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Patel HR
Department of Genetics and Plant Breeding, Navsari Agricultural University, Gujarat, India

Patel PB
Department of Genetics and Plant Breeding, Navsari Agricultural University, Gujarat, India

Corresponding Author:
Patel HR
Department of Genetics and Plant Breeding, Navsari Agricultural University, Gujarat, India

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

Patel HR and Patel PB

Abstract

The present investigation was carried out at Main Rice Research Centre, Navsari Agricultural University, Navsari during *kharif* 2018-19. The experimental material for the present investigation comprising of five generation *viz.,* P_1, P_2, F_1, F_2 and F_3 of following three crosses of rice (*Oryza sativa* L.) were used to study heterosis and inbreeding depression of yield, its components and qualitative traits. Heterosis of hybrids over mid parent and better parent varied from cross to cross and character to character. For grain yield per plant only cross-I (IET-25475 x IET-25477) exhibited significant and positive relative heterosis as well as heterobeltosis and cross-I also exhibited positive and significant relative heterosis for three important yield attributing traits *viz.*, productive tillers per plant, grains per panicle and 100 grain weight.

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

Introduction

Rice (*Oryza sativa* L.) is a well-known cereal crop grown in almost every part of the world. Although, the plant is naturally self-pollinated, strong heterosis is observed in their F1 hybrids. The term heterosis was coined by Shull (1908) [16] for quantitative measure of superiority of F1 over its parents. The phenomenon of heterosis has been a powerful force in the evolution of plants and has been exploited extensively in crop production (Birchler *et al*., 2003) [4]. Heterosis in rice can often be poorly expressed as reported by some scientists (Mohammed and Mohanty, 1992 and Vive kananden and Giridheram, 1995) [8, 19].

The phenomenon of heterosis has been observed in many self-pollinated crop species including several of the grain legumes. 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) [10]. Heterosis may be positive or negative. 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 (Amrita Kumari and Senapati, 2019).

Material and Methods

The material comprising of five genetically diverse parents of rice (IET-25475, IET-25477, GNR-7, GNR-3 and GAR-13) selected on the basis of their geographic origin, variation in morphological characters and based on their mineral nutrient content. Three crosses (Cross-I: IET-25475 x IET-25477, Cross-II: GNR-7 x GNR-3 and Cross-III: GAR-13 x IET-25477) obtained by crossing of five diverse parents during summer 2018 at Main Rice Research Centre, Navsari Agricultural University, Navsari. A part of fresh F1s seeds of above crosses and parents kept reserve and part of F1s seeds were grown and selfed in kharif 2018 to get F2s seeds. Selfing of F2s was done during summer-2019 to get F3s seeds. The experimental material consisting of three families, each having five generations (P1, P2, F1, F2 and F3) was grown in compact family block design with three replications, whereas, different generations *viz*., P1, P2, F1, F2 and F3 of each family represented individual experimental unit within family. The individual replication was represented by three family blocks, two rows each of P1, P2 and F1, thirty rows of F2 and fifteen rows of F3 generations of each crosses. Twenty plants were planted in each row. The experiment was surrounded by four guard rows to avoid damage and border effects.

Observations were recorded for eleven different characters *viz* days to flowering, days to maturity, plant height, productive tillers per plant, grains per.panicle, 100 grain weight, grain yield per plant, straw yield per plant, L: B ratio, amylose content and Zn content.

Heterosis for F1 hybrids and inbreeding depression for F2 populations were estimated using following formula.

Estimation of heterosis and inbreeding depression

Heterosis, expressed as per cent increase or decrease of F1 over its mid parent (relative heterosis) and over better or superior parent (heterobeltiosis):

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

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

Where,

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

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

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

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

Where,

$\overline{F}_1$ = Mean value of the F_1 hybrid

$\overline{F}_2$ = Mean value of the F_2 generation

Results and Discussion

The manifestation of relative heterosis, heterobeltiosis and inbreeding depression are presented in table 1 and table 2. For grain yield per plant only cross-I (IET-25475 x IET-25477) exhibited significant and positive relative heterosis as well as heterobeltiosis. The highest heterosis of 17.75% and heterobeltiosis of 14.80% were exhibited by cross IET-25475 x IET-25477, which also performed well for productive tillers per plant, grains per panicle and 100 grain weight. High and positive heterosis for grain yield in rice had been reported by several earlier workers *viz*., Panwar and Ali (2010) [11], Adilakshmi and Reddy (2011) [1], Patil *et al*. (2011) [12], Soni and Sharma (2011) [17], Reddy *et al*. (2013) [13], Venkanna *et al*. (2014) [18], Anis *et al*. (2016) [2], Borah *et al*. (2017) [5] and Rumanti *et al*. (2017) [14].

In case of days to flowering, none of the crosses depicted significant relative heterosis, whereas significant heterobeltiosis in desired direction was exhibited by the cross-II (GNR-7 x GNR-3) and cross-III (GAR-13 x IET-25477). These results are in conformity with those obtained by Patil *et al*. (2011) [12] and Soni and Sharma (2011) [17].

For days to maturity, none of the crosses exhibited significant relative heterosis, whereas cross-II (GNR-7 x GNR-3) exhibited positive and significant heterobeltiosis in desirable direction. These results are in conformity with those obtained by Patil *et al*. (2011) [12] and Soni and Sharma (2011) [17].

Two crosses i.e., cross-II (GNR-7 x GNR-3) and cross-III (GAR-13 x IET-25477), out of three crosses exhibited positive and significant hetrobeltosis and none of the cross depicted significant relative heterosis for plant height. Similar results were reported by Patil *et al*. (2011) [12], Soni and Sharma (2011) [17] and Venkanna *et al*. (2014) [18].

In case of productive tillers per plant, all the crosses depicted significant and positive relative heterosis and cross-III (GAR 13 x IET-25477) exhibited significant and positive heterobeltiosis. These results are in conformity with those obtained by Soni and Sharma (2011) [17], Ghara *et al*. (2014) [6], Venkanna *et al*. (2014) [18], Anis *et al*. (2016) [2], Borah *et al*. (2017) [5] and Rumanti *et al*. (2017) [14].

Out of three crosses, cross-I (IET-25475 x IET-25477) showed significant and positive relative heterosis and cross-III (GAR-13 x IET-25477) displayed significant superiority in grains per pani cle over better parents. The results are in conformity with the findings of Sharma *et al*. (2013), Ghara *et al*. (2014) [6], Venkanna *et al*. (2014) [18], Anis *et al*. (2016) [2], Borah *et al*. (2017) [5] and Rumanti *et al*. (2017) [14].

For 100 grain weight, out of three crosses, cross-I (IET-25475 x IET-25477) showed significant and positive relative heterosis and cross-II (GNR-7 x GNR-3) and cross-III (GAR-13 x IET-25477) displayed significant and negative heterobeltosis. Similar results were reported by Soni and Sharma (2011) [17], Latha *et al*. (2013) [7], Venkanna *et al*. (2014) [18], Anis *et al*. (2016) [2], Borah *et al*. (2017) [5] and Rumanti *et al*. (2017) [14].

For straw yield per plant, only cross-III (GAR-13 x IET-25477) had positive and significant relative heterosis and heterobeltosis. These results are in akin with those obtained by Soni and Sharma (2011) [17], Reddy *et al*. (2013), Venkanna *et al*. (2014) [18], Anis *et al*. (2016) [2], Borah *et al*. (2017) [5] and Rumanti *et al*. (2017) [14].

For L:B ratio, cross-III (GAR-13 x IET-25477) showed positive and non-significant relative heterosis, whereas cross-I and cross-II (GNR-7 x GNR-3) exhibited negative and significant heterbeltosis. Similar results were reported by Patil *et al*. (2011) [12] and Venkanna *et al*. (2014) [18].

Positive and significant heterosis for Zn content found in cross-II (GNR-7 x GNR-3) and cross-III (GAR-13 x IET-25477). Out of three crosses, cross-III exhibited negative and significant heterobeltosis, which is not desirable. Similar result was reported by Nagesh *et al*. (2012) [9].

For amylose content, cross-III (GAR-13 x IET-25477) showed positive and significant relative heterosis, whereas cross-I exhibited negative and significant heterobeltosis. Similar result was reported by Nagesh *et al*. (2012) [9].

All the three crosses exhibited non-significant inbreeding depression for days to flowering, days to maturity, plant height, productive tillers per plant, grains per panicle, 100 grain weight, L: B ratio, grain yield per plant, straw yield per plant, Zn content and amylose content. The results are matching with the results of Panwar and Ali (2010) [11], Adilakshmi and Reddy (2011) [1], Nagesh *et al*. (2012) [9], Reddy *et al*. (2013) [13] and Venkanna *et al*. (2014) [18].

Significant positive heterosis for grain yield per plant and its related traits indicated major role of non-additive gene actions in the inheritance of grain yield per plant and its attributes. Crosses with higher and positive estimates of heterosis for grain yield and its related traits exhibited negative heterosis for nutritional quality traits like zinc content and amylose content suggested population improvement approach for improvement of those characters along with high grain yield and earliness. These findings are similar to those of Adilakshmi and Reddy (2011) [1], Nagesh *et al*. (2012) [9] and Venkanna *et al*. (2014) [18].

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 and 100 grain weight in three crosses of rice

Estimates (%)	Days to flowering			Days to maturity			Plant height			Productive tillers per plant			Grains per panicle			100 grain weight		
Cross-I (IET-25475 x IET-25477)																		
RH% ±SE	0.25	±	2.57	-1.58	±	3.52	0.85	±	4.63	12.45*	±	0.58	14.13*	±	13.75	13.46**	±	0.10
BH% ±SE	3.46	±	2.10	2.75	±	2.87	2.53	±	3.78	6.75	±	0.47	9.17	±	11.22	-2.07	±	0.08
ID% ±SE	-1.09	±	5.08	-1.43	±	6.23	-7.41	±	8.94	19.69	±	2.73	2.41	±	15.90	5.37	±	0.34
Cross-II (GNR-7 x GNR-3)																		
RH% ±SE	4.42	±	3.02	2.94	±	3.57	3.02	±	2.87	12.60*	±	0.48	10.80	±	14.34	-3.85	±	0.09
BH% ±SE	11.63**	±	2.46	7.78**	±	2.92	7.27**	±	2.34	6.01	±	0.39	0.98	±	11.71	-28.49**	±	0.07
ID% ±SE	-0.107	±	6.42	0.44	±	7.36	3.36	±	4.41	18.35	±	2.14	7.35	±	21.56	-12.57	±	0.34
Cross-III (GAR-13 x IET-25477)																		
RH% ±SE	3.28	±	2.92	-0.30	±	2.11	1.73	±	6.40	12.39*	±	0.50	-3.52	±	13.76	-1.50	±	0.07
BH% ±SE	10.16**	±	2.38	2.11	±	1.72	10.99*	±	5.22	8.78*	±	0.40	-12.38**	±	11.24	-8.81**	±	0.06
ID% ±SE	0.63	±	3.50	-1.26	±	3.94	-1.60	±	6.15	15.06	±	2.15	1.60	±	22.93	0.69	±	0.15

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

Table 2: Estimates of relative heterosis (RH %), heterobeltiosis (HB %) and inbreeding depression (ID %) for grain yield per plant, straw yield per plant, L: B ratio, amylose content and Zn content in three crosses of rice

Estimates (%)	Grain yield per plant			Straw yield per plant			L: B ratio			Amylose content			Zn content		
Cross-I (IET-25475 x IET-25477)															
RH% ±SE	17.75*	±	1.01	5.57	±	1.52	-4.51	±	0.12	0.33	±	0.29	3.82	±	0.47
BH% ±SE	14.80*	±	0.82	-2.82	±	1.24	-14.55**	±	0.09	-1.89*	±	0.23	-1.09	±	0.38
ID% ±SE	17.41	±	2.28	16.98	±	3.46	-9.52	±	0.29	0.72	±	1.23	3.88	±	1.19
Cross-II (GNR-7 x GNR-3)															
RH% ±SE	12.88	±	1.40	14.06	±	2.11	-1.74	±	0.13	3.45	±	0.47	4.86**	±	0.28
BH% ±SE	2.44	±	1.14	3.83	±	1.72	-10.50**	±	0.10	1.64	±	0.38	2.56	±	0.23
ID% ±SE	13.46	±	2.78	14.64	±	4.14	3.00	±	0.24	3.85	±	1.41	3.13	±	0.55
Cross-III (GAR-13 x IET-25477)															
RH% ±SE	12.92	±	1.07	15.54*	±	1.60	1.76	±	0.11	5.83**	±	0.49	14.22**	±	0.26
BH% ±SE	5.23	±	0.87	15.36**	±	1.30	-3.90	±	0.09	-0.96	±	0.40	-4.26**	±	0.21
ID% ±SE	15.81	±	2.24	16.80	±	5.45	3.50	±	0.22	3.28	±	1.67	6.33	±	2.62

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

Conclusion

In the present investigation, heterosis for grain yield per plant was observed due to heterosis for component characters *viz*., productive tillers per plant, grains per panicle and 100 grain weight which resulted in increased yield. So, these characters should be given due consideration while improving yield.

The significant relative heterosis and/or heterobeltiosis in desired direction were observed for plant height, productive tillers per plant, grains per panicle, 100 grain weight, grain yield per plant, straw yield per plant, L: B ratio, amylose content and Zn content there by heterosis breeding would be more practical approach for higher grain yield in rice. Though the traits, days to 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 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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