HETEROSIS AND COMBINING ABILITY IN HYBRID RICE (*Oryza sativa* L.)

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Abstract: *Twelve hybrids developed from crossing three CMS lines and four testers were evaluated for the extent of heterosis better parent and standard checks for yield and yield contributing traits in rice (Oryza sativa L.) during kharif 2016. Two crosses out of twelve hybrids exhibited highly significant heterobeltosis and standard heterosis for grain yield plant*^{1}*. Heterosis for grain yield plant*^{1} *was manifested due to the significant and positive heterosis for its components viz., total productive tillers plant*^{1}*, panicle length, number of filled spikelets panicle*$^{-1}$*, spikelet fertility, 1000 grain weight and harvest index. IR58025A, NPQ-49 and Chedo Local was found to be good general combiner for most of the characters and may be extensively used in future hybrid rice breeding programme. The top two heterotic combinations identified for grain yield plant*^{1} *were IR58025A x NPQ-49 and RTN12A x NPQ-49 which exhibited more than 40% heterobeltosis and standard heterosis ranged from 3.64% to 53.14%.*

Key words: *CMS lines, testers, heterosis, heterobeltosis, standard heterosis, rice and yield contributing traits.*

Introduction

Rice is staple food of more than 60% of Indian population. It accounts for about 43% of total food grain production and 46% of total cereal production in the country. Rice occupies pivotal place in Indian Agriculture. In order to meet the domestic demand of the increasing population the present day production of 107.40 million tons (Annonymous, 2015-16) of milled rice has to be increased to 125 million tons by the year 2030. Since the yield of high yielding varieties (HYVs) of rice is plateauing, it is rather difficult to achieve this target with the present day inbred varieties. Therefore, to sustain the self sufficiency in rice, additional production of 1.17 million tons is needed every year. Among many genetic approaches being explored to break the yield barrier in rice and increased productivity, hybrid rice technology appears to be the most feasible and readily adaptable one. The commercial exploitation of heterosis in rice has been possible, primarily, by use of WA cytoplasmic-genetic male sterility and fertility restoration system (Lin and Yuan 1980, Virmani and Edwards, 1983). Hybrid rice technology appears to be the most feasible and readily adoptable to increase the yield level in rice. Extensive research work is going throughout India and abroad on different aspects of hybrid rice. Several pioneer hybrids have shown a yield advantage of around 20% over current threeline hybrids on commercial scale. The average yield of rice hybrids is 6.3 t/ha while that of the inbred varieties is 4.5 t/ha (Long ping, 2004). Therefore, the breeders are now making concentrated efforts to evolve better hybrids for varying ecological situation and to develop appropriate agronomy along with augmenting seed supply by producing quality seeds of recommended hybrids. Therefore, the present piece of research work reports the results of magnitude of heterosis for yield and its attributes. Therefore, hybridization programme made at Regional Agriculture Research Station, Karjat. Dist. Raigad. (MS) to estimate the nature and magnitude of heterosis and combining ability studies for different yield and yield contributing traits in rice.

Materials and Methods

The experiment was conducted at the Experimental farm of Regional Agriculture Research Station, Karjat (Raigad). The identified parents were growing during December, 2015 and the crossing programme was under taken during April, 2016 and evaluation of F_{1s} along with parents and three standard checks was done during *kharif* 2016. Three CMS lines *viz*., IR58025A, RTN 12A and RTN17A were crossed with four testers Chedo Local, CR-2829-PLN-36, NPQ-49 and RP-5898-19-8-6-1-1-1 in a Line × Tester mating design developed 12 hybrids. The experiment was laid out in a Randomized Block Design with three replications during *kharif,* 2016 at Regional Agriculture Research Station, Karjat (Raigad). The experimental material consisting of twelve F_{1s}, three CMS lines, four restorers and three standard checks were sown on 21 June 2016. Then twenty-five days old seedlings were transplanted in the main field at 20 x 15 cm spacing with single seedling per hill having plot size 3 x 0.60 m. The recommended fertilizers @ 100 kg N, 50 kg P_2O_5 and 50 kg K_2O alongwith 7.5 tonnes of FYM per hectare were applied. All standard agronomic recommended practices and plant protection measures were adopted for raising healthy crop. Five sample plants were randomly selected from each plot excluding the border plants and the following data were recorded: Plant height, days to 50% flowering, number of productive tillers plant^{-1}, panicle length, total spikelet panicle^{-1}, filled spikelet panicle^{-1}, spikelet fertility, grain yield plant, straw yield plant, harvest index, 1000 grain weight and days to maturity. The estimation of heterosis was calculated as procedure given by Fonseca and Patterson (1968) and combining ability analysis using line × tester mating design by Kempthorne (1957).

Results and Discussion

The analysis of variance revealed significant genotypic effect for all the charactres under study for parents except for productive tillers plant^{-1} and panicle length. This provides evidence for the presence of sufficient genetic variability among lines, testers and test crosses indicating wide diversity among treatment themselves (Table no.1). Significance mean sum squares of females and males indicated prevalence of additive variance whereas, non additive variance by line x tester. Variance due to interaction effect of male and female were found to be highly significant for all the traits under study except number of productive tillers plant^{-1}, panicle length and grain yield plant^{-1}. The mean square due to hybrids were found to be highly significant for all the traits under study except number of productive tillers plant^{-1}. This indicated existence of considerable amount of genetic variability among parents and hybrids for all the traits under study. The parents vs. hybrids comparison was found significant for all the characters indicating substantial amount of heterosis in hybrids. Similar results reported by Khute *et al.* (2015).

Earlyness being a desirable trait and helps to develop early variety. Significant negative heterobeltosis was observed in hybrid IR58025A x RP-5898-19-8-6-1-1-1 (-4.73%). Similar results reported by Joshi *et al.* (2004). Dwarf plant strature is desirable to develop semi-dwarf high yielding varieties which will be lodging resistant and fertilizer responsive. The range of heterobeltosis was -10.32% to -0.71%. Similar results reported by Kshirsagar *et al.* (2005).

Total of number of productive tillers plant^{-1} generally associated with higher productivity. The maximum heterobeltosis manifested by IR58025A x NPQ-49 (60.00%). Similar results reported by Kunkerkar *et al.* (2012). Longer Panicle length is associated with more number of spikelets panicle^{-1} resulting in higher productivity. Maximum heterobeltosis observed in hybrid RTN17A x Chedo Local (22.15%). Panicle length (cm) reported by Ghara *et al.* (2014).

Total number of spikelets panicle^{-1} is desirable component for yield. Significant positive standard heterosis observed in all the hybrids over varietal check Karjat-7. Number of filled spikelets panicle^{-1} is one of the most important yield component. Significant positive standard heterosis showed in all the hybrids over check Karjat-7. Similar results reported by Kshirsagar *et al.* (2005).

Spikelet fertility (%) is generally associated with higher productivity. The range of heterobeltosis was -3.15% to 7.35%. Spikelet fertility (%) reported by Kumar and Adilakshmi (2016). The heterobeltosis for 1000 grain weight ranged from -0.14% (RTN17A x NPQ-49) to 17.01% (IR58025A x CR-2829-PLN-36). Maximum significant positive heterotic effects for straw yield plant^{-1} is 49.66% (IR58025A x NPQ-49).

Maximum significant positive heterotic effects for grain yield plant^{-1} over better parent 62.91% and checks 53.14% (Karjat-7), 35.51% (Sahyadri-2) and 10.05% (Sahyadri-3) in IR58025A x NPQ-49. The range of heterobeltosis was varied from -0.62% to 62.91%. The standard heterosis over checks Karjat-7, Sahyadri-2 and Sahyadri-3 ranged from -1.98% to 53.14%, -13.26% to 35.51% and -29.56% to 10.05%, respectively. Significant positive heterosis for grain yield plant^{-1} (g) have been reported by many researchers, some of them are Kunkerkar *et al.* (2012) and Kumar and Adilakshmi (2016).

Harvest index is generally associated with higher productivity. Value of heterobeltosis ranged from -0.68% to 9.21%. The standard heterosis over checks Karjat-7, Sahyadri-2 and Sahyadri-3 ranged from -10.38% to -3.12%, 2.38% to 10.68% and 4.75% to 13.24%, respectively.

A perusal of (Table no. 3) showed a good agreement between best Best performing cross combinations alongwith their gca effects, sca effects, heterobeltosis and standard heterosis for various traits in rice. It is also evident from (Table no. 3) that the two best performing hybrids for various characters also had high heterotic response over better parent and standard checks and also having desired sca effect. The three parents *viz.*, IR58025A, NPQ-49 and Chedo Local was found to be good general combiner for the characters and may be extensively used in future hybrid rice breeding programme. These findings are in agreement with those reported by Khute *et al.* (2015).

The best two hybrids (Table no. 4.) for grain yield plant^{-1} were IR58025A x NPQ-49 (average x good) and RTN12A x NPQ-49 (average x good) had positive desired sca effects and significant desired heterotic response over better parents as well as over all the standard checks. Similar kinds of results have also been reported by Prajapati and Mistry (2014) and Priyanka *et al.* (2014).

From the above discussion, it is clear that hybrids IR58025A x NPQ-49 and RTN12A x NPQ-49 having high mean, high heterosis over better parent and standard checks, desirable sca effects for grain yield plant^{-1} and its related traits can be exploited in practical breeding. It is also clear that high degree of non-additive gene action for grain yield and its component traits observed in the present study favours hybrid breeding programme.

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Table 1: Analysis of variance in Line x Tester analysis for twelve characters of Rice

Source of variation	DF	Characters											
		Days to 50 per cent flowering	Plant height (cm)	No. of productive tillers plant-1	Panicle length (cm)	Total no. of spikelets panicle-1	No. of filled spikelets panicle-1	Spikelet fertility (%)	1000 Grain weight (g)	Grain yield plant-1 (g)	Straw yield plant-1 (g)	Harvest index (%)	Days to maturity
Replication	2	0.018	7.78	1.31	0.36	92.57	49.42	5.14	0.025	0.14	0.36	0.40	0.018
Parents	6	5.38**	370.27**	0.79	0.39	445.97**	370.02**	31.23**	9.15**	6.22**	88.1**	6.60**	5.38**
Male	3	9.33**	326.52**	0.83	0.67	722.92**	298.51**	39.64**	2.27	3.44	122.2**	57.56**	9.33**
Female	2	1.00	36.00**	0.05	0.12	22.46**	9.00	5.75**	4.78**	13.09**	6.88	3.21**	1.01
Male vs Female	1	2.28**	1170**	2.15	0.09	462.13**	1306.61**	56.96**	38.5**	0.82	148.1**	77.19**	2.27
Hybrids	11	54.45**	107.38**	1.15	8.55**	85.67**	234.96**	19.08**	4.74**	63.25**	55.15**	4.48**	54.46**
Parents vs. Hybrids	1	102.92**	7.86**	154.54**	112.6**	2725.1**	9036.16**	359.4**	87.15**	838.3**	221.1**	206.56**	102.91**
Line effect	2	22.75**	11.86**	0.475	0.510	196.82**	566.75**	19.33**	3.95**	10.42**	4.49**	8.08**	22.7**
Tester effect	3	155.00**	376.48**	2.77**	30.08**	104.21**	380.48**	35.24**	8.55**	224.29**	194.36**	9.21**	155.00**
Line vs. Tester effect	6	14.75**	4.67**	0.578	0.479	39.34**	51.59**	10.92**	3.10**	0.353	1.77	0.915	14.7**
Error	36	3.24	18.58	0.71	1.07	87.03	50.65	2.64	0.54	5.17	4.14	6.47	3.25
Variance component													
б2gca		7.06	18.05	0.100	1.41	10.59	40.19	1.56	0.30	11.14	9.40	0.73	7.05
б2sca		3.54	-6.40	-0.07	-0.12	-2.67	7.38	3.10	0.83	-1.73	-0.75	-1.54	3.58
б2gca / б2sca		1.99	-2.82	-1.43	-11.75	-3.97	5.45	0.50	0.36	-6.44	-12.53	-0.47	1.96

*p< 0.05, **p< 0.01

Table 2: Range of standard heterosis for yield, its components and number of hybrids exhibiting significant heterosis

Sr. No.	Characters	Range (%)	S.E. ±	No. of hybrids showing desirable significant over checks			
				BP	Karjat-7	Sahyadri-2	Sahyadri-3
1.	Days to 50 per cent flowering	-2.11 to 20.23	1.17	1	0	0	0
2.	Plant height (cm)	-18.44 to 12.98	2.80	4	0	0	9
3.	No. of productive tillers plant^{-1}	-13.06 to 37.14	0.51	0	0	3	10
4.	Panicle length (cm)	15.07 to 20.28	0.53	11	11	10	4
5.	Total spikelets panicle^{-1}	-4.67 to 55.97	0	12	0	0	0
6.	No. of filled spikelets panicle^{-1}	-5.48 to 80.30	3.13	6	12	6	0
7.	Spikelet fertility (%)	-0.91 to 10.06	0.74	8	12	11	11
118.	1000 grain weight (g)	-19.35 to 15.45	0.45	0	2	5	12
9.	Grain yield plant^{-1} (g)	-28.02 to 53.14	1.36	10	10	7	2
10.	Straw yield plant^{-1} (g)	-38.53 to 36.51	1.16	3	9	8	0
11.	Harvest index (%)	-10.38 to 13.24	1.36	5	0	9	12
12.	Days to maturity	-3.91 to 15.06	1.17	1	0	0	1

BP- Better Parent

Table 3: Best performing cross combinations alongwith their gca effects, sca effects, heterobeltosis and standard heterosis for various traits in rice.

Sr. No.	Characters	Best performing hybrids	GCA effects		SCA effects	Hetero-beltiosis (%)	Standard heterosis over checks		
			P_1	P_2			Karjat-7	Sahyadri-2	Sahyadri-3
1.	Days to 50 per cent flowering	RTN17A x NPQ-49	A	A	-2.41*	3.12	13.36**	12.50**	4.21*
		RTN17A x RP-5898-19-8-6-1-1-1	A	A	-1.91	3.37	16.79**	15.91**	7.37**
2.	Plant height (cm)	RTN17A x Chedo Local	A	P	-1.97	-10.32*	8.55*	7.80	-8.17
		RTN12A x NPQ-49	A	G	-1.11	-2.17	-3.59	-4.26	-18.44**
3.	No. of productive tillers plant^{-1}	IR58025A x NPQ-49	A	A	0.55	60.00**	37.14**	16.36**	6.67**
		RTN17A x RP-5898-19-8-6-1-1-1	A	A	0.36	51.35**	20.00**	1.82*	-6.67**
4.	Panicle length (cm)	RTN12A x Chedo Local	A	A	0.56	21.28**	21.51**	19.52**	4.00**
		IR58025A x CR-2829-PLN-36	A	A	0.32	13.26**	12.44**	10.61**	-3.76**

Sr. No.	Characters	Best performing hybrids	GCA effects P1	GCA effects P2	SCA effects	Hetero-beltiosis (%)	Karjat-7	Sahyadri-2	Sahyadri-3
5.	Total spikelets panicle-1	RTN17A x NPQ-49	P	P	6.06**	3.33	50.16**	2.22	-1.89
		IR58025A x CR-2829-PLN-36	G	P	1.93	6.16	55.45**	5.82	1.57
6.	No. of filled spikelets panicle-1	RTN17A x Chedo Local	P	G	4.46**	9.33**	75.40**	10.65*	6.19
		IR58025A x RP-5898-19-8-6-1-1-1	G	P	3.41*	9.55**	73.10**	9.20*	4.80

Sr. No.	Characters	Best performing hybrids	GCA effects		SCA effects	Hetero-beltiosis (%)	Standard heterosis over		
			P_1	P_2			Karjat-7	Sahyadri-2	Sahyadri-3
	No. of filled spikelets panicle-1	RTN12A x RP-5898-19-8-6-1-1-1	A	P	2.68*	6.39	68.70**	6.43	2.14
		RTN17A x NPQ-49	P	A	2.34*	4.96	68.39**	6.23	1.95
7.	Spikelet fertility (%)	RTN17A x Chedo Local	A	A	2.65*	6.26**	17.23**	8.73**	8.78**
		IR58025A x NPQ-49	A	A	1.59	7.35**	18.61**	10.01**	10.06**
8.	1000 grain weight (g)	IR58025A x Chedo Local	A	A	-0.91	3.01*	1.63*	-4.60**	-14.07**
		RTN17A x CR-2829-PLN-36	A	A	-0.89	2.25*	8.02**	1.39*	-8.67**
9.	Grain yield plant-1 (g)	IR58025A x NPQ-49	A	G	0.96	62.91**	53.14**	35.51**	10.05**
		RTN12A x NPQ-49	A	G	-1.01	48.41**	46.40**	29.55**	5.20**
		RTN17A x NPQ-49	A	G	0.11	48.54**	44.21**	27.61**	3.64
10.	Straw yield plant-1 (g)	IR58025A x NPQ-49	A	G	0.90	49.66**	36.51**	23.61**	-13.08**
		RTN17A x CR-2829-PLN-36	A	P	0.82	-0.48	2.79	-6.93**	-34.55**
11.	Harvest index (%)	IR58025A x CR-2829-PLN-36	A	A	0.84	9.21**	-4.50**	9.10**	11.62**
		RTN17A x NPQ-49	A	A	0.50	3.37	-4.35**	9.27**	11.80**
12.	Days to maturity	RTN17A x NPQ-49	A	A	-1.90	2.38	9.94**	9.32**	0.78
		RTN12A x RP-5898-19-8-6-1-1-1	A	A	-2.40*	-2.85	6.53**	5.93**	-2.34

*p< 0.05, **p< 0.01 G = Good parent having significant GCA effects in desirable direction; A = Average parent having either positive or negative but non-significant GCA effects; P = Poor parent having significant GCA effects in undesirable direction.

Table 4: Promising hybrids for grain yield plant-1 with heterobeltiosis, standard heterosis, gca effects, sca effect and component showing significant desired heterosis in rice.

Sr. No.	Hybrids	Grain yield Plant-1	Hetero-beltosis	Standard heterosis (%)			GCA effects	SCA effects	Useful and significant for component traits			
				SC-I	SC-II	SC-III			Hetero-beltiosis	Karjat-7	Sahyadri-2	Sahyadri-3
1.	IR58025A x NPQ-49	39.75	62.91**	53.14**	35.51**	10.05**	A x G	0.96	PT, PL, FS, SF, GY, SY, HI.	PT PL, TSPP FS, SF, GY, SY.	PT, PL, FS, SF, TW, SY, GY, HI.	PH, PT, PL, SF, TW, GY, HI.
2.	RTN12A x NPQ-49	32.00	48.41**	46.40**	29.55**	5.20**	A x G	0.05	PT, PL, SF, GY, SY, HI.	PT, PL, TSPP, FS, SF, TW, GY, SY.	PT, PL, SF, TW, GY, SY, HI.	PH, SF, TW, GY, HI.

*p< 0.05, **p< 0.01

G = Good parent having significant GCA effects in desirable direction; A = Average parent having either positive or negative but non-significant GCA effects; P = Poor parent having significant GCA effects in undesirable direction.

PT = Productive tillers plant-1
FS = Filled spikelets panicle-1
DF = Days to 50 per cent flowering
TSPP = Total spikelets panicle-1
HI = Harvest index (%)
PL = Panicle length (cm
DM = Days to maturity
GY = Grain yield plant-1 (g)
SF = Spikelet fertility (%)
TW = 1000 Grain weight (g)
PH = Plant height (cm)
SY = Straw yield plant-1 (g)