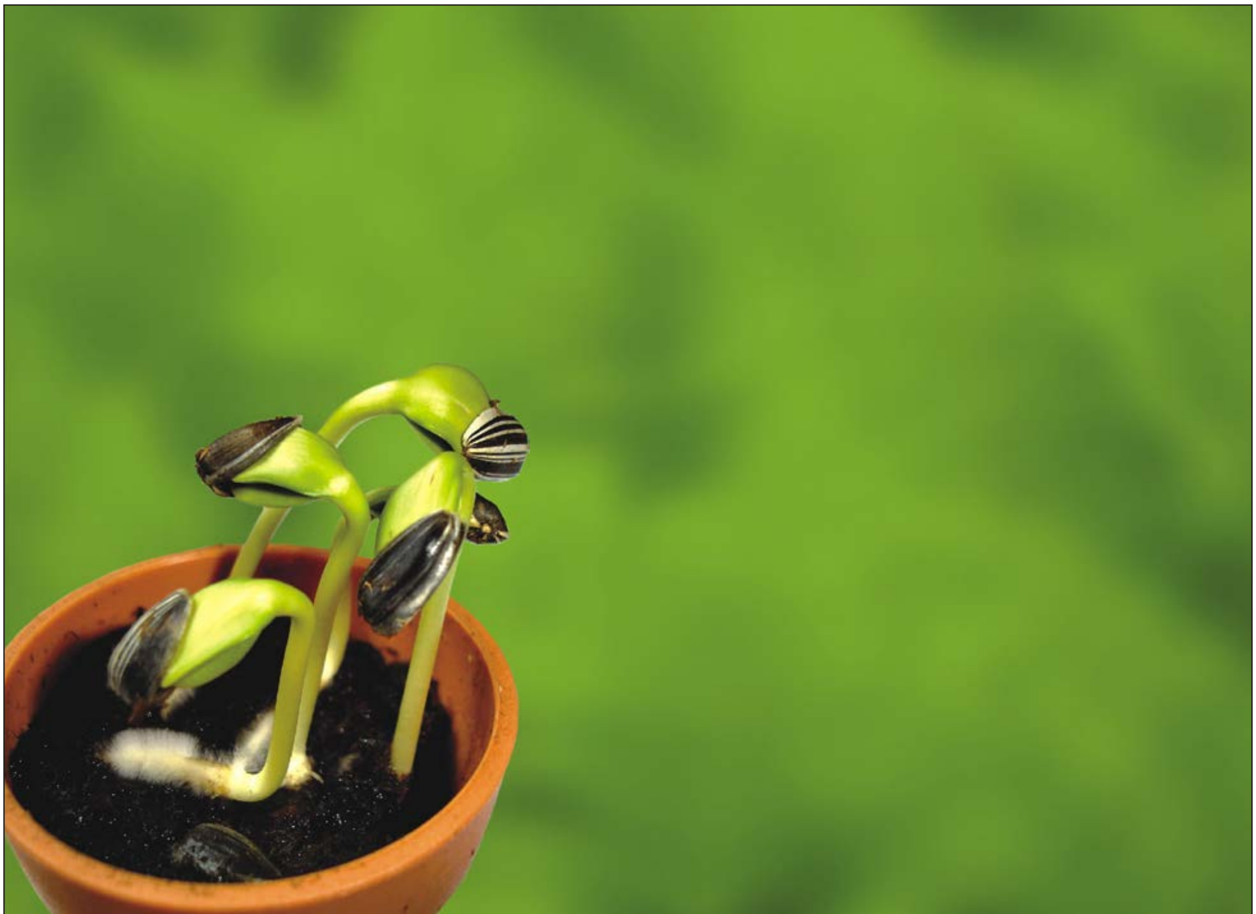

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Study on Heterosis in Boro × High Yielding Rice Hybrids

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ABSTRACT

The objective of the present study was to determine the extent of heterosis over better parent and standard checks in order to identify promising hybrids with high mean performance and high magnitude of heterosis for yield and yield components. Three boro rice cultivars were selected as female and single crosses were made randomly with six non boro, high yielding rice cultivars. 25 genotypes including check varieties were evaluated in a randomized block design with three replication in kharif 2008 and magnitude of heterosis over better parent and standard check was computed for yield and yield traits. Significant difference among genotypes for all characters studied indicated that good amount of variation was present for effective selection. The hybrids in general recorded high mean values as compared to those of parents for plant height, effective tillers per plant, panicle length, grains per panicle, thousand grain weight and grain yield.Heterobeltiosis and standard heterosis were studied in 16 crosses. These crosses showed marked variations in the expression of heterobeltiosis and standard heterosis for yield and yield component and revealed the existence of considerable heterosis both in positive and negative direction for all the traits. Four hybrids IR64×HUBR2-1, IR64×JAYA, Krishna Hansa×Jaya and Krishna Hansa×BPT 5204 were identified for their high mean performance and high magnitude of heterosis for yield and yield components. With appropriate choice of parental lines, it is possible to develop F_1 rice hybrid possessing distinct yield superiority over the best-inbred lines.

Key words: Boro rice, heterosis, hybrid vigor, heterobeltiosis, standard heterosis

INTRODUCTION

Rice occupies enviable prime position among the food crops cultivated around the world. As the rice productivity continues to decline due to reducing acreage of rice cultivation and increasing urbanization, the only possible source of output growth is yield improvement. Boro rice cultivation pertains to rice cultivation in waterlogged low-lying (chawar land) or medium lands with irrigation during November to May (Singh *et al*., 2003). It makes a significant contribution in enhancing the overall rice production in West Bengal, Assam and North Eastern states and is grown in Bihar and part of Uttar Pradesh and Orissa. Population explosion demands the commercial exploitation of heterosis for genetic improvement of several crops especially rice which has received the top priority to enhance the productivity (Alam *et al*., 2004). The success of hybrid rice programme depends upon the magnitude of heterosis which also helps in the identification of potential cross combination to be used in the conventional breeding programme to create wide array of variability in the segregating generations (Krishna Veni and Shobha Rani, 2003). Heterosis has been exploited commercially in several crops like maize (Bashir Alvi *et al.*, 2003), Wheat (Inamullah *et al.*, 2006), cotton (Mendez-Natera *et al.*, 2007). In rice (*Oryza sativa*) this phenomenon was first reported by Jones (1926). Borah and Burman (2010) studied heterosis in various yield traits of intermutant hybrids of rice and reported the presence of both positive and negative heterosis. However, for some practical importance, a hybrid should be more profitable than the best available commercial variety to the farmer. Kumar *et al.* (2010) studied the extent of heterosis in a set of 36 hybrids generated from 9×9 diallel mating design and observed that standard heterosis for grain yield ranged from 14.12 to 65.32%. Parental combination giving high heterosis to produce transgrssive segregants along with higher magnitude of exploitable hybrid vigor is the prerequisite for making a break through in yield. Such exploitations are required to enhance the yield level with better adaptability.

This study would be of considerable advantage as it aims to predict the yield performance of boro rice hybrids on the basis of mean performance, heterobeltiosis and standard heterosis in order to include only the promising heterotic hybrids in subsequent evaluation trials before extensive field trials are taken up.

MATERIALS AND METHODS

Field experiments were conducted during kharif 2007-2008 at Agriculture Research Farm, Institute of Agriculture Sciences B.H.U. Three boro rice cultivars Gautam, Krishna Hansa and IR 64 were selected as female and single crosses were made randomly with six non boro, high yielding rice cultivars BPT 5204, HUBR2-1, HUR3022, Jaya, MTU 7029, NDR 359.

The experimental material comprised of 25 rice genotypes (3 female, 6 male and 16 F_1 hybrids including two checks Krishna Hansa and NDR 359). All the recommended practices were followed to raise and maintain healthy crop in the nursery. Twenty five days old seedling were transplanted into the main field with 20×15 cm spacing for heterosis studies.

The female parents (3) male parents (6) their hybrids (16) along with check varieties were evaluated in a randomized block design with three replication in kharif 2008. Observations on yield and yield component traits were recorded on 10 randomly selected competitive plants for each entry/line, in each replication. The observation of days to panicle initiation, days to panicle emergence, days to 50% flowering and days to maturity was recorded on plot basis.

Heterosis is expressed as percent increase of the F_1 hybrids above the Better Parent (BP) and Commercial cultivar (CC), where F_1 is the average performance of the F_1; BP, the average performance of better parent and CC, average performance of commercial cultivar F_1 hybrid performance was evaluated on the basis of the estimates of heterobeltiosis and standard heterosis by following the procedures outlined by Liang *et al.* (1972) as follows:

$$\text{Heterobeltiosis} = \{(F_1\text{-BP/BP})\}\ 100$$

$$\text{Standard heterosis} = \{(F_1\text{-CC})/\text{CC}\}\ 100$$

RESULTS

The analysis of variance Table 4 (ANOVA) of 25 genotypes for yield, yield components traits revealed the presence of significant difference among genotypes for all characters studied. The hybrids in general recorded high mean values as compared to those of parents for plant height, effective tillers per plant, panicle length, grains per panicle, thousand-grain weight and grain yield.

Table 1: Heterobeltiosis for yield and yield components in 16 boro×high yielding rice hybrids

Crosses	Panicle initiation	Panicle emergence	50% flowering	Dayd to maturity	Plant Ht (cm)	Tillers /Plant	Panicle length	Grains /Panicle	Thousand grain Wt (g)	Grain yield
GAUTAM× BPT 5204	-43.77**	-39.63**	-36.95**	-29.53**	2.49	18.60	-0.64	68.45**	-11.51**	4.10
GAUTAM×HUR 3022	-16.00**	-15.09**	-18.53**	-9.95**	-15.93**	4.65	-2.56	2.95	18.53**	16.40
GAUTAM×JAYA	-20.73**	-17.52**	-17.69**	-12.37**	-10.93**	23.26*	0.00	12.27**	10.42*	-16.07**
GAUTAM×MTU 7029	-15.96**	-13.68*	-14.67**	-11.98**	-2.85	-4.65	1.28	44.90**	0.00	4.18
GAUTAM×NDR 359	-8.80**	-10.60**	-10.31**	-8.12**	4.15*	16.28	-1.28	40.29**	42.66**	9.61
KRISHNA HANSA ×BPT 5204	9.76**	8.67**	8.21**	-7.21**	-7.87**	66.67**	-11.90**	9.75*	-14.21**	39.29**
KRISHNA HANSA ×HUR 3022	6.28**	3.68**	5.21**	3.44**	5.43*	36.36**	-2.38	17.10**	-0.38	8.47
KRISHNA HANSA ×JAYA	-7.72**	-9.85**	-11.22**	-7.63**	-13.83**	63.64**	-7.14*	-28.64**	17.05**	9.76
KRISHNA HANSA ×MTU 7029	-1.20	0.00	0.27	0.00	11.61**	12.12	-8.33**	-7.88*	-27.01**	12.43
KRISHNA HANSA ×NDR 359	5.20**	12.37**	16.15**	11.78	13.84**	3784**	9.52**	7.05	13.60**	28.25**
IR 64×BPT 5204	-25.59**	-19.20**	-16.72**	-14.65**	-3.07	7.89	-19.75**	57.10**	-33.50**	18.62**
IR 64×HUBR 2-1	-10.80**	-11.58**	-15.97**	-7.85**	-1.36	15.79	3.70	8.16	26.79**	52.57**
IR 64×HUR 3022	14.10**	11.63**	9.85**	7.92**	10.14**	2.63	8.64**	17.43**	18.55**	-5.95
IR 64×JAYA	-9.76**	-9.12**	-11.22**	-7.63**	-9.00**	39.47**	7.32*	9.17**	6.97	8.11
IR 64×MTU 7029	-29.82**	-25.93**	-23.91**	-19.17**	14.18**	-2.63	3.71	48.79**	-21.38**	12.11
IR 64×NDR 359	-12.80**	-12.37**	-9.28**	-6.54**	-10.73**	21.05*	-23.46**	3.65	53.85**	15.10*
SE+	2.5708	1.3194	3.1244	1.4441	5.5644	2.5544	1.1290	56.8844	0.7688	2.0550
CD at 5%	2.63	1.89	2.90	1.97	3.87	2.62	1.74	12.38	1.44	2.35
CDat 1%	3.51	2.52	3.87	2.63	5.17	3.50	2.33	16.52	1.92	3.14

*Significant at 5%. **Significant at 1%

The results on heterosis over better parent (heterobeltiosis) for yield and yield components are presented in Table 1. Maximum hetrobeltiosis for grain yield was observed for IR64×HUBR-1 (52.57%) followed by Krishna Hansa×BPT 5204. (39.29%) while negative significant heterobeltiosis for grain yield was exhibited by Gautam×Jaya (-16.07). The crosses of Gautam and high yielding varieties mostly exhibited low level of heterobeltiosis for grain yield.

Significant and positive heterobeltiosis for yield and yield attributing traits like grains/panicle (9.75), tillers per plant (66.67), days to 50% flowering (8.21), pancle emergence (8.67) and panicle initiation (9.76) was exhibited by the cross Krishna Hansa×BPT 5204 (Table 1). Krishna hansa× NDR 359 showed significant and positive heterobeltiosis for grain yield and all yield attributing traits except for grains per panicle. IR64×BPT 5204 exhibited significant and positive heterobeltiosis for grain yield (18.62) and grains per panicle (57.10). IR64×HUBR2-1 and IR64×NDR 359 showed significant and positive heterobeltiosis for grain yield (52.57) and thousand grain weight (26.79). Negative significant heterobeltiosis for several traits was observed in

Table 2: Standard heterosis (superiority over check Krishna hansa) for yield and yield components in 16 boro×igh yielding rice hybrids

Crosses	Panicle initiation	Panicle emergence	50% flowering	Days to maturity	Plant Ht (cm)	Tillers /Plant	Panicle length	Grains /Panicle	Thousands grain wt (g)	Grain yield
GAUTAM×BPT 5204	-30.13**	-28.31**	-25.35**	-19.84**	7.87**	54.55**	-7.74*	43.98**	0.19	5.27
GAUTAM×HUR 3022	-12.13**	-11.03**	-11.46**	-8.99	-7.12**	36.36**	-9.52**	-5.81	17.62**	-17.14*
GAUTAM×JAYA	-18.41**	-16.91**	-15.97**	-11.90**	3.75	60.61**	-2.38	42.32**	9.58*	5.27
GAUTAM×MTU 7029	16.74**	11.40**	9.03**	6.88**	2.25	24.24*	-5.95	23.86**	19.16	-21.66**
GAUTAM×NDR 359	-4.60**	-6.99**	-9.38**	-7.14**	12.73**	51.52**	-8.33**	19.92**	41.57**	5.27
KRIHNA HANSA ×BPT 5204 1	36.40**	29.04**	28.13**	5.56**	-7.87**	66.67**	-11.90**	9.75*	-2.87	40.87**
KRISHNA HANSA ×HUR 3022**	6.28**	3.68**	5.21**	3.44**	8.99**	36.36**	-2.38	17.01**	-0.38	8.47
KRISHNA HANSA ×JAYA	-5.02**	-9.19**	-9.38**	-7.14**	0.37	63.64**	-7.14**	-9.54**	17.05**	37.66**
KRISHNA HANSA ×MTU 7029	37.24**	29.04**	28.13**	21.43**	11.61**	12.12	-8.33**	-7.88*	-13.03**	12.43
KRISHNA HANSA ×NDR 359	10.04**	16.91**	17.36**	12.96**	23.22**	54.55**	9.52**	7.05	13.60**	28.25**
IR64×BPT 5204	-7.53**	-4.04**	-1.39	-2.91**	-5.24*	24.24*	-22.62**	21.58**	-24.71**	19.56**
IR 64×HUBR 2-1	-6.69**	-7.35**	-8.68**	-6.88**	8.99**	33.33**	0.00	-1.04	-8.43*	39.92**
IR 64×HUR 3022	8.37**	5.88**	4.51**	4.50	13.86**	18.18	4.76	-9.13*	0.38	-13.75*
IR 64×JAYA	-7.11**	-8.64**	-9.38**	-7.14**	5.99**	60.61**	4.76	38.38**	-14.75**	35.59**
IR 64×MTU 7029	-2.50	-4.41**	-2.78	-1.85*	11.61**	12.12	0.00	15.15**	6.32	2.82
IR 64×NDR	-8.79**	-8.82**	-8.33**	-5.56**	-3.37	39.39**	-26.19**	-17.43**	11.11**	10.55
SE+	2.5708	1.3194	3.1244	1.4441	5.5644	2.5544	1.1290	56.8844	0.7688	2.0550
CD at 5%	2.63	1.89	2.90	1.97	3.87	2.62	1.74	12.38	1.44	2.35
CD at 1%	3.51	2.52	3.87	2.63	5.17	3.50	2.33	16.52	1.92	3.14

*Significant at 5%, **Significant at 1%

cross combinations of Krishna Hansa×BPT 5204, IR64× BPT5204, IR64×HUBR 2-1, IR64× NDR 359.

The results on hybrid vigor over the standard checks Krishna Hansa and NDR 359 are presented in Table 2 and 3, respectively. The highest commercial heterosis over check Krishna Hansa (40.87) and over check NDR 359 (46.77) for grain yield per plant was recorded in the cross Krishna Hansa×BPT 5204 followed by IR 64×HUBR 2-1 and Krishna hansa×Jaya.

Significant and positive heterosis over check Krishna Hansa and NDR 359 were exhibited by the crosses, Krishna Hansa×BPT 5204, Krishna Hansa×Jaya, Krishna Hansa×NDR 359, IR 64×HUBR 2-1, IR64×Jaya for yield and several yield traits. Several traits like plant height, days to panicle initiation, days to panicle emergence, days to 50% flowering, days to maturity exhibited significant negative heterosis in some of the crosses.

Out of the sixteen Boro×Non boro rice hybrids studied four most promising crosses were identified and their heterotic performance for different traits were analyzed. The four hybrids namely Krishna Hansa×BPT 5204, Krishna hansa×Jaya, IR 64×HUBR2-1, IR64×Jaya did express high mean performance and high magnitude of heterosis for yield and yield traits.

Table 3: Standard heterosis (superiority over check NDR 359) for yield and yield components in 16 boro×igh yielding rice hybrids

Crosses	Panicle initiation	Panicle emergence	50% flowering	Days to maturity	Plant Ht (cm)	Thillers /Plant	Panicle length	Grains /Panicle	Thousands grain Wt (g)	Grain yield
GAUTAM×BPT 5204	-33.20**	-31.10**	-26.12**	-20.68**	0.35	37.84**	6.16	80.73**	44.48**	9.61
GAUTAM×HUR 3022	-16.00**	-14.49**	-12.37**	-9.95**	-14.19**	21.62*	4.11	18.23**	69.61**	-13.73
GAUTAM×JAYA	-22.00**	-20.14**	-16.84**	-12.83**	-4.15*	43.24**	12.33**	78.65**	58.01**	9.61
GAUTAM×MTU 7029	11.60**	7.07**	7.90**	5.76**	-5.54**	10.81	8.22**	55.47**	71.82**	-18.43
GAUTAM×NDR 359	-8.80**	-10.60**	-10031.00**	-8.12**	4.15	35.14**	5.48	50.52**	104.14**	9.61
KRISHNA HANSA ×BPT 5204	30.40**	24.03**	26.80**	4.45**	-14.88**	48.65**	1.37	34.76**	40.06**	46.77**
KRISHNA HANSA ×HUR 3022	1.60	-0.35	4.12**	2.36**	0.69	21.62*	12.33**	46.88**	43.65**	12.94
KRISHNA HANSA ×JAYA	-9.20**	-12.72**	-10.31**	-8.12**	-7.27**	45.95**	6.85	13.54**	68.78**	43.33**
KRISHNA HANSA ×MTU 7029	31.20**	24.03**	26.80**	20.16**	3.11	0.00	5.48	15.63**	25.41**	17.06*
KRISHNA HANSA ×NDR 359	5.20**	12.37**	16.15**	11.78**	13.84**	37.48**	26.03**	34.38**	63.81**	33.53**
IR 64×BPT 5204	-11.60**	-7.77**	-2.41	-3.93**	-12.46**	10.81	-10.96**	52.60**	8.56	24.90**
IR 64×HUBR 2-1	-10.80**	-10.95**	-9.62**	-7.85**	0.69	18.92	15.07**	24.22**	32.04**	45.69**
IR 64×HUR 3022	3.60*	1.77	3.44*	3.40**	5.19*	5.41	20.55**	14.06	44.75**	-10.20
IR 64 64× JAYA	-11.20**	-12.01**	-10.31**	-8.12**	-2.08	43.24**	20.55**	73.70**	22.93**	41.18**
IR 64×MTU 7029	-6.80**	-8.13**	-3.78*	-2.88**	3.11	0.00	15.07**	44.53**	35.08**	7.06
IR 64×NDR 359	-12.80**	-12.37**	-9.28**	-6.64**	-10.73**	24.32*	-15.07**	3.65	60.22**	15.10*
SE+	2.5708	1.3194	3.1244	1.4441	5.5644	2.5544	1.1290	56.8844	0.7688	2.0550
D at 5%	2.63	1.89	2.90	1.97	3.87	2.62	1.74	12.38	1.44	2.35
CD at 1%	3.51	2.52	3.87	2.63	5.17	3.50	2.33	16.52	1.92	3.14

*Significant at 5%. **Significant at 1%

Table 4: Analysis of variance for yield and yield components in 25 rice genotypes

Source of variation	Degree of freedom	Days to Panicle initiation	Days to Panicle emergence	Days to 50% flowering	Days to maturity	Plant height	Tillers per plant	Panicle length	Grains per panicle	Thousand grain weight	Grain yield
Replicates	2	1.9733	1.3333	1.0133	0.6533	19.4533*	1.6933	0.9033	2.7733	1.0065	3.6665
Treatments	24	566.43***	542.62***	576.19***	487.42***	158.641***	29.8144***	16.283***	4113.64***	30.4860***	51.0426***
Error	48	2.5708	1.3194	3.1244	1.4441	5.5644	2.5544	1.1290	56.8844	0.7688	2.0550

***Significancent at 0.1%. **significant at 1%. *Significant at 5%

DISCUSSION

The significant difference among genotypes for all characters revealed by the analysis of variance indicated that good amount of variation is present for effective selection. Potential hybrids can be exploited for heterosis breeding by comparing the *per se* performance and hybrid vigor (Premalatha *et al*., 2006). In this study a close association between *per se* performance and heterosis of hybrids was observed for all traits. The performance of hybrids in general was better as compared to parents for yield and yield contributing traits. Better performance of hybrids for yield traits than parental lines was reported by Sarial *et al*. (2006).

The prime objective of hybrid programme is to converge the desirable genes from the parent on to a single genetic background. Scope for exploitation of hybrid vigor will depend upon *per se* performance of hybrid and magnitude of heterosis. Magnitude of heterosis was estimated over, better parent and standard parent. Each one has its own importance in genetic analysis. The real performance of a hybrid can not be predicted based on relative heterosis and heterobeltiosis. A hybrid is commercially valuable only when it exhibits significantly high standard heterosis over best locally adopted variety. Standard heterosis is also a reflection of *per se* performance. Swaminathan *et al*. (1972) also emphasized the need for computing heterosis over standard variety. It was also reported by Shivani and Reddy (1999) that superiority of hybrid over check variety could be utilized for the development of hybrids in rice breeding.

The results in the present study revealed the existence of considerable heterosis both in positive and negative direction for all the traits. Presence of both negative and positive heterosis was reported earlier by Ganesan *et al*. (1997), Souframanien *et al*. (1998), Verma *et al*. (2004) and Shanthala *et al*. (2006) thus there may be variation in the expression of heterosis for different crosses and characters. Almost all the yield contributing traits showed expression of significant and desirable heterobeltiosis and commercial heterosis significant positive heterosis for number of productive tillers per plant is generally associated with higher productivity this is in conformity with the findings of Peng and Virmani (1991). Positve significant heterobeltiosis for grain yield in the crosses Krishna hansa×BPT 5204 and Krisna Hansa×NDR 359 was contributed by high and significant heterosis for number of effective tillers per plant. The cross IR64×BPT 5204 showed high grain yield mainly because of the positive significant heterobeltiosis exhibited by number of grains per panicle. Inamullah *et al*. (2006) studied heterosis in some wheat genotypes and reported that grains per spike directly determined the yield potential.

The results of standard heterosis over check Krishna Hansa (Table 2) exhibited high heterosis for grain yield for the cross Krishna hansa×BPT 5204 , Krishna Hansa×Jaya, Krishna Hansa×NDR 359 mainly due to increased number of tillers per plant. Significant and positive heterosis for the cross IR 64×BPT 5204 was due to the contribution of tillers per plant ,grains per panicle.

Standard heterosis over check NDR 359 (Table 3) revealed the presence of significant heterosis for grain yield in Krishna hansa×BPT 5204 due to the positive significant heterosis present in grains per panicle and thousand grain weight. Significant and positive heterosis for tillers per plant, grains per panicle and thousand grain weight contributed towards yield improvement in Krishna hansa×Jaya. All yield traits exhibited significant and positive heterosis in the cross Krishna hansa×NDR 359, which directly contributed towards yield improvement. Increased number of grains per panicle was responsible for yield improvement in the cross IR64×BPT 5204 while panicle length, number of grains per panicle and thousand grain weight enhanced yield in IR64 ×HUBR 2-1. Tillers per plant, panicle length, grains per panicle and thousand grain weight contributed positively for positive significant heterosis in grain yield in IR64×Jaya. Hybrids are generally characterized by having larger panicles which enhances its efficiency in partitioning of assimilates to reproductive parts. This is one of the attributes of higher yields in hybrids. Studies have reported high yields of hybrids due to increased effective tillers per plant (Sarial *et al* ., 2006; Yamauchi and Yosida, 1985; Patnaik *et al*., 1990), panicle length (Usha Kumari *et al*., 2006; Singh and Richharia, 1980) number of grains per panicle (Sarial and Singh, 2006; Saravanan *et al.,* 2006) and spikelet fertility (Usha Kumari *et al*., 2006; Alam *et al*., 2004), Further perusal of data indicated that the expression of grain yield heterosis in the best crosses was realized through differential expression of heterosis in various yield attributing traits. Yadav *et al.* (1999) reported that yield is an end product of multiplicative interaction among various yield components. Patnaik *et al.* (1990) and Mishra and Pandey (1998) reported that panicle length, number of filled grains per panicle and 1000 seed weight had contributed for increased grain yield. Gouri Shankar *et al.* (2010) reported the contribution of yield traits for high heterosis in grain yield in some thermosensitive genetic male sterile lines in rice.

Significant negative heterosis for several traits like days to panicle initiation, days to panicle emergence, days to 50% flowering and days to maturity was found to be desirable as early flowering contributed to high heterosis for grain yield. Heterosis for earliness has been reported by Young and Virmani (1990) and Mishra and Pandey (1998). Significant negative standard heterosis for days to flowering was also indicated by Patil *et al.* (2003). Days to 50% flowering is an important character for improvement of yield.

Negative significant heterosis, which is desired for plant height, was exhibited by some of the selected crosses, which contributed towards high yield. Shorter plant type is an important character of a hybrid to withstand lodging further tall plants require more energy to translocate solutes to the grain and have lower grain weight. Negative heterosis for plant height was also observed by Rao *et al.* (1996).

In contradiction to the above reports which states that negative heterosis is desirable for panicle initiation, panicle emergence, days to 50% flowering, days to maturity and plant height, the present study revealed the presence of significant and positive heterosis for these characters in the crosses Krishna hansa×BPT 5204 and Krishna Hansa×NDR 359 and still showed high heterosis for grain yield in these crosses. The other yield attributing characters like grains per panicle, panicle length, thousand grain weight and effective tillers per plant overshadowed the undesirable effect on yield caused by late flowering and greater plant height.

CONCLUSION

Out of sixteen boro×non boro rice hybrids studied,four hybrids Krishna hansa×BPT 5204, IR64 ×HUBR2-1, Krishna Hansa×Jaya., IR64×Jaya were identified promising for their high mean performance and high magnitude of heterosis for yield and yield components. These hybrids could be effectively utilized in the double haploid breeding or conventional breeding programme which would be helpful to develop high yielding varieties.

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