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# HETEROSIS IN LOCAL BORO RICE (*Oryza sativa* L.)

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## ABSTRACT

An experiment was conducted to study the heterosis of 27 $F_1$ hybrids produced from nine CMS lines and three restorer lines of rice with their parental lines and BRRI Dhan29 as standard check for 17 yield and its contributing traits. Mid parent, better parent and standard heterosis of most of the crosses were significant for most of the characters studied either in positive or in negative direction. Desirable and significant mid parent and better parent heterosis was observed in 13 and seven cross combinations, respectively for grain yield and most of its related traits. Considering more than 20% mid parent and better parent heterosis for grain yield along with most of its related traits, nine and five cross combinations, respectively were identified as good heterotic combinations over mid parental and better parental value. On the basis of individual trait significant and desirable mid parent heterosis was observed in eight cross combinations for plant height, 12 for leaf blade length, nine for flag leaf blade length, 13 for flag leaf sheath length, eight for tillers per hill, eight for panicles per hill, 14 for days to 50% flowering, four for days to maturity, four for panicle length, 14 for panicle weight, nine for primary branches per panicle, 16 for secondary branches per panicle, six for filled grains per panicle, 15 for 1000 seed weight, 13 for grain yield per hill and 15 for harvest index. Significant and desirable better parent heterosis was observed in 12 cross combinations for plant height, 11 for leaf blade length, 5 for flag leaf blade length, nine for flag leaf sheath length, seven for tillers per hill, seven for panicles per hill, 25 for days to 50% flowering, one for days to 100% flowering, seven for days to maturity, three for panicle length, nine for panicle weight, five for primary branches per panicle, 12 for secondary branches per panicle, four for filled grains per panicle, nine for 1000 seed weight, seven for grain yield per hill and nine for harvest index. None of the crosses were identified as good heterotic over standard check for grain yield per hill but many good and desirable heterotic crosses were identified over standard check for most of the yield related characters. Twenty cross combinations were identified as heterotic over standard check due to desirable and significant standard heterosis for most of the yield related traits.

**Keywords**: Heterosis, rice, *Oryza sativa*, boro

## INTRODUCTION

Currently, heterosis is a major factor for increased crop production in maize, rice, sorghum, pearl millet, cotton, sunflower, tomato, eggplants, chilies, onion and sugar beet (Virmani, 1996, 1997 and Hallauer, 1999). It has become the basis of multi-billion

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dollar agri-business in the world (Philips, 1999). Commercial hybrid rice cultivars have been successfully released in China, India, Vietnam and the Philippines, giving estimated yield increases of 15-20%. Thus heterosis has not only helped to achieve food security, but it also contributes to environmental protection. Presently rice production of the country is very close to its requirement, but due to continuous increasing population growth rates there is an enormous need to increase rice production. Rice production must be increased either by expending the land under cultivation or by increasing yield per hectare. In densely populated country like Bangladesh the probability of increasing cultivable land is nearly impossible. The promising alternative, therefore, is to increase productivity. Development of hybrid heterosis can help to release sizeable area under a given crop for other high value crops. Considering, the above facts the experiment was undertaken with the following objectives (i) to study heterosis for some desirable yield contributing characters, and (ii) to select the desirable heterotic cross combinations

## MATERIALS AND METHODS

The experiment was carried out at the Genetics and Plant Breeding Research Farm of Banghabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, during January 2008 to June 2008 with a view to study the heterosis of different lines of rice. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. A total of 27 $F_1$ hybrids were used in this study. These hybrids were originated from crosses between nine A lines viz. Luhagura, Manikmudha, Kalamanik, Kuchi Aus, Gan46, Inda, IR 62829, ACC 2206 Boro 6/2A with 3 R lines viz. China1, China2, BAU522. For heterosis evaluation one check variety BRRI Dhan29 was used. Standard agronomic practices were followed to raise a good crop. Ten randomly selected plants were used from each plot for data collection. Observations were recorded on plant height (cm), leaf blade length (cm), flag leaf blade length (cm), flag leaf sheath length (cm), tillers per hill, panicles per hill, days to 50% flowering, days to 100% flowering, days to maturity, panicle length (cm), panicle weight (g), primary branches per panicle, secondary branches per panicle, filled grains per panicle, 1000 seed weight (g), grain yield per hill (g) and harvest index. Heterosis was recorded (Fehr, 1987) as mid parent heterosis (mp), better parent heterosis (bp) and standard heterosis (CV). The t-test was employed by critical different test (CD) whether $F_1$ hybrids mean were statistically different from mid parent and better parent values.

## RESULTS AND DISCUSSION

Mid parent heterosis of most of the crosses were significant for most of the characters studied either in positive or in negative direction. Significant and desirable mid parent heterosis was observed in cross combination IR62829A × China1R for grain yield per hill, harvest index, 1000 seed weight, filled grains per panicle, secondary branches per panicle, tillers per hill and leaf length (Table 1a). Hybrid Kuchi AusA × China1R showed desirable and significant heterosis for grain yield with most of the yield related characters such as harvest index, 1000 seed weight, branching habit of panicle and early flowering over mid parent (Table 1b). Suresh *et al*. (1999) reported similar results for days to 50% flowering. Cross combination KalamanikA × China1R showed significant and desirable mid parent heterosis for flag leaf sheath length, tillering ability, early flowering, branching habit of panicle and 1000 seed weight. Cross combination ACC 2206 Boro 6/2A × China1R played significant role for achieving more heterosis over mid parent for shorter plant stature, tillering ability, early flowering, growth and branching habit, 1000 seed weight and harvest index (Table 1a and 1b). ACC 2220 Boro 70/2A×China1R was found to be good heterotic over mid parental value due to significant and desirable heterosis for grain yield, 1000 seed weight, harvest index, panicle weight, growth duration, panicles per hill and leaf blade length (Table 1a and 1b).

Hybrid LuhaguraA × China1R played significant role for achieving more heterosis over mid parent for grain yield and most of its related characters, i.e. 1000 seed weight, harvest index, panicle weight, panicles per hill and for leaf characters (Table 1b). Annadurai and Nadarajan (2001) found similar results for 1000 seed weight. Cross combination IndaA×China1R showed significant and desirable mid parent heterosis for leaf characters, growth habit, panicle traits, branching habit and harvest index (Table 1b). Hybrid Gan46A×China1R was found heterotic over mid parent for grain yield per hill with other yield contributing characters i.e. leaf quality, panicle length, branching habit, filled grains per panicle, 1000 seed weight and harvest index (Table 1a and 1b). In cross combination Kuchi AusA×China2R significant mid parent hetrosis was observed for grain yield per hill and most of its yield related traits i.e. harvest index, 1000 seed weight, secondary branches per panicle, growth duration and leaf blade length. Significant mid parent heterosis was observed for leaf blade length, early flowering, secondary branches per panicle, filled grains per panicle, 1000 seed weight, grain yield per hill and harvest index in the cross KalamanikA×China2R (Table 1b).

Cross combination IndaA×China2R showed significant and desirable mid parent heterosis for 1000 seed weight, grain yield per hill, harvest index, secondary branches per panicle, panicle trait, early flowering habit and leaf characters. Hybrid Gan46A×China2R showed desirable and significant heterosis over mid parent for 1000 seed weight, grain yield per hill, harvest index, secondary branches per panicle, shorter growth habit, panicle weight, leaf characters and shorter plant stature (Table 1a and 1b). IR62829A×BAU522R was found heterotic over mid parent for shorter plant stature, flag leaf sheath length, tillering ability, early flowering, branching habit and1000 seed weight. Significant and desirable heterosis was found for shorter plant stature, flag leaf sheath length, tillering ability, panicle weight and branching habit in ACC 2206 Boro 6/2A×BAU522R over mid parent. ManikmudhaA×BAU522R performed better over mid parent for flag leaf sheath length, tillering ability, panicle traits and branching habit. Significant mid parent hetrosis was observed in IndaA×BAU522R for shorter plant stature, flag leaf sheath length, tillering capacity, panicle weight, secondary branches per panicle and panicle weight.

Cross combination Gan46A×BAU522R was found to be heterotic over mid parent for better grain yield as well as 1000 seed weight, harvest index, secondary branches per panicle, tillering capacity, leaf characters and shorter plant stature. Desirable and significant mid parent heterosis was observed for 4 yield related characters in the cross ManikmudhaA×China1R, IR62829A×China2R, ACC 2206 Boro 6/2A×China2R, ACC 2220 Boro 70/2A×China2R, ACC 2220 Boro70/2A×BAU522R and LuhaguraA×BAU522R, 3 characters in cross LuhaguraA×China2R and KalamanikA×BAU522R, 5 characters in ManikmudhaA×China2R & Kuchi AusA×BAU522R. Considering individual trait significant and desirable mid parent heterosis was observed in 8 cross combinations for plant height, 12 for leaf blade length, 9 for flag leaf blade length, 13 for flag leaf sheath length, 8 for tillers per hill, 8 for panicles per hill, 14 for days to 50% flowering, 4 for days to maturity, 4 for panicle length, 14 for panicle weight, 9 for primary branches per panicle, 16 for secondary branches per panicle, 6 for filled grains per panicle, 15 for 1000 seed weight, 13 for grain yield per hill and 15 for harvest index.

**Table 1a. Heterosis over mid parent for 17 different characters of different CMS and restorer lines of rice**

| Characters / Cross Combinations | Plant height | Leaf blade length | Flag leaf blade length | Flag leaf sheath length | Tillers per hill | Panicles per hill | Days to 50% flowering | Days to 100% flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| IR62829A × China1R | 19.55** | 26.46** | 7.44** | -24.13** | 4.32** | -16.67** | 10.50** | 0.74 | 7.12** |
| Kuchi AusA × China1R | 16.30** | -11.75** | -8.27** | 17.54** | -36.22** | -5.41** | -12.57** | -1.07 | 0.00 |
| KalamanikA × China1R | 2.95 | -4.14** | -16.85** | 16.67** | 3.03** | 11.11** | -9.89** | -4.35 | 8.70** |
| ACC 2206 Boro 6/2A × China1R | -18.98** | -11.89** | 0.39 | -16.48** | 34.75** | -2.29** | -14.75** | 1.47 | -7.69** |
| ACC 2220 Boro 70/2A × China1R | 22.99** | -25.72** | 33.99** | -43.27** | -4.93** | 9.63** | -3.33* | -0.73 | -5.45* |
| LuhaguraA × China1R | 23.10** | 18.31** | 34.71** | -28.19** | -7.89** | 16.44** | -1.66 | -2.19 | -4.53 |
| ManikmudhaA × China1R | 7.35** | 11.43** | -26.06** | -15.40** | -17.56** | -4.69** | -5.56** | -2.19 | -7.12** |
| IndaA × China1R | 26.20** | 20.74** | -20.63** | 60.21** | -27.74** | -42.86** | 2.22 | 0.74 | -9.15** |
| Gan46A × China1R | -2.17 | 35.70** | -9.81** | 44.52** | -25.25** | -33.76** | 1.62 | 0.00 | 2.31 |
| IR62829A × China2R | -20.51** | -0.49 | 1.71 | 16.92** | -21.50** | -27.62** | -1.10 | 8.11* | 13.44** |
| Kuchi AusA × China2R | 0.78 | -3.61** | 60.16** | -44.49** | -58.14** | -44.38** | -16.30** | -3.70 | -6.63** |
| KalamanikA × China2R | 5.58* | 1.42 | 25.62** | -30.41** | -34.17** | -29.71** | -14.75** | -1.89 | -1.32 |
| ACC 2206 Boro 6/2A × China2R | 9.53** | -7.48** | 6.35** | -49.70** | -47.22** | -52.64** | -17.39** | 1.15 | -0.98 |
| ACC 2220 Boro 70/2A × China2R | 19.93** | -28.90** | 41.91** | -50.95** | -24.42** | -23.33** | 1.66 | 1.90 | 0.64 |
| LuhaguraA × China2R | 12.00** | 24.42** | -10.36** | -34.81** | -22.47** | -30.23** | 2.20 | 2.66 | 10.54** |
| ManikmudhaA × China2R | 9.72** | 10.99** | -23.42** | 40.19** | -44.17** | -42.48** | 3.87* | 4.94 | 14.75** |
| IndaA × China2R | 13.14** | 26.75** | -25.00** | 32.69** | -54.78** | -64.54** | -14.92** | 1.93 | 12.90** |
| Gan46A × China2R | -13.86** | 63.58** | 16.72** | -28.33** | -54.29** | -55.51** | -18.28** | 1.11 | -8.54** |
| IR62829A × BAU522R | -20.94** | 0.41 | -11.51** | 60.27** | 34.39** | 36.07** | -12.22** | 5.02 | 4.00 |
| Kuchi AusA × BAU522R | -11.94** | -4.64** | -13.67** | 58.36** | 60.68** | 132.14** | 2.20 | -2.22 | 5.81* |
| KalamanikA × BAU522R | 3.21 | -12.60** | -9.09** | -4.35* | -4.92** | -6.87** | 6.08** | 1.13 | 3.68 |
| ACC 2206 Boro 6/2A × BAU522R | -6.86** | -10.22** | -15.91** | 17.25** | 47.86** | 26.61** | -1.10 | 3.45 | -0.66 |
| ACC 2220 Boro70/2A × BAU522R | 4.87* | -37.50** | 7.41** | -46.11** | 18.92** | 10.62** | -1.68 | 4.94 | -0.98 |
| LuhaguraA × BAU522R | 15.74** | 37.42** | -30.85** | 4.10* | 3.94** | -3.23** | 0.00 | 0.38 | 1.95 |
| ManikmudhaA × BAU522R | 6.60** | 2.84* | -32.31** | 87.17** | 13.92** | 32.08** | -3.91* | 4.18 | 15.33** |
| IndaA × BAU522R | -10.68** | -1.16 | -34.66** | 62.79** | 19.30** | 16.44** | -3.91* | 5.02 | 14.75** |
| Gan46A × BAU522R | -24.22** | 18.03** | -17.87** | 60.00** | 35.71** | -5.19** | -5.43** | 1.85 | 8.36** |
| CD 1% | 5.97 | 2.99 | 5.97 | 5.17 | 2.59 | 1.72 | 5.17 | 8.99 | 6.61 |
| CD 5% | 4.46 | 2.23 | 4.46 | 3.86 | 1.93 | 1.29 | 3.87 | 6.70 | 4.94 |

* indicates significant at 5% level of significance, ** indicates significant at 1% level of significance

**Table 1b. Heterosis over mid parent for 17 different characters of different CMS and restorer lines of rice**

| Characters / Cross Combinations | | Panicle length | Panicle weight | Primary branches per panicle | Secondary branches per panicle | Filled grains per panicle | 1000 seed weight | Grain yield per hill | Harvest index |
|---|---|---|---|---|---|---|---|---|---|
| IR62829A × China1R | | -4.69* | -18.28** | 0.00 | 22.14** | 13.80** | 10.40** | 24.24** | 9.09** |
| Kuchi AusA × China1R | | -10.61** | -8.38** | 50.00** | 83.33** | -12.68** | 29.14** | 30.95** | 22.08** |
| KalamanikA × China1R | | 6.85** | -30.97** | 0.00 | 21.79** | -3.46 | 8.26** | -18.89** | -20.99** |
| ACC 2206 Boro 6/2A × China1R | | -8.10** | -22.98** | 20.00** | 40.33** | -1.75 | 81.97** | -0.68 | 22.73** |
| ACC 2220 Boro 70/2A × China1R | | -0.36 | 24.42** | -20.00** | -20.87** | -13.38** | 89.25** | 27.56** | 15.22** |
| LuhaguraA × China1R | | -6.60** | 16.03** | 0.00 | -25.98** | -3.10 | 9.23** | 14.62** | 4.35** |
| ManikmudhaA × China1R | | -5.66** | -18.02** | -20.00** | -32.91** | -7.72** | 10.42** | -0.09 | 0.00 |
| IndaA × China1R | | -21.22** | 14.00* | -20.00** | 32.30** | -19.54** | -18.36** | -13.69** | 17.07** |
| Gan46A × China1R | | 13.35** | -5.04** | -33.33** | 18.11** | 40.15** | 19.28** | 12.42** | 18.31** |
| IR62829A × China2R | | -3.95* | -43.72** | 33.33** | 52.82** | -5.65* | -14.38** | -14.34** | -19.51** |
| Kuchi AusA × China2R | | -2.96 | -0.13 | -33.33** | 6.98** | -11.11** | 15.36** | 26.55** | 15.49** |
| KalamanikA × China2R | | -13.13** | -35.46** | 0.00 | 13.64** | 18.91** | 16.59** | 62.20** | 17.33** |
| ACC 2206 Boro 6/2A × China2R | | -0.92 | 7.90** | 42.86** | -32.42** | -17.87** | -5.15** | -29.04** | -26.83** |
| ACC 2220 Boro 70/2A × China2R | | -7.69** | -8.48** | -42.86** | -47.89** | 7.43** | -2.20 | 15.02** | 4.65** |
| LuhaguraA × China2R | | -6.73** | -22.81** | 33.33** | -15.42** | -0.56** | -1.94 | 0.00 | 11.63** |
| ManikmudhaA × China2R | | 1.93 | 10.96** | -42.86** | 2.40** | 13.25** | -10.21** | 6.29** | -7.32** |
| IndaA × China2R | | 5.82** | 44.43** | -14.29** | 51.52** | 1.82 | 48.75** | 50.59** | 21.05** |
| Gan46A × China2R | | -3.31 | 11.75** | -50.00** | 37.21** | 0.55 | 80.68** | 83.70** | 41.54** |
| IR62829A × BAU522R | | 1.24 | -2.23** | 60.00** | 35.17** | -17.56** | 35.08** | -7.29** | -10.42** |
| Kuchi AusA × BAU522R | | -8.07** | 55.76** | -20.00** | -6.00** | -18.72** | -7.75** | -6.38** | -3.53** |
| KalamanikA × BAU522R | | 3.22 | 22.29** | -14.29** | -8.48** | 6.89** | 3.19* | 22.11** | -1.12** |
| ACC 2206 Boro 6/2A × BAU522R | | -9.25** | 10.25** | 33.33** | -10.29** | -25.84** | -3.43* | -45.23** | -37.50** |
| ACC 2220 Boro70/2A × BAU522R | | 0.45 | 38.12** | -33.33** | -11.43** | -2.06 | -12.79** | -9.00** | -10.00** |
| LuhaguraA × BAU522R | | 0.66 | 74.12** | 20.00** | -16.60** | -9.65** | -9.94** | -17.33** | -4.00** |
| ManikmudhaA × BAU522R | | 21.49** | 4.80** | 33.33** | 6.09** | 1.37 | -3.84* | -17.86** | -20.83** |
| IndaA × BAU522R | | -2.63 | 48.13** | 0.00 | 108.83** | -8.64** | -16.45** | 12.51** | 2.22** |
| Gan46A × BAU522R | | 0.06 | -17.66** | -42.86** | 49.31** | -10.06** | 51.03** | 33.29** | 16.46** |
| CD | 1% | 5.17 | 0.59 | 0.59 | 5.17 | 5.97 | 4.16 | 5.92 | 0.08 |
| | 5% | 3.87 | 0.45 | 0.45 | 3.87 | 4.46 | 3.12 | 4.42 | 0.06 |

* indicates significant at 5% level of significance, ** indicates significant at 1% level of significance.

Better parent heterosis of most of the crosses were significant for most of the characters studied either in positive or in negative direction. Significant and desirable better parent heterosis was observed in the cross combination IR62829A×China1R for grain yield per hill and other yield contributing characters like harvest index, filled grains per panicle, secondary branches per panicle and leaf characters (Table 2a). Hybrid Kuchi AusA×China1R showed significant and desirable better parent heterosis for grain yield per hill with other yield related characters such as harvest index, 1000 seed weight, branching habit of panicle and early flowering (Table 2a and 2b). ACC 2206 Boro 6/2A×China2R showed significant and desirable better parent heterosis for shorter plant stature, tillering ability, early flowering, and shorter growth habit, secondary branches per panicle, 1000 seed weight, and harvest index (Table-2a and 2b). Cross combination ACC 2220 Boro 70/2A×China1R was found to be good heterotic over better parent for grain yield per hill, 1000 seed weight, harvest index, panicle weight, shorter growth habit and leaf blade length (Table-2a and 2b). Significant and desirable better parent heterosis was observed in cross combination IndaA×China1R for harvest index, secondary branches per panicle, panicle weight, shorter growth habit, early flowering and leaf characters.

Gan46A×China1R played significant role for achieving more heterosis over better parent for shorter plant stature, leaf characters, early flowering, panicle length, secondary branches per panicle, filled grains per panicle and 1000 seed weight (Table 2a and 2b). Kuchi AusA×China2R played significant role for achieving more heterotic over better parent for grain yield per hill as well as harvest index, shorter plant stature, secondary branches per panicle, shorter growth duration and for flag leaf blade length (Table 2a and 2b). Better parent heterosis of cross combination IndaA×China2R showed significant and desirable better parent heterosis for 1000 seed weight, grain yield per hill, harvest index, secondary branches per panicle, panicle traits, early flowering and leaf blade length (Table 2a and 2b). Hybrid Gan46A×China2R showed desirable and significant better parent heterosis for 1000 seed weight, grain yield per hill, harvest index, secondary branches per panicle, early growth habit, leaf blade length and shorter plant stature (Table 2a and 2b). IR62829A×BAU522R was found to be good heterotic over better parental value due to significant and desirable heterosis for shorter plant stature, flag leaf sheath length, tillering ability, early flowering, branching habit and 1000 seed weight (Table 2a and 2b).

In cross combination Kuchi AusA × BAU522R showed significant and desirable better parent heterosis for shorter plant stature, flag leaf sheath length, tillering ability, early flowering, panicle weight and secondary branches per panicle. Significant better parent hetrosis was observed for ACC 2206 Boro70/2A×BAU522R shorter plant stature, tillering ability and early flowering. ManikmudhaA×BAU522R showed desirable and significant better parent heterosis for flag leaf sheath length, panicles per hill, early flowering, panicle length and branching habit. Hybrid IndaA×BAU522R played significant role for achieving more heterotic over better parent for shorter plant stature, flag leaf sheath length, tillering ability, early flowering, panicle weight and secondary branches per panicle (Table 2a and 2b). Good heterotic performance over better parental value due to significant and desirable heterosis for shorter plant stature, leaf characters, tillering ability, early flowering, secondary branches per panicle and1000 seed weight was observed in cross combination Gan46A×BAU522R. Desirable and significant better parent heterosis was observed for 3 yield related characters in the cross KalamanikA × China1R, ManikmudhaA × China1R, IR62829A × China2R, ACC 2220 Boro 70/2A × BAU522R and LuhaguraA × BAU522R, 5 characters in cross LuhaguraA × China1R, KalamanikA × China2R, ManikmudhaA × China2R, ACC 2206 Boro70/2A×

**Table 2a. Heterosis over better parent for 17 different characters of different CMS and restorer lines of rice**

| Characters<br>Cross Combinations | | Plant height | Leaf blade length | Flag leaf blade length | Flag leaf sheath length | Tillers per hill | Panicles per hill | Days to 50% flowering | Days to 100% flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| IR62829A × China1R | | 7.66** | 21.27** | 6.99** | -36.46** | -14.71** | -27.71** | -0.99 | -2.86 | 0.00 |
| Kuchi AusA × China1R | | 0.00 | -18.00** | -15.88** | 9.38** | -46.70** | -15.66** | -20.79** | -1.42 | -1.13 |
| KalamanikA × China1R | | -5.69* | -10.84** | -30.75** | -5.21* | 0.00 | 2.41** | -18.81** | -5.71 | 1.16 |
| ACC 2206 Boro 6/2A × China1R | | -31.04** | -22.70** | -6.67* | -25.49** | 11.76** | -22.89** | -22.77** | -1.43 | -13.29** |
| ACC 2220 Boro 70/2A × China1R | | 15.93** | -33.01** | 29.08** | -47.32** | -20.59** | -10.84** | -13.86** | -2.86 | -9.83** |
| LuhaguraA × China1R | | 20.68** | 17.13** | 3.40 | -40.83** | -17.65** | 2.41** | -11.88** | -4.29 | -8.67** |
| ManikmudhaA × China1R | | -5.84* | 8.94** | -41.63** | -32.50** | -36.47** | -26.51** | -15.84** | -4.29 | -13.29** |
| IndaA × China1R | | 13.33** | 10.88** | -39.78** | 27.50** | -34.12** | -43.53** | -8.91** | -2.86 | -13.87** |
| Gan46A × China1R | | -13.74** | 24.39** | -22.53** | 16.67** | -32.94** | -37.35** | -6.93** | -0.70 | 2.31 |
| IR62829A × China2R | | -22.81** | -5.22** | -0.67 | -6.79** | -47.50** | -48.72** | -11.76** | 7.69 | 11.61** |
| Kuchi AusA × China2R | | -6.97** | -11.03** | 50.74** | -51.19** | -62.50** | -59.83** | -24.51** | -7.80* | -12.43** |
| KalamanikA × China2R | | 4.45 | -6.29** | 7.04** | -46.06** | -50.63** | -48.03** | -23.53** | -4.41 | -3.23 |
| ACC 2206 Boro 6/2A × China2R | | 0.00 | -19.33** | 1.52 | -52.45** | -64.38** | -68.55** | -25.49** | 0.00 | -1.94 |
| ACC 2220 Boro 70/2A × China2R | | 17.58** | -36.27** | 40.52** | -51.61** | -48.75** | -48.03** | -9.80** | 0.00 | 0.00 |
| LuhaguraA × China2R | | 5.57* | 22.31** | -29.81** | -48.81** | -45.00** | -50.09** | -8.82** | 0.75 | 9.49** |
| ManikmudhaA × China2R | | 3.52 | 9.28** | -38.27** | 6.88** | -64.06** | -62.39** | -7.84** | 2.99 | 12.90** |
| IndaA × China2R | | 9.52** | 15.65** | -41.97** | 0.92 | -67.50** | -71.97** | -24.51** | 1.54 | 12.90** |
| Gan46A × China2R | | -18.26** | 50.93** | 2.68 | -44.77** | -67.50** | -66.50** | -25.49** | -3.52 | -13.29** |
| IR62829A × BAU522R | | -21.96** | -8.21** | -20.11** | 48.15** | 17.24** | 36.07** | -21.00** | 4.62 | 4.00 |
| Kuchi AusA × BAU522R | | -15.37** | -15.39** | -15.49** | 31.87** | 26.33** | 125.00** | -7.00** | -6.38 | -2.26 |
| KalamanikA × BAU522R | | 0.00 | -22.38** | -16.67** | -8.33** | -9.38** | -12.86** | -4.00 | -1.47 | 3.33 |
| ACC 2206 Boro 6/2A × BAU522R | | -11.52** | -24.54** | -18.87** | -15.03** | 31.03** | 13.11** | -10.00** | 2.27 | -1.32 |
| ACC 2220 Boro70/2A × BAU522R | | -1.33 | -46.08** | 0.00 | -59.82** | 6.21** | 2.46** | -12.00** | 2.99 | -3.18 |
| LuhaguraA × BAU522R | | 4.89 | 29.48** | -42.26** | -1.93 | 0.00 | -4.76** | -10.00** | -1.49 | -0.63 |
| ManikmudhaA × BAU522R | | 4.81 | 0.00 | -41.63** | 83.57** | -6.90** | 14.75** | -14.00** | 2.24 | 15.33** |
| IndaA × BAU522R | | -11.56** | -13.27** | -46.17** | 60.21** | 17.24** | 0.00 | -14.00** | 4.62 | 12.90** |
| Gan46A × BAU522R | | -25.04** | 13.51** | -22.03** | 54.58** | 31.03** | -13.51** | -13.00** | -2.82 | 1.16 |
| CD | 1% | 6.90 | 3.44 | 6.90 | 5.97 | 2.99 | 1.99 | 5.97 | 10.34 | 7.63 |
| | 5% | 5.15 | 2.57 | 5.15 | 4.46 | 2.23 | 1.49 | 4.46 | 7.73 | 5.70 |

* indicates significant at 5% level of significance, ** indicates significant at 1% level of significance

**Table 2b. Heterosis over better parent for 17 different characters of different CMS and restorer lines of rice**

| Characters / Cross Combinations | Panicle length | Panicle weight | Primary branches per panicle | Secondary branches per panicle | Filled grains per panicle | 1000 seed weight | Grain yield per hill | Harvest index |
|---|---|---|---|---|---|---|---|---|
| IR62829A × China1R | -7.77** | -37.12** | 0.00 | 10.70** | 9.85** | 0.00 | 9.13** | 6.67** |
| Kuchi AusA × China1R | -13.25** | -15.24** | 50.00** | 73.26** | -22.86** | 21.18** | 6.59* | 9.30** |
| KalamanikA × China1R | 2.77 | -42.28** | -25.00** | -0.26 | -6.86* | 5.36** | -30.26** | -25.58** |
| ACC 2206 Boro 6/2A × China1R | -11.14** | -37.00** | 0.00 | 27.00** | -2.51 | 65.64** | -7.01** | 20.00** |
| ACC 2220 Boro 70/2A × China1R | -3.31 | 15.68** | -33.33** | -38.93** | -21.41** | 70.04** | 24.20** | 8.16** |
| LuhaguraA × China1R | -7.12** | 8.15** | 0.00 | -43.97** | -9.39** | -3.04 | -4.48 | -2.04** |
| ManikmudhaA × China1R | -11.85** | -21.55** | -33.33** | -45.00** | -14.51** | 2.77 | -6.06* | -2.22** |
| IndaA × China1R | -22.72** | 7.55** | -33.33** | 23.05** | -23.73** | -24.02** | -27.57** | 11.63** |
| Gan46A × China1R | 10.93** | -22.02** | -50.00** | 13.21** | 29.02** | 16.09** | -13.54** | -2.33** |
| IR62829A × China2R | -8.37** | -54.07** | 0.00 | 49.50** | -11.68** | -14.49** | -19.95** | -26.67** |
| Kuchi AusA × China2R | -4.45 | -0.27 | -50.00** | 4.55* | -23.61** | -1.18 | 23.70** | 10.81** |
| KalamanikA × China2R | -15.25** | -42.28** | 0.00 | -0.52 | 18.41** | 3.18 | 55.18** | 15.79** |
| ACC 2206 Boro 6/2A × China2R | -2.80 | -5.80** | 25.00** | -34.00** | -21.04** | -5.54** | -37.78** | -33.33** |
| ACC 2220 Boro 70/2A × China2R | -11.69** | -8.85** | -50.00** | -57.27** | -5.27* | -3.21 | -6.67* | -8.16** |
| LuhaguraA × China2R | -8.59** | -23.32** | 0.00 | -32.14** | -9.73** | -4.24* | -28.08** | -2.04** |
| ManikmudhaA × China2R | -6.05** | 7.24** | -50.00** | -10.26** | 8.16** | -12.70** | -7.17** | -15.56** |
| IndaA × China2R | 5.33* | 26.81** | -25.00** | 31.12** | -0.42 | 44.63** | 48.27** | 17.95** |
| Gan46A × China2R | -6.72** | -2.02** | -50.00** | 32.17** | -4.60 | 59.90** | 67.02** | 24.32** |
| IR62829A × BAU522R | 1.15 | -36.78** | 33.33** | 22.74** | -20.17** | 26.67* | -22.04** | -15.69* |
| Kuchi AusA × BAU522R | -13.65** | 13.90** | -33.33** | -10.99** | -23.61** | -25.14** | -26.71** | -19.61** |
| KalamanikA × BAU522R | -3.87 | -16.49** | -25.00** | -24.93** | -3.25 | -13.71** | 0.65 | -13.73** |
| ACC 2206 Boro 6/2A × BAU522R | -15.06** | -25.80** | 33.33** | -18.67** | -30.09** | -9.90** | -51.09** | -41.18** |
| ACC 2220 Boro70/2A × BAU522R | 0.08 | 1.35** | -33.33** | -31.54** | -5.27* | -17.52* | -11.22** | -11.76** |
| LuhaguraA × BAU522R | -2.14 | 27.99** | 0.00 | -36.79** | -9.73** | -13.71** | -28.08** | -5.88** |
| ManikmudhaA × BAU522R | 17.26** | -21.55** | 33.33** | -12.89** | -11.62** | -12.27** | -26.34** | -25.49* |
| IndaA × BAU522R | -7.59** | 19.50** | 0.00 | 93.85** | -18.63** | -23.77** | -9.36** | -9.80** |
| Gan46A × BAU522R | -1.17 | -44.44** | -50.00** | 43.40** | -22.05** | 26.29** | -1.04 | -9.80** |
| CD 1% | 5.97 | 0.69 | 0.69 | 5.97 | 6.90 | 4.81 | 6.83 | 0.09 |
| CD 5% | 4.46 | 0.52 | 0.52 | 4.46 | 5.15 | 3.60 | 5.11 | 0.07 |

* indicates significant at 5% level of significance, ** indicates significant at 1% level of significance

BAU522R and ManikmudhaA × BAU522R and 2 characters in cross ACC 2206 Boro 6/2A×China2R, ACC 2220 Boro 70/2A×China2R and LuhaguraA×China2R (Table 2a and 2b). Considering better parent heterosis significant and desirable values was observed in 12 cross combinations for plant height, 11 for leaf blade length, 5 for flag leaf blade length, 9 for flag leaf sheath length, 7 for tillers per hill, 7 for panicles per hill, 25 for days to 50% flowering, 1 for days to 100% flowering, 7 for days to maturity, 3 for panicle length, 9 for panicle weight, 5 for primary branches per panicle, 12 for secondary branches per panicle, 4 for filled grains per panicle, 9 for 1000 seed weight, 7 for grain yield per hill and 9 for harvest index.

Most of the crosses showed significant and standard heterosis for most of the characters either in positive or in negative direction. None of the crosses were identified as good heterotic over standard check for grain yield per hill but many good and desirable heterotic crosses were identified over standard check for most of the yield related characters. Cross combination Kuchi AusA×China1R played significant role for achieving more heterosis over standard check for leaf characters, panicles per hill, early flowering, panicle weight and secondary branches per panicle (Table 3a). Desirable and significant standard heterosis was found for secondary branches per panicle, panicle length, days to 50% flowering, tillering ability, leaf characters and plant height in the cross combination KalamanikA×China1R. Hybrid ACC 2206 Boro 6/2A×China1R was found heterotic over standard check for shorter plant stature, leaf characters, tillering and panicle ability, early flowering, panicle weight, secondary branches per panicle, 1000 seed weight and harvest index. ACC 2220 Boro 70/2A×China1R showed significant and desirable heterosis for leaf characters, panicles per hill, early flowering, panicle weight, 1000 seed weight and harvest index (Table 3a and 3b). Significant standard heterosis was observed for leaf characters, panicles per hill, early flowering and panicle weight in cross combination LuhaguraA×China1R. Cross combination Gan46A×China1R showed significant and desirable heterosis for shorter plant stature, leaf characters, early flowering and panicle traits. Hybrid IR62829A×China2R performed better over standard check for shorter plant stature, leaf characters, tillering ability, early flowering and branching habit of panicle (Table 3a). Cross combination Kuchi AusA×China2R played significant role over standard check for leaf characters, early flowering and panicle traits (Table 3a and 3b). Hybrid KalamanikA×China2R might be selected for improvement of leaf characters, tillering ability, early flowering and for branching habit of panicle (Table-3a). Standard heterosis for cross combination ACC 2206 Boro 6/2A×China2R showed significant and desirable standard heterosis for leaf characters, early flowering, panicle traits and branching habit. Hybrid ACC 2220 Boro 70/2A×China2R played significant role for achieving more heterosis over standard check for leaf characters, tillering ability, early flowering and panicle weight. Significant standard heterosis was observed for leaf characters, tillering ability, early flowering and branching habit in cross combination LuhaguraA×China2R. IndaA×China2R showed significant and desirable standard heterosis for leaf characters, early flowering, panicle traits, secondary branches per panicle and 1000 seed weight (Table 3a and 3b). Hybrid Gan46A×China2R showed desirable and significant standard heterosis for 1000 seed weight, branching habit for panicle, panicle weight, early flowering, leaf characters and shorter plant stature. Cross combination IR62829A×BAU522R was found to be heterotic over standard check for leaf characters as well as shorter plant stature, tillering ability, early flowering, panicle weight, branching habit for panicle and 1000 seed weight (Table 3a and 3b). Hybrid Kuchi AusA×BAU522R showed significant and desirable standard heterosis for shorter plant stature, leaf characters, tillering ability, early flowering and panicle weight (Table 3a and 3b).

**Table 3a. Standard heterosis for 17 different characters of different CMS and restorer lines of rice**

| Characters<br>Cross Combinations | Plant height | Leaf blade length | Flag leaf blade length | Flag leaf sheath length | Tillers per hill | Panicles per hill | Days to 50% flowering | Days to 100% flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| IR62829A × China1R | 6.31* | 96.97** | -13.80** | 35.56** | -5.84** | -4** | -3.85 | 1.49 | 10.19** |
| Kuchi AusA × China1R | 9.91** | 42.42** | -19.44** | 133.33** | -12.34** | 12** | -23.08** | 3.73 | 11.46** |
| KalamanikA × China1R | -10.36** | 54.55** | -16.90** | 102.22** | 10.39** | 36** | -21.15** | -1.49 | 11.46** |
| ACC 2206 Boro 6/2A × China1R | -22.34** | 52.73** | -13.24** | 102.67** | 23.38** | 2.4** | -25.00** | 2.99 | -4.46 |
| ACC 2220 Boro 70/2A × China1R | 3.60 | 24.24** | 11.27** | 31.11** | -12.34** | 18.4** | -16.35** | 1.49 | -0.64 |
| LuhaguraA × China1R | -0.63 | 78.18** | 54.37** | 26.22** | -9.09** | 36** | -14.42** | 0.00 | 0.64 |
| ManikmudhaA × China1R | -1.26 | 62.42** | -19.44** | 44.00** | -29.87** | -2.4** | -18.27** | 0.00 | -4.46 |
| IndaA × China1R | 12.61** | 97.58** | -7.04* | 172.00** | -27.27** | -23.2** | -11.54** | 1.49 | -5.10 |
| Gan46A × China1R | -10.63** | 85.45** | -13.80** | 148.89** | -25.97** | -16.8** | -9.62** | 5.22 | 12.74** |
| IR62829A × China2R | -23.78** | 53.94** | -16.06** | 125.78** | 9.09** | 20** | -13.46** | 4.48 | 10.19** |
| Kuchi AusA × China2R | 2.25 | 54.55** | 44.37** | 18.22** | -22.08** | -6** | -25.96** | -2.99 | -1.27 |
| KalamanikA × China2R | -0.72 | 62.42** | 28.45** | 30.67** | 2.60* | 21.6** | -25.00** | -2.99 | -4.46 |
| ACC 2206 Boro 6/2A × China2R | 12.61** | 59.39** | -5.63* | 29.33** | -25.97** | -26.4** | -26.92** | -1.49 | -3.18 |
| ACC 2220 Boro 70/2A × China2R | 9.37** | 18.18** | 21.13** | 20.44** | 6.49** | 21.6** | -11.54** | 0.00 | 0.00 |
| LuhaguraA × China2R | -1.80 | 86.06** | 4.79 | 24.00** | 14.29** | 16.8** | -10.58** | 0.75 | 10.19** |
| ManikmudhaA × China2R | 8.56** | 60.61** | -14.79** | 158.89** | -25.32** | -12** | -9.62** | 2.99 | 11.46** |
| IndaA × China2R | 8.83** | 106.06** | -10.42** | 144.44** | -32.47** | -34.4** | -25.96** | -1.49 | 11.46** |
| Gan46A × China2R | -15.32** | 121.82** | 14.25** | 33.78** | -32.47** | -21.6** | -26.92** | 2.24 | -4.46 |
| IR62829A × BAU522R | -20.90** | 49.09** | -20.11** | 113.33** | 10.39** | 32.8** | -24.04** | 1.49 | -0.64 |
| Kuchi AusA × BAU522R | -6.98** | 46.97** | -15.49** | 142.22** | 107.79** | 134** | -10.58** | -1.49 | 10.19** |
| KalamanikA × BAU522R | 1.35 | 34.55** | 0.00 | 22.22** | -5.84** | -2.4** | -7.69** | 0.00 | -1.27 |
| ACC 2206 Boro 6/2A × BAU522R | -0.36 | 49.09** | -18.87** | 131.11** | 23.38** | 10.4** | -13.46** | 0.75 | -4.46 |
| ACC 2220 Boro70/2A × BAU522R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | -15.38** | 2.99 | -3.18 |
| LuhaguraA × BAU522R | 6.31* | 96.97** | -13.80** | 35.56** | -5.84** | -4** | -13.46** | -1.49 | 0.00 |
| ManikmudhaA × BAU522R | 9.91** | 42.42** | -19.44** | 133.33** | -12.34** | 12** | -17.31** | 2.24 | 10.19** |
| IndaA × BAU522R | -10.36** | 54.55** | -16.90** | 102.22** | 10.39** | 36** | -17.31** | 1.49 | 11.46** |
| Gan46A × BAU522R | -22.34** | 52.73** | -13.24** | 102.67** | 23.38** | 2.4** | -16.35** | 2.99 | 11.46** |
| CD 1% | 6.90 | 3.44 | 6.90 | 5.97 | 2.99 | 1.99 | 5.97 | 10.34 | 7.63 |
| CD 5% | 5.15 | 2.57 | 5.15 | 4.46 | 2.23 | 1.49 | 4.46 | 7.73 | 5.70 |

* indicates significant at 5% level of significance, ** indicates significant at 1% level of significance

**Table 3b. Standard heterosis for 17 different characters of different CMS and restorer lines of rice**

| Characters / Cross Combinations | | Panicle length | Panicle weight | Primary branches per panicle | Secondary branches per panicle | Filled grains per panicle | 1000 seed weight | Grain yield per hill | Harvest index |
|---|---|---|---|---|---|---|---|---|---|
| IR62829A × China1R | | -4.84* | 23.26** | -33.33** | 10.70** | -11.34** | -2.83 | -31.91** | -5.88** |
| Kuchi AusA × China1R | | -4.88* | 5.32** | 0.00 | 58.19** | -24.45** | -4.44* | -33.50** | -7.84** |
| KalamanikA × China1R | | 14.81** | -9.30** | 0.00 | 27.09** | -30.04** | -16.91** | -56.49** | -37.25** |
| ACC 2206 Boro 6/2A × China1R | | -1.83 | 4.65** | 0.00 | 27.42** | -25.63** | 59.20** | -41.98** | 5.88** |
| ACC 2220 Boro 70/2A × China1R | | -0.24 | 42.19** | -33.33** | -8.70** | -27.54** | 68.25** | -18.20** | 3.92** |
| LuhaguraA × China1R | | -4.17 | 32.23** | -33.33** | -11.37** | -21.80** | -1.40 | -10.62** | -5.88** |
| ManikmudhaA × China1R | | -9.05** | -9.30** | -33.33** | -30.10** | -35.79** | -5.92** | -41.39** | -13.73** |
| IndaA × China1R | | -17.11** | 13.62** | -33.33** | 0.00 | -42.71** | -30.44** | -54.81** | -5.88** |
| Gan46A × China1R | | 14.45** | 28.24** | -33.33** | 0.33 | -3.09 | -8.46** | -46.06** | -17.65** |
| IR62829A × China2R | | -2.62 | -9.97** | 33.33** | 49.50** | -28.72** | -16.91** | -62.21** | -35.29** |
| Kuchi AusA × China2R | | 4.76* | 23.92** | -33.33** | 0.00 | -25.18** | -4.23* | -49.25** | -19.61** |
| KalamanikA × China2R | | -5.32* | -9.30** | 33.33** | 26.76** | -16.64** | 0.00 | -30.30** | -13.73** |
| ACC 2206 Boro 6/2A × China2R | | 7.38** | 56.48** | 66.67** | -33.78** | -39.76** | -8.46** | -66.13** | -41.18** |
| ACC 2220 Boro 70/2A × China2R | | -6.15** | 12.96** | -33.33** | -36.12** | -12.67** | -4.23* | -38.53** | -11.76** |
| LuhaguraA × China2R | | -2.86 | -4.98** | 33.33** | 7.36** | -22.09** | -2.62 | -32.70** | -5.88** |
| ManikmudhaA × China2R | | -0.16 | 32.89** | -33.33** | 14.05** | -23.86** | -15.39** | -49.00** | -25.49** |
| IndaA × China2R | | 12.98** | 57.14** | 0.00 | 25.42** | -29.90** | 40.17** | -37.24** | -9.80** |
| Gan46A × China2R | | -0.87 | 61.13** | -33.33** | 26.42** | -32.84** | 54.97** | -31.48** | -9.80** |
| IR62829A × BAU522R | | -2.38 | 23.92** | 33.33** | 22.74** | -31.22** | 40.59** | -46.02** | -15.69** |
| Kuchi AusA × BAU522R | | -5.32* | 41.53** | -33.33** | -18.73** | -25.18** | -16.91** | -49.25** | -19.61** |
| KalamanikA × BAU522R | | 7.38** | 31.23** | 0.00 | -4.35 | -16.64** | -4.23* | -30.30** | -13.73** |
| ACC 2206 Boro 6/2A × BAU522R | | -6.15** | 23.26** | 33.33** | -18.39** | -39.76** | 0.00 | -66.13** | -41.18** |
| ACC 2220 Boro70/2A × BAU522R | | -2.86 | 24.58** | -33.33** | 2.34 | -12.67** | -8.46** | -38.53** | -11.76** |
| LuhaguraA × BAU522R | | -0.16 | 56.48** | 0.00 | 0.00 | -22.09** | -4.23* | -32.70** | -5.88** |
| ManikmudhaA × BAU522R | | 12.98** | -9.30** | 33.33** | 10.70** | -23.86** | -2.62 | -49.00** | -25.49** |
| IndaA × BAU522R | | -0.87 | 11.96** | 0.00 | 58.19** | -29.90** | -15.39** | -37.24** | -9.80** |
| Gan46A × BAU522R | | -2.38 | -8.64** | -33.33** | 27.09** | -32.84** | 40.17** | -31.48** | -9.80** |
| CD | 1% | 5.97 | 0.69 | 0.69 | 5.97 | 6.90 | 4.81 | 6.83 | 0.09 |
| | 5% | 4.46 | 0.52 | 0.52 | 4.46 | 5.15 | 3.60 | 5.11 | 0.07 |

* indicates significant at 5% level of significance, ** indicates significant at 1% level of significance

ACC 2206 Boro 6/2A×BAU522R played significant role for achieving more heterosis over standard check for leaf characters, tillering ability, early flowering, panicle weight and branching habit of panicle. ManikmudhaA×BAU522R showed significant and desirable standard heterosis for leaf characters, panicles per hill, early flowering, panicle length and branching habit of panicle. Significant and desirable standard heterosis was observed for shorter plant stature, leaf characters, tillering ability, early flowering, panicle weight and branching habit in IndaA×BAU522R (Table 3a and 3b). Cross combination Gan46A×BAU522R played significant role over standard check for shorter plant stature, leaf characters, tillering ability, early flowering, branching habit and 1000 seed weight (Table 3a and 3b). Desirable and significant standard heterosis was observed for four yield related characters in the cross IR62829A×China1R and LuhaguraA×BAU522R, three characters in cross ManikmudhaA×China1R, five characters in IndaA×China1R, ManikmudhaA×China2R & KalamanikA×BAU522R and two characters in ACC 2220 Boro70/2A×BAU522R. Considering standard heterosis significant and desirable values was observed in 9 cross combinations fot plant height, 26 for leaf blade length, 6 for flag leaf blade length, 26 for flag leaf sheath length, 11 for tillers per hill, 15 for panicles per hill, 24 for days to 50% flowering, seven for panicle length, 20 for panicle weight, seven for primary branches per panicle, 14 for secondary branches per panicle, six for 1000 seed weight, and two for harvest index.

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