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Analysis of Component of Genetic Variance, Combining Ability, Gene Action and Heterotic Response in Rice (*Oryza sativa*. L)

Y. S. Yadav [a*], P. K. Singh [a] and P. K. Yadav [a]

[a] *Department of Genetics and Plant Breeding, N.D.U.A.T, Faizabad, Uttar Pradesh, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rice (*Oryza sativa* L.) is an important staple crop, particularly in Asia, where it feeds more than half the world's population. The analysis of variance (ANOVA) for nine traits in a rice breeding experiment with seven lines, three testers, 24 F1 hybrids, and two checks indicated significant variations between treatments, showing significant genetic diversity. General combining ability (GCA) effects revealed that line MTU 1010 and tester NDR 2026 had favorable GCA effects on grain yield per plant, but NDR 2064 and Barani Deep had negative effects. Three crosses, showed considerable favorable benefits on grain yield due to specific combining ability (SCA). Heterosis analysis identified promising crosses, including Gopal Bhag × Prakhar and NDR-2064 × NDR-2026, that demonstrated considerable positive heterosis above the parent and standard

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**Corresponding author: E-mail: yashsingh240490@gmail.com;*

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varieties Shushk Samrat and Ashwani. These findings emphasize the possibility of specific crosses to improve grain production in rice breeding efforts.

Keywords: Rice (Oryza sativa L.); randomized complete block design; combining ability; gene action, and heterosis.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the world's most important staple food crop, contributing significantly to global food security. It is especially important in poor countries, where over half of the worldwide population relies on it as their primary source of food. Asia is the core of rice production, accounting for over 90% of global output. Countries such as India and China lead this production, with India having the world's largest rice farming area, but ranking second in total production behind China. India's rice productivity averages roughly 2000 kilos per hectare, making it a major player in the worldwide rice market. Rice is more than just a food crop; it is an integral part of many Asian cultures. Asia, also known as the "rice bowl of the world," produces and consumes more than 90% of the worldwide rice supply. The region is home to around 60% of the world's population and two-thirds of the poor, highlighting the importance of rice in many Asian countries' daily diets and economies. This strong reliance on rice for nutrition and money emphasizes rice's relevance in food security and economic stability.

With the world's population continuing to grow, rice demand is expected to rise even further. As a staple for billions of people, particularly in Asia, crop production must expand to fulfill future food demand. Ensuring high rice yields is critical, especially in areas where agricultural production is strongly tied to poverty reduction and hunger alleviation. This quest will require advances in rice breeding, agronomy, and technology, as well as sustainable techniques that preserve productivity while protecting the environment. Increasing rice output will also help to stabilize food prices and ensure food availability for some of the world's most vulnerable populations.

Rice's significance to global nutrition and economics makes it a crop of unprecedented relevance, especially in alleviating hunger and malnutrition in regions largely reliant on it. [1]

2. MATERIALS AND METHODS

The experiment was carried out at the NDUAT in Kumarganj, Faizabad, Uttar Pradesh, India. The experimental material was based on a line x tester set of twenty-one hybrids (F_1's) developed by crossing seven lines (females) with three testers (males), namely (HUR 917, CR Dhan 800, Gopal Bhag, JGL 384, NDR 2064, Lalaat, and MTU 1010 with three testers (male) *viz.,* (Prakhar, Barani Deep, and NDR 2026). An attempt was made to make twenty-one cross combinations (F_1's) during *Kharif* season 2012. Geographically experimental site is located at 26°32'27.8"N latitude; 81°49'58.1"E longitude. The twenty-one F_1's along with parents and a check verity *i.e.* Shushk Samrat and Ashwani were evaluated to find out the Analysis of variance for design of experiment and Heterosis over better-parent and standard variety of their various attributes on grain yield in Randomized Complete Block Design with three replications during *Kharif* 2013. The observations were recorded on nine different traits *i.e.* days to 50% flowering, panicle bearing tillers/plant, spikelets/panicle, grains/panicle, spikelet fertility (%), biological yield/plant (g), L/B ratio, 1000 grain weight and grain yield/plant (g) in rice (*Oryza sativa* L). A collection of parentals seven lines, three testers and twenty-one hybrids (F1 generation), and check varieties. These genotypes were chosen for their genetic variety, agronomic qualities, and potential for hybrid vigor (heterosis). To increase genetic variety and heterotic potential, the parental lines included both indica and japonica subspecies.

2.1 Statistical Analysis

Line x Tester analysis which was given by Kempthorne (1957) and further elaborated by Arunachalam (1974) to estimate general combining ability (GCA) and specific combining ability (SCA) variances and their effects using the observations taken on hybrids generated through line x tester sets of crosses. The heterosis was estimated as per cent increase or decrease of the mean values of crosses (F_1's) over better parent (heterobeltiosis) and standard variety (standard/economic heterosis) by Fonseca and Patterson (1968) and Meredith and Bridge (1972), respectively. Critical difference was used to test the significance of difference mean value of F_1's over better parent and standard variety which signified with respective heterosis.

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance for Design of Experiment

Analysis of variance was carried out with respect of nine characters to test the significance of differences between various treatments (genotypes) *viz.,* seven lines, three testers, twenty-four F_1s and two checks (Shushk Samrat and Ashwani) as depicted in Table 1. The mean squares due to treatments were highly significant for all the nine characters except L/B ratio which showed significant differences, indicating presence of sufficient variability in the materials of F_1s. The variances due to replications were non- significant for all characters, except panicle bearing tillers/plant, grains/panicle, and biological yield/plant (g). [2-10].

3.2 Estimates of Combining Ability Effects

The estimates of general combining ability (gca) effects in respect of eleven parents (seven lines and three testers) for the nine characters have been set out in Table 2. The lines, MTU 1010 (1.19) in F_1's possessed significant and positive gca effects for grain yield per plant. The lines, NDR 2064 (-0.37) in F_1's recorded negative and significant gca effects for grain yield per plant. Among the testers NDR 2026 (1.81) recorded significant and positive gca effects, whereas Barani Deep (-3.8) exhibited significant and negative gca effect in F_1's for grain yield per plant.

The estimates of specific combining ability effects for twenty-one crosses of line×tester set for nine characters are presented in Table 3. Three crosses emerged with positive and significant sca effects for grain yield per plant *viz.,* MTU-1010 x Barani Deep (5.13), JGL 384 x Barani Deep (3.47), and NDR-2064 x NDR-2026 (2.06). The undesirable negative and significant sca effects for grain yield per plant were exhibited by two crosses in F_1's. [11-20].

3.3 Gene Action

The grain yield per plant (g) for various rice crosses was analyzed, with significant specific combining ability (SCA) effects observed. The cross MTU-1010 x Barani Deep exhibited the highest SCA effect of 5.13 and a mean performance of 49.33 g per plant, categorized under high x low (HxL) general combining ability (GCA) effects. Another notable cross, JGL 384 x Barani Deep, showed an SCA effect of 3.47 with a mean performance of 41.00 g per plant, falling under low x low (LxL) GCA effects. Similarly, the cross NDR-2064 x NDR-2026 recorded an SCA effect of 2.06 and a mean performance of 36.67 g per plant, also categorized under LxL GCA effects are presented in Table 4.

Table 1. Analysis of variance for randomized complete block design for 9 characters in rice

S.N.	Characters	Sources of variation		
		Replications	**Treatments**	**Error**
	d.f.	**2**	**32**	**62**
		F_1s	**F_1s**	**F_1s**
1	Days to 50% flowering	9.39	290.23**	6.61
2	Panicle bearing tillers/plant	2.60*	29.38**	1.94
3	Spikelets/panicle	2.10	643.83**	9.36
4	Grains/panicle	18.46*	523.70**	11.69
5	Spikelet fertility (%)	10.55	121.29**	7.26
6	Biological yield/plant (g)	14.22**	372.70**	10.15
7	L/B ratio	0.07	0.27	1.30
8	1000 -grain weight (g)	6.78	25.30**	3.96
9	Grain yield/plant (g)	5.35	129.88**	4.60

**, ** significant at 5 and 1 per cent probability levels, respectively*

Table 2. Estimates of general combining ability (gca) effects of F_1's parents (lines and testers) for 9 characters in rice

S.N.	Parents	Days to 50% flowering	Panicle bearing tillers/plant	Spikelets /panicle	Grains/panicle	Spikelet fertility (%)	Biological yield/plant (g)	L/B ratio	1000 -grain weight (g)	Grain yield/plant (g)
Lines										
1	HUR 917	-0.98	-0.59	-6.68	3.74	5.39	-1.52	-0.93	-1.64	-0.03
2	CR Dhan 800	-7.7	-1.57	-2.62	-7.63**	-4.64**	-4.86	-1.08	0.15	-1.02
3	Gopal Bhag	3.8**	0.68**	1.17	-0.64	-1.63	3.91**	-1.02*	-0.97	3.75
4	JGL 384	-4.97	0.53**	-3.18*	-3.63*	-1.92	-2.19	-1.01	-0.19**	-2.8
5	NDR 2064	-5.52**	-0.73	5.0**	-13.19	-11.97**	4.91	-1.19	-0.63	-0.37**
6	Lalaat	1.58	-2.01*	3.6**	7.95	2.05	-0.2**	-0.68	-1.12	-1.8
7	MTU 1010	4.47	-0.6	2.96	8.25	2.67	4.12	-0.95**	0.02	1.19**
SE (gi) Line		0.77	-0.17	-0.29	0.08	0.28	-0.06	-0.19	-0.82	-0.53
SE (gi – gj) Lines		1.10	0.18	0.01	0.54	0.69	0.33	0.15	-0.74	-0.33
Tester										
8	Prakhar	-4.22	0.79	9.04**	3.81	-3.07	-0.32**	-1.01	-0.7	-1.01
9	Barani Deep	1.31**	-3.85*	-15.65	-11.71	-0.11**	-5.69	-1.01	0.45**	-3.8**
10	NDR 2026	-0.1	0.067	3.61	4.89	0.18	3.01	-0.98	-2.75	1.81**
SE (gi)Tester		0.47	-0.49	-0.57	-0.34	-0.27	-0.43	-0.51	-0.89	-0.71
SE(gi – gj)Testers		0.67	-0.28	-0.38	-0.06	0.03	-0.19	-0.3	-0.85	-0.59

, Significant at 5% and 1% probability levels, respectively*

Table 3. Estimates of specific combining ability (sca) effects of crosses (F_1's) for 9 characters in rice

S.N.	Crosses	Days to 50% flowering	Panicle bearing tillers/plant	Spikelets /panicle	Grains /panicle	Spikelet fertility (%)	Biological yield/plant (g)	L/B ratio	1000 -grain weight (g)	Grain yield/plant (g)
1	HUR-917*Prakhar	-2.44	1.85*	-0.6**	4.5*	3.6*	1.98	0.8	4.4**	1.9
2	HUR-917*Barani Deep	2.01**	0.243	11.76	12.37*	3.18	1.02*	1.15	-0.01	2.02
3	HUR-917*NDR-2026	3.43	0.91**	-8.16*	-13.87	-3.79	-0.01	1.05	-1.41*	-0.93**
4	CR Dhan 800*Prakhar	6	2.36	-0.66	-11.44	-6.61*	-1.02	1.33	1.26	0.24
5	CR Dhan 800*Barani Deep	7.12	0.74	4.37*	12.74	7.23	2.69**	0.78	1.37	2.36
6	CR Dhan 800*NDR-2026	-10.12**	-0.1	-0.71	1.7	2.37	1.32	0.89	0.37	0.41
7	Gopal Bhag*Prakhar	1.77	2.68**	18.87	8.88	-3.36	11.2	0.67	-0.39	8.12
8	Gopal Bhag*Barani Deep	-0.76	0.01	-10.02	-3.91	3.94**	-6.08	1.44	1.68*	-2.75
9	Gopal Bhag*NDR-2026	1.98	0.31	-5.84	-1.96	2.41	-2.12*	0.89	1.71	-2.37*
10	JGL 384*Prakhar	1.88**	1.27	3.22	12.55**	7.11	-6.68	1.29	-0.59	-0.65
11	JGL 384*Barani Deep	3.01	0.26	-14.73	-14.25	-0.66**	9.69	1.1	-0.85	3.47**
12	JGL 384*NDR-2026	-1.93	1.46**	14.51**	4.7	-3.45	-0.01	0.61	4.45**	0.19
13	NDR-2064*Prakhar	-0.22	0.46	4.28	-17.56**	-11.7	4.54	1.08	0.18	-1.76
14	NDR-2064*Barani Deep	-1.76	1.45	10.32	4.3	-3.05	-2.08*	0.65	2.21	2.69
15	NDR-2064*NDR-2026	4.98	1.09	-11.61	16.25	17.75**	0.55	1.27	0.62	2.06**
16	Lalaat*Prakhar	-1.33	0.48	13.77**	16.95	3.71	-6.4**	1.1	2.52*	0.69

S.N.	Crosses	Days to 50% flowering	Panicle bearing tillers/plant	Spikelets /panicle	Grains /panicle	Spikelet fertility (%)	Biological yield/plant (g)	L/B ratio	1000 -grain weight (g)	Grain yield/plant (g)
17	Lalaat*Barani Deep	3.12**	1.45	-1.65	-2.84**	0.48	5	0.78	-2	-0.19
18	Lalaat*NDR-2026	1.2	1.06**	-9.11	-11.11	-1.19	4.32	1.12	2.48**	2.51
19	MTU-1010*Prakhar	-3.55	-0.61	-19.25**	-12.08	3.58**	-0.66**	0.63	1.61	-5.32
20	MTU-1010*Barani Deep	-0.43	1.7**	18.22	12.27	-1	2.7	1.27	0.12	5.13**
21	MTU-1010*NDR-2026	6.98**	1.91	4.03*	2.73**	0.43*	0.97	1.09	1.26	3.18
SE (Sij)		2.34	1.57	2.88	3.07	2.63	2.96	1.31	1.82	2.38
SE (Sij – Skl)		2.9	1.81	3.66	3.93	3.31	3.78	1.45	2.16	2.96
SE (Sij – Sik)		4.3	2.4	5.62	6.09	5.01	5.8	1.78	3.01	4.39

, Significant at 5% and 1% probability levels, respectively.*

Table 4. Most promising cross combinations for different characters along with their mean performance, sca effects and gca effects of parents in F_1s

S.N.	Characters	Crosses with significant effects	sca effects	Mean performance of crosses	gca effects of parents
1	Days to 50% flowering	MTU-1010*NDR-2026	6.98	75	HxA
		Lalaat*Barani Deep	3.12	91.33	LxL
		HUR-917*Barani Deep	2.01	89.67	LxH
2	Panicle bearing tillers/plant	Gopal Bhag*Prakhar	2.68	91.59	AxA
		HUR-917*Prakhar	1.85	93.33	HxL
		JGL 384*NDR-2026	1.46	95.43	LxA
3	Spikelets/panicle	JGL 384*NDR-2026	14.51	169.11	LxH
		Lalaat*Prakhar	13.77	178	AxH
		CR Dhan 800*Barani Deep	4.37	154.44	HxL
4	Grains/panicle	JGL 384*Prakhar	12.55	152.67	HxH
		HUR-917*Barani Deep	12.37	131.89	LxH
		HUR-917*Prakhar	4.5	117.33	LxL
5	Spikelet fertility (%)	NDR-2064*NDR-2026	17.75	92.19	LxH
		Gopal Bhag*Barani Deep	3.94	94.69	HxL
		MTU-1010*Prakhar	3.98	88.71	LxA
6	Biological yield/plant (g)	CR Dhan 800*Barani Deep	2.69	82	HxA
		HUR-917*Barani Deep	1.02	69	LxL
		MTU-1010*Prakhar	-0.66	66.33	AxL
7	L/B ratio				
8	1000-grain weight (g)	JGL 384*NDR-2026	4.45	20.99	LxH
		HUR-917*Prakhar	4.4	28.32	AxL
		Lalaat*Prakhar	2.52	28.91	LxA
9	Grain yield/plant (g)	MTU-1010*Barani Deep	5.13	49.33	HxL
		JGL 384*Barani Deep	3.47	41	LxL
		NDR-2064*NDR-2026	2.06	36.67	LxL

Table 5. Extent of per cent heterosis over better parent (BP) and two standard varieties (SV1 and SV2) of F1s for 9 characters in rice

S N	Crosses	Days to 50% flowering			Panicle bearing tillers/plant			Spikelets/panicle			Grains/panicle		
		BP	**SV1**	**SV2**	**BP**	**SV1**	**SV2**	**BP**	**SV1**	**SV2**	**BP**	**SV1**	**SV2**
1	HUR-917*Prakhar	-18.3	6.45	41.44	59.9	6.47	6.45	6.45	41.44	59.9	6.47	1.66	-6.09
2	HUR-917*Barani Deep	-15.15	-9.84	-15.34	-4.34	-8.12	-9.84	-9.84	-15.34	-4.34	-8.12	-12.26	-18.94
3	HUR-917*NDR-2026	-14.11	1.98	26.3	42.78	-4.48	1.98	1.98	26.3	42.78	-4.48	-8.79	-15.74
4	Cr Dhan 800*Prakhar	3.19	3.23	37.14	55.04	-6.9	3.23	3.23	37.14	55.04	-6.9	-3.25	-10.62
5	Cr Dhan 800*Barani Deep	-16.67	-6.89	-19.82	-9.41	-13.84	-6.89	-6.89	-19.82	-9.41	-13.84**	-10.47**	-17.29**
6	Cr Dhan 800*NDR-2026	-32.82**	-12.66**	8.14**	22.23	-9.56	-12.66	-12.66**	8.14**	22.23**	-9.56	-6.01	-13.17
7	Gopal Bhag*Prakhar	-3.81*	20.82*	60.56*	81.55	-0.18	20.82	20.82	60.56	81.55	-0.18	-0.73	-8.3
8	Gopal Bhag*Barani Deep	-13.33	-9.12	-5.96	6.27	-1.92	-9.12	-9.12	-5.96	6.27	-1.92	-2.46	-9.89
9	Gopal Bhag*NDR-2026	-11.04	6.85	32.36	49.63	-6.99	6.85	6.85	32.36	49.63	-6.99	-7.5	-14.54
10	JGL 384*Prakhar	-3.46	10.09	46.28	65.38	-10.48	10.09	10.09	46.28	65.38	-10.48	-17.83	-24.08
11	JGL 384*Barani Deep	-17.88*	-19.51*	-5.17*	7.16	2.14	-19.51	-19.5	-5.17	7.16	2.14	-6.26	-13.4
12	JGL 384*NDR-2026	-22.7	14.17	41.44	59.9	-8.74	14.17	14.17	41.44	59.9	-8.74	-15.25	-21.7
13	NDR-2064*Prakhar	-6.9	-4.05	27.45	44.08	-20.92	-4.05	-4.05**	27.45**	44.08**	-20.92**	-26.64**	-32.21**
14	NDR-2064*Barani Deep	-22.73**	-5.37**	-5.63**	6.65	-3.92	-5.37	-5.37	-5.63	6.65	-3.92	-10.88	-17.67
15	NDR-2064*NDR-2026	-16.87	2.29	26.7	43.23	-3.22	2.29	2.29	26.7	43.23	-3.22	-10.12	-16.96
16	Lalaat*Prakhar	-17.92	-12.64	16.01	31.14	4.79	-12.64	-12.64	16.01	31.14	4.79	-6.26	-13.4
17	Lalaat*Barani Deep	-20.82	1	-17.28	-6.53	3.15	1	0.11	-17.28	-6.53	3.15	-5.77	-12.95
18	Lalaat*NDR-2026	-11.8	-7.29	14.8	29.77	-2.59	-7.29	-7.29	14.8	29.77	-2.59	-9.54	-16.43
19	MTU-1010*Prakhar	-15.82	-10.36	19.04	34.56	-9.15	-10.36	-10.36	19.04	34.56	-9.15	-13.81	-20.37
20	MTU-1010*Barani Deep	-16.42**	-0.23**	-2.15**	10.59	-0.01	-0.23	-0.23	-2.15	10.59	-0.01	-5.15	-12.37
21	MTU-1010*NDR-2026	-6.4	9.29	35.38	53.06	-9.9	9.29	9.29	35.38	53.06	-9.9	-14.52	-21.03
Range of heterosis	Min.	-32.82	-19.51	-19.82	-9.41	-20.92	-19.51	-19.5	-19.82	-9.41	-20.92	-26.64	-32.21
	Max.	3.19	20.82	60.56	81.55	6.47	20.82	20.82	60.56	81.55	6.47	1.66	-6.09
No. of crosses with significant positive heterosis		0	1	2	0	0	0	0	2	2	0	0	0
No. of crosses with significant negative heterosis		5	4	3	0	0	0	2	0	0	2	2	2

*, ** significant at 5 and 1 per cent probability levels, respectively

Table 6. Biological yield of different croses

S. N.	Crosses	Spikelet fertility (%)			Biological yield/plant (g)			L/B ratio			1000 -grain weight (g)			Grain yield/plant (g)		
		BP	SV1	SV2	BP	SV1	SV2	BP	SV1	SV2	BP	SV1	SV2	BP	SV1	SV2
1	HUR-917*Prakhar	-2.58	10.9	6.17	5.81	79.18	21.99	2.12	21.99	14.98	10.05*	8*	34.98*	21.43**	65**	63.01**
2	HUR-917*Barani Deep	0.13	13.99	9.13	-4.35	61.91	10.26	13.85	36.03	28.2	-15.08	-5.12	18.54	12.83	53.31	51.44
3	HUR-917*NDR-2026	-7.01*	5.85*	1.34*	7.95	82.82	24.46	11.95	33.76	26.06	-22.03*	-23.48*	-4.44*	21.43**	65.03**	63.01**
4	CR Dhan 800*Prakhar	-19.39**	15.8*	-17.47*	3.89	61.88	10.24	13.03	36.7	28.83	19.98**	2.56**	28.17**	36.06*	53.3*	51.44*
5	CR Dhan 800*Barani Deep	2.04	6.7	2.15	1	57.36	7.17	-4.96	14.91	8.3	-3.76	7.53	34.39	17.2	50.38	48.55
6	CR Dhan 800*NDR-2026	-3.29	1.13	-3.18	13.79**	77.36**	20.75**	-0.1	20.79	13.85	-3.58	-9.23	13.4	47.7	66.5	64.46
7	Gopal Bhag* Prakhar	-12.25**	-6.16**	-10.15**	74.91*	119.18*	49.15*	-9.76	13.03	6.54	14.8	-8.48	14.34	92.89	108.97	106.41
8	Gopal Bhag*Barani Deep	0.38	6.35	1.82	5.88	57.36	7.17	14.63	43.65	35.38	-6.61**	4.35**	30.41**	16.06**	48.92**	47.1**
9	Gopal Bhag*NDR-2026	-1.03	4.85	0.39	53.17**	91.91**	30.63**	-1.77	23.06	15.98	-2.61	-8.32	14.54	84.08**	75.28**	73.14**
10	JGL 384*Prakhar	-0.65	6.26	1.73	-13.72	53.73	4.7	23.93	37.9	29.96	0.53	-6.17	17.23	5.35**	41.6**	39.87**
11	JGL 384*Barani Deep	-3.56	0.39	-3.88	3.03*	83.73*	25.078*	29.21	30.41	22.91	-12.89*	-2.67*	21.61*	9.7	47.46	45.66
12	JGL 384*NDR-2026	-4.03*	-2.66*	-6.8*	1.51	81	23.22	0.76	12.1	5.66	12.27	5.68	32.07	17.3	57.71	55.78
13	NDR-2064*Prakhar	-37.83*	-28.93*	-31.94*	26.99	103.73	38.65	0.13	22.26	15.23	10.72	-4.85	18.89	24.46	47.46	45.66
14	NDR-2064*Barani Deep	-25.48	-14.78	-18.4	6.65	71	16.43	-14.08	4.88	-1.14	-3.51	7.81	34.74	20.62**	54.78**	52.89**
15	NDR-2064*NDR-2026	-3.02	10.95	6.22	25.86	101.91	37.42	7.78	31.62	24.05	-5.81	-11.33	10.78	49.15**	76.75**	74.59**
16	Lalaat*Prakhar	0.01	6.97	2.41	28.74	60.09	9.02	29.57	44.18	35.88	14.83	2.47	28.05	40.19*	51.85*	49.99*
17	Lalaat*Barani Deep	1.59	6.63	2.08	18.68**	76.45**	20.14**	30.27	31.48	23.92	-20.33**	-11**	11.19**	5.81	35.74	34.08
18	Lalaat*NDR-2026	0	4.95	0.48	59.39	98.27	34.95	31.49	46.32	37.9	-0.01	-5.88	17.6	69.25**	72.35**	70.25**
19	MTU-1010*Prakhar	-1.22	7.55	2.97	1.49	87.36	27.54	-1.3	14.37	7.8	-1.19	3.45	29.28	1.12	38.67	36.98
20	MTU-1010*Barani Deep	-3.03	5.57	1.07	-1.45	81.91	23.84	20.7	39.9	31.85	-8.68	2.03	27.5	25.61**	72.35**	70.25**
21	MTU-1010*NDR-2026	-1.11	7.67	3.08	8.79	100.9	36.73	15.86	34.29	26.56	-10.39	-6.18	17.22	37.33	88.46	86.16
Range of heterosis	Min.	-37.83	-28.93	-31.94	-13.72	53.73	4.7	- 14.08	4.88	-1.14	-22.03	-23.48	-4.44	1.12	35.74	34.08
	Max.	2.04	15.8	9.13	74.91	119.18	49.15	31.49	46.32	37.9	19.98	8	34.98	92.89	108.97	106.41
No. of crosses with significant positive heterosis		0	2	1	5	5	5	0	0	0	2	3	5	11	11	11
No. of crosses with significant negative heterosis		5	3	4	0	0	0	0	0	0	4	3	1	0	0	0

3.4 Heterosis over better-Parent and Standard Variety

Heterosis was estimated as a per cent increase or decrease of F_1 value over better-parent (BP) and standard variety (SV), *viz.,* Shushk Samrat (SV_1) and Ashwani (SV_2). The estimates of standard heterosis for characters are presented in Table 3. For grain yield per plant, the heterosis over better-parent varied from 1.12% (MTU-1010 x Prakhar) to 92.89% (Gopal Bhag x Prakhar). The eleven crosses showed positive and significant heterosis over BP and the best three among them were 84.08% (Gopal Bhag x NDR-2026), 69.25% (Lalaat x NDR-2026), and 49.15% (NDR-2064 x NDR-2026). The standard heterosis for grain yield per plant ranged from 35.74% (Lalaat x Barani Deep) to 108.97% (Gopal Bhag x Prakhar) over SV_1; and from 34.08% (Lalaat x Barani Deep) to 106.41% (Gopal Bhag x Prakhar) over SV_2. The eleven showed positive and significant heterosis over SV_1 and the best three among them were NDR-2064 x NDR-2026 (76.75%), Gopal Bhag x NDR-2026 (75.28%), and Lalaat x NDR-2026 (72.35%). However, eleven crosses showed positive and significant heterosis over SV_2 and the most promising three crosses were NDR-2064 x NDR-2026 (74.59%), Gopal Bhag x NDR-2026 (73.14%), and Lalaat x NDR-2026 (70.25%).

4. CONCLUSION

The analysis of variance for the design of experiment found significant differences across genotypes for most features, apart from the L/B ratio, indicating significant variability among materials, particularly in F1 hybrids. Most features have non-significant variance due to replications, indicating stability across experimental blocks. MTU 1010 and NDR 2026 showed positive GCA effects for grain yield, while some crosses, such as MTU-1010 x Barani Deep, exhibited high SCA effects, indicating favorable gene combinations for yield improvement. Furthermore, heterosis study revealed the possibility for specific crossings to exceed their parents and standard varieties, particularly Gopal Bhag x Prakhar and NDR-2064 x NDR-2026, which demonstrated strong heterosis for grain yield per plant. The findings are consistent with prior studies, stressing the importance of both GCA and SCA in rice breeding and the potential for selecting promising hybrids with higher yields. This study emphasizes the relevance of combining ability in hybrid breeding and highlights crucial crosses that may contribute to producing high-yielding rice cultivars.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Khush GS, Virk PS. Rice breeding: achievements and future strategies; 2000.
2. Adarsha B. Screening of fertility restorers for cytoplasmic genic male sterile (CGMS) lines in rice *(Oryza sativa L.)* (Doctoral dissertation, Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara); 2011.
3. AIeH SS. Genetic variability in rice with relation to their grain development and genetics of yield components (Doctoral dissertation, Bidhan Chandra Krishi Vishwavidyalaya; Nadia); 2003.
4. AL Mamun SA. Caracterization and genetic diversity for agronomic traits in exotic rice (Doctoral dissertation, Bangabandhu Sheikh Mujibur Rahman Agricultural University); 2011.
5. DEY SR. Combining ability and heterosis in inter-ecotypic classes of rice *(Oryza sativa* L.*)* (doctoral dissertation, department of genetics and plant breeding, sher-e-bangla agricultural university, dhaka, bangladesh); 2010.
6. Mahmud MS. Genetic variability, correlation and path coefficient analysis in aman rice *(Oryza saliva L.)* (Doctoral dissertation, department of genetics and plant breeding, sher-e-bangla agricultural university, dhaka, bangladesh); 2010.
7. Patra BC, Mishra P, Patnaik SSC. Genetic variability and improvement of long awned rice genotypes for areas vulnerable to elephant depredation. *Oryza-an* International Journal on Rice. 2010;47(2):148-150.
8. Ram Milan RM, Verma GP, Manoj Kumar MK, Singh ON. Combining ability analysis

for grain yield and its components in short duration rice (*Oryza sativa* L.); 2010.
9. Shankar VG, Ansari NA, Ahmed MI, Rao P. Heterosis studies using thermo-sensitive genetic male sterile lines in rice. *ORYZA*-An International Journal on Rice. 2010;47(2):100-105.
10. Virmani SS, Ahmed MI. Rice breeding for sustainable production. Breeding major food staples. 2007;141-191.
11. Akram M, Munir M, Saifullah Ajmal SA, Shaukat Mehmud SM, Yahya Ashraf YA. Combining ability analysis for yield and yield components in rice (*Oryza sativa* L.); 2007.
12. Akter A, Hasan MJ, Begum H, Kulsum MU, Hossain MK. Combining ability analysis in rice (*Oryza sativa* L.). Bangladesh Journal of plant Breeding and Genetics. 2010;23 (2):7-14.
13. Allahgholipour M, Ali AJ. Gene action and combining ability for grain yield and its components in rice. Journal of Sustainable Agriculture. 2006;28(3):39-53.
14. Dey SR. Combining ability and heterosis in inter-ecotypic classes of rice *(Oryza sativa* L*.)* (doctoral dissertation, department of genetics and plant breeding, sher-e-bangla agricultural university, dhaka, bangladesh); 2010.
15. Jagadeesan S, Ganesan J. Combining ability in rice (*Oryza sativa* L.). Indian Journal of Agricultural Research. 2006;40 (2):139-142.
16. Jayasudha S, Sharma D. Combining ability and gene action analysis for yield and its components in rice (*Oryza sativa* L.). Journal of Rice Research. 2009;2(2): 105-111.
17. Saleem MY, Mirza JI, Haq MA. Combining ability analysis for yield and related traits in basmati rice (*Oryza sativa* L.). Pak. J. Bot. 2010;42(1):627-637.
18. Mirarab M, Ahmadikhah A, Pahlavani MH. Study on combining ability, heterosis and genetic parameters of yield traits in rice. African Journal of Biotechnology. 2011;10(59):12512-12519.
19. Saleem MY, Mirza JI, Haq MA. Combining ability analysis for yield and related traits in basmati rice (*Oryza sativa* L.). *Pak. J. Bot*. 2010;*42*(1):627-637.
20. Virmani SS, Ahmed MI. Rice breeding for sustainable production. Breeding Major Food Staples. 2007;141-191.

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