International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 2045-2048
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Received: 16-07-2019
Accepted: 18-08-2019

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Estimation of heterosis and inbreeding depression for yield, various yield components, physiological and quality traits in rice (*Oryza sativa* L.)

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Abstract
The present investigation was carried out during *kharif* 2017-2018, at Main Rice Research Centre farm, Navsari Agricultural University, Navsari. The experimental material for present investigation comprised of Six generations *viz.*, P_1, P_2, F_1, F_2, BC_1 and BC_2 of following four crosses were involved eight diversified cultivars of rice (*Oryza sativa* L.) were used to study the genetic analysis of quantitative and qualitative traits. The F_1s deviated positively from their better parent for days to 50% flowering, days to maturity, plant height, productive tillers per plant, grains per panicle, 100 seed weight, grain yield per plant, straw yield per plant, harvest index, kernel L:B ratio, protein content, amylose content, Fe content, Zn content, leaf area, photosynthetic rate, chlorophyll content, hulling (%), milling (%) and head rice recovery (%) in majority of crosses, indicating importance of heterosis. Hybrid matures late in cross 1 (NAUR-1 X IET-25457) and cross 2 (GNR-3 X IET-25446) than their respective early parent as evidence from the higher value of heterosis.

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

Introduction
Rice, being one of the most important cereal crops of India and Asia, is cultivated as pure culture mainly in *Kharif*. The crop is cultivated in large area but is characterized by very low productivity due to lack of high yielding varieties adapted to different seasons and agronomic conditions at different parts of country. As we know, yield is a complex end product of a number of components most of which are under polygenic control. So, all changes in yield must be accompanied by changes in one or more of the components as have been pointed out by Grafius (1959) [6]. The ultimate goal of any plant breeding programme is to develop improved genotypes which are better than their existing ones in one or more traits which producing the economic yield. The enhancement of mineral nutrients in rice is today's vital need to reduce malnutrition/anemic conditions in poor people of the world. Sufficient understanding of the inheritance of quantitative traits and information about heritability of grain yield, its components and quality traits are essential to develop an efficient breeding strategy.

The heterosis expresses the superiority of F_1 hybrid over its parents in term 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. The magnitude of heterosis helps in the identification of potential cross combinations to be used in conventional breeding programme to enable create wide array of variability in segregating generations. The knowledge of heterosis accompanied by the extent of inbreeding depression in subsequent generations is essential for maximum exploitation of such heterosis by adopting appropriate breeding methodology. In crop improvement, only the genetic component of variation is important since only this component is transmitted to next generation.

Material and Methods
The material comprising of eight genetically diverse parents of rice (NAUR-1, IET-25457, GNR-3, IET-25446, GNR-5, IET-25471, IET-15429 and IET-25453) selected on the basis of their geographic origin and variation in morphological characters and based on their mineral nutrient content. four crosses (NAUR-1 X IET-25457, GNR-3 X IET-25446, GNR-5 X IET-25471 and IET-15429 X IET-25453) obtained by crossing of diverse parents during

Kharif-2016 at Main Rice Research Centre farm, Navsari Agricultural University, Navsari. Backcrossing was done in *summer*-2016-17 with its respective parents. Selfing of F_1s was done in the same season (*summer*- 2016-17) to get F_2s. The evaluation trial was conducted in *Kharif*- 2017-18 at Main Rice Research Centre farm, Navsari Agricultural University, Navsari. The experimental material consisting of six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of each of the four crosses were sown during *Kharif*-2017-18 in compact family block design with three replications. Each replication was divided in four compact blocks. Each four crosses consisting of six generations were randomly allotted to each plot within a block. Each plot consisted of one row of parents and F_1s, two rows of the backcrosses and four rows of the F_2 generations of each cross. Inter and intra row spacing was 20 cm and 15 cm respectively. The experiment was surrounded by four guard rows to avoid damage and border effects.

Results and Discussion

Out of four hybrids studied all the four hybrids exhibited positive and significant heterosis for grain yield per plant, respectively. The highest heterosis of 14.64% and heterobeltiosis of 4.90% were exhibited by cross GNR-5 X IET-25471, respectively. High and positive heterosis for grain yield in rice had been reported by several earlier workers, *viz*., Panwar and Ali (2010) [13], Adilakshmi and Reddy (2011) [1], Patil *et al*. (2011) [14], Soni and Sharma (2011) [18], Sharifi *et al*. (2011), Vennila *et al.* (2011) [20], Venkanna *et al.* (2014) [19], Anis *et al.* (2016) [3], Borah *et al.* (2017) [5], Rumanti *et al.* (2017) [15]. Close examination of data on inbreeding depression for grain yield indicated that, in general, crosses showing moderate to high heterotic effect also displayed significant inbreeding depression. Further, the values obtained for relative heterosis was generally greater than the values for inbreeding depression. This was anticipated since the estimates of inbreeding depression, theoretically account for only 50% of the expected change and consequently they will usually be much less than the estimates of heterosis. The results were in agreement with the findings of kheradanam *et al.* (1975) [11] who reported parallel relationship between heterosis and inbreeding depression. For practical utility, it would be worthwhile to compare the performance of hybrids with the best available pureline.

Out of four hybrids NAUR-1 X IET-25457 hybrid showed positive and significant heterosis for all the three important components (productive tillers per plant, grains per panicle and 100 seed weight). From these results, it is apparent that NAUR-1 X IET-25457 hybrid has potentiality for improving yield through adjustment of three vital yield components.

Out of four heterotic crosses for two important components of grain yield, three and four crosses were with positively significant heterotic effects for number of grains per panicle and 100 seed weight and productive tillers per plant and grains per respectively.

The results on inbreeding depression revealed that high inbreeding depression for grain yield was mainly due to the inbreeding depression for its components. Relationship between heterotic response and inbreeding depression (i.e. crosses showing high heterosis also show high inbreeding depression) suggests the importance of non- additive gene in cowpea. The result is in close agreement with those of Kheradanam *et al.* (1975) [11].

It is pertinent to note that some hybrids of low x low and low x high yielding parents manifested relatively high heterobeltiosis while some hybrids involving high x high yielding parents exhibited low heterobeltiosis. The probable explanation for this type of behavior is that poor yielding parents might have different constellations of genes with complementary action when brought together in a hybrid combination. It is therefore, desirable to select hybrid based on their mean performance rather than heterotic effect. These results are in agreement with the finding of Singh (1983) [17] who observed high heterosis in high x High and high x low yielding parental combination. While Bhaskaraish *et al.* (1980) [4] did not observed high heterosis in low x low yielding parents.

Table 1: Estimates of relative heterosis (RH %), heterobeltiosis (HB %) and inbreeding depression (ID %) for days to flowering, days to maturity, plant height, productive tillers per plant, grains per panicle, 100 seed weight (g) and grain yield per plant (g) in four crosses of rice.

Estimates (%)	Days to flowering	Days to maturity	Plant height (cm)	Productive tillers per plant	Grains per panicle	100 seed weight (g)	Grain yield per plant (g)
Cross I (NAUR-1 X IET-25457)							
RH %	1.92**	1.19**	5.13**	2.90**	7.51**	1.05**	3.72**
HB %	6.83**	4.57**	10.20**	-0.80	-2.27	-3.99	-5.43
ID %	2.29	3.02	9.27	2.62	8.45	11.08	7.71
Cross II (GNR-3 X IET-25446)							
RH %	1.21**	0.76**	12.87**	8.62**	-1.78**	-3.36**	4.62**
HB %	2.74**	1.07	15.97**	2.44	-9.12**	-7.07*	-10.70**
ID %	2.22	2.25	-2.14**	3.17	5.73	2.89	4.13
Cross III (GNR-5 X IET-25471)							
RH %	-1.04**	0.11**	2.49**	-1.75**	8.54**	5.39*	14.64**
HB %	-0.43	0.28	7.10*	-3.45	1.67	4.41	4.90
ID %	1.61	1.86	10.67	-12.95	8.61**	-6.68**	1.34**
Cross IV (IET-15429 X IET-25453)							
RH %	-1.89*	-1.02**	6.93**	6.42**	3.95*	-3.96**	4.71**
HB %	-1.74	-0.94	9.69**	0.87	1.24	-8.26*	3.54
ID %	-0.42**	0.22	2.46**	0.65	8.61**	3.40	-8.22

* and **, significant at 5% and 1%, respectively.

Table 2: Estimates of relative heterosis (RH %), heterobeltiosis (HB %) and inbreeding depression (ID %) for straw yield per plant (g), harvest index (%), kernel L: B ratio, protein content (%), amylose content (%), iron contentand zinc content in four crosses of rice.

Estimates (%)	Straw yield per plant (g)	Harvest index (%)	Kernel L:B ratio	Protein content (%)	Amylose content (%)	Fe content (ppm)	Zn content (ppm)
Cross I (NAUR-1 X IET-25457)							
RH %	7.24**	-1.55**	-4.14**	-2.80*	2.83*	-2.10**	-0.43**
HB %	0.26	-2.67*	-6.72*	-2.94*	0.33	-4.95**	-18.37**
ID %	5.85	1.15	2.84	5.47**	20.45**	2.70	14.48**
Cross II (GNR-3 X IET-25446)							
RH %	-3.86**	4.54**	-0.98**	12.23**	6.86**	4.37**	14.45**
HB %	-12.08	0.39	-4.37	-2.40**	2.06	1.77**	-1.93
ID %	-4.34	3.60	6.05**	8.86**	12.82**	7.41**	10.87**
Cross III (GNR-5 X IET-25471)							
RH %	5.39**	3.68**	4.30**	-9.52**	3.59*	-2.39**	8.10**
HB %	3.20	-.017	6.18**	-2.89	-0.54	-4.34**	-8.21**
ID %	-6.28	2.81	5.71**	-4.47	12.23**	0.37	12.72**
Cross IV (IET-15429 X IET-25453)							
RH %	0.70**	1.57**	1.07**	2.16*	9.22**	1.43**	-9.20**
HB %	-4.53	-1.57	-2.74	3.34*	6.68	0.97**	-14.40**
ID %	-11.56	0.79	8.53**	14.87**	5.19	6.28**	10.40**

* and **, significant at 5% and 1%, respectively

Table 3: Estimates of relative heterosis (RH %), heterobeltiosis (HB %) and inbreeding depression (ID %) for leaf area (cm^2), photosynthetic rate ($\mu mol/m^2/s$), chlorophyll content, hulling (%), milling (%) and head rice recovery (%) in four crosses of rice.

Estimates (%)	Leaf area (cm^2)	Photosynthetic rate ($\mu mol/m^2/s$)	Chlorophyll content	Hulling (%)	Milling (%)	Head rice recovery (%)
Cross I (NAUR-1 X IET-25457)						
RH %	6.50**	4.48**	6.22**	4.58**	4.52**	4.40*
HB %	5.50	3.73	5.28	3.94*	3.85*	3.73
ID %	10.02	8.06	9.60**	6.69**	7.40**	6.90**
Cross II (GNR-3 X IET-25446)						
RH %	6.81**	4.62**	6.50**	3.71**	5.17**	5.52**
HB %	5.74	3.84	5.50	2.89*	4.45*	4.57*
ID %	8.77	7.06**	9.02**	6.29**	7.52**	9.74
Cross III (GNR-5 X IET-25471)						
RH %	9.32**	5.94**	8.80**	4.67**	5.24**	3.57*
HB %	2.79	1.63	2.70	4.01*	4.49*	5.74**
ID %	4.99	4.16	4.81	6.82**	7.62**	9.76**
Cross IV (IET-15429 X IET-25453)						
RH %	7.16	4.48**	6.81*	4.83**	5.39**	8.08**
HB %	6.01	3.73	5.74	4.22*	4.70*	6.757*
ID %	8.11*	7.05**	10.47**	6.84**	7.60**	11.19**

* and **, significant at 5% and 1%, respectively.

Conclusion

The significant relative heterosis and/or heterobeltiosis in desired direction were observed for plant height, grains per panicle, 100 seed weight, harvest index, amylose content, Fe content, kernel L:B ratio, hulling (%), milling (%) and head rice recovery (%) there by heterosis breeding would be more practical approach for higher grain yield in rice. Though the traits *viz*., days to 50% flowering and days to maturity had negative estimates in those crosses that showed significantly positive relative heterosis and/or heterobeltiosis for grain yield, revealed the negative association among grain yield and its component traits. For improvement of such traits along with high grain yield, population improvement methods such as reciprocal recurrent selection would be beneficial. But it was too much difficult in crop like rice. The crosses which depicted positively significant heterosis for protein content, iron content, zinc content and amylose content had less grain yield, the quality of rice could be improved by heterosis breeding but it might resulted into lower yields therefore population improvement is a good option to improve all these traits.

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