International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(5): 07-12

Received: 02-07-2017
Accepted: 03-08-2017

BS Thorat
Regional Agriculture Research Station, Karjat, Raigad, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, MS, India

RL Kunkerkar
Regional Agriculture Research Station, Karjat, Raigad, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, MS, India

TA Bagkar
Regional Agriculture Research Station, Karjat, Raigad, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, MS, India

Correspondence
BS Thorat
Regional Agriculture Research Station, Karjat, Raigad, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, MS, India

Studies on heterosis for yield and its contributing traits in hybrid rice (*Oryza sativa* L.)

BS Thorat, RL Kunkerkar and TA Bagkar

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. Three 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 (cm), number of filled spikelets panicle^{-1}, spikelet fertility (%), 1000 grain weight (g) and harvest index (%). 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%.

Keywords: CMS lines, testers, heterosis, heterobeltosis, standard heterosis, rice, 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) [1] 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) [9, 17]. 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 three line 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. 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 studies for different yield and yield contributing traits in rice.
Therefore, hybridization programme made at Regional Agriculture Research Station, Karjat. Dist. Raigad. (MS) to estimate the nature and magnitude of heterosis 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 along with 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) [3].

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 Sanghera *et al.* (2012) [8], Latha *et al.* (2013) [8].

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 Singh *et al.* (2002) [11].

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% (RTN17A x Chedo Local) to -0.71% (RTN12A x RP-5898-19-8-6-1-1-1). The hybrid IR58025A x NPQ-49 recorded maximum negative heterotic effect over better parent -2.17% and standard checks (Karjat-7), (Sahyadri-2) and (Sahyadri-3) -3.80%, -4.47% and -18.62%. 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%). The hybrid IR58025A x NPQ-49 recoeded maximum positive heterotic effect over better parent 60.00% and standard checks (Karjat-7), (Sahyadri-2) and (Sahyadri-3) 37.14%, 16.36% and 6.67%. Similar results reported by Ram (1991) [13], Yadav *et al.* (2004) [18], Kunkerkar *et al.* (2012) [7], Latha *et al.* (2013) [8], Ghara *et al.* (2014) [4] and Kumar and Adilakshmi (2016) [6].

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%). Maximum significant positive standard heterosis observed in the hybrid RTN12A x Chedo Local over checks (Karjat-7) 21.51%, (Sahyadri-2) 19.52% and (Sahyadri-3) 4.00%. Panicle length (cm) reported by Pandey *et al* (1995) [10], Singh *et al.* (1999) [16], Yadav *et al.* (2004) [18] and Ghara *et al.* (2014) [4].

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. The standard heterosis over Karjat-7, Sahyadri-2 and Sahyadri-3 ranged from 45.91% (RTN17A x RP-5898-19-8-6-1-1-1) to 55.97% (IR58025A x Chedo Local), -0.68% (RTN17A x RP-5898-19-8-6-1-1-1) to 6.18% (IR58025A x Chedo Local) and -4.67% (RTN17A x RP-5898-19-8-6-1-1-1) to 1.91% (IR58025A x Chedo Local), respectively.

Number of filled spikelets panicle^{-1} is one of the most important yield component. Thus, the hybrids with positive heterosis for Number of filled spikelets panicle^{-1} are desirable for higher yields. Significant positive standard heterosis showed in all the hybrids over check Karjat-7. Maximum standard heterosis manifested by cross IR58025A x Chedo Local over checks (Karjat-7) 80.30%, (Sahyadri-2) 13.75% and (Sahyadri-3) 9.16%. Similar results reported by Kshirsagar *et al*. (2005).

Spikelet fertility (%) is generally associated with higher productivity. The range of heterobeltosis was -3.15% (RTN17A x RP-5898-19-8-6-1-1-1) to 7.35% (IR58025A x NPQ-49). Maximum positive significant heterotic effects over better parent 7.35%, (Karjat-7) 18.61%, (Sahyadri-2) 10.01% and (Sahyadri-3) 10.06% exhibited by the cross IR58025A x NPQ-49. Spikelet fertility (%) reported by Panday *et al.* (1995), Panwar *et al.* (1998) [11], Ramlingam *et al.* (2000), Ghara *et al.* (2014) [4] and Kumar and Adilakshmi (2016) [6].

The heterobeltosis for 1000 grain weight ranged from -0.14% (RTN17A x NPQ-49) to 17.01% (IR58025A x CR-2829-PLN-36). Out of 12 hybrids two, five and twelve crosses exhibited significant negative standard heterosis over checks Karjat-7, Sahyadri-2 and Sahyadri-3, respectively.

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% (RTN12A x CR-2829-PLN-36) to 62.91% (IR58025A x NPQ-49). The standard heterosis over checks Karjat-7, Sahyadri-2 and Sahyadri-3 ranged from -1.98% (RTN12A x CR-2829-PLN-36) to 53.14% (IR58025A x NPQ-49), -13.26% (RTN12A x CR-2829-PLN-36) to 35.51% (IR58025A x NPQ-49) and -29.56% (RTN12A x CR-2829-PLN-36) to 10.05% (IR58025A x NPQ-49), respectively. Significant positive heterosis for grain yield plant^{-1} (g) have been reported by many researchers, some of them are Virmani *et al.* (1982) [17], Faiz *et al.* (2006) [2], Kunkerkar *et al.* (2012) [7], Latha *et al.* (2013) [8], Ghara *et al.* (2014) [4] and Kumar and Adilakshmi (2016) [6].

Harvest index is generally associated with higher productivity. Value of heterobeltosis ranged from -0.68% (RTN17A x CR-2829-PLN-36) to 9.21% (IR58025A x CR-2829-PLN-36). The standard heterosis over checks Karjat-7, Sahyadri-2 and Sahyadri-3 ranged from -10.38% (RTN17A x CR-2829-PLN-36) to -3.12% (IR58025A x NPQ-49), 2.38% (RTN17A x CR-2829-PLN-36) to 10.68% (IR58025A x NPQ-49) and 4.75% (RTN17A x CR-2829-PLN-36) to 13.24% (IR58025A x NPQ-49), respectively.

Earlyness being a desirable trait and helps to develop early variety. The standard heterosis for days to maturity over checks Karjat-7, Sahyadri-2 and Sahyadri-3 ranged from 4.83% (IR58025A x CR-2829-PLN-36) to 15.06% (RTN17A x Chedo Local), 4.24% (IR58025A x CR-2829-PLN-36) to 14.41% (RTN17A x Chedo Local) and -3.91% (IR58025A x CR-2829-PLN-36) to 5.47% (RTN17A x Chedo Local), respectively.

Table 1: List of females, male lines and their hybrids

S. No.	CMS Lines	Restorer Lines	Hybrids
1	IR58025A	Chedo Local	IR58025A x Chedo Local
2	RTN12A	CR-2829-PLN-36	IR58025A x CR-2829-PLN-36
3	RTN17A	NPQ-49	IR58025A x NPQ-49
4		RP-5898-19-8-6-1-1-1	IR58025A x RP-5898-19-8-6-1-1-1
5			RTN12A x Chedo Local
6			RTN12A x CR-2829-PLN-36
7			RTN12A x NPQ-49
8			RTN12A x RP-5898-19-8-6-1-1-1
9			RTN17A x Chedo Local
10			RTN17A x CR-2829-PLN-36
11			RTN17A x NPQ-49
12			RTN17A x RP-5898-19-8-6-1-1-1

Table 2: Analysis of variance in Line x Tester analysis for twelve characters of Rice *Oryzasativa* L.

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**
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

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

Table 3: Estimates of heterosis over better parent and standard checks for days to 50 per cent flowering and plant height (cm).

S. No.	Crosses	BP	SC-I	SC-II	SC-III	S. No.	Crosses	BP	SC-I	SC-II	SC-III
1	IR58025A x Chedo Local	6.55**	17.94**	17.05**	8.42**	1	IR58025A x Chedo Local	-7.37	12.05**	11.28**	-5.20
2	IR58025A x CR-2829-PLN-36	-2.44	6.49**	5.68**	-2.11	2	IR58025A x CR-2829-PLN-36	-10.31*	2.41	1.70	-13.36**
3	IR58025A x NPQ-49	5.26**	14.50**	13.64**	5.26**	3	IR58025A x NPQ-49	-2.17	-3.80	-4.47	-18.62**
4	IR58025A x RP-5898-19-8-6-1-1-1	-4.73**	7.63**	6.82**	-1.05	4	IR58025A x RP-5898-19-8-6-1-1-1	-2.87	-3.59	-4.26	-18.44**
5	RTN12A x Chedo Local	7.58**	19.08**	18.18**	9.47**	5	RTN12A x Chedo Local	-5.90	13.77**	12.98**	-3.75
6	RTN12A x CR-2829-PLN-36	-1.04	8.78**	7.95**	0.00	6	RTN12A x CR-2829-PLN-36	-8.43*	4.45	3.72	-11.64**
7	RTN12A x NPQ-49	5.20**	15.65**	14.77**	6.32**	7	RTN12A x NPQ-49	-2.17	-3.59	-4.26	-18.44**
8	RTN12A x RP-5898-19-8-6-1-1-1	-3.71	8.78**	7.95**	0.00	8	RTN12A x RP-5898-19-8-6-1-1-1	-0.71	-1.45	-2.13	-16.62**
9	RTN17A x Chedo Local	8.62**	20.23**	19.32**	10.53**	9	RTN17A x Chedo Local	-10.32*	8.55*	7.80	-8.17
10	RTN17A x CR-2829-PLN-36	-1.04	8.78**	7.95**	0.00	10	RTN17A x CR-2829-PLN-36	-10.00*	2.84	2.13	-13.00**
11	RTN17A x NPQ-49	3.12	13.36**	12.50**	4.21*	11	RTN17A x NPQ-49	-2.17	-3.59	-4.26	-18.44**
12	RTN17A x RP-5898-19-8-6-1-1-1	3.37	16.79**	15.91**	7.37**	12	RTN17A x RP-5898-19-8-6-1-1-1	-1.79	-2.52	-3.19	-17.53**
	S.E.±	1.36	1.36	1.17			S.E.±			2.80	
	C.D. at 5%	3.99	3.99	3.44			C.D. at 5%			8.21	
	C.D. at 1%	5.43	5.43	4.68			C.D. at 1%			11.16	
Sig. Crosses	+ ve	5	12	12	7	Sig. Crosses	+ ve	0	3	2	0
	-ve	1	0	0	0		-ve	4	0	0	9

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

Table 4: Estimates of heterosis over better parent and standard checks for productive tillers plant-1 and panicle length (cm).

S. No.	Crosses	BP	SC-I	SC-II	SC-III
1	IR58025A x Chedo Local	27.41**	17.86**	0.00	-8.33**
2	IR58025A x CR-2829-PLN-36	34.40**	20.00**	1.82**	-6.67**
3	IR58025A x NPQ-49	60.00**	37.14**	16.36**	6.67**
4	IR58025A x RP-5898-19-8-6-1-1-1	45.94**	15.71**	-1.82*	-10.00**
5	RTN12A x Chedo Local	25.09**	15.71**	-1.82*	-10.00**
6	RTN12A x CR-2829-PLN-36	30.80**	16.79**	-0.91	-9.17**
7	RTN12A x NPQ-49	49.58**	28.21**	8.79**	-0.28
8	RTN12A x RP-5898-19-8-6-1-1-1	44.73**	17.86**	0.00	-8.33**
9	RTN17A x Chedo Local	20.84**	11.79**	-5.15**	-13.06**
10	RTN17A x CR-2829-PLN-36	36.00**	21.43**	3.03**	-5.56**
11	RTN17A x NPQ-49	41.25**	21.07**	2.73**	-5.83**
12	RTN17A x RP-5898-19-8-6-1-1-1	51.35**	20.00**	1.82*	-6.67**
	S.E.±	1.36	0.51		
	C.D. at 5%	3.99	1.49		
	C.D. at 1%	5.43	2.09		
Sig. Crosses	+ ve	12	12	6	1
	-ve	0	0	3	10

S. No.	Crosses	BP	SC-I	SC-II	SC-III
1	IR58025A x Chedo Local	19.76**	18.11**	16.18**	1.09
2	IR58025A x CR-2829-PLN-36	13.26**	12.44**	10.61**	-3.76**
3	IR58025A x NPQ-49	16.41**	19.82**	17.86**	2.55**
4	IR58025A x RP-5898-19-8-6-1-1-1	3.73**	2.30**	0.63	-12.44**
5	RTN12A x Chedo Local	21.28**	21.51**	19.52**	4.00**
6	RTN12A x CR-2829-PLN-36	8.86**	9.06**	7.28**	-6.65**
7	RTN12A x NPQ-49	14.10**	17.43**	15.52**	0.51
8	RTN12A x RP-5898-19-8-6-1-1-1	-0.95	-0.77	-2.39**	-15.07**
9	RTN17A x Chedo Local	22.15**	20.28**	18.31**	2.95**
10	RTN17A x CR-2829-PLN-36	11.24**	10.45**	8.64**	-5.47**
11	RTN17A x NPQ-49	16.26**	19.66**	17.71**	2.42**
12	RTN17A x RP-5898-19-8-6-1-1-1	5.77**	4.15**	2.45**	-10.86**
	S.E.±			0.53	
	C.D. at 5%			1.55	
	C.D. at 1%			2.11	
Sig. Crosses	+ ve	11	11	10	4
	-ve	0	0	1	6

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

Table 5: Estimates of heterosis over better parent and standard checksfor total spikelets and filled spikeletspanicle-1.

S. No.	Crosses	BP	SC-I	SC-II	SC-III
1	IR58025A x Chedo Local	8.07	55.97**	6.18	1.91
2	IR58025A x CR-2829-PLN-36	6.16	55.45**	5.82	1.57
3	IR58025A x NPQ-49	3.16	48.88**	1.35	-2.72
4	IR58025A x RP-5898-19-8-6-1-1-1	3.59	52.67**	3.93	-0.25
5	RTN12A x Chedo Local	4.79	54.58**	5.23	1.00
6	RTN12A x CR-2829-PLN-36	3.37	52.49**	3.80	-0.37
7	RTN12A x NPQ-49	0.53	48.29**	0.95	-3.11
8	RTN12A x RP-5898-19-8-6-1-1-1	1.74	50.07**	2.16	-1.95
9	RTN17A x Chedo Local	2.86	49.48**	1.76	-2.33
10	RTN17A x CR-2829-PLN-36	1.27	48.29**	0.95	-3.11
11	RTN17A x NPQ-49	3.33	50.16**	2.22	-1.89
12	RTN17A x RP-5898-19-8-6-1-1-1	-0.99	45.91**	-0.68	-4.67
	S.E.±	1.36	3.97		
	C.D. at 5%	3.99	11.65		
	C.D. at 1%	5.43	15.84		
Sig. Crosses	+ ve	0	12	0	0
	-ve	0	0	0	0

S. No.	Crosses	BP	SC-I	SC-II	SC-III
1	IR58025A x Chedo Local	14.11**	80.30**	13.75**	9.16
2	IR58025A x CR-2829-PLN-36	10.19*	74.10**	9.84*	5.40
3	IR58025A x NPQ-49	11.91*	76.82**	11.55*	7.05
4	IR58025A x RP-5898-19-8-6-1-1-1	9.55*	73.10**	9.20*	4.80
5	RTN12A x Chedo Local	11.51*	76.82**	11.55*	7.05
6	RTN12A x CR-2829-PLN-36	8.73	72.41**	8.77	4.38
7	RTN12A x NPQ-49	7.81	70.95**	7.85	3.49
8	RTN12A x RP-5898-19-8-6-1-1-1	6.39	68.70**	6.43	2.14
9	RTN17A x Chedo Local	9.33*	75.40**	10.65*	6.19
10	RTN17A x CR-2829-PLN-36	2.48	64.40**	3.72	-0.47
11	RTN17A x NPQ-49	4.96	68.39**	6.23	1.95
12	RTN17A x RP-5898-19-8-6-1-1-1	-2.67	56.13**	-1.50	-5.48
	S.E.±			3.13	
	C.D. at 5%			9.19	
	C.D. at 1%			12.49	
Sig. Crosses	+ ve	6	12	6	0
	-ve	0	0	0	0

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

Table 6: Estimates of heterosis over better parent and standard checks for spikelets fertility (%) and 1000 grain weight (g).

S. No.	Crosses	BP	SC-I	SC-II	SC-III
1	IR58025A x Chedo Local	4.70**	15.45**	7.08**	7.13**
2	IR58025A x CR-2829-PLN-36	1.43	11.84**	3.74**	3.78**
3	IR58025A x NPQ-49	7.35**	18.61**	10.01**	10.06**
4	IR58025A x RP-5898-19-8-6-1-1-1	2.68*	13.22**	5.02**	5.06**
5	RTN12A x Chedo Local	6.44**	14.25**	5.98**	6.03**
6	RTN12A x CR-2829-PLN-36	5.24**	12.96**	4.78**	4.83**
7	RTN12A x NPQ-49	4.18**	15.10**	6.76**	6.81**
8	RTN12A x RP-5898-19-8-6-1-1-1	4.57**	12.24**	4.11**	4.16**
9	RTN17A x Chedo Local	6.26**	17.23**	8.73**	8.78**
10	RTN17A x CR-2829-PLN-36	0.35	10.71**	2.69*	2.73*
11	RTN17A x NPQ-49	1.36	11.99**	3.88**	3.93**
12	RTN17A x RP-5898-19-8-6-1-1-1	-3.15**	6.83**	-0.91	-0.86
	S.E.±	1.36	0.74		
	C.D. at 5%	3.99	2.17		
	C.D. at 1%	5.43	2.94		
Sig. Crosses	+ ve	8	12	11	11
	-ve	1	0	0	0

S. No.	Crosses	BP	SC-I	SC-II	SC-III
1	IR58025A x Chedo Local	3.01*	1.63*	-4.60**	-14.07**
2	IR58025A x CR-2829-PLN-36	17.01**	15.45**	8.37**	-2.39*
3	IR58025A x NPQ-49	1.50*	0.15	-6.00**	-15.33**
4	IR58025A x RP-5898-19-8-6-1-1-1	2.25*	0.89	-5.30**	-14.70**
5	RTN12A x Chedo Local	14.46**	8.17**	1.53*	-8.54**
6	RTN12A x CR-2829-PLN-36	11.79**	5.65**	-0.84	-10.68**
7	RTN12A x NPQ-49	1.57	-4.01**	-9.90**	-18.84**
8	RTN12A x RP-5898-19-8-6-1-1-1	0.94	-4.61**	-10.46**	-19.35**
9	RTN17A x Chedo Local	0.28	5.94**	-0.56	-10.43**
10	RTN17A x CR-2829-PLN-36	2.25*	8.02**	1.39*	-8.67**
11	RTN17A x NPQ-49	-0.14	5.50**	-0.98	-10.80**
12	RTN17A x RP-5898-19-8-6-1-1-1	0.28	5.94**	-0.56	-10.43**
	S.E.±			0.45	
	C.D. at 5%			1.32	
	C.D. at 1%			1.80	
Sig. Crosses	+ ve	7	8	3	0
	-ve	0	2	5	12

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

Table 7: Estimates of heterosis over better parent and standard checks for grain yield plant-1 (g) and straw yield plant-1 (g).

S. No.	Crosses	BP	SC-I	SC-II	SC-III	S. No.	Crosses	BP	SC-I	SC-II	SC-III
1	IR58025A x Chedo Local	35.23**	27.12**	12.49**	-8.65**	1	IR58025A x Chedo Local	-11.94**	20.21**	8.84**	-23.46**
2	IR58025A x CR-2829-PLN-36	13.22**	5.56**	-6.59**	-24.14**	2	IR58025A x CR-2829-PLN-36	-6.43**	-3.35	-12.49**	-38.46**
3	IR58025A x NPQ-49	62.91**	53.14**	35.51**	10.05**	3	IR58025A x NPQ-49	49.66**	36.51**	23.61**	-13.08**
4	IR58025A x RP-5898-19-8-6-1-1-1	43.24**	22.51**	8.41**	-11.96**	4	IR58025A x RP-5898-19-8-6-1-1-1	2.10	17.19**	6.11**	-25.38**
5	RTN12A x Chedo Local	24.98**	23.28**	9.09**	-11.41**	5	RTN12A x Chedo Local	-14.89**	16.18**	5.20**	-26.03**
6	RTN12A x CR-2829-PLN-36	-0.62	-1.98	-13.26**	-29.56**	6	RTN12A x CR-2829-PLN-36	-6.53**	-3.45*	-12.58**	-38.53**
7	RTN12A x NPQ-49	48.41**	46.40**	29.55**	5.20*	7	RTN12A x NPQ-49	34.14**	30.45**	18.12**	-16.94**
8	RTN12A x RP-5898-19-8-6-1-1-1	19.77**	18.15**	4.55	-15.10**	8	RTN12A x RP-5898-19-8-6-1-1-1	-0.57	14.11**	3.33	-27.34**
9	RTN17A x Chedo Local	24.24**	20.62**	6.74**	-13.32**	9	RTN17A x Chedo Local	-11.17**	21.26**	9.80**	-22.79**
10	RTN17A x CR-2829-PLN-36	3.17	0.17	-11.36**	-28.02**	10	RTN17A x CR-2829-PLN-36	-0.48	2.79	-6.93**	-34.55**
11	RTN17A x NPQ-49	48.54**	44.21**	27.61**	3.64	11	RTN17A x NPQ-49	33.49**	31.44**	19.02**	-16.31**
12	RTN17A x RP-5898-19-8-6-1-1-1	20.10**	16.60**	3.18	-16.21**	12	RTN17A x RP-5898-19-8-6-1-1-1	3.40	18.68**	7.46**	-24.44**
S.E.±		1.36	1.36			S.E.±				1.16	
C.D. at 5%		3.99	3.99			C.D. at 5%				3.40	
C.D. at 1%		5.43	5.43			C.D. at 1%				4.63	
Sig. Crosses	+ ve	10	10	7	2	Sig. Crosses	+ ve	3	9	8	0
	-ve	0	0	3	9		-ve	5	1	3	12

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

Table 8: Estimates of heterosis over better parent and standard checks for harvest index (%) and days to maturity.

Sr. No.	Crosses	BP	SC-I	SC-II	SC-III	Sr. No.	Crosses	BP	SC-I	SC-II	SC-III
1	IR58025A x Chedo Local	7.14**	-6.32**	7.03**	9.50**	1	IR58025A x Chedo Local	5.00**	13.35**	12.71**	3.91*
2	IR58025A x CR-2829-PLN-36	9.21**	-4.50*	9.10**	11.62**	2	IR58025A x CR-2829-PLN-36	-1.86	4.83**	4.24*	-3.91*
3	IR58025A x NPQ-49	4.70*	-3.12	10.68**	13.24**	3	IR58025A x NPQ-49	4.00*	10.80**	10.17**	1.56
4	IR58025A x RP-5898-19-8-6-1-1-1	6.59**	-6.79**	6.48**	8.95**	4	IR58025A x RP-5898-19-8-6-1-1-1	-3.62*	5.68**	5.08**	-3.13
5	RTN12A x Chedo Local	2.49	-6.07**	7.31**	9.79**	5	RTN12A x Chedo Local	5.78**	14.20**	13.56**	4.69**
6	RTN12A x CR-2829-PLN-36	0.09	-8.27**	4.79*	7.22**	6	RTN12A x CR-2829-PLN-36	-0.79	6.53**	5.93**	-2.34
7	RTN12A x NPQ-49	4.68*	-3.14	10.66**	13.22**	7	RTN12A x NPQ-49	3.96*	11.65**	11.02**	2.34
8	RTN12A x RP-5898-19-8-6-1-1-1	1.01	-7.42**	5.76**	8.21**	8	RTN12A x RP-5898-19-8-6-1-1-1	-2.85	6.53**	5.93**	-2.34
9	RTN17A x Chedo Local	0.45	-9.35**	3.56	5.96**	9	RTN17A x Chedo Local	6.57**	15.06**	14.41**	5.47**
10	RTN17A x CR-2829-PLN-36	-0.68	-10.38**	2.38	4.75*	10	RTN17A x CR-2829-PLN-36	-0.79	6.53**	5.93**	-2.34
11	RTN17A x NPQ-49	3.37	-4.35*	9.27**	11.80**	11	RTN17A x NPQ-49	2.38	9.94**	9.32**	0.78
12	RTN17A x RP-5898-19-8-6-1-1-1	-0.22	-9.96**	2.87	5.25*	12	RTN17A x RP-5898-19-8-6-1-1-1	2.59	12.50**	11.86**	3.13
	S.E.±	1.36	1.36				S.E.±			1.17	
	C.D. at 5%	3.99	3.99				C.D. at 5%			3.44	
	C.D. at 1%	5.43	5.42				C.D. at 1%			4.68	
Sig. Crosses	+ ve	5	00	9	12	Sig. Crosses	+ ve	4	12	12	2
	-ve	0	8	0	0		-ve	1	0	0	1

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

Conclusion

In the hybrids, *viz*., IR58025A X NPQ-49 and RTN12A X NPQ-49 were recorded highly positive significant heterosis over better parent and three standard checks (Karjat-7, Sahyadri-2 and Sahyadri-3) in most of the yield and yield contributing characters. While in case of the traits *viz*., plant height (cm) negative heterosis was also observed in these combinations which are desirable for those traits.

References

1. Anonymous. Directorate of Economics and Statistics, DAC and FW, GOI, 2015-16.
2. Faiz FA, Sabar M, Awan TH, Ijaz M, Manzoor Z. Heterosis and combining ability analysis in basmati rice hybrids. J Anim. Pl. Sci. 2006; 16(1-2):56-59.
3. Fonseco S, Patterson FL. Hybrid vigour in a seven parent diallel cross in comman winter wheat *Triticum aestivum*. Crop Sci. 1968; 8:85-88.
4. Ghara Ammar Gholizadeh, Ghorbanali Nematzadeh, Nadali Bagheri Morteza Oladi, Asghar Bagheri. Heritability and heterosis of agronomic traits in rice lines. Int. J Farm & Alli. Sci. 2014; 3(1):66-70.
5. Jayasudha S, Deepak Sharma. Heterosis studies for yield and physiological traits in rice hybrids under shallow low land condition Ele. J of Plant Breeding. 2010; 1(6):1464-1467.
6. Kumar A. Satyaraj, Adilakshmi D. Heterosis for yield, yield components and quality traits in rice hybrids *Oryza sativa* L. Plant Archives. 2016; 16(1):237-242.
7. Kunkerkar RL, Sawant DS, Shetye VN, Vanave PB. Heterosis studies in rice hybrids involving diverse cytosteriles Oryza. 2012; 49(1):60-61.
8. Latha Srikrishna, Deepak Sharma, Gulzar S. Sanghera Combining ability and heterosis for grain yield and its component traits in rice *Oryza sativa* L. Not. Sci. Biol. 2013; 5(1):90-97.
9. Lin SC, Yuan LP. Hybrid rice breeding in China. In: Innovative approaches to Rice Breeding, Int. Rice Res. Inst., Philippines. 1980, 35-51.
10. Pandey MP, Singh JP, Singh H. Heterosis breeding for grain yield and other agronomic characters in rice *Oryza sativa* L. Indian J Genet. 1995; 55(4):438-445.
11. Panwar DVS, Kumar R, Singh A, Mehla BS. Studying heterosis for grain yield and its components in hybrid rice. IRRN. 1998; 23(2):15.
12. Panse VG, Sukhatme PV. Statistical methods for agriculture workers, I.A.R.I, New Delhi, 1978.
13. Ram T. Heterosis and inbreeding depression in rice. Int. Rice Res. News Lett. 1991; 71(5):7.
14. Ramalingam J, Nadarajan N, Vanniarajan C. Heterotic ability involving cytoplasmic male sterile lines in rice. Madras Agric. J. 2000; 87(1-3):140-141.

15. Satyaraj Kumar A. Adilakshmi D. Heterosis for yield, yield components and quality traits in rice hybrids *Oryza sativa* L. Plant Archives. 2016; 16(1):237-242.
16. Singh AK, Payasi SK. Stability assessment in early duration genotypes of rice. Crop Res. 1999; 18(3):433-436.
17. Virmani SS, Aquino RC, Khush GS. Heterosis breeding in rice *Oryza sativa* L. Theo. and App. Gen. 1982; 63(4):373-380.
18. Yadav LS, Maurya DM, Giri SP, Singh SB. Nature and magnitude of heterosis for growth yield and yield components in hybrid rice. Oryza. 2004; 41(1&2):1-3.