Original Research Article

STUDIES ON HETEROSIS FOR GRAIN YIELD AND YIELD ATTRIBUTES IN RICE (*Oryza sativa.* L)

Abstract

The present study was carried out to determine the best heterotic combinations in terms of grain yield and its attributes in rice. For this, 5 lines are crossed with 2 testers in the Line x Tester mating design and their F_1s are evaluated along with their parents and checks in randomized block design with three replications at Agriculture Research Station Kampasagar, Nalgonda during *Kharif* 2022.The degree of heterosis varied between traits. Out of the 10 hybrids studied, significant positive heterosis, heterobeltiosis and standard heterosis for grain yield were observed in six hybrids, which outperformed the best-check RNR 15048. Hybrids JGL 27356 x PTB 33 and KPS 3018 x PTB were stable hybrids with favourable SCA effects, heterosis and per se performance for grain yield, its components and grain quality traits. These two experimental hybrids will be evaluated further in locations suitable for large-scale commercialization.

Keywords: *Heterosis, heterobeltiosis, standard heterosis, Grain yield, Line x Tester*

1.Introduction

Rice is known as the "grain of life" because itis the most important *basic food* in the *world* and nearly 2 billion *people* depend on it for more than 80% of their calories. It is not only a basic need but also the number one cereal in the human diet and provides 21% of global human per capita energy and 15% of per capita protein. Besides being the chief source of carbohydrate and protein in Asia (Veereshaet *al*., 2015). According to Indiastat, the country with the most rice acreage is India, which has 46.27 million ha (24 percent of cropped area) and an annual production of 129.47MT and productivity 2798 kg/ha in 2021-22.

Heterosis is the increased vigour of F_1 progeny of a cross in terms of size, duration or yield of economic product over the mean of the parents or better parent (Hayes *et al.* 1955). Shull (1914) first coined the term heterosis. After the discovery of hybrid vigour in plants, heterosis has received much interest by plant breeders and successfully exploited to increase the crop production. Exploitation of heterosis has been associated in the rice breeding programme since the revolutionizing contribution of hybrids in the rice production of China during the last two decades.

The availability of diverse parental lines and genetic knowledge of a trait are critical factors in the development of heterotic hybrids. In rice, the utility of heterosis *per se* may not be of much use but cross combinations showing excellent hybrid vigour can be used to isolate a higher frequency of productive derivatives in the advanced generations. Knowledge of the nature and magnitude of genetic variation governing the inheritance of quantitative characters such as yield and its components is critical for genetic improvement and is required before beginning any crop improvement programme or using appropriate selection techniques.

2. Materials and methods

During the *Kharif* season of 2021, 19 genotypes, which consists of 5 lines (WGL 962, KNM 1638, KPS 3018, RNR 21278 and JGL 273562), two testers (IET 23993 and PTB 33), 10 hybrids, one standard varietal check and one resistance check for BPH (RNR 15048 and PTB 33), were evaluated in randomised block design with two replications at Agricultural Research Station, Kampasagar, Nalgonda.

To raise and maintain a healthy crop, all the recommended practises were followed. Days to 50% flowering, plant height, panicle length, panicle weight, number of productive tillers per plant, spikelet fertility percent, number of grains per panicle, grain yield per plant, 1000 grain weight, grain length, grain breadth and length-breadth ratio were all observed. The obtained data was subjected to analysis of variance and heterosis and standard heterosis over high yielding hybrid and varietal checks RNR 15048 and PTB 33 were computed and expressed in percentage as follows:

Heterosis over mid parent: Heterosis was expressed as per cent increase or decrease observed in the F_1 over the mid-parent as per the following

$$\text{Heterosis} = \frac{\text{Mean of } F_1 - \text{Mean of mid parent}}{\text{Mean of mid parent}} \times 100$$

Heterosis over better parent: Heterobeltiosis was expressed as per cent increase or decrease observed in F_1 over the better parent as per the formula.

$$\text{Heterobeltiosis} = \frac{\text{Mean of } F_1 - \text{Mean of better parent}}{\text{Mean of better parent}} \times 100$$

Heterosis over standard checks: Standard heterosis was expressed as per cent increase or decrease observed in F_1 over standard checks.

$$\text{Standard heterosis} = \frac{\text{Mean of } F_1 - \text{Mean of check}}{\text{Mean of check}} \times 100$$

3. Results and discussion

The analysis of variance revealed that there was a significant difference between all treatments **(Table 1).** It indicates that the genotypes are sufficiently diverse. As a result, additional heterotic studies were conducted (**Table 2-8**).

For days to 50% flowering, standard heterosis over varietal check RNR15048, ranged from -12.50 (WGL 962 x IET 23993) to 3.44 (RNR 21278 x IET 23993. Out of 10 hybrids, three hybrids WGL 962 x IET 23993 (-12.50), JGL 27356 x IET 23993(-9.69) and KNM 1638 x IET 23993 (-8.13) showed significant negative standard heterosis over varietal check (RNR 15048). Hybrids with significant negative standard heterosis indicate early flowering. Early-maturing hybrids are desirable as they produce more yield per day and fit well in multiple cropping systems. Deoraj*et* *al.,*(2007), Srijan *et al.,* (2016), Sudeepthi *et al.,* (2018), Parimala *et al.,* (2018) and Essam *et al.,* (2022) previously reported significant negative heterosis for this trait.

When compared to the standard check (RNR 15048), the standard heterosis ranged from -9.22 (JGL 27356 x IET 23993) to 10.82 (KPS 3018 x PTB 33) for plant height. Three hybrids, out of 10 showed significant negative standard heterosis over the varietal check (RNR 15048). The short plant type is an important hybrid trait for lodging resistance. Several rice researchers, including Ghosh (2002), Kumari Priyanka *et al.,* (2014) and Parimala *et al.,* (2018) expressed significant negative heterosis over mid parent and better parent.

When compared to varietal check RNR 15048, the standard heterosis for number of tillers per plant ranged from -1.09 (RNR 21278 x IET 23993) to 37.09 (KPS 3018 x PTB 33). Three hybrids KPS 3018 x PTB 33 (37.09), JGL 27356 x PTB 33 (24.00) and WGL 962 x IET 23993 (22.91), outperformed standard check in terms of standard heterosis (RNR 15048).

When comparing the number of productive tillers per plant to varietal check RNR 15048, the standard heterosis ranged from -6.05 (RNR 21278 x IET 23993) to 26.51 (KPS 3018 x PTB 33. Out of 10 hybrids, two hybrids, KPS 3018 x PTB 33 (26.51) and JGL 27356 x PTB 33 (21.40), exhibited significant positive standard heterosis over standard check (RNR 15048). The number of productive tillers per plant is known to have a direct impact on grain yield and can be utilised. The greater the number of productive tillers, the greater the yield and vice versa. However, hybrids showing significant positive heterosis, heterobeltiosis and standard heterosis are desirable. Hari Ramakrishnan *et al.,* (2009), Gouri Shankar *et al*., (2010) and Rukmini *et al.,* (2014) reported positive mid parental heterosis.

When comparing panicle length to varietal check RNR 15048, the standard heterosis ranged from -11.32 (WGL 962 x PTB 33) to 3.27 (JGL 27356 x IET 23993). None of the hybrids out of 10 showed significant positive standard heterosis over varietal control (RNR 15048), hybrid KPS 3018 x PTB 33 exhibited significant positive heterosis over mid parent and heterobeltiosis. Kumari Priyanka *et al*., (2014), Bedi *et al*., (2016) and Parimala *et al.,* (2018) all observed standard heterosis of a similar nature. Hybrids are distinguished by longer panicles, which indicate their efficiency in partitioning assimilates into reproductive parts. This is one of the important attributes for higher yields in hybrids.

The standard heterosis over check variety (RNR 15048) for number of grains per panicle ranged from -31.69 (RNR 21278 x IET 23993 to 4.69 (JGL 27356 x PTB 33). Out of ten hybrids, none of the hybrids exhibited significant positive and significant heterosis. Hybrid JGL 27356 x PTB 33 exhibited significant positive heterosis over mid parent and heterobeltiosis. Similar results reported by Krishna *et al.,* (2016), Manjunath *et al.,* (2019) and Essam *et al.,* (2022). The number of grains per panicle is positively correlated to grain yield and is known to contribute to grain yield by increasing the number of grains.

The standard heterosis over varietal check RNR 15048 ranged from 28.04 (WGL 962 x PTB 33) to 81.45 (KNM 1638 x IET 23993 for 1000 grain weight. Ten hybrids, out of ten demonstrated statistically significant positive standard heterosis. Deoraj*et al.,* (2007), Thorat *et al.,* (2017), Vanave*et al.,* (2018) and Mohammad, I. (2022) reported significant positive heterobeltiosis and standard heterosis for this character.

For hulling percent, the standard heterosis over standard varietal check RNR 15048 ranged from -13.61 (KNM 1638 x PTB 33) to 5.29 (KNM 1638 x IET 23993. Over varietal check RNR 15048, two hybrids showed significant positive standard heterosis while five hybrids showed significant negative standard heterosis. Singh, R.K. (2005), Utharasu*et al.,* (2013), Krishna *et al.,* (2016), Parimala *et al.,* (2018) and Manjunath *et al.,* (2019) reported positive standard heterosis for this character.

In order to milling percent, the standard heterosis over the varietal check RNR 15048 ranged from -14.66 (KNM 1638 x PTB 33) to 5.38 (KNM 1638 x IET 23993). Out of 10 hybrids, only one hybrid showed significant positive standard heterosis, while four hybrids showed significant negative standard heterosis over the standard varietal check (RNR 15048). Parimala *et al.,* (2018) Manjunath *et al.,* (2019) and Lingaiah *et al.,* (2023) reported positive standard heterosis for this character.

For head rice recovery percent, standard heterosis over varietal check RNR 15048 ranged from -14.55 (KNM 1638 x PTB 33) to 8.17 (KNM 1638 x IET 23993). Out of 10 hybrids, two hybrids KNM 1638 x IET 23993 (8.17) and JGL 27356 x PTB 33 (6.27), showed significant positive standard heterosis and four hybrids showed significant negative standard heterosis.

When compared to varietal check RNR 1508, the standard heterosis for kernel length (mm) ranged from -0.43 (KPS 3018 x PTB 33) to 16.31 (KNM 1638 x PTB 33). Seven of the 10 hybrids had significant positive standard heterosis, while none of the hybrids showed significant negative standard heterosis. The hybrids with the highest positive significant standard heterosis were recorded in KNM 1638 x PTB 33 (16.31), RNR 21278 x PTB 33 (15.09), KPS 3018 x IET 23993 (15.03) and RNR 21278 x IET 23993 (14.56) over varietal check RNR 15048. Because long grain type is preferred, positive significant standard heterosis is desired. Sandhyakishore*et al.,* (2009), Sanjeev Kumar *et al.,* (2010) and Bedi *et al.,* (2016) reported significant positive heterobeltiosis and heterosis for this character respectively, whereas standard heterosis of similar nature was reported by Dar *et al.,* (2015) and Parimala *et al.,* (2018).

When compared to varietal check RNR 15048, the standard heterosis for kernel breadth ranged from -18.97 (KPS 3018 x PTB 33) to 34.38 (KNM 1638 x IET 23993). Out of 10, two hybrids KPS 3018 x PTB 33 and JGL 27356 x IET 23993 showed significant negative standard heterosis. For this character, both significant negative heterosis, heterobeltiosis and standard heterosis was reported by Sandhyakishore*et al.,* (2009), Sanjeev Kumar *et al.,* (2010), Panwar and Mashiat Ali (2010), Srijan *et al.,* (2016) and Parimala *et al.,* (2018) respectively. The most preferred grain type is slender grain. As a result, negative significant standard heterosis is preferable.

When compared to varietal check RNR 15048, the standard heterosis for kernel length-breadth ratio ranged from -18.88 (RNR 21278 x IET 23993) to 23.03 (KPS 3018 x PTB 33). Out of 10, three hybrids KPS 3018 x PTB 33, JGL 27356 x IET 23993 and KNM 1638 x PTB 33 had significant positive standard heterosis, while five hybrids exhibited significant negative standard heterosis. Because long/medium slender grain type is preferred, positive significant standard heterosis is preferred. Sanjeev Kumar *et al.,* (2010) and Ghara*et al.,* (2014) reported significant positive heterobeltiosis and heterosis for this character, respectively, whereas Sanghera and Hussain (2012), Dar *et al.,* (2014) and Sarvanan *et al.*, 2018) reported standard heterosis of similar nature.

When compared to varietal check RNR 15048, the standard heterosis for grain yield per plant (g) ranged from -5.22 (WGL 962 x PTB 33) to 50.43 (KNM 1638 x IET 239933). Six of, 10 hybrids had significant positive standard heterosis, while none of the hybrids exhibited significant negative standard heterosis. The hybrids *viz.,* KNM 1638 x IET 23993, WGL 962 x IET 23993,JGL 27356 x PTB 33 and KPS 3018 x PTB 33 exhibited highest significant positive heterosis, heterobeltiosis and standard heterosis over varietal check for yield and its component characters. These findings explain why significant heterosis of various component characters is desirable for improving grain yield. Sanjeev Kumar *et al.* (2010) reported both significant positive heterobeltiosis and heterosis for this character, as did Chamundeswari*et al.,* (2012), Utharasu*et al.,* (2013) and Parimala *et al.,* (2018), whereas standard heterosis of similar nature was reported by Dar *et al.,* (2014), Ramesh *et al.,* 2017, Gokulakrihnan *et al.,* (2018), Manjunath *et al.* (2019) and Mohammad, I. (2022).

4. Conclusion

This study found that heterosis for grain yield per plant is primarily caused by the simultaneous manifestation of heterosis for yield component traits. JGL 27356 x PTB 33 and KPS 3018 x PTB were stable hybrids with favourable SCA effects, heterosis and per se performance for grain yield, its components and grain quality traits. These two experimental hybrids are recommended for additional testing in various locations and seasons to determine their suitability for large scale commercialization.

Future scope

One of the inventions responsible for the dramatic increase in rice productivity over the past century was hybrid rice. However, the development of traits in parental lines for an ideal plant type with significant yield, grain quality and resistance/tolerance to numerous biotic and abiotic stresses is required in order to meet the challenge of rising demand for rice and making hybrid more sustainable under impeding climatic changes. It is simple to improve the parents and hybrids for desirable traits with high precision when conventional plant breeding is combined with cutting-edge molecular techniques.

Table: 1 Analysis of variance for different characters in rice

Source of variations	Degrees of freedom	Days to 50% flowering	Plant height (cm)	Number of tillers per plant	Productive tillers per plant	Panicle length (cm)	No. of grains /panicle	1000 grain weight (g)
Replicates	2	4.47	23.60	2.39	1.48	1.37	2333.45	0.32
Treatments	16	169.29**	849.36**	12.54**	5.75**	6.18**	7560.20**	38.36**
Parents	6	265.94**	2091.09**	3.02	1.25	7.16**	14142.16**	48.12**
Lines	4	66.43**	9.66*	3.19	1.45	6.91**	159.46	8.37**
Testers	1	228.17**	1209.84**	4.51	1.50	10.72*	4471.74**	3.34**
Line x Testers	1	1101.72**	11298.03**	0.88	0.23	4.63	79743.34	251.90**
Parents vs Crosses	1	155.47**	39.96*	48.24**	15.31**	25.43**	10774.46**	168.47**
Crosses	9	106.39**	111.48**	14.91	7.68**	3.39*	2815.10**	17.39**
Error	32	4.35	7.52	3.44	1.74	1.51	407.19	0.34
Total	50	57.13	277.56	6.31	3.01	3.00	2773.20	12.51

Table 1 continues….

Table: 1 Analysis of variance for different characters in rice

Source of variations	Degrees of freedom	Grain yield per plant (g)	Kernel length (mm)	Kernel breadth (mm)	Kernel length breadth ratio	Hulling (%)	Milling (%)	Head rice recovery (%)
Replicates	2	41.78	0.01	0.002	0.01	0.13	1.24	1.43
Treatments	16	225.37**	0.53**	0.50**	0.94**	78.28**	64.09**	69.77**
Parents	6	115.87**	0.14**	0.75**	1.32**	50.13**	53.55**	56.41**
Lines	4	36.10*	0.12**	0.05**	0.27**	22.81**	9.97	8.98
Testers	1	48.17*	0.14**	0.06**	0.09**	47.02**	72.41**	79.63**
Line x Testers	1	502.65**	0.19**	4.26**	6.70**	162.53**	209.03**	222.91**
Parentsvs Crosses	1	1523.21**	4.18**	0.24**	0.02	113.03**	97.76**	164.06**
Crosses	9	154.16**	0.38**	0.37**	0.80**	93.18**	67.37**	68.20**
Error	32	11.50	0.01	0.02	0.01	5.58	5.45	4.98
Total	50	81.15	0.18	0.16	0.31	28.62	24.05	25.57

Table 2. Heterosis, heterobeltiosis and standard heterosis of hybrids for days to 50% flowering and plant height (cm)

Crosses	Days to 50% flowering			Plant height (cm)		
	Heterosis		Standardheterosis	Heterosis		Standardheterosis
	MP	BP	RNR 15048	MP	BP	RNR 15048
WGL 962 x IET 23993	-14.89 **	-17.16 **	-12.50 **	-8.37 **	-22.04 **	-5.35*
KNM 1638 x IET 23993	-15.40 **	-21.60 **	-8.13 **	-14.33 **	-32.45 **	-0.32
KPS 3018 x IET 23993	2.73	-5.33 **	0.00	-7.00 **	-19.86 **	-2.77
RNR 21278 x IET 23993	0.30	-11.73 **	3.44 *	-13.46 **	-30.99 **	1.84
JGL 27356 x IET 23993	-10.53 **	-14.50 **	-9.69 **	-13.65 **	-25.18 **	-9.22 **
WGL 962 x PTB 33	-3.66 *	-12.27 **	2.81	-17.07 **	-33.55 **	-1.94
KNM 1638 x PTB 33	-2.89 *	-5.62 **	-0.31	0.06	-14.64 **	3.56
KPS 3018 x PTB 33	-10.37 **	-17.07 **	-2.81	-4.98 **	-24.91 **	10.82 **
RNR 21278 x PTB 33	0.93	-3.25 *	2.19	-5.08 **	-18.04 **	-0.56
JGL 27356 x PTB 33	-8.03 **	-16.00 **	-1.56	-20.23 **	-36.28 **	-5.96 **

Table 3. Heterosis, heterobeltiosis and standard heterosis of hybrids for number of tillers perplant andnumber of productive tillers per plant

Crosses	Number of tillers per plant			Number of productive tillers per plant		
	Heterosis		Standardheterosis	Heterosis		Standardheterosis
	MP	BP	RNR 15048	MP	BP	RNR 15048
WGL 962 x IET 23993	21.58 **	16.96 *	22.91 *	17.59 *	12.44	13.49
KNM 1638 x IET 23993	17.74 *	16.85 *	13.45	14.50 *	13.37	6.51
KPS 3018 x IET 23993	2.12	0.00	5.09	-0.47	-2.76	-1.86
RNR21278 x IET 23993	0.74	-1.81	-1.09	-1.22	-2.42	-6.05
JGL 27356 x IET 23993	9.47	8.90	15.64	6.88	6.39	8.37
WGL 962 x PTB 33	-0.54	-5.48	0.36	-3.56	-7.31	-5.58

KNM 1638 x PTB 33	3.20	0.35	5.45	-0.92	-0.92	0.00
KPS 3018 x PTB 33	40.67 **	38.10 **	37.09 **	29.83 **	25.35 **	26.51 **
RNR 21278 x PTB 33	1.21	1.04	6.18	-0.46	-0.91	0.93
JGL 27356 x PTB 33	23.77 **	18.40 *	24.00 **	23.99 **	19.18 *	21.40 **

***Significant at 5% level, **Significant at 1% level, MP=Mid parent, BP= Better parent**

Table 4. Heterosis, heterobeltiosis and standard heterosis of hybrids for panicle length (cm)andnumber of grains per panicle

Crosses	Panicle length (cm)			Number of grains per panicle		
	Heterosis		Standardheterosis	Heterosis		Standardheterosis
	MP	BP	RNR 15048	MP	BP	RNR 15048
WGL 962 x IET 23993	9.76 *	7.94	2.05	39.02 **	7.63	0.86
KNM 1638 x IET 23993	11.39 *	6.64	-2.53	48.86 **	-0.79	-7.03
KPS 3018 x IET 23993	1.95	-1.22	-0.41	20.86 *	-5.38	-14.06 *
RNR 21278 x IET 23993	1.79	-6.91	-6.14	11.96	-24.79 **	-31.69 **
JGL 27356 x IET 23993	6.76	4.38	3.27	27.55 **	0.69	-10.60
WGL 962 x PTB 33	3.78	1.57	-11.32 *	27.85 **	-13.61	-23.30 **
KNM 1638 x PTB 33	7.51	3.88	-1.79	14.96	-11.54	-15.66 *
KPS 3018 x PTB 33	18.41 **	15.35 **	1.69	55.33 **	3.08	-1.73
RNR 21278 x PTB 33	5.43	1.40	-4.13	14.67	-9.96	-18.87 **
JGL 27356 x PTB 33	8.63 *	0.21	-0.86	72.60 **	16.17 *	4.69

Table 5. Heterosis, heterobeltiosis and standard heterosis of hybrids for1000 grain weight (g) and hulling per cent

Crosses	1000 grain weight (g)			Hulling per cent		
	Heterosis		Standardheterosis	Heterosis		Standardheterosis
	MP	BP	RNR 15048	MP	BP	RNR15048
WGL 962 x IET 23993	21.75 **	0.50	58.83 **	8.50 **	4.60	2.11
KNM 1638 x IET 23993	33.51 **	7.40 **	81.45 **	13.10 **	7.85 **	5.29 *
KPS 3018 x IET 23993	5.32 *	-12.06 **	38.99 **	4.16	-0.20	-1.32
RNR 21278 x IET	-5.44 *	-23.09 **	29.93 **	-7.04 **	-11.88 **	-12.87 **

23993						
JGL 27356 x IET 23993	14.75 **	4.17	64.64 **	0.30	-0.62	-8.28 **
WGL 962 x PTB 33	-14.02 **	-24.21 **	28.04 **	13.88 **	11.58 **	2.98
KNM 1638 x PTB 33	17.65 **	-4.05	51.65 **	-4.56 *	-4.64	-13.61 **
KPS 3018 x PTB 33	15.93 **	-7.81 **	55.75 **	5.83 *	4.73	-5.28 *
RNR 21278 x PTB 33	2.81	-15.99 **	32.77 **	-1.34	-3.79	-8.28 **
JGL 27356 x PTB 33	20.91 **	-3.68	62.73 **	13.79 **	9.75 **	4.63 *

***Significant at 5% level, **Significant at 1% level, MP=Mid parent, BP= Better parent**

Table 6. Heterosis, heterobeltiosis and standard heterosis of hybrids for hulling milling per cent and head rice recovery per cent

Crosses	Milling per cent			Head rice recovery (%)		
	Heterosis		Standardheterosis	Heterosis		Standardheterosis
	MP	BP	RNR 15048	MP	BP	RNR 15048
WGL 962 x IET 23993	7.82 **	4.02	0.08	9.87 **	5.36	2.03
KNM 1638 x IET 23993	16.87 **	9.53 **	5.38 *	20.44 **	11.70 **	8.17 **
KPS 3018 x IET 23993	2.65	-1.47	-4.19	3.57	-1.12	-3.34
RNR21278 x IET 23993	-4.64	-11.07 **	-13.52 **	-3.06	-10.48 **	-12.49 **
JGL 27356 x IET 23993	1.73	-0.47	-6.95 **	2.66	-0.72	-5.52 *
WGL 962 x PTB 33	13.37 **	7.70 **	0.68	16.21 **	8.64 **	3.40
KNM 1638 x PTB 33	-5.15 *	-5.72 *	-14.66 **	-5.00	-6.11 *	-14.55 **
KPS 3018 x PTB 33	10.23 **	6.34 *	-3.75	12.45 **	7.37 *	-2.29
RNR 21278 x PTB 33	-1.86	-4.78	-9.45 **	0.30	-1.77	-8.92 **
JGL 27356 x PTB 33	15.24 **	8.60 **	3.27	21.11 **	14.62 **	6.27 *

Table 7. Heterosis, heterobeltiosis and standard heterosis of hybrids for kernel breadth (mm) and kernel length breadth ratio

	Kernel length (mm)	Kernel breadth (mm)

Crosses	Heterosis		Standardheterosis	Heterosis		Standardheterosis
Crosses	MP	BP	RNR 15048	MP	BP	RNR 15048
WGL 962 x IET 23993	-1.03	-2.12	1.22	7.65 **	-12.64 **	22.65 **
KNM 1638 x IET 23993	5.29 **	3.61 *	4.77 **	12.19 **	-11.64 **	34.38 **
KPS 3018 x IET 23993	15.41 **	11.24 **	15.03 **	-0.57	-16.16 **	17.70 **
RNR 21278 x IET 23993	18.21 **	17.03 **	14.56 **	7.64 **	-12.08 **	33.71 **
JGL 27356 x IET 23993	6.67 **	4.90 **	8.48 **	-28.19 **	-39.83 **	-15.52 **
WGL 962 x PTB 33	5.90 **	4.79 **	4.77 **	-14.32 **	-30.42 **	5.81 **
KNM 1638 x PTB 33	18.69 **	12.47 **	16.31 **	-11.01 **	-25.86 **	4.09 *
KPS 3018 x PTB 33	4.55 **	1.72	-0.43	-34.03 **	-46.72 **	-18.97 **
RNR 21278 x PTB 33	16.27 **	11.30 **	15.09 **	21.88 **	-4.94 **	33.45 **
JGL 27356 x PTB 33	7.46 **	5.64 **	3.41	6.34 **	-19.35 **	22.65 **

***Significant at 5% level, **Significant at 1% level, MP=Mid parent, BP= Better parent**

Table 8. Heterosis, heterobeltiosis and standard heterosis of hybrids for head rice recovery (%)and grain yield per plant (g)

Crosses	Kernel length breadth ratio			Grain yield per plant (g)		
	Heterosis		Standardheterosis	Heterosis		Standardheterosis
	MP	BP	RNR 15048	MP	BP	RNR 15048
WGL 962 x IET 23993	-12.20 **	-28.68 **	-17.58 **	50.20 **	29.77 **	42.61 **
KNM 1638 x IET 23993	-5.22	-26.19 **	-14.70 **	71.81 **	36.89 **	50.43 **
KPS 3018 x IET 23993	14.25 **	-1.51	-1.82	38.64 **	27.46 **	21.57 **
RNR 21278 x IET 23993	-1.14	-18.62 **	-18.88 **	25.41 **	5.58	0.70
JGL 27356 x IET 23993	36.80 **	15.16 **	21.59 **	28.48 **	17.79 *	13.04
WGL 962 x PTB 33	23.17 **	-0.84	4.70	17.61 *	-1.23	-5.22
KNM 1638 x PTB 33	30.58 **	12.88 **	11.77 **	38.72 **	29.83 **	19.13 *
KPS 3018 x PTB 33	50.54 **	24.25 **	23.03 **	69.28 **	44.80 **	32.87 **
RNR 21278 x PTB 33	-10.05 **	-28.10 **	-13.32 **	10.00	-5.47	5.22

JGL 27356 x PTB 33	-8.85 **	-30.07 **	-15.69 **	55.47 **	23.28 **	37.22 **

***Significant at 5% level, **Significant at 1% level, MP=Mid parent, BP= Better parent**

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