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Heterosis and inbreeding depression for yield, its contributing characters and physiological parameters in rice (*Oryza sativa* L.) under stress condition

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Abstract
Heterosis and inbreeding depression studies in rice were carried out on seventeen characters against two crosses: Cross I (NDRK 5004 × NUD 3) and Cross II (PANT 10 X IR 28) at Student's Instructional Farm of Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya-224229 (U.P.), India. Heterosis of F1 hybrids over Standard parent and better parent varied from character to characters in the two crosses. Significant positive heterosis was observed for harvest index and grain yield per plant in both the crosses. Highest inbreeding depression was observed for grain yield per plant and lowest for biological yield per plant in Cross I. While highest inbreeding depression was observed for harvest index and lowest for leaf nitrogen in Cross II. Grain yield per plant in Cross I and spikelet per panicle in Cross II recorded high level of heterosis and inbreeding depression. Significance of dominance gene effects and epistatic interactions for most of the traits in six crosses indicated that exploitation of heterosis through hybrid varieties appears to be a potential alternative. The positive and significant heterobeltiosis was noted for panicle length and grain yield per plant in sodic conditions. Above studies suggested that for crop improvement it would be desirable to follow different selection methods/breeding methods to be improve varieties and yield also.

Keywords: rice, heterosis, inbreeding depression, segregating generation, grain yield, physiological parameters

Introduction
Rice is the important cereal food crop and serves as the primary source of staple food for more than half of the global population. Because of higher population growth rate than crop productivity, there are food shortages in most of the area of India. Use of hybrid variety is an important strategy to meet the demand of increasing population. Hybrid rice is an economically viable option to increase cultivars yield potential. Heterosis in yield contributing traits ultimately brought about yield improvement in F1 hybrid rice (Vanaja and Babu, 2004) [7]. The superiority of F1 hybrid over both its parents in terms of yield and some other characters is known as heterosis. 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 poor crosses in early generations. In the present study two crosses were made in rice to study the manifestation of heterosis for yield and its components as well as to estimate the inbreeding depression.

Materials and Methods
The present investigation was conducted during *Kharif*, 2017, 2018 and 2019 at Student's Instructional Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya-224229 (U.P.), India. The experimental material was based on generation mean analysis set of 2 hybrids (F1), 2 segregant (F2), 2 BC1 and 2 BC2 developed by crossing of six parameters. Six genetically diverse genotypes *viz.*, NDRK 5004, NUD 3, Pant 10, IR 28, CSR 10, Sushk samrat were inter crossed in generation mean analysis fashion were evaluated in Randomized Block Design with three replication during *Kharif* 2019 each plot was consisting of a double row of 3 meter long beds with intra row spacing spaced 20 cm apart. Seed to seed distance within a row will be kept 15 cm. Similar planting distance will be maintained for P1, P2, F1's, F2's, and B1 and B2.The desired observation will be recorded on five randomly selected plants for parents, 10 plants for F1's, 15 plants for B1, B2 and 20

plants for F2 generation. The soil type of the experimental site was sandy loam, low in organic carbon, nitrogen, and phosphorus and rich in potash (EC-3.2dSm^{-1}; ESP-45% and pH-9.2). Observations were made on the characters *viz.,* days to 50 % flowering, day to maturity, chlorophyll content, leaf nitrogen, leaf temperature, flag leaf area (cm^2), plant height (cm), panicle bearing tillers/plant, panicle length (cm), spikelet per panicle, grains per panicle, spikelet fertility (%), biological yield per plant, harvest index (%), 1000-grain weight (g), protein content (%) and grain yield per plant (g). Analysis of variance was calculated on the method suggested by Singh and Chaudhary (1995) for all the crosses. The heterosis over better and standard parent in F_1 and inbreeding depression in F_2 were computed according to Fonseca and Patterson, 1968.

Results and Discussion

Four parents and two F_1 crosses were studied during *Kharif* 2019. Analysis of variance revealed significant difference among the parents, F_1's hybrids and F_2's generation against all characters studied except leaf nitrogen and panicle length (Table 1). Among the yield component in grains per panicle exhibited highest significant difference and days to 50 % flowering exhibited lowest significant difference. Heterobeltiosis, standard heterosis and inbreeding depression for 17 characters in cross I and II are given in Table 2. In Cross I significant positive desirable relative heterobeltiosis (heterosis over better parent) was observed for panicle length (18.48 %), harvest index (30.86 %) and grains yield per plant (36.51 %), 1000-grain weight (10.21%). Chlorophyll content (14.81 %), leaf nitrogen (1.98 %), flag leaf area (4.31 %), panicle bearing tillers per plant (22.84 %) also showed the significant positive relative heterosis but not in desired direction but significant negative relative heterosis in desired direction was observed for plant height (-8.77 %), spikelet per panicle (-2.03 %), grains per panicle (-3.22 %), spikelet fertility (-9.71 %) and biological yield per plant (-6.70 %). Thorat *et al*. (2017) [5] reported significant positive heterosis for fertility percentage (%). Significant positive desirable (heterosis over standard parent) was observed for days to maturity (5.90 %), chlorophyll content (29.38 %), leaf temperature (22.56 %), spikelet per panicle (9.04 %), grains per panicle (17.35 %), harvest index (25.99 %) and grain yield per plant (59.70 %) and but significant negative Standard heterosis in desired direction was observed for plant height (-5.93 %) and days of 50% flowering (-3.34 %). Negative heterosis is desirable for leaf nitrogen, flag leaf area, panicle bearing tillers/plant, panicle length, spikelet fertility, biological yield, 1000 grain weight (g) and protein content (%) because this will help the hybrid to mature earlier. Short duration varieties are of breeders interest for cultivation, therefore, heterosis in negative direction is desirable for days to 50 % flowering and plant height. Reddy *et al*. (2012) [4] reported significant negative heterosis over better parent for days to 50% flowering. While cross II exhibited high significant desirable positive heterosis over standard parent for chlorophyll content (17.06 %), leaf temperature (18.46 %), plant height (7.16 %), panicle length (34.33 %), spikelet per panicle (9.39 %), grains per panicle (15.23 %), spikelet fertility (3.60 %), harvest index 20.31 %) and grains yield per plant (23.42 %) but significant negative relative heterosis was observed for days of 50% flowering (-3.52 %) and days to maturity (-3.61 %). Raju *et al*. (2005) [2] reported high degree of heterosis for number of tillers per plant. Flag leaf area (9.66), panicle bearing tillers/plant (23.64) and protein content (8.39) also showed the positive relative heterosis but not in desired direction. However, Cross II showed high significant positive heterosis over better parent in desired direction for chlorophyll content (36.81%), plant height (38.19%) panicle length (12.09%), spikelets per panicle (42.14%), grains per panicle (43.49%) and biological yield per plant (72.24%). Vanaja and Babu (2004) [7] reported significant and favorable heterosis in number of panicles per plant. They found that yield increase was largely due to significant and favorable heterosis. Significant negative heterobeltiosis in desired direction was observed for days to maturity (-4.36 %) and 1000 grain weight (-9.07 %). The present findings are akin to the findings of Gontcharova and Gontcharova (2003) [1] who reported significant heterosis for plant height. Heterosis in positive as well as negative direction for grain length has been reported by Reddy *et al.* (2012) [4]. Several workers have also reported wide range of variation in expression of heterosis for grain yield trait (Reddy 2004, Tiwari *et al*. (2011) [3, 6] and Thorat *et al*. (2017) [5]. Among the different characters studied highest inbreeding depression was observed for all characters. The highest inbreeding depression show grain yield per plant (10.52%) and lowest inbreeding depression was observed for biological yield per plant (-8.50 %) of cross I. Among the different characters studied highest inbreeding depression was observed for all characters but the highest inbreeding depression show harvest index (20.50%) and lowest inbreeding depression was observed for leaf nitrogen (-12.80%) of cross II. Raju *et al*. (2005) [2] studied heterosis and inbreeding depression in rice for yield components and kernel characteristics.

Conclusion

The present investigation highlighted the differential performance in two rice crosses for heterosis and inbreeding depression against different component characters. In cross I (NDRK 5004 x NUD 3) most of the yield attributing characters were recorded as positively significant heterosis over standard parent and better parents. To develop commercial hybrids it is important to have significantly better heterotic combinations in component characters ultimately enhance the grain yield which significantly enhances the yield performance. If high heterosis is followed by high inbreeding depression, indicates presence of non- additive gene action. Grain yield per plant in Cross I and spikelet per panicle in Cross II showed high level of heterosis coupled with inbreeding depression was revealed the importance of dominance gene effects for controlling the said varieties. Since dominance makes the large contribution to heterosis in Grain yield per plant and spikelet per panicle in rice, therefore, heterosis breeding and recombinant breeding are adequate to improve these traits. High heterosis is well-known to be a result of the effects of non-additive genes. Therefore simple selection procedures *i.e,* pure line selection and mass selection method are sufficient to harness the additive gene action.

Table 1: Analysis of variance for differences between families (crosses) for 17 metric traits in sodic soil condition

Characters	Replications	Families	Error
D.F.	**2**	**3**	**6**
Days to 50% flowering	0.87	7.50*	1.00
Days to maturity	4.86	52.22**	3.67
Chlorophyll content	1.15	14.57**	0.25
Leaf Nitrogen	0.00	0.00	0.00
Leaf temperature	2.23*	21.08**	0.36
Flag leaf area (cm2)	2.95	9.16*	1.46
Plant height (cm)	7.27**	484.28**	0.34
Panicle bearing tillers/plant	0.97*	14.75**	0.14
Panicle length (cm)	2.60	3.74	2.24
Spikelet/panicle	0.06	3845.34**	0.62
Grains/panicle	2.43	4795.73**	1.46
Spikelet fertility (%)	0.70	119.65**	2.71
Biological yield/plant (g)	2.32	29.13**	2.38
Harvest index (%)	0.73	76.35**	2.04
1000 -grain weight (g)	2.28	16.55**	0.44
Protein content (%)	0.31	2.75**	0.09
Grain yield/plant (g)	3.04*	49.57**	0.42

*, ** significant at 5% and 1% level of probability, respectively.

Table 2: Heterosis over standard-parent and over better-parent (%) for 17 metric traits in cross I and II under sodic soil condition

Characters	Heterosis over standard-parent (%)		Heterosis over better-parent (%)		Inbreeding depression (%) in F_2 over F_1	
	Cross I	**Cross II**	**Cross I**	**Cross II**	**Cross I**	**Cross II**
Days to 50% flowering	-3.34*	-3.52**	-2.06	-1.76	-1.62**	-2.80**
Days to maturity	5.90**	-3.61**	-0.39	-4.36**	1.95**	-4.31**
Chlorophyll content	29.38**	17.06*	14.81	36.21**	1.68**	14.12**
Leaf Nitrogen	-1.91	-2.38	1.98	10.06	-1.22**	-12.80**
Leaf temperature	22.56**	18.46**	-4.33	1.82	8.42**	4.83**
Flag leaf area (cm2)	-4.14	9.66	4.31	2.79	-6.36**	15.17**
Plant height (cm)	-5.93**	7.16**	-8.77**	38.19**	-1.06**	-0.62**
Panicle bearing tillers/plant	-2.58	23.64	22.84	5.57	7.91**	0.31**
Panicle length (cm)	-0.58	34.33**	18.48**	12.09**	5.63**	1.11**
Spikelet/panicle	9.04**	9.39**	-2.03**	42.14**	1.65**	5.12**
Grains/panicle	17.35**	15.23**	-3.22**	43.49**	4.57**	4.58**
Spikelet fertility (%)	-0.89	3.60**	-9.71**	1.65	-6.22**	4.22**
Biological yield/plant (g)	3.05	-3.98	-6.70*	72.24**	-8.50**	8.57**
Harvest index (%)	25.99**	20.31**	30.86**	-4.11	1.38**	20.50**
1000-grain weight (g)	1.51	-7.38	10.21*	-9.07*	1.00**	-0.86**
Protein content (%)	-2.13	8.39	-8.48	22.58	-1.59**	1.57**
Grain yield/plant (g)	59.70**	23.42**	36.51**	11.68	10.52**	3.44**

*, ** Significant at 5% and 1% level of probability, respectively

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