

Original Research Article

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Heterosis for Grain Yield and its Component Traits in Rice

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ABSTRACT

Keywords

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Twenty one Kerala rice varieties were crossed with four CMS lines in LxT fashion. The hybrid developed from twenty two crosses between identified restorers and 4 CMS lines were evaluated for heterosis in yield and yield contributing traits. Identified promising hybrids were UPRI95-17A x Aiswarya, UPRI95-17A x Neeraja, UPRI95-17A x Remya and CRMS31A x Kanakom based on high mean grain yield per plant and high standard heterosis over standard check Uma with respect to grain yield and yield contributing traits. Identified superior hybrids can be released for commercial purpose after trail.

Introduction

The challenge of increasing the annual rice production of the country calls for both short and long term planning encompassing genetic as well as crop management options. Among the innovative genetic options available, hybrid rice technology is practically feasible and readily adoptable (Viraktamath *et al.*, 2010). Hybrid rice technology aims to increase the yield potential of rice beyond the level of popular high yielding varieties (HYVs) by exploiting hybrid vigour or heterosis. Hybrid rice technology particularly utilizing the Cytoplasm Genic Male Sterility (CGMS) has now been widely adopted across several countries in Asia and USA. This technology has been successfully developed

and widely adopted by farmers in China during the past 25 years. During 2006, hybrids were cultivated in India in around 1 m.ha, and the National Food Security Mission (NFSM) has set a target of expanding the hybrid rice cultivation to 3 m.ha by 2011-12. Yield barrier in semi – dwarf inbred rice was broken by successful development of rice hybrids in China which yielded about 20 percent more than conventional inbred rice (Virmani *et al.*, 1982).

Commercial success of hybrid rice in China has clearly demonstrated the potential of this technology to meet the ever-increasing demands for rice world over.

Rice is a self-pollinating crop, even though strong heterosis is observed in their F₁ hybrids. Heterosis or hybrid vigour in the first generation (F₁) seeds, obtained by crossing genetically distant breeding lines, is well known in crop breeding (Shull, 1952). Heterosis is the superiority of F₁ hybrids over their parents. Heterosis may be positive or negative depending upon the breeding objectives. Both positive and negative heterosis is useful for crop improvement. Investigations on heterosis provide fundamental information regarding the expression of cross combinations and its potential for commercial exploitation. Vanaja *et al.*, 2003, reported the additive and non-additive gene effects in governing yield and yield attributes of rice. With a view to evaluate the heterotic crosses, the present investigation was undertaken.

Materials and Methods

The materials used in the research comprised of breeder seed of twenty one rice varieties collected from three different rice research centre's representing two soil and climatically different rice growing tracts of Kerala namely Regional Agricultural Research station, Pattambi, Palakkad, Kerala Agricultural University (KAU), Rice Research station, Moncompu, Alappuzha, Kerala and Rice research station Mannuthy, Thrissur, Kerala, along with four different CMS lines namely IR58025A, UPRI95-17A, CRMS31 and CRMS32A collected from IIRR, Hyderabad, GBPUAT, Pantnagar and NRRI, Cuttak respectively.

Plant varieties were raised in the nursery by staggered sowing for synchronization of flowering. Seedlings of these varieties were then transplanted to main field as and when they attend the maturity of 25 days. At boot leaf initiation stage, the male sterile female plants were uprooted in series from the main

field and planted in pots. In the CMS lines individual plants with complete pollen sterility was identified by observing the pollen grains under the microscope using one per cent Iodine potassium iodide (I₂KI) stain. Plant showing 100% pollen sterility was chosen as for hybridization.

Emasculation was done in the female parents by the clipping method. One day before the pollination spikelets were clipped off one third from the top without damaging the stigma. Immediately after clipping, the panicles were covered with butter bag to prevent contamination from any foreign pollen. Crossing between clipped male sterile female parent and 21 Kerala rice varieties was done on the next day morning.

The harvested F₁ seed of each cross were sown in nursery. Seedlings of these varieties were then transplanted to main field as and when they attend the maturity of 25 days. At flowering stage Pollen fertility recorded as microscopic pollen grain count.

$$\text{Pollen fertility \%} = \frac{\text{No. of fertile pollen grains}}{\text{Total no. of Pollen grains}} \times 100$$

Observation was taken on other characters at maturity stage.

Estimation of heterosis

Heterosis, expressed as per cent increase or decrease in the performance of F₁ hybrid over the mid-parent (average or relative heterosis), better parent (heterobeltiosis) and check parent (standard heterosis) was calculated as per the method of Hayes *et al.*, (1955).

$$\text{Per cent Heterosis over Mid Parent (MP)} = \frac{F_1 - MP}{MP}$$

Where, Mid Parent (MP) = $\frac{P1 + P2}{2}$

Per cent Heterosis over Better Parent (BP) = $\frac{F1 - \overline{BP}}{\overline{BP}}$

Per cent Heterosis over standard check hybrid (CH) = $\frac{F1 - \overline{CH}}{\overline{CH}}$

$\overline{F1}$ = Mean performance of F1 hybrid

$\overline{P1}$ = Mean performance of parent one

$\overline{P2}$ = Mean performance of parent two

\overline{BP} = Mean performance of better parent

\overline{CP} = Mean performance of check parent

\overline{MP} = Mean mid-parental value i.e.

$$\frac{P1 + P2}{2}$$

For better parent value (BP) for each trait, superior value exhibited by any of the parent in a cross was taken for computation of heterosis.

Results and Discussion

In the present study, magnitude of heterosis for each trait under study in the form of Mid-parent heterosis or relative heterosis, Better parent heterosis or heterobeltiosis and Standard heterosis or commercial heterosis was computed for all the eighty four (84) crosses. For traits in which an increasing

expression of character is desirable, the crosses with significant and positive heterotic effects were considered superior and the trait where low scores are desirable, the crosses with significant and negative heterotic effects were considered promising.

Among 21 rice varieties three (PTB 9, PTB 10 and PTB 32) were found to be maintainers in the entire cross combinations with four CMS lines. While some varieties were restorer in one cross combination but partial maintainer or partial restorers in other crosses. As the partial maintainers and partial restorers yield less in F₁ generation, they have not been included here. Only cross combinations showing fertility restoration ability more than 80% were included in result.

Plant height

Highest significant negative heterosis over mid parent was recorded in cross combination IR58025A x Manupriya (-15.65%) followed by IR58025A x Swarnaprabha (-13.48%), IR58025A x Varsha (-12.91%) and UPRI95-17A x Remya (-11.72), whereas highest significant negative heterosis over better parent was recorded in cross combination CRMS32A X Remya (-21.30%) followed by CRMS32A X Kanakom (-21.15%), CRMS31A X Kanakom (-20.83%) and IR58025A X Manupriya (-18.52%). While highest significant heterosis in desirable direction over commercial check Uma was reported in cross combination CRMS32A X Kanakom (-11.48%) followed by IR58025A X Manupriya (-11.25%), CRMS31A X Kanakom (11.11%) and CRMS32A X Remya (-10.59%). Results are presented in table 2.

Total number of tillers/plant

Almost all crosses revealed significant heterosis for this character (Table 2). Highest significant positive heterosis over mid parent was recorded in cross combination UPRI95-

17A X Neeraja (29.2%) followed by UPRI95-17A X Remya (28.55%), UPRI95-17A X Aiswarya (24.29%), CRMS31A X Kanakom (22.48%) and CRMS32A X Mattatriveni (21.38%). Hybrid UPRI95-17A X Remya (15.33%) registered highest significant positive heterosis over better parent followed by UPRI95-17A X Neeraja (13.07%), UPRI95-17A X Aiswarya (11.71%) and IR58025A X Manupriya (7.17%). Hybrid UPRI95-17A X Remya (40.40%) registered highest significant heterosis over commercial check followed by UPRI95-17A X Neeraja (37.65%), UPRI95-17A X Aiswarya (36%), CRMS31A X Swarnaprabha (32.28%) and CRMS31A X Kanakom (32.23%).

Number of productive tillers

Hybrid CRMS31A x Kanakom (24.83%) registered highest significant positive heterosis over mid-parent followed by CRMS32A x Mattatriveni (20.92%), UPRI95-17A x Aiswarya (20.94%) and UPRI95-17A x Neeraja (17.74) (Table 2). The hybrid CRMS31A x Kanakom registered highest positive significant heterosis of 15.75 per cent over better parent followed by UPRI95-17A x Aiswarya (14.62%), UPRI95-17A x Neeraja (12.07%) and IR58025A x Manupriya (11.66). The hybrid UPRI95-17A x Aiswarya (25.12%) recorded significant positive heterosis over Uma followed by UPRI95-17A x Neeraja (22.33%), UPRI95-17A x Remya (21.55%) and IR58025A x Manupriya (19.60%).

Pollen fertility

Heterosis for this trait is presented in table 3. Hybrid UPRI95-17A x Neeraja (13.68%) registered highest significant positive heterosis over mid-parent followed by CRMS31A x Jayathi (12.92%), CRMS31A x Swarnaprabha (12.85%) and CRMS31A x Neeraja (12.30). The hybrid IR58025A x

Manupriya manifested highest significant positive heterosis of 10.92 per cent over midparent followed by CRMS31A x Jayathi (10.88%), CRMS31A x Kanakom (9.63%) and CRMS31A x Swarnaprabha (8.43%). The hybrid CRMS31A X Jayathi (9.56) recorded highest significant heterosis over standard check Uma followed by IR58025A X Manupriya (8.33), UPRI95-17A X Jayathi (8.33) and UPRI95-17A X Remya (7.24).

Number of spikelets per panicle

The hybrid CRMS31A X Kanakom (26.66%) showed highest significant heterosis over mid parent followed by CRMS32A X Kanakom (21.94%), UPRI95-17A X Neeraja (18.95%) and UPRI95-17A X Aiswarya (16.74%). The cross UPRI95-17A x Aiswarya (13.09%) recorded highest better parent heterosis followed by UPRI95-17A x Remya (10.71%), UPRI95-17A x Neeraja (10.11) and UPRI95-17A x Pavizham (7.73%). The hybrid UPRI95-17A X Aiswarya manifested highest significant positive heterosis of 25 per cent over standard check Uma followed by UPRI95-17A x Remya (22.37%), UPRI95-17A x Neeraja (21.71%) and UPRI95-17A x Pavizham (19.07%).

Number of filled grains per panicle

Most of the cross combinations revealed significant heterosis over mid parent, better parent and standard check (Table 3). The hybrid CRMS31A x Kanakom (29.40%) showed highest significant heterosis over mid parent followed by UPRI95-17A x Remya (25.44%), UPRI95-17A x Neeraja (23.65%) and CRMS32A x Kanakom (21.4). The hybrid UPRI95-17A x Remya manifested highest significant positive heterosis of 14.47 per cent over better parent followed by UPRI95-17A x Aiswarya (12.93%), UPRI95-17A x Neeraja (12.55%) and CRMS31A x Swarnaprabha (9.51%). The hybrid UPRI95-

17A x Remya manifested highest significant positive heterosis of 25.92 per cent over better parent followed by UPRI95-17A x Aiswarya (24.23%), UPRI95-17A x Neeraja (23.80%) and CRMS31A x Swarnaprabha (17.09%).

Spikelet fertility

The hybrid UPRI95-17A x Remya manifested highest significant positive heterosis of 20.24 per cent over midparent followed by UPRI95-

17A x Neeraja (13.97%), CRMS31A x Kanakom (12.71%) and CRMS31A x Neeraja (12.51%). Only four hybrids registered positive heterosis over better parent but they were all non-significant (Table 4). Hybrid IR58025A x Manupriya (10.70%) showed highest significant heterosis over standard check Uma followed by UPRI95-17A x Remya (8.25%), UPRI95-17A x Neeraja (7.01%) and CRMS31A x Swarnaprabha (7.01%).

Table.1 List of Rice varieties used in the experiment

Serial No	Name of Varieties	Place of collection
Male parents		
1	PTB-9	RARS, Pattambi
2	PTB-10	RARS, Pattambi
3	PTB-32	RARS, Pattambi
4	Aiswarya	RARS, Pattambi
5	Annapoorna (PTB-35)	RARS, Pattambi
6	Jyothi (PTB-39)	RARS, Pattambi
7	Bharathy (PTB-41)	RARS, Pattambi
8	Swarnaprabha (PTB-42)	RARS, Pattambi
9	Mattatriveni (PTB-45)	RARS, Pattambi
10	Jayathi (PTB-46)	RARS, Pattambi
11	Neeraja (PTB-47)	RARS, Pattambi
12	Kanchana (PTB-50)	RARS, Pattambi
13	Manupriya	RRS, Mannuthy
14	Varsha (PTB-56)	RARS, Pattambi
15	Kanakom (MO-11)	RRS, Moncombu
16	Karthika (MO-7)	RRS, Moncombu
17	Aruna (M0-8)	RRS, Moncombu
18	Remya (MO-10)	RRS, Moncombu
19	Aruna (MO-8)	RRS, Moncombu
20	Pavizham (MO-6)	RRS, Moncombu
21	Uma (M0-16)	RRS, Moncombu
Reported Restorers		
22	KMR-3R	DRR, Hyderabad
23	IR42266-29-3R	CRRRI, Cuttack
Female parents		
24	IR58025A	IIRR, Hyderabad
25	UPRI95-17A	GBPUAT, Pantnagar
26	CRMS31A	NRRI, Cuttak
27	CRMS 32A	NRRI, Cuttak

Table.2 Estimated heterosis for the traits Plant height, Total no of tillers/plant and No. of Productive tillers/plant

S. No.	Cross	PLANT HEIGHT			TOTAL NO OF TILLERS			PRODUCTIVE TILLERS		
		Heterosis over		Standard heterosis over	Heterosis over		Standard heterosis over	Heterosis over		Standard heterosis over
		MP	BP	UMA	MP	BP	UMA	MP	BP	UMA
1.	IR58025A XRemya	-12.43	-17.09**	-5.82**	19.24**	7**	30.26**	3.85*	2.69	12.49**
2.	IR58025A XSwarnaprabha	-13.48**	-17.84**	-7.26**	10.57**	-0.07	21.65*	-9.75**	-10.87**	-4.54
3.	IR58025A XManupriya	-15.65**	-18.52**	-11.25**	17.79**	7.19**	30.49**	16.29**	11.66**	19.60**
4.	IR58025A XVarsha	-12.91**	-15.4**	-8.92**	7.84**	-3.71*	17.21**	-1.76	-5.33**	1.39
5.	IR58025A XAiswarya	-0.93**	-2.35**	-0.88*	18.89**	6.85**	30.08**	4.24*	-0.30	6.78**
6.	UPRI95-17A XRemya	-11.72**	-16.42**	-5.05**	28.55**	15.33**	40.40**	11.16**	10.96**	21.55**
7.	UPRI95-17A XJayathi	4.01**	-0.29	10.34**	2.14	-8.59**	11.27**	-5.45**	-10.55**	-2.36
8.	UPRI95-17A XAnnapoorna	-6.48**	-11.60**	0.75**	9.51**	-0.59	21.01**	-5.97**	-10.67**	-2.49
9.	UPRI95-17A XNeeraja	-9.50**	-12.49**	-4.89**	29.2**	13.07**	37.65**	17.74**	12.07**	22.33**
10.	UPRI95-17A XAiswarya	-0.24	-4.87**	-0.19	24.29**	11.71**	36**	20.94**	14.62**	25.12**
11.	UPRI95-17A XPavizham	-3.21**	-6.37**	1.66**	16.44**	5.52**	28.46**	9.91**	4.787**	14.3**
12.	CRMS31A XRemya	-6.40**	-17.30**	-6.04**	14.37**	1.58*	26.57**	-3.07**	0.63	2.40**
13.	CRMS31A XJayathi	7.46**	-3.95**	6.28**	19.28**	5.65**	31.65**	13.80**	11.35**	13.30**
14.	CRMS31A XSwarnaprabha	-7.05**	-17.64**	-7.04**	18.69**	6.16**	32.28**	11.16**	9.79**	14.60**
15.	CRMS31A XKanakom	-10.86**	-20.83**	-11.11**	22.48**	6.11**	32.23**	24.83**	15.75**	17.78**
16.	CRMS31A XNeeraja	-4.31**	-13.78**	-6.30**	18.54**	2.69**	27.97**	11.27**	9.56**	11.48**
17.	CRMS32A XRemya	-11.38**	-21.30**	-10.59**	12.73**	0.68	23.88*	-4.95**	-2.04	1.10**
18.	CRMS32A XJayathi	10.00**	-1.17**	9.36**	-17.29**	-26.33**	-9.36	-19.70**	-21.98**	-19.47**
19.	CRMS32A XSwarnaprabha	-8.86**	-18.83**	-8.38**	8.03**	-2.82**	19.56**	-10.15**	-10.67**	-6.71**
20.	CRMS32A XAnnapoorna	-4.23**	-15.07**	-3.20**	17.94**	6.54**	31.10**	14.64**	11.88**	15.48**
21.	CRMS32A XMattatriveni	-2.57**	-10.15**	-6.17**	21.38**	3.58**	27.44**	20.92**	3.23**	6.55**
22.	CRMS32A XAiswarya	4.30**	-1.19**	-2.59**	11.26**	-0.47	22.46**	6.52**	3.71**	7.04**

* Significant at 0.05 level, ** Significant at 0.01 level

Table.3 Estimated heterosis for the traits Pollen fertility, Spikelet/panicle and filled grain/panicle

S. No.	Cross	POLLEN FERTILITY %			SPIKELETS/PANICLE			FILLED GRAINS/PANICLE		
		Heterosis over		Standard heterosis over	Heterosis over		Heterosis over	Standard heterosis over		Heterosis over
		MP	BP	UMA	MP	BP	UMA	MP	BP	UMA
1.	IR58025A XRemya	4.61**	3.65**	1.19*	2.41**	1.43**	4.76**	5.74**	-2.08**	1.67*
2.	IR58025A XSwarnaprabha	7.28**	3.69**	1.22*	-14.64**	-13.37**	-10.52**	-10.04	-15.37**	-12.11**
3.	IR58025A XManupriya	11.31**	10.92**	8.33**	0.22	2.93**	6.32**	11.88**	7.74	11.88**
4.	IR58025A XVarsha	6.09**	6.09**	3.57**	4.73**	0.53	3.83**	10.07*	1.71	5.62**
5.	IR58025A XAiswarya	-1.50**	-7.09**	2.30**	0.82	0.98	4.31**	1.87	-2.65*	1.09*
6.	UPRI95-17A XRemya	9.52**	7.24**	7.24**	15.53**	10.71**	22.37**	25.44**	14.47**	25.92**
7.	UPRI95-17A XJayathi	10.97**	8.33**	8.33**	14.71**	2.97**	13.81**	3.58**	-3.17**	6.51**
8.	UPRI95-17A XAnnapoorna	4.96**	2.77**	2.77**	13.72**	1.79*8	12.50**	7.05**	-1.93*	7.874**
9.	UPRI95-17A XNeeraja	13.68**	7.93**	7.93**	18.95**	10.11**	21.71**	23.65**	12.55**	23.80**
10.	UPRI95-17A XAiswarya	-1.03	3.96**	3.96**	16.74**	13.09**	25**	20.07**	12.93**	24.23**
11.	UPRI95-17A XPavizham	8.97**	4.76**	4.76**	10.19**	7.73**	19.07**	14.15**	7.59**	18.35**
12.	CRMS31A XRemya	8.89**	7.25**	5.98**	2.62**	-0.79**	7.68**	3.18**	-4.61**	1.99**
13.	CRMS31A XJayathi	12.92**	10.88**	9.56**	14.86**	3.93**	12.82**	6.83**	1.19**	8.1**
14.	CRMS31A XSwarnaprabha	12.85**	8.43**	7.14**	7.12**	6.04**	15.10**	16.64**	9.51**	17.09**
15.	CRMS31A XKanakom	11.65**	9.63**	8.3**	26.66**	6.19**	15.27**	29.40**	5.19**	12.48**
16.	CRMS31A XNeeraja	12.30**	7.23**	5.95**	10.63**	3.27**	12.10**	13.64**	4.78**	12.04**
17.	CRMS32A XRemya	0.30	-2.35**	-1.19	-16.71**	-19.01**	-13.15**	-17.12**	-22.87**	-18.72**
18.	CRMS32A XJayathi	6.71**	3.57**	4.80**	-20.43**	-27.60**	-22.36**	-25.94**	-29.37**	-25.56**
19.	CRMS32A XSwarnaprabha	2.78**	-2.35**	-1.19	-31.62**	-31.90**	-26.97**	-30.56**	-34.36**	-30.83**
20.	CRMS32A XAnnapoorna	6.34**	3.52**	4.76**	14.73**	4.08**	11.62**	14.30**	6.79**	12.54**
21.	CRMS32A XMattatriveni	-3.68**	-7.10**	1.19	2.20**	3.74**	11.25**	11.41**	3.68*	9.27**
22.	CRMS32A XAiswarya	-4.22**	-8.10**	1.19	5.56**	3.78**	11.29**	9.07**	4.69**	10.33**

* Significant at 0.05 level, ** Significant at 0.01 level

Table.4 Estimated heterosis for the traits Spikelet fertility and Grain yield/plant

Sl. No.	Cross	Spikelet fertility %			Grain yield/plant		
		Heterosis over		Standard heterosis over	Heterosis over		Standard heterosis over
		MP	BP	UMA	MP	BP	UMA
1.	IR58025A XRemya	12.63**	-6.73**	2.09**	14.77**	1.12	9.88**
2.	IR58025A XSwarnaprabha	0.82	-5.87**	3.32**	-0.04	-3.30*	5.06**
3.	IR58025A XManupriya	5.68**	1.12	10.70**	5.98**	5.76**	14.92**
4.	IR58025A XVarsha	1.51*	-2.24**	7.01**	2.93**	-2.63*	5.80**
5.	IR58025A XAiswarya	-7.33**	-7.80**	1.95	1.73	0.12	8.79**
6.	UPRI95-17A XRemya	20.24	0.01	8.25**	22.57**	4.13*	23.36**
7.	UPRI95-17A XJayathi	-9.68**	-10.31**	-1.55*	-1.03	-7.01**	10.15**
8.	UPRI95-17A XAnnapoorna	-7.67**	-6.81**	0.86	-1.83	-7.70**	9.34**
9.	UPRI95-17A XNeeraja	13.97*	-1.13	7.01**	21.91**	4.94**	24.31**
10.	UPRI95-17A XAiswarya	-4.44**	-5.45**	4.55**	13.25**	6.93**	26.67**
11.	UPRI95-17A XPavizham	1.58**	-3.40**	4.55**	5.25**	-0.45	17.91**
12.	CRMS31A XRemya	11.42**	-6.89**	-0.36	15.21**	0.86	11.24**
13.	CRMS31A XJayathi	-6.92**	-8.09**	0.88	9.20**	6.17**	17.10**
14.	CRMS31A XSwarnaprabha	5.69**	0.003	7.01**	10.80**	6.41**	17.37**
15.	CRMS31A XKanakom	12.51**	-4.07**	2.64*	35.73**	7.40**	18.46**
16.	CRMS31A XNeeraja	12.71**	-1.75*	5.13**	16.01**	2.96*	13.56**
17.	CRMS32A XRemya	8.98**	-9.55**	-1.54*	-0.70	-14.40**	-2.09
18.	CRMS32A XJayathi	-7.73**	-8.11**	0.86	-8.03**	-12.14**	0.49
19.	CRMS32A XSwarnaprabha	-2.48**	-8.47**	-0.36	-13.23**	-18.09**	-6.31**
20.	CRMS32A XAnnapoorna	-3.18**	-2.56**	6.06**	6.97**	2.26	16.96**
21.	CRMS32A XMattatriveni	2.35**	-5.08**	3.32**	12.12**	-2.73*	11.24**
22.	CRMS32A XAiswarya	-4.95**	-5.68**	4.28**	1.314	-2.73*	11.24**

* Significant at 0.05 level, ** Significant at 0.01 level

Yield per plant

The hybrid CRMS31A x Kanakom manifested highest significant positive heterosis of 35.73 per cent over mid-parent followed by CRMS32A x Kanakom (22.72%), UPRI95-17A x Remya (22.57%) and UPRI95-17A x Neeraja (21.91%). Hybrid CRMS31A x Kanakom manifested highest significant positive heterosis of 7.40 per cent over better parent followed by UPRI95-17A x Aiswarya (6.93%), CRMS31A x Swarnaprabha (6.41%) and CRMS31A x Jayathi (6.17%). Hybrid UPRI95-17A x Neeraja (24.31%) showed highest significant heterosis over standard check Uma followed by UPRI95-17A x Remya (23.36%), CRMS31A x Kanakom (18.26) and UPRI95-17A x Pavizham (17.91%).

Semi-dwarf plant height (80-100cm) is desirable for recording high yield in rice variety as vigour in plant height may lead to unfavorable grain/straw ratio and optimum yield due to lodging (Tiwary *et al.*, 2011). Significant negative heterosis were found in four hybrids over mid parent (IR58025A x Manupriya, IR58025A x Swarnaprabha, UPRI95-17A x Remya and IR58025A x Varsha), better parent (CRMS32A x Remya, CRMS32A x Kanakom, CRMS31A x Kanakom, IR58025A x Manupriya) and standard check (CRMS32A x Kanakom, IR58025A x Manupriya, CRMS31A x Kanakom, CRMS32A x Remya). Expression of significant negative heterosis for plant height was reported by Tiwary *et al.*, (2011), Aditya Kumar *et al.*, (2012) and Dwivedi and Pandey (2012).

Four hybrids UPRI95-17A x Neeraja, UPRI95-17A x Remya, UPRI95-17A x Aiswarya and CRMS31A x Kanakom exhibited highest significant positive heterosis for number of tillers per plant over the check variety Uma as well as midparent. Hybrids

UPRI95-17A x Remya, UPRI95-17A x Neeraja, UPRI95-17A x Aiswarya and IR58025A x Manupriya exhibited highest positive significant heterosis over better parent for the trait number of tillers /plant. Among them 3 hybrids (UPRI95-17A x Neeraja, UPRI95-17A x Remya and CRMS31A x Kanakom) showed highest significant positive heterosis over standard check. Highly significant heterosis for this trait is closely associated with high grain yield per plant resulting high productivity as also noticed by Tiwary *et al.*, (2011). The positive heterosis for above traits were reported by Dwivedi and Pandey (2012).

Generally productive tillers per plant is positively correlated with the yield, therefore hybrids with positive heterosis for this trait is desirable. Hybrids viz; CRMS31A x Kanakom, CRMS32A x Mattatriveni, UPRI95-17A x Aiswarya and UPRI95-17A x Neeraja registered highest significant heterosis over midparent whereas hybrids CRMS31A x Kanakom, UPRI95-17A x Neeraja and IR58025A x Manupriya registered significant heterosis over better parent for number of productive tillers/plant. Four hybrids UPRI95-17A x Aiswarya, UPRI95-17A x Neeraja, UPRI95-17A x Remya and IR58025A x Manupriya manifested significant heterosis over standard check variety. Two hybrids UPRI95-17A x Aiswarya and UPRI95-17A x Neeraja recorded significant heterosis over mid parent, better parent as well as commercial check. Similar result had been reported by Amudha *et al.*, (2010) and Cahndiraka and Thiyagarajan (2010).

Pollen fertility is one of the constraints in hybrid rice breeding programme, which affects the yield considerably. Only one single hybrid (CRMS31A x Jayathi) registered significant heterosis over mid parent, better parent and standard variety, whereas hybrid

IR58025A x Manupriya registered significant heterosis over mid parent and better parent for pollen fertility. Expression of significant positive heterosis for pollen fertility was reported by Amudha *et al.*, (2010), Dwivedi and Pandey (2012) and Behera (2016).

Number of spikelets per panicle is one of the important yield contributing trait and number of fertile spikelets directly contribute to the seed yield, hence hybrids with positive heterosis for this trait are desirable. In the present study, almost all the hybrids showed positive heterosis for number of spikelet. Two hybrids UPRI95-17A x Remya and UPRI95-17A x Aiswarya registered significant heterosis, heterobeltiosis and standard heterosis for this trait. Two hybrids viz; IR58025A x Mupriya and UPRI95-17A x Remya registered high significant positive heterosis and standard heterosis for the trait spikelet fertility percentage. None of the hybrid registered significant positive heterosis over better parent for spikelet fertility percentage. The Significant heterosis in the hybrids for spikelets per panicle was reported by Vanaja and Babu (2004, Kumar *et al.*, (2012) and Dwivedi and Pandey (2012). Significant heterosis for spikelet fertility was reported by Veerasha *et al.*, (2015) and Behera (2016).

Higher number of filled grains per panicle positively correlated with the yield, therefore hybrids with positive heterosis for number of filled grains/panicle are desirable. The hybrids UPRI95-17A x Remya and UPRI95-17A x Neeraja registered high significant positive heterosis, heterobeltiosis and standard heterosis whereas hybrids UPRI95-17A x Aiswarya and CRMS31A x Swarnaprabha registered high significant positive heterosis over better parent and standard check. Similar significant heterosis for filled grain per panicle was reported by

Cahndiraka and Thiyagarajan (2010) and Roy (2013).

Grain yield is a complex and dependent trait. The hybrid CRMS31A x Kanakom registered high significant positive heterosis, heterobeltiosis and standard heterosis for grain yield per plant. Hybrids UPRI95-17A x Aiswarya and UPRI95-17A x Neeraja registered high significant positive heterosis over midparent and standard check. The Significant heterosis in the hybrids for Grain yield per plant was reported by Roy (2013), Veerasha *et al.*, (2015) and Behera (2016).

The check Uma used in this study is a highly stable and higher yielding commercial rice variety in the state. But the yield of this variety comparably less than hybrid rice. Therefore the present study undertook to develop hybrid rice having characteristic similar to Kerala rice variety and which can yield more than the local rice varieties. The present study resulted in identification of promising hybrids UPRI95-17A x Aiswarya, UPRI95-17A x Neeraja, UPRI95-17A x Remya and CRMS31A x Kanakom based on high mean grain yield per plant and high standard heterosis over standard check Uma (26.67%, 24.31%, 23.36% and 18.46% respectively). All the high yielding hybrids had red kernel except hybrids developed from male parent Neeraja.

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