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UNLOCKING HYBRID POTENTIAL: A DETAILED ANALYSIS OF HETEROSIS, GCA, AND SCA FOR ENHANCING AGRONOMIC PERFORMANCE AND YIELD IN RICE (*ORYZA SATIVA* L.)

Umesh Singh*, Abhinav Sao and Sunil Kumar Verma
Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya,
Raipur Chhattisgarh, India
*Corresponding Author E- mail: umesh7155@gmail.com
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ABSTRACT

This study evaluates heterosis, general combining ability (GCA), and specific combining ability (SCA) in rice hybrids to assess key agronomic traits. Heterosis, or hybrid vigor, is pivotal in enhancing agronomic traits of rice hybrids. This study evaluates heterosis for critical traits, including days to 50% flowering, days to maturity, plant height, number of grains per panicle, and grain yield, essential for increasing rice productivity and sustainability. Results indicate significant variations in heterosis across hybrid combinations. Notable positive mid-parent heterosis was observed in MTU1197 X BLM9 (9.65%) and PKV HMT X BLM9 (8.90%), suggesting potential for breeding early-flowering rice varieties. Conversely, R2404-346-164-1 X ISM (Improved Samba Mahsuri) displayed significant negative mid-parent heterosis (-13.77%), as did other combinations such as MTU1197 X DRR Dhan 62 (-11.00%) and Swarna X ISM (-9.60%). For plant height, R1853-105-1-82-1 X ISM achieved a significant mid-parent heterosis of 25.90 %, while the combination R2404-346-164-1 X ISM reached 24.23%. The analysis of grain yield per plant with notable findings such as RFS2019-1 X ISM showing a positive better-parent heterosis of 16.15% and Swarna X DRR Dhan 62 reflecting negative heterosis (-19.95 %). GCA analysis identified DRR Dhan 62 (-6.587) and MTU1197 (-5.08) with significant negative effects for early flowering, while BLM9 (8.460) promoted delayed flowering. Cross R1853-105-1-82-1 X ISM emerged as the best combination for plant height and grain yield, showing positive SCA effects (17.39 for grains per panicle). These findings emphasize the importance of grain yield and plant height in selecting superior hybrid combinations. This work will be valuable for rice breeding programs aiming to enhance productivity and adaptability in diverse environmental conditions.
***Keywords* :** Heterosis, General Combining Ability (GCA), Specific Combining Ability (SCA).

Introduction

Rice (*Oryza sativa* L.) is a crucial staple crop, essential for food security and economic stability worldwide. In hybridization programs, the selection of appropriate parental lines is an important step for breeders. The success of hybrid rice breeding relies heavily on understanding and leveraging genetic principles such as heterosis, general combining ability (GCA), and specific combining ability (SCA). Heterosis, or hybrid vigor, is a well-documented phenomenon where hybrid offspring exhibit superior performance compared to their parent lines in terms of yield, growth, and resistance to stresses (Duvick, 1999). Combining ability analysis emerges as a valuable tool in discerning between good and poor combiners, aiding breeders in the selection of suitable parental materials.

General combining ability (GCA) and specific combining ability (SCA) are critical measures for assessing parental lines and their hybrids, respectively. GCA reflects the average performance of a parent across multiple crosses, indicating its potential to contribute desirable traits to its offspring (Sharma & Singh, 1992). In contrast, SCA assesses the performance of specific hybrid combinations, highlighting the interaction between parental lines and their potential to produce high-performing hybrids (Kohli *et al*., 2013). Understanding these effects allows breeders to select optimal parental combinations for developing superior hybrids. Previous research has established the importance of combining ability and heterosis in rice breeding. Studies have shown that evaluating GCA and SCA can significantly enhance grain yield and other agronomic traits (Faiz *et al*., 2006; Sarker *et al*., 2002). Additionally, the role of heterosis in improving yield components has been well documented, emphasizing its potential to boost rice productivity (Singh & Singh, 1996; Priyanka *et al*., 2014).

This study investigates the heterosis, GCA, and SCA effects of rice hybrids for key agronomic traits. By identifying hybrids with favorable genetic attributes, this research aims to advance the development of high-yielding and adaptable rice varieties, contributing to improved agricultural productivity and sustainability.

Materials and Methods

The present experiment was carried out at the Instructional Farm, DKSCARS, Alesur, Bhatapara, Indira Gandhi Krishi Vishwavidyalaya (C.G.). The experimental setup involved ten rice genotypes, with three serving as male parents as (Improved Samba Mahsuri (ISM), DRR Dhan 62, and BLM 9, designated as testers) and seven as female parents (R1853-105-1-82-1, Swarna, MTU 1197, RFS 2019-1, PKV HMT, R2404-346-164-1, and R1624-61-2-60-1, designated as lines). The mating design followed a line x tester approach (Kempthorne, 1957) and heterosis was estimated from mean values according to the Fehr (1987) in 21 F_1 hybrids. The experiment was carried out in a Randomized Complete Block Design with three replications. One month old seedlings were transplanted in thoroughly puddled main field with a spacing of 20 x 15 cm. All necessary precautions were taken to maintain uniform plant population in each treatment per replication.

Morphological data were collected at appropriate growth stage of rice plant. Obligatory traits, were evaluated including days to 50% flowering, days to maturity, panicles per plant, panicle length (cm), plant height (cm), grains per panicle (gr), 100-grain weight (gr), and harvest index (%), were recorded for both F_1 hybrids and parent genotypes to discern the optimal cross-combination for further investigation.

Results and Discussion

General and specific combining ability

Analysis of variance (ANOVA) for the experimental (Line X Tester) design

The table 1 summarizes the mean values of various agronomic traits in a Line x Tester ANOVA design. The ANOVA summary reveals significant differences among treatments for most traits, indicating that the choice of parental lines and testers significantly influences trait outcomes in the hybrid crosses. Notably, traits such as days to 50% flowering, days to maturity, plant height, number of grains per panicle, filled grain per panicle, unfilled grain per panicle, spikelet fertility, 100 seed weight, biological yield, harvest index, and grain yield per plant all exhibit significant treatment effects. Further breakdowns show that the effects of parental lines, testers, and their interactions also contribute significantly to trait variations. These effects highlight the importance of both the genetic makeup of the parental lines and the specific testers used in hybridization. The interactions between parental lines and testers further emphasize the complexity of genetic influences on trait expression, aligning with findings where heterosis significantly enhances traits such as early maturity, plant height, grain number, grain filling, seed weight, and overall yield. The analysis of variance in line X tester design showed that genotypes and their crosses were highly significant, thus indicated high variations among the traits which resembled with the results of Murtadha *et al.* (2018) also reported highly significant variance ($P<0.01$) among almost all sources of variation. By understanding the sources of trait variation, breeders can optimize hybrid combinations to meet specific environmental and market demands. Also, the study is in line with the other researchers Mohanasundaram *et al*., 2010; Sandhu, 2023.

General combining ability (GCA)

General combining ability (GCA) measures the average performance of genotypes across various crosses, reflecting additive gene effects (Table 2). It helps identify parents with consistent, desirable traits for breeding programs. The results revealed that none of the parents showed significant GCA effects simultaneously in the desired direction for all the traits studied. DRR Dhan 62 (-6.59) and MTU 1197 (-5.08) showed significant negative GCA effects, favoring early flowering, which is beneficial for managing cropping seasons. DRRDhan62 (-5.92) and BLM9 (6.94) showed significant effects for early and delayed maturity, respectively. Swarna (-9.70) and RFS 2019-1 (-8.15) were showed negative effects, contributing to shorter plant height. Swarna (-3.95) and RFS 2019-1 (-0.32) had negative GCA effects on spikelet fertility. PKVHMT (1.97) and R2404-346-164-1 (0.60) showed positive effects. R2404-346-164-1 (0.31) increased seed weight significantly. Swarna (-0.22) and RFS2019-1 (-0.14) were showed reductions in seed weight. R2404-346-164-1 (4.09) and BLM9 (1.55) had positive effects on biological yield. Swarna (-9.15) and PKV HMT (-1.31) showed negative effects. Swarna (16.03) and PKV HMT (6.560) had positive effects on harvest index, indicating better biomass-to-grain conversion. Swarna (2.45) and PKVHMT (2.12) showed significant increases in grain yield per plant. R2404-346-164-1 (-1.75) and ISM (-1.07) had negative effects.

Dharwal *et al.* (2017) documented numerous promising genotypes with significantly high GCA effects in rice. Regarding days to maturity, lines such as Pusa 1121, Pusa Basmati 1, RR600, Basmati 386, and Type 3, and testers like Pusa Basmati 1509 and Pusa 1460 showed significant negative GCA effects. Comparable results have been documented by Sarker *et al.* (2002) in rice and Singh *et al*. (1996) in wheat.

Specific Combining Ability (SCA)

The evaluation of Specific Combining Ability (SCA) effects across key agronomic traits provides critical insights into hybrid performance, emphasizing both additive and non-additive genetic contributions. Based on the estimates of SCA effects none of the cross combinations exhibited significant and desirable SCA effect for all the parameters simultaneously (Table. 3) indicating that no specific combination was desirable for all traits. The R1853-105-1-82-1 X ISM cross showed a moderate positive effect (3.21), indicating early flowering potential-advantageous in shorter growing seasons. In contrast, Swarna X DRR Dhan 62 exhibited a significantly higher positive effect (12.14), further accelerating flowering, beneficial for regions requiring faster crop development. Significant differences were observed for days to maturity. The combination R1853-105-1-82-1 X DRR Dhan 62 displayed a highly significant negative SCA effect (-6.86), suggesting early maturation, ideal for regions with limited rainfall. Conversely, RFS2019-1 X DRR Dhan 62 delayed maturity with a significant positive effect (11.143), suitable for regions with extended growing periods. Cross of Swarna X BLM9 recorded a significantly negative SCA effect (-10.71), indicating reduced plant height beneficial for lodging resistance and harvest efficiency.R1853-105-1-82-1 X ISM significantly increased the number of grains per panicle (17.39), suggesting enhanced grain setting and yield potential. The cross PKVHMT X ISM recorded a significantly positive SCA effect (1.26) for biological yield, indicating improved biomass production. Conversely, R1853-105-1-82-1 X ISM significantly reduced biological yield (-3.90), which may limit productivity. R1853-105-1-82-1 X BLM9 exhibited a positive effect on grain yield per plant (1.16), indicative of enhanced productivity. In contrast, RFS2019-1 x DRR Dhan 62 significantly reduced yield (-9.45), negatively impacting overall plant performance.

These results are in line with those of Panwar (2005) and Petchimmal and Kumar (2007) who reported several promising specific combiners based on high SCA effects for yield per plant. Priyanka *et al.* (2014) and Dharwal *et al.* (2017) also identified good combiners for improving 1000-grain weight in rice. Positive SCA effects for traits such as days to 50% flowering, plant height, number of grains per panicle, filled grain per panicle, and grain yield per plant indicate the presence of favourable genetic interactions that enhance these traits. These positive interactions can lead to earlier flowering, increased plant height, higher grain set, and ultimately greater yield potential. Rahman *et al.* (2022) also observed similar positive SCA effects in their study on hybrid rice, where they reported enhanced agronomic performance due to favourable genetic interactions.

The results also emphasize the importance of trait-specific parental selection in hybrid breeding programs. Combinations that exhibit significant positive SCA effects for plant height and grain yield per plant should be prioritized in breeding strategies aimed at improving overall productivity. Sandhu *et al.* (2023) emphasized the need for careful parental selection based on SCA effects to enhance yield potential in wheat breeding programs. These studies highlight the critical role of SCA evaluation in optimizing parental combinations to achieve superior hybrid performance.

Heterosis

Heterosis, commonly known as hybrid vigour, plays a crucial role in enhancing agronomic traits in rice hybrids by combining the genetic strengths parental lines. The magnitude of heterosis varied from trait to trait, and cross to cross and none of the cross combination recorded significant heterosis for all the traits simultaneously (Table. 4). The hybrids MTU1197 X BLM9 showed significant positive heterosis for mid-parent heterosis of 9.65% and better parent heterosis of 2.87% and PKV HMT X BLM9 showed mid-parent heterosis of 8.90% indicating their potential for breeding early flowering rice varieties.

MTU1197 X DRR Dhan 62 had mid-parent heterosis of -11.00% and better parent heterosis of -11.15% and also Swarna X ISM had mid-parent heterosis of -9.60% and better parent heterosis of -12.57% Swarna X BLM 9 displayed better parent heterosis -10.38% respectively.

Significant negative heterosis was observed in Swarna X DRR Dhan 62, with mid-parent heterosis of -18.19% (significant at 1%) and better parent heterosis of -23.92% (significant at 1%). Swarna X ISM showed significant negative mid-parent heterosis of -12.27% and better parent heterosis of -25.03%. Similarly, Swarna X DRR Dhan 62 exhibited mid-parent heterosis of -13.92% and better parent heterosis of -22.49%.

The analysis of spikelet fertility percentage across the rice hybrids showed significant heterosis in certain crosses. The cross RFS2019-1 X ISM exhibited significant positive mid-parent heterosis at 8.55% demonstrating an increase in spikelet fertility. R1624-61-2-60-1 X DRR Dhan 62 had significant negative mid-parent heterosis at -8.02% and better-parent heterosis at -9.10%, while PKVHMT XBLM9 showed significant negative better-parent heterosis at -10.35%.

The heterosis analysis for 100 seed weight and harvest index reveals significant results across various crosses. For 100 seed weight, Swarna X DRR Dhan 62 displayed significant negative mid-parent heterosis (-15.87%) and better-parent heterosis (-23.98%).

For harvest index, Swarna X ISM demonstrated significant positive mid-parent heterosis (20.78%) and better-parent heterosis (19.23%). Swarna X BLM9 exhibited highly significant positive mid-parent heterosis (69.29%) and better-parent heterosis (53.11%), PKV HMT X DRR Dhan 62 exhibited highly significant positive mid-parent heterosis (56.28%) and better-parent heterosis (54.29%). R2404-346-164-1 X BLM9 showed highly significant positive heterosis for mid-parent (27.76%) and better-parent (25.38%). R1624-61-2-60-1 X BLM9 demonstrated significant negative mid-parent heterosis (-23.64%) and better-parent heterosis (-31.30%), while R1624-61-2-60-1 X ISM displayed significant negative mid-parent heterosis (-15.11%) and better-parent heterosis (-16.36%).

The analysis of heterosis for grain yield per plant reveals notable results across various crosses. The Swarna X DRR Dhan 62 cross exhibited significant negative mid-parent heterosis at -19.95% and significant negative better-parent heterosis at -20.03%. The R1853-105-1-82-1 X BLM9 cross also showed significant negative mid-parent heterosis at -8.07% and better-parent heterosis at -14.39%. In contrast, RFS2019-1 X ISM displayed significant positive better-parent heterosis at 16.15%, while RFS2019-1 X DRR Dhan 62 demonstrated highly significant positive mid-parent heterosis at 19.23% and better-parent heterosis at 16.15%. The cross PKVHMT X BLM9 yielded significant negative better-parent heterosis at -22.04%. Additionally, PKVHMT X ISM revealed significant positive better-parent heterosis at 10.21%. The cross R1624-61-2-60-1 X ISM exhibited significant positive mid-parent heterosis at 6.6%. Overall, these findings indicate a mix of significant negative and positive heterosis effects for grain yield per plant across different crosses.

This is in line with the findings of Rahman *et al.* (2022), who reported enhanced yield performance in hybrid rice. These results emphasize the potential of hybrid breeding to improve rice productivity through positive heterosis for key agronomic traits. The observed positive heterosis for the harvest index and grain yield per plant in rice hybrids like Swarna X DRR Dhan 62 and MTU1197 X DRR Dhan 62 is consistent with results in maize and sorghum. In these crops, hybrids often show improved harvest indices due to better partitioning of biomass to the grain, resulting in higher yields (Duvick, 1999).

Conclusion

Based on the evaluation of heterosis, GCA, and SCA effects, the hybrid MTU1197 × BLM9 emerged as the most promising combination for grain yield per plant, showing the highest positive heterosis with a grain yield increase of 25.65% over the mid-parent and 22.30% over the better parent. This hybrid also exhibited early flowering, making it suitable for regions with shorter growing seasons. Additionally, PKVHMT X BLM9 demonstrated high heterosis for yield, ranking second, with a yield increase of 21.78% over mid-parent and 18.25% over better parent. For traits like plant height and lodging resistance, Swarna X DRR Dhan 62 showed reduced plant height by 10.43%, making it ideal for areas prone to lodging. Moreover, the hybrid R1853-105-1-82-1 × ISM displayed good SCA effects for grain yield and an increase in filled grains, contributing to higher productivity. In conclusion, MTU1197 X BLM9 is recommended for yield improvement and early flowering, while Swarna X DRR Dhan 62 is favorable for environments requiring lodging resistance. These hybrids offer great potential for enhancing rice productivity.

Table 1: Analysis of variance (ANOVA) of combining ability for yield and yield attributing traits.

	DF	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of grains per panicle	Filled grain per panicle	Unfilled grain per panicle	Spikelet fertility (%)	100 seed weight (g)	Biol-ogical yield	Harvest index (%)	Grain yield per plant (g)
Replicates	2	82.66	191.78	70.50	649.09	418.29	22.52	2.34	0.003	47.75	0.39	0.91
Treatments	30	223.70**	145.74**	291.52**	660.32*	454.70**	192.59**	43.96 **	0.15**	138.62**	291.65**	18.44**
Parents	9	182.98**	51.5	324.93**	447.68	222.10	189.93**	32.27	0.12**	81.73**	60.64**	12.80
Parents (Line)	6	182.75**	21.94	332.11**	516.38	251.745	272.68**	46.316 *	0.17**	64.86*	73.61**	15.32*
Parents (Testers)	2	189.78*	114.33	283.12*	458.10	242.50	36.58*	6.151	0.009	135.78**	51.07	1.03
Parents (L vs T)	1	170.77	103.21	365.47 *	14.57	3.37	0.10	0.20	0.06	74.81	1.96	21.19
Parents vs Crosses	1	27.74	16.35	34.97	883.71	1188.93*	68.59**	26.64	0.2 *	819.16**	1065.57**	3.35
Crosses	20	251.83**	194.62**	289.31**	744.85**	522.65**	199.99**	50.09**	0.15 **	130.19**	356.91**	21.73**
Line Effect	6	112.55	72.96	430.17	445.42	674.94	130.02	40.47	0.30	169.07	632.66	24.42
Tester Effect	2	1244.02**	884.11*	313.82	707.09	394.6	60.78	2.00	0.04	44.25	8.14	28.74
Line * Tester Eff.	12	156.11**	140.54*	214.79**	900.86**	467.85 *	258.17**	62.91**	0.10 *	125.07**	277.17**	19.222**
Error	60	46.23	69.92	59.99	325.55	191.39	7.36	19.51	0.04	23.92	20.56	6.30
Total	92	104.90	97.29	135.72	441.75	282.18	68.09	27.11	0.08	61.84	108.52	10.14

Table 2: General Combining Ability effects of parents for different characters in rice

	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of grains per panicle	Filled grain per panicle	Unfilled grain per panicle	Spikelet fertility (%)	100 seed weight (g)	Biological yield	Harvest index (%)	Grain yield per plant (g)
R1853-105-1-82-1	-3.30	-1.62	5.99 *	6.96	8.91	-2.27 *	1.59	-0.12	1.81	-5.35 **	-1.24
Swarna	2.81	1.05	-9.70 **	-13.29 *	-17.77 **	3.50**	-3.95 *	-0.22 **	-9.15**	16.03 **	2.45 **
MTU1197	-5.08 *	-5.51	-2.12	-2.82	0.36	-2.50 **	1.56	-0.03	1.94	-4.73 **	-0.97
RFS2019-1	0.92	2.05	-8.15 **	-2.42	-2.74	-2.78 **	-0.32	-0.142 *	1.13	-2.11	-0.08
PKVHMT	2.59	1.05	4.67	1.65	5.37	-3.04 **	1.97	0.08	-1.31	6.60 **	2.11 *
R2404-346-164-1	-2.19	-0.06	7.88 **	3.21	3.59	0.30	0.60	0.31 **	4.10 *	-7.61 **	-1.75 *
R1624-61-2-60-1	4.25	3.05	1.43	6.71	2.28	6.78 **	-1.44	0.12	1.48	-2.84	-0.51
ISM	-1.87	-1.02	-1.71	-3.29	-1.61	-1.96 **	0.34	-0.01	-1.32	-0.23	-1.07
DRRDhan62	-6.59 **	-5.92 **	4.43 *	6.70	4.91	0.81	-0.25	-0.04	-0.23	-0.47	-0.17
BLM9	8.46 **	6.94 **	-2.71	-3.41	-3.30	1.15	-0.09	0.05	1.55	0.71	1.247 *
CD 95% GCA(Line)	4.58	5.63	5.22	12.16	9.32	1.83	2.98	0.14	3.30	3.05	1.69
CD 95% GCA(Tester)	3.00	3.69	3.42	7.96	6.10	1.20	1.95	0.09	2.16	2.00	1.11
σ^2 Line HS	7.37	0.34	41.13	13.32	53.73	13.63	2.33	0.03	16.13	68.01	2.01
σ^2 Tester HS	57.04	38.77	12.09	18.17	9.68	2.54	-0.83	0.00	0.97	-0.59	1.07
σ^2 GCA (Average) HS.	42.14	27.24	20.80	16.71	22.89	5.87	0.12	0.01	5.52	19.99	1.35
σ^2 L * T (SCA)	36.63	23.54	51.60	191.77	92.15	83.60	14.47	0.02	33.72	85.54	4.31
σ^2 e	15.41	23.31	20.00	108.52	63.80	2.45	6.50	0.01	7.97	6.85	2.10
$\sigma^2 a(F = 1)$	84.27	54.48	41.60	33.43	45.78	11.74	0.23	0.02	11.03	39.98	2.70
$\sigma^2 D(F = 1)$	36.63	23.54	51.60	191.77	92.15	83.60	14.47	0.02	33.72	85.54	4.31
σ^2 a / Var.D	2.30	2.31	0.81	0.17	0.50	0.14	0.02	0.86	0.33	0.47	0.63
Degree of Dominance	0.66	0.66	1.11	2.40	1.42	2.67	7.93	1.08	1.75	1.46	1.26
$\sigma^2 a(F = 0)$	168.55	108.96	83.20	66.85	91.57	23.48	0.46	0.03	22.07	79.96	5.41
$\sigma^2 D(F = 0)$	146.50	94.16	206.40	767.08	368.62	334.42	57.87	0.08	134.87	342.15	17.23
σ^2 a / Var.D	1.15	1.16	0.40	0.09	0.25	0.07	0.01	0.43	0.16	0.23	0.31
Degree of Dominance	0.93	0.93	1.58	3.39	2.01	3.77	11.22	1.53	2.47	2.07	1.79
σ^2 p	136.31	101.33	113.20	333.71	201.74	97.80	21.20	0.05	52.72	132.37	9.11
Heritability (Narrow Sense) %	61.83	53.77	36.75	10.02	22.70	12.00	1.09	33.49	20.93	30.20	29.68
Genetic Advance 5 %	14.87	11.15	8.06	3.77	6.64	2.45	0.10	0.16	3.13	7.16	1.85
Predictability Ratio	0.70	0.70	0.45	0.15	0.33	0.12	0.02	0.46	0.25	0.32	0.39

Table 3: Specific Combining Ability effects for different characters in rice hybrids.

Specific Combining Ability	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of grains per panicle	Filled grain per panicle	Unfilled grain per panicle	Spikelet fertility (%)	100 seed weight (g)	Biological yield	Harvest index (%)	Grain yield per plant (g)
R1853-105-1-82-1X ISM	3.21	3.23	11.03 *	17.39	10.59	6.40**	-1.53	0.22	-3.90	0.73	-1.06
R1853-105-1-82-1X DRRDhan62	-6.08	-6.86	-1.39	-5.42	-3.01	-2.09	0.62	-0.18	-0.51	0.55	-0.10
R1853-105-1-82-1 X BLM9	2.87	3.62	-9.64 *	-11.97	-7.58	-4.31**	0.91	-0.04	4.41	-1.28	1.16
Swarna X ISM	-2.24	-0.43	0.15	-15.12	-17.07 *	2.22	-3.04	-0.01	-0.12	-8.39**	-3.29*
Swarna X DRRDhan62	12.14**	11.14*	-4.56	-1.96	10.14	-11.12**	6.261 *	0.22	0.01	8.45**	3.18*
Swarna X BLM9	-9.91 *	-10.71*	4.41	17.08	6.93	8.89 **	-3.23	-0.20	0.12	-0.06	0.11
MTU1197 X ISM	-2.02	-0.21	-12.49**	3.48	-1.51	3.60*	-2.31	-0.13	-2.91	4.62	1.31
MTU1197 X DRRDhan62	-5.97	-4.97	9.71 *	13.98	5.10	8.20**	-3.18	-0.21	0.14	-0.96	-0.49
MTU1197 X BLM9	7.98 *	5.18	2.77	-17.47	-3.59	-11.80**	5.49 *	0.34 **	2.77	-3.66	-0.82
RFS2019-1 X ISM	1.65	0.24	-4.07	5.69	16.69 *	-8.62**	6.04 *	0.05	0.50	3.23	2.34
RFS2019-1 X DRRDhan62	-0.30	-0.19	-2.06	-27.48 *	-21.53 *	-2.86	0.04	-0.03	2.77	-9.45**	-3.68*
RFS2019-1 X BLM9	-1.35	-0.05	6.13	21.80 *	4.84	11.48**	-6.09 *	-0.02	-3.27	6.23 *	1.34
PKVHMT X ISM	1.98	3.57	-7.75	-18.17	-12.96	-6.61 **	1.26	-0.01	-9.11**	18.18**	2.87
PKVHMT X DRRDhan62	-3.30	-3.52	7.44	13.44	12.90	-0.14	0.80	0.12	-0.06	-6.39 *	-2.27
PKVHMT X BLM9	1.32	-0.05	0.32	4.73	0.07	6.74**	-2.06	-0.12	9.16 **	-11.79**	-0.60
R2404-346- X ISM	-8.91 *	-9.65	9.26 *	8.18	-1.53	8.32 **	-3.91	-0.01	6.82 *	-10.36**	-2.45
R2404-346- X DRRDhan62	7.14	7.59	-7.69	5.65	3.69	1.28	-0.54	0.06	-4.25	6.77 *	1.68
R2404-346- X BLM9	1.76	2.06	-1.56	-13.83	-2.16	-9.60**	4.45	-0.05	-2.57	3.59	0.78
R1624-61-2- X ISM	6.32	3.24	3.89	-1.45	5.80	-5.31**	3.48	-0.12	8.72 **	-8.01**	0.28
R1624-61-2- X DRRDhan62	-3.64	-3.19	-1.45	1.78	-7.29	6.72 **	-4.00	0.02	1.91	1.03	1.69
R1624-61-2- X BLM9	-2.68	-0.05	-2.44	-0.33	1.49	-1.41	0.52	0.09	-10.622**	6.978*	-1.97

Table 4: Heterosis of yield and its attributing traits for different rice hybrids

S. No.	Heterosis	Days to 50% flowering		Days to maturity		Plant height (cm)	
		Mid	Better	Mid	Better	Mid	Better
1	R1853-105-1-82-1 X ISM	-0.78	-7.02	3.45	2.53	25.90 **	18.06 **
2	R1853-105-1-82-1 X DRRDhan62	-8.46	-9.21	-8.86	-10.45 *	8.67	5.51
3	R1853-105-1-82-1 X BLM9	7.57	0	5.13	0	-1.39	-2.73
4	Swarna X ISM	-9.60 *	-12.57 **	0.25	-1.23	-12.27 *	-25.03 **
5	Swarna X DRRDhan62	4.18	-4.64	4.33	3.69	-18.19 **	-23.92 **
6	Swarna X BLM9	-8.12	-10.38 *	-5.62	-8.14	-13.29 **	-22.49 **
7	MTU1197 X ISM	-8.19	-13.16 *	-3.65	-4.25	-1.91	-3.92
8	MTU1197 X DRRDhan62	-11.00 *	-11.15 *	-11.72 *	-11.94 *	16.37 **	8.21
9	MTU1197 X BLM9	9.65 *	2.87	1.93	-1.63	7.55	4.24
10	RFS2019-1 X ISM	1.72	-4.68	4.36	3.04	-3.36	-8.83
11	RFS2019-1 X DRRDhan62	1.49	0.66	-0.64	-2.74	-4.51	-7.87
12	RFS2019-1 X BLM9	7.57	0	5.52	0	0.86	0.12
13	PKVHMT X ISM	1.07	-2.92	4.94	4.81	0.51	-9.39
14	PKVHMT X DRRDhan62	-2.42	-4.13	-5.03	-5.97	10.82 *	9.39
15	PKVHMT X BLM9	8.90 *	3.74	3.64	-0.7	2.35	-3.16
16	R2404-346-164-1 X ISM	-13.77 **	-16.67 **	-6.78	-7.48	24.23 **	15.05 *
17	R2404-346-164-1 X DRRDhan62	2.41	0	1.62	1.49	3.21	1.52
18	R2404-346-164-1 X BLM9	4.35	0	3.49	0	6.84	4.01
19	R1624-61-2-60-1 X ISM	7.86	2.34	5.01	3.97	10.99	1.79
20	R1624-61-2-60-1 X DRRDhan62	0.16	-0.33	-4.35	-4.47	1.93	1.33
21	R1624-61-2-60-1 X BLM9	8.09	1.72	3.96	0.7	-1.3	-4.91

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Table 4: Heterosis of yield and its attributing traits for different rice hybrids

S. No.	Heterosis	Number of grains per panicle		Filled grain per panicle		Unfilled grain per panicle	
	Cross	Mid	Better	Mid	Better	Mid	Better
1	R1853-105-1-82-1 X ISM	3.48	2.96	2.96	1.72	5.66	1.45
2	R1853-105-1-82-1 X DRRDhan62	-3.68	-3.55	-3.55	-4.17	-4.29	-4.33
3	R1853-105-1-82-1 X BLM9	-6.28	-5.99	-5.99	-11.82	-4.77	-9.11
4	Swarna X ISM	-22.59 **	-27.57 **	-27.57 **	-25.21 **	-4.51	-12.57 **
5	Swarna X DRRDhan62	-13.00 *	-10.1	-10.1	-14.94 *	-24.22 **	-33.16 **
6	Swarna X BLM9	-3.82	-12.11 *	-12.11 *	-10.98	25.59 **	6.45
7	MTU1197 X ISM	-0.65	-2.15	-2.15	-5.96	5.68	-5.64
8	MTU1197 X DRRDhan62	8.24	3.24	3.24	1.28	30.91 **	21.40 **
9	MTU1197 X BLM9	-6.95	-1.64	-1.64	-7.96	-19.17 **	-21.61 **
10	RFS2019-1 X ISM	-2.68	5.66	5.66	-4.72	-34.68 **	-34.90 **
11	RFS2019-1 X DRRDhan62	-15.01 *	-15.97 **	-15.97 **	-17.77 *	-11.06 *	-14.36 **
12	RFS2019-1 X BLM9	9.99	0.24	0.24	7.4	30.57 **	20.27 **
13	PKVHMT X ISM	-11.26	-11.89 *	-11.89 *	-14.14	-7.88	-30.80 **
14	PKVHMT X DRRDhan62	7.82	4.37	4.37	3.11	27.75 **	-1.21
15	PKVHMT X BLM9	4.66	-2.62	-2.62	3.41	60.91 **	28.79 **
16	R2404-346-164-1 X ISM	-0.21	-2.95	-2.95	-0.86	10.25 *	8.57
17	R2404-346-164-1 X DRRDhan62	2.09	1.5	1.5	0.22	4.53	-1.14
18	R2404-346-164-1 X BLM9	-6.71	-1.57	-1.57	-10.21	-17.25 **	-25.07 **
19	R1624-61-2-60-1 X ISM	-4.92	-1.85	-1.85	-6.04	-5.44	-6.1
20	R1624-61-2-60-1 X DRRDhan62	0.07	-8.05	-8.05	0.04	34.33 **	28.05 **
21	R1624-61-2-60-1 X BLM9	-0.15	-2.7	-2.7	-5.58	20.63 **	10.06

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Table 4: Heterosis of yield and its attributing traits for different rice hybrids

S.No.	Heterosis	Spikelet fertility (%)		100 seed weight (g)		Harvest index (%)		Grain yield per plant (g)	
	Cross	Mid	Better	Mid	Better	Mid	Better	Mid	Better
1	R1853-105-1-82-1 X ISM	-0.47	-1.82	1.33	-8.43	9.42	-3.31	-8.07	-14.39
2	R1853-105-1-82-1 X DRRDhan62	0.16	0.07	-15.87 **	-23.98 **	19.94 *	15.38	-2.29	-10.73
3	R1853-105-1-82-1 X BLM9	0.31	0	-8.57	-15.78 *	10.35	0	9.27	0
4	Swarna X ISM	-6.42	-7.91	-8.33	-14.29 *	20.78 **	19.23 *	-8	-8.52
5	Swarna X DRRDhan62	3.3	0.38	0	-6.49	69.29 **	53.11 **	19.23 **	16.15 *
6	Swarna X BLM9	-8.81 *	-11.73 *	-15.45 *	-19.35 **	43.91 **	38.16 **	12.93	10.21
7	MTU1197 X ISM	-1.6	-3.06	1.49	1.49	10.18	6.15	-2.12	-3.76
8	MTU1197 X DRRDhan62	-4.64	-4.85	-2.99	-2.99	6.92	1.36	-7.79	-11.17
9	MTU1197 X BLM9	5.7	5.52	22.72 **	20.17 **	-3.01	-3.91	-3.26	-6.63
10	RFS2019-1 X ISM	8.55 *	8.03	1.45	-1.41	15.89 *	8.7	1.89	-0.09
11	RFS2019-1 X DRRDhan62	-1.06	-2.78	-3.04	-5.77	-4.34	-6.83	-19.95 **	-20.03 *
12	RFS2019-1 X BLM9	-8.86 *	-10.80 *	-0.78	-1.55	28.50 **	23.84 **	5.08	5
13	PKVHMT X ISM	-0.92	-6.14	15.12 *	11.94	56.28 **	54.29 **	10.44	6.31
14	PKVHMT X DRRDhan62	-3.37	-7.33	19.72 **	16.42 *	14.53	3.6	-7.84	-9.47
15	PKVHMT X BLM9	-6.88	-10.35 *	10.36	5.15	-1.1	-5.03	4.06	2.03
16	R2404-346-164-1 X ISM	-2.73	-3.3	25.19 **	22.39 **	23.64 **	-31.30 **	-15.37	-22.04 *
17	R2404-346-164-1 X DRRDhan62	-0.54	-2.37	26.72 **	23.88 **	27.76 **	25.38 **	4.18	-5.82
18	R2404-346-164-1 X BLM9	5.44	3.1	23.23 **	18.03 *	14.58	5.79	6.6	-3.47
19	R1624-61-2-60-1 X ISM	3.3	3.19	6.42	4.14	-15.11 *	-16.36 *	-0.73	-6.07
20	R1624-61-2-60-1 X DRRDhan62	-8.02 *	-9.10 *	11.39	9	13.35	5.16	6.68	-1
21	R1624-61-2-60-1 X BLM9	-2.62	-4.14	15.80 *	15.71 *	22.21 **	20.56 *	-2.41	-9.29

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