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Genetic Control on Yield and its Attributing Traits in Rice with Combining Abilities of the Parent for the Traits

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Abstract

Eleven genotypes of rice were evaluated for different yield and its attributing characters. Out of these eight parents were chosen as female and three parents were considered as male. These lines and tester were combined following Line × Tester crossing design to estimate combining abilities (gca effect) of Parentts and crosses (sca effect). Line × Tester analysis confirmed the influence of sca variance on most of the yield related characters which predicted that some characters were predominantly controlled by dominance gene actions with substantial amount of epistatic gene interactions. Some genotypes were found to be high general combiners for yield plant^{-1} with number of yield related characters like number of grains plant^{-1} and number of grains panicle^{-1}.

Keywords

Rice; Plant height; Combining ability; Line × tester and yield

Introduction

Rice (*Oryza sativa* L.) is an important cereal crop for more than 40 percent world population as source of main food and earnings. Rice can provide on an average 75% calories with 55% protein in their daily diet [1]. Global coverage of rice cultivated area is over 159 million hectares producing 659.9 million tons per annum [2,3]. Breeding for high yield with concomitant improvement on yield related characters helps to establish a well-built source-sink system to break the present plateau level in yield. Thus the policy for boosting rural development which is based on agriculture and mainly with rice cultivation may be finally pay off by increasing productivity to accelerate the transition from need based agriculture to highly productive farm industry accompanied by wider expansion of rural employment and foreign trade.

The main yield attributing traits considered in the present investigation were plant height (cm), number of grains panicle^{-1}, number of grains plant^{-1}, days to 50% flowering, days to maturity and yield plant^{-1}. Tillering habit had been proved as an yield determining factor as prolific tillering is responsible for higher crop growth rate with increased yield.

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Success in breeding improvement for increased yield failed to compromise the gap for demand from ever increasing population which perused for new efforts from the breeder to excel yield level from present plateau level.

Materials and Methods

The field experiment of the present study was carried out at the Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, at Jaguli, Nadia, West Bengal, India. Twenty genotypes of rice were collected from different sources for evaluation of yield and its attributing traits and the different characters were as follows - plant height (cm), effective tillers plant^{-1}, panicle length (cm), number of grains panicle^{-1}, number of grains plant^{-1}, days to 50% flowering, days to maturity, yield plant^{-1}. Out of these genotypes eleven genotypes were selected to produce 24 hybrids on crossing 8 parents as females and 3 as males following line × testers combinations. The female genotypes were Annada, IET 826, MTU 1010, Vandana, NC 1281, ND 97, IR 8, PNR 381 and selected on the basis of their superior performance with respect to yield accompanied by some yield related parameters. On the other hand Satabdi, pusasugandha and IR 69705 were considered as testers which were found to be superior other yield related characters. The experiment was conducted in RBD with three replications of twenty genotypes. The plant to plant distance were 20-25 cm and row to row were 30 cm. Five randomly selected plants were taken per replication per genotype for recording data. Line × Testers methods of Kempthrone [4] were followed for data analysis for combining ability, variances and other genetic parameters.

Results and Discussion

Line X tester analysis for yield

Analysis of variance for combining ability following Line × Tester mating were presented in Table 1 showing estimates of variance for different components and predictability ratio. Variance due to hybrids were further portioned into three components- (i) females in hybrids, (ii) males in hybrids and (iii) female × male in hybrids which help to measure contribution of females, males and their interactions to the hybrid.

Analysis of variance revealed significant difference for all the characters among entries, parents, parent *vs.* crosses but for days to 50% flowering which showed only significant variation for parents, whereas crosses showed significant variation for all the characters. Lines (females) failed to exhibit significant variation for grains panicle^{-1} and days to 50% flowering while the testers showed significant variation on these characters. Significant variation was absent in tester for the characters number of effective tillers plant^{-1} which was conspicuously significant in lines. All the crosses and lines × testers interactions showed significant variation for all the characters. Significance of parents and hybrids for all the characters except 1000-grain weight indicated wider genetic differences among them and the variation present in hybrids for 1000-grain weight may be attributable to interaction between lines × testers. The significant variances due to parents vs. hybrids for all the characters except days to 50% flowering indicated prevalence of heterosis for all these characters.

Table 1: Analysis for combining ability of different characters in rice. *= significant at 5% and **=significant at 1% level.

Source	d.f	Plant height (cm)	Effective tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	No. of grains plant^{-1}	Days to 50% flowering	Days to maturity	Yield plant^{-1} (g)
Replication	2	0.704	0.226	0.045	0.963	679.849	17.857	0.055	0.102
Entries	34	1227.446**	2.418**	22.155**	322.202**	57529.596**	658.515	435.367**	25.42**
Parents	10	1649.398**	1.823**	16.293**	117.655**	57317.722**	750.606**	497.000**	13.705**
P vs. C	1	98.825**	6.409**	453.638**	1899.087**	249774.502**	125.477	786.585**	23.130**
Crosses	23	1093.059**	2.503**	5.943**	342.576**	49263.242**	641.654**	394.734**	30.623**
Lines	7	2572.146**	2.225**	13.319*	736.695	324946.344*	719.097	1682.168**	62.774**
Testers	2	3137.795**	5.942	9.943*	454.206	40045.115**	587.648*	710.317**	45.813*
L X T	14	61.410**	0.823**	2.889**	230.458**	14489.004**	657.648**	72.709**	12.378**
Error	68	0.299	0.176	0.096	2.810	1512.470	29.376	0.365	0.190

But comparative estimates of variance due to gca and sca and their ratios confirmed the importance of sca variance and from predictability ratio it was highly predictable that these characters were predominantly controlled by dominance and epistatic gene action (Table 2). From the result it was observed that lines showed significant variation for some characters, testers for some characters but lines × testers for all characters which indicated that the selected lines differ from testers for most of the characters.

Contribution by females was high for plant height, number of effective tillers plant^{-1}, panicle length, grain yield plant^{-1}, days to flowering and maturity and that for testers in grains plant^{-1} (Table 3).

Vandana and Annada were found to be high yielding genotypes accompanied by a number of yield attributing characters showing superior performance like number of effective tillers, grains panicle^{-1}. Satabdi was also found to be a high yielding variety. Other high yielding varieties accompanied by a number of yield attributing characters were MTU-1010, PNR-381, ND-97, IET-826 and NC-1281.

General combining ability of parents

General combining ability of parents are presented in Table 4. Parents with significant negative gca estimates for plant height, days to 50% flowering, days to maturity, and positive significant estimates for other characters could be considered as good general combiners. Parents with non-significant gca estimates for any character should be considered as average general combiners for the character. Only one parent ND-97 from line was found to be best general combiner for plant height and all other parents from lines as well as testers had significant positive gca. Vandana and PNR-381 from lines, Satabdi and IR-69705 from testers were good general combiners for days to 50% flowering; out of which Vandana was found to be best general combiner for the character while other parents except Annada, IR-8 and Pusasugandha were average general combiners. Best general combiner for days to maturity was PNR-381 from lines followed by Vandana, ND-97, MTU-1010. IR-69705 and Satabdi from testers was also good general combiner. Other parents were either average or poor general combiners. All the parents were found to be average general combiners for number of effective tillers plant^{-1}, panicle length, 1000-grain weight. Best general combiner for grains panicle^{-1} was identified as IR-8 followed by IET-826 from lines which were followed by Satabdi from tester and Annada from lines. All other parents except ND-97, NC-1281, MTU-1010 were found to be average general combiners for grains panicle^{-1}.

All the parents from lines and testers were found to be good general combiners for grains plant^{-1} except IR-69705 which was found to be poor general combiner and ND-97 as average general combiner among which Annada followed by IR-8 were found to be best.

Annada followed by IET-826 were found to be good general combiners for grain yield plant^{-1} and other parents from lines or testers were found to be either average or poor general combiners.

The estimates of specific combining ability effects of the crosses for different characters

Highest significant negative sca estimates for plant height was found in [Vandana × Satabdi] followed by [PNR-381 × Satabdi], [ND-97 × Pusa sugandha], [IET-826 × Pusasugandha], [Annada × Pusasugandha], [MTU-1010 × Satabdi], [NC-1281 × Pusasugandha] and most of the crosses involved parents with poor combiners except in [ND-97 × Pusasugandha] and [Vandana × Satabdi] which involved high × poor and average x poor general combining parents respectively (Table 5).

All the crosses failed to show significant positive sca estimates for number of effective tillers plant^{-1} though [Vandana × IR-69705] followed by [ND-97 × Satabdi] showed higher positive sca. None of the crosses showed significant sca estimates for panicle length and for these two characters all the parents involved in hybrids were found to be average general combiners.

Eight crosses showed significant positive estimates for grains panicle^{-1} and the best three were [IR-8 × Pusasugandha], [PNR-381 × IR-69705] and [MTU-1010 × IR-69705]. One or both of the parents involved in the crosses were good general combiners for the trait.

Only [MTU-1010 × IR-69705] showed significant positive estimates and [MTU-1010 × Satabdi] negative estimate while, rest of the crosses showed average sca estimates for 1000-grain weight. All the combining parents in the crosses were found to be average general combiners.

Desirable sca estimates were found in six crosses for days to 50% flowering and seven crosses for days to maturity of which five crosses showed desirable estimates for both the characters and these crosses were [Annada × IR-69705], [NC-1281 × Satabdi], [ND-97 × IR-69705], [IR-8 × Satabdi], [PNR-381 × Pusasugandha]. Highest estimate of sca for days to 50% flowering towards desirable direction was evident in [NC-1281 × Satabdi] and that for days to maturity in [PNR-381 × Pusasugandha] which was immediately followed by [IR-8 × Satabdi]. One of the parents in all these crosses were found to be good general combiner.

Significant positive sca estimates for grain yield plant^{-1} was observed in [Vandana × Satabdi] followed by [NC1281 × IR-69705] and [Annada × Satabdi] where combining parents had either average gca estimates or high and average gca estimates.

The distribution of crosses in relation to gca effect of parents (Table 6) showed that almost all types of sca effect were obtained from any

Table 2: Estimates variance and predictability ratios for different characters in rice.

Characters	Plant height (cm)	Effective tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	No. of grains plant^{-1}	Days to 50% flowering	Days to maturity	Yield plant^{-1} (g)
δ² gca	23.751	0.038	0.070	2.581	800.608	1.1161	7.4071	0.4201
δ² sca	554.072	0.792	2.615	147.527	38724.777	1421.785	242.1803	11.8369
δ² A	95.007	0.154	0.281	10.325	3202.432	4.664	14.8142	0.8402
δ² D	1108.145	1.596	5.231	295.054	77449.554	2843.570	242.1803	11.8369
Predictability ratio	0.08	0.08	0.05	0.03	0.039	0.063	0.06	0.07

Table 3: Proportional contribution of lines, testers and their interactions to total variance in rice.

Source	Plant height (cm)	Effective tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	No. of grains plant^{-1}	Days to 50% flowering	Days to maturity	Yield plant^{-1} (g)
Due to lines	71.61	72.24	50.91	40.35	24.73	39.45	51.68	62.38
Due to testers	24.96	7.72	19.48	18.69	57.35	24.56	37.09	13.00
Due to line X tester	3.41	20.02	29.59	40.94	17.90	35.97	11.22	24.60

Table 4: General combining ability effects of parents for different characters.

Characters/ Parents	Plant height (cm)	Effective tillers plant^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	No. of grains plant^{-1}	Days to 50% flowering	Days to maturity	Yield plant^{-1} (g)
Line								
Annada	20.34**	0.81	-0.04	4.31**	93.06**	-0.68	0.34	3.34**
IET-826	15.05**	0.84	1.35	6.02**	75.72**	10.05**	-0.11	3.13**
MTU-1010	12.12**	-0.62	-0.30	-2.10*	16.13**	-3.21**	-0.17	-0.89
Vandana	0.10	0.72	-0.98	-0.11	39.23**	-8.65**	0.16	0.67
NC-1281	29.72**	-0.81	-1.59	-4.66**	48.15**	9.98**	-0.21	-3.11**
ND-97	-5.72**	-1.26	1.49	-13.39**	-1.57	-6.03**	-0.45	-3.25**
IR-8	12.58**	0.06	0.18	9.62**	90.12**	9.20**	0.40	1.82
PNR-381	11.75**	0.25	-0.11	0.30	67.13**	-10.64**	0.04	-1.71
SE	0.18	0.14	0.10	0.55	12.96	0.20	0.04	0.14
SED	0.25	0.19	0.14	0.79	18.33	0.28	0.06	0.20
Tester								
Satabdi	6.48**	0.35	0.61	4.70**	72.17**	-4.58**	-0.44	1.49
Pusa sugandha	13.20**	0.14	0.21	1.39	62.05**	9.66**	0.31	-0.27
IR-69705	6.72**	0.20	-0.82	-6.10**	-34.23**	-5.07**	0.12	-1.20
SE	0.11	0.08	0.06	0.34	7.93	0.12	0.02	0.08
SED	0.15	0.20	0.08	0.48	11.22	0.17	0.04	0.12

kind of combination of gca effect and hence performance of hybrids was considered to be independent of that of parents. Similar results were also reported by Peng and Virmani [7]. The manifestation of high, low or non-significant sca effect by any sort of combination among the parents might be due to differential expression of component traits in specific residual genetic background.

Hybrids with good sca effect involving (H × H) combining parents indicated (additive × additive) type of gene interactions and such interaction could be fixed in subsequent generations in absence of repulsion phase of linkage. Such interaction were observed in [NC1281 × IR-69705] for grains panicle^{-1} and for early maturity in [MTU-1010 × IR-69705], [Vandana × Satabdi], [Vandana × IR-69705]. The best specific combining hybrids involving (Low × Low) combining parents indicated over dominance and epistatic interactions. This may be due to genetic diversity in the form of heterozygous loci as observed by Lavanya [5] in hybrid rice. The hybrids with good sca effect involving 'Low × High' combinations suggested additive × dominance interactions. [Annada × IR-69705] was one such hybrids showing additive × dominance interaction for grains panicle^{-1}. Peng and Virmani [7] also reported interaction between positive alleles from good combiner and negative alleles from poor combiners in high × low combiner crosses and suggested for exploitation of heterosis in F_1 generation as their high yield potential via the influence of that character would be unfixable in succeeding generations. Following cyclic selection or biparental breeding programme desirable transgressive segregants might be obtained from such crosses involving poor combiners, average and poor combiners as suggested by Parihar and Pathak [6].

Conclusion

From the evaluation of parents Annada, IET-826, MTU-1010, NC-1281, ND-97, IR-8 and PNR-381 were found to be superior for yield and Satabdi, Pusa sugandha for some of yield attributing characters. IR-69705 and these two groups of parents were considered as lines and testers for combination breeding following line × testers crossing fashion to estimate general combining abilities of parents and sca for crosses.

The characters were considered to be controlled by dominance and epistatic gene action. So population improvement method with concurrent random mating along with mass selection in early segregating generations had been suggested to exploit superiority resulting from various allelic and non-allelic interactions in the hybrids.

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Table 5: Estimates of specific combining ability effects of the crosses for different characters.

Crosses	Plant height (cm)	Effective tillers plant^{-1}	Panicle length (cm)	Number of grains panicle^{-1}	Number of grains plant^{-1}	Days to 50% flowering	Days to maturity	Yield plant^{-1} (g)
Annada X Satabdi	1.75	0.31	-0.23	-0.47	69.03**	-0.35	1.85	2.10*
Annada × Pusasugandha	-3.56**	-0.18	1.11	-2.55*	11.83**	3.37**	0.35	0.27
Annada × IR-69705	1.80	-0.12	-0.88	3.03**	57.19**	-3.01**	-2.21*	-2.37*
IET-826 × Satabdi	2.44**	-0.03	0.28	-0.49	-10.40**	-3.27**	-1.15	0.51
IET-826 × Pusasugandha	-3.87**	0.26	-0.19	0.97	0.07	1.02	0.79	-0.46
IET-826 × IR-69705	1.43	-0.22	-0.09	-0.48	10.33**	2.25*	0.35	-0.05
MTU-1010 × Satabdi	-2.32*	0.00	-0.04	-0.89	54.95**	1.16	4.87**	-0.95
MTU-1010 × Pusasugandha	6.14**	0.36	0.46	4.54**	40.69**	-0.48	-1.95	0.18
MTU-1010 × IR-69705	-3.82**	-0.36	-0.41	-3.64**	95.65**	-0.68	-2.92**	0.77
Vandana × Satabdi	-5.10**	-0.02	0.37	17.66**	57.11**	2.56*	-1.26	2.57*
Vandana × Pusasugandha	6.60**	-0.71	-0.57	-10.60**	57.66**	-2.87**	4.85**	-1.65
Vandana × IR-69705	-1.49	0.73	0.19	-7.06**	0.54	0.31	-3.58**	-0.92
NC-1281 × Satabdi	5.56**	-0.40	-1.44	-11.94**	-4.56**	-8.21**	-3.91**	-3.90**
NC-1281 × Pusa sugandha	-2.34*	0.41	-0.50	5.28**	0.43	5.21**	2.31*	1.40
NC-1281 × IR-69705	-3.21**	-0.01	1.95	6.66**	4.12**	2.99**	1.60	2.50*
ND-97 × Satabdi	3.49**	0.61	0.91	-7.62**	69.89**	4.26**	1.28	-2.20*
ND-97 × Pusa sugandha	-3.91**	0.04	-1.25	7.54**	-32.21**	1.60	1.89	1.07
ND-97 × IR-69705	0.41	-0.65	0.33	0.08	37.68**	-5.87**	-3.17**	1.13
IR-8 × Satabdi	-1.01	0.04	-0.38	9.97**	65.11**	-3.06**	-7.43**	1.72
IR-8 × Pusasugandha	-0.66	0.13	0.59	-7.15**	102.80**	-2.79**	-0.41	-0.72
IR-8 × IR-69705	1.67	-0.17	-0.21	-2.82**	37.69**	5.86**	7.84**	-1.00
PNR-381 × Satabdi	-4.81**	-0.51	0.52	-6.19**	32.85**	6.91**	5.75**	0.15
PNR-381 × Pusasugandha	1.61	-0.32	0.34	1.95	65.97**	-5.05**	-7.85**	-0.10
PNR-381 × IR69705	3.19**	0.83	-0.87	4.23**	98.82**	-1.85	2.09*	-0.05
SE	0.31	0.24	0.17	0.96	22.45	38.50	0.34	0.25
SED	0.44	0.34	0.25	1.36	31.75	54.44	0.49	0.35

Table 6: Distribution of crosses in relation to gca effect of parents. H × H= High × High, H × A= High × Average, A × A= Average × Average, H × L = High × Low, A × L = Average × Low, L × L = Low × Low.

Characters	SCA of cross		GCA of parents						Total no. of crosses
			H × H	H × A	A × A	H × L	A × L	L × L	
Plant height (cm)	+	6	0	0	0	1	1	4	24
	0	9	0	0	0	1	1	7	24
	-	9	0	0	0	1	1	7	24
Effective tillers plant^{-1}	+	0	0	0	0	0	0	0	24
	0	24	0	0	24	0	0	0	24
	-	0	0	0	0	0	0	0	24
Panicle length (cm)	+		0	0	0	0	0	0	24
	0	24	0	0	24	0	0	0	24
	-	0	0	0	0	0	0	0	24
Grains panicle^{-1}	+	8	3	3	0	0	1	1	24
	0	7	1	0	1	2	0	5	24
	-	9	1	0	1	2	1	0	24
Grains plant^{-1}	+	18	0	0	0	7	1	10	24
	0	3	0	0	0	0	0	2	24
	-	3	0	0	3	0	1	1	24
1000-grain weight. (g)	+	0	0	0	0	0	0	0	24
	0	24	0	0	24	0	0	0	24
	-	0	0	0	0	0	0	0	24
Days to 50 % flowering	+	8	2	2	0	2	2	0	24
	0	8	2	2	1	0	2	1	24
	-	8	0	4	0	3	0	1	24
Days to Maturity	+	6	3	2	1	0	0	0	24
	0	11	3	5	3	0	0	0	24
	-	7	3	4	0	0	0	0	24

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Annada and IET-826 could be utilized for high yielding varieties as these were found to be best general combiners for yield and other yield related characters with per-se high yield level.

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