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SELECTION EFFECTS IN RICE AS ASSESSED BY GENETIC ANALYSIS IN SEGREGATING POPULATIONS

ABSTRACT

Estimation of selection effects on changes of a trait is of vital importance for the success of any plant breeding program, and helps to select the desirable breeding method. Heritability and genetic advance are important selection parameters, and selection success is a reflectance of selection response. To estimate selection effects on rice genetic parameters, a research was conducted using 4 different generations (two parents: Neda and Sadri, and two segregating populations: BC_1F_1 and BC_1S_1). After development of a backcross population, a single plant (BC_1#4) was selected based on its desirable performance, particularly in heading date and seven other morphological traits. BC_1F_1 population compared to mid-parent performance showed advance for heading date, plant height, tiller number, hundred seed weight, weight of filled seeds per panicle and grain yield per plant, while mean performance of BC_1F_1 population compared to BC_1S_1 population showed advance only for heading date, plant height, tiller number and grain yield. Prevalence of additive genetic effects in controlling panicle weight, hundred seed weight, weight of filled seeds per panicle, plant height and heading date was observed, and in contrast prevalence of non-additive effects in controlling grain yield was observed. High general heritability was observed for most traits, while only heading date and plant height showed a considerable specific heritability (60.7% and 67.5%, respectively), and grain yield showed a relatively low specific heritability (37.0%). High expected genetic advance (ΔGe) was obtained for tiller number (49.4%), followed by grain yield (43.5%) and plant height (35.5%), while the highest real genetic advance (ΔGe) was obtained for heading date (-8.5%) and tiller number (5.4%). High selection success was obtained only for heading date (51.8%). Altogether, the obtained results gave promise for selecting progenies with early maturity and semi-dwarfism in early segregating generations, while they suggested preference of heterosis for improvement of grain yield.

Key words: heritability, heterosis.rice, selection

INTRODUCTION

Rice is one of the most important agricultural products in the world earning substantial foreign exchange and is a staple food crop in densely populated Asia

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(Alavi *et al.,* 2009). Genetic improvement of this crop plant will serve the mankind living on our planet. Evaluation of important traits with direct or indirect effect on grain yield and sustainability of rice growers is indispensable for successful breeding of rice. Estimation of genetic parameters helps our understanding about gene action, identification of components of genetic variances and, finally facilitates the selection of a desirable breeding method (Ahmadikhah *et al.,* 2007, Immanuel *et al.,* 2013; Ahmadikhah *et al.,* 2015). The knowledge of genetic variability present in a given crop species for the character under improvement is of paramount importance for the success of any plant breeding program. Heritability and genetic advance are important selection parameters. Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone (Bisne *et al.,* 2009, Immanuel *et al.,* 2013).

Heritability values have been variable depending upon the genetic nature of genotypes for different studied characters. Vivek *et al.* (2000) observed high heritability coupled with high genetic advance for harvest index, biological yield per plant and grain yield per plant in evaluation of 39 tropical Japonica rice genotypes. Mishra and Verma (2002) evaluated 16 rice genotypes along with 72 F_1 hybrids and noted high heritability with high genetic advance for flag leaf area and plant height, indicating dominant role of additive gene action. The association of high heritability with high genetic advance was observed for plant height and grain yield per plant by Mahto *et al.* (2003). Swati and Ramesh (2004) reported high heritability for grain yield while moderate heritability for flag leaf area and plant height. Hosseini *et al.* (2005) observed 61 percent broad sense heritability for grain yield in rice. Saleem *et al.* (2008) noted high broad sense heritability and expected genetic advance in response to selection in next generation for all the studied traits. Genetic advance for plant height and yield per plant, calculated equal to19.4% and 14.6%, respectively.

High heritability coupled with high genetic advance was exhibited by harvest index, total number of chaffy spikelets per panicle, grain yield per plant, total number of filled spikelets per panicle and spikelet fertility percentage and selection may be effective for these characters (Bisne *et al.,* 2009). Bisne *et al.* (2009) obtained 98.7% general heritability for plant height, 89.4% for panicle length, 63.9% for tiller number, 98.0% for 100-seed weight, 98.7% for panicle length and 93.4% for yield per plant. Our objectives were to estimate the genetic parameters of some important traits in response to selection, to estimate the genetic advance and real selection success in rice.

MATERIAL AND METHODS

Plant material and trait evaluation

Two parental rice lines, Neda (P_1) and Sadri (P_2), were crossed in 2007 to produce F_1 hybrid. First generation of backcross (BC_1) was produced in 2008 by crossing of F_1 with Neda. BC_1 population (consisted of 25 plants) was sown in 2009. One BC plant was selected based on some desirable morphological characters, particularly early maturation, shorter height and longer panicle. The self-pollinated seeds of this plant (BC_1S_1) were sown next year (spring 2010). Each generation was sown in three replicats with crop spacing of 35 cm x 35 cm. For each parent 30 plants were analyzed, however for two BC_1 and BC_1S_1 generations, 25 and 78 plants were analyzed, respectively. Eight important quantitative traits including heading date (HD; days from germination to panicle emergence), plant height (PLH; cm), panicle length (PL; cm), tiller number (TN), hundred seed weight (HSW; g), panicle weight (PW; g), filled seed weight of panicle (WFS; g) and grain yield per plant (GY; g plant^{-1}) were evaluated on two parents, F_1, BC_1 and BC_1S_1 plants.

Studied genetic parameters

Some important parameters were evaluated on plants of each generation (P_1, P_2 and BC_1 and BC_1S_1) including mean, coefficient of variation (*C.V*), phenotypic variance (*VP*), environmental variance (*VE*), genetic variance (*VG*), broad-sense heritability (h^2b), narrow-sense heritability (h^2n) and genetic advance due selection (ΔG). Data were analyzed using GLM procedure and subsequent univariate tests in SPSS software (Kinnear and Collin 2000). Trait means were compared using Duncan multiple test, and graphs were drawn in excel spreadsheet. Mean square of experimental error (EMS) in ANOVA was considered as environmental variance (V).

Degree of dominance (*d*) was calculated as:

$$d = \sqrt{\frac{VD}{VA}}$$

where, *VA* and *VD* are additive and dominance genetic variances, respectively. Broad-sense heritability (h^2_b) and narrow-sense heritability (h^2n) were calculated as:

$$h_b^2 = \frac{VG}{VP}$$

$$h_n^2 = \frac{R}{D}$$

where, *VG* is genetic variance, *VP* is phenotypic variance, *R* is selection response and *D* is differential of selection. Expected genetic advance (ΔG_e) and real genetic advance due selection (ΔG_r) were calculated as:

$$\Delta G_e = k \times h_n^2 \times \sqrt{VP}$$

$$\Delta G_r = \frac{R}{GM}$$

where, *k* is a constant coefficient (here, *k* was considered equal to 2.06 for selection severity of 5%) and *GM* is grand mean in the experiment.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA)

Analysis of variance for 4 generations is shown in Table 1. This analysis showed that all eight traits significantly differed in studied generations, indicating that selection had significant effect on mean performance of studied traits. Grain yield h showed highest coefficient of variation (C.V) (13.1%), followed by tiller number (8.8%), while plant height and heading date had the least C.V (~1.9%).

Table 1

Analysis of variance (ANOVA) for different traits in the study

S.O.V	HD [day]	PLH [cm]	PL [cm]	TN	HSW [g]	PW [g]	WFS [g]	GY [g×plant^{-1}]
Generation	405.85**	1942.17**	28.36**	327.58**	0.40**	1.99**	1.86**	4770.59**
Error	9.204	10.378	0.948	11.732	0.033	0.177	0.182	298.225
Grand mean	79.4	87.0	22.7	19.5	2.22	3.59	3.33	65.9
C.V (%)	1.91	1.86	2.14	8.77	4.08	5.86	6.41	13.09

** differences are significant at 1% level of probability.

Selection effect on mean performance in BC_1F_1 generation

Mean performance of different traits for two parents, BC_1F_1, BC_1S_1 and selected plant in BC_1F_1 (BC_1#4) is shown in Table 2. As seen, mean of BC_1F_1 population compared to mid-parent mean was advanced in heading date (-1.6 days), plant height (-14 cm), tiller number (9.3), hundred seed weight (0.23 g), weight of filled seeds per panicle (0.56 g) and grain yield per plant (7.7 g). However, its mean compared to mid-parent mean did not differ for the remained traits. Based on better performance, particularly in heading date and plant height one plant (BC_1#4) in this population was selected to develop next generation

(Table 2). This plant had superiority over mean performance of BC_1F_1 generation in most other studied traits, too (Table 2; Fig 1) and hence, BC_1S_1 generation was developed from its self-pollination.

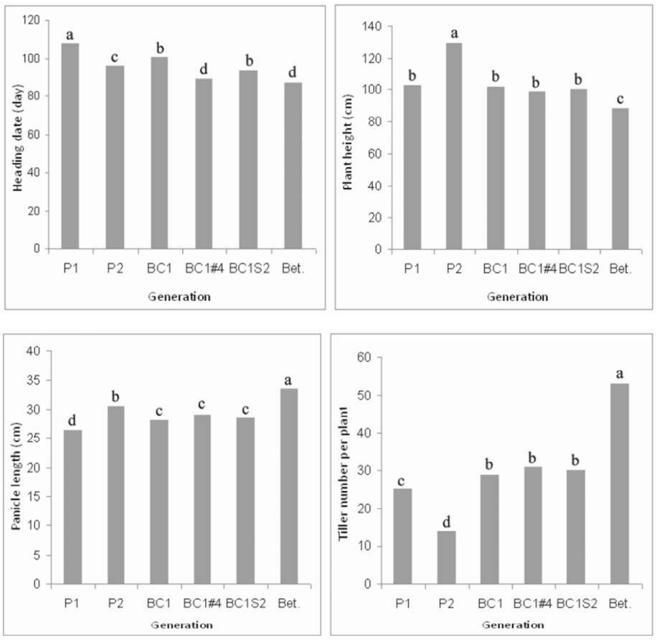
Table 2

Mean performance of studied generations

Parameters	P_1	P_2	Mid-parents	BC_1F_1	BC_1F_1#4	BC_1S_1	Better plants in BC_1S_1	S.E
HD	107.4	96.1	101.8	100.2	89.0	93.4	87.0	1.631
PLH	102.8	129.2	116.0	102.0	99.0	100.0	88.0	1.732
PL	26.4	30.5	28.45	28.1	29.0	28.5	33.5	0.523
TN	25.0	13.9	19.5	28.8	31.0	29.9	53.0	1.841
HSW	2.7	2.55	2.66	2.89	2.91	2.9	3.55	0.098
PW	4.3	3.89	4.14	4.82	4.88	4.85	6.91	0.226
WFS	4.2	3.5	3.86	4.44	4.5	4.47	6.42	0.229
GY	79.8	41.7	60.8	102.6	110.3	105.5	211.7	9.282

Selection effect on mean performance in BC_1S_1 generation

As seen in Table 2, mean performance of BC_1S_1 population compared to BC_1F_1 population was advanced in heading date (-6.8 days), plant height (2 cm), tiller number (1.1) and grain yield (2.9 g per plant). However, for the remained traits was not observed further progress compared to BC_1F_1 generation. Mean performance of different traits for best single plants in BC_1S_1 population is shown in Table 2. As seen, these plants have advantage in all studied traits over all preceded generations including two parents, encouraging possibility for continuing selection to obtain relatively supper rice lines (each harboring one or more desirable traits). Such lines had an improved performance even compared to better BC_1F_1 plant (BC_1#4); their superiority in heading date (-2 days), plant height (-11 cm), panicle length (4.5 cm), tiller number (22), grain yield (~101 g) and in the remained traits was considerable over selected BC_1#4 plant (Table 2; Figs 1 and 2).


Heading date (day)
P1 P2 BC1 BC1#4 BC1S2 Bet.
Generation
Plant height (cm)
P1 P2 BC1 BC1#4 BC1S2 Bet.
Generation
Panicle length (cm)
P1 P2 BC1 BC1#4 BC1S2 Bet.
Generation
Tiller number per plant
P1 P2 BC1 BC1#4 BC1S2 Bet.
Generation

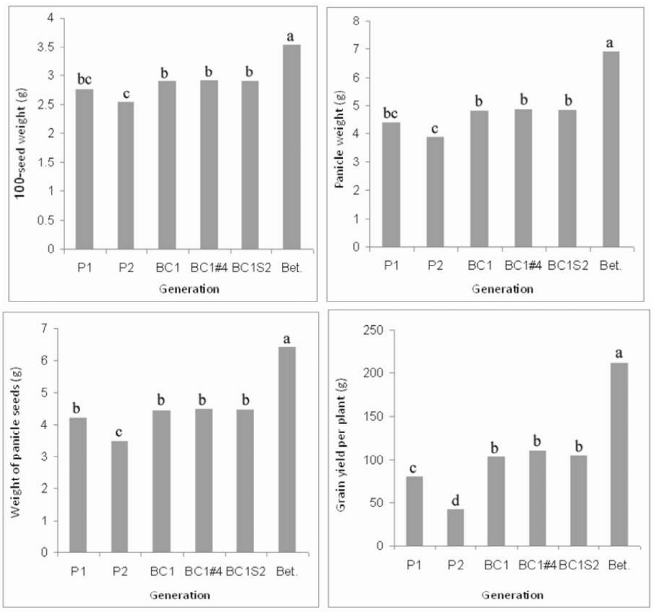

100-seed weight (g)
P1 P2 BC1 BC1#4 BC1S2 Bet.
Generation
Panicle weight (g)
P1 P2 BC1 BC1#4 BC1S2 Bet.
Generation
Weight of panicle seeds (g)
P1 P2 BC1 BC1#4 BC1S2 Bet.
Generation
Grain yield per plant (g)
P1 P2 BC1 BC1#4 BC1S2 Bet.
Generation

Fig. 1. Comparison of mean performance of studied generations for 4 phenological traits (heading date, plant height, panicle length and tiller number per plant). Means with common letters have no significant differences. Bet., better single plants in BC_1S_1.

Fig. 2. Comparison of mean performance of studied generations for 4 yield traits (100-seed weight, panicle weight, weight of panicle seeds and grain yield per plant). Means with common letters have no significant differences. Bet., better single plants in BC_1S_1.

Estimation of genetic parameters

Some important genetic parameters of the studied traits are shown in Table 3. As seen, degree of dominance (d) for panicle weight (0.523), hundred seed weight (0.573), weight of filled seeds per panicle (0.664), plant height (0.671) and heading date (0.71) is significantly lower than 1, indicating predominance of additive genetic effects in controlling these traits. However, value of this parameter for panicle length (0.856) and tiller number (0.879) is skewed toward 1, indicating that these traits are controlled by partial dominance. It seems that only grain yield is controlled by non-additive gene effects of dominance nature (d=~1.065). Shahid *et al.* (2012) also reported that grain yield of autotetraploid rice mainly was regulated by dominance variance. Above results show that improvement of most studied traits is possible via selection in segregating populations, while for grain yield breeders must rely on heterosis vigor (Shahid *et al.,* 2012).

It seems that half traits have a high degree of general heritability (h^2_b). Four traits such as plant height, heading date, panicle length and tiller number showed 87-91% general heritability (Table 3), a considerable part of which could be due to non-additive effects, because both additive and non-additive variances form the genetic variance. For the remained traits h^2_b exhibited only a moderate value between 69.7- 78.9%. In contrast to general heritability, the specific heritability (h^2_n) is more applicable for selection issues and genetic progress (Zhao *et al.,* 2006, Ahmadikhah *et al.,* 2007). Actual heritability can be equalized to specific heritability when many generations (parents, F_1, F_2, BC_1F_1 etc) are not available to breeders. Therefore, with availability of two non-segregating generations (two parents) and two segregating sequential generations (such as BC_1F_1 and BC_1S_1 in this research), it is possible to obtain selection response and differential of selection and hence, narrow-sense heritability can easily be calculated using their values. Values of selection response, differential of selection and h_2n have been shown in Table 3. As seen, only heading date and plant height have a considerable h^2_n (60.7% and 67.5%, respectively). This gives promise for selection of progenies with early maturity and semi-dwarfism in early segregating generations. Grain yield showed a relatively low h_2n (37.0%), again showing preference of heterosis for improvement of this trait.

High heritability with high genetic advance indicates the control of trait by additive gene effects and selection may be effective for those characters (Ahmadikhah *et al.,* 2007, Saleem *et al.,* 2010). High expected genetic advance (ΔGe) was obtained for tiller number (49.4%), followed by grain yield (43.5%) and plant height (35.5%) (Table 3). Ahmadikhah (2008) noted highest heritability and genetic advance for 1000-seed weight and plant height. Similar findings were also reported by Vanniarajan *et al.* (1996), Shivani and Reddy (200), Iftekharuddaula *et al.* (2001) and Gannamani (2009).

The highest real genetic advance (ΔGr) was obtained for heading date (-

Parameters	HD [day]	PLH [cm]	PL [cm]	TN
V_E	9.20	10.39	0.95	11.73
V_G	99.16	482.95	6.85	78.96
V_P	108.37	493.33	7.80	90.69
h^2_b	0.92	0.98	0.88	0.87
R	-6.80	-2.03	0.47	1.06
D	-11.00	-3.00	0.93	2.17
h^2_n	0.61	0.68	0.51	0.49
V_A	65.82	333.11	3.95	44.54
V_D	33.35	149.84	2.90	34.42
d	0.71	0.67	0.86	0.88
ΔGe [%]	16.4	35.5	12.8	49.4
ΔGr [%]	8.5[a]	2.3[a]	2.1	5.4
Selection success [%]	51.8	6.5	16.4	10.9
Parameters	**HSW [g]**	**PW [g]**	**WFS [g]**	**GY [g × plant^{-1}]**
V_E	0.03	0.18	0.18	298.23
V_G	0.92	0.45	0.42	1118.09
V_P	0.125	0.63	0.60	1416.32
h^2_b	0.74	0.72	0.70	0.79
R	0.01	0.03	0.03	2.84
D	0.02	0.06	0.06	7.68
h^2_n	0.55	0.57	0.48	0.37
V_A	0.07	0.36	0.29	523.98
V_D	0.02	0.10	0.13	594.11
d	0.57	0.52	0.66	1.07
ΔGe [%]	18.2	25.7	23.2	43.5
ΔGr [%]	0.4	0.9	0.8	4.3
Selection success [%]	2.2	3.5	3.4	9.9

8.5%) and tiller number (5.4%) followed by grain yield (4.3%), while for the remained traits value of ΔGr was very low (0.4-2.3%). On the basis of obtained results, selection success was high only for heading date (51.8%; Table 3), giving the promise for further advance in few next generations, as noted by Saleem *et al.* (2010) and Immanuel *et al.* (2013).

Table 3

Important genetic parameters of eight studied traits of rice

a. The sign of ΔG_r for these traits was negative.

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