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Estimation of heterosis for seed yield and yield attributing traits in rice (*Oryza sativa*) under salinity condition

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Abstract
Realizing the potential of hybrid rice to increase productivity, the present experiment was undertaken with a fixed model i.e. line x tester mating design involving 3 tester (male) and 18 line (female) to identify the best heterotic combinations. The results indicated that the heterobiltiosis for grain yield was significantly superior for 2 hybrids ranging from -59.40 to 27.12%. Standard heterosis ranged from -52.52 to 48.64% and 16 hybrids showed significantly and positive standard heterosis over Narendra User Dhan 2009. Cross, NDRK 50001 × Narendra Usar Dhan 2009 exhibited heterobiltiosis for grain yield per plant, also showed significant heterobiltiosis for plant height, biological yield per plant and 1000 grain weight. This hybrid also recorded high standard heterosis for grain yield per plant along with significant standard heterosis for panicle bearing tillers per plant, spikeltes per panicle, grains per panicle, kernel length, biological yield per plant, 1000 grain weight and L: B Ratio. Cross NDRK 5035 × Narendra Usar Dhan 3 also exhibited significant heterobiltiosis and standard heterosis for grain yield per plant along with other quantitative traits.

Keywords: Heterobiltiosis, standard heterosis and rice

Introduction
Rice (*Oryza sativa* L.) is the most important food crop of India with world ranking first in area and second to China in production. At the current growth of population rice necessity increases dramatically, hence, it is challenging task to certifying food and nutritional security to the country. Therefore, enhancing productivity of rice through novel genetic approaches like hybrid rice was felt necessary. Exploitation of heterosis is considered to be one of the outstanding achievements of plant breeding. The presence of sufficient hybrid vigour is an important pre-requisite for successful production of hybrid varieties. Hybrid vigour in rice was first reported by Jones (1926) [12]. According to Malthus (1989) [24] the food grains increase in arithmetical progressions while the population increases in geometrical progression, thus improved technologies are required to bridge the gap to feed the increasing population. Therefore, for breaking the yield barrier level and make rice cultivation more attractive, it is now necessary to explore alternative approaches. Among the all possible alternatives, heterosis is an important approach for increasing rice production. It has not only contributed to food security, but has also benefited the environment (Duvick, 1999) [9]. The various crop species in which hybrid varieties are used commercially, rice ranks very high. Heterosis has been commercially exploited in rice with a yield advantage of 20-25% over the best pure lines (Rather *et al*., 2001) [35]. Hybrids offer opportunity to break through the yield ceilings of semi dwarf rice varieties. Significant heterosis, heterobiltiosis and standard heterosis have been reported in rice by a number of workers Devarathinam, 1984; Peng and Virmani, 1991; Lokaprakash *et al*., 1992; Watanesk, 1993; Zhang *et al*., 1994; Ali and Khan 1995; Rao *et al*., 1996; Mishra and Pandey, 1998; Dwivedi *et al.,* 1999; Li *et al*., 2002; Faiz *et al*., 2006; Saleem *et al*., 2008; Rashid *et al*., 2007; Rahimi *et al.,* 2010) [8, 31, 23, 54, 59, 2, 25, 10, 11, 32]. The increased yield of rice hybrids alone does not ensure profitability to farmers if their grain quality is not acceptable and if they fetch a low price in the market. Khush *et al*. (1988) [19] studied this subject intensively and concluded that hybridity *per se* did not harm grain quality in terms of physical and chemical characteristics as long as both parents possess acceptable grain quality, hybrid rice breeding programs must give emphasis (if they have not done so in the past) to the critical evaluation of parental lines and hybrids for grain quality before these are released for commercialization. Most of the Asian countries have been able to keep pace between rice production growth rate

and that of population during the last four decades. After a brief review of rice research in India and considering the gains obtained through green revolution technologies, the possibilities and prospects of utilizing the gene revolution technologies are considered for further enhancing the production and productivity of rice for not only ensuring food security but also nutritional security. Natural resources including cultivable land is decreasing day by day. Therefore, rigorous efforts are needed to improve the production of rice in the country by diversifying its cultivation in harsh saline-alkali soils and by developing rice hybrids for specific traits having salt tolerance capability. Therefore, the present investigation was aimed to evaluate rice hybrids for yield, adaptability and grain quality for successful commercial cultivation in salt affected areas.

Materials and Methods

The parental material comprised of 3 tester viz; Narendra Usar Dhan 2, Narendra Usar Dhan 3 and Narendra Usar Dhan 2009 used as male (lines) were crossed with 18 diverse genotypes used as females (testers) in a line x tester mating design in 2013-14. Thus, the resultant 54 hybrids along with their 21 parents and one standard check variety were evaluated in a randomized block design with three replications at Genetics and Plant Breeding Research Farm of N. D. University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad during 2014-15. Each genotype was raised in 3 m long single row plot keeping 20 cm row to row and 15 cm plant to plant spacing. The recommended agronomic practices followed to raise good crop stand. The data were recorded on 10 randomly selected plants from each replication for various quantitative traits viz., days to 50% flowering, plant height (cm), panicle bearing tillers per plant, panicle length (cm), flag leaf area (cm^2), spikelets per panicle, grains per panicles, spikelet fertility (%), 1000 grain weight (g), kernel length (mm), kernel breadth (mm), L:B ratio, biological yield per plant (g), harvest index (%) and grain yield per plant (g). The general reference for data collection was standard evaluation system for rice (Anonymous, 2002; Virmani *et al*., 1997) [5, 50]. The per cent increase or decrease of F_1 hybrids over better parent as well as standard check was calculated to estimate possible heterotic effects for above mentioned parameters (Fonseca and Patterson, 1968) [12].

To estimate significant differences among hybrids and parents, the mean data of each character were subjected to Analysis of Variance (ANOVA) as suggested by Steel and Torrie (1980) [45]. The characters showing significant differences were subjected to heterosis calculation. Deviation of F_1 from its either of the parental values was interpreted by depicting type of gene action operating for controlling the trait. The‘t’ test was applied to determine significant difference of F_1 hybrid means from respective better parent and standard variety values using formulae as reported by Wynne *et al*. (1970) [57].

Results and Discussion

The analysis of variance (Table 1) revealed highly significant differences among treatment, crosses and line × tester for all the characters while, variance among parents were highly significant for most of the traits except kernel breadth and L:B ratio. In the case of parents vs. crosses, most of the characters showed highly significant mean sum of squares except days to 50% flowering, panicle bearing tiller per plant, panicle length, 1000 grain weight, kernel length and grains yield per plant. The mean squares due to lines were significant for the characters plant height, panicle length, 1000 grain weight and grain yield per plant. Janardhanam *et al*. (2000) [16], Panwar (2005) [29], Kumar *et al*. (2006) [20] and Salgotra *et al*. (2009) [40].

Estimation of heterosis

Heterosis was computed as per cent increase or decrease in F_1 value over better parent (heterobeltiosis) and over best commercial variety (standard heterosis) are accessible in Table 2. The relative magnitude of heterosis over better parent and standard variety were studied for 15 characters viz., days to 50% flowering, plant height (cm), panicle bearing tillers per plant, panicle length (cm), flag leaf area (cm^2), spikelets per panicle, grains per panicles, spikelet fertility (%), 1000 grain weight (g), kernel length, kernel breadth, L:B ratio, biological yield per plant (g), harvest index (%) and grain yield per plant (g) in 54 crosses. The nature and magnitude of hybrid vigour differed for different traits in various hybrid combinations. The nine best crosses combinations based on *per se* performance and *sca* effects were given in table 3. The salient results obtained on different aspects and conclusions drawn from the experiment are discussed below.

Days to 50% flowering

Negative heterosis is desirable for days to flowering because this will make the hybrids to mature earlier as compared to parents. Almost all the crosses had either equal or early flowering than the standard variety. When compared to better parent, none of the crosses were observed significant earlier flowering plants while; nineteen crosses were identified for late flowering. The magnitude of heterosis observed over better parent ranged from -6.06 (IR 74095 AC 64 × Narendra Usar Dhan-2009) to 17.41% (NDRK 5092× Narendra Usar Dhan-3) with a mean of 1.57% over the better parent, the magnitude of standard heterosis ranged from -7.07 (LD 183-4×Narendra Usar Dhan-3) to 15.82% (NDRK 5092×Narendra Usar Dhan-3) with mean value of -0.55%. Out of fifty four crosses none of the cross exhibited early flowering over standard variety. Heterosis in both negative and positive directions for days to flowering have also been reported by Peng and Virmani (1991) [31], Murthy and Kulkarni (1996) [26], Dwivedi *et al.* (1999) [10]. Most data have indicated negative heterosis in days to flowering in hybrids reported by Xu and Wang (1980) [58], Fujimaki and Yoshida (1984). These researchers found that days to maturity in hybrids depend on the male plant. Lin and Yuan, (1980) [22] and Tian *et al*. (1980) [46] have reported hybrids having long growth duration.

Plant height (cm)

Semi-dwarf plant height (80-100 cm) is desirable for recording high yield in rice varieties as vigour in plant height may lead to unfavourable grain/straw ratios and reduces optimum yield due to lodging. The minimum amount of heterosis for plant height over better parent and standard variety were recorded by hybrid IR 27579-B-2R × Narendra Usar Dhan-2 (-24.05%) and IR 27579-B-2R × Narendra Usar Dhan-2 (-24.13%), respectively. However, the maximum significant heterosis observed over the better parent was 51.34% (IR SST N 27 × Narendra Usar Dhan-3), while in case of standard heterosis, it was 21.99% (NDRK 50001 × Narendra Usar Dhan-2) and mean heterosis over better parent and standard variety was 6.58 and 3.62% respectively. Five crosses namely, IR 27579-B-2R × Narendra Usar Dhan-2 (-24.05%), NDRK 5016 × Narendra Usar Dhan-3 (-16.57), NDRK 5035 × Narendra Usar Dhan-2 (-13.16), IR 27579-B-

2R × Narendra Usar Dhan-2009 (-12.32) and NDRK 50001 × Narendra Usar Dhan-3 (-9.95%) exhibited significant negative heterobiltiosis, whereas, seven hybrids possessed negative and significant heterosis over standard variety. Best five hybrids were NDRK 5071 × Narendra Usar Dhan-3 (-19.04), NDRK 5035 × Narendra Usar Dhan-2 (-7.62), NDRK 5062 × Narendra Usar Dhan-2 (-6.93), NDRK 5062 × Narendra Usar Dhan-3 (-6.69) and NDRK 5071 × Narendra Usar Dhan-2009 (-5.60), it was obvious from the data (Table 2) that the hybrid combinations have a tendency of dwarfness of trait in most of the cases. Out of fifty four only one (NDRK 5071 × Narendra Usar Dhan 3) of the desirable cross combination were common for both the heterosis, suggesting that heterosis for plant height is cross specific. Present observations are in close agreement with earlier report of several workers (Sharma and Mani, 1989; Peng and Virmani, 1991; Lokaprakash *et al*., 1992; Nuruzzaman *et al*., 2002; Alam *et al.,* 2004) [18, 23, 31, 1].

Panicle bearing tillers per plant

More panicle bearing tillers per plant is believed to be closely associated with high grain yield per plant resulting high productivity. Therefore, the cross combinations with more panicle bearing tillers per plant were to be identified. The significant positive heterosis for this trait was exhibited by 9 and 18 hybrids over better parent and standard variety, respectively. The mean heterosis was observed-10.78% over better parent and 9.12% over standard variety. Further the heterobeltiosis varied from -48.78 (NDRK 5014 × Narendra Usar Dhan-2009) to 39.11% (NDRK 5032 × Narendra Usar Dhan-3) and standard heterosis from -30.46 (NDRK 5081 × Narendra Usar Dhan-3) to 82.33% (NDRK 5092 × Narendra Usar Dhan-2009). As regards the expression of heterobeltiosis, the most promising crosses were NDRK 5032 × Narendra Usar Dhan-3 (39.11%), NDRK 5092 × Narendra Usar Dhan-2009 (28.64%), NDRK 50001 × Narendra Usar Dhan-2 (26.24%), NDRK 5043 × Narendra Usar Dhan 2 (25.89%) and IR 27579-B-2R × Narendra Usar Dhan-2 (24.38%). Considering standard heterosis, the five superior cross combinations were NDRK 5092 × Narendra Usar Dhan-2009 (82.33%), NDRK 5032 × Narendra Usar Dhan-3 (80.65%), NDRK 5032 × Narendra Usar Dhan-2 (51.44%), NDRK 50001 × Narendra Usar Dhan-2 (47. 86) and NDRK 5043 × Narendra Usar Dhan-2 (40.22%). Results for significantly high number of productive tillers per plant are in conformity with those obtained, by Srivastava and Seshu (1982) [44], Govindraj (1983) [14], Viraktamath (1987) [48]. However these findings are in disagreement with the findings of Virmani *et al*. (1981) [49] who reported hybrids possess significantly lower tillers than mid parent, better parent and check variety.

Panicle length

Generally, larger panicle is associated with high number of grains per panicle resulting into higher productivity, therefore, hybrids with positive heterosis for panicle length are desirable. The present study revealed that heterosis for panicle length was relatively low as indicated by mean heterosis of -2.42% over better parent and -6.95% over standard variety. Out of 54 crosses 9 and 4 crosses showed higher panicle length over the better parent and standard variety, respectively, whereas 13 crosses possessed significant negative heterobeltiosis and 33 crosses exhibited negative standard heterosis with shorter panicle. The observed heterobeltiosis values ranged between from -21.69 (NDRK 5062 × Narendra Usar Dhan-2009) to 28.49 % (CSR 28 × Narendra Usar Dhan-3) with mean heterosis of -2.42% and standard heterosis between -26.89 (CSR 23 × Narendra Usar Dhan-3) to 18.34% (NDRK 5092 × Narendra Usar Dhan-2) with a mean heterosis of -6.95%. The five superior cross combinations having heterobeltiosis for panicle length were CSR 28 × Narendra Usar Dhan-3 (28.49%), NDRK 5092 × Narendra Usar Dhan-2 (26.29%), NDRK 5032 × Narendra Usar Dhan-3 (25.82%), NDRK 5071 × Narendra Usar Dhan-3 (22.21%) and NDRK 5092 × Narendra Usar Dhan-3 (20.38%). As regards standard heterosis out of 54 crosses only 4 crosses were found most promising for panicle length were NDRK 5092 × Narendra Usar Dhan-2 (18.34%), CSR 28 × Narendra Usar Dhan-3 (16.45%), NDRK 5032 × Narendra Usar Dhan-3 (14.03%), NDRK 5071 × Narendra Usar Dhan-3 (10.84%) and NDRK 5092 × Narendra Usar Dhan-2009 (10.04%). Similar findings were also reported by Chang *et al*. (1973); Anandakumar and Sreerangasamy (1984) [3]; Vivekanandan (1991) [37]; Lokaprakash *et al*. (1992) [23] and who observed positive as well as negative heterosis for panicle length.

Flag leaf area

For flag leaf area, the hybrids with positive heterosis are desirable. This play an important in the photosynthesis. The range of heterosis for the flag leaf area varied from -41.79 (NDRK 5043 × Narendra Usar Dhan-2) to 63.52% (CSR 28 × Narendra Usar Dhan-3) for BP and for SV ranged from -42.22 (NDRK 5043 × Narendra Usar Dhan-2) to 38.76% (CSR 28 × Narendra Usar Dhan-3). The estimates of mean heterosis over BP and SV were -3.60 and -12.41%, respectively. For flag leaf area, desirable positive and significant heterosis over better parent were exhibited by five hybrids and there were CSR 28 × Narendra Usar Dhan-3 (63.52%), LD 183-4 × Narendra Usar Dhan-2009 (44.87%), IR SST N 27 × Narendra Usar Dhan-2009 (24.47%), CSR 23 × Narendra Usar Dhan-3 (19.47%) and IR 74095 AC 64 × Narendra Usar Dhan-3 (18.46%). Only two hybrids exhibited significant and positive heterosis for flag leaf area over SV i.e., CSR 28 × Narendra Usar Dhan-3 (38.76%) and LD 183-4 × Narendra Usar Dhan-2009 (14.74%).

Spikelets per panicle

For number of spikelets per panicle, the hybrids with positive heterosis are desirable. The lowest estimates of heterosis -49.55% (NDRK 5035 × Narendra Usar Dhan-2) over better parent and -36.95% (IR SST N 27 × Narendra Usar Dhan-3) standard variety were recorded while, maximum heterosis over better parent and standard variety was observed in case of cross IR 74095 AC 64 × Narendra Usar Dhan-3 (41.79%) and IR 74095 AC 64 × Narendra Usar Dhan-3 (52.73%). Out of 54 crosses studied 6 crosses over better parent and 16 crosses over standard variety exhibited significant higher number of spikelets per panicle. Significantly poor spikelets per panicle over the better parent and standard variety were observed in 42 and 21 crosses, respectively. The five superior cross combinations for heterobilitiosis were IR 74095 AC 64 × Narendra Usar Dhan-3 (41.79%), NDRK 5016 × Narendra Usar Dhan-2009 (34.03%), NDRK 5043 × Narendra Usar Dhan-3 (26.34%), CSR 28 × Narendra Usar Dhan-3 (18.97%) and NDRK 5081 × Narendra Usar Dhan-3 (18.04%) while for standard heterosis crosses were IR 74095 AC 64 × Narendra Usar Dhan-3 (52.73%), NDRK 50001 × Narendra Usar Dhan-2 (51.57%), IR 74095 AC 64 × Narendra Usar Dhan-2 (41.09%), NDRK 5043 × Narendra Usar Dhan-3 (36.08%) and CSR 28 × Narendra Usar Dhan-2 (35.74%). Results revealed that three hybrids expressed heterosis in desired direction with significant value when tested against better parent and almost 48 hybrids showed heterobeltiosis in negative. Positive heterosis over better parent and standard variety was reported by Virmani *et al*. (1981, 1982) [49] they concluded that heterosis in yield was primarily due to increased number spikelets per panicle.

Grains per panicle

The number of fertile spikelets directly contributes to the seed yield hence positive heterotic effect would be highly desirable. In the present study, more number of fertile spikelets is closely associated with high yield per plant resulting in high productivity. Therefore, the main interest is to find out the cross combinations with more number of grains per panicle. In the present study, the significant and positive heterosis for this trait was exhibited by 5 and 17 hybrids over better parent and standard variety, respectively. Significant negative heterosis was observed in case of 9 crosses over better parent and in 2 crosses over standard variety with mean heterosis was observed in negative and positive direction for better parent (-15.71 %) and standard variety (3.70%), respectively. The range of heterosis observed over better parent and standard variety was 46.68 (NDRK 5035 × Narendra Usar Dhan-2) to 43.74% (IR 74095 AC 64 × Narendra Usar Dhan-3) and –34.74 (IR SST N 27 × Narendra Usar Dhan-3) to 63.78% (IR 74095 AC 64 × Narendra Usar Dhan-3), respectively. The five superior crosses considering heterobeltiosis were IR 74095 AC 64 × Narendra Usar Dhan-3 (43.74%), NDRK 5016 × Narendra Usar Dhan-2009 (41.79%), NDRK 5043 × Narendra Usar Dhan-3 (27.50%), CSR 28 × Narendra Usar Dhan-3 (20.97%) and NDRK 5081 × Narendra Usar Dhan-3 (10.58%), while, for standard heterosis, IR 74095 AC 64 × Narendra Usar Dhan-3 (63.78%), NDRK 50001 × Narendra Usar Dhan-2 (47.39%), NDRK 5043 × Narendra Usar Dhan-3 (45.27%), IR 74095 AC 64 × Narendra Usar Dhan-2 (42.68%) and NDRK 5016 × Narendra Usar Dhan-2009 (41.79%).

Spikelet fertility

Spikelet fertility is very important in hybrid breeding programme. Since this trait has a direct attitude on the yield, hence manifestation of heterosis in positive direction is desirable for this trait. Out of 54 crosses, only one cross expressed as positive and significant heterobeltiosis and standard heterosis. The range of heterosis over better parent and standard variety varied from -21.96 (NDRK 5071 × Narendra Usar Dhan-3) to 7.68% (LD 183-4 × Narendra Usar Dhan-2) and –19.49 (CSR 28 × Narendra Usar Dhan-2) to 8.97% (NDRK 5081 × Narendra Usar Dhan-2009), with mean heterosis of -1.98 and 2.34%, respectively. As regards heterosis over better parent the best cross was LD 183-4 × Narendra Usar Dhan-2 (7.68%). Results revealed that four hybrids NDRK 5081 × Narendra Usar Dhan-2009 (8.96%), CSR 28 × Narendra Usar Dhan-2009 (8.24%), NDRK 5092× Narendra Usar Dhan-3 (7.93%) and HPU-CIJ × Narendra Usra Dhan 3 (6.08%)) expressed heterosis in desired direction with significant value when tested against better parent and as many as 2 hybrids showed heterosis in negative direction over standard variety. Positive heterosis over better parent and standard variety was reported by Virmani *et al*. (1981) [49] they concluded that heterosis in yield was primarily due to increased fertile spikelets
per panicle.

1000 grain weight

The 1000 grain weight is one of the important common traits which influence the yield. The extent of heterosis was - 44.51 (NDRK 5016×Narendra Usar Dhan 2009) to 17.57% (NDRK 50001 × Narendra Usar Dhan-2009) over better parent with the mean heterosis of –9.64% and from 44.51 (NDRK 5016 × Narendra Usar Dhan-2009) to 17.57% (NDRK 50001 × Narendra Usar Dhan-2009) with the mean heterosis of –9.03% over standard variety. Significantly higher 1000 grain weight was observed only in case of single cross when tested against their better parents and standard variety. The heterosis cross combination in respect of heterobeltiosis for 1000 grain weight was NDRK 50001 × Narendra Usar Dhan-2009 (17.57). The standard heterosis over the check for one promising cross was NDRK 50001 × Narendra Usar Dhan-2009 (17.57). Among 54 crosses, 1 and 23 hybrids showed significant heterobeltiosis over better parent in positive and negative direction, respectively, whereas 1 and 20 hybrids exhibited significant heterosis over standard variety in positive and negative direction. Heterosis with respect to 1000 grain weight in positive and negative direction have also been reported by Virmani *et al*. (1981) [49], Srivastava and Seshu (1982) [44], Viraktamath (1987) [48], Sharma and Mani (1989) [49] and Lokaprakash *et al*. (1992) [23].

Kernel length

Kernel length helps in increasing the quality of rice as well as yield. Heterobiltiosis for kernel length ranged from -20.00 (NDRK 5014 × Narendra Usar Dhan-3) to 14.24% (NDRK 5032 × Narendra Usar Dhan-2009) with mean heterosis of –8.08%. Two crosses showed significant and positive heterobiltiosis and the crosses in order merit were NDRK 5032 × Narendra Usar Dhan-2009 (14.24%) and CSR 28 × Narendra Usar Dhan-2009 (11.86%). Standard heterosis for kernel length ranged from –4.18 (NDRK 5014 × Narendra Usar Dhan-3) to 18.42% (NDRK 5062 × Narendra Usar Dhan-2). The estimate of mean standard heterosis was -5.40%. Thirty hybrids exhibited significant and positive heterosis over standard variety (SV). The crosses in order merit were NDRK 5062×Narendra Usar Dhan-2 (18.42%), NDRK 5032 × Narendra Usar Dhan-2009 (14.24%), CSR 23 × Narendra Usar Dhan-3 (13.90%), NDRK 5030 × Narendra Usar Dhan-3 (13.33%) and NDRK 5035 × Narendra Usar Dhan-3 (12.66%).

Kernel breadth

Kernel breadth also helps in increasing the quality as well as yield. The mean heterosis for kernel breadth over better-parent and SV were –2.12 and -7.40%, respectively. The magnitude of better-parent heterosis varied from -13.53 (IR SST N 27 × Narendra Usar Dhan-3) to 12.54% (CSR 28 × Narendra Usar Dhan-2) while standard heterosis ranged from -21.20 (NDRK 5071 × Narendra Usar Dhan-3) to 3.15% (CSR 28 × Narendra Usar Dhan-2). Out of 54 crosses only thirteen crosses expressing positive and significant heterosis over better parent (BP). Out of them the best five crosses were CSR 28 × Narendra Usar Dhan-2 (12.54%), NDRK 5035 × Narendra Usar Dhan-3 (10.00%), NDRK 5092× Narendra Usar Dhan-3 (8.92%), NDRK 5030 × Narendra Usar Dhan-2 (8.41%) and LD 183-4 × Narendra Usar Dhan-3 (7.54%). Two crosses showed positive and significant heterosis over SV. The cross combinations were CSR 28 × Narendra Usar Dhan-2 (3.15%) and NDRK 5030 × Narendra Usar Dhan-2 (2.33%).

L: B ratio

For L: B ratio, the heterobiltiosis ranged from -30.24 (HPU-CIJ × Narendra Usra Dhan 3) to 15.90% (NDRK 5035 × Narendra Usar Dhan-2009). The mean heterosis was -12.39. Eight hybrids possessed positive and significant heterobiltiosis for L: B ratio. The most promising five crosses for heterosis over BP were NDRK 5035 × Narendra Usar Dhan-2009 (15.90%), IR SST N 27 × Narendra Usar Dhan-2009 (15.28%), NDRK 5032 × Narendra Usar Dhan-2009 (10.96%), NDRK 5081 × Narendra Usar Dhan-2009 (10.82%) and NDRK 5062 × Narendra Usar Dhan2009 (5.73%). The standard heterosis ranged from -5.06 (CSR 28 × Narendra Usar Dhan-2) to 33.60% (NDRK 5071 × Narendra Usar Dhan-3) with over all mean value of 14.43%. Fifty cross combinations showed positive and significant heterosis over standard variety. The most promising five crosses for heterosis over SV were NDRK 5071 × Narendra Usar Dhan-3 (33.60%), NDRK 5016 × Narendra Usar Dhan-2 (31.65%), NDRK 5062 × Narendra Usar Dhan-2 (29.41%), NDRK 50001 × Narendra Usar Dhan-3 (27.96%) and NDRK 5030 × Narendra Usar Dhan-3 (27.92%).

Biological yield

The hybrid, -46.81 (NDRK 5016 × Narendra Usar Dhan-2009) to 49.85% (NDRK 5035 × Narendra Usar Dhan-3) had expressed heterosis for this trait over their better parent while, 44.04 (NDRK 5030 × Narendra Usar Dhan-3) to 52.65% (NDRK 5035 × Narendra Usar Dhan-3) recorded heterosis in case of standard variety. In general, out of 54 hybrids only 8 crosses recorded significantly higher in both, heterobiltiosis and standard heterosis. The top five cross combinations in relation to heterobiltiosis for biological yield were NDRK 5035 × Narendra Usar Dhan-3 (49.85%), NDRK 5016 × Narendra Usar Dhan-3 (41.99%), NDRK 5032 × Narendra Usar Dhan-2 (35.39%), CSR 23 × Narendra Usar Dhan-2 (25.29%) and NDRK 50001 × Narendra Usar Dhan-3 (24.32%) while, for standard heterosis, NDRK 5035 × Narendra Usar Dhan-3 (52.65%), NDRK 5016 × Narendra Usar Dhan-3 (52.64%), CSR 23 × Narendra Usar Dhan-2 (42.43%), NDRK 5032 × Narendra Usar Dhan-2 (40.04%) and NDRK 50001 × Narendra Usar Dhan 3 (38.50%). Significant but negative heterosis was exhibited by 14 and 9 hybrids over better parent and standard variety, respectively. These results are in close agreement with Peng and Virmani (1991) [31] and Virmani *et al*. (1993) [51].

Harvest index

Harvest index which indirectly influences the grain yield through controlling the mechanism of distribution of photosynthates to economic and non-economic organs as such is not a yield component. Therefore, it is an important consideration for genetic improvement. The minimum heterosis for harvest index was -54.39 and –54.75% over better parent and standard variety, respectively in cross NDRK 5016 × Narendra Usar Dhan 3 and NDRK 5016 × Narendra Usar Dhan-3, however, the maximum heterosis was 4.16% over better parent in cross NDRK 5081 × Narendra Usar Dhan-2 and 1.33% over standard variety in cross NDRK 5081 × Narendra Usar Dhan-2. Among 54 cross combinations none of the cross showed significant positive heterobiltiosis and standard heterosis. Fourteen and sixteen crosses showed negative and significant heterobiltiosis and standard heterosis, respectably. The positive heterosis was also reported by Virmani *et al*. (1982) [52] and Peng and Virmani (1991) [31]. The significant and negative heterosis over better parent for harvest index was also reported by Nijaguna and Mahadevappa (1982) [27] and over standard variety by Sarwagi and Srivastava (1988) [44].

Grain yield

The grain yield is very complex trait. It is multiplicative end product of several basic components of yield (Grafius, 1959). A number of workers have reported wide range of variation in the expression of heterosis for this character (Kaushik and Sharma, 1986; Sahai *et al*., 1987; Virmani *et al*., 1981; Govindraj, 1983; Tseng and Huang, 1987; Sampath *et al*., 1989; Peng and Virmani, 1991; Vivekanandan, 1991; Lokaprakash *et al*., 1992; Wilfred and Prasad, 1992; Ali and Khan, 1995) [23, 2, 49, 50, 14, 18, 31]. From practical point of view, heterosis over standard variety is more relevant. Virmani *et al*. (1981) [49] reported as high standard heterosis as 27 and 34% during wet and dry seasons, respectively. They further suggested that a yield advantage of 20-30% over best available standard variety should be sufficient to encourage farmers to take-up hybrid rice cultivation. Present investigation suggested that the heterosis over better-parent varied from -59.40 (NDRK 5030 × Narendra Usar Dhan-3) to 27.12% (NDRK 5035 × Narendra Usar Dhan-3) with mean heterosis of -14.84% for grain yield per plant. Only two crosses *i.e.,* NDRK 5035 × Narendra Usar Dhan-3 (27.12%) and NDRK 50001 × Narendra Usar Dhan-2009 (11.76%) showed significant and positive heterobeltiosis for grain yield. The standard heterosis for grain yield per plant ranged from -52.52 (NDRK 5030 × Narendra Usar Dhan-3) to 48.64% (NDRK 5035 × Narendra Usar Dhan-3) with mean of -0.42%. Out of 54 crosses, sixteen hybrids showed positive and significant heterosis over SV and the best five crosses among them were NDRK 5035 × Narendra Usar Dhan-3 (48.64), NDRK 50001 × Narendra Usar Dhan-2009 (38.67), CSR 23 × Narendra Usar Dhan-2 (20.71), LD 183-4 × Narendra Usar Dhan-2 (17.92) and LD 183-4 × Narendra Usar Dhan-2009 (17.19). These findings were in close agreement with the earlier findings (Watanesk, 1993; Patel *et al*., 1994; Zhang *et al*., 1994; Rao *et al*., 1996; Mishra and Pandey, 1998; Nuruzzaman *et al*., 2002; Li *et al*., 2002; Faiz *et al*., 2006; Saleem *et al*., 2008; Bagheri and Jelodar, 2010; Rahimi *et al*., 2010) [54, 59, 25, 11, 32]. Reddy *et al*. (1984) [36]. China has shown 20-30% higher yield potential for hybrids in large-scale production plots, with wider adaptability than conventionally bred varieties (Li, 1977; Lin and Yuan, 1980; Wu *et al*., 1980) [22].

In table 3, the cross NDRK 5035 × Narendra Usar Dhan-3 showed highest mean performance (32.02g), heterobiltiosis (27.12%), standard heterosis (48.64%) over Narendra Usar Dhan-2009 with SCA effect -8.28 for grain yield per plant. Second cross (CSR 23 × Narendra Usar Dhan-2) among saline condition exhibited high mean performance (26.00 g) among the crosses with the heterobiltiosis of 3.59%, standard heterosis (20.71%) and SCA effect (-2.04). The LD 183-4 × Narendra Usar Dhan-2 showed highest mean performance (25.40 g), heterobiltiosis (1.20%), standard heterosis (17.92 %) over Narendra Usar Dhan-2009 with SCA effect -0.07 for grain yield per plant and at fifth rank cross LD 183 4 × Narendra Usar Dhan-2009 showed mean performance (25.24), heterobiltiosis (1.18%), standard heterosis (17.19 %) over Narendra Usar Dhan-2009 and SCA effect 0.31 for grain yield per plant under saline condition. Similar finding were also reported by Anil *et al.,* (2013) [14] and Reddy *et al.* (2013) [37].

The crosses mentioned above also showed highly significant and positive SCA effects for grain yield per plant as well as for some other yield contributing characters. These crosses should be tested and evaluated in adaptive trails to find out their feasibility for recommendation for use as hybrid verities in respective groups for the target environments.

Table 1: Analysis of variance for 15 characters of line × tester set of crosses and their parents in rice

Characters	Sources of variation								
	Replications	Treatments	Parents	Parents *vs* Crosses	Crosses	Lines	Testers	Lines × testers	Error
d.f.	2	74	20	1	53	17	2	34	148
Days to 50% flowering	8.62	39.71**	20.31**	0.01	47.78**	38.96	130.36	47.33**	7.63
Plant height (cm)	4.84	163.66**	110.16**	686.59**	173.98**	260.66*	53.17	137.74**	3.70
Panicle bearing tillers per plant	0.30	5.38**	6.17**	1.77	5.15**	3.58	3.01	6.06**	0.59
Panicle length (cm)	1.78	15.46**	9.52**	3.08	17.93**	26.51*	14.67	13.84**	1.40
Flag Leaf area (cm^2)	1.06	41.64**	23.18**	43.65**	48.56**	48.37	42.80	49.00**	2.45
Spikelets per panicle	1.70	2146.21**	1293.56**	6185.30**	2391.75**	2395.73	2919.79	2358.70**	7.11
Grains per panicle	7.37	1789.41**	1214.18**	2837.40**	1986.70**	1733.99	2645.87	2074.29**	7.99
Spikelet fertility (%)	6.76	62.52**	26.41**	120.06**	75.07**	78.01	14.30	77.17**	4.99
1000- grains weight (g)	0.53	21.96**	32.74**	4.54	18.22**	25.60*	6.20	15.24**	1.45
Kernel length (mm)	0.01	0.45**	0.23	0.06	0.55**	0.44	0.95	0.57**	0.17
Kernel breadth (mm)	0.13**	0.05**	0.03*	0.57**	0.05**	0.03	0.03	0.07**	0.02
L:B ratio	0.24*	0.21**	0.11*	0.73**	0.24**	0.17	0.43	0.26**	0.07
Biological yield per plant (g)	5.61	268.72**	172.51**	235.94**	305.64**	327.52	504.84	282.98**	5.22
Harvest-index (%)	3.41	101.38**	65.67**	88.73**	115.09**	141.73	33.40	106.58**	4.92
Grains yield per plant(g)	2.48	50.56**	46.36**	0.65	53.09**	98.45*	31.00	31.71**	1.36

*** Significant at 5% and 1% probability levels, respectively

Table 2: Extent of per cent heterosis over better parent (BP) and standard varieties (SV) for 15 characters in rice

S. No	Crosses	Days to 50% flowering		Plant height (cm)		Panicle bearing tillers per plant		Panicle length (cm)		Flag leaf area (cm^2)	
		BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
1	NDRK 5014 × Narendra Usar Dhan 2	2.05	0.67	4.61	2.77	-31.55**	3.74	-0.21	-5.22	-13.79*	-14.43
2	NDRK 5016 × Narendra Usar Dhan 2	1.71	0.34	2.52	6.52	-8.29	12.14	-10.36**	-16.00**	-26.19**	-26.73**
3	NDRK 5030 × Narendra Usar Dhan 2	4.21	0.00	-4.42	2.01*	0.92	12.41	-19.99**	-13.72**	-24.96**	-19.09**
4	NDRK 5032 × Narendra Usar Dhan 2	2.73	1.35	5.80	-0.17	16.61**	51.44**	-6.14	-12.05**	9.96	9.14
5	NDRK 5035 × Narendra Usar Dhan 2	2.39	1.01	-13.16**	-7.62*	-13.19**	-3.31	-5.79	-11.71**	-27.74**	-28.28**
6	NDRK 5043 × Narendra Usar Dhan 2	3.50	-0.34	19.22**	8.16**	25.89**	40.22**	0.13	-6.17	-41.79**	-42.22**
7	NDRK 5062 × Narendra Usar Dhan 2	2.39	1.01	1.41	-6.93**	-31.21**	-8.24	-7.71	-13.52**	-11.75	-12.41
8	NDRK 5071 × Narendra Usar Dhan 2	-2.73	-4.04	23.30**	9.46**	8.03	20.33**	-6.10	-12.01**	-11.46	-12.12
9	NDRK 5081 × Narendra Usar Dhan 2	-2.39	-3.70	4.34	8.04	-13.53**	-3.69	-10.07*	-15.73**	-18.21**	-18.82**
10	NDRK 5092 × Narendra Usar Dhan 2	-1.88	-3.20	0.28	6.30*	-6.47	4.17	26.29**	18.34**	-6.66	-7.35
11	NDRK 50001 × Narendra Usar Dhan 2	1.71	0.34	21.28**	21.99	26.24**	47.86**	0.00	-6.29	-22.04**	-22.62**
12	CSR 23 × Narendra Usar Dhan 2	-3.07	-4.38	1.19	3.23	12.02*	24.77**	8.84*	1.99	-17.76**	-18.37**
13	CSR 28 × Narendra Usar Dhan 2	15.71**	1.68	7.02	9.01	-30.61**	-22.71**	-0.49	-6.75	-20.30**	-20.90**
14	IR SSTN 27 × Narendra Usar Dhan 2	-4.50	-7.07	33.09**	3.84**	-14.99**	-5.31	-7.26	-13.09**	-1.60	-2.33
15	IR 74095 AC 64 × Narendra Usar Dhan 2	-1.02	-2.36	12.23**	5.93	-11.53*	22.66**	-0.89	-7.12	-8.86	-9.54
16	IR 27579-B-2R × Narendra Usar Dhan 2	8.30	1.01	-24.05**	-24.13	24.38**	38.54**	-4.07	-10.11**	-7.03	-7.72
17	HPU-CIJ × Narendra Usar Dhan 2	0.00	-1.35	-1.47	4.49*	-7.59	2.93	-9.40*	-15.10**	-14.59*	-15.22*
18	LD 183-4 × Narendra Usar Dhan 2	-0.69	-3.70	1.14	0.41	-17.08**	-7.64	-2.79	-8.90*	1.95	1.20
19	NDRK 5014 Narendra Usar Dhan 3	7.07	7.07	-4.87	-6.55	-30.40**	5.47	-3.81	-8.63*	-4.70	-9.48
20	NDRK 5016 × Narendra Usar Dhan 3	0.00	-0.34	-16.57**	-13.31	-25.58**	-9.00	2.41	-6.02	-4.36	-12.23
21	NDRK 5030 × Narendra Usar Dhan 3	4.56	0.34	-4.69	0.94*	8.36	8.94	-16.57**	-10.04**	-27.22**	-21.52**
22	NDRK 5032 × Narendra Usar Dhan 3	1.66	3.37	2.44	-3.35	39.11**	80.65**	25.82**	14.03**	-3.20	-14.93*
23	NDRK 5035 × Narendra Usar Dhan 3	-1.00	-0.34	4.66	10.84*	3.92	4.82	9.56*	0.68	1.23	-6.97
24	NDRK 5043 × Narendra Usar Dhan 3	-2.80	-6.40	6.22	-3.63**	-15.92**	-11.54	-7.81	-16.45**	-17.65*	-27.76**
25	NDRK 5062 × Narendra Usar Dhan 3	0.99	2.69	1.68	-6.69**	-31.13**	-8.13	-3.84	-12.85**	6.43	-9.69
26	NDRK 5071 × Narendra Usar Dhan 3	-3.38	-3.70	-8.80**	-19.04**	14.18*	14.80	22.21**	10.84**	-12.49	-20.63**
27	NDRK 5081 × Narendra Usar Dhan 3	-2.33	-1.35	-4.63	-1.25	-32.51**	-30.46**	-0.30	-9.64**	10.78	-6.00
28	NDRK 5092× Narendra Usar Dhan 3	17.41**	15.82**	10.11**	16.62*	10.19	10.79	20.38**	9.10**	11.96	-5.00
29	NDRK 50001 × Narendra Usar Dhan 3	-4.65	-3.37	-9.95**	-9.42	-6.89	9.05	-0.63	-9.61*	3.55	-5.81
30	CSR 23 × Narendra Usar Dhan 3	-1.34	-1.01	3.12	5.20	-8.25	-7.75	-19.34**	-26.89**	19.74*	2.28
31	CSR 28 × Narendra Usar Dhan 3	12.64*	-1.01	11.72**	13.79	-8.25	-7.75	28.49**	16.45**	63.52**	38.76**
32	IR SST N 27 × Narendra Usar Dhan 3	-1.04	-3.70	51.34**	18.08**	18.83**	30.68**	4.14	-5.62	12.96	-4.15
33	IR 74095 AC 64 × Narendra Usar Dhan 3	-4.32	-3.03	23.50**	16.58	-14.97**	17.89**	5.02	-4.82	18.46*	2.02
34	IR 27579-B-2R × Narendra Usar Dhan 3	6.86	-0.34	8.50**	8.38	1.33	11.44	8.30*	-1.85	-13.63	-26.71**
35	HPU-CIJ × Narendra Usra Dhan 3	-0.66	1.01	9.42**	15.88*	-12.86*	-10.35	0.22	-9.17*	-4.27	-17.15**

36	LD 183-4 × Narendra Usar Dhan 3	-4.17	-7.07	7.70*	6.92	24.20**	24.88**	5.41	-4.47	7.73	-8.59
37	NDRK 5014 × Narendra Usar Dhan 2009	2.02	2.02	10.16**	8.22	-48.78**	-22.38**	-10.31**	-10.31**	2.84	-2.32
38	NDRK 5016 × Narendra Usar Dhan 2009	1.35	1.01	10.38**	10.38	-36.41**	-9.86	-7.63*	-7.63*	-2.89	-10.88
39	NDRK 5030 × Narendra Usar Dhan 2009	6.67	2.36	4.14	4.14	-31.05**	-2.28	-13.22**	-6.43	-15.72**	-9.12
40	NDRK 5032 × Narendra Usar Dhan 2009	0.34	0.34	10.22**	4.00	-19.16**	14.58*	7.10	7.10	-23.24**	-32.54**
41	NDRK 5035 × Narendra Usar Dhan 2009	0.00	0.00	2.23	2.23	-24.74**	6.67	-11.82**	-11.82**	10.94	1.96
42	NDRK 5043 × Narendra Usar Dhan 2009	3.85	0.00	7.61*	-2.38**	-35.11**	-8.02	-11.51**	-11.51**	5.49	-7.47
43	NDRK 5062 × Narendra Usar Dhan2009	0.00	0.00	12.49**	3.24**	-27.23**	3.14	-21.69**	-21.69**	-0.92	-21.52**
44	NDRK 5071 × Narendra Usar Dhan 2009	1.35	1.01	6.33	-5.60**	-22.52**	9.81	-6.29	-6.29	-14.60*	-22.55**
45	NDRK 5081 × Narendra Usar Dhan 2009	-2.69	-2.69	15.88**	15.88	-30.29**	-1.19	-17.27**	-17.27**	-3.58	-22.88**
46	NDRK 5092 × Narendra Usar Dhan 2009	0.00	-1.35	8.66**	8.66	28.64**	82.33**	10.04**	10.04**	6.42	-14.80*
47	NDRK 50001 × Narendra Usar Dhan 2009	0.00	0.00	15.66**	15.66	-2.98	37.51**	-8.02*	-8.02*	-14.17	-21.93**
48	CSR 23 × Narendra Usar Dhan 2009	1.01	1.01	9.78**	9.78	-36.44**	-9.92	-16.27**	-16.27**	-4.93	-18.79**
49	CSR 28 × Narendra Usar Dhan 2009	8.81	-4.38	7.44*	7.44	-38.01**	-12.14	-6.43	-6.43	2.31	-18.97**
50	IR SST N 27 × Narendra Usar Dhan 2009	0.35	-2.36	47.24**	14.88**	-40.54**	-15.72*	-10.04**	-10.04**	24.47**	-0.19
51	IR 74095 AC 64 × Narendra Usar Dhan 2009	-6.06	-6.06	2.59	-3.16	-33.77**	-6.12	-6.64	-6.64	-9.93	-22.44**
52	IR 27579-B-2R × Narendra Usar Dhan 2009	9.39	2.02	-12.32**	-12.41	-18.32**	15.77*	-9.24*	-9.24*	2.04	-16.99**
53	HPU-CIJ × Narendra Usra Dhan 2009	2.36	2.36	9.61**	9.61	-18.74**	15.18*	-11.30**	-11.30**	-10.06	-22.16**
54	LD 183-4 × Narendra Usar Dhan 2009	2.08	-1.01	2.10	1.36	-8.07	30.30**	-3.61	-3.61	44.87**	14.74*
	Range of heterosis MIN	-6.06	-7.07	-24.05	-24.13	-48.78	-30.46**	-21.69	-26.89	-41.79	-42.22
	MAX	17.41	15.82	51.34	21.99	39.11	82.33**	28.49	18.34	63.52	38.76
	Mean heterosis (%)	1.57	-0.55	6.58	3.62	-10.78	9.12	-2.42	-6.95	-3.60	-12.41
	No. of crosses with significant positive heterosis	3	0	24	13	9	18	9	4	5	2
	No. of crosses with significant negative heterosis	0	0	6	7	30	4	12	33	15	26

S. No	**Crosses**	**Spikelets per panicle**		**Grains per panicle**		**Spikelet fertility (%)**		**1000 seed weight (g)**		**Kernel length (mm)**	
		BP	**SV**	**BP**	**SV**	**BP**	**SV**	**BP**	**SV**	**BP**	**SV**
1	NDRK 5014 × Narendra Usar Dhan 2	-18.15**	23.15**	-13.67**	28.92**	1.00	4.68	-4.44	-2.95	-10.56**	8.14**
2	NDRK 5016 × Narendra Usar Dhan 2	-35.12**	-2.39	-30.60**	3.64	5.26	6.21	-0.48	1.07	-7.94**	11.30**
3	NDRK 5030 × Narendra Usar Dhan 2	-40.06**	-9.81**	-39.46**	-9.60*	-4.41	0.25	-12.23**	-4.91	-7.66**	11.64**
4	NDRK 5032 × Narendra Usar Dhan 2	-27.37**	9.28**	-22.52**	15.70**	1.63	5.90	-7.63	-6.19	-17.38**	-0.11
5	NDRK 5035 × Narendra Usar Dhan 2	-49.55**	-24.10**	-46.68**	-20.37**	5.62	4.95	-21.23**	-20.00**	-13.36**	4.75*
6	NDRK 5043 × Narendra Usar Dhan 2	-40.51**	-10.50**	-40.62**	-11.32*	-0.19	-0.90	-36.20**	-35.21**	-13.64**	4.41*
7	NDRK 5062 × Narendra Usar Dhan 2	-43.19**	-14.53**	-40.09**	-10.53*	-0.13	4.72	-8.25*	-6.83	-2.06	18.42**
8	NDRK 5071 × Narendra Usar Dhan 2	-24.13**	14.15**	-29.36**	5.49	-12.14**	-7.59	-7.64	-6.21	-14.95**	2.82
9	NDRK 5081 × Narendra Usar Dhan 2	-36.06**	-3.81	-39.26**	-9.30*	-13.79**	-5.71	-26.85**	-25.72**	-10.56**	8.14**
10	NDRK 5092 × Narendra Usar Dhan 2	-30.78**	4.14	-27.46**	8.33	-1.85	4.11	3.60	5.21	-14.11**	3.84
11	NDRK 50001 × Narendra Usar Dhan 2	0.75	51.57**	-1.30	47.39**	-7.42*	-2.74	0.94	2.51	-10.47**	8.25**
12	CSR 23 × Narendra Usar Dhan 2	-34.10**	-0.85	-37.70**	-6.97	-11.16**	-6.17	-3.87	-2.38	-14.95**	2.82
13	CSR 28 × Narendra Usar Dhan 2	-9.78**	35.74**	-26.79**	9.33*	-21.94**	-19.49**	-14.59**	-13.26**	-18.97**	-2.03
14	IR SSTN 27 × Narendra Usar Dhan 2	-32.34**	1.80	-28.07**	7.42	4.49	5.54	0.61	2.17	-12.24**	6.10**
15	IR 74095 AC 64 × Narendra Usar Dhan 2	-6.22**	41.09**	-4.45	42.68**	1.85	1.12	-8.35*	-6.93	-19.07**	-2.15
16	IR 27579-B-2R × Narendra Usar Dhan 2	-34.78**	-1.87	-35.29**	-3.37	-9.65**	-1.51	-2.40	-0.88	-13.83**	4.18*
17	HPU-CIJ × Narendra Usar Dhan 2	-31.81**	2.59	-28.18**	7.25	0.54	4.55	-5.08	-3.60	-12.24**	6.10**
18	LD 183-4 × Narendra Usar Dhan 2	-39.13**	-8.42*	-34.43**	-2.08	7.68*	6.91	3.05	4.65	-18.50**	-1.47
19	NDRK 5014 Narendra Usar Dhan 3	-19.77**	-13.58**	-27.62**	-17.53**	-9.74**	-4.54	-27.30**	-27.88**	-20.00**	-4.18*
20	NDRK 5016 × Narendra Usar Dhan 3	-9.03**	-2.01	-8.16*	4.64	0.95	6.77	-13.11**	-13.79**	-14.15**	2.82
21	NDRK 5030 × Narendra Usar Dhan 3	-18.36**	-12.07**	-20.32**	-9.21*	-2.37	3.27	-15.68**	-8.65*	-5.38**	13.33**
22	NDRK 5032 × Narendra Usar Dhan 3	-13.21**	-6.52	-13.87**	-1.86	-0.75	4.98	3.85	3.02	-17.36**	-1.02
23	NDRK 5035 × Narendra Usar Dhan 3	-13.41**	-6.73	-21.23**	-10.25*	-9.04*	-3.80	6.18	5.34	-5.94**	12.66**
24	NDRK 5043 × Narendra Usar Dhan 3	26.34**	36.08**	27.50**	45.27**	0.92	6.74	-27.07**	-27.65**	-14.72**	2.15
25	NDRK 5062 × Narendra Usar Dhan 3	-16.32**	-1.05	-17.79**	1.87	-2.66	2.96	-8.23	-8.96*	-10.38**	7.34**
26	NDRK 5071 × Narendra Usar Dhan 3	-12.04**	-5.26	-31.36**	-21.79**	-21.96**	-17.46**	-1.63	-2.40	-12.17**	5.20**
27	NDRK 5081 × Narendra Usar Dhan 3	18.04**	29.03**	10.58**	32.22**	-6.31	2.47	-11.13**	-11.84**	-16.98**	-0.56
28	NDRK 5092× Narendra Usar Dhan 3	-26.35**	1.65	-25.06**	9.70	1.75	7.93*	-3.24	-4.00	-8.30**	9.83**
29	NDRK 50001 × Narendra Usar Dhan 3	-9.47**	10.29**	-8.89*	16.61**	-0.04	5.73	-6.17	-6.91	-12.26**	5.08**
30	CSR 23 × Narendra Usar Dhan 3	-14.99**	-8.43*	-13.65**	-1.62	1.56	7.42	-4.09	-4.85	-4.91**	13.90**
31	CSR 28 × Narendra Usar Dhan 3	18.97**	28.15**	20.97**	37.83**	1.68	7.55	0.58	-0.22	-16.60**	-0.11
32	IR SST N 27 × Narendra Usar Dhan 3	-41.46**	-36.95**	-42.72**	-34.74**	-2.15	3.50	-26.63**	-27.21**	-15.28**	1.47
33	IR 74095 AC 64 × Narendra Usar Dhan 3	41.79**	52.73**	43.74**	63.78**	1.37	7.22	-5.72	-6.47	-10.66**	7.01**
34	IR 27579-B-2R × Narendra Usar Dhan 3	-36.11**	-31.18**	-39.41**	-30.97**	-7.96*	0.33	-1.39	-2.17	-13.63**	3.45

35	HPU-CIJ × Narendra Usra Dhan 3	0.47	8.22*	2.35	16.62**	1.88	7.75*	-6.26	-7.00	-16.04**	0.56
36	LD 183-4 × Narendra Usar Dhan 3	-2.28	5.26	-7.05	5.90	-4.85	0.64	-2.35	-3.12	-9.25**	9.72**
37	NDRK 5014 × Narendra Usar Dhan 2009	-7.95**	-7.95*	-5.10	-2.12	2.59	6.32	-8.05	-8.05	8.59**	8.59**
38	NDRK 5016 × Narendra Usar Dhan 2009	34.03**	34.03**	41.79**	41.79**	4.86	5.80	-44.51**	-44.51**	2.34	8.70**
39	NDRK 5030 × Narendra Usar Dhan 2009	7.65**	7.65*	9.71*	9.71*	-2.79	1.95	-13.46**	-6.25	-12.82**	2.94
40	NDRK 5032 × Narendra Usar Dhan 2009	-1.19	5.25	-1.17	9.70*	0.03	4.23	-12.31**	-12.31**	14.24**	14.24**
41	NDRK 5035 × Narendra Usar Dhan 2009	-12.73**	-8.20*	-16.04**	-12.25**	-4.41	-4.41	-4.10	-4.10	10.73**	10.73**
42	NDRK 5043 × Narendra Usar Dhan 2009	-29.28**	-29.28**	-28.78**	-28.78**	0.68	0.68	-20.17**	-20.17**	-2.65	7.80**
43	NDRK 5062 × Narendra Usar Dhan2009	-4.38	13.07**	-2.81	20.44**	1.58	6.51	-12.87**	-12.87**	0.68	0.68
44	NDRK 5071 × Narendra Usar Dhan 2009	-16.42**	-16.42**	-13.50**	-13.50**	-1.64	3.46	-38.55**	-38.55**	-12.74**	4.52*
45	NDRK 5081 × Narendra Usar Dhan 2009	-18.32**	-10.71**	-18.63**	-2.70	-0.38	8.97*	-3.89	-3.89	5.40**	12.54**
46	NDRK 5092 × Narendra Usar Dhan 2009	-27.48**	0.08	-27.12**	6.68	0.52	6.62	-24.09**	-24.09**	6.78**	6.78**
47	NDRK 50001 × Narendra Usar Dhan 2009	-12.22**	6.94*	-13.48**	10.74*	-1.42	3.56	17.57**	17.57**	2.28	6.33**
48	CSR 23 × Narendra Usar Dhan 2009	-21.16**	-16.84**	-20.66**	-11.71*	0.55	6.20	-13.56**	-13.56**	-9.07**	-1.47
49	CSR 28 × Narendra Usar Dhan 2009	-10.90*	-7.25*	-6.57	0.31	4.88	8.18*	3.05	3.05	11.86**	11.86**
50	IR SST N 27 × Narendra Usar Dhan 2009	-13.39**	-13.39**	-11.19*	-11.19*	1.51	2.53	-25.70**	-25.70**	6.35**	7.91**
51	IR 74095 AC 64 × Narendra Usar Dhan 2009	-15.12**	-15.12**	-16.77**	-16.77**	-1.91	-1.91	-6.09	-6.09	1.81	1.81
52	IR 27579-B-2R × Narendra Usar Dhan 2009	5.48	5.48	5.82	12.62**	-2.03	6.80	0.46	0.46	-1.81	-1.81
53	HPU-CIJ × Narendra Usra Dhan 2009	-18.68**	-18.68**	-19.06**	-15.85**	-0.49	3.48	-17.64**	-17.64**	4.07	4.07*
54	LD 183-4 × Narendra Usar Dhan 2009	-9.60**	-9.60**	-6.64	-6.64	3.30	3.30	3.51	3.51	-15.89**	1.69
	Range of heterosis MIN	-49.55	-36.95	-46.68	-34.74	-21.96	-19.49	-44.51	-44.51	-20.00	-4.18
	MAX	41.79	52.73	43.74	63.78	7.68	8.97	17.57	17.57	14.24	18.42
	Mean heterosis (%)	-15.39	1.37	-15.71	3.70	-1.98	2.34	-9.64	-9.03	-8.08	5.40
	No. of crosses with significant positive heterosis	6	16	5	17	1	4	1	1	2	30
	No. of crosses with significant negative heterosis	42	21	37	17	9	2	23	20	39	1

S. No	cross	Kernel breadth (mm)		L:B ratio		Biological yield per plant (g)		Harvest index (%)		Grains yield per plant (g)	
		BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
1	NDRK 5014 × Narendra Usar Dhan 2	-2.09**	-10.26**	-8.57**	20.77**	-2.55	1.28	-2.33	-4.98	-4.38	11.42**
2	NDRK 5016 × Narendra Usar Dhan 2	-7.46**	-15.18**	-0.33	31.65**	-25.11**	-19.49**	-43.17**	-44.71**	-55.84**	-48.55**
3	NDRK 5030 × Narendra Usar Dhan 2	8.41**	2.33**	-17.46**	9.02**	-6.41	-3.19	-15.39*	-15.14*	-18.58**	-5.12
4	NDRK 5032 × Narendra Usar Dhan 2	-1.94**	-10.12**	-13.96**	13.65**	35.39**	40.04**	-53.00**	-54.28**	-36.39**	-25.87**
5	NDRK 5035 × Narendra Usar Dhan 2	-1.79**	-9.99**	-11.82**	16.48**	-0.14	3.29	-8.16	-10.65	-8.23*	6.93
6	NDRK 5043 × Narendra Usar Dhan 2	5.07**	-3.69**	-18.85**	8.40**	-31.97**	-29.64**	-0.43	-3.13	-32.27**	-21.08**
7	NDRK 5062 × Narendra Usar Dhan 2	-2.05**	-8.62**	-2.03	29.41**	-33.08**	-30.78**	-21.05**	-22.73**	-46.93**	-38.16**
8	NDRK 5071 × Narendra Usar Dhan 2	-9.85**	-17.37**	-9.44**	25.98**	-4.10	-0.81	-2.50	-5.15	-6.51	8.94*
9	NDRK 5081 × Narendra Usar Dhan 2	-4.86**	-8.89**	-9.84**	19.09**	-14.60*	-11.67	4.16	1.33	-11.02**	3.68
10	NDRK 5092 × Narendra Usar Dhan 2	-2.54**	-10.67**	-12.05**	16.18**	0.00	3.43	0.63	-2.10	0.57	17.19**
11	NDRK 50001 × Narendra Usar Dhan 2	-5.52**	-11.08**	-7.34**	22.39**	2.19	13.85*	-8.89	-11.37	-5.90	16.76**
12	CSR 23 × Narendra Usar Dhan 2	-5.37**	-13.27**	-10.14**	18.69**	25.29**	42.43**	-24.60**	-26.64**	3.59	20.71**
13	CSR 28 × Narendra Usar Dhan 2	12.54**	3.15**	-28.13**	-5.06**	-10.87	-7.81	-9.29	-10.35	-17.93**	-4.36
14	IR SSTN 27 × Narendra Usar Dhan 2	-12.47**	-9.71**	-11.31**	17.15**	-5.52	-2.27	0.40	-1.56	-4.38	11.42**
15	IR 74095 AC 64 × Narendra Usar Dhan 2	0.00	-8.34**	-19.07**	6.90**	-3.96	-0.66	-9.29	-11.75	-12.99**	1.39
16	IR 27579-B-2R × Narendra Usar Dhan 2	-4.12**	-10.81**	-11.63**	16.73**	3.93	7.50	-3.92	-6.52	-0.40	16.06**

Table 3: Most promising crosses based on *per se* performance, heterobeltiosis, standard heterosis and SCA effect for grains yield per plant

S. No.	Crosses	*per se* Performance	Heterosis over better-parent	Heterosis over Standard variety	SCA effect
1	NDRK 5035 × Narendra Usar Dhan 3	32.02	27.12	48.64	-8.28
2	CSR 23 × Narendra Usar Dhan 2	26.00	3.59	20.71	-2.04
3	LD 183-4 × Narendra Usar Dhan 2	25.40	1.20	17.92	-0.07
4	LD 183-4 × Narendra Usar Dhan 2009	25.24	1.18	17.19	0.31
5	NDRK 5092 × Narendra Usar Dhan 2	25.24	0.57	17.19	1.00
6	NDRK 50001 × Narendra Usar Dhan 2	25.15	-5.90	16.76	1.04
7	IR 27579-B-2R × Narendra Usar Dhan 2	25.00	-0.40	16.06	1.96
8	CSR 28 × Narendra Usar Dhan 2009	24.67	-1.14	14.52	0.34
9	HPU-CIJ × Narendra Usra Dhan 2009	24.67	-1.14	14.52	-1.77

References

1. Alam MF, Khan MR, Nuruzzaman M, Parvez S, Swaraz AM, Alam I, *et al*. Genetic basis of heterosis and inbreeding depression in rice (*Oryza sativa* L.). J. Zhejiang Univ. Sci. 2004; 5:406-411.
2. Ali SS, Khan GM. IRRI rice hybrids evaluated at Rice Research Institute (RRI), Kala Shah Kaku. Pak. IRRN. 1995; 18:17-18.
3. Anandakumar CR, Sreerangasamy SR. Studies on heterosis in rice hybrid involving different dwarfs. Madras Agric. J. 1984; 71:189-190.
4. Anil Kumar, Mani SC. Nature and magnitude of heterosis and inbreeding depression for grain yield and yield attributing traits in basmati rice (Oryza sativa L.). Pantnagar Journal of Research. 2013; 11(1):50-57.
5. Anonymous. Standard Evaluation System for Rice. 5th Edn, IRRI, Manila, Los Banos, Philippines, 2002.
6. Bagheri N, Jelodar NB. Heterosis and combining ability analysis for yield and related-yield traits in hybrid rice. Int. J. Biol. 2010; 2:222-231.
7. Chang TT, Li CC, Tagumpay O. Genetic correlation, heterosis, inbreeding depression and transgressive segregation of agronomic traits in a diallel cross of rice (*Oryza sativa* L.) cultivars. Bot. Bull. Acad. Sin. Taipei. 1973; 14:83-93.
8. Devarathinam AA. Study of heterosis in relation to combining ability and per se performance in rainfed rice. Madras Agric. J. 1984; 71:568-572.

9. Duvick DN. Heterosis: Feeding People and Protecting Natural Resources. In: The Genetics and Exploitation of Heterosis in Crops, Coors, J.G. and S. Pandey (Eds.). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA. 1999, 19-29.
10. Dwivedi DK, Pandey MP, Pandey SK, Rongbai Li. Heterosis in inter and intra sub-specific crosses over three environments in rice. Euphytica. 1999; 99:155-165.
11. Faiz FA, Sabar M, Awan TH, Tjaz M, Manzoor Z. Heterosis and combining ability analysis in basmati rice hybrids. J. Anim. PI. Sci. 2006; 16:56-59.
12. Fonseca S, Patterson FL. Hybrid vigor in a seven-parent diallel cross in common winter wheat (*Triticum aestivum* L.). Crop Sci. 1968; 8:85-88.
13. Fujimaki H, Yoshida H. Development of male sterile-restoring system for hybrid rice production. 2. Variation of days to heading of half-sib F1 hybrids with a common female parent Akihikari. Jpn. J. Breed. 1984; 34:196-197.
14. Govindraj K. Studies on problems of hybrid rice with special reference to genetic and biometrical basis of male sterility and fertility restoration system. Ph.D. Thesis, IARI, New Delhi, India, 1983.
15. Grafius, J.E. Heterosis in barley. Agron. J. 1959; 51:551-54.
16. Janardhanam V, Nadrajan N, Ganesh SK, Jebraj S, Chozhan K. Combining ability studies for yield and its components in rice (*Oryza sativa* L.). Madras Agric. J. 2000; 87:542-544.
17. Jones JW. Hybrid vigor in rice. J. Am. Soc. Agron. 1926; 18:423-428.
18. Kaushik RP, Sharma KD. Extent of heterosis in rice (*Oryza sativa* L.) under cold stress conditions-yield and its components. TAG Theor. Applied Gent. 1986; 73:136-140.
19. Khush GS, Kumar I, Vermani SS. Grain Quality of Hybrid Rice: IRRI, Manila, Philippines. 1988, 201-215.
20. Kumar A, Singh NK, Sharma VK. Combining ability analysis for identifying elite parents for heterotic rice hybrids. Oryza. 2006; 43:82-86.
21. Li W, Zhang JZ, Zhang GQ, Zuo QF. Analysis of heterosis of main agronomic traits in indica-japonica lines of rice. J. Southwest Agric. Univ. 2002; 24:317-320.
22. Lin SC, Yuan LP. Hybrid rice breeding in China. In Innovative approaches to rice breeding. International Rice Research Institute, Manila, Philippines. 1980, 35-51.
23. Lokaprakash R, Shivashankar G, Mahadeveppa M, Shankare G, Kulkarni RS. Heterosis in rice. Oryza. 1992; 29:293-297.
24. Malthus A. Statistical Methods for Agricultural Research Workers. 4th Edn. ICAR, New Delhi.
25. Mishra M, Pandey MP. Heterosis breeding in rice for irrigated sub-humid tropics in North India. Oryza. 1998; 35:8-14.
26. Murthy N, Kulkarni RS. Heterosis in relation to combining ability in rice. Oryza. 1996; 33:153-156.
27. Nijaguna G, Mahadevappa M. Heterosis in intervarietal hybrids of rice. Oryza. 1982; 20:159-161.
28. Nuruzzaman M, Alam MF, Ahmed MG, Shohael AM, Biswas MK, Amin MR, Hossain MM. Studies on parental variability and heterosis in rice. Pak. J. Biol. Sci. 2002; 5:1006-1009.
29. Panwar LL. Line × tester analysis of combining ability in rice (*Oryza sativa* L.). Indian J. Genet. Plant Breed. 2005; 65:51-52.
30. Patel SR, Desai NM, Kukadia MU. Heterosis for yield contributing characters in upland rice. Gujrat Agric. Univ. Res. J. 1994; 20:162-163.
31. Peng JY, Virmani SS. Heterosis in some international crosses of rice. Oryza. 1991; 28:31-36.
32. Rahimi M, Rabiei B, Samizadeh H, Ghasemi AK. Combining ability and heterosis in rice (*Oryza sativa* L.) cultivars. J. Agric. Sci. Tech. 2010; 12:223-231.
33. Rao AM, Ramesh S, Kulkarni RS, Savithramma DL, Madhusudhan K. Heterosis and combining ability in rice. Crop Improve. 1996; 23:53-56.
34. Rashid M, Cheema AA, Ashraf M. Line × Tester analysis in Basmati rice. Pak. J. Bot. 2007; 39:2035-2042.
35. Rather AG, Zargar MA, Sheikh FA. Genetic divergence in rice (*Oryza sativa* L.) under temperate conditions. Indian J. Agric. Sci. 2001; 71:344-345.
36. Reddy MR, Raju CS, Sravani D, Reddy TD, Reddy GN. Heterosis for yield and kernal size in aromatic rice (Oryza sativa L), Annals of Biological Research. 2013; 3(6):2662-2666.
37. Reddy GS, Rao GM, Ali MS. Possibility of hybrid rice production utilizing male sterility and fertility restoration system. Oryza. 1984; 21:143-147.
38. Sahai VN, Saran S, Chaudhary RC. Hybrid rice research in Bihar, India. Int. Rice Res. Newslett. 1987; 12:23-23.
39. Saleem MY, Mirza JI, Haq MA. Heritability, genetic advance and Heterosis. In Line × Tester crosses of basmati rice. J. Agric. Res. 2002, 2008; 46:15-27.
40. Salgotra RK, Gupta BB, Singh P. Combining ability studies for yield and yield components in basmati rice. Oryza. 2009; 46:12-16.
41. Sampath N, Rajsekharan S, Vivekanandan P. Heterosis in intervarietal hybrids of rice (*Oryza sativa* L.). Madras Agric. J. 1989; 76:507-511.
42. Sarwagi AK, Shrivastava MN. Heterosis in rice under irrigated and rainfed situations. Oryza. 1988; 25: 10-15.
43. Sharma JP, Mani SC. A study of heterosis by utilizing male sterility-fertility system in rice (*Oryza sativa* L.). Oryza. 1990; 27:202-204.
44. Srivastava MN, Seshu DV. Heterosis in rice involving parents with resistance for various stresses. Oryza. 1982; 19:172-177.
45. Steel RGD, Torrie JH. Principles and Procedures of Statistics. 2nd Edn, McGraw Hill Co., New York, 1980.
46. Tian C, Cheng X, Liang Z. Several views on popularization of Xian (Indica) hybrid rice in Chinese. Kunming Yunnan Nongye Keji Yunnan Agric. Sci. Technol. 1980; 2:12-18.
47. Tseng TH, Huang CS. Yield and combining ability of hybrid rice. J. Agric. Res. China. 1987; 36:151-164.
48. Viraktamath BC. Heterosis and combining ability studies in rice (*Oryza sativa* L.) with respect to yield, yield components and some quality characteristics. Ph.D. Thesis, IARI, New Delhi, India, 1987.
49. Virmani SS, Chaudhary RC, Khush GS. Current outlook on hybrid rice. Oryza. 1981; 18:67-84.
50. Virmani SS, Viraktamath BC, Casal CL, Toledo RS, Lopez MT, Manalo JO. Hybrid Rice Breeding Manual. International Rice Research Institute, Philippines, 1997.
51. Virmani SS, Manalo J, Toledo R. A self-sustaining system for hybrid rice seed production. Int. Rice Res. New slett. 1993; 18:4-4.
52. Virmani SS, Aquino RC, Khush GS. Heterosis breeding in rice (*Oryza sativa* L.). Theoret. Applied Genet. 1982; 63:373-380.

53. Vivekanandan, P. Comparative studies on grain yield and its components characters in certain F1 hybrids. Oryza. 1991; 28:269-272.
54. Watanesk O. Heterosis and combining ability evaluation of cytoplasmic male sterile (A) lines and restorer (R) lines. Int. Rice Res. Not. 1993; 10:5-6.
55. Wilfred MW, Prasad MN. Combining ability and heterosis in rice (*Oryza sativa* L.). Oryza. 1992; 29:15-18.
56. Wu Z, Wu T, Liang Y. Potential for increased yields as determined from the growth characteristics of hybrid rice in Chinese. Fujian Nongye Keji. Fujian Agric. Sci. Technol. 1980; 1:8-10.
57. Wynne JC, Emery DA, Rice PW. Combining ability estimates in *Arachis hypogaea* L. II. Field performance of F_1 hybrids. Crop Sci. 1970; 10:713-715.
58. Xu J, Wang L. A preliminary study on heterosis and combining ability of rice in Chinese. Beijing Yichuan (Hereditas). Anhui Inst. Agric. Hefei. 1980; 2:17-19.
59. Zhang Q, Gao YJ, Yang SH, Ragab RA, Maroof MAS, Li ZB. A diallel analysis of heterosis in elite hybrid rice based on RFLPs and micro satellites. Theor. Applied Genet. 1994; 89:185-192.