

Analysis of component of genetic variance, combining ability, gene action and heterotic response in rice (*Oryza sativa*. L).

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, including MTU-1010 × Barani Deep, 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 varieties Samrat and Ashwani. These findings emphasize the possibility of specific crosses to improve grain production in rice breeding efforts.

Key words: Rice (*Oryzasativa* L.), RBD, combining ability, Gene action, and heterosis.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food crop of the world. Asia is the leader in rice production, accounting for about 90% of the world's production. India has the largest area under rice cultivation, constituting a significant percentage of the global rice area and ranking second in total production next to China, with an average productivity of approximately 2000 Kg/hectare (FAO, 2010). It is one of the major food crops of the developing world and forms the staple diet of about half of the world's population. More than 90% of the world's rice is

grown and consumed in Asia, known as the rice bowl of the world, where 60% of the earth's people and two-thirds of the world's poor live (Khush and Virk, 2000). Asia's dominance in rice production underlines the crop's immense importance to food security in the region, with about 75% of the world's rice supply being consumed by people in Asian countries. The demand for rice is expected to increase with the continuous growth in global population. [10]

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). An attempt was made to make twenty-one cross combinations (F_1 's) during *Kharif* season 2012. The twenty-one F_1 's along with parents and a check variety *i.e.* 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 parental seven lines, three testers and twenty-one hybrids (F_1 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.

RESULTS AND DISCUSSION

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_1 s and two checks (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_1 s. The variances due to replications were non-significant for all characters, except panicle bearing tillers/plant, grains/panicle, and biological yield/plant (g). [1, 2, 5, 7, 12, 14, 15, 18, 19].

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 \times 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 \times Barani Deep (5.13), JGL 384 \times Barani Deep (3.47), and NDR-2064 \times 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. [3, 4, 6, 7, 8, 9, 11, 13, 16, 17]

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 \times Barani Deep exhibited the highest SCA effect of 5.13 and a mean performance of 49.33 g per plant, categorized under high \times low (HxL) general combining ability (GCA) effects. Another notable cross, JGL 384 \times Barani Deep, showed an SCA effect of 3.47 with a mean performance of 41.00 g per plant, falling under low \times low (LxL) GCA effects. Similarly, the cross NDR-2064 \times 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.

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., 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%).

S.N.	Characters	Sources of variation
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UNDER PEER REVIEW

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

		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 F₁'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 (F₁'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
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 F₁s.

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

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

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.

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

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	

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.

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