ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Combining Ability Analysis for Yield and Yield Contributing Traits in Hybrid Rice (*Oryza sativa* L.).

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Received: 30th December, 2016 Accepted: 4th April, 2017

Abstract

Combining ability on grain yield and its components from line × tester analysis of 12 rice hybrids produced by crossing three CMS lines and four testers were studied. The additive gene action was observed for days to 50 per cent flowering, number of filled spikelets panicle^{-1} and days to maturity. Plant height, number of productive tillers plant^{-1}, panicle length, total number of spikelets panicle^{-1}, spikelet fertility, 1000 grain weight, grain yield plant^{-1}, straw yield plant^{-1} and harvest index showed the non-additive gene action. IR58025A was the good general combiner among the female parent for a total number of spikelets panicle^{-1} and number of filled spikelets panicle^{-1}. Male parent NPQ-49 was best general combiner for grain yield plant^{-1} and straw yield plant^{-1}. The crosses IR58025A x NPQ-49 and RTN12A x NPQ-49 were identified as most promising for yield and desired traits based on SCA effects, *per se* performance and GCA effects of parents for grain yield and its components in rice which could be exploited beneficially in future rice breeding program by adopting heterosis breeding strategy.

Keywords: CMS lines, testers, hybrids, GCA, SCA, rice, yield contributing traits.

Introduction

Rice is the 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 a pivotal place in Indian Agriculture. In order to meet the domestic demand of the increasing population, the present day production of 107.40 million tonnes (Annonymous, 2015-16) of milled rice has to be increased to 125 million tonnes 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 selfsufficiency in rice, additional production of 1.17 million tonnes 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. In a hybrid breeding program, choice of suitable parents is of primary importance since *per se* performance of parents is not always a true indicator of its combining ability in hybrid combination (Swamy *et al*., 2003). Therefore, performance of a F_1 hybrid depends on choice of parents. Several methods like *per se* performance, genetic diversity, combining ability *etc.*, have been attempted to select the parents. Among them combining ability analysis offers a powerful tool for estimating the value of a parent to produce superior hybrid. The combining ability studies of the parents provide information which helps in the selection of better parents for effective breeding. Its role is important to decide parents, crosses and appropriate breeding procedure to be followed to select desirable segregants (Salgotra *et al.*, 2009). Keeping this in view, the present investigation was carried out to study the combining ability in order to identify good combiners and superior hybrid combinations.

Materials and Methods

The experiment was conducted at the Experimental farm of Regional Agriculture Research Station, Karjat (Raigad). The identified parents were grown 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 were done during *kharif* 2016. Three CMS lines *viz*., IR58025A, RTN 12A and RTN17A were crossed with four testers *viz.*, Chedo Local, CR-2829-PLN-36, NPQ-49 and RP-5898-19-8-6-1-1-1 in a Line × Tester mating design and 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 21st June 2016. Then twenty-five days old seedlings were transplanted in the main field at 20x15 cm spacing with single seedling per hill having plot size 3x0.60 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

Table 1. Analysis of variance in Line x Tester analysis for twelve characters in 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													
б^{2}gca		7.06	18.05	0.100	1.41	10.59	40.19	1.56	0.30	11.14	9.40	0.73	7.05
б^{2}sca		3.54	-6.40	-0.07	-0.12	-2.67	7.38	3.10	0.83	-1.73	-0.75	-1.54	3.58
б^{2}gca / б^{2}sca		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*

applied. All standard agronomic recommended practices and plant protection measures were adopted for raising a 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 per plant, straw yield per plant, harvest index, 1000 grain weight and days to maturity. Collected data were subjected to statistical analysis using line × tester analysis by Kempthorne (1957).

Results and Discussion

The analysis of variance of Line X Tester analysis revealed that significant genotypic effect for all the characters 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 presence of diversity among treatments (Table 1). Significant variance due to females and males indicated the 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}. Variance 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 the considerable amount of genetic variability among parents and hybrids for all the traits under study. The parents vs. hybrids comparison were found to be significant for all the characters indicating a substantial amount of heterosis in hybrids. Similar results reported by Sanghera *et al.*, (2012), Latha *et al.*, (2013), Islam *et al.*, (2015) and Khute *et al.*, (2015).

The general combining ability (GCA) identifies superior parents while specific combining ability (SCA) helps in identification of good hybrid combinations which may ultimate lead to the development of hybrids (Shiva Prasad *et al.*, 2011). Based on estimates of *per se* general combining ability effects for various characters (Table 2). It was observed that among three females, IR58025A was found to be good general combiner for the characters like total number of spikelets panicle^{-1} and number of filled spikelets panicle^{-1} and NPQ-49 were found to be good general combiner for the character plant height, grain yield plant^{-1} and straw yield plant^{-1}. The male parent, Chedo Local found to be good general combiner

Table 2. Crosses with SCA effects, Mean performance and GCA effects of parents for different characters of rice

Crosses	Days to 50 per cent flowering					Plant height (cm)				
	Mean performance	SCA Effects	GCA Effects: Female parent	GCA Effects: Male Parent	GCA Status	Mean performance	SCA Effects	GCA Effects: Female parent	GCA Effects: Male Parent	GCA Status
IR58025A x Chedo Local	103	0.33	-1.33	5.16**	A x P	104	0.86	-0.306	8.72**	A x P
IR58025A x CR-2829-PLN-36	93	0.00		-4.50**	A x G	95	-0.47		1.05	A x A
IR58025A x NPQ-49	100	1.33		1.16	A x A	89	0.30		-5.38**	A x G
IR58025A x RP-5898-19-8-6-1-1-1	94	-1.66		-1.83	A x A	90	-0.69		-4.38**	A x G
RTN12A x Chedo Local	104	0.08	-0.08	5.16**	A x P	106	1.11	1.11	8.72**	A x P
RTN12A x CR-2829-PLN-36	95	0.75		-4.50**	A x G	97	0.11		1.05	A x A
RTN12A x NPQ-49	101	1.08		1.16	A x A	90	-1.11		-5.38**	A x G
RTN12A x RP-5898-19-8-6-1-1-1	95	-1.91		-1.83	A x A	92	-0.11		-4.38**	A x G
RTN17A x Chedo Local	105	-0.41	1.41	5.16**	A x P	101	-1.97	-0.80	8.72**	A x P
RTN17A x CR-2829-PLN-36	95	-0.75		-4.50**	A x G	96	0.36		1.05	A x A
RTN17A x NPQ-49	99	-2.41*		1.16	A x A	90	0.80		-5.38**	A x G
RTN17A x RP-5898-19-8-6-1-1-1	102	3.58*		-1.83	A x A	91	0.80		-4.38**	A x G
	No. of productive tillers plant^{-1}					Panicle length (cm)				
IR58025A x Chedo Local	11.00	0.03	0.22	-0.48	A x A	25.63	-0.46	0.06	1.53	A x A
IR58025A x CR-2829-PLN-36	11.20	-0.16		-0.08	A x A	24.40	0.32		-0.48	A x A
IR58025A x NPQ-49	12.80	0.55		0.79	A x A	26.00	0.11		1.32	A x A
IR58025A x RP-5898-19-8-6-1-1-1	10.80	-0.42		-0.22	A x A	22.20	0.02		-2.38*	A x P
RTN12A x Chedo Local	10.80	0.11	-0.06	-0.48	A x A	26.37	0.56	-0.23	1.53	A x A
RTN12A x CR-2829-PLN-36	10.90	-0.18		-0.08	A x A	23.67	-0.11		-0.48	A x A
RTN12A x NPQ-49	11.97	0.00		0.79	A x A	25.48	-0.10		1.32	A x A
RTN12A x RP-5898-19-8-6-1-1-1	11.00	0.06		-0.22	A x A	21.53	-0.34		-2.38*	A x P
RTN17A x Chedo Local	10.43	-0.15	-0.16	-0.48	A x A	26.10	-0.09	0.16	1.53	A x A
RTN17A x CR-2829-PLN-36	11.33	0.35		-0.08	A x A	23.97	-0.21		-0.48	A x A
RTN17A x NPQ-49	11.30	-0.56		0.79	A x A	25.97	-0.01		1.32	A x A
RTN17A x RP-5898-19-8-6-1-1-1	11.20	0.36		-0.22	A x A	22.60	0.32		-2.38*	A x P
IR58025A x Chedo Local	261.90	0.67	3.73*	3.90**	G x G	245.75	-2.48*	6.29**	8.23**	G X G
IR58025A x CR-2829-PLN-36	261.03	1.93		1.77	G x A	237.30	-1.12		-1.57	G x A
IR58025A x NPQ-49	250.00	-4.11**		-3.20*	G x P	241.00	0.19		0.80	G x A
IR58025A x RP-5898-19-8-6-1-1-1	256.37	1.50		-2.46*	G x P	235.93	3.41*		-7.47**	G x P
RTN12A x Chedo Local	259.57	1.51	0.56	3.90**	A x G	241.00	-1.97	1.03	8.23**	A x G
RTN12A x CR-2829-PLN-36	256.05	0.12		1.77	A x A	235.00	1.83		-1.57	A x A
RTN12A x NPQ-49	249.00	-1.94		-3.20*	A x P	233.00	-2.54*		0.80	A x A
RTN12A x RP-5898-19-8-6-1-1-1	252.00	0.31		-2.46*	A x P	229.94	2.68*		-7.47**	A x P
RTN17A x Chedo Local	251.00	-2.18	-4.30**	3.90**	P x G	239.07	4.46**	-7.33**	8.23**	P x G
RTN17A x CR-2829-PLN-36	249.00	-2.05		1.77	P x A	224.08	-0.71		-1.57	P X A
RTN17A x NPQ-49	252.14	6.06**		-3.20*	P x P	229.52	2.34*		0.80	P x A
RTN17A x RP-5898-19-8-6-1-1-1	245.00	-1.82		-2.46*	P x P	212.80	-6.09**		-7.47**	P x P

	Spikelet fertility (%)					1000 Grain weight (g)				
IR58025A x Chedo Local	93.84	-1.30	1.14	1.84	A x A	22.80	-0.91	0.10	0.26	A x A
IR58025A x CR-2829-PLN-36	90.91	-1.14		-1.24	A x A	25.90	1.18		1.26	A x A
IR58025A x NPQ-49	96.41	1.59		1.51	A x A	22.47	-0.19		-0.78	A x P
IR58025A x RP-5898-19-8-6-1-1-1	92.03	0.84		-2.11	A x A	22.63	-0.07		-0.74	A x A
RTN12A x Chedo Local	92.88	-1.34	0.22	1.84	A x A	24.27	1.27	-0.61	0.26	A x A
RTN12A x CR-2829-PLN-36	91.83	0.69		-1.24	A x A	23.70	-0.29		1.26	A x A
RTN12A x NPQ-49	93.56	-0.32		1.51	A x A	21.53	-0.40		-0.78	A x P
RTN12A x RP-5898-19-8-6-1-1-1	91.24	0.98		-2.11	A x A	21.40	-0.58		-0.74	A x A
RTN17A x Chedo Local	95.29	2.65*	-1.36	1.84	A x A	23.77	-0.35	0.51	0.26	A x A
RTN17A x CR-2829-PLN-36	89.99	0.44		-1.24	A x A	24.23	-0.89		1.26	A x A
RTN17A x NPQ-49	91.04	-1.27		1.51	A x A	23.67	0.59		-0.78	A x P
RTN17A x RP-5898-19-8-6-1-1-1	86.84	-1.82		-2.11	A x A	23.77	0.65		-0.74	A x A
IR58025A x Chedo Local	33.00	0.06	0.26	0.78	A x A	39.80	0.07	0.27	0.77	A x A
IR58025A x CR-2829-PLN-36	27.40	-0.93		-6.01**	A x P	32.00	-0.92		-6.00**	A x P
IR58025A x NPQ-49	39.75	0.96		5.28**	A x G	45.20	0.90		5.24**	A x G
IR58025A x RP-5898-19-8-6-1-1-1	31.80	-0.09		-0.05	A x A	38.80	-0.08		-0.06	A x A
RTN12A x Chedo Local	32.00	-0.17	-0.83	0.78	A x A	38.47	-0.18	-0.84	0.77	A x A
RTN12A x CR-2829-PLN-36	25.44	0.13		-6.01**	A x P	31.97	0.14		-6.00**	A x P
RTN12A x NPQ-49	38.00	0.05		5.28**	A x G	43.19	0.06		5.24**	A x G
RTN12A x RP-5898-19-8-6-1-1-1	30.67	-0.01		-0.05	A x A	37.78	-0.02		-0.06	A x A
RTN17A x Chedo Local	31.31	0.11	0.56	0.78	A x A	40.15	0.12	0.57	0.77	A x A
RTN17A x CR-2829-PLN-36	26.00	0.80		-6.01**	A x P	34.03	0.82		-6.00**	A x P
RTN17A x NPQ-49	37.43	-1.01		5.28**	A x G	43.52	-1.00		5.24**	A x G
RTN17A x RP-5898-19-8-6-1-1-1	30.27	0.10		-0.05	A x A	39.29	0.11		-0.06	A x A
	Harvest index (%)					Days to maturity				
IR58025A x Chedo Local	45.27	-0.25	0.70	-0.29	A x A	133	0.32	-1.32	5.14**	A x A
IR58025A x CR-2829-PLN-36	46.14	0.84		-0.52	A x A	123	0.01		-4.51**	A x G
IR58025A x NPQ-49	46.81	-0.50		1.49	A x A	130	1.30		1.17	A x A
IR58025A x RP-5898-19-8-6-1-1-1	45.03	-0.09		-0.68	A x A	124	-1.67		-1.84	A x A
RTN12A x Chedo Local	45.38	0.36	0.19	-0.29	A x A	134	0.08	-0.09	5.14**	A x A
RTN12A x CR-2829-PLN-36	44.32	-0.46		-0.52	A x A	125	0.74		-4.51**	A x G
RTN12A x NPQ-49	46.80	-0.00		1.49	A x A	131	1.07		1.17	A x A
RTN12A x RP-5898-19-8-6-1-1-1	44.73	0.10		-0.68	A x A	125	-1.90		-1.84	A x A
RTN17A x Chedo Local	43.80	-0.11	-0.90	-0.29	A x A	135	-0.42	1.40	5.14**	A x A
RTN17A x CR-2829-PLN-36	43.30	-0.38		-0.52	A x A	125	-0.76		-4.51**	A x G
RTN17A x NPQ-49	46.21	0.50		1.49	A x A	129	-2.40*		1.17	A x A
RTN17A x RP-5898-19-8-6-1-1-1	43.51	-0.014		-0.68	A x A	132	3.56*		-1.84	A x A

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 an undesirable direction.

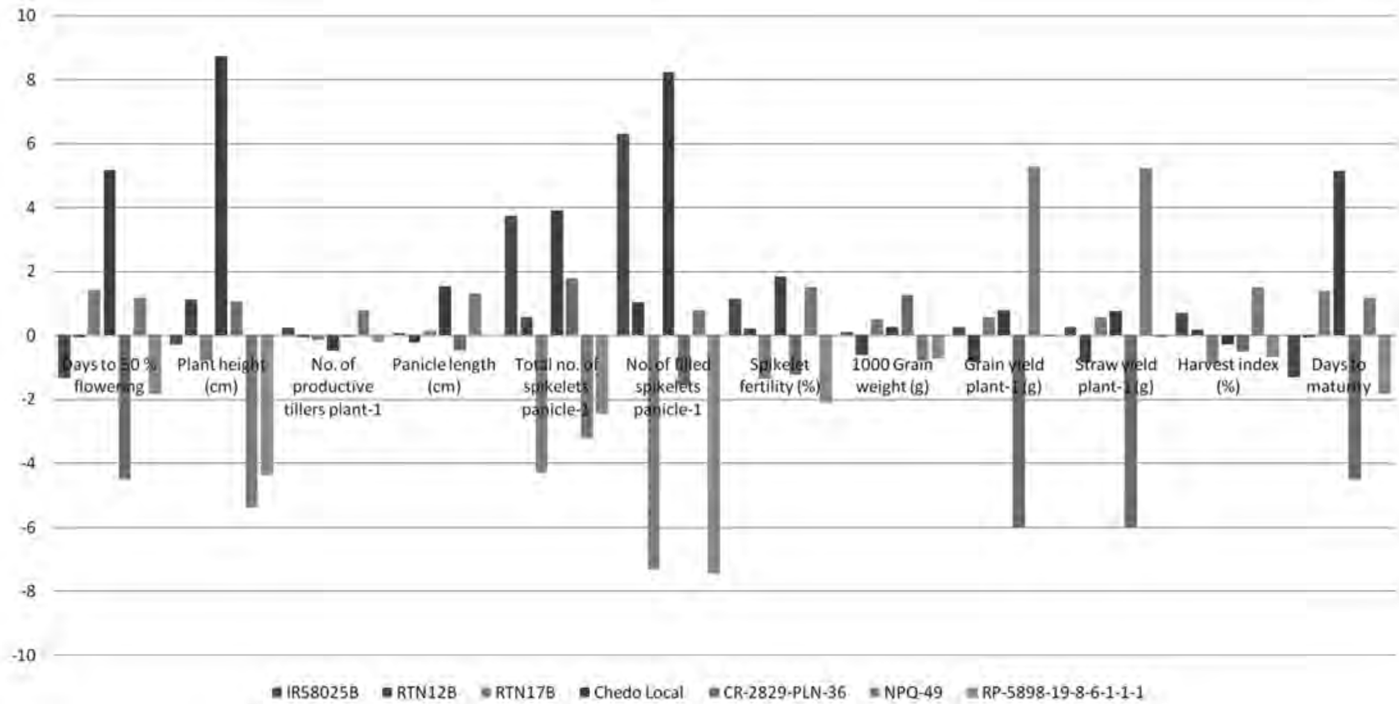

Figure 1. Multiple bar diagram – indicating GCA effects of seven parents for twelve characters

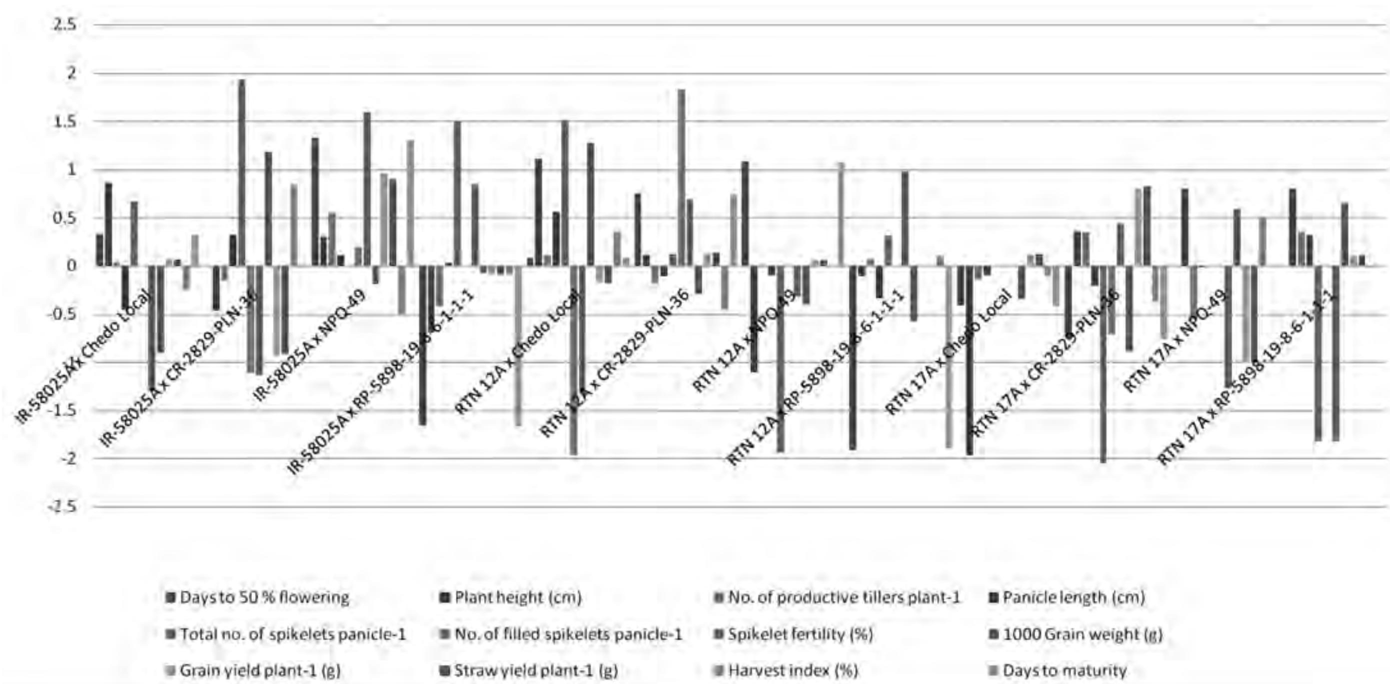

Figure 2. Multiple bar diagram – indicating SCA effects of twelve hybrids for twelve characters.

for the characters total number of spikelets panicle^{-1} and number of filled spikelets panicle^{-1}.

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 Sanghera *et al.*, (2012), Latha *et al.*, (2013), Islam *et al.*, (2015), Khute *et al.*, (2015) and Showkat *et al.*, (2015).

The specific combining ability (SCA) of crossess is the estimation and the understanding of the effect of non-additive gene action for a trait which is an indicator for the selection of a hybrid combination. The estimates of SCA effect revealed that none of the hybrids was consistently proved superior for all the traits. As many as 7 cross combinations exhibited positive SCA effect for grain yield plant^{-1}. Interestingly, two hybrids IR58025A x NPQ-49 and RTN12A x NPQ-49 exhibited positive SCA effect for this trait. These two crosses also manifested significant and desirable SCA effect for most of the yield attributing traits. Thus, hybrids with high SCA effect for grain yield plant^{-1} were also associated with high and desired SCA effect for yield contributing characters. Similar results were also reported by Thakare *et al.*, (2009), Sanghera *et al.*, (2012), Sharma *et al.*, (2013), Priyanka *et al.*, (2014) and Rahaman (2016).

On the basis of *per se* performance and combining ability three parents *viz*., IR58025A, NPQ-49 and Chedo Local were identified as good combiners for most of the traits. Hence they may be extensively used in future hybrid rice breeding programme and the hybrids *viz*., IR58025A x NPQ-49 and RTN12A x NPQ-49 was found to be the best crosses for yield contributing traits and may be evaluated critically to judge its superiority in performance and seed production technique for its utility on a commercial scale.

References

Anonymous, 2015-16. Maharashtra State Annual Rice Workshop Progress Report, pp:12.

Islam Ariful, MD, Khaleque Mian MA, Golam Rasul, Khaliq QA and Mannan Akanda, MA 2015. Estimation of gene action and variance components of some reproductive traits of rice (*Oryza sativa* L.) through line x tester analysis *J. Rice Res.*, 3 (3), pp:2-9.

Kempthorne, O. 1957. An introduction to genetic statistics. John Wiley and Sons. Inc., New York. pp:453-471.

Khute Ishu Kumar, Satyapal Singh, Parmeshwar Sahu and Deepak Sharma 2015. Gene action and combining ability analyses to develop NPT based rice hybrids in Chhattisgarh plains. *Electronic Journal of Plant Breeding*, 6 (2), pp:366-372.

Latha Srikrishna, Deepak Sharma, Gulzar S. Sanghera 2013. Combining ability and heterosis for grain yield and its component traits in rice (*Oryza sativa* L.) *Not. Sci. Biol*., 5 (1), pp:90-97.

Priyanka, Kumari, Jaiswal, H.K. and Showkat, A. Waza 2014. Combining ability and heterosis for yield, its component traits and some grain quality parameters in rice (*Oryza sativa* L.). *J. of Applied and Natural Sci.* 6 (2), pp:495-506.

Rahaman, Asadur Md. 2016. Study of nature and magnitude of gene action in hybrid rice (*Oryza sativa* L.) through experiment of line x tester mating design. *Int. J. of Applied Res.*, 2 (2), pp:405-410.

Salgotra, R.K., Gupta, B.B. and Singh, Praveen 2009. Combining ability studies for yield and yield components in Basmati rice, *Oryza* 46 (1), pp:12-16.

Sanghera Gulzar, S. and Hussain Waseem 2012. Heterosis and combining ability estimates using line x tester analysis to develop rice hybrids for temperate conditions. *Notulae Scientia Biologicae*, 4 (3), pp:131-142.

Sharma, C.L., Singh, N.K., Mall, A.K., Kumar, K. and Singh, O.N. 2013. Combining ability for yield and yield attributes in rice (*Oryza sativa* L.) genotypes using cms system. *SAARC J. Agri*., 11 (1), pp:23-33.

Shiv Prasad, G., Subba Rao, L.V., Sujata, M. and Chaitanya, U. 2013. Heterosis and combining ability analysis for few cold tolerant rice germplasm lines at seedling stage *International Journal of Development Research* 3(8) pp:010-012.

Showkat, A., Waza, H.K., Jaiswal, T., Sravan, Kumari Priyanka, Dilruba, A., Bano and Ved, P. Rai 2015. Combining ability analysis for various yield and quality traits in rice (*Oryza sativa* L.). *J. of App. and Nat. Sci.* 7 (2), pp:865-873.

Swamy MH, Gururaja Rao MR and Vidyachandra B 2003. Studies on combining ability in rice hybrids involving new CMS lines. *Karnataka J. Agril. Sci*. 16(2):228-233.

Thakare, I.S., Mehta, A.M., Patel, J.S. and Takle, S.R. 2009. Combining Ability Analysis for Yield and Grain Quality Traits in Rice Hybrids. *Journal of Rice Research.* 3 (1), pp:1-5.