Assessment of Heterosis and inbreeding Depression for Yield, and its associated components Traits in rice (*Oryza sativa* L.)

ABSTRACT

The present investigation entitled was carried out at Main Rice Research Centre, Navsari Agricultural University, Navsari during *kharif-2023*with anobjectives to obtain information on manifestation of heterosis and extent of inbreeding depression involved in the inheritance of various yield attributing characters in rice (*Oryza sativa* L.). This study comprised three crosses using four diverse lines. The experimental material comprised of five generations each cross of pair parents i.e. P_1, P_2, F_1, F_2 and F_3 of three different crosses were conducted in Compact Family Block Design with three replications during *kharif* 2023. For grain yield per plant all the three crosses (IRBB 55 × Mahisagar, IRBB 55 × GR-11 and IRBB 55 × TN-1) exhibited significant and positive relative heterosis as well as heterobeltiosis. Among them the highest mid parent heterosis of 39.67 % and heterobeltiosis of 7.56 % were exhibited by cross IRBB 55 × GR-11. This hybrid showed positive and significant relative heterosis for all the four important characters *viz.*, productivetillers per plant, panicle length, grains per panicle and 100 grain weight. While, the inbreeding depression was found significant and positive for all the three crosses which is not desirable for grain yield per plant. Here, all the three crosses exhibited positive heterosis followed by positive inbreeding depression indicated that trait is under influence of non-additive type of gene action and heterosis breeding would be found rewarding for improvement for grain yield per plant.

Keywords: Heterosis, inbreeding depression, rice (*Oryza sativa* L.)

Introduction

“Rice (*Oryza sativa* L.), the most important agronomical crop, occupies the enviable prime place among the food crops around the world.Being a major cereal crop, nutritionally it is one of the world’s most important staple foods, with approximately half of the world’s population dependent on it. To indicate it’s over whelming importance in sense of highly consumed food, year 2004 was celebrated as the international year of rice with the theme “Rice is life”. Rice has become a paramount element of food security as over 90 per cent of the world's rice is grown and consumed in Asia and approximately 60 to 70 per cent of the caloric requirements of the Asian population is gained from rice. Rice stands second most cultivated crop species in the world after wheat and its food grain of billions of lives for survival as it remains a source of staple food for the majority of the population around the world”(Nguyen and Ferrero, 2006).

“Cultivated rice (*O. sativa*) is predominantly selfpollinating and has lower out crossing ability. A crosspollination rate of *O. sativa* is less than one percent” (Messeguer*et al.*, 2001). “However, the estimated out crossing rates among wild rice populations ranges from 4.3% to 55.9%” (Oka, 1988). “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). “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” (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). “It is commonly found that the level of heterosis exhibited by a hybrid is a function of the genetic divergence between parents” (Onyia *et al.*, 2012). “Heterosis may be positive or negative.Heterosis expresses the superiority of F_1 hybrid over its parents in terms of yield and other traits. On the other hand, the inbreeding depression reflects on reduction or loss in vigour, fertility and yield as a result of inbreeding. Both positive and negative heterosis is useful in crop improvement, depending on the breeding objectives and nature of the traits. Heterosis is useful for deciding the direction of future breeding programme and to identify the superior cross combinations.Knowledge on heterosis together with inbreeding depression would be helpful for identification of potential crosses in early generations" (Kumari and Senapati 2019).

Materials and Methods

The material comprising of four genetically diverse parents of rice (IRBB 55, Mahisagar,GR-11 and TN-1) selected on the basis of their geographic origin, variation in morphological characters and behaviour towards bacterial leaf blight resistance of rice. GNR-3 used as a check. The crossing program was initiated during *summer*-2022 to produce among four selected genotypes. The F_1S were generated by crossing of above four parents during *summer*-2022. Selfing of F_1S was done in *kharif*-2022 with their respective parents to produce F_2S. Selfing of F_2S was done during *summer*-2023 to get F_3S. The evaluation trial was conducted in *kharif*-2023 at Main Rice Research Centre, Navsari Agricultural University, Navsari. The evaluation trial involved three F_1 hybrids *i.e.*, IRBB 55 × Mahisagar, IRBB 55 × GR-11 and IRBB 55 × TN-1. The experimental material consisting of five generations (P_1, P_2, F_1, F_2 and F_3) of each of the three crosses were sown during *Kharif*-2023 in Compact Family Block Design with three replications. Each replication was divided in five compact blocks. Each three crosses consisting of five generations were randomly allotted to the blocks. Five generations were then randomly allotted to each plot within a block. Each plot consisted of two rows of parents and F_1S, fifteen rows of the F_3 and thirty rows of the F_2 generations of each cross. Inter and intra row spacing was 20 cm and 15 cm, respectively. The observation was recorded for eleven traits *viz*, days to flowering, plant height (cm), productive tillers per plant, panicle length (cm), grains per panicle, 100 grain weight (g), grain yield per plant (g), kernel length (mm), kernel breadth (mm), L:B ratio and amylose content (%)

Estimation of heterosis

Heterosis was estimated as per cent increase or decrease in the mean value of F_1 hybrid over the mid-parent, *i.e.*, relative heterosis (Briggle, 1963), over the better parent, *i.e.*, heterobeltiosis (Fonseca and Patterson, 1968) and standard check, *i.e.*, standard heterosis (Meredith and Bridge, 1972) for each character as follows:

$$\text{Heterosis (\%)} = \frac{\bar{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobeltiosis (\%)} = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis (\%)} = \frac{\bar{F}_1 - \overline{SC}}{\overline{SC}} \text{x} 100$$

Where,

$\bar{F}_1$ = Mean performance of the F_1

$\overline{MP}$ = Mean value of the parents (P_1 and P_2) of a hybrid

$\overline{BP}$ = Mean value of better parent

$\overline{SC}$ = Mean value of standard check

The standard error and calculated't' value for test of significance for relative heterosis, heterobeltiosis and economic heterosis were calculated as under:

Standard error:

$$\text{S.E.(MP) (Standard error for heterosis)} = \sqrt{\frac{3Me}{2r}}$$

$$\text{S.E.(BP) (Standard error for heterobeltiosis)} = \sqrt{\frac{2Me}{r}}$$

$$\text{S.E.(SC) (Standard error for Standard heterosis)} = \sqrt{\frac{2Me}{r}}$$

Where,

Me = Error mean square
r = Number of replications

t-test

The test of significance of the heterosis and heterobeltiosis was carried out by comparing the calculated values of 't' with the tabulated values 't' at 5 per cent (1.96) and 1 per cent (2.58) levels of significance.

$$t = \frac{\bar{F}_1 - \overline{MP}}{S.E.\left(\bar{F}_1 - \overline{MP}\right)} \qquad \text{(For relative heterosis)}$$

$$t = \frac{\bar{F}_1 - \overline{BP}}{S.E.\left(\bar{F}_1 - \overline{BP}\right)} \qquad \text{(For heterobeltiosis)}$$

$$t = \frac{\bar{F}_1 - \overline{SC}}{S.E.\left(\bar{F}_1 - \overline{SC}\right)} \qquad \text{(For standard heterosis)}$$

The test of significance of relative heterosis, heterobeltiosis and economic heterosis were carried out by comparing the calculated values of ‘t’ with the tabulated values of ‘t’ at 5 % (1.960) and 1 % (2.576) levels of significance.

Estimation of inbreeding depression

Inbreeding depression was computed by using the following formulae:

$$\text{Inbreeding depression(\%)} = \frac{\bar{F}_1 - \bar{F}_2}{\bar{F}_2} \times 100$$

Standard error for inbreeding depression:

$$S.E.(\bar{F}_1 - \bar{F}_2) = \sqrt{\frac{[V_{F_1}(n_1 - 1)] + [V_{F_2}(n_2 - 1)]}{n_1 + n_2 - 2}}$$

‘t’ test for inbreeding depression

$$t\,(\bar{F}_1 - \bar{F}_2) = \frac{\bar{F}_1 - \bar{F}_2}{S.E.(\bar{F}_1 - \bar{F}_2)}$$

Where,

$\bar{F}_1$ = Mean value of the F_1
$\bar{F}_2$ = Mean value of the F_2
VF_1 = Variance F_1
VF_2 = Variance F_2
n_1 = Number of observations in F_1
n_2 = Number of observations in F_2

The test of significance of the inbreeding depression was performed by comparing the calculated value with the tabulated values of ‘t’ at 5 % (1.960) and 1 % (2.576) levels of significance.

Result and discussion

The extent of heterotic effects *i.e*., relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) as well as inbreeding depression (ID) were estimated for all the twelve characters under study. The relative heterosis, heterobeltiosis, standard heterosis and inbreeding depression for eleven characters in study of three crosses are presented in Table 1 and 2.

Days to flowering: An experimentation of the data indicated that all crosses exhibited significant and negative relative heterosis for days to flowering which is desirable for earliness. The estimates of relative heterosis (RH) for days to flowering in three crosses ranged from -2.89 % (cross II) to -0.43 % (cross I) in desirable direction. Negative and significant heterobeltiosis was observed only in cross III (IRBB 55 × TN-1) which is desirable. The result of standard heterosis depicts that all three crosses showed negative and significant heterosis in desirable direction. The range of standard heterosis was varied from -2.92 per cent (IRBB 55 × Mahisagar) to -0.35 per cent (IRBB 55 × GR-11) for days to flowering. The magnitude of inbreeding depression was found negative and significant for cross IRBB 55 × GR-11 (-3.74%) and cross IRBB 55 × Mahisgar (-2.48%). Significant and negative heterosis is desirable for days to flowering and it helps to get early maturity of plants. Moreover, inbreeding depression in the positive direction for this trait could help to get desired early maturing transgressive segregants in upcoming generations. Similar result were reported earlier byBalat*et al.* (2018),Thakor *et al.* (2018),Makwana *et al.* (2018), Lingaiah *et al.* (2019), and Patel *et al.* (2019a).

Plant height: Positive and significant relative heterosis was found for all three crosses under study. Highest positive heterosis was shown in cross IRBB 55 × TN-1 (20.32 %) followed by cross IRBB 55 × GR-11 (15.05%). Heterobeltiosis was ranged from 3.01% (IRBB 55 × GR-11) to 17.88 % (IRBB 55 × TN-1). The cross IRBB 55 × TN-1 (17.88%) exhibited the highest significant positive heterosis followed by cross IRBB 55 × Mahisagar (6.02%). The result of standard heterosis depicts that all three crosses showed negative and significant heterosis in desirable direction for plant height. The range of standard heterosis for plant height was between -11.27 per cent (IRBB 55 × Mahisagar) to -0.14 per cent (IRBB 55 × GR-11). Two of the three crosses *i.e*., IRBB 55 × GR-11 (12.87%) and IRBB 55 × TN-1 (5.20%) exhibited positive and significant inbreeding depression whereas cross IRBB 55 × Mahisagar (-1.64%) showed negative and significant inbreeding depression. Positive and significant inbreeding depressions were found in cross II and Cross III which is desirable for this trait. Similar results were also reported by Kumari and senapati (2019), Patel *et al.* (2019a) and Patel and Patel (2020a).

Productive tillers per plant: The parent having higher number of productive tillers per plant considered as better parent. All the three crosses *viz.,* IRBB 55 × Mahisagar (6.10%), IRBB 55 × GR-11 (21.00%) and IRBB 55 × TN-1 (12.28%) exhibited positive and significant relative heterosis in desirable direction. All of the three crosses *i.e.,* IRBB 55 × Mahisagar (5.23%), IRBB 55 × GR-11 (3.91%) and IRBB 55 × TN-1 (8.18%) depicted significant positive heterobeltiosis in desired direction which depicts the importance of dominance gene action.Standard heterosis for this trait was found highly significant for all the three crosses. The estimates of inbreeding depression were significant and positive in crosses IRBB 55 × Mahisagar (11.29%) and IRBB 55 × GR-11 (12.74%) which is not desirable for getting transgressive segregants in the desired direction for productive tillers per plant. All the three crosses showing high heterosis also show high inbreeding depression suggests the importance of non-additive gene for governing this trait.Similar result were reported by Sravan and Jaiswal (2017), Balat*et al.* (2018), Patel*et al.* (2019a) and Ramakrishnan*et al.* (2023).

Panicle length: for this trait,the minimum and maximum values of relative heterosis were from 2.04 per cent (IRBB 55 × Mahisagar) to 20.52 per cent (IRBB 55 × GR-11). Positive and significant heterobeltiosis was found in cross IRBB 55 × GR-11 (1.95%) and cross IRBB 55 × TN-1 (3.79%). Whereas, cross IRBB 55 × Mahisagar (1.68%) showed non-significant but positive heterobeltiosis. Estimates of standard heterosis were ranged from 4.09 per cent (IRBB 55 × Mahisagar) to 8.29 Per cent (IRBB 55 × TN-1). Highly significant and positive standard heterosis was observed in cross IRBB 55 × Mahisagar (8.29%) followed by cross IRBB 55 × GR-11 (7.51%) and cross IRBB 55 × TN-1 (4.09%). The estimates of inbreeding depression were significant and positive in all crosses and ranged from 4.65 % (IRBB 55 × GR-11) to 7.99% (IRBB 55 × Mahisagar). Highest inbreeding depression was found in cross IRBB 55 × Mahisagar (7.99%). All the three crosses exhibited positive heterosis followed by positive inbreeding depression indicated that trait is under influence of non additive type of gene action and heterosis breeding would be found rewarding for improvement for this trait. Earlier similar result observed by Thakor*et al.*(2018), Balat*et al.*(2018) and Makwana*et al.* (2018).

Grains per panicle:highest significant and positive relative heterosis was found in cross IRBB 55 × TN-1 (35.29%) followed by IRBB 55 × Mahisagar (24.17%) and cross IRBB 55 × GR-11 (10.30%). Better parent heterosis ranged from 3.50% (IRBB 55 × GR-11) to 18.23% IRBB 55 × Mahisagar. Highest heterobeltiosis recorded by the cross IRBB 55 × Mahisagar (18.23%).While, negative and significant standard heterosis over check was observed by cross IRBB 55 × GR-11 (-3.71%) and is undesirable direction. The estimates for inbreeding depression, two of the three crosses *i.e.*, IRBB 55 × Mahisagar (2.33%) and cross IRBB 55 × GR-11 (8.33%) showed positive and significant inbreeding depression which may not be rewarding to getting transgressive segregants in desired direction, while negative and significant inbreeding depression was observed in cross IRBB 55 × TN-1 (-0.33%) which may be helpful to getting desired plant in the further generations for this trait. The result is in accordance withSharma *et al.* (2013),Venkanna *et al.* (2014), Kumari and senapati (2019) andPatel and Patel (2020).

100 Grain weight: All the three crosses exhibited positive and significant relative heterosis ranging from 11.51 percent (IRBB 55 × TN-1) to 37.62 percent (IRBB 55 × GR-11) for 100 grain weight in desirable direction. Highest relative heterosis was observed in cross IRBB 55 × GR-11 (37.62%).Highest and positive heterobeltiosis was recorded in cross IRBB 55 × GR-11 (18.59%) followed by cross IRBB 55 × Mahisagar (12.56%) and IRBB 55 × TN-1 (3.47%) in desirable direction as it is directly affecting the grain yield. Estimation of standard heterosis were found significant in negative direction for all the three crosses and it ranged from -13.47% (IRBB 55 × GR-11) to -5.15% (IRBB 55 × Mahisagar). The estimates of inbreeding depression were found positive and significant for all the crosses ranged from 3.78 percent (IRBB 55 × Mahisagar) to 6.82 percent (IRBB 55 × GR-11).These results have similarities with finding of Latha *et al.* (2013),Sravan and Jaiswal (2017) and Patel *et al.* (2019a).

Grain yield per plant: All the three crosses exhibited significant and positive relative heterosis with a range from 23.59 % (IRBB 55 × Mahisagar) to 39.67 % (IRBB 55 × GR-11) which is desirable for this trait. The maximum heterobeltiosis was recorded by cross IRBB 55 × GR-11 (7.56 %) followed by cross IRBB 55 × TN-1 (6.94 %) and IRBB 55 × Mahisagar (5.42 %) in the desired direction. Highest significant and positive standard heterosis were recorded by cross IRBB 55 × GR-11 (15.94%) followed by cross IRBB 55 × Mahisagar (14.35%) and cross IRBB 55 × TN-1 (13.64%). The inbreeding depression was found significant and positive for all the three crosses which ranged from 3.42 % (IRBB 55 × GR-11) to 11.75 % (IRBB 55 × TN-1) which is not desirable for this trait. These results are concurrence withRumanti*et al.*(2016),Patel and Patel (2020), Singh and Patel (2020b)and Ramakrishnan *et al.* (2023).

Kernel length: The significant and positive relative heterosis was exhibited by IRBB 55 × GR-11 (7.69 %) followed by IRBB 55 × TN-1 (5.37 %) for kernel length. While non significant but positive relative heterosis was observed in cross IRBB 55 × Mahisagar (0.31%). All three crosses recorded relative heterosis in desired direction which also contributes toward kernel length. Negative and significant heterobeltiosis was observed only in cross IRBB 55 × TN-1 (-1.97%). While non-significant but positive heterobeltiosis was recorded in cross IRBB 55 × GR-11 (-0.14%) and cross IRBB 55 × Mahisagar (-1.12%). Moreover, all three crosses were recorded significant and positive standard heterosis over their respective F_{1S} and ranged from 8.19 percent (IRBB 55 × TN-1) to 12.42 per cent (IRBB 55 × Mahisagar). Negative and significant inbreeding depression was observed only in cross IRBB 55 × GR-11 (0.086%) in desirable direction which revealed there would be chances to get better individuals in upcoming generation for this trait.This result is in accordance with Sravan and Jaiswal (2017) and Ramakrishnan *et al.* (2023).

Kernel breadth: The result depicts that, negative and non significant relative heterosis was recorded only in cross IRBB 55 × TN-1 (-0.78%) for kernel breadth which is desirable for fine kernel. From all the three crosses negative and significant heterobeltiosis was observed in cross IRBB 55 ×

TN-1 (-1.74%) and cross IRBB 55 × GR-11(-3.31%). While positive and significant heterobeltiosis was recorded in cross IRBB 55 × Mahisagar (3.83%). In addition, only one cross IRBB 55 × Mahisagar was found to record significant positive standard heterosis (0.97%). While other two cross IRBB 55 × GR-11 (-6.63%) and cross IRBB 55 × TN-1 (-4.10%) recorded negative and significant heterosis. Two out of three crosses depicted positive and significant inbreeding depression *i.e.,* cross IRBB 55x TN-1 (2.05%) and cross IRBB 55 × Mahisagar (5.00%) which is desirable for obtaining breadth with fine grain in further generations. Similar results were also reported by Sravan and Jaiswal (2017), Balat*et al.* (2018) and Ramakrishnan *et al.* (2023).

L: B ratio: Range of relative heterosis for L:B ratio was observed from -4.26 per cent (IRBB 55 × Mahisagar) to 6.24 per cent (IRBB 55 × TN-1). The significantly positive relative heterosis was exhibited by two crosses *viz,* IRBB 55 × GR-11(4.08 %) and IRBB 55 × TN-1 (6.24 %). Moreover negative and non significantheterobeltiosis was recorded in cross IRBB 55 × TN-1 (-0.27%). The range of standard heterosis was 17.84 % (IRBB 55 × GR-11) to 11.31 % (IRBB 55 × Mahisagar). Magnitude of inbreeding depression ranged from -0.61% (IRBB 55 × GR-11) to -4.80 (IRBB 55 × Mahisagar). Two crosses IRBB 55 × GR-11 (-0.61%) and IRBB 55 × TN-1(-0.95%) recorded negative and non significant inbreeding depression which indicates there would be less variation among the individuals of F_2 population for L:B ratio.

Amylose content: Two out of three crosses namely, IRBB 55 × TN-1 (5.12%) and IRBB 55 ×Mahisagar (5.74%) depicted positive and significant relative heterosis for amylose content (%). While single cross IRBB 55 × GR-11 (0.28%) exhibited positive but non significant relative heterosis. Only one cross IRBB 55 × Mahisagar (3.64%) depicted positive and significant better parent heterosis. For the estimation of standard heterosis, two out of three crosses found positive and significant standard heterosis *viz,* cross IRBB 55 × TN-1 (5.49%) and IRBB 55 × Mahisagar (2.21%). While,only one cross IRBB 55 × GR-11 (-6.63%) found negative and significant heterosis. The estimates of inbreeding depression was positive and significant for cross IRBB 55 × TN-1(12.04%) and cross IRBB 55 × Mahisagar (6.28%). While positive and non significant inbreeding depression was observed in cross IRBB 55 × GR-11 (0.74%). Similar result were earlier recorded by Sravan and Jaiswal (2017), Thakor *et al.* (2018)Patel *et al.* (2019a) and Patel and Patel (2020a).

Table 1 :Estimates of relative heterosis (%), heterobeltiosis (%), standard heterosis (%) and inbreeding depression (%) for days to flowering, plant height (cm), productive tillers per plant, panicle length (cm), grain per panicle and 100 grain weight in cross I, II and III

Particulars	Days to flowering	Plant height (cm)	Productive tillers per plant	Panicle length (cm)	Grains per panicle	100 grain weight (g)
Cross I (IRBB 55 × Mahisagar)						
RH % ± SE	-0.43** ± 0.28	10.28** ± 0.59	6.10** ± 0.25	2.04* ± 0.20	24.17** ± 2.20	18.64** ± 0.02
HB % ± SE	2.35** ± 0.30	6.02** ± 0.69	5.23* ± 0.20	1.68 ± 0.22	18.23** ± 3.74	12.56** ± 0.02
SH % ± SE	-2.92** ± 0.02	-11.27** ± 0.07	7.97** ± 0.01	4.09** ± 0.01	4.92** ± 4.79	-5.15** ± 0.01
ID % ± SE	-2.48** ± 0.43	-1.64* ± 0.79	11.29** ± 0.28	7.99* ± 0.17	2.33** ± 2.07	3.78** ± 0.02
Cross II (IRBB 55 xGR-11)						
RH % ± SE	-2.89** ± 0.42	15.05** ± 0.44	21.00** ± 0.15	20.52** ± 0.11	10.30** ± 1.76	37.62** ± 0.01
HB % ± SE	0.45** ± 0.47	3.01** ± 0.63	3.91* ± 0.18	1.95** ± 0.10	3.50** ± 1.90	18.59** ± 0.02
SH % ± SE	-0.35** ± 0.41	-0.14 ± 0.90	5.98** ± 0.01	7.51** ± 0.01	-3.71* ± 2.01	-13.47** ± 0.01
ID % ± SE	-3.74** ± 0.60	12.87** ± 0.90	12.74** ± 0.19	4.65** ± 0.20	8.33** ± 1.55	6.82** ± 0.02
Cross III (IRBB 55 xTN-1)						
RH % ± SE	-2.12** ± 0.39	20.32** ± 0.47	12.28** ± 0.15	8.30** ± 0.11	35.29** ± 1.45	11.51** ± 0.01
HB % ± SE	-3.30** ± 0.48	17.88** ± 0.49	8.18** ± 0.17	3.79** ± 0.12	12.83** ± 1.93	3.47** ± 0.02
SH % ± SE	-1.32** ± 0.02	-5.63** ± 0.31	11.50** ± 0.01	8.29** ± 0.01	4.91** ± 5.22	-12.90 ± 0.01
ID % ± SE	0.23 ± 0.58	5.20** ± 0.93	5.71** ± 0.16	5.88** ± 0.19	-0.33** ± 2.48	6.02** ± 0.02

*,** significant at 5% and 1% level of significance respectively

Table 2: Estimates of relative heterosis (%), heterobeltiosis (%), standard heterosis (%) and inbreeding depression (%) for grain yield per plant (g), kernel length (mm), kernel breadth (mm), L:B ratio and amylose content (%) in cross I, II and III

Particulars	Grain yield per plant (g)	Kernel length (mm)	Kernel breadth (mm)	L:B Ratio	Amylose content (%)
Cross I (IRBB 55 × Mahisagar)					
RH % ± SE	23.59** ± 0.18	0.31 ± 0.02	4.82** ± 0.01	-4.26** ± 0.02	5.74** ± 0.13
HB % ± SE	5.42** ± 0.18	-1.12 ± 0.02	3.83** ± 0.02	-6.49** ± 0.02	3.64** ± 0.12
SC % ± SE	14.35** ± 0.01	12.42** ± 0.01	0.97** ± 0.01	11.31** ± 0.01	2.21** ± 0.01
ID % ± SE	5.05** ± 0.27	0.94 ± 0.02	5.00** ± 0.02	-4.80** ± 0.03	6.28** ± 0.13
Cross II (IRBB 55 × GR-11)					
RH % ± SE	39.67** ± 0.20	7.69** ± 0.02	3.48** ± 0.01	4.08** ± 0.02	0.28 ± 0.13
HB % ± SE	7.56** ± 0.16	-0.14 ± 0.02	-3.31* ± 0.01	3.22** ± 0.02	-1.24 ± 0.15
SC % ± SE	15.94** ± 0.05	10.19** ± 0.01	-6.63** ± 0.02	17.84** ± 0.02	-6.63** ± 0.02
ID % ± SE	3.42** ± 0.22	-0.86* ± 0.02	-1.08 ± 0.01	-0.61 ± 0.03	0.74 ± 0.12
Cross III (IRBB 55 × TN-1)					
RH % ± SE	37.63** ± 0.10	5.37** ± 0.02	-0.78 ± 0.01	6.24** ± 0.02	5.12** ± 0.07
HB % ± SE	6.94** ± 0.12	-1.97** ± 0.03	-1.74* ± 0.01	-0.27 ± 0.02	-0.67 ± 0.08
SC % ± SE	13.64** ± 0.01	8.19** ± 0.01	-4.10** ± 0.01	12.78** ± 0.01	5.49** ± 0.01
ID % ± SE	11.75** ± 0.39	1.30** ± 0.03	2.05** ± 0.01	-0.95 ± 0.02	12.04** ± 0.10

*,** significant at 5% and 1% level of significance respectively

Conclusion

This investigation revealed that the heterosis for grain yield per plant was observed due to heterosis of the four important yield attributing component *viz.*, productive tillers per plant, panicle length, grains per panicle and 100 grain weight which resulted in increased yield. Therefore, attention should be given to these traits when aiming to improve yield.The results revealed significant positive and negative mid parent and better parent's heterosis in many crosses for different characters studied. The high values for heterotic effects also indicated that the parents used for the study were widely diverse. The significant relative heterosis and/or heterobeltiosis in desired direction were observed for plant height, productive tillers per plant, panicle length, grains per panicle, 100 grain weight, grain yield per plant, kernel length, L: B ratio and amylose content there by heterosis breeding would be more practical approach for higher grain yield in rice. The cross II (IRBB 55 × GR-11) and III (IRBB 55 × TN-1) showed positive and significant relative heterosis and better parent heterosis for the important yield contributing components *i.e.*, productive tillers per plant, panicle length (cm), grains per panicles and 100 grain weight (g). From these results, it is apparent that these two crosses have potentiality for improving yield through adjustment of yield components. The results on inbreeding depression revealed that significant and positive inbreeding depression for grain yield. Relationship between significant heterotic response followed by significant inbreeding depression which suggests the importance of non-additive type of gene action. So, the heterosis breeding was seems to be beneficial for further improvement of the grain yield and yield attributes.Significant heterosis over mid-parent and better parent, along with positive inbreeding depression, may be attributed to a major contribution from dominance (h) and dominance x dominance (l) gene effects, where use of heterosis breeding would be effective.

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