International Journal of Agriculture Sciences
ISSN: 0975-3710&E-ISSN: 0975-9107, Volume 10, Issue 6, 2018, pp.-5630-5634.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

COMBINING ABILITY AND GENE ACTION FOR GRAIN YIELD AND ITS ATTRIBUTING TRAITS IN RICE (*Oryza sativa* L.)

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Received: March 24, 2018; Revised: March 27, 2018; Accepted: March 28, 2018; Published: March 30, 2018

Abstract- The experiment was conducted with three CMS lines *i.e.*, IR 68887 A, IR 79159 A and APMS 6 A which were crossed with eleven diverse male parents in line x tester fashion in order to estimate combining ability and gene action for grain yield and yield attributing traits in rice. The analysis of variances for combining ability revealed that significant mean sum of square for hybrids, females, female x male interaction for all the traits except effective tillers per plant. The results in respect to estimates of genetic variance revealed importance of additive genetic variance for panicle length. For other yield contributing characters like days to fifty percent flowering, plant height, grains per panicle, test weight, grain yield per plant, grain length, hulling%, milling% and head rice recovery % indicated importance of both additive and non-additive genetic variances with predominant role of non-additive gene effect was observed. Estimates of general combining ability effects among female parents, CMS line APMS 6 and among male parents, MILYANG 63, IR 09A 104, IR 77186-148-3-4-3, IR 04N 106, IR 07N 166 and IR 09N 534 were found to be good general combiners for grain yield per plant and at least for two to three important yield contributing characters. The estimates of specific combining ability revealed that among the crosses, cross combination namely IR 79159 A x IR 09A 104, IR-8887 A x IR 77186-148-3-4-3, IR 68887 A x POKKALI, APMS 6 A x IR 05N 412 and IR 68887 A x MILYANG 63 depicted significant and positive sca effect for seed yield and yield contributing traits. In general, the crosses depicted high sca effects for grain yield per plant and different component characters did not always involve parents possessing high gca effects, there by suggesting importance of both intra and inter-allelic interactions. Thus, these cross combinations could be utilized for further use in breeding programme for amelioration of grain yield and other desirable characters in rice.

Key words- Line x Tester, Combining ability, Gene action and Rice.

Citation: Prajapati K.N. and Kathiria K.B. (2018) Combining Ability and Gene Action for Grain Yield and Its Attributing Traits in Rice (*Oryza sativa* L.). International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 10, Issue 6, pp.-5630-5634.

Introduction

Rice is one of the most important food crops in the world, second only to wheat in terms of annual production for human consumption. Rice belongs to family *poaceae* and genus *oryza.* There are 24 species of *Oryza* among which, only two species *viz., Oryza sativa* L. and *Oryza glaberimma* steaud are under cultivation. The primary centre of origin of *Oryza sativa* L. is large belt extending from north east hills in India to the mountain ranges of the mainland south-east Asia and south west China. The majority of rice comes from China, India, Japan, Indonesia, Thailand, Myanmar, Bangladesh, and Pakistan. India has the world's largest area under rice with 36.84 million ha and is the second largest producer (124.05 million tonnes in 2015-16) next only to China. In Gujarat rice is cultivated in an area of 8.36 lakh ha with a productivity of 2.162 t/ha and the annual rice production of 17.64 lakh tons [1]. In the Gujarat State rice occupies about 7 to 8% of the gross cropped area of the State and accounts for around 14% of the total food grain production. It is grown on an average about 7.5 to 8.5 lakh hectares of land comprising nearly 65 to 70% of low land (transplanted) and 30 to 35% of upland (Drilled) rice. Rice is predominantly self-pollinated crops, in which the technique of line x tester analysis has proved useful for screening lines rapidly and with a reasonable degree of confidence. The line x tester analysis has been extensively used in almost all the major field crops in evaluation of breeding material for general and specific combining ability as well as to study the extent of heterosis for yield and yield contributing characters. The knowledge of nature and magnitude of gene action controlling yield and yield components is very useful for development of the breeding procedure to be followed for crop improvement. In this broader perspective, the present investigation was planned and executed to assess the nature of gene action involved and combining ability of parental genotypes for various traits to drive productive varieties/hybrids in rice.

Materials and Methods

The three CMS lines *i.e.*, IR 68887 A, IR 79159 A and APMS 6 A which were crossed with eleven diverse male parents in line x tester fashion to developed 33 hybrids at Main Rice Research Station, Anand Agricultural University, Nawagam (Gujarat) during *kharif*-2014. The resultants 33 hybrids, 14 parents and three varieties and a hybrid KRH 2 as checks were evaluated in a Randomized Complete Block Design with three replications during *kharif*-2015. Each plot consisted of twenty plants in a row keeping 20 and 15 cm inter and intra row spacing, respectively. Non-experimental border row was also planted on both sides of experimental blocks to eliminate border effects. The recommended package of agronomical practices and plant protection measures, obligatory to raise good crop were followed both in nursery as well as field. Five randomly selected competitive plants from each replication were tagged for the purpose of recording the observations on thirteen characters *viz.*, plant height (cm), panicle length (cm), number of effective tillers per plant, number of grains per panicle, grain yield per plant (g), test weight (g), grain length (mm), grain breath (mm), grain L/B ratio, hulling (%), milling (%) and head rice recovery (%), whereas days to 50% flowering was recorded on population basis. The mean data was analysed to compute combining ability effect and their variance as per Kempthorne [2].

Results and Discussion

The results obtained under the present investigation are presented in [Table-1] to 5]. Analysis of variance revealed that the mean squares due to genotypes were highly significant for all the characters except effective tillers per plant, milling (%) and head rice recovery (%). The mean squares due to parents for all the characters were found highly significant except effective tillers per plant and milling %. Among parents, mean square due to females differed significantly for the characters plant height, panicle length, effective tillers per plant, grains per panicle, test weight and grain yield per plant. The mean squares due to males were highly significant for all the characters except days to fifty per cent flowering, panicle length, effective tillers per plant, hulling %, milling % and head rice recovery %. The analysis of variances further revealed that hybrids showed significant differences for all the traits except days to fifty percent flowering, effective tillers per plant and hulling %. This indicated the presence of wide genetic variability among the parents as well as hybrids with respect to most of the characters under study. The analysis of variances for combining ability [Table-1] indicated significant mean squares for hybrids, females, males and female x male for all the characters except effective tillers per plant.

Table-1 *Analysis of variance and variance estimates for combining ability for various characters in rice*

Sr. No.	Source	Degree of freedom	Days to 50 % flowering	Plant height (cm)	Panicle length (cm)	Number of effective tillers per plant	Number of grains per panicle	Test weight (g)	Grain yield per plant (g)	Grain length (mm)	Grain breadth (mm)	Grain L/B ratio	Hulling (%)	Milling (%)	Head rice recovery (%)
1	Replication	2	91.25**	101.83**	75.72**	0.27	23.88**	12.01**	50.94**	20.71**	0.38**	0.22	182.79**	204.33**	1927.89**
2	Hybrid	32	136.23**	1043.62**	7.07**	0.33	5737.04**	63.89**	729.85**	2.06**	0.25**	0.60**	7.07**	15.45**	116.01**
3	Females	2	284.24**	1609.15**	23.67**	0.47	856.40**	223.38**	87.94**	6.03**	0.24**	0.56**	5.27**	15.22**	121.89*
4	Males	10	162.58**	641.50**	6.17*	0.28	12067.53**	44.20**	145.93**	1.98**	0.34**	0.66**	6.10**	11.60**	153.59**
5	F x M	20	108.45**	1188.14**	5.86**	0.34	3059.86**	77.78**	46.53**	1.70**	0.16**	0.58**	7.74**	7.39**	101.63**
6	Error	64	5.41	6.65	2.29	0.39	16.21	0.24	6.69	0.50	0.03	0.20	3.06	5.31	38.31
					Variance Estimates										
7	$\sigma^2 f$		5.27**	12.76**	0.54**	0.00	66.77**	5.02**	1.26**	0.13**	0.00	0.00	0.07**	0.07**	0.61**
8	$\sigma^2 m$		6.01**	60.74**	0.04*	0.01	1000.85**	1.51**	11.05**	0.03**	0.01**	0.01**	0.18**	0.64**	4.66**
9	$\sigma^2 gca$		5.42**	2.99**	0.43**	0.00	162.00**	3.61**	3.35**	0.11**	0.00	0.00	0.09**	0.18**	1.48**
10	$\sigma^2 sca$		34.36**	393.82**	0.11**	0.01	1014.56**	19.19**	13.28**	0.38**	0.08**	0.12**	1.55**	4.00**	21.10**
11	Potence ratio		0.39	0.02	9.62	0.42	0.39	0.46	0.62	0.71	0.18	0.03	0.15	0.11	0.17
12	Predictable ratio		0.24	0.01	0.89	0.25	0.24	0.27	0.34	0.37	0.13	0.02	0.11	0.08	0.12
13	$\sigma^2 \hat{A}$		21.71	11.96	1.73	0.01	648.02	14.78	13.41	0.44	0.02	0.01	0.39	0.76	5.93
14	$\sigma^2 \hat{Y}$		137.39	1575.37	0.46	0.06	4058.20	76.72	53.11	1.61	0.24	0.50	6.24	16.11	84.43
15	$\sigma^2 \hat{A} / \sigma^2 \hat{Y}$		0.16	0.01	3.76	0.17	0.16	0.19	0.25	0.27	0.08	0.02	0.06	0.05	0.07

Note: * and ** indicate significance at 5% and 1% level, respectively.

The results in respect to estimates of genetic variance revealed importance of additive genetic variance for panicle length. The results are in agreement with the reports of [3-5] as they reported preponderance of additive gene effect for panicle length. For other yield and yield contributing characters like days to fifty percent flowering, plant height, grains per panicle, test weight, grain yield per plant, grain length, hulling%, milling% and head rice recovery% indicated importance of both additive and non-additive genetic variances with predominant role of non-additive gene effect.

Table-2 *Estimates of general combining ability (gca) effects of parents for various characters in rice*

Sr. No.	Parents	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Number of effective tillers per plant	Number of grains per panicle	Test weight (g)	Grain yield per plant (g)	Grain length (mm)	Grain breadth (mm)	Grain L/B ratio	Hulling (%)	Milling (%)	Head rice recovery (%)
						Lines (Female Parents)								
1	IR 68887 B	-2.90**	7.75**	-0.70*	-0.13	-0.27	0.04	0.26	0.32**	-0.03	0.14**	0.26	-0.17	0.32
2	IR 79159 B	-0.05	-1.96**	0.94**	0.02	5.22**	-2.62**	-1.75**	0.49**	-0.08*	-0.04	-0.46*	-0.58*	-2.06**
3	APMS 6 B	2.95**	-5.80**	-0.24	0.11	-4.96**	2.58**	1.49**	0.17*	0.12*	-0.11*	0.20	0.75**	1.74*
	S.Ed±	**0.28**	**0.31**	**0.28**	**0.07**	**0.48**	**0.06**	**0.31**	**0.08**	**0.08**	**0.02**	**0.05**	**0.21**	**0.27**
						Testers (Male Parents)								
1	MILYANG 54 (GAYABYEO)	-0.25	8.08**	0.10	0.18	-15.75**	-2.71**	-4.61**	0.13	-0.27**	0.43**	0.79	1.55*	2.01
2	MILYANG 55	-0.25	13.82**	-0.69	0.18	-19.91**	-0.71**	-1.94**	-1.01**	-0.15**	-0.22	0.74	0.38	-3.01
3	MILYANG 63	-3.25**	10.36**	-0.99	-0.31	81.22**	-2.31**	8.88**	-0.03	0.11*	-0.13	1.21*	0.21	9.04**
4	POKKALI	0.41	-7.50**	-0.70	0.12	-7.49**	1.56**	-2.34**	0.09	0.00	0.00	-0.24	0.95	1.30
5	IR77186-148-3-4-3	-8.59**	-0.64	0.97	-0.19	-9.44**	-0.14	2.04**	0.21	-0.08	0.17	0.14	0.31	3.98*
6	IR 04N 106	0.08	-6.04**	0.21	0.14	36.28**	-0.51**	1.96**	-0.21	0.03	-0.08	-0.57	0.35	-2.28
7	IR 05N412	1.08	-2.97**	1.00	0.01	-56.67**	1.03**	-4.86**	0.55	-0.25**	0.51**	-0.29	-0.29	-0.54
8	IR 07A 166	0.19	-4.84**	-0.21	-0.15	23.32**	5.09**	1.98**	0.80**	0.28**	-0.04	0.81	-0.16	-3.89*
9	IR 09A 104	-1.47*	-3.84**	-1.23	-0.19	9.68**	-0.24	2.96**	-0.04	0.19*	-0.27*	-1.58**	-1.25*	4.41**
10	IR 09N 534	2.86**	6.48**	1.04	0.14	-18.88**	1.15**	-1.87**	-0.30	0.21*	-0.33**	-0.39	0.60	-2.65
11	IR 10 A 117	9.19**	-12.92**	0.51	0.07	-22.36**	-2.21**	-2.22**	-0.19	-0.06	-0.04	-0.61	-2.67**	-0.43
	S.Ed ±	**0.62**	**0.69**	**0.63**	**0.17**	**1.07**	**0.13**	**0.69**	**0.19**	**0.19**	**0.05**	**0.12**	**0.47**	**0.61**

Note: * and ** indicate level of significance at 5% and 1 %, respectively

Looking to the significance of both types of gene actions in the expression of different characters studied in this work, it is suggested that bi-parental mating with reciprocal recurrent selection should be employed so that additive as well as non-additive gene action could be exploited simultaneously for population improvement. Similar results were also reported by [5-9] as they reported preponderance of non-additive gene effect for above said traits. An overall appraisal of general combining ability effects of parents [Table-2] revealed among parents, female APMS 6 B and males MILYANG 63, IR 09A 104, IR 77186-148-3-4-3, IR 04N 106, IR 07A 166 and IR 09N 534 were found to be good general combiners for grain yield per plant. The female lines APMS 6 A was good general combiner for grain yield per plant, plant height, test weight, grain length, milling % and head rice recovery %. Female line, IR 68887 A had favourable genes for days to fifty percent flowering, grain length and grain length to breadth ratio. Female parent IR 79159 A found good combiner for plant height, panicle length, grains per panicle, grain length and grain breadth. The male parent MILYANG 63 was good general combiner for five traits viz., days to fifty percent flowering, grains per panicle, grain yield per plant, hulling % and head rice recovery percent. Pollinator IR 09A 104 was proved as good combiner for five characters namely days to fifty percent flowering, plant height, grains per panicle, grain yield per plant and head rice recovery percent. Similarly, male parent IR 07A 166 was good combiner for plant height, grains per panicle, test weight, grain yield per plant and grain length. The male parent IR 77186-148-3-4-3 had increase genes for three traits *viz.*, days to fifty percent flowering, grain yield per plant and head rice recovery percentage, whereas, IR 04N 106 was good combiner for plant height, grains per panicle and grain yield per plant, which was evident from the high and significant gca effects of these component traits. In general, it was evident from the [Table-2] that the parents who were good general combiners for grain yield per plant were also good general combiners for some of its yield contributing traits like days to 50%flowering, panicle length, number of grain per panicle, grain length, grain breadth and test weight. This suggested that none of the parents was found to be good combiner for all the traits, therefore, parental line possessing favourable genes for many traits should be selected for breeding objectives. These findings are also in agreement with results of [10-13]. In respect to gca effect of parents involved in a particular cross, females and males were categorized into good, average and poor combiners [Table-3].

Table-3 *Estimates of specific combining ability (sca) effects for various characters in rice*

Sr. No.	Hybrids	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Number of effective tillers per plant	Number of grains per panicle	Test weight (g)	Grain yield per plant (g)	Grain length (mm)	Grain breadth (mm)	Grain L/B ratio	Hulling (%)	Milling (%)	Head rice recovery (%)
1	IR 68887 A x MILYANG 54	-4.32**	15.63**	-0.52	0.17	13.47**	0.35	3.06**	0.14	0.08	-0.09	-0.10	0.00	-4.56
2	IR 68887 A x MILYANG 55	-2.32**	30.50**	-2.32*	0.04	3.64*	0.65*	0.52	-0.04	0.03	-0.04	1.07	2.85**	5.34*
3	IR 68887 A x MILYANG 63	2.68**	29.75**	-0.02	-0.14	-37.58**	-1.75**	4.36**	0.09	-0.15*	0.18	-0.31	1.34	4.64*
4	IR 68887 A x POKKALI	0.01	-15.78**	-2.04*	-0.03	61.41**	5.39**	4.44**	0.75**	-0.04	-0.21	-0.59	1.40	2.12
5	IR 68887 A x IR77186-148-3-4-3	12.1**	-18.45**	1.09	0.02	8.28**	3.39**	4.93**	0.42	0.12	-0.02	0.53	-0.50	-0.99
6	IR 68887 A x IR 04N 106	-2.66**	-15.25**	1.77*	0.02	27.08**	-3.35**	-1.27	-0.84**	-0.45**	0.23	-2.67**	-0.77	1.77
7	IR 68887 A x IR 05N412	1.34	6.09**	1.98*	0.08	-25.31**	-3.38**	-4.97**	0.61*	-0.02	0.31	0.62	0.51	4.77
8	IR 68887 A x IR 07A 166	3.57**	3.75**	0.94	0.44	-1.00	2.45**	-1.91*	-0.1	0.17*	-0.26	-0.74	-1.36	-8.57**
9	IR 68887 A x IR 09A 104	-2.77**	3.35**	0.16	-0.38	2.68	-3.61**	-1.73	0.91**	0.29**	0	2.91**	3.75**	1.01
10	IR 68887 A x IR 09N 534	-2.1**	-28.4**	-0.49	0.15	-52.92**	1.66**	-5.99**	0.05	0.17*	0.18	0.47	-0.90	-5.43*
11	IR 68887 A x IR 10 A 117	-5.43**	-11.2**	0.44	-0.38	0.25	-1.11**	-1.46	-0.48	0.13	-0.28	-1.19	-6.27**	-0.10
12	IR 79159 A x MILYANG 54	4.16**	-10.03**	0.21	-0.24	2.42	2.75**	1.96*	0.74**	-0.24**	0.70**	-0.46	6.35**	-3.73
13	IR 79159 A x MILYANG 55	7.16**	-21.76**	0.82	-0.04	9.91**	2.55**	-1.90	0.35	-0.04	0.17	-0.49	-0.59	-2.24
14	IR 79159 A x MILYANG 63	-4.84**	-8.51**	0.31	0.18	-0.11	-4.65**	-4.11**	0.11	-0.16*	0.18	-0.40	-1.73*	1.45
15	IR 79159 A x POKKALI	4.49**	10.56**	0.42	0.09	-12.36**	-7.62**	-4.14**	-0.24	0.18*	-0.30	1.41*	0.72	4.22
16	IR 79159 A x IR77186-148-3-4-3	-7.51**	-5.31**	-2.05*	0.27	-20.73**	3.78**	-1.56	0.81**	-0.15*	0.50**	0.39	0.56	-2.50
17	IR 79159 A x IR 04N 106	7.83**	3.29**	-0.09	0.53*	-26.45**	-0.85**	-1.04	0.65*	0.20*	0.14	1.77**	0.84	-2.61
18	IR 79159 A x IR 05N412	-5.17**	-6.77**	-1.1	-0.27	-19.38**	2.81**	0.53	-0.76**	0.01	-0.33	0.81	-0.26	-10.26**
19	IR 79159 A x IR 07A 166	-2.28**	-2.71**	-0.7	-0.31	9.75**	-2.25*	1.12	-0.70	0.29**	-0.55**	0.59	1.24	7.79**
20	IR 79159 A x IR 09A 104	1.38	-6.71**	0.34	-0.2	17.39**	-0.72**	5.04**	-1.13**	-0.17*	-0.24	-4.10**	-3.27**	0.26
21	IR 79159 A x IR 09N 534	-1.95*	40.37**	1.19	-0.33	39.07**	0.89**	3.26**	0.03	0.38**	-0.37*	0.03	0.54	7.04**
22	IR 79159 A x IR 10 A 117	-3.28**	7.56**	1.32	0.33	0.50	3.30**	0.84	0.14	-0.10	0.11	0.46	2.58**	0.59
23	APMS 6 A x MILYANG 54	0.16	-5.6**	0.31	0.07	-15.89**	-2.40**	-5.02**	-0.88**	0.17*	-0.61**	0.56	-0.35	8.29**
24	APMS 6 A x MILYANG 55	-4.84**	-8.74**	1.50	0	-13.54**	-3.20**	1.37	-0.31	0.02	-0.13	-0.58	-1.26	-3.10
25	APMS 6 A x MILYANG 63	2.16*	-21.25**	-0.29	-0.04	37.69**	6.40**	-0.25	-0.20	0.31**	-0.36*	0.72	0.39	-6.09**
26	APMS 6 A x POKKALI	-4.51**	5.22**	1.61	-0.06	-49.04**	2.23**	0.30	0.99**	0.13	0.51**	-0.81	-2.13*	-6.33**
27	APMS 6 A x IR77186-148-3-4-3	-4.51**	23.75**	0.96	-0.28	12.45**	-7.17**	-3.37**	-1.23**	0.03	-0.48**	-0.92	-0.02	3.49
28	APMS 6 A x IR 04N 106	-5.17**	11.95**	-1.68	-0.75**	-0.63	4.20**	2.32**	0.19	0.43**	-0.37*	0.90	-0.07	0.84
29	APMS 6 A x IR 05N412	3.83**	0.69	0.13	0.18	44.68**	0.57	4.44**	0.15	0.01	0.02	-1.42*	0.25	5.50*
30	APMS 6 A x IR 07A 166	-1.28	-1.05	-0.24	-0.13	-8.75**	-0.20	0.78	0.80**	0.47**	0.81**	0.14	0.12	0.77
31	APMS 6 A x IR 09A 104	1.38	3.35**	0.18	0.58*	-20.07**	4.33**	-3.32**	0.22	-0.13	0.24	1.19	0.48	-1.27
32	APMS 6 A x IR 09N 534	4.05**	-11.97**	-0.7	0.18	13.85**	-2.56**	2.73**	-0.08	-0.21**	0.20	-0.50	0.35	-1.60
33	APMS 6 A x IR 10 A 117	8.72**	3.64**	-1.76*	0.05	-0.75	-2.20**	0.61	0.35	-0.03	0.17	0.73	3.69**	-0.49
	S. Ed ±	**0.88**	**0.97**	**0.88**	**0.23**	**1.52**	**0.18**	0.97	**0.27**	0.07	0.17	**0.66**	0.87	**2.33**

Note: * and ** indicate level of significance at 5% and 1 %, respectively

Top five heterotic hybrids involved good x good and good x poor / poor x good combiners as parents. The hybrids IR 68887 A x MILYANG 63, IR 68887A x IR 7186-148-3-4-3, IR 79159 A x IR 09 A 104, APMS 6 A x IR 04N 160 and APMS 6 A x IR 07 A 166 resulted from one good and one poor/average general combiner. It appeared that crosses with one good and one poor/ average general combiner would produce hybrids with specific cross combinations. The crosses showing high sca effects involving one good general combiner, indicated additive x dominance type of gene interaction, which could produce desirable transgressive segregants in subsequent generations. The presence of two good general combiners in a hybrid in majority of the crosses invariably brought about an enhancement in the character expression. High gca effects of their parents, good x good involved interaction between additive x additive alleles revealed that it could be fixable in subsequent generations if no repulsion phase linkages are involved and thus may be exploited for selection of homozygous pure lines through pedigree method of breeding. The estimates of sca effects [Table-4] revealed that 10 crosses exhibited significant positive sca effects.

Table-4 *Classification of parents with respect to general combining ability (gca) effects for various characters in rice*

Sr. No.	Parents	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Number of effective tillers per plant	Number of grains per panicle	Test weight (g)	Grain yield per plant (g)	Grain length (mm)	Grain breadth (mm)	Grain L/B ratio	Hulling (%)	Milling (%)	Head rice recovery (%)
Females														
1	IR 68887 B	G	P	P	A	A	A	A	G	P	G	A	A	A
2	IR 79159 B	A	G	G	A	G	P	P	G	G	A	P	P	P
3	APMS 6 B	P	G	A	A	P	G	G	G	P	P	A	G	G
Males														
1	MILYANG 54 (GAYABYEO)	A	P	A	A	P	P	P	A	G	G	A	G	A
2	MILYANG 55	A	P	A	A	P	P	P	P	G	A	A	A	A
3	MILYANG 63	G	P	P	A	G	P	G	A	P	A	G	A	G
4	POKKALI	A	G	P	A	P	G	P	A	A	A	A	A	A
5	IR77186-148-3-4-3	G	A	A	A	P	A	G	A	A	A	A	A	G
6	IR 04N 106	A	G	A	A	G	P	G	P	A	A	A	A	A
7	IR 05N412	A	G	A	A	P	G	P	A	G	G	A	A	A
8	IR 07A 166	A	G	P	A	G	G	G	G	P	A	A	A	P
9	IR 09A 104	G	G	P	A	G	A	G	A	P	P	P	P	G
10	IR 09N 534	P	P	A	A	P	G	P	A	P	P	A	A	A
11	IR 10 A 117	P	G	A	A	P	P	P	A	A	A	A	P	A

Note: G = Good general combiner, A = Average general combiner, P = Poor general combiner.

The most promising five cross combinations with significant and positive sca effects were IR 79159 A x IR 09A 104, IR-68887 A x IR 77186-148-3-4-3, IR 68887 A x POKKALI, APMS 6 A x IR 05N 412 and IR 68887 A x MILYANG 63. The component traits including effective tillers per plant, panicle length, grains per panicle and test weight were found to be associated with all of hybrids possessing desirable sca effects for grain yield per plant. All the cross combinations with significant sca effects for grain yield possess significant and desirable sca effects for at least two to three component traits, which suggested that at least one trait resulted into significant and desirable sca effects for grain yield.

Table-5 *Top three crosses with respect to their per se performance and sca effects for various traits in rice*

Characters	Best three crosses according to *per se* performance	sca effects
Days to 50% flowering	IR 79159 A x IR77186-148-3-4-3	IR 79159 A x IR77186-148-3-4-3
	APMS 6 A x IR77186-148-3-4-3	IR 79159 A x IR 05N412
	IR 79159 A x MILYANG 63	APMS 6 A x IR 04N 106
Plant height (cm)	APMS 6 A x MILYANG 63	IR 79159 A x MILYANG 55
	IR 68887 A x IR 10 A 117	APMS 6 A x MILYANG 55
	IR 68887 A x POKKALI	IR 68887 A x POKKALI
Panicle length (cm)	IR 79159 A x IR 09N 534	IR 68887 A x IR 05N412
	IR 79159 A x IR 10 A 117	IR 68887 A x IR 04N 106
	APMS 6 A x IR77186-148-3-4-3	APMS 6 A x MILYANG 63
Number effective tillers per plant	IR 79159 A x IR 04N 106	APMS 6 A x IR 09A 104
	APMS 6 A x IR 09N 534	IR 79159 A x IR 04N 106
	IR 79159 A x IR 10 A 117	IR 68887 A x IR 07A 166
Number of grains per panicle	APMS 6 A x MILYANG 63	IR 68887 A x POKKALI
	IR 79159 A x MILYANG 63	IR 79159 A x IR 09N 534
	IR 68887 A x IR 04N 106	APMS 6 x IR 05N412
Test weight (g)	IR 68887 A x IR 07A 166	APMS 6 A x MILYANG 63
	APMS 6 A x IR 07A 166	APMS 6 A x IR 04N 106
	IR 68887 A x POKKALI	IR 79159 A x IR77186-148-3-4-3
Grain yield per plant (g)	IR 68887 A x MILYANG 63	IR 79159 A x IR 09A 104
	IR 68887 A x IR77186-148-3-4-3	IR 68887 A x IR77186-148-3-4-3
	IR 79159 A x IR 09A 104	IR 68887 A x POKKALI
Grain length (mm)	APMS 6 A x IR 07A 166	APMS 6 A x POKKALI
	IR 68887 A x IR 05N412	IR 68887 A x IR 09A 104
	APMS 6 A x POKKALI	APMS 6 A x IR 07A 166
Grain breadth (mm)	IR 79159 A x MILYANG 54 (GAYABYEO)	IR 68887 A x IR 04N 106
	IR 68887 A x IR 04N 106	IR 79159 A x MILYANG 54 (GAYABYEO)
	IR 79159 A x IR 05N412	APMS 6 A x IR 09N 534
Grain L/B ratio	IR 79159 A x MILYANG 54 (GAYABYEO)	APMS 6 A x IR 07A 166
	APMS 6 A x IR 07A 166	IR 79159 A x MILYANG 54 (GAYABYEO)
	IR 79159 A x IR77186-148-3-4-3	APMS 6 A x POKKALI
Hulling (%)	APMS 6 A x MILYANG 63	IR 68887 A x IR 09A 104
	IR 68887 A x MILYANG 55	IR 79159 A x IR 04N 106
	APMS 6 A x MILYANG 54 (GAYABYEO)	IR 79159 A x POKKALI
Milling (%)	IR 68887 A x MILYANG 55	IR 79159 A x MILYANG 54 (GAYABYEO)
	IR 68887 A x IR 09A 104	IR 68887 A x IR 09A 104
	IR 68887 A x IR77186-148-3-4-3	APMS 6 A x IR 10 A 117
Head rice recovery (%)	IR 68887 A x MILYANG 63	IR 68887 A x IR 07A 166
	APMS 6 A x MILYANG 54 (GAYABYEO)	IR 79159 A x IR 07A 166
	IR 79159 A x MILYANG 63	IR 79159 A x IR 09N 534

This was due to the fact that all the component characters are responsible for sum total of metabolic substances produced by the plant and the conditions, which favour the development of one component, could have adverse effect on the other. Further, all the crosses had close correspondence with mean value and significant sca effects which suggested that *per se* performance and magnitude of sca effects of hybrids could be considered for judging heterosis for grain yield. Similar results have been earlier reported by [14]. The top three crosses on the basis of their *per se* performance and sca effects [Table-5] for various characters displayed differences in their ranking, which suggested that crosses exhibiting high sca effects would not necessarily give either higher mean value or high heterotic effects and *vice versa*; therefore, while selecting a cross for further uses plant breeder has to consider all aspects independently. For seed yield per plant, hybrids IR 79159A x IR 77186-148-3-4-3, IR 79159 A x IR 05N 412 and APMS 6 A x IR 04N 106 exerted significant and positive sca effects. High *per se* performance along with high sca effects was recorded with cross IR 79159 A x IR 77186-148-3-4-3 for days to 50% flowering, IR 68887 A x POKKALI for plant height, IR 79159 A x IR 04N 106 for effective tillers per plant and IR 79159A x MILYANG 54 for grain breadth and length: breadth ratio.

Conclusion

From the above discussion it can be concluded that among the parents, female APMS 6 B and male parents MILYANG 63, IR 09A 104, IR 77186-148-3-4-3, IR 04N 106, IR 07A 166, IR 09N 534 were good general combiners, whereas hybrids IR 79159 A x IR 09A 104, IR-8887 A x IR 77186-148-3-4-3, IR 68887 A x POKKALI, APMS 6 A x IR 05N 412 and IR 68887 A x MILYANG 63 depicted significant and positive sca effect for seed yield and yield contributing traits. Since, the experiment was carried out only for one season over a single location, it is expected that the estimates of genetic variances would be biased upwards due to genotype x environment interaction and this would lead to differences between expected and realized response to selection as advocated. Hence, it is suggested that these crosses should be further tested over the environments or locations to drive productive varieties/hybrids in rice. It is also clear that high magnitude of non-additive type of gene action for grain yield per plant and some of its important components traits observed in the present study favours hybrid breeding programme.

Application of research: In the present research high magnitude of non-additive type of gene action per grain yield per plant and some of its important components traits observed and it is useful to drive productive varieties/hybrids in rice

Research Category: Plant Breeding

Abbreviations:
GCA: general combining ability

Acknowledgement / Funding: Author thankful to Anand Agricultural University, Anand, 388110, Gujarat

***Research Guide or Chairperson of research:** Dr. K. B. Katharia, Director of Research and Dean
University: Anand Agricultural University, Anand, 388110, Gujarat
Research project name or number: PhD Thesis

Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

References

[1] Pathak A. R. and Mehta A. M. (2014) Handbook of Package of Practices for Rice. Directorate of Rice Research, Book No. 80/2014. Page No 112-120
[2] Kempthorne O. (1957) John Willey and Sons. Ind., New York. pp. 468-470.
[3] Sarma M. K., Sharma R. K., Agrawal R. K. and Richharia A. K. (2007) *Indian J. Genet.*, **67**(3), 278-280.
[4] Rewainy I. M. O., Hassan H. M. and Abd A. B. (2011) *J. Agric. Res.*, **37**(4), 583-287.
[5] Sanghera G. S. and Hussain W. (2012) *Not. Sci. Biol.,* **4**(3), 131-142.
[6] Ghosh S. C., Chandrakar P. K., Rastogi N. K., Sharma D. and Sarawgi A. K. (2012) *Bangladesh J. Agril. Res.,* **37**(4), 583-592.
[7] Thakre I. S. and Mehta A. M (2012) *The Bioscan*, **8**(4), 1379-1381.
[8] Bhadra D., Reddy D. L. and Ramesha M. S. (2013) *Greener Journal of Agricultural Sciences,* **3**(9), 669-686.
[9] Utharasu S. and Anandakumar C. R. (2013) *Electronic Journal of Plant Breeding*, **4**(4), 1271-1279.
[10] Sharma R. K. and Mani S. C. (2001) *Crop Improvement*, **28**(2), 236-243.
[11] Patil D. V., Thiyagarajan K. and Kamble P. (2003) *Crop Res.*, **25**(3), 520-524.
[12] Raju C. S., Rao M. V., Reddy G. L., Ra, J. S. and Reddy K. S. (2003) *Ann. of Agric. Res.,* **24**(2), 227-233.
[13] Veni B. K. and Rani N. S. (2003) *Madras Agric. J.*, **90**(10-12), 633-636.
[14] Babu S. S. and Reddy P. S. (2002) *Research on Crops*, **3**(3), 592-598.