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Jignesh R Balat
Department of Genetics & Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Ranjit P Thakor
Department of Genetics & Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Indrajay R Delvadiya
Department of Genetics & Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat India

Sahadev R Rathva
Department of Genetics & Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat India

Correspondence
Jignesh R Balat
Department of Genetics & Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Heterosis and inbreeding depression in F_2 population of rice (*Oryza sativa* L.) for yield and related traits

Jignesh R Balat, Ranjit P Thakor, Indrajay R Delvadiya and Sahadev R Rathva

Abstract
This study was conducted to evaluate genetic variation among eight parents and their six F_2 populations for various morphological attributes at the Regional Rice Research Station, N.A.U., Vyara during Kharif – 2015. For grain yield per plant all the six crosses were displayed highly significant average heterosis in desired direction. Whereas, significant heterobeltiosis in desired direction was exhibited by the crosses NVSR 2031 x GAR-13, IR-28 x GAR-13, Gurjari x Varalu and GR-7 x GAR-13. The significantly negative relative heterosis for days to flowering was depicted by the crosses Gurjari x Varalu and GR-7 x GAR-13, respectively. Which indicates the chances of desired transgressive segregants for this trait. In plant height three out of six viz., NVSR 2031 x GAR-13, IR-28 x GAR-13 and Gurjari x Varalu expressed significantly positive inbreeding depression. These crosses might be useful for getting dwarf stature in segregating generations.

Keywords: heterosis, inbreeding depression

Introduction
Rice (*Oryza sativa* L., 2n = 2x = 24) is second most widely grown cereal crop and the staple food for more than half of world's population, providing two thirds of calorie intake for more than three billion people in Asia and one -third of calorie intake of nearly 1.5 billion people in Africa and Lat in America. Global production of rice (Rough rice-paddy) is 685 million tons from 158 million hectares area and its productivity is 4.3 t/ha. In India, rice is cultivated in 44.13 million hectares during 2015 with production of 106.19 million tones and productivity of 2416 kg per hectare (Anon., 2015) [2]. In Gujarat, rice is cultivated in 7.88 lakh hectares with product ion of 16.36 lakh tones and productivity of 2076 kg per hectare (Anon., 2015) [2]. 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.

Materials and Method
Experiment was conducted in non-replicated trial as it was segregating material. Each row consisted of 20 plants with spacing of 20 cm x 15 cm inter and intra row spacing. Each F_2 was raised with minimum of 500 plant population and individual plant observations were recorded from 100 randomly selected plants. While, each parent and F_1 consisted of 50 plants and observations were recorded from 20 randomly selected plants. The experiment was planted in the month of July, 2015 at Regional Rice Research Station, N.A.U., Vyara. Data were recorded on days to flowering, days to maturity, plant height (cm), panicle length (cm), productive tillers per plant, no. of grains per panicle, 100 grain weight (g), kernel length (mm), kernel breadth (mm), kernel L/B ratio, grain yield per plant (g), straw yield per plant (g), harvest index (%) and leaf area (cm^2).

Statistical analysis
Heterosis: Heterosis, expressed as per cent increase or decrease in the mean value of F1 hybrid over the mid and bet ter parent (Heterobeltiosis) was computed for

Heterosis (H_1) (%) = {(F_1 – MP)/ MP} x 100
Where, F1 = Mean performance of hybrid, MP = Mean performance of mid parent

Heterosis (H_2) (%) = {(F_1 – BP)/ BP} x 100
Where, F_1 = Mean performance of hybrid, BP = Mean variance of better parents (P_1 or P_2) of hybrid.

Inbreeding depression: Inbreeding depression is est imated when both F1 and F2 populat ion of the same cross available. It is measured,

Inbreeding depression = {(F_1 – F_2)/ F_1} x 100

Where, F_1 and F_2 are the mean value of F_1 and F_2 progeny. Inbreeding depression may be high, medium, low and nil.

Results and Discussion
In case of grain yield per plant all the six crosses were displayed highly significant ralative heterosis in desired direction. Whereas, significant heterobeltiosis in desired direction was exhibited by the crosses NVSR 2031 x GAR-13, IR-28 x GAR-13, Gurjari x Varalu and GR-7 x GAR-13. It was further observed that the cross combination that had significant relative heterosis or heterobeltiosis for grain yield per plant in general, occupied significant relative heterosis or heterobeltiosis for panicle length and No. of grain per panicle.

Table 1.1: Estimation of relative heterosis (H1 %), heterobeltiosis (H2 %) and inbreeding depression (ID %) for fourteen quantitative of six different crosses.

Characters	IR-28 x Lalkada			NVSR-2031 x GAR-13			IR-28 x GAR-13		
	H_1 (%)	H_2 (%)	ID (%)	H_1 (%)	H_2 (%)	ID (%)	H_1 (%)	H_2 (%)	ID (%)
DF	-0.49	2.79*	-10.42**	-1.20	10.41**	-1.93	-5.96	11.96**	-11.49**
DM	-0.31	2.03*	-7.80**	-0.52	8.76**	-1.63	-3.95**	9.18	-8.20**
PH	2.91	18.53**	-13.85*	8.34**	12.46**	3.05**	7.30**	10.77**	10.00**
PL	15.31**	12.44**	6.62	38.46**	33.33**	16.03**	13.39**	6.93*	6.94
PTP	-2.78	-12.50*	16.43	28.57**	18.87*	8.25	51.40**	35.00**	48.77**
NGP	31.92**	15.69**	27.97**	10.45**	7.69**	7.35**	19.94**	8.45**	20.73**
100 GW	-0.93	-2.63**	0.96	5.82	-11.08**	0.53	3.63	-13.80**	-4.46**
KL	4.26	-5.94**	7.78*	6.66**	-6.13**	5.45*	0.58	-9.72**	-3.98
KB	4.94	-3.54**	2.28	10.69	4.00**	-1.31	16.53**	10.24**	8.17**
L/B ratio	-2.35	-18.25**	5.47	-3.20	-9.73**	5.84	-13.42**	-18.11**	-13.60**
GYP	25.24*	-1.10	40.65**	49.11**	19.86*	15.39	77.64**	26.12**	57.55**
SYP	10.26	-22.37**	43.07**	46.07**	18.72*	9.18	79.27**	32.16**	42.86**
HI	3.56	-5.85**	1.79	1.47	0.67	4.85**	0.81	-2.50*	17.56**
LA	61.70**	56.95**	24.83**	8.61	-14.71**	-7.33	-14.50*	-26.75**	-43.37

Characters	Gurjari x Varalu			GR-7 x GAR-13			Jaya x Lalkada		
	H_1 (%)	H_2 (%)	ID (%)	H_1 (%)	H_2 (%)	ID (%)	H_1 (%)	H_2 (%)	ID (%)
DF	-10.79*	3.01**	-11.73**	-8.35**	0.34	-3.37	-4.07	3.63**	-1.41
DM	-8.11*	1.95**	-8.69**	-6.11*	0.59	-2.34	-4.09	2.60**	-1.15
PH	12.29*	36.66**	15.25**	3.67	10.08**	-3.21	1.34	10.84**	-17.97**
PL	22.48**	15.93**	3.74	18.31**	17.56**	9.44	9.42**	8.72**	-2.12
PTP	-7.55	-14.04	5.51	31.25**	21.74**	37.62**	8.33	-15.58**	20.46*
NGP	59.25**	42.87**	30.28**	31.02**	15.09**	27.41**	27.86**	23.05**	-7.55**
100 GW	2.63*	-8.31	2.48	10.83*	-3.65**	0.69	2.47	-2.46**	3.21**
KL	0.99	-0.67	2.84	1.91	-9.52**	-1.64	4.58	-4.27**	-2.69
KB	-2.31	-16.43**	9.01**	6.77*	-0.57	-1.55	-1.14	-2.60**	6.19**
L/B ratio	0.70	-12.65**	-6.95**	-4.20*	-9.00**	-0.20	5.95*	-1.67*	-9.75**
GYP	51.90**	31.73**	35.70**	94.73**	78.58**	55.09**	43.11**	12.54	17.62
SYP	72.70**	48.20**	49.87**	86.63**	72.53**	46.92**	23.20	-10.10	28.74**
HI	-7.10**	-7.35**	-14.53**	2.37**	1.87**	79.56**	6.66**	0.21	-7.62**
LA	0.25	-22.79**	-8.30	5.15	-10.57**	-23.20**	3.40	-2.94	-61.57**

DF- Days of flowering, **DM**- Days of maturity, **PH**- Plant height (cm), **PL**- Panicle length (cm), **PTP**- Productive tillers per plant, **NGP**- No. of grains per panicle, **100 GW**- 100 grain weight (g), **KL**- Kernel length (mm), **KB**- Kernel breadth (mm), **GYP**- Grain yield per plant (g), **SYP**- Straw yield per plant (g), **HI**- Harvest index (%),
- Significant at **1.0 per cent level of probability, *- Significant at **5.0** per cent level of probability

Generally, most of these hybrids expressed negatively significant heterobeltiosis for 100 grain weight, kernel length, and kernel breadth. This indicated that grain yield had negative association with the quality parameters, therefore population improvement programme should be adapted for improvement of grain yield as well as quality traits. The relative heterosis and heterobeltiosis for grain yield per plant and its related traits was also reported by Reddy and Nerkar (1995) [8], Reddy (1996) [9], Singh and Maurya (1999) [12], Alam *et al.* (2004) [1], Joshi *et al.* (2004) [3], Reddy (2004) [10], Patil *et al.* (2005) [6], Raju *et al.* (2005) [7], Veni *et al.* (2005) [14], Pandya and Tripathi (2006) [4], Panwar and Ali (2010) [5], Reddy *et al.* (2013) [11], Venkanna *et al.* (2014) [15].
The significantly negative relative heterosis for days to flowering was depicted by the crosses Gurjari x Varal and GR-7 x GAR-13, respectively. Similar findings were reported by Joshi *et al.* (2004) [3].
The significantly positive relative heterosis as well as heterobeltiosis for panicle length and no. of grain per panicle was depicted by all the F_2 populations. The crosses NVSR 2031 x GAR-13 and IR-28 x GAR-13 showed significantly positive relative heterosis as well as heterobeltiosis for plant height, productive tillers per plant, straw yield per plant and

grain yield per plant; Gurjari x Varalu for plant height, straw yield per plant and grain yield per plant; GR-7 x GAR-13 for productive tillers per plant, straw yield per plant and grain yield per plant; IR-28 x Lalkada for leaf area. Similar findings were reported by Vanaja and Babu (2004) [13] for panicle length, grain yield per plant and leaf area; Venkanna *et al*. (2014) [15] for grain yield per plant.

The crosses, IR-28 x GAR-13, Gurjari x Varalu and GR-7 x GAR-13 manifested significant and positive high relative heterosis and heterobeltiosis for grain yield per plant also showed significant inbreeding depression. This indicated that degree of inbreeding depression expressed by the F_2 populations was somewhat related to the amount of heterosis in F_1 for grain yield per plant. The results further revealed that the crosses which depicted significant inbreeding depression for grain yield per plant also exhibited positive inbreeding depression for its related traits.

For days to flowering and day to maturity, all the crosses had negative inbreeding depression. In grain yield per plant four out of six *viz.*, IR-28 x alkada, IR-28 x GAR-13, Gurjari x Varalu and GR-7 x GAR-13 showed high heterosis and its components was invariably accompanied by high inbreeding depression in F_2 generation. Similar findings were reported by Reddy (2004) [10]. No. of grain per panicle showed positive and significant inbreeding depression. High heterosis accompanied by high positive inbreeding depression for no. of grain per panicle indicated the presence of non-additive gene effects governing the inheritance of these traits. In plant height three out of six *viz.*, NVSR 2031 x GAR-13, IR-28 x GAR-13 and Gurjari x Varalu expressed significantly positive inbreeding depression. These crosses might be useful for getting dwarf stature in segregating generations.

The results are matching with the results of Reddy and Nerkar (1995) [8], Reddy (1996) [9], Singh and Maurya (1999) [12], Joshi *et al.* (2004) [3], Reddy (2004) [10], Raju *et al.* (2005) [7], Veni *et al.* (2005) [14], Panwar and Ali (2010) [5], Reddy *et al.* (2013) [11] and Venkanna *et al.* (2014) [15].

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