
MTU-1010 (H-1)	77.66				67.18				59.30				5.86			
DRRH-3 (H-2)	76.88				65.16				58.04				5.15			
BPT-5204 (H-3)	76.68				69.00				61.6				6.15			
CV (%)	1.58				2.25				4.66				3.35			

Table 5 (Cont.): Mean, Standard heterosis of aerobic rice hybrids (Quality characters)

Genotypes	Kernel breadth				Kernel L/B ratio				Kernel length after cooking				Kernel elongation ratio			
Crosses	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**
CMS23 X MTU-1001	1.91	-3.38	-9.35**	-5.92	2.98	0.45	21.80 **	-1.87	10.2	18.51 **	4.72 *	4.37 *	1.80	21.95**	-4.94	13.00**
CMS23 X SU-315-081R	1.91	-3.38	-9.35**	-5.92	3.38	13.82 **	38.01 **	11.20 **	11.6	35.05 **	19.34 **	18.93 **	1.81	22.62**	-4.41	13.63**
CMS23 X RNR-21280	1.99	0.84	-5.39	-1.81	2.16	-27.08 *	-11.58 *	-28.76 **	9.95	15.61 **	2.16	1.81	2.32	57.47 **	22.75 **	45.91 **
CMS23 X NH12-103R	2.19	10.98 **	4.12	8.06 **	2.49	-16.18 *	1.63	-18.11 **	10.2	17.97 **	4.24 *	3.89	1.87	26.70 **	-1.23	17.40 **

Genotypes	Kernel breadth				Kernel L/B ratio				Kernel length after cooking				Kernel elongation ratio			
Crosses	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**	**Mean**	**H-1**	**H-2**	**H-3**
CMS23 X SVHR-3005	2.12	7.26 *	0.63	4.44	2.57	-13.26 *	5.18	-15.26 **	9.91	15.18 **	1.78	1.43	1.82	23.53 **	-3.70	14.47 **
CMS23 X KMP-175	2.27	15.20 **	8.08 **	12.17 **	2.49	-16.18 *	1.63	-18.11 **	8.97	4.18	-7.94 **	-8.25 **	1.59	7.92	-15.87 *	0.00
CMS23 X MTU1075	2.13	8.11 *	1.43	5.26	2.60	-12.47 *	6.13	-14.49 **	10.2	19.02 **	5.17 *	4.81 *	1.85	25.79 **	-1.94	16.56 **
CMS23 X KMP-128	2.08	5.41	-1.11	2.63	2.56	-13.82*	4.50	-15.81 **	9.16	6.47 **	-5.92 **	-6.24 **	1.74	17.87 **	-8.11 *	9.22 *
CMS59A X MTU-1001	2.05	3.89	-2.54	1.15	2.69	-9.21 *	10.08 *	-11.31 **	8.84	2.75	-9.21 **	-9.52 **	1.61	9.05	-14.99*	1.05
CMS59A X SU-315-081R	1.81	-8.28 **	-13.95 **	-10.69 **	2.73	-8.09 *	11.44 *	-10.21 **	8.82	2.52	-9.41 **	-9.72 **	1.80	21.95 **	-4.94	13.00 **
CMS59A X RNR-21280	1.77	-10.47 **	-16.01 **	-12.83 **	2.61	-11.91*	6.81	-13.94 **	8.57	-0.43	-12.01 **	-12.31 **	1.89	28.05 **	-0.18	18.66 **
CMS59A X NH12-103R	1.98	0.51	-5.71	-2.14	3.27	10.11 *	33.51 **	7.57 *	10.4	20.88 **	6.81 **	6.45 **	1.61	9.50 *	-14.64 *	1.47
CMS59A X SVHR-3005	1.57	-20.61 **	-25.52 **	-22.70 **	3.47	16.97 **	41.83 **	14.27 **	9.46	9.88 **	-2.91	-3.24	1.74	18.33 **	-7.76 *	9.64 *
CMS59A X KMP-175	1.91	-3.04	-9.03 **	-5.59	2.95	-0.67	20.44 **	-2.96	8.89	3.33	-8.69 **	**	1.58	7.24	-16.40 *	-0.63
CMS59A X MTU-1075	1.92	-2.70	-8.72 **	-5.26	3.54	19.33 **	44.69 **	16.58 **	11.0	27.92 **	13.04 **	12.65 **	1.62	10.18 *	-14.11 *	2.10
CMS59A X KMP-128	1.86	-5.74	-11.57 **	-8.22 **	3.11	4.72	26.98 **	2.31	10.5	21.42 **	7.29 **	6.92 **	1.81	22.62 **	-4.41	13.63 **
CMS64A X MTU-1001	2.04	3.55	-2.85	0.82	2.65	-10.56*	8.45	-12.62 **	8.12	-5.69 *	-16.67 **	-16.95 **	1.50	1.81	-20.63 *	-5.66
CMS64A X SU-315-081R	1.75	-11.32 **	-16.80 **	-13.65 **	3.02	1.69	23.30 **	-0.66	9.17	6.51 **	-5.89 **	-6.21 **	1.74	17.87 **	-8.11 *	9.22 *
CMS64A X RNR-21280	1.71	-13.18 **	-18.54 **	-15.46 **	2.68	-9.78 *	9.40 *	-11.86 **	9.66	12.20 **	-0.86	-1.19	2.11	42.99 **	11.46 **	32.49 **
CMS64A X NH12-103R	1.83	-7.09 *	-12.84 **	-9.54 **	3.61	21.69 **	47.55 **	18.88 **	9.53	10.77 **	-2.12	-2.46	1.44	-2.04	-23.63 *	-9.22 *
CMS64A X SVHR-3005	1.35	-31.42 **	-35.66 **	-33.22 **	3.40	14.72 **	39.10 **	12.07 **	9.50	10.42 **	-2.43	-2.76	2.07	40.27 **	9.35 *	29.98 **
CMS64A X KMP-175	1.96	-0.84	-6.97 *	-3.45	2.70	-8.88 *	10.49 *	-10.98 **	8.40	-2.40	-13.76 **	-14.05 **	1.59	8.14	-15.70 *	0.21
CMS64A X MTU-1075	1.92	-2.87	-8.87 **	-5.43	2.74	-7.75 *	11.85 *	-9.88 *	9.31	8.21 **	-4.38 *	-4.71 *	1.78	20.59 **	-6.00	11.74 **
CMS64A X KMP-128	1.96	-0.68	-6.81 *	-3.29	3.15	6.18	28.75 **	3.73	10.06	16.89 **	3.29	2.93	1.63	10.63 *	-13.76 *	2.52
IR68897A X MTU-1001	1.84	-6.93 *	-12.68 **	-9.38 **	2.27	-23.60*	-7.36	-25.36 **	8.51	-1.12	-12.63 **	-12.93 **	2.04	38.46 **	7.94 *	28.30 **
IR68897A X SU-315-081R	1.98	0.51	-5.71	-2.14	2.73	-8.09 *	11.44 *	-10.21 **	10.26	19.25 **	5.37 *	5.01 *	1.90	28.96 **	0.53	19.50 **
IR68897A X RNR-21280	1.87	-5.07	-10.94 **	-7.57 *	2.69	-9.21 *	10.08 *	-11.31 **	8.43	-2.09	-13.48 **	-13.78 **	1.67	13.57 **	-11.46*	5.24
IR68897A X NH12-103R	1.91	-3.21	-9.19 **	-5.76	3.29	10.79 **	34.33 **	8.23 *	9.13	6.12 *	-6.23 **	-6.55 **	1.46	-1.13	-22.93 *	-8.39
IR68897A X SVHR-3005	1.49	-24.49 **	-29.16 **	-26.48 **	3.05	2.81	24.66 **	0.44	13.02	51.24 **	33.64 **	33.19 **	2.86	94.34 **	51.50 **	80.08 **
IR68897A X KMP-175	2.09	5.74	-0.79	2.96	2.63	-11.24 *	7.63	-13.28 **	8.50	-1.28	-12.77 **	-13.06 **	1.55	4.98	-18.17 *	-2.73
IR68897A X MTU-1075	2.02	2.53	-3.80	-0.16	2.82	-5.06	15.12 **	-7.24	10.87	26.26 **	11.57 **	11.19 **	1.91	29.64 **	1.06	20.13 **
IR68897A X KMP-128	1.61	-18.24 **	-23.30 **	-20.39 **	3.22	8.54 *	31.61 **	6.04	7.69	-10.61 *	-21.01 **	-21.28 **	1.48	0.68	-21.52 *	-6.71
Checks																
MTU-1010 (H-1)	1.97				2.96				8.60				1.47			
DRRH-3 (H-2)	2.10				2.44				9.74				1.89			
BPT-5204 (H-3)	2.02				3.03				9.77				1.59			
CV (%)	3.80				4.75				2.58				4.46			

Studies on grain quality analysis revealed that the CMS64A x RNR-21280 exhibited high mean, significant SCA effect and standard heterosis for hulling percentage, milling percentage, head rice recovery and kernel elongation ratio. The hybrids CMS23A x SV-315-081R, CMS59A x MTU-1075, CMS59A x NH12-103R, CMS64A x SVHR-3005 CMS64A x NH12-103R, CMS59A x KMP-128 and IR68897A x MTU-1001 were found to be good for most of the grain quality traits (Table 5). [10,15,16,17] Also reported heterosis for head rice recovery at varying levels depending on parents involved. [5,10,11,18,19] Also reported manifestation of heterosis for kernel length after cooking and kernel elongation ratio in several combinations emphasizing usage of both additive types of genetic variation.

4. CONCLUSION

In the present investigation, it was concluded that among the parents, CMS23A, CMS59A, SV-315-081R, KMP-175 and MTU-1075 with high GCA and among the hybrids, CMS23A x SV-315-081R, CMS59A x KMP-175 and CMS23A x MTU-1075 with high *per se* performance, SCA effects, in addition to high heterotic effects for grain yield and majority of yield components were better. With similar measurements and estimates in desirable side, other hybrids were, CMS23A x MTU-1001, CMS59A x RNR-21280, CMS59A x NH12-103R, CMS64A x SV-315-081R, CMS64A x NH12-103R, CMS64A x KMP-128 and IR68897A x MTU-1075.

With respect to heterosis for quality, the cross CMS64A x RNR-21280 exhibited considerable performance over standard checks for hulling percentage, milling percentage, head rice recovery and kernel elongation ratio. Significant standard heterosis was registered in case of CMS23A x SV-315-081R hybrid for head rice recovery, kernel length, L/B ratio and Kernel length after cooking. The crosses *viz.,* CMS59A x SVHR-3005 and CMS64A x SVHR-3005 showed highly significant negative heterosis for kernel breadth and positive heterosis for kernel L/B ratio, which is desirable. Along with other cross combinations like CMS23A x SV-315-081R, CMS59A x MTU-1075, CMS59A x NH12-103R, CMS64A x NH12-103R, CMS59A x KMP-128 and IR68897A x MTU-1001 also could be made use for exploitation of hybrid vigour for grain quality improvement in rice [19].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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