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# Magnitude of Heterosis and Combining Ability in Relation to Yield and Some Morphological Traits for Improvement of Upland Rice (*Oryza Sativa* L.)

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**The present study was conducted to estimate the extent of heterosis and combining ability for various morphological traits using line x tester analysis during *Kharif* 2009 and *Kharif* 2010 in Randomized Block Design with three replications under rainfed condition. Five lines and three testers were used in crossing programme to obtain the fifteen crosses. Analysis of variance for all quantitative characters showed significant differences for all twelve characters under study except harvest index. Out of fifteen crosses, seven crosses were identified for high grain yield per plant. The maximum heterobeltiosis for grain yield per plant recorded for IR74371-54-1-1/ IR67017-124-2-4. The maximum standard heterosis and *sca* effect for grain yield was exhibited by IR 81413-B-B-75-4/ IR 81429-B-31. Among the lines, IR81413-B-B-75-3 was identified as good general combiner for grain yield per plant with five other characters. Among the testers, IR74371-54-1-1 was identified as good general combiner for grain yield per plant with seven other characters. Thus hybrid IR81413-B-B-75-3/ IR81429-B-31 was identified as best specific combiner for grain yield per plant with some other morphological traits.**

**Key words:** Rice, heterosis, *gca, sca,* gene interaction, *per se,* lines, testers, crosses.

Rice is one of the most important food crop of the world but yield is often affected due to erratic climatic conditions and non availability of high yielding varieties that perform better under this type of climatic condition. Drought situation is becoming precarious year after year due to inadequate precipitation and less water efficient irrigation methods in rice farm. The temperature is increasing day by day resulting loss of soil moisture by evaporation. The water label is going down. Hence, we need to develop rice varieties that perform better under drought condition and gives higher grain yield. Upland rice may be the option for this situation because it has genetic potential to survive under this type of climatic conditions. Upland rice having some unique characters *i.e.* leaf rolling character, high tissue water content, high cell membrane stability, deep root system, waxy layer on leaves etc. help in survival of rice plant under water deficit condition. In India, upland rice area lies in eastern region (Datta, 1993).

Generally, the yield of upland rice is very poor. So we need to develop high yielding varieties. This aim may be achieved by heterosis breeding by using desired lines/ varieties. Heterosis breeding an important genetic tool which can facilitate yield enhancement between 30 to 400 per cent and helps enrich many other desirable quantitative traits in rice (Srivastava, 2000). The basic requirment of successful hybrid breeding programme is a sufficient magnitude of economically important traits to make hybrid commercially competitive (Duvick and Cassman, 1999). Success of any plant breeding programme also depends upon the choice of suitable genotypes as a parent in hybridization programme. The combining ability analysis provides the information about the parents for hybridization. Efficient identification of superior cross combination is another fundamental issue in hybrid breeding. Phenotypic selection of promising parental lines can be performed either based on *gca* or *per se* performance of parental lines. The ratio of *gca* and *sca* is most important for predicting hybrids performance based on *gca* effect (Fischer *et al.,* 2008). The predominance of *gca* variance over sca variance indicated the early generation selection become relatively more effective and superior crosses can be identified and selected. In contrast, some studies reported the importance of *sca* variance over *gca* variance. Hence, it is of interested to study the relative importance of *gca* and *sca* variances. The objective of this study were to [1] examine the magnitude of heterosis over better parent and standard variety for yield and its components [2] identify the best combiner for grain yield and its component characters [3] isolate the high heterotic crosses and [4] choice of suitable breeding prosedure for improvement of rice under rainfed upland condition.

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## Materials and Methods

Five lines and three testers were crossed in L x T mating design to obtaining the fifteen crosses during *kharif* 2009. These crosses along with parents and one standard cheek variety Vandana were evaluated during *kharif* 2010 at Field Experimentation Centre, Allahabad School of Agriculture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad in Randomized Block Design with three replications. Five plants were randomly selected to record the observations for all morphological traits studied except days to 50 per cent flowering. Days to 50 per cent flowering was computed on plot basis. The analysis of variance for different characters was done as formula suggested by Panse and Sukhatme (1967). The total variance and degree of freedom were portioned into three components *namely* replications, treatments and error. Significance of variance was determined by F-test. Analysis of variance for experiment design was performed to test the significant differences between genotypes for all the character with fixed effect model. The per cent heterosis over better parent and standard check were calculated formula suggested by Fonesca & Patterson (1968) and Meredith and Bridge (1972), respectively. The combining ability analysis for Lx T mating design as performed as per method suggested by Kempthrone (1957).

## Results and Discussion

Analysis of variance for all morphological traits studied, revealed significant differences, indicated the presence of adequate genetic variability among the crosses and their parents (Table 1). Parent *v/s* crosses showed significant differences for all the characters under study except harvest index. The analysis of variance showed highly significant differences among the genotypes for all the yield and yield contributing characters that revealed wide range of variability for the genotypes. The mean sum of square due to lines were non significant for all the characters. The mean sum of square due to testers were observed highly significant for days to 50 per cent flowering, plant height, number of tillers per plant, flag leaf length, flag leaf width, panicle length and number of spikelets per panicle. The mean sum of square due to testers were non significant for harvest index, test weight and grain yield per plant. The mean sum of square due to line x tester were highly significant for all the quantitative characters. The ratio of *gca* and *sca* variance were observed more than one for days to 50 per cent flowering, number of effective tillers per plant, flag leaf length and panicle length. It indicated that predominance of additive gene action over non additive gene action. The estimates of mean degree of dominance were less than one for these traits, which suggested the partial dominance type of gene action. Similar findings have earlier been reported by several workers for days to 50 per cent flowering (Vanjana *et al*., 2003), for panicle length (Lavanya, 2000; Sharma mad Mani, 2008). The ratio of *gca* and *sca* variance were less than one for plant height, flag leaf width, number of spikelets per panicle, harvest index, test weight and grain yield per plant. Several workers *viz.,* Kumar *et al.* (2007), Venkatesan *et al.* (2008), Dalvi and Patel (2009), Saleem *et al.* (2010) also reported that non additive gene effects were predominant than additive gene effects for various traits. It indicated the preponderance of non additive gene action over the additive gene action. In this situation the most appropriate and efficient breeding approach would

**Table 1. Analysis of variance for experimental design for various quantitative characters in upland rice.**

| Source of variation | Characters | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | d f | DFF | PH | TPP | FLL | FLW | PL | SPP | HI | TW | GY |
| Replicates | 2 | 1.87 | 6.05 | 0.47 | 0.03 | 0.01 | 0.50 | 30.82 | 3.17 | 0.94 | 0.03 |
| crosses | 14 | 45.95** | 1617.74** | 33.42** | 202.5** | 40.06** | 32.37** | 2471.28** | 333.23** | 11.62** | 210.58** |
| Parents | 7 | 30.20** | 346.40** | 1.27** | 46.44** | 0.06** | 9.05** | 1000.80** | 328.48** | 3.50** | 4.24** |
| Parent v/s crosses | 1 | 452.20** | 8874.71** | 354.39** | 469.24** | 0.21** | 272.19** | 54.37** | 0.10** | 16.56** | 1617.91** |
| Line Effect | 4 | 10.94 | 1113.76 | 12.41 | 54.79 | 0.01 | 20.77 | 1918.03 | 279.20 | 5.07 | 50.71 |
| Tester Effect | 2 | 256.27** | 5279.87* | 156.80** | 880.21* | 0.20* | 119.68* | 3990.49 | 3.97 | 7.25 | 633.59 |
| L x T | 8 | 10.88** | 954.19** | 13.08** | 106.99** | 0.04** | 16.34** | 2368.10** | 442.55** | 15.99** | 184.77** |
| *GCA* | | 10.92 | 266.20 | 7.01 | 38.89 | 0.008 | 5.77 | 245.83 | 11.66 | 6.48 | 28.49 |
| *SCA* | | 2.79 | 317.29 | 4.22 | 35.41 | 0.01 | 5.13 | 787.95 | 146.97 | 5.20 | 61.50 |
| *GCA/ SCA* | | 3.91 | 0.83 | 1.66 | 1.09 | 0.70 | 1.12 | 0.31 | 0.07 | 0.09 | 0.46 |
| Error | 28 | 2.03 | 1.05 | 0.44 | 1.01 | 0.01 | 1.29 | 3.35 | 2.05 | 0.41 | 0.34 |

**Table 2. Proportional contribution of lines, testers and L x T interactions to total variance in upland rice.**

| SV | DF | DFF | PH | TPP | FLL | FLW | PL | SPP | HI | TW | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lines | 4 | 6.80 | 19.67 | 10.61 | 7.72 | 7.39 | 18.33 | 22.17 | 23.93 | 12.47 | 6.87 |
| Testers | 2 | 7.66 | 46.62 | 67.02 | 62.08 | 50.50 | 52.81 | 23.06 | 0.17 | 8.90 | 42.98 |
| L x T | 8 | 13.52 | 33.70 | 22.36 | 30.18 | 42.10 | 28.84 | 54.75 | 75.89 | 78.61 | 50.13 |

SV= Source of variation, DF= Degree of freedom, DFF= days to 50 per cent flowering, PH= Plant height, TPP= Number of effective tillers per plant, FLL= Flag leaf length, FLW= flag leaf width, PL= Panicle length, SPP= Number of spikelets per panicle, DM= Days to maturity, BY= Biological yield per plant, HI= Harvest index, TW= Test weight, GY= Grain yield per plant be to make up the additive gene simultaneously maintaining the degree of heterozygosity for exploring the non additive components.

The contribution of testers was higher than corresponding contribution of lines for all the characters studied, except harvest index and test weight (Table 2). The contribution of testers was higher than corresponding contribution of testers for all the characters studied, except days to 50per cent flowering, harvest index and test weight. The contribution of interaction was higher than corresponding contribution of lines for all the characters studied. Sarker *et al.* (2002) observed higher estimates of *gca* variance due to tester in rice. Contribution of interactions of line x testers was higher than that of lines or testers for days to 50 per cent flowering, number of spikelets per panicle, and harvest index, indicating higher estimates of *gca* variances for interaction.

***Heterobeltiosis and standard heterosis***

Heterosis expressed as per cent increase or decrease in the mean value of $F_1$ hybrid better parent (heterobeltiosis) and standard check variety (standard heterosis). The expression of hetorosis varied with crosses, so also with characters (Lokaprakash *et al*.,1992). To know the magnitude and direction potentiality of crosses is important (Singh *et al.,* 1995) . Both positive and negative heterosis is useful in crop improvement. In general positive heterosis is desired for yield and negative heterosis for early flowering and plant height (Nuruzzaman *et al.,* 2002).

The spectrum of variation for days to 50 per cent flowering ranged from -2.34 to 8.66 per cent for heterobeltoisis and 12.11 to 28.70 per cent for standard heterosis . Two crosses *viz.,* IR 81421-B-B-25-4/ IR 81429-B-31 and IR 81413-B-75-3/ IR 81429-B-31 showed negative but non significient hetrobeltiosis. None of the cross exhibited negative heterosis over standard variety Vandana for days to 50 per cent flowering (Table 3). Several workers *viz*., Tang *et al*. (2002), Jayasudha and Sharma (2010) observed the negative hecterosis over better parent for days to 50 per cent flowering. They suggested that negative heterosis for days to 50 per cent flowering indicated the possibility of developing early maturing hybrids. Some workers (Lokaprakash *et al*., 1992, Patil *et al*., 2003) recorded the negative heterosis over better parent and standard variety for most of the hybrids in rice.

**Table 3. Heterobeltiosis (hb) and Standard heterosis (hc) for days to 50% flowering, plant height (cm), number of effective tillers per plant and flag leaf length (cm) and flag leaf width (cm) in upland rice**

| Crosses | Days to 50 per cent flowering | | Plant height (cm) | | Number of effective tillers per plant | | Flag leaf width (cm) | | Flag leaf length (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | hb | hc | hb | hc | hb | hc | hb | hc | hb | hc |
| IR 81423-B-B-111-3/ IR 67017-124-2-4 | 7.87** | 22.87** | 24.81** | -6.83** | 93.33** | 107.14** | -21.57** | -9.49** | 8.15 | 39.63** |
| IR 81423-B-B-111-3/ IR 81413-B-B-75-4 | 2.53 | 27.35** | 32.57** | -0.72 | 63.64** | 28.57* | 3.08 | 16.65** | -9.83* | 16.41** |
| IR 81423-B-B-111-3/ IR 81429-B-31 | 5.86** | 21.52** | 13.41** | 9.17** | 153.33** | 171.43** | 56.77** | 49.27** | -2.85 | 37.15** |
| IR 81421-B-B-25-4/ IR 67017-124-2-4 | 7.09** | 21.97** | 43.90** | 6.42** | 133.33** | 150.00** | -22.34** | -10.38** | 0.00 | 28.79** |
| IR 81421-B-B-25-4/ IR 81413-B-B-75-4 | 1.44 | 26.01** | 9.51** | -18.00** | 81.82** | 42.86** | -6.00** | 6.37* | -0.24 | 28.48** |
| IR 81421-B-B-25-4/ IR 81429-B-31 | -2.34 | 12.11** | 19.18** | 14.73** | 133.33** | 150.00** | 37.86** | 43.24** | 6.36 | 50.15** |
| IR 81413-B-B-75-3/ IR 67017-124-2-4 | 8.66** | 23.77** | 36.04** | 8.13** | 166.67** | 185.71** | -4.34* | 10.38** | 11.14* | 26.63** |
| IR 81413-B-B-75-3/ IR 81413-B-B-75-4 | 2.53 | 27.35** | -30.80** | -44.99** | 0.00 | -21.43 | -29.40** | -20.11** | -7.71 | 14.86* |
| IR 81413-B-B-75-3/ IR 81429-B-31 | -0.78 | 13.90** | 20.86** | 16.35** | 86.67** | 100.00** | 72.53** | 74.59** | 6.80 | 50.77** |
| IR 81063-B-94-U-3-1/ IR 67017-124-2-4 | 3.15* | 17.49** | 47.28** | 8.97** | 113.33** | 128.57** | -1.51 | 13.65** | 17.66** | 34.06** |
| IR 81063-B-94-4-U-1/IR 81413-B-B-75-4 | 3.61* | 28.70** | -29.48** | -47.19** | 27.27 | 0.00 | -31.67** | -22.67** | -12.19* | 9.29 |
| IR 81063-B-94-4-U-1/ IR 81429-B-31 | 0.78 | 15.70** | -11.69** | -14.99** | 6.67 | 14.29 | 32.16** | 25.85** | 3.73 | 46.44** |
| IR 74371-54-1-1/ IR 67017-124-2-4 | 6.69** | 21.52** | 50.39** | 11.05** | 166.67** | 185.71** | 12.71** | 30.07** | 14.95** | 30.96** |
| IR 74371-54-1-1/ IR 81413-B-B-75-4 | 1.44 | 26.01** | 35.66** | 1.59 | 30.77* | 21.43 | 0.17 | 13.36** | 1.99 | 26.93** |
| IR 74371-54-1-1/ IR 81429-B-31 | 1.56 | 16.59** | 14.40** | 10.13** | 53.33** | 64.29** | 34.84** | 36.81** | -16.45** | 17.96** |
| Minimum | -2.34 | 12.11 | -30.80 | -47.19 | 0.00 | -21.43 | -31.67 | -22.67 | -16.45 | 9.29 |
| Maximum | 3.66 | 28.70 | 50.39 | 16.35 | 166.67 | 185.71 | 72.53 | 74.59 | 17.66 | 50.77 |

hb= heterobeltiosis, hc= Standard heterosis , * = Significant at 0.05 level of significance and ** = 0.01 level of significance

For plant height (Table 3), heterobeltiosis and standard heterosis ranged from -30.80 to 50.39 per cent and -47.19 to 16.35 per cent, respectively. Three crosses *viz.,* IR 81413-B-B -75-3/ IR 1413-B-B-75-4, IR 81063-B-94-4-U-1/ IR 81413-B-B-75-4 and IR 81063-B-94-4-U-1/ IR 81429-B-31 showed negative significant heterobeltiosis. Five crosses *viz.,* IR 81423-B-B-111-3/ IR 67017-124-2-4, IR 81421-B-B-25-4/ IR 81413-B-B-75-4, IR 81413-B-B-75-3/ IR 81413-B-B-75-4, IR 81063-B-94-U-3-1/ IR 81413-B-B-75-4 and IR 8413-B-B-75-3/ IR 81413 -B-B-75-4 expressed negative significant heterosis over standard variety Vandana. Rahimi *et al* . (2010) reported that negative heterosis is desired for plant height shorter plant height is an important character of hybrids to withstand lodging. Vishwakarma *et al.* (1999) suggested the short structure is desirable to develop the semi dwarf high yielding varieties, which will be lodging resistant and fertilizer responsive. Borah and Baraman (2010) also observed the negative heterosis over better parent.

The spectrum of variation for heterobeltiosis and standard heterosis in number of productive tillers per plant (Table 3) was ranged from 0.00 to 166.67 per cent and -21.43 to 185.71 per cent, respectively.

**Table 4. Heterobeltiosis (hb) and Standard heterosis (hc) for number of spikelets per panicle, harvest index, test weight and grain yield per plant in upland rice**

| Crosses | Panicle length (cm) | | No. of spikelets per panicle | | Harvest Index | | Test weight (g) | | Grain yield per plant (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | hb | hc | hb | hc | hc | hc | hb | hc | hb | hc |
| IR 81423-B-B-111-3/ IR 67017-124-2-4 | 6.86* | 38.65** | 21.62** | -34.59** | -20.81** | -10.46** | 2.29 | 25.29** | 64.40** | 8.44* |
| IR 81423-B-B-111-3/ IR 81413-B-B-75-4 | 7.68* | 39.72** | -22.68** | -34.59** | -22.21** | -12.04** | -0.52 | 26.14** | 8.74* | -11.35** |
| IR 81423-B-B-111-3/ IR 81429-B-31 | 20.05** | 55.76** | 8.04** | -10.17** | -48.55** | -41.82** | -1.18 | 14.23** | 214.80** | 107.65** |
| IR 81421-B-B-25-4/ IR 67017-124-2-4 | 33.85** | 54.11** | -18.64** | -47.97** | 9.87** | -11.52** | 10.16** | 34.94** | 123.98** | 45.38** |
| IR 81421-B-B-25-4/ IR 81413-B-B-75-4 | 15.02** | 32.00** | -45.36** | -53.78** | 8.12** | -5.21** | -3.55 | 22.31** | 18.12** | -3.69 |
| IR 81421-B-B-25-4/ IR 81429-B-31 | 23.38** | 56.79** | -18.88** | -32.56** | 19.90** | -20.26** | 2.03 | 19.30** | 235.34** | 120.32** |
| IR 81413-B-B-75-3/ IR 67017-124-2-4 | 18.13** | 53.32** | -16.79** | -32.27** | 8.94** | -11.11** | 1.14 | 30.35** | 118.44** | 84.43** |
| IR 81413-B-B-75-3/ IR 81413-B-B-75-4 | -19.70** | 4.22 | -41.58** | -50.58** | -7.21** | -18.65** | -14.36** | 10.36** | -25.00** | -36.68** |
| IR 81413-B-B-75-3/ IR 81429-B-31 | 22.77** | 59.34** | 71.68** | 42.73** | -12.08** | -28.26** | 22.22** | 57.50** | 231.56** | 179.95** |
| IR 81063-B-94-U-3-1/ IR 67017-124-2-4 | 24.59** | 43.46** | -41.39** | -53.49** | -2.64 | 3.21 | -1.08 | 21.17** | 209.48** | 89.45** |
| IR 81063-B-94-4-U-1/ IR 81413-B-B-75-4 | -4.99 | 9.04* | -25.43** | -36.92** | -29.26** | -25.00** | -4.94* | 20.54** | 28.16** | 4.49 |
| IR 81063-B-94-4-U-1/ IR 81429-B-31 | 2.36 | 30.07** | -23.78** | -36.63** | -7.78** | -2.23 | 7.28** | 30.48** | 35.34** | -11.08** |
| IR 74371-54-1-1/ IR 67017-124-2-4 | 41.62** | 63.07** | 30.71** | -3.49* | -36.91** | -32.99** | 3.67 | 26.99** | 269.92** | 140.11** |
| IR 74371-54-1-1/ IR 81413-B-B-75-4 | 15.19** | 32.54** | -34.71** | -44.77** | 0.77 | 7.03** | 0.06 | 26.88** | 17.48** | -4.22 |
| IR 74371-54-1-1/ IR 81429-B-31 | 10.21** | 40.05** | -32.52** | -43.90** | 27.51** | 35.44** | 2.25 | 18.75** | 81.93** | 19.53** |
| Minimum | -19.70 | 4.22 | -45.36 | 53.78 | -48.55 | -32.99 | -14.36 | 10.36 | -25.00 | -36.68 |
| Maximum | 41.62 | 63.07 | 71.68 | 42.73 | 27.51 | 35.44 | 22.22 | 57.50 | 269.92 | 179.95 |

hb= heterobeltiosis, hc= Standard heterosis , * = Significant at 0.05 level of significance and ** = 0.01 level of significance

Out of 15 crosses, 12 crosses and 11 crosses showed positive significant heterosis over better parent and standard variety, respectively. Significant positive heterosis for number of productive tillers per plant were earlier reported by several workers *viz*., Alam *et al*. (2004) and Shankar *et al*. (2010). They reported that hybrids are generally characterized by having large number of panicles indicating their efficiency in partitioning of assimilates to reproductive parts.

The spectrum of variation for heterobeltiosis and standard heterosis in panicle length (Table 3) was observed from -19.70 to 41.62 per cent and 4.22 to 63.07 per cent, respectively. Out of 15 crosses, 12 crosses and 14 crosses expressed significant heterobeltiosis and standard heterosis in desired direction. For test weight, heterotic effect over better parent and standard check Vandana ranged from -14.36 to 22.22 per cent and 10.36 to 57.50 per cent, respectively. Three crosses showed positive significant hetrobeltiosis and all crosses expressed positive significant heterosis over standard variety Vandana. Positive standard heterosis for test weight was earlier reported by Banumathy *et al*. (2003).

Heterobeltiosis for grain yield per plant ranged from -25.00 (IR 81413-B-B-75-3/ IR 81413-B-B-75-4) to 269.92 (IR 74371-54-1-1/ IR 67017-124-2-4) (Table 4). A high range of heterobeltiosis was earlier reported by Vanjana *et al.*, 2003 (-93.3 to 356.0%), Jayasudha and Sharma, 2010 (2.76 to 164.95). Significant and positive heterobeltiosis for grain yield per plant were exhibited by 14 crosses, while one cross IR 81413-B-B-75-3/IR 81413-B-B-75-4 (-25.00) showed significant and negative heterobeltiosis. Standard heterosis ranged from -3.69 (IR 81421-B-B-25-4/ IR 81413-B-B-75-4) to 173. 95 (IR 81413-B-B-75-3/ IR 81429-B-31). Significant and positive standard heterosis for grain yield per plant were observed in seven crosses (Table 3). Among all the characters studied, test weight was found to be emerged as the first heterotic trait, because all crosses showed significant positive heterosis over standard variety Vandana for this character. This was followed by flag leaf width

**Table 5. General combining ability effects of parents for various quantitative characters in upland rice**

| Parents | Characters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DFF | PH | TPP | FLL | FLW | PL | SPP | HI | TW | GY |
| IR 81423-B-B-111-3 | 1.78* | 4.17** | 0.64** | 0.50* | 0.01** | 0.73* | 5.82** | -5.57** | -0.69** | -1.76** |
| IR 81421-B-B-25-4 | -1.11** | 4.76** | 1.20** | -1.24** | 0.06** | 1.28** | -15.18** | -0.42** | -0.03** | 0.65** |
| IR 81413-B-B-75-3 | 0.11 | -4.33** | -0.02** | 1.35** | 0.00** | -0.35** | 20.82** | -4.38** | 1.28** | 3.42** |
| IR 81063-B-94-4-3-1 | -0.67** | -16.89** | -1.91** | -3.51** | -0.01** | -2.50** | -12.40** | 2.03** | -0.29** | -2.68** |
| IR 74371-54-1-1 | -0.11** | 12.29** | 0.09 | 2.90** | -0.06 | 0.83 | 0.93 | 8.34** | -0.27** | 0.37** |
| IR 67017-124-2-4 | 0.00 | 9.94** | 2.93** | -3.13** | 0.02** | 1.83** | -3.24 | -0.55** | 0.37** | 3.12** |
| IR 81413-B-B-75-4 | 4.13** | -21.64** | -3.47** | -5.60** | -0.12** | -3.25** | -14.44** | 0.46** | -0.80** | -7.47** |
| IR 81429-B-31 | -4.13** | 11.70** | 0.53** | 8.73** | 0.11** | 1.43** | 17.69** | 0.09* | 0.43** | 4.35** |
| SE(gi)line | 0.52 | 0.50 | 0.20 | 0.29 | 0.02 | 0.32 | 0.68 | 0.42 | 0.20 | 0.16 |
| Se(gi)tester | 0.40 | 0.39 | 0.16 | 0.22 | 0.01 | 0.24 | 0.53 | 0.32 | 0.15 | 0.12 |

DFF= days to 50% flowering, PH= Plant height, TPP= number of productive tillers per plant, FLL= Flag leaf length, FLW= flag leaf width, PL= Panicle length, SPP= Number of spikelets per panicle, DM= Days to maturity, BY= Biological yield per plant, HI= Harvest index, TW= Test weight, GY= Grain yield per plant

(14 crosses), panicle length (14 crosses), number of tillers per plant (11 crosses), flag leaf length (11 crosses) and grain yield per plant (9 crosses). This revealed that grain yield per plant was one of the most heterotic trait in respect to hetrobeltiosis because out of 15 crosses, 14 crosses showed positive significant heterobeltiosis for grain yield per plant. Seven of the crosses exhibited significant and positive heterosis over standard check Vandana for grain yield per plant (Table 4). Other workers (Borah and Barman, 2010; Rahimi *et al.*, 2010) also reported positive heterosis for grain yield per plant. It was evident that all the yield contributing traits did not contribute equally towards heterosis.

***General Combining Ability***

Negative *gca* effects were desirable for days to 50 per cent flowering and plant height, while in other traits positive *gca* effects were desirable. None of the lines or testers (pollinators) was observed to be good general combiner for all the traits studied (Table 5). The positive significant *gca* effect for grain yield per plant were exhibited by parents IR 81429-B-31 (4.34) and IR 81413-B-B-75-3 (3.41). Thus the parents IR 81429-B-31 and IR 81413-B-B-75-3 were identified as good combiners for grain yield per plant. Among the lines, IR81413-B-B-75-3 was identified as a good general combiner for grain yield per plant

**Table 6. Specific combining ability effects of crosses for various quantitative characters in upland rice**

| Parents | Characters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DFF | PH | TPP | FLL | FLW | PL | SPP | HI | TW | GY |
| IR 81423-B-B-111-3/ IR 67017-124-2-4 | -0.77 | -18.42** | -2.71** | -5.45** | 0.77 | -2.96** | -0.08** | 6.76** | 0.24 | -6.46** |
| IR 81423-B-B-111-3/ IR 81413-B-B-75-4 | -1.57 | 20.18** | 0.02 | 4..94** | -0.03 | 2.31** | 5.11** | 4.85** | 1.57** | 1.62** |
| IR 81423-B-B-111-3/ IR 81429-B-31 | 2.35* | -1.75 | 2.689** | 0.51 | -0.04 | 0.65 | 0.97 | -11.62** | -1.81** | 4.84** |
| IR 81421-B-B-25-4/ IR 67017-124-2-4 | 1.44 | -3.75** | -1.267** | -3.98** | -0.09* | -0.60 | -0.42 | 1.01 | 1.33** | -4.21** |
| IR 81421-B-B-25-4/ IR 81413-B-B-75-4 | 0.31 | -0.30 | 0.133 | 3.56** | 0.04 | 0.31 | 4.11** | 3.56** | 0.22 | 0.18 |
| IR 81421-B-B-25-4/ IR 81429-B-31 | -1.75 | 4.05** | 1.13** | 0.42 | 0.04 | 0.29 | -3.68** | -4.57** | -1.55** | 4.02** |
| IR 81413-B-B-75-3/ IR 67017-124-2-4 | 1.55 | -22.31** | 1.62** | -0.27 | -0.06 | 0.87 | -18.42** | 5.20** | -0.80* | -2.04** |
| IR 81413-B-B-75-3/ IR 81413-B-B-75-4 | 0.08 | 15.01** | -1.64** | -7.06** | -0.04 | -3.27** | -18.22** | -0.07 | -3.24** | -6.67** |
| IR 81413-B-B-75-3/ IR 81429-B-31 | -1.64 | 20.82** | 0.02 | 7.33** | 0.10* | 2.40** | 46.64** | -5.13** | 4.04** | 8.78** |
| IR 81063-B-94-U-3-1/ IR 67017-124-2-4 | -2.33* | -12.29** | 0.84* | 5.57** | 0.02 | 1.17** | -9.53** | 1.90** | -0.89* | 4.68** |
| IR 81063-B-94-U-3-1/IR 81413-B-B-75-4 | 1.86 | -8.77** | 1.21** | -2.98** | -0.10* | -0.22 | 20.66** | -10.07** | 0.16 | 4.54** |
| IR 81063-B-94-U-3-1/ IR 81429-B-31 | 0.46 | -5.95** | -2.08** | -2.59** | 0.07 | -0.94 | -11.13** | 3.17** | 0.73* | -9.23** |
| IR 74371-54-1-1/ IR 67017-124-2-4 | 0.11 | 14.72** | 1.51** | 4.14** | 0.04 | 1.53* | 34.46** | -19.88** | 0.13 | 8.03** |
| IR 74371-54-1-1/ IR 81413-B-B-75-4 | -0.68 | -8.77** | 0.24 | 1.53** | 0.14** | 0.86 | -1.66 | 1.72* | 1.28** | 0.39 |
| IR 74371-54-1-1/ IR 81429-B-31 | 0.57 | 0.87 | -2.08 | -5.67** | -0.18** | -2.39** | -32.80** | 18.16** | -1.41** | -8.42** |
| SE(Sij) | 0.91 | 1.79 | 0.36 | 0.50 | 0.04 | 0.55 | 1.18 | 0.73 | 0.35 | 0.28 |

DFF= days to 50% flowering, PH= Plant height, , TPP= number of productive tillers per plant, FLL= Flag leaf length, FLW= flag leaf width, PL= Panicle length, SPP= Number of spikelets per panicle, DM= Days to maturity, BY= Biological yield per plant, HI= Harvest index, TW= Test weight, GY= Grain yield per plant

with some other characters *viz.,* plant height, number of spikelets per panicle and test weight. Among the testers, IR74371-54-1- 1 (4.34) was identified as a good general combiner for grain yield per plant with some other characters *viz.,* days to 50 per cent flowering, number of tillers per plant, flag leaf width, panicle length and number of spikelets per panicle. Desirable *gca* effect observed in 3 parents for days to 50 per cent flowering, panicle length, flag leaf length, 2 parents for plant height, number of tillers per plant, for flag leaf width, for number of spikelets per panicle, harvest index, one parent for test weight and grain yield per plant.

***Specific Combining Ability***

For days to 50 per cent flowering and plant height negative *sca* effects were desirable where as in other traits positive *sca* effects were desirable. None of the cross combinations was observed to be a good cross combination for all the traits studied (Table 6). The maximum *sca* effect for grain yield per plant exhibited by hybrid IR81413-B-B-75-3/ IR81429-B-31. Thus hybrid IR81413-B -B-75-3/ IR81429 -B- 31 was identified as best specific combiner for grain yield per plant. Hybrids IR81423-B-B-75-3/ IR81429-B-31, IR81063-B-94-U-3-1/ IR67017-124-2-4, IR81063-B-94-U-3-1/ IR81413-B-B-75-4, IR81421-B-B-25-4/ IR81429-B-31, IR74371-54-1-1/ IR67017-124-2- 4 and IR81413-B-B-111-3/ IR81413-B-B-75-4 were identified as good specific combiner for grain yield per plant. Above cross combination was found to be a good specific combination with high heterotic effects for grain yield along with some of the yield contributing traits. Hasib *et al.* (2002) observed similar findings for good specific cross combinations in rice. Maximum *sca* effect and standard heterosis for grain yield per plant was exhibited by cross IR81413-B-B-75-3/ IR81429-B-31 and was originated from high x high general combiner parents. High x high interaction for grain yield per plant was earlier reported by Hasib *et al.* (2002). Hybrids IR 81423-B-B-75-3/ IR 81429-B-31, IR 81063-B-94-U-3-1/ IR 67017-124-2-4, IR 81063-B-94-U-3-1/ IR 81413-B-B-75-4, IR 81421-B-B-25-4/ IR 81429-B-31, IR 74371-54-1-1/ IR 67017-124-2-4 and IR 81413-B -B- 111-3/ IR 81413-B-B- 75-4 were originated from all types of combinations (low x high, low x high, low x high, high x high, low x low general combiner parents). Similar parental *gca* combinations for grain yield has earlier been reported by Sarker *et al.* (2002).

**Table 7. Comparative study of seven top most heterotic crosses for grain yield per plant along with *per se* performance, heterosis over Vandana, parental *gca* combination and gene action for other yield component characters**

| Crosses | Mean values for grain yield per plant (g) | Standard heterosis for grain yield per plant (%) | Parental *gca* Combination | Nature of gene action | Desirable SH for other yield component characters |
|---|---|---|---|---|---|
| IR 81413-B-B-75-3/ IR 81429-B-31 | 35.36 | 179.95 | H x H | Additive | TPP, FLL, FLW, PL, SPP, TW |
| IR 74371-54-1-1/ IR 67017-124-2-4 | 30.33 | 140.11 | H x H | Additive | TPP, FLL, FLW, PL, TW |
| IR 81421-B-B-25-4/ IR 81429-B-31 | 27.88 | 120.32 | H x H | Additive | TPP, FLL, FLW, PL, TW |
| IR 81423-B-B-111-3/ IR 81429-B-31 | 26.23 | 107.65 | L x H | Non-additive | TPP, FLL, FLW, PL,TW |
| IR 81063-B-94-U-3-1/ IR 67017-124-2-4 | 33.93 | 89.45 | H xH | Additive | TPP, FLL, FLW, PL, TW |
| IR 81413-B-B-75-3/ IR 67017-124-2-4 | 23.30 | 84.43 | L x H | Non-additive | TPP, FLL, FLW, PL, TW |
| IR 81421-B-B-25-4/ IR 67017-124-2-4 | 18.36 | 45.38 | H x H | Additive | TPP, FLW, PL, TW |
| Vandana (Check) | 12.63 | - | - | - | - |

TPP= Number of effective tillers per plant, FLL= Flag leaf length, FLW= flag leaf width, PL= Panicle length, SPP= Number of spikelets per panicle, DM= Days to maturity, BY= Biological yield per plant, HI= Harvest index, TW= Test weight, GY= Grain yield per plant, SH= Standard heterosis

***Isolation of heterotic crosses based on* per se *performance, heterosis and combining ability***

Based on *per se* performance, standard heterosis and combining ability, seven heterotic combinations were isolated for grain yield per plant along with some other yield components in desired direction over standard check Vandana (table 7). The cross IR 81413-B-B- 75-3/ IR 81429-B-31 showed highest standard heterosis and highly associated with number of effective tillers per plant, flag leaf width, panicle length, biological yield per plant and test weight. This cross was originated from high x high general combiner parents. Thus, suggesting the development of better segregates from the early segregating generation for yield improvement under rainfed condition. Two crosses *viz*., IR81423-B-B-111 -3/ IR67017-124-2-4 and IR81063-B- 94-U-3-1/ IR81413-B-B-75-4 also showed high standard heterosis for grain yield per plant and these crosses were originated from low x low combination. Thus, these two cross combinations may be used in hybrid breeding progamme for crop improvement for upland rice under rainfed condition.

## Conclusion

The findings from the present study indicated that all the component characters were not expressed in a single cross combination in higher and desirable magnitude. Seven heterotic combinations *viz.,* IR 81423-B-B-75-3/ IR 81429-B-31, IR 81063-B-94-U-3-1/ IR 67017-124-2-4, IR 81063-B-94-U-3-1/ IR 81413-B-B-75-4, IR 81421-B-B-25-4/ IR 81429-B-31, IR 74371-54-1-1/ IR 67017-124-2-4 and IR 81413-B-B-111-3/ IR 81413-B-B-75-4 were isolated for grain yield per plant along with some other yield components in desired direction over standard check Vandana. Three parents *viz.,* IR 81429-B-31, IR 81413-B-B-75-3 and IR74371- 54- 1-1 were identified for good general combiner for grain yield per plant. Heterotic crosses along with high *per se* performance involving high x high parental *gca* combination can be utilize in isolation of transgressive segregants through selection in segregating generation. However, high x low heterotic combining crosses may be exploit for heterosis breeding to improve of rice production.

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