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Heterosis in inter-ecotypic classes of rice (*Oryza sativa* L.)

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Abstract: An experiment of six-parent half diallel analysis on rice (*Oryza sativa* L.) was conducted to evaluate the heterosis for seven characters. Analysis of variance indicated highly significant differences for all the characters suggested the presence of genetic variability among the studied materials. Out of fifteen hybrids, only one possessed the desired significant negative better parent heterosis for days to 50% flowering. Two hybrids expressed desirable significant negative heterobeltiosis for plant height. Significant positive mid parent heterosis was found in six hybrids for effective tiller plant^{-1}, eleven for panicle length, ten for filled grain panicle^{-1} and four hybrids for 1000 grain weight. The numbers of hybrids with significant positive heterobeltiosis for panicle length, filled grain panicle^{-1}, and 1000 grain weight were seven, three and one respectively. For grain yield plant^{-1} highly significant positive heterosis was observed in eleven hybrids over mid parent and in three hybrids over better parent. The degree of heterosis was higher for grain yield plant^{-1}, effective tiller plant^{-1} and filled grain panicle^{-1}. The highest heterotic hybrid for grain yield plant^{-1} was P3×P5 followed by P3×P6. The hybrids with desirable heterosis should be further evaluated with standard check varieties for their higher yield potentiality and earliness.
Key words: Heterosis, Rice yield, Days 50% flowering.

Introduction

Rice (*Oryza sativa* L.) belonging to the family Poaceae; is life and princes among the cereals and is the leading crop in our agro based country, Bangladesh. It is grown as Boro, Aus, and Aman crops in three overlapping seasons with large number of varieties that suit various agro-ecological and climatic niches. Thus the varietal requirements for each type varied on respect of plant type, growth duration, and biotic and abiotic stress factors (Das, 2005). Boro rice has become the leading rice crop in Bangladesh through the last ten years. It was cultivated in 4.77 million ha of land and its record production was 18.62 million metric ton which was 41.4% of total rice production during 2010-2011 (BBS, 2011). But high yielding Boro rice varieties require a very long period of 150-165 days to be matured. On the other hand, Aus varieties require comparatively shorter (80-120 days) duration (Alam 1982). The trait, earliness can be transferred from Aus to those of high yielding Boro varieties through hybridization. Thus the study was undertaken to estimate the extent and magnitude of heterosis and to select early materials with high yield potential to utilize them directly in varietal improvement program.

Materials and Methods

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207. Six different BRRI released rice varieties of two ecotypes, Aus and Boro were selected and collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur. Three Aus varieties were namely BR21 (P1), BR24 (P2) and BR26 (P3) and three Boro varieties were BRRI dhan28 (P4), BRRI dhan29 (P5) and BRRI dhan36 (P6). Collected rice varieties of two ecotypes were hybridized in all possible combinations following half diallel fashion during the November, 2009 to April, 2010. Fifteen hybrids were divided into three groups such as Aus×Aus (group 1), Aus×Boro (group 2) and Boro×Boro (group 3). Fifteen hybrids along with their parents were evaluated during November, 2010 to April, 2011. The experiment was conducted under Randomized Complete Block Design (RCBD) with three replications. Each entry was grown in an individual plot of 2.5m × 2m with a spacing of 25cm×20cm with single seedling per hill. Data were recorded on days to 50% flowering, plant height, effective tiller per plant, panicle length, filled grain per panicle, 1000 grain weight and yield per plant for all the parental lines and hybrids on ten randomly selected plants in each replication. The significance in increase or decrease in F_1 hybrids over their corresponding mid parent an better parent were tested by comparing their means with the help of appropriate standard error values in percentage.

Results and Discussion

Highly significant difference among genotypes was observed for all the traits studied (Table 1). The mean performance of six parents and the nature and magnitude of heterosis for different characters of the F_1 hybrids over their respective mid and better parental values are shown in Table 2.

Negative heterosis is desirable for days to 50% flowering. In Table 2 it was noticed that none of fifteen hybrids exhibited negative heterosis over mid patent. One hybrid of group-1, eight of group-2 and one of group-3 demonstrated significant positive heterosis and the rest five hybrids showed non-significant values. The range of mid parent heterosis was 0.87% to 14.52%. The hybrid of group-2, P3×P5 exhibited the highest and highly significant positive heterosis (14.52%) and the hybrid of group-3, P4×P6 showed the lowest and non-significant positive (0.87%) heterosis. Therefore, on an average the hybrids of group-2 took more days to 50% flowering than mid parents and none from any of three groups was early flowering than the average of their corresponding parents. Perusal of data on better parent heterosis for days to 50% flowering revealed that preferable highly significant negative heterobeltiosis (-8.06%) was found in one hybrid only and that was of group-2, namely P1×P5. Two hybrids of group-2 and two of group-3 exhibited negative but insignificant heterosis over better parent. Two hybrids of group-2 and one hybrid of group-3 expressed undesirable significant positive heterosis. The range of heterosis was from -1.02% to 8.87 %. Torres and Geraldi (2007) found significant mid parent heterosis in hybrids in their study. Verma *et al.* (2002_b) found a few hybrids with heterobeltiosis. Dwivedi *et al*. (1998), Malini, *et al*. (2006) Patil *et al*. (2011) and Raju *et al*. (2005) observed many hybrids with high degree of heterosis for days to 50 % flowering in their study.

All of fifteen hybrids exhibited positive heterosis over the mid parent for plant height. Most of the hybrids (except P1×P3 and P5×P6) were highly significant. The range of the heterosis was from 1.63% to 18.71%. The highest significant positive heterosis (18.71%) was observed in the hybrid of group-2, P3×P6 and the lowest (1.63%) was in the hybrid of group-1, P1×P3. Consequently, all hybrids of three groups were taller than relevant mid parents which was unfavorable to get shorter stature of plant. Heterobeltiosis varied from -6.79% to 14.50%. More than 50% (8 hybrids) of the total hybrids exhibited significant positive heterosis and two had significant negative values while negative heterosis was desirable. Four hybrids showed insignificant negative heterosis over better parent. The hybrid of group-1, P1×P3 (-6.79%), demonstrated the lowest and highly significant negative value of heterobeltiosis followed by significant negative heterosis (-1.60%) in the hybrid of group-2, P1×P6. The hybrids with significant negative heterobeltiosis were favorable. Similarly, Torres and Geraldi (2007) observed significant mid parent heterosis. Ali and Khan (1995) also found two significantly negative heterotic hybrids for this trait in their study. Patil *et al*. (2011) and Verma *et al*. (2002a) found significant heterosis for plant height.

Table 1. Analysis of variance (ANOVA) for seven quantitative traits in rice

Source of Variation	df	Days to 50% flowering	Plant height (cm)	Effective tillers plant^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	1000 grain Weight (g)	Grain yield plant^{-1}(g)
Replication	2	8.11	0.08	28.43	2.31	41.29	0.11	7.63
Genotypes	20	202.31**	224.20**	20.27**	10.09**	2358.35**	2.90**	213.32**
Cross (C)		173.79**	147.17**	9.24	6.74**	2356.61**	2.75**	209.52**
Parent (P)		223.07**	276.20**	29.43**	11.53**	1610.36**	2.80**	130.76**
P vs C		497.78**	1042.64**	128.93**	49.88**	6122.69**	5.40**	679.23**
Error	40	8.29	0.92	7.93	0.55	215.15	0.49	5.05

‘*’ Significant at 5%level; ‘**Significant at 1% level

For effective tiller per plant all hybrids studied provided positive heterosis over mid parent ranging from 1.52% to 33.33% and five of them were with significant values. The highest highly significant and desirable value (33.33%) was observed in the hybrid of group-1, P2×P3 which was followed by two hybrids of group-2, P2×P6 (31.48%), and P3×P5 (27.27%). Accordingly, hybrids with significant positive heterosis produce more effective tiller than corresponding mid parents. None of fifteen hybrids expressed significant heterosis for effective tillers plant^{-1} over better parent in either direction. Heterobeltiosis varied from -1.64% to 21.57%. Twelve hybrids exhibited positive heterosis; two hybrids showed negative heterobeltiosis and one revealed no heterosis. The highest positive but insignificant heterobeltiosis (21.57%) was observed in P2×P3 (group-1). Torres and Geraldi (2007) also observed significant mid parent heterosis for this character. Ali and Khan (1995) observed significant positive heterobeltiosis for tillers plant^{-1}. Patil *et al*. (2011), Raju *et al*. (2005) and Verma *et al*. (2002b) found significant heterosis in majority of hybrids they studied.

More encouraging results were observed for panicle length where twelve hybrids manifested significant positive mid parent heterosis which was desirable. The range of heterosis over mid parent was from -0.93% to 16.28%. The one and only negative heterotic (-0.93%) hybrid was the hybrid of group-1, P1×P3 indicating that it was the poorest hybrid for panicle length. Two hybrids of group-1, eight hybrids of group-2 and two hybrids of group-3 expressed significant positive mid parent heterosis. The highest and highly significant value (16.28%) was observed in the hybrid of group-2, P2×P6 specified that it was the best hybrid for panicle length. The range of heterobeltiosis was from -4.49% to 9.89%. Eleven hybrids out of fifteen had positive heterosis over better parents; seven of them showed significant values. One hybrid of group-1, five hybrids of group-2 and one hybrid of group-3 possessed significant positive hetrosis over better parent. The best hybrid with the highest highly significant positive heterosis (9.89%) was within the group-2, namely P2×P6 which was followed by P3×P6 (8.43%) and P1×P6 (8.01%). On the other hand, four hybrids exhibited negative but insignificant heterobeltiosis. Those hybrids having significant positive heterosis were good for this important trait as positive heterosis was preferred for this character. Torres and Geraldi (2007) observed significant mid parent heterosis for this trait. Patil *et al*. (2011) found desirable heterosis for panicle length.

Significant positive heterosis was expected in case of number of filled grains panicle^{-1}, being a very important yield contributing character. Out of thirteen positive mid parent heterotic hybrids ten manifested significant value. Two hybrids were observed with insignificant negative percentage. Heterosis over mid parent ranged from -12.14% to 30.23%. One hybrid of group-1, six hybrids of group-2 and all hybrids of group-3 accounted for significant positive heterosis. The desirable highest positive heterosis was (30.23%) found in P2×P5 followed by 27.07% in P1×P5 and 26.92 % in P2×P6. In case of heterobeltiosis twelve hybrids were positively heterotic and only three of them exhibited significant values. The range was from -17.44% to 24.17%. The highest significant heterosis (24.17%) was observed in a hybrid of group-3, P4×P6 which was followed by 20.20% in P2×P6 (group-2) and 18.97% in P3×P6 (group-2). In terms of heterobeltiosis hybrids of P6 performed the best. Torres and Geraldi (2007) also found significant mid parent heterosis for grains per panicle. High degrees of heterosis were found by Patil *et al*. (2011), Iftekharuddaula *et al*. (2004), Satish and Ramaiah (2003) for number of filled grains panicle^{-1}. Raju *et al*. (2005), Ali and Khan (1995) found low heterosis for this trait which was contradictory with this study.

For thousand grain weight out of fifteen hybrids thirteen manifested positive mid parent heterosis and four of them possessed significant values. Only two hybrids exhibited negative and insignificant heterosis. The range of the mid parent heterosis was from -1.98% to 12.76%. Three hybrids of group-2 with positive and significant value were P1×P6 (12.76%), P1×P5 (9.92%) and P2×P6 (9.01%) indicating that those offered heavier grains than mid parents. Among them P1×P6 was the highest. One hybrid of group-3 possessed significant positive heterosis. Eight hybrids provided positive heterobeltiosis and the rest seven provided negative and insignificant heterosis over better parent. Heterobeltiosis ranged from -5.99% to 6.38%. None but the hybrid P2×P6 possessed significant positive heterosis (6.38%) over better parent which was in group-2. The nearest to the highest (5.86) but insignificant positive heterotic hybrid was another hybrid of group-2, P1×P6. Torres and Geraldi (2007) also observed significant mid parent heterosis for this trait. Raju *et al*. (2005) observed low degree of heterosis for 1000 grain weight. Suh *et al*. (2005) found that 1000 grain weight in hybrids was almost same as parents and the finding was almost similar with this study.

Table 2. Extent of heterosis (%) over mid-parent (MPH) and better parent (BPH) for seven quantitative traits in 15 hybrids of rice

Group of hybrids	Hybrid/ Parents	Mean performance	Days to 50 % flowering		Mean performance	Plant height (cm)		Mean performance	Effective tillers plant^{-1}	
			HMP	HBP		HMP	HBP		HMP	HBP
1 (Aus× Aus)	P1×P2		2.20	0.72		2.78**	1.33		25.93*	3.03
	P1×P3		3.56	2.60		1.63*	-6.79**		17.95	4.55
	P2×P3		6.10*	3.61		17.11**	8.82**		33.33*	21.57
2 (Aus×Boro)	P1×P4		4.90*	2.48		5.68**	-1.25		10.24	6.06
	P1×P5		1.99	-8.06**		9.80**	-0.63		15.20	9.09
	P1×P6		3.55	-1.02		10.86**	-1.60*		1.52	1.52
	P2×P4		4.47*	3.55		13.24**	7.25**		16.50	-1.64
	P2×P5		5.56**	-3.58		16.22**	6.55**		18.81	1.69
	P2×P6		5.59*	2.37		10.67**	-0.52		31.48**	7.58
	P3×P4		12.45**	8.87**		7.95**	5.79**		12.50*	3.28
	P3×P5		14.52**	2.39		11.97**	10.34**		27.27*	18.64
	P3×P6		12.70**	6.78**		18.71**	14.50**		16.24	3.03
3 (Boro× Boro)	P4×P5		6.65**	-1.79		8.81**	5.12**		1.67	0.00
	P4×P6		0.87	-1.36		8.81**	2.94**		2.36	-1.52
	P5×P6		11.75**	5.07*		1.90*	-0.29		26.40**	19.70
	P1	89.67			106.13			22.00		
	P2	92.33			103.13			14.00		
	P3	88.00			88.54			17.00		
	P4	94.00			92.22			20.33		
	P5	111.67			85.97			19.67		
	P6	98.33			82.27			22.00		
	SE		2.036	2.352		0.678	0.783		1.991	2.299

Group of hybrids	Hybrid/ Parents	Mean performance	Panicle length (cm)		Mean performance	Filled grains panicle^{-1}	
			HMP	HBP		HMP	HBP
1 (Aus× Aus)	P1×P2		5.78*	4.10		1.42	-1.38
	P1×P3		-0.93	-4.49		-12.14	-17.44
	P2×P3		13.31**	7.57**		17.93*	13.85
2 (Aus×Boro)	P1×P4		4.00	-0.92		-3.01	-12.09
	P1×P5		5.72*	-4.39		27.07**	3.89
	P1×P6		12.55**	8.01**		10.28	1.72
	P2×P4		13.99**	6.95*		18.73*	10.43
	P2×P5		13.13**	0.85		30.23**	8.89
	P2×P6		16.28**	9.89**		26.92**	20.20*
	P3×P4		7.97**	6.63*		8.87	4.74
	P3×P5		11.90**	4.70		22.58**	5.56
	P3×P6		8.94**	8.43**		21.36**	18.97*
3 (Boro× Boro)	P4×P5		6.29**	0.62		17.46*	4.63
	P4×P6		9.74**	8.89**		26.57**	24.17**
	P5×P6		3.07	-3.14		15.64*	1.30
	P1	20.88			114.33		
	P2	20.22			121.00		
	P3	22.50			130.00		
	P4	23.07			140.67		
	P5	25.82			180.00		
	P6	22.71			135.33		
	SE		0.523	0.604		10.372	11.976

group of hybrids	Hybrids/ Parents	Mean performance	1000 grain weight (g)		Mean performance	Yield plant^{-1} (g)	
			HMP	HBP		HMP	HBP
1 (Aus× Aus)	P1×P2		-1.98	-5.80		2.73	-1.37
	P1×P3		-0.84	-5.99		-9.39	-19.94
	P2×P3		0.71	-0.70		18.74	8.86
2 (Aus×Boro)	P1×P4		3.97	-1.92		17.89	-4.75
	P1×P5		9.92**	2.37		62.27**	13.48*
	P1×P6		12.76**	5.86		53.12**	24.58*
	P2×P4		0.36	-1.57		33.31**	11.27
	P2×P5		0.70	-2.54		56.25**	11.98
	P2×P6		9.01**	6.38*		46.41**	23.10*
	P3×P4		4.03	3.48		28.26**	15.62
	P3×P5		3.28	1.36		77.14**	34.60**
	P3×P6		1.92	0.86		76.43**	60.35**
3 (Boro× Boro)	P4×P5		0.17	-1.19		29.12**	6.36
	P4×P6		2.60	2.07		32.39**	31.19**
	P5×P6		5.30*	4.41		33.09**	8.85
	P1	16.97			12.06		
	P2	18.40			13.11		
	P3	18.93			15.73		
	P4	19.13			19.59		
	P5	19.67			30.26		
	P6	19.33			19.23		
	SE		0.497	0.574		1.589	1.835

‘*’ P<0.05, ‘**’ P<0.01, NB: P1= BR21, P2= BR24, P3=BR26, P4=BRRI dhan28, P5=BRRI dhan29 and P6=BRRI dhan 36

Considering mid parent heterosis and heterobeltiosis estimated excellent heterotic hybrids were observed for grain yield plant^{-1}. All the hybrids exhibited positive heterosis over mid parent except one hybrid of group-1, P1×P3. The range of mid parent heterosis was from -9.39% to 77.14%. So, positive heterosis was found in 93.33% (14) of hybrids while significantly positive heterotic hybrid was 73% (11) of total fifteen hybrids. Eleven hybrids were found with significant and positive heterosis over mid parent. All hybrids of group-2 except

P1×P4 and also all hybrids of group-3 confirmed highly significant positive heterosis over mid parent. The highest and highly significant positive (77.14%) mid parent heterosis was found in the hybrid of group-2, P3×P5 followed by some other hybrids of group-2, P3×P6 (76.43%), P1×P5 (62.27%), P2×P5 (56.25%), P1×P6 (53.12%) and P2×P6 (46.41%). So, maximum hybrids of group-2 performed as per expectation. It was impressive that the hybrids of common parent, P5 provided outstanding performance in case of grain yield plant^{-1}. Hybrids where P6 was common parent took the position next to the hybrids of P5.

Eighty percent (12 hybrids) hybrids manifested positive heterobeltiosis and percentage of significant positive heterotic hybrid was 40% (six hybrids). Three hybrids exhibited insignificant and negative heterosis over better parent. The heterosis over better parent varied from -19.94% to 60.35%. One hybrid of group-1 was found with insignificant positive and two with insignificant negative heterosis over better parent. All hybrids of group-2 except P1×P4 exhibited positive heterosis. The highest significant positive value was observed in the hybrid of group-2, P3×P6 followed by other hybrids of group-2, P3×P5(34.60%), P1×P6(24.58%), P2×P6(23.10%), and P1×P5(13.48%). The hybrid of group-3, BRRI dhan28×BRRI dhan36 possessed high degree of positive (31.19%) heterobeltiosis. On the contrary, the lowest, negative and insignificant heterosis (-19.94%) was found in P1×P3 (Table 2). Consequently, in terms of heterosis over better parent performance of most of the hybrids of group-2 were wonderful. Hybrids having common Boro parent P6 were better than others and hybrids of P5 were next to them in case of heterobeltiosis which was just opposite of the result in terms of mid parent heterosis. Kumar *et al*. (2005) found 70% hybrids with positive mid parent heterosis in their study and in this study 93% hybrids showed positive heterosis over mid parent. Ali and Khan (1995) found significant positive heterobeltiosis in most of the hybrids for grain yield/plant. Kumar *et al*. (2005) found 60% hybrids with positive heterosis over better parent while we have found positive heterobeltiosis in 80% hybrid. Bansal *et al*. (2000), Iftekharuddaula *et al*. (2004), Patil *et al*. (2011), Raju *et al*. 2005 and Satish and Ramaiah (2003) observed significant positive heterosis for grain yield in most of the hybrids under their study.

It was importantly noticed that the hybrids of group-2, P1×P5, P1×P6, P3×P5 and P3×P6 with highly significant heterosis over both mid parent and better parent for yield were also positively heterotic and significant in most cases for other yield contributing traits such as number of effective tillers plant^{-1}, panicle length, filled grains panicle^{-1}. Among those P3×P5 and P3×P6 were excellent considering overall performance. One hybrid of group-3, P4×P6 also showed significant preferable heterosis in some important yield contributing characters such as panicle length and filled grains panicle^{-1}. Kumer *et al*. (2010) found positively heterotic hybrids for yield which were also heterotic for panicle length, and 1000 grain weight. Satish and Ramaiah (2003) noticed that heterosis for yield was due to favorable heterosis in tiller plant^{-1}, filled grain panicle^{-1}. Vanaja and Babu (2004) reported that positive heterosis in spikelets panicle^{-1} and panicle length resulted positive heterosis for grain yield plant^{-1}. Lokaprokash *et al*. (1992) recorded favorable heterosis for grain yield plant^{-1} resulted for favorable heterosis for number of productive tillers, panicle length, fertile spikelets panicle^{-1} and 1000 grain weight.

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