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ESTIMATION OF STANDARD HETEROSIS FOR REPRODUCTIVE TRAITS IN NEWLY SYNTHESIZED TEST RICE (*Oryza sativa* L.) HYBRIDS

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ABSTRACT

An experiment was carried to estimate heterotic performances of newly developed test hybrids utilizing CMS system during Rabi 2011 using RCBD design. Five known CMS lines and sixteen developed R-lines were crossed through line × tester analysis. Heterosis for days to first flowering varied from -6.23% to 16.35% with a SD of 4.47 meanwhile heterosis for days to 80% flowering varied from -9.24% to 11.04% with a SD of 4.03. Among eighty crosses seventy two were found positive heterosis for days to first flowering but sixty four crosses were found for days to 80% flowering. RG-BU08-016R crosses with IR58025A (-2.68*) and IR62820A (-3.42**) showed significant negative standard heterosis for days to first flowering. Five crosses of IR58025A showed significant negative heterosis with RG-BU 08-005R (-3.42*), RG-BU 08-006R (-5.28**), RG-BU 08-013R (-4.129**), RG-BU 08-016R (-5.78**), RG-BU 08-018R (-4.06*) for days to 80% flowering. Besides these 4 crosses of IR62820A showed significant negative heterosis with RG-BU 08-007R (-2.32*), RG-BU 08-016R (-6.03*), RG-BU 08-018R (-4.58**) followed by GAN 46A/RG-BU 08-006R (-4.58*), BRRI 1A/RG-BU 08-001R (-2.55**) and BRRI 1A/RG-BU 08-006R (-9.24**) resulted significant negative heterosis for days to 80% flowering. Positive heterosis were recorded for IR58025A with RG-BU 08-007R (26.97**), RG-BU 08-0046R (8.77**) and RG-BU 08-105R (14.44**) for PER and RG-BU 08-018R (42.46**), RG-BU 08-046R (112.30**), RG-BU 08-057R (27.46*) for SER. While two R-lines, RG-BU 08-013R (25.41**) and RG-BU 08-057R (7.21*) were found having significant positive heterosis for panicle exertion rate crosses with IR62820A but RG-BU 08-025R (52.82**), RG-BU 08-057R (122.66**) and RG-BU 08-063R (37.38**) were found having significant positive heterosis for SER. IR62820A/RG-BU08-057R showed significant positive heterosis for both panicle and stigma exertion rate. GAN46A/RG-BU 08-063R (5.65* & 133.02**) was recorded showing significant positive heterosis for both panicle and stigma exertion rate where. But the crosses of IR68888A was not shown exhibiting a great contribution for panicle and stigma exertion rate except RG-BU08-018R (25.94**). Meanwhile the crosses of BRRI1A was recorded having significant positive heterosis for PER with RG-BU08-005R (13.41**), RG-BU08-007R (5.65*) and RG-BU08-097R (25.94**) as well as RG-BU08-007R (133.02**), RG-BU08-013R (48.19**) and RG-BU08-038R (29.21*) were recorded having significant positive heterosis for SER.

Keywords: Rice; heterosis; days to flowering; panicle exertion; stigma exertion

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INTRODUCTION

Heterosis is an important genetic phenomenon, synonymous with hybrid vigour refers to the manifested superiority of the F_1 hybrid resulting from the cross of genetically dissimilar homozygous parents. The best way to utilize heterosis in crop is to produce F_1 hybrids, which possess maximum heterozygosity (Chetia *et al.,* 2000). Heterosis in rice has been known since 1926, its commercial exploitation was demonstrated only when Chinese rice scientists developed commercial rice hybrids with 20 percent yield advancement over semi-dwarf varieties (Sun *et al.,* 2006). Heterosis is estimated to determine the superiority of F_1 over mid parent or better parent or standard check variety (Hien *et al.,* 2007). Moreover yield potentialities of HYV are in static position.

Therefore, there is an ample scope of enhancement of yield potentiality of rice through development of hybrid variety utilizing CMS system in the country. Nonetheless, the geographical location of Bangladesh is quite favorable for hybrid rice production (Banumathy and Thiyagarajan, 2005). Evaluation of heterosis is a crucial part of hybrid breeding. Heterosis will help the breeder to observe superiority of the hybrids in respect of their parents or standard rice varieties. The observation related to heterosis of different characters of rice showed both positive and negative values (Chahal and Gosal, 2008).

Considering above ideas the present investigation was undertaken with the following objectives: (i) to develop short duration variety; (ii) to estimate standard heterosis for panicle and stigma exertion rate and (iii) to estimate standard heterosis for yield in newly synthesized test hybrids.

MATERIALS AND METHODS

The experiment was carried out at the experimental farm, Department of Genetics and Plant Breeding, BSMRAU, Gazipur 1706 during Rabi 2011. The experimental site is located at the centre of Madhupur Tract (24º29 N latitude and 90º26 E longitude) having an elevation of 8.2m from the sea level. The soil type of experimental field belongs to the shallow red brown terrace type under Salna series of Madhupur Tract (AEZ- 28) which is characterized by sandy clay with p^H value of 6.5. 5 known CMS lines and 16 developed R-lines were crossed through line × tester analysis and 80 test hybrids were developed. These 80 test hybrids were sown in the subsequent generation to assess heterotic performances in randomized complete block design.

Data on the following parameters were recorded from 10 randomly selected plants and on whole plot basis on days to 1^{st} flowering, days to 80% flowering, panicle exertion rate (%PER), stigma exertion rate (%PER) and finally grain yield.

Data obtained for each character was subjected to the analysis of variance following three replicated randomized complete block design by using MSTAT-C computer software and the analysis of variance for each of the characters was performed by F-test. Mean, range and standard deviation for each character were also estimated for the hybrids performed by Microsoft Excel program 2007. Standard heterosis was calculated as percentage increase or decrease of F_1 mean performance over the check variety.

Materials used in the experiment

Table 1. Male Parents, Female, Parents and the F_1s used for standard heterosis estimation over BRRI dhan28

Female parents:	
1.	IR 58025A, 2. BRRI 1A, 3. GAN46A, 4. IR 68888A and 5. IR 62820A

Male parents:							
1.	RG-BU08-001R,	**5.**	RG-BU08-007R,	**9.**	RG-BU08-025R,	**13.**	RG-BU08-057R,
2.	RG-BU08-002R,	**6.**	RG-BU08-013R,	**10.**	RG-BU08-034R,	**14.**	RG-BU08-063R,
3.	RG-BU08-005R,	**7.**	RG-BU08-016R,	**11.**	RG-BU08-038R,	**15.**	RG-BU08-097R
4.	RG-BU08-006R,	**8.**	RG-BU08-018R,	**12.**	RG-BU08-046R	**16.**	RG-BU08-105R

Crosses					
1	IR 58025A × RG-BU08-001R	**33**	BRRI 1A× RG-BU08-001R	**65**	IR 62820A× RG-BU08-001R
2	IR 58025A × RG-BU08-002R	**34**	BRRI 1A× RG-BU08-002R	**66**	IR 62820A× RG-BU08-002R
3	IR 58025A × RG-BU08-005R	**35**	BRRI 1A× RG-BU08-005R	**67**	IR 62820A× RG-BU08-005R
4	IR 58025A × RG-BU08-006R	**36**	BRRI 1A× RG-BU08-006R	**68**	IR 62820A× RG-BU08-006R
5	IR 58025A × RG-BU08-007R	**37**	BRRI 1A× RG-BU08-007R	**69**	IR 62820A× RG-BU08-007R
6	IR 58025A × RG-BU08-013R	**38**	BRRI 1A× RG-BU08-013R	**70**	IR 62820A× RG-BU08-013R
7	IR 58025A × RG-BU08-016R	**39**	BRRI 1A× RG-BU08-016R	**71**	IR 62820A× RG-BU08-016R
8	IR 58025A × RG-BU08-018R	**40**	BRRI 1A× RG-BU08-018R	**72**	IR 62820A× RG-BU08-018R
9	IR 58025A × RG-BU08-025R	**41**	BRRI 1A× RG-BU08-025R	**73**	IR 62820A× RG-BU08-025R
10	IR 58025A × RG-BU08-034R	**42**	BRRI 1A× RG-BU08-034R	**74**	IR 62820A× RG-BU08-034R
11	IR 58025A × RG-BU08-038R	**43**	BRRI 1A× RG-BU08-038R	**75**	IR 62820A× RG-BU08-038R
12	IR 58025A × RG-BU08-046R	**44**	BRRI 1A× RG-BU08-046R	**76**	IR 62820A× RG-BU08-046R
13	IR 58025A × RG-BU08-057R	**45**	BRRI 1A× RG-BU08-057R	**77**	IR 62820A× RG-BU08-057R
14	IR 58025A × RG-BU08-063R	**46**	BRRI 1A× RG-BU08-063R	**78**	IR 62820A× RG-BU08-063R
15	IR 58025A × RG-BU08-097R	**47**	BRRI 1A× RG-BU08-097R	**79**	IR 62820A× RG-BU08-097R
16	IR 58025A × RG-BU08-105R	**48**	BRRI 1A× RG-BU08-105R	**80**	IR 62820A× RG-BU08-105R
17	GAN 46A× RG-BU08-001R	**49**	IR 68888A× RG-BU08-001R		
18	GAN 46A× RG-BU08-002R	**50**	IR 68888A× RG-BU08-002R		
19	GAN 46A× RG-BU08-005R	**51**	IR 68888A× RG-BU08-005R		
20	GAN 46A× RG-BU08-006R	**52**	IR 68888A× RG-BU08-006R		
21	GAN 46A× RG-BU08-007R	**53**	IR 68888A× RG-BU08-007R		
22	GAN 46A× RG-BU08-013R	**54**	IR 68888A× RG-BU08-013R		
23	GAN 46A× RG-BU08-016R	**55**	IR 68888A× RG-BU08-016R		
24	GAN 46A× RG-BU08-018R	**56**	IR 68888A× RG-BU08-018R		
25	GAN 46A× RG-BU08-025R	**57**	IR 68888A× RG-BU08-025R		
26	GAN 46A× RG-BU08-034R	**58**	IR 68888A× RG-BU08-034R		
27	GAN 46A× RG-BU08-038R	**59**	IR 68888A× RG-BU08-038R		
28	GAN 46A× RG-BU08-046R	**60**	IR 68888A× RG-BU08-046R		
29	GAN 46A× RG-BU08-057R	**61**	IR 68888A× RG-BU08-057R		
30	GAN 46A× RG-BU08-063R	**62**	IR 68888A× RG-BU08-063R		
31	GAN 46A× RG-BU08-097R	**63**	IR 68888A× RG-BU08-097R		
32	GAN 46A× RG-BU08-105R	**64**	IR 68888A× RG-BU08-105R		

Estimation of Standard Heterosis

Mean value of check variety and F_1s in all replications were taken for heterosis estimation.

Hs % $= (F_1 - CV)/CV \times 100$

$$SE\ (Hs) = \frac{(2Ve)}{r}$$

"t" value $= F_1$ - CV/SE (Hs)

Where,
Ve = Error mean sum of squares from RCBD ANOVA,
F_1 = Mean of F_1,
CV = Mean of check variety,
Hs = Standard heterosis,
SE = Standard error

RESULTS AND DISCUSSION

Estimation of standard heterosis for days to first and 80% flowering

BRRI dhan28 is an outstanding variety due to its fine grain shape and earliness in nature. It is very difficult to find a hybrid earlier to BRRI dhan28 as life cycle of 140 days. Heterosis for days to first flowering varied from -6.23% to 16.35% with a SD of 4.47 meanwhile heterosis for days to 80% flowering varied from -9.24% to 11.04% with a SD of 4.03. Among eighty crosses seventy two crosses were found positive heterosis for days to first flowering but 64 were found for days to 80% flowering. Normally the number of crosses for first flowering and 80% flowering are same but deviation might be due to prolongs flowering period. Some crosses completed their flowering period within 7 days but some crosses took 12-17 days for completion of flowering. This might be due to abiotic factor (effect of photoperiod, temperature and humidity) and inaccuracy of pollination.

Table 02. Estimation of standard heterosis over BRRI dhan28 for days to first flowering in newly developed 80 F_1 hybrids

Crosses	Days to first flowering				
	IR 58025A	**IR 62829A**	**GAN 46 A**	**IR 68888A**	**BRRI 1A**
RG-BU 08-001R	5.88 ± 3.32	25.74** ± 3.75	25.74** ± 3.60	15.81** ± 3.22	2.82** ± 4.01
RG-BU 08-002R	11.99** ± 3.32	16.33** ± 3.75	16.33** ± 3.60	13.53** ± 3.22	31.88** ± 4.01
RG-BU 08-005R	0.52 ± 3.32	13.53** ± 3.75	13.53** ± 3.60	11.23** ± 3.22	36.45** ± 4.01
RG-BU 08-006R	-4.29 ± 3.32	-16.85** ± 3.75	-2.54 ± 3.60	8.93** ± 3.22	-14.77** ± 4.01
RG-BU 08-007R	20.90** ± 3.32	2.06 ± 3.75	18.11** ± 3.60	11.23** ± 3.22	22.70** ± 4.01
RG-BU 08-013R	-1.78 ± 3.32	8.06* ± 3.75	10.48** ± 3.60	22.70** ± 3.22	22.70** ± 4.01
RG-BU 08-016R	-6.35* ± 3.32	-8.11 ± 3.75	15.81** ± 3.60	20.41** ± 3.22	29.58** ± 4.01
RG-BU 08-018R	-2.54 ± 3.32	-2.54 ± 3.75	13.46** ± 3.60	11.23** ± 3.22	34.18** ± 4.01
RG-BU 08-025R	2.82 ± 3.32	2.65 ± 3.75	38.75** ± 3.60	15.81** ± 3.22	21.92** ± 4.01
RG-BU 08-034R	-8.18* ± 3.32	8.39* ± 3.75	22.70** ± 3.60	18.11** ± 3.22	-12.75** ± 4.01
RG-BU 08-038R	14.03** ± 3.32	13.79** ± 3.75	22.70** ± 3.60	20.41** ± 3.22	9.69** ± 4.01
RG-BU 08-046R	15.05** ± 3.32	14.95** ± 3.75	29.58** ± 3.60	15.81** ± 3.22	15.81** ± 4.01
RG-BU 08-057R	22.70** ± 3.32	22.59** ± 3.75	34.18** ± 3.60	13.53** ± 3.22	13.56** ± 4.01
RG-BU 08-063R	21.16** ± 3.32	21.26** ± 3.75	21.92** ± 3.60	27.28** ± 3.22	13.51** ± 4.01
RG-BU 08-097R	7.28** ± 3.32	-7.26** ± 3.75	2.75** ± 3.60	2.70** ± 3.22	-7.28** ± 4.01
RG-BU 08-105R	18.87** ± 3.32	16.73** ± 3.75	-9.69** ± 3.60	20.41** ± 3.22	22.70** ± 4.01
Minimum	**38.75**				
Maximum	**-14.77**				
SD	**10.628**				
SE	**3.329**				
t (5%)/SE (gi)	**6.036**				
t (1%)/SE (gi - gj)	**8.714**				

*p= 0.05, **p= 0.01 and ^{ns} = Insignificant

It is to be noted that only eleven crosses were found exhibiting negative heterosis among which only two crosses were found significantly earlier than BRRI dhan28 in context of days to first flowering. RG-BU08-016R crosses with IR58025A (-2.68*) and IR62820A (-3.42**) showed significant negative standard heterosis for days to first flowering. 5 crosses of IR58025A showed significant negative heterosis with RG-BU 08-005R (-3.42*), RG-BU 08-006R (-5.28**), RG-BU 08-013R (-4.129**), RG-BU 08-016R (-5.78**), RG-BU 08-018R (-4.06*) for days to 80% flowering. Besides these 4 crosses of IR62820A showed significant negative heterosis with RG-BU 08-007 R (-2.32*), RG-BU 08-016R (-6.03*), RG-BU 08-018R (-4.58**) followed by GAN 46A/RG-BU 08-006R (-4.58*), BRRI 1A/RG-BU 08-001R (-2.55**) and BRRI 1A/RG-BU 08-006R (-9.24**) resulted significant negative heterosis for days to 80% flowering.

Biju *et al*. (2006) observed magnitude of standard heterosis and per se performance of thirty four hybrids and found significant negative heterosis for plant height and days to 50% flowering. Bhave *et al.* (2002) evaluated thirty-two rice hybrids from two CMS lines for heterosis (mid-parent) and standard heterosis and observed 58.50 to 80.43% heterosis for days to maturity. Ali (2007) while studying on fifty test hybrid demonstrated that hybrid-4 and hybrid-9 exhibited all types of heterosis in desirable direction for most of the characters, especially for days to 80% flowering and days to maturity. Roy (2006) found ten specific cross combinations performed excellent and most promising hybrids showed positive significant negative heterosis for days to 80% flowering and maturity. In fact from this table it might be concluded that there is few possibilities to found test hybrid having a significant negative heterosis compared to BRRI dhan28.

Table 03. Estimates of standard heterosis over BRRI dhan28 for days to days to 80% flowering in newly developed 80 F_1 hybrids

Crosses	Days to 80% flowering				
	IR 58025A	**IR 62829A**	**GAN 46 A**	**IR 68888A**	**BRRI 1A**
RG-BU 08-001R	7.61* ± 3.30	26.81** ± 4.55	24.01** ± 4.07	15.08** ± 3.22	1.09 ± 3.77
RG-BU 08-002R	13.72** ± 3.30	17.40** ± 4.55	14.60** ± 4.07	12.80** ± 3.22	30.15** ± 3.77
RG-BU 08-005R	2.25 ± 0.30	14.60** ± 4.55	11.80** ± 4.07	10.50** ± 3.22	34.72** ± 3.77
RG-BU 08-006R	-2.56 ± 0.30	-17.92** ± 4.55	-4.27 ± 4.07	8.20* ± 3.22	-16.50** ± 3.77
RG-BU 08-007R	22.63** ± 3.30	3.13 ± 0.55	16.38** ± 4.07	10.50** ± 3.22	20.97** ± 3.77
RG-BU 08-013R	-0.95 ± 0.30	9.13** ± 4.55	8.75** ± 4.07	21.97** ± 3.22	20.97** ± 3.77
RG-BU 08-016R	-4.62 ± 0.30	-7.04* ± 4.55	14.08** ± 4.07	19.68** ± 3.22	27.85** ± 3.77
RG-BU 08-018R	-0.81 ± 0.30	-1.47 ± 0.55	11.73** ± 4.07	10.50** ± 3.22	32.45** ± 3.77
RG-BU 08-025R	4.55 ± 3.30	3.72 ± 0.55	37.02** ± 4.07	15.08** ± 3.22	20.19** ± 3.77
RG-BU 08-034R	-9.91* ± 3.30	9.25** ± 4.55	20.97** ± 4.07	17.38** ± 3.22	-11.02** ± 3.77
RG-BU 08-038R	15.76** ± 3.30	14.86** ± 4.55	20.97** ± 4.07	19.68** ± 3.22	7.96* ± 3.77
RG-BU 08-046R	16.78** ± 3.30	16.02** ± 4.55	27.85** ± 4.07	15.08** ± 3.22	14.08** ± 3.77
RG-BU 08-057R	24.43** ± 3.30	23.66** ± 4.55	32.45** ± 4.07	12.80** ± 3.22	11.83** ± 3.77
RG-BU 08-063R	22.89** ± 3.30	22.33** ± 4.55	20.19** ± 4.07	26.55** ± 3.22	11.78** ± 3.77
RG-BU 08-097R	9.01** ± 3.30	-8.33** ± 4.55	-9.02** ± 4.07	1.97** ± 3.22	-5.55** ± 3.77
RG-BU 08-105R	20.60** ± 3.30	17.80** ± 4.55	-7.96* ± 4.07	19.68** ± 3.22	20.97** ± 3.77
Minimum	**37.02**				
Maximum	**-16.50**				
SD	**10.197**				
SE	**3.572**				
t (5%)/SE (gi)	**6.833**				
t (1%)/SE (gi - gj)	**8.444**				

*p= 0.05, **p= 0.01 and ^{ns} = Insignificant

Estimation of standard heterosis for panicle exertion rate (%PER) and stigma exertion rate (%SER)

Highly significant positive heterosis for panicle and stigma exertion rate indicates greater suitability of the cross combination over check varieties. Among 80 crosses, positive heterosis were recorded for the crosses of IR58025A with RG-BU 08-007R (26.97**), RG-BU 08-0046R (8.77**) and RG-BU 08-105R (14.44**) for panicle exertion rate and RG-BU 08-018R (42.46**), RG-BU 08-046R (112.30**), RG-BU 08-057R (27.46*) for stigma exertion rate. While two R-lines, RG-BU 08-013R (25.41**) and RG-BU 08-057R (7.21*) were found having significant positive heterosis for panicle exertion rate crosses with IR62820A but RG-BU 08-025R (52.82**), RG-BU 08-057R (122.66**) and RG-BU 08-063R (37.38**) were found having significant positive heterosis for stigma exertion rate. Here it is to be noted that IR62820A/RG-BU08-057R showed significant positive heterosis for both panicle and stigma exertion rate. GAN46A/RG-BU08-063R (5.65* & 133.02**) was recorded showing significant positive heterosis for both panicle and stigma exertion rate where. But the crosses of IR68888A was not shown exhibiting a great contribution for panicle and stigma exertion rate except RG-BU08-018R (25.94**).

Table 5. Estimation of standard heterosis over BRRI dhan28 for panicle exertion rate (% PER) in 80 F_1

Crosses	Panicle exertion rate (% PER)				
	IR 58025A	IR 62820A	GAN 46A	IR 68888A	BRRI 1A
RG-BU 08-001R	2.07 ± 0.95	1.00 ± 0.83	12.87** ± 0.85	-5.79* ± 0.78	1.02 ± 0.80
RG-BU 08-002R	3.85 ± 0.95	0.51 ± 0.83	-0.56 ± 0.85	-10.02** ±0.78	-3.69 ± 0.80
RG-BU 08-005R	-4.63 ± 0.95	2.29 ± 0.83	-1.05 ± 0.85	-2.12 ± 0.78	13.41** ±0.80
RG-BU 08-006R	-3.83 ± 0.95	-6.20* ± 0.83	0.72 ± 0.85	1.04 ± 0.78	-0.03 ± 0.80
RG-BU 08-007R	26.97** ± 0.95	-5.40* ± 0.83	-7.76* ± 0.85	2.82 ± 0.78	5.65* ± 0.80
RG-BU 08-013R	-2.17 ± 0.95	25.41** ± 0.83	-6.96* ± 0.85	-5.66* ± 0.78	-12.11** ± 0.80
RG-BU 08-016R	-9.00** ± 0.95	-3.73 ± 0.83	23.84** ± 0.85	-4.86* ± 0.78	-1.08 ± 0.80
RG-BU 08-018R	-2.97 ± 0.95	-10.56** ± 0.83	-5.29* ± 0.85	25.94** ± 0.78	-5.79* ± 0.80
RG-BU 08-025R	-3.42 ± 0.95	-4.53* ± 0.83	-12.13** ± 0.85	-3.20 ± 0.78	11.31 ± 0.80
RG-BU 08-034R	-4.89* ± 0.95	-4.98* ± 0.83	-6.09* ± 0.85	-10.03** ±0.78	-2.12 ± 0.80
RG-BU 08-038R	1.41 ± 0.95	-6.45* ± 0.83	-6.54* ± 0.85	-4.00 ± 0.78	1.04 ± 0.80
RG-BU 08-046R	8.77** ± 0.95	-0.15 ± 0.83	-8.01** ± 0.85	-4.44 ± 0.78	2.82 ± 0.80
RG-BU 08-057R	-8.99** ± 0.95	-4.23 ± 0.83	-1.71 ± 0.85	-5.92* ± 0.78	-5.66* ± 0.80
RG-BU 08-063R	2.04 ± 0.95	-10.55** ± 0.83	-1.08 ± 0.85	0.38 ± 0.78	-4.86* ± 0.80
RG-BU 08-097R	14.44** ± 0.95	7.21* ± 0.83	5.65* ± 0.85	11.31** ± 0.78	25.94** ±0.80
RG-BU 08-105R	-2.67 ± 0.95	0.48 ± 0.83	-12.11** ± 0.85	7.75 ± 0.78	-3.20 ± 0.80
Minimum	**-12.13****				
Maximum	**26.97****				
SD	**8.74**				
t (5%)/SE (gi)	**0.97**				
t (1%)/SE (gi - gj)	**4.459**				

*p= 0.05, **p= 0.01 and [ns] = Insignificant

Meanwhile the crosses of BRRI1A was recorded having significant positive heterosis for panicle exertion rate with RG-BU08-005R (13.41**), RG-BU08-007R (5.65*) and RG-BU08-097R (25.94**) as well as RG-BU08-007R (133.02**), RG-BU08-013R (48.19**) and RG-BU08-038R (29.21*) recorded having significant positive heterosis for stigma exertion rate which reveals that among all the cross combinations these crosses exceeded the standard variety. The higher panicle and stigma exertion might be due to synchronized flowering due to application of growth inhibiting substances within virgin panicle initiation stage (PI-6) to heading. The higher panicle exertion might also be due to proper application of micronutrients (GA_3) just before panicle initiation stage as well as active tillering stage @ 12µm as dose 01, 24µm as dose 02, 36µm as dose 03 and 48/54µm as dose 04. It is to be noted that dose 04 (48/54µm) is used depending on environment and reproductive phase of the panicle initiation stage. Banumathy *et al.* (2005) studied the magnitude of heterosis, of 100 rice hybrids for grain yield and its related traits and observed maximum significant positive relative heterosis (205.29%) and heterobeltiosis (187.25%). He also stated that most of the high yielding hybrids manifested positive heterosis for filled grains and spikelet fertility. Meanwhile, Bhave *et al.* (2002) evaluated thirty-two rice hybrids from two CMS lines (IR58025A and IR62829A) and 16 local restorers and found that standard heterosis -58.50 to 80.43%, respectively for spikelets fertility.

Table 6. Estimation of standard heterosis over BRRI dhan28 for stigma exertion rate (% SER) in 80 F_1

Crosses	Stigma exertion rate (% SER)				
	IR 58025A	IR 62820A	GAN 46A	IR 68888A	BRRI 1A
RG-BU 08-001R	-68.83** ± 0.91	-8.68 ± 0.87	-5.39 ± 2.85	-69.17** ±2.22	7.22 ±1.05
RG-BU 08-002R	-14.74 ± 0.91	-58.47** ± 0.87	1.68 ± 2.85	-79.28** ±2.22	8.15 ±1.05
RG-BU 08-005R	-74.39** ±0.91	-4.38 ± 0.87	-48.10** ±2.85	-72.20** ±2.22	-1.96 ±1.05
RG-BU 08-006R	-15.75 ± 0.91	-64.03** ± 0.87	5.98 ± 2.85	-55.04** ±2.22	-79.13** ±1.05
RG-BU 08-007R	-80.03** ±0.91	-5.39 ± 0.87	-53.66** ± 2.85	-0.95 ±2.22	-66.24** ±1.05
RG-BU 08-013R	-48.10** ±0.91	-69.67** ± 0.87	4.97 ± 2.85	-60.60** ±2.22	48.19** ±1.05
RG-BU 08-016R	2.44 ± 0.91	-37.74** ± 0.87	-59.31** ± 2.85	-1.96 ±2.22	14.15 ±1.05
RG-BU 08-018R	27.46* ± 0.91	37.83** ± 0.87	48.19** ± 2.85	126.09** ±2.22	133.02** ±1.05
RG-BU 08-025R	-36.31** ±0.91	52.82** ± 0.87	23.17* ± 2.85	-34.31** ±2.22	4.97 ±1.05
RG-BU 08-034R	-7.50 ± 0.91	-25.95* ± 0.87	63.18** ± 2.85	16.23 ±2.22	12.05 ±1.05
RG-BU 08-038R	-1.68 ± 0.91	2.86 ± 0.87	-15.59 ± 2.85	56.25** ±2.22	29.21* ±1.05
RG-BU 08-046R	112.30** ±0.91	8.68 ± 0.87	13.23 ± 2.85	-22.52 ±2.22	-0.95 ±0.65
RG-BU 08-057R	-5.64 ± 0.91	122.66** ± 0.87	19.04 ± 2.85	6.29 ±2.22	-60.60** ±1.05
RG-BU 08-063R	-6.57 ± 0.91	3.79 ± 0.87	133.02** ±2.85	12.11 ±2.22	-1.96 ±1.05
RG-BU 08-097R	42.46** ± 0.91	12.81 ± 0.87	-27.38* ± 2.85	-66.24** ±2.22	15.08 ±1.05
RG-BU 08-105R	-15.75 ± 0.91	4.72 ± 0.87	-70.09** ± 2.85	41.26** ±2.22	-34.31** ±1.05
Minimum	**-80.03****				
Maximum	**133.02****				
SD	**24.90**				
t (5%)/SE (gi)	**2.77**				
t (1%)/SE (gi - gj)	**24.904**				

*p= 0.05, **p= 0.01 and ^{ns} = Insignificant

Estimation of standard heterosis for yield (t/ha)

In order to formulate efficient breeding programs, for improvement of yield, it is essential to characterize the nature and mode of gene action that determines the yield and its components (Verma, 2005). It is important to know the degree and direction of hybrid vigor for its commercial exploitation (Venkatesan *et al*., 2007). Heterosis in yield varied from -90.83 to 189.40%. Highly significant heterosis were found from the crosses of IR58025A with 6 R-lines i.e., RG-BU 08-006R (42.46**), RG-BU 08-013R (61.74**), RG-BU 08-018R (24.86*), RG-BU 08-046R (28.54**), RG-BU 08-063R (30.55**), RG-BU 08-105R (36.62**). Three crosses of IR62820A were shown exhibiting significant positive standard yield heterosis with RG-BU 08-007R (70.69**), RG-BU 08-063R (31.28**), RG-BU 08-097R (52.43**).

Seven crosses of GAN 46A showed significant positive standard yield heterosis with RG-BU 08-001R (22.45*), RG-BU 08-005R (50.04**), RG-BU 08-013R (21.82*), RG-BU 08-025 R (47.46**), RG-BU 08-038R (57.02**) and RG-BU 08-057R (62.51**). Three crosses of IR 68888A showed significant positive standard yield heterosis with RG-BU 08-007R (33.14**), RG-BU 08-018R (67.31**) and RG-BU 08-097R (22.45*). And it was observed that five crosses of BRRI 1A showed significant positive standard yield heterosis with R-lines RG-BU 08-001R (41.25**), RG-BU 08-005R (31.87**), RG-BU 08-016R (74.31**), RG-BU 08-025R (71.67**) and RG-BU 08-063R (31.92**). It is to ne noted that crosses of four R-lines (RG-BU 08-001R, RG-BU 08-025R, RG-BU 08-038R and RG-BU 08-097R) showed significant positive standard yield heterosis with all five CMS lines. These crosses showed marked variations in the expression of standard heterosis for yield and yield components.

Table 7. Estimation of Standard heterosis over BRRI dhan28 for grain yield (ton/ha) in 80 F_1

Crosses	Grain yield (ton/ha)				
	IR 58025A	IR 62820A	GAN 46A	IR 68888A	BRRI 1A
RG-BU 08-001R	42.25** + 5.21	37.08**+ 5.20	38.34**+ 5.21	47.26**+ 8.21	31.20**+ 7.21
RG-BU 08-002R	-10.37*+ 2.24	-9.10+ 3.21	-5.08+ 3.21	-11.91+ 3.22	-11.46*+ 1.23
RG-BU 08-005R	-15.39**+ 3.25	1.40+ 3.27	37.41**+7.22	-4.94+ 3.24	22.99**+ 6.25
RG-BU 08-006R	13.94**+ 3.27	-14.26**+ 3.24	-12.18*+ 3.24	-9.80+ 3.24	-0.24+ 0.16
RG-BU 08-007R	-11.54*+ 3.28	54.07**+ 9.21	4.60+ 0.29	26.72**+ 1.25	0.67+ 0.29
RG-BU 08-013R	47.89**+ 8.29	-0.99+ 0.24	15.32**+ 3.23	-1.01+ 3.241	-15.56*+ 3.20
RG-BU 08-016R	-1.09+ 0.26	9.55+ 3.21	12.15*+ 3.24	-5.15+ 3.28	55.64**+ 8.22
RG-BU 08-018R	25.67**+ 3.27	15.45**+ 3.23	8.11+ 3.27	51.64**+ 9.22	-2.86+ 0.20
RG-BU 08-025R	42.23**+ 7.22	47.55**+ 8.25	54.60**+ 3.28	55.39**+ 8.20	59.33**+ 9.20
RG-BU 08-034R	-4.15+ 0.20	-4.69+ 3.27	6.69+ 3.24	-2.55+ 3.29	-6.44+ 3.23
RG-BU 08-038R	50.59**+ 9.20	36.34**+ 3.29	45.33**+ 3.28	49.41**+ 8.23	55.30**+ 8.27
RG-BU 08-046R	38.60**+ 8.21	-8.21+ 3.24	-3.01+ 3.20	-5.17+ 3.20	1.86+ 1.29
RG-BU 08-057R	-14.23**+ 3.22	-10.68*+ 3.20	51.48**+ 3.29	51.41**+ 3.22	49.63**+ 8.21
RG-BU 08-063R	34.89**+ 3.21	34.84**+ 3.22	-6.25+ 3.24	-0.66+ 3.20	34.04**+ 5.23
RG-BU 08-097R	92.96**+ 12.21	54.58**+ 8.27	51.60**+ 3.22	54.34**+ 9.21	35.57**+ 3.20
RG-BU 08-105R	40.45**+ 4.29	6.93+ 3.20	9.48+ 3.25	4.86+ 3.23	13.12+ 1.21
Minimum	**-43.39****				
Maximum	**64.96****				
SD	**26.085**				
t (5%)/SE (gi)	**10.32**				
t (1%)/SE (gi - gj)	**13.09**				

*p= 0.05, **p= 0.01 and ^{ns} = Insignificant

From this study it is observed that highly positive and significant cross combinations, could be exploited beneficially in future rice breeding program by adopting appropriate breeding strategy in order to evolve high yielding hybrid varieties. Occurrence of both additive and non-additive gene effects with preponderance of non-additive gene action for yield and important yield components in rice were reported by Singh 2005, Soni *et al.* 2005 and Tangwen *et al*. 2004. An importance of both additive and non-additive gene effects in governing yield and most of the yield attributes with predominance of non-additive gene action for most of the yield attributes. In this situation, both non-additive and additive components were important for the expression of characters. At the same time population improvement program may allow to accumulate the fixable gene effects as well as to maintain considerable variability and heterozygosity for exploiting non-fixable gene effects. The higher grain yield might be due to higher amount of effective tillers/plant, higher number of filled grains/panicle and maximum out crossing rate.

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