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# THE ESTIMATES OF HETEROBELTIOSIS AND STANDARD HETEROSIS IN AEROBIC RICE (*ORYZA SATIVA* L.)

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## Abstract

The combining ability experiment (Experiment-II) was based on evaluation of a line x tester set of 72 hybrids (F1's) and their 22 parents along with two checks for twelve characters under aerobic condition in randomized block design with three replications during *Kharif*, 2013. The 72 $F_1$'s were generated by crossing 18 testers with 4 CMS lines during *Kharif*, 2012. The analysis of variance revealed highly significant mean squares due to genotypes, crosses, parents and testers for all the twelve characters. Heterosis was estimated as per cent increase or decrease of $F_1$ value over better- parent (BP) and two standard varieties (SV) namely, Baranideep ($SV_1$) and MTU 1010 ($SV_2$). For grain yield per plant, the heterosis over better-parent varied from -42.57 per cent to 97.87 per cent with mean heterosis of 5.15 per cent. Twenty-one crosses exhibited positive and significant heterosis over BP. The standard heterosis for GY/P ranged from -48.62 per cent to 43.00 per cent over $SV_1$ and from -45.97 per cent to 50.38 per cent over $SV_2$. The mean heterosis value was -10.75 per cent and -6.14 per cent for standard heterosis over $SV_1$ and $SV_2$, respectively. Out of 72 cross combinations, only eight crosses exhibited positive and significant standard heterosis over $SV_1$. Fourteen cross combination exhibited positive and significant heterosis over standard variety $SV_2$ for grain yield per plant and the best five cross combination were IR 68897 A × IR 83614-3 (50.38%), IR 68888 A × IR 83614-673 (48.15%), IR 58025 A × IR 80416-B (42.16%), IR 68888 A × R-RF-45 (32.22%) and IR 58025 A × IR 79906-B (30.60%).

***Keywords :*** Aerobic rice, heterobeltiosis, standard heterosis, yield

## Introduction

The exploitation of heterosis for improving yield potential of crop plants has emerged as one of the most outstanding contributions of science of genetics to agriculture. The assessment of nature and magnitude of heterosis for different characters serves in the identification of potential hybrid combinations for exploitation as hybrid varieties or breeding materials for isolating transgressive segregants for developing high yielding pure line varieties. Hybrid rice technology has also showed increased yield, farmer profitability and better adaptability to stress environments such as water scarce and with high yield potential for aerobic conditions would be one of the exciting research aspects to be carried out to overcome the existing water crisis in India in relation to agricultural production.

The efforts for development of commercial hybrids in rice, started earlier, are becoming fruitful. In fact, the hybrid rice research was initiated in 1964 (Yuan, 1966) and the genetic tools essential for breeding hybrid rice varieties such as the male sterile lines (A-line), maintainer lines (B-line), and restorer lines (R-line) were developed during 1973 (Yuan and Virmani, 1988). The hybrid breeding methodology involves the three approaches (a) Three line method or CMS system which is possible and has been found to be most effective genetic tool for developing hybrids, (b) Two line method or PGMS and TGMS system, and (c) One line system or apomictic system. Among them, three line approaches is being widely adopted in India and had resulted in the development more than 35 rice hybrids. The CGMS is essentially CMS with a provision of fertility restoration by nuclear gene (s). Hence, it is also referred to as CMS system. The role of cytoplasm in causing male sterility in rice was reported back in the fifties and the first usable cytoplasmic male sterility-fertility restoration system in

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rice was developed by substituting nuclear genes of *japonica* variety, Taichung 65 in to the cytoplasm of the *indica* variety, Chinsurah Boro II (Sampath and Mohanty, 1954). The first commercially usable CMS line was developed in China during 1973 from a spontaneous male sterile plant isolated in a population of wild rice, *O. sativa* f. sp. *spontanea* on Hainen Island. Discovery of this source, designated as Wild Abortive or "WA" type is considered a land mark in the history of hybrid rice. In present study the data was subjected to line x tester analysis of combining ability following Kempthorne (1957) to estimate combining ability variances and effects and other genetic parameters. The estimates of heterosis over better-parent and two standard varieties were computed for study of heterosis.

## Materials and methods

Four cytoplasmic male sterile (CMS) lines *viz*., IR 58025 A, IR-68888 A, IR-68897A and IR-79156A were crossed with sixteen genetically diverse aerobic rice pollen parents in a line × tester mating fashion. The eighteen testers were IR 83614-673-B, IR 84899-B-185-CRA-1-1, IR 83614-61-B, R-RF-45, R-84856-159-CRA-12-1, IR 78875-207-B-1-B, IR 64, LALIT, R-RF-65, IR 81057-B-132-U-4-4, IR 80416-B-152-4, IR 79906-B-5-3-3, IR 84887-B-153-CRA-2-5-1, IR 78537-B-4-B-B-B, IR 79956-B-60-2-3, IR 81039-B-137-U-3-3, IR 84614-203-B, and IR 83614-315-B-AROBIC-E-7. The seeds of CMS lines were treated with 0.02 per cent mercuric chloride solution followed by subsequent washing with sterilized distilled water and then placed in petri-dishes holding a moist towel paper for proper germination at room temperature. The 7-10 days old seedlings of CMS lines were transplanted in earthen pots for their normal growth, while male lines were direct seeded in fully prepared nursery beds at three different dates to coincide the flowering dates with CMS lines for crossing purpose. A total of 72 $F_1$'s were produced during *Kharif,* 2012. The resulting set of 72 $F_1$'s along with their 22 parents and standard 2 check varieties (Baranideep and MTU-1010) were evaluated in randomized complete block design with three replications during *Kharif,* 2013. The seeds of each entry were sown on 21$^{th}$ June, 2013 in separate pots and 33 days (24$^{th}$ July, 2013) old seedlings were transplanted single seedling per hill in single row plots of 3 m length with inter- and intra- row spacing of 20 cm and 15 cm, respectively. All the recommended cultural practices were followed to raise a good crop. The fertilizers were applied @ 120 kg nitrogen, 60 kg phosphorus and 60 kg potash per hectare through urea, DAP and murate of potash, respectively. The full dose of phosphorus and potash and half dose of nitrogen were applied as basal and rest of nitrogen was applied in two split doses as top dressing at tillering and panicle initiation stage of crop growth. Twelve plant characters *viz*., days to 50% flowering (DFF), days to maturity (DM), plant height (PH in cm), flag leaf area (FLA in cm), ear bearing tillers per plant (EBT/P), panicle length (PL in cm), spikelets per panicle (S/P), spikelet fertility (SF in %), 1000-grain weight (TW in g), biological yield per plant (BY/P in g), grain yield per plant (GY/P in g) and harvest-index (HI in %) were studied in both the experiments. The heterosis was computed as per cent increase or decrease of the mean values of crosses (F1's) over better-parent (Heterobeltiosis) and standard variety (Standard Heterosis).

## Results and discussion

### Heterosis

The heterosis breeding has been used extensively in improving yield potential through development of hybrid cultivars in most of the allogamous crops and some autogamous crops like rice as well. The exploitation of heterosis for developing high yielding commercial hybrids in aerobic rice has been found highly fruitful inspite of its autogamous nature because significant heterosis is encountered in $F_1$ hybrids and successful and economical technology for commercial hybrid seed production is available. The presence of high heterosis for economically important characters is not only useful for developing hybrids, synthetic or composites through exploitation of heterosis, but also helps in obtaining transgressive segregants for development of superior homozygous lines. In present study, the estimates of heterosis over better-parent and standard variety, $SV_1$ (Baranideep) and $SV_2$ (MTU 1010) were calculated for 72 $F_1$'s to assess their genetic potential as breeding material. A wide range of variation in the estimates of heterobeltiosis and standard heterosis in positive and negative direction was observed for grain yield per plant (table 1). In case of grain yield per plant, heterobeltiosis ranged from from -42.57 % to 97.87 % and standard heterosis varied -48.62 % to 43.00 % over $SV_1$ and from -45.97 % to 50.38 % over $SV_2$. Twenty-one crosses exhibited positive and significant heterosis over BP. The best five cross combinations were IR 68897 A × IR 83614, IR 68888 A × IR 83614-673, IR 79156 A × IR 83614-61, IR 68888 A × R-RF-45 and IR 58025 A × IR 79906-B. Only eight crosses exhibited positive and significant standard heterosis over $SV_1$ and the best five crosses was IR 68897 A × IR 83614-3, IR 68888 A × IR 83614-673, IR 58025 A × IR 80416-B, IR 68888 A × R-RF-45 and IR 58025 A × IR 79906-B. Fourteen cross combination exhibited positive and

**Table 1: Extent of per cent heterosis over better parent (BP) and standard varieties (SV) for GY/P in aerobic rice.**

| Crosses | Grain yield per plant (g.) | | | Crosses | Grain yield per plant (g.) | | |
|---|---|---|---|---|---|---|---|
| | BP | $SV_1$ | $SV_2$ | | BP | $SV_1$ | $SV_2$ |
| IR 58025 A x IR 83614-673 | 3.0 | -26.3** | -22.5** | IR 68888 A x IR 78537-B | 0.4 | -7.9 | -3.2 |
| IR 58025 A x IR 84899-B | 41.66** | -7.8 | -3.0 | IR 68888 A x IR 79956-B | -0.7 | -8.1 | -3.4 |
| IR 58025 A x IR 83614-61 | 14.7* | -15.1** | -10.7* | IR 68888 A x IR 81039-B | -5.1 | 3.1 | 8.4 |
| IR 58025 A x R-RF-45 | -30.1** | -47.1** | -44.4** | IR 68888 A x IR 84614-2 | 5.2 | 9.8 | 15.4** |
| IR 58025 A x IR 84856-1 | -9.2 | -24.3** | -20.4** | IR 68888 A x IR 83614-3 | 45.6** | 5.2 | 10.7* |
| IR 58025 A x IR 78875-2 | 0.1 | -23.8** | -19.8** | IR 68897A x R 83614-673 | -4.0 | -31.5** | -27.8** |
| IR 58025 A x IR 64 | -24.2** | -2.6 | 2.5 | IR 68897 A x IR 84899-B | 41.5** | -7.9 | -3.1 |
| IR 58025 A x LALIT | 5.6 | -7.2 | -2.4 | IR 68897 A x IR 83614-61 | 29.7** | -3.9 | 0.9 |
| IR 58025 A x R-RF-65 | 18.1** | 2.3 | 7.5 | IR 68897 A x R-RF-45 | 11.97 | -15.2** | -10.9* |
| IR 58025 A x IR 81057-B | 4.6 | 6.2 | 11.7* | IR 68897 A x IR 84856-1 | -38.4** | -48.6** | -45.9** |
| IR 58025 A x IR 80416-B | 18.3** | 35.2** | 42.2** | IR 68897 A x IR 78875-2 | -4.2 | -27.1** | -23.3** |
| IR 58025 A x IR 79906-B | 57.3** | 24.2** | 30.6** | IR 68897 A x IR 64 | -35.1** | -16.6** | -12.3* |
| IR 58025 A x IR 84887-B | 12.6 | -29.7** | -26.1** | IR 68897 A x LALIT | 10.2 | -3.2 | 1.9 |
| IR 58025 A x IR 78537-B | -21.8** | -28.3** | -24.5** | IR 68897 A x R-RF-65 | 24.2** | 7.5 | 13.1* |
| IR 58025 A x IR 79956-B | -17.8** | -23.9** | -19.9** | IR 68897 A x IR 81057-B | 9.7 | 11.4* | 17.2** |
| IR 58025 A x IR 81039-B | -25.4** | -19.1** | -14.9** | IR 68897 A x IR 80416-B | -2.3 | 11.6* | 17.4** |
| IR 58025 A x IR 84614-2 | -15.1** | -11.5* | -6.9 | IR 68897 A x IR 79906-B | -11.3 | -29.9** | -26.3** |
| IR 58025 A x IR 83614-3 | -3.4 | -30.2** | -26.6** | IR 68897 A x IR 84887-B | -2.3 | -39.0** | -35.9** |
| IR 68888 A x IR 83614-673 | 96.99** | 40.88** | 48.15** | IR 68897 A x IR 78537-B | -10.50 | -17.88** | -13.64* |
| IR 68888 A x IR 84899-B | 1.76 | -33.75** | -30.33** | IR 68897 A x IR 79956-B | -11.46* | -18.02** | -13.79* |
| IR 68888 A x IR 83614-61 | 26.46** | -6.34 | -1.51 | IR 68897 A x IR 81039-B | -19.80** | -12.90* | -8.40 |
| IR 68888 A x R-RF-45 | 66.07** | 25.73** | 32.22** | IR 68897 A x IR 84614-2 | -34.87** | -32.07** | -28.56** |
| IR 68888 A x IR 84856-1 | 1.25 | -15.62** | -11.27* | IR 68897 A x IR 83614-3 | 97.87** | 43.00** | 50.38** |
| IR 68888 A x IR 78875-2 | -8.47 | -30.28** | -26.68** | IR 79156 A x IR 83614-673 | 23.10** | -11.97* | -7.42 |
| IR 68888 A x IR 64 | -30.68** | -10.86* | -6.25 | IR 79156 A x IR 84899-B | 1.16 | -34.15** | -30.75** |
| IR 68888 A x LALIT | 8.48 | -4.66 | 0.26 | IR 79156 A x IR 83614-61 | 66.86** | 23.58* | 29.95** |
| IR 68888 A x R-RF-65 | 20.90** | 4.66 | 10.06 | IR 79156 A x R-RF-45 | 16.90* | -11.50* | -6.93 |
| IR 68888 A x IR 81057-B | -3.46 | -1.93 | 3.13 | IR 79156 A x IR 84856-1 | -6.88 | -22.39** | -18.39** |
| IR 68888 A x IR 80416-B | -14.21** | -1.97 | 3.09 | IR 79156 A x IR 78875-2 | -24.13** | -42.21** | -39.22** |
| IR 68888 A x IR 79906-B | 2.77 | -18.85** | -14.66** | IR 79156 A x IR 64 | -28.53** | -8.10 | -3.35 |
| IR 68888 A x IR 84887-B | 12.28 | -29.92** | -26.30** | IR 79156 A x LALIT | 17.33** | 3.12 | 8.44 |

***contined ... table 1***

*contined ... table 1*

| Crosses | Grain yield per plant (g.) | | |
|---|---|---|---|
| | BP | $SV_1$ | $SV_2$ |
| IR 79156 A x R-RF-65 | 26.8** | 9.8 | 15.4** |
| IR 79156 A x IR 81057-B | 3.6 | | |
| IR 79156 A x IR 80416-B | -40.9** | -32.5** | -29.0** |
| IR 79156 A x IR 79906-B | 25.1** | -1.2 | 3.9 |
| IR 79156 A x IR 84887-B | 53.9** | -3.9 | 0.9 |
| IR 79156 A x IR 78537-B | -8.0 | -15.6** | -11.2* |
| IR 79156 A x IR 79956-B | -42.6** | -46.8** | -44.1** |
| IR 79156 A x IR 81039-B | -32. | | |
| IR 79156 A x IR 84614-2 | -18.5** | -14.9** | -10.6 |
| IR 79156 A x IR 83614-3 | 33.5** | -3.6 | 1.4 |
| **No. of crosses with significant positive heterosis** | 21 | 8 | 14 |
| **No. of crosses with significant negative heterosis** | 19 | 38 | 32 |
| **Range of heterosis** | -42.57 to 97.87 | -48.62 to 43.00 | -45.97 to 50.38 |

significant heterosis over standard variety $SV_2$ for grain yield per plant. The best five cross combination were IR 68897 A × IR 83614-3, IR 68888 A × IR 83614-673, IR 58025 A × IR 80416-B, IR 68888 A × R-RF-45 and IR 58025 A × IR 79906-B.

Besides, grain yield, substantial heterosis over better-parent and standard varieties was also observed in negative as well as positive direction for different characters. However, the number of crosses showing significant estimates and the range of heterosis varied from one character to another. The mean heterosis was both positive and negative in direction for different characters. For grain yield per plant, the mean heterosis for heterobeltiosis and standard heterosis over $SV_2$ were negative while mean standard heterosis over $SV_1$ was positive. In general, some crosses showed appreciable and high heterosis for most of the characters under study.

The existence of wide spectrum of heterosis in either direction with expression of high degree of desirable heterosis by some crosses for all the characters observed in present study is in conformity with the earlier reports reporting presence of high heterosis for such characters in rice (Roy *et al.,* 2009; Krishna *et al.,* 2011; Tiwari *et al.,* 2011; Reddy *et al*., 2012;. Anil *et al*. 2013; Thalapati *et al*., 2014). It was also noted that higher heterosis over better-parent was found in some lower yielding crosses when compared to other crosses which have displayed high yield. This suggested that while selecting the best hybrid, besides the heterotic response over better-parent, the mean performance of the crosses should also be given due to consideration. Since, heterosis estimate results from $F_1$-BP and depends more or less on the mean of the parents in question, there is every possibility of getting a cross with lower mean performance but high heterotic response, in case the parental performance is very poor. On the contrary, there can be a cross with high mean performance but low heterosis in case parental performance is also high. The mean performance being the realized value and the heterotic response being an estimate, the former should be given due to consideration while making selection of cross combinations especially when objective is to identify a hybrid for commercial cultivation as in present case. In this context, the most desirable crosses showing high mean performance and high and significant heterosis of one or both types for grain yield per plant were IR 68897 A × IR 83614-3, IR 68888 A × IR 83614-673, IR 58025 A × IR 80416-B, IR 68888 A × R-RF-45 and IR 58025 A × IR 79906-B for aerobic rice as listed in table 3. These crosses merit further testing and evaluation in adaptive trails to find out their feasibility for recommendation for use as hybrid

**Table 2:** Relationship of positive heterobeltiosis for GY/P with desirable heterobeltiosis of other characters

| Crosses \ Characters | GY/P | DFF | PH | FLA | EBT/P | PL | S/P | SF | TW | BY/P | HI | DM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IR 68897 A × IR 83614-3 | 97.87** | - | - | - | - | 0 | - | - | 0 | - | + | + |
| IR 68888 A × IR 83614-673 | 96.99** | + | - | 0 | - | 0 | - | 0 | 0 | - | + | 0 |
| IR 79156 A × IR 83614-61 | 66.86** | + | - | 0 | - | - | - | 0 | 0 | - | + | + |
| IR 68888 A × R-RF-45 | 66.07** | + | - | 0 | - | 0 | - | 0 | - | - | + | + |
| IR 58025 A × IR 79906-B | 57.26** | 0 | 0 | - | - | 0 | - | - | - | - | + | 0 |
| IR 79156 A × IR 84887-B | 53.85** | 0 | 0 | 0 | - | 0 | - | 0 | - | - | + | + |
| IR 68888 A × IR 83614-3 | 45.61** | - | - | 0 | - | - | - | 0 | + | - | + | + |
| IR 58025 A × IR 84899-B | 41.66** | + | 0 | - | - | 0 | - | 0 | + | - | 0 | + |

**Table 3:** Relationship of positive and significant standard heterosis for GY/P with standard heterosis for other characters

| Crosses \ Characters | GY/P | DFF | PH | FLA | EBT/P | PL | S/P | SF | TW | BY/P | HI | DM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IR 68897 A x IR 83614-3 | 50.38** | - | + | - | - | 0 | 0 | - | - | + | + | + |
| IR 68888 A x IR 83614-673 | 48.15** | + | + | - | 0 | 0 | - | - | 0 | + | + | 0 |
| IR 58025 A x IR 80416-B | 42.16** | - | 0 | 0 | 0 | 0 | - | 0 | + | + | + | 0 |
| IR 68888 A x R-RF-45 | 32.22** | 0 | + | 0 | 0 | 0 | 0 | 0 | 0 | 0 | + | 0 |
| IR 58025 A x IR 79906-B | 30.60** | 0 | + | - | - | 0 | - | - | 0 | + | + | 0 |

Where, + = Significant and positive heterosis; - = Significant and negative heterosis; 0 = Non-significant heterosis.
GY/P: Grain yield plant$^{-1}$; DFF: Days to 50 % flowering; PH: Plant height; FLA: Flag leaf area; EBT/P: Ear bearing plant$^{-1}$; PL: Panicle length; S/P: Spikelet plant$^{-1}$; SF: Spikelet Fertility; TW: Test weight; BY/P: Biological yield plant$^{-1}$; HI: Harvest index and DM: Days to maturity

**Table 4:** Most promising crosses based on mean performance, heterobeltiosis and standard heterosis for GY/P

| S. N. | Crosses | *per se* Performance | Heterosis over better-parent | Heterosis over SV |
|---|---|---|---|---|
| 1 | IR 68897 A x IR 83614-3 | 13.30 | 97.87 ** | 50.38** |
| 2 | IR 68888 A x IR 83614-673 | 13.11 | 96.99** | 48.15** |
| 3 | IR 58025 A x IR 80416-B | 12.58 | 18.31 ** | 42.16** |
| 4 | IR 68888 A x R-RF-45 | 11.70 | 66.07** | 32.22** |
| 5 | IR 58025 A x IR 79906-B | 11.55 | 57.26 ** | 30.60** |

cultivars in respective groups.

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