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HETEROSIS IN RICE UNDER PHOSPHORUS STRESS

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ABSTRACT

Seven parental rice varieties, 3 exotic and 4 indigenous, involved in a diallel cross, revealed heterosis for grain yield components and root and shoot characters, under phosphorus stress conditions of northeastern hill region of India. Pawnbuh, an indigenous cultivar, revealed unidirectional dominance in respect of flag leaf area/plant, good grains/panicle, panicle weight, and grain yield/plant. Further, Pawnbuh in combination with Khonorullo, another local cultivar, gave the highest positive heterosis for grain yield/plant.

Key words: Heterosis, phosphorus stress, rice.

Production of hybrid rice is a comparatively recent phenomenon in rice breeding. Exploitation of heterosis, particularly for yield characters, is expected to be of practical use for making breakthrough in yield. Such exploitations are much needed in the rice growing areas, particularly when various kinds of stress conditions prevail. One such area is the northeastern hill (NEH) region of India, where phosphorus deficiency, soil moisture deficiency, and low temperature are some of the major stress conditions limiting rice production. In the present study, an attempt has been made to analyse the heterotic effect in the F_1 of a set of diallel crosses involving low-phosphorus tolerant types evolved by IRRI and indigenous cultivated types of the northeastern hill region in India.

MATERIALS AND METHODS

The low-phosphorus tolerant types, IR 28, IR 29 and IR 30, developed at IRRI, Philippines [1], and indigenous cultivated types of NEH region, Khonorullo, Mirikrak, Pawnbuh, and Ngoba, were used in a one-way diallel set of crosses. The parents and all possible cross combinations involving seven parents were sown in Nayabunglow, Meghalaya, NEH region of India, at the altitude of 800 m, in 3-replicated randomized block design. The soil was tested for available phosphorus content prior to sowing. The precropping soil analysis indicated that the soil was acidic (pH 5.0) with low P content (5 ppm). In the fertilizer schedule, P was withdrawn and only N and K were applied @ 20 and 30 kg/ha, respectively. Culture

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and replication wise observations were recorded for 16 different vegetative and reproductive characters, including grain yield. Heterosis was estimated as percentage over the better parent (BP) of each cross. The best commercial variety, Ngoba, was considered for estimation of economic heterosis of the F_1 lines. Combining ability analysis was undertaken following Griffing's Model II, Method 2 [2].

RESULTS AND DISCUSSIONS

Heterosis. The parental line Pawnbuh in crosses with all other lines exhibited considerable positive heterosis in respect of flag leaf area, good grains/panicle, panicle weight, and grain yield/plant (Table 1), indicating unidirectional dominance of higher character values. In respect of other yield characters, the effect of variety Pawnbuh was, however, variable both in magnitude and in direction. Similar unidirectional

Table 1. Estimation of BP and economic heterosis (%) for yield characters in rice

Cross	Plant height	Flag leaf area per plant	Ear-bearing tillers	Panicle length	Main branches per panicle	Good grains per panicle	Grain density	1000-grain weight	Panicle weight	Grain yield per plant	Economic heterosis for grain yield
IR 28 × IR 29	1.1	−20.9	−29.1	8.0**	1.4*	−52.8	−27.6	2.5**	−40.2	−51.2	−60.6
IR 28 × IR 30	16.8**	35.8**	0.6	6.3**	−0.7	4.8	−9.9	−1.1	2.6	5.2**	−26.4
IR 28 × Khonorullo	−15.4	102.5**	1.3	1.2	21.1**	−24.6	−67.5	46.7**	1.7	10.6**	−22.6
IR 28 × Mirikrak	−5.7	16.0**	−54.3	−8.0	−8.5	0.9	−8.7	−0.5	2.5	10.7**	1.1
IR 28 × Pawnbuh	−7.2	79.0**	9.2**	−8.2	−5.2	167.7**	72.8**	−19.4	117.8**	159.9**	123.5**
IR 28 × Ngoba	4.6	19.5**	39.5**	−7.2	−16.2	14.4	−16.3	2.3**	15.9**	17.4**	17.4**
IR 29 × IR 30	−1.6	63.9**	39.3**	−4.9	0.1	64.0**	8.5**	−1.4	54.9**	63.3**	31.9**
IR 29 × Khonorullo	−7.7	177.7**	17.1**	−3.1	52.3**	125.1**	−1.7	35.0**	168.1**	200.6**	142.9**
IR 29 × Mirikrak	−11.1	24.2**	−8.8	−12.8	−12.2	−6.0	−62.8	33.3**	18.8**	39.4**	27.4**
IR 29 × Pawnbuh	−11.0	92.5**	2.6*	−14.9	−9.3	101.4**	36.1**	−22.4	85.4**	115.4**	85.2**
IR 29 × Ngoba	13.7**	9.4	13.3**	−3.2	−7.0	86.3**	40.2**	−11.2	53.7**	54.6**	54.6**
IR 30 × Khonorullo	−24.9	33.2**	−28.3	−4.5	−6.5	−30.2	−37.0	1.5	15.2**	1.0	−30.1
IR 30 × Mirikrak	−16.4	35.2**	−11.2	−6.2	−15.5	−49.9	−65.4	−3.4	−31.1	−46.4	−51.0
IR 30 × Pawnbuh	−0.9	135.1**	26.2**	−2.6	−4.8	174.5**	19.5**	2.1*	165.3**	178.7**	139.6**
IR 30 × Ngoba	1.9	−40.4	−2.6	−14.3	−18.9	3.2	10.9**	−5.3	−1.4	−6.5	−6.5
Khonorullo × Mirikrak	5.2**	−0.4	49.9**	−6.4	−21.3	−58.3	−66.5	50.6**	−25.5	−31.3	−37.3
Khonorullo × Pawnbuh	23.3**	161.2**	80.8**	6.4**	5.8**	138.2**	−12.9	11.5**	158.7**	204.4**	161.7**
Khonorullo × Ngoba	2.5	5.8	−28.9	18.5**	14.5**	−25.6	−23.2	20.9**	37.7**	−9.4	−9.4
Mirikrak × Pawnbuh	10.8**	37.0**	26.6**	10.5**	−1.8	23.4**	−34.8	−15.1	82.4**	69.7**	55.0**
Mirikrak × Ngoba	7.8**	88.1**	−5.9	8.3**	−6.1	93.4**	−28.8	23.7**	154.9**	148.6**	148.6**
Pawnbuh × Ngoba	0.2	5.5	−21.7	−6.4	−6.0	27.9**	45.9**	−22.0	26.4*	33.6**	33.6**
Parental mean	99.9	201.4	7.6	21.8	8.2	520.5	4.6	21.6	14.7	11.1	—
Hybrid mean	117.8	337.0	9.5	23.7	9.4	795.6	4.5	24.7	25.5	19.4	—
h^2,%	17.9	67.3	25.3	8.7	14.7	52.9	−2.4	14.1	73.0	74.6	—

Parental yield, g/plant: IR 28 9.9, IR 29 11.4, IR 30 7.4, Khonorullo 9.8, Mirikrak 12.9, Pawnbuh 12.1, and Ngoba 14.1.
*, **Significant at 5% and 1% levels, respectively.

dominance was shown by Khonorullo for grain weight and, consequently, cross Khonorullo × Pawnbuh showed highest positive heterosis for grain yield/plant. Other noteworthy crosses exhibiting economic heterosis are IR 29 × Khonorullo, IR 30 × Pawnbuh, and IR 28 × Pawnbuh. Heterosis for these characters were also reported earlier by many workers under normal conditions [3–10]. Table 3 further shows that other parental lines and cross combinations are character specific for positive heterotic effects. The maximum heterosis for grain yield (>200%) was obtained in crosses Khonorullo × Pawnbuh and IR 29 × Khonorullo. A similar range of heterotic effects was reported earlier in sorghum [11] and wheat [12]. Of the 10 direct yield contributing characters studied, crosses of varieties Khonorullo and Pawnbuh showed the highest positive heterosis for plant height, ear bearing tillers, and grain yield/plant, while for the remaining seven characters either Khonorullo or Pawnbuh was one of the parents exhibiting highest heterosis.

Table 2. Estimates of gca effects of different parent varieties in rice

Variety	Plant height	Flag leaf area per plant	Ear bearing tiller	Panicle length	Branches per panicle	Good grains per panicle	Grain density	1000-grain weight	Panicle weight	Yield
IR 28	−16.24**	−44.95**	0.61**	−1.90**	−1.21**	−101.14**	−0.47**	−1.26**	−5.01**	−3.25**
IR 29	−19.50**	−23.40*	1.74**	−2.72**	−0.74**	85.08**	−0.35**	−1.05**	−0.25	1.00
IR 30	−17.95**	−44.50**	0.66**	−1.97**	−0.66**	−115.73**	−0.92**	−1.78**	−4.09**	−3.41**
Khonorullo	20.32**	−3.94	−1.29**	1.39**	−0.46**	−100.71**	−0.01	2.11**	−0.78	−0.56
Mirikrak	17.93**	44.14**	−2.19**	2.26**	1.32**	−25.08	1.39**	−0.26	−0.09	−0.83
Pawnbuh	22.07**	44.40**	−0.49**	2.96**	1.49**	150.59**	0.22	3.51**	7.70**	6.13**
Ngoba	−6.64**	27.90**	0.96**	−0.02	0.31*	106.99**	0.13	−1.27**	2.52**	0.92
± Sgi	1.08	10.52	0.19	0.21	0.12	21.89	0.12	0.19	0.70	0.55
± S(gi-gj)	1.64	16.07	0.29	0.32	0.19	33.44	0.18	0.30	1.07	0.84

*, **Significant at 5% and 1% levels, respectively.

For the characters studied, Pawnbuh generally exhibited the highest gca effects due to preponderance of additive genes. On the contrary, other parents did not show similar trend. Thus, the heterotic effect is mainly due to additive × dominance or dominance × dominance interactions. The per se performance of parents and hybrids (Table 1) and the estimates of heritability for yield (74.6%), followed by panicle weight (73.0%), flag leaf area/plant (67.3%), good grains/panicle (52.9%), and ear bearing tillers (25.3%) indicates the relative merit of characters in respect of heterotic response. Among the parents, highest grain yield was recorded in Ngoba (14.1 g/plant) followed by Mirikrak (12.9) and Pawnbuh (12.1).

Combining ability effects. Table 2 shows the gca effects of parents. These results indicate clear superiority of Pawnbuh, followed by other indigenous lines for all the characters studied. A few noteworthy crosses listed in Table 3 further revealed that the crosses involving Pawnbuh or Khonorullo were mostly better combinations. The other two local varieties, i.e. Ngoba and Mirikrak, exhibited considerable

Table 3. Estimates of sca effects in important hybrids of rice

Cross	Plant height	Flag leaf area per plant	Ear bearing tiller	Panicle length	Branches per panicle	Good grains per panicle	Grain density	1000-grain weight	Panicle weight	Grain yield per plant
IR 28 × Pawnbuh	6.1*	53.8	1.86**	0.55	1.06**	532.9**	1.64**	−1.68**	12.2**	11.4**
IR 29 × Khonorullo	14.2**	170.8**	2.85**	1.07	2.08**	543.7**	1.65**	2.69**	16.6**	16.5**
IR 30 × Pawnbuh	16.2**	164.7**	2.08**	2.14**	0.55	347.8**	0.17	5.28**	19.5**	13.8**
Khonorullo × Pawnbuh	15.9**	176.4**	2.29**	1.23**	1.52**	323.0**	0.42	4.23**	15.1**	14.1**
Mirikrak × Ngoba	20.2**	191.4**	1.74**	2.81**	0.10	536.6**	0.45	3.99**	22.9**	17.7**
± Sij	3.1	30.6	0.56	0.62	0.36	63.7	0.34	0.56	2.03	1.6

*, **Significant at 5% and 1% levels, respectively.

heterosis, indicating that the indigenous varieties Khonorullo and Pawnbuh and other genotypes are better parents for producing heterosis under phosphorus stress in the NEH region of India. It also indicates that only selective parents are useful for hybrid vigour exploitation in rice where P deficiency is a limiting factor.

Table 4. Correlation coefficients (r) of heterosis between various yield influencing characters

Characters	r
Flag leaf area/plant vs good grains/plant	0.720**
Flag leaf area/plant vs panicle weight	0.811**
Flag leaf area/plant vs grain yield/plant	0.848**
Good grains/plant vs panicle weight	0.909**
Good grains/plant vs grain yield/plant	0.942**
Grain density vs 1000-grain weight	−0.694**
Panicle weight vs grain yield/plant	0.974**
Root length vs grain yield	0.678**
Root volume vs grain yield	0.531*
Fresh shoot weight vs grain yield	0.815**
Dry shoot weight vs grain yield	0.846**

*, **Significant at 5% and 1% levels, respectively.

Correlation studies. In order to derive maximum advantage of heterosis, the correlation between heterosis for other characters and grain yield/plant was studied (Table 4). The importance for grain yield of flag leaf area ($r = 0.848$), good grains/plant ($r = 0.942$) and panicle weight ($r = 0.974$) is evident from the strong association of heterosis for these characters and grain yield, on the one hand, and between flag leaf area and good grains/plant ($r = 0.720$) and panicle weight ($r = 0.811$) as well as between grains/plant and panicle weight ($r = 0.909$), on the other. The strong negative association between grain density and 1000-grain weight ($r = -0.694$) points toward only a limited use of grain density for maximization of grain yield. Earlier, Murayama [13] reported that heterosis for yield and 1000-grain weight were highly correlated. The significant positive correlation between heterosis for grain yield with that for root length ($r = 0.678$), root volume ($r = 0.531$), fresh shoot weight (r = 0.815), and dry shoot weight (r = 0.846) confirms the importance of root and shoot parameters in the expression of heterosis for grain yield and, thus, suggest their judicious use as selection criteria for increasing yield.

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