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Study on selection effect, genetic advance and genetic parameters in rice

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ABSTRACT

Knowledge of selection effect on positive or negative changes of a character under improvement is of paramount importance for the success of any plant breeding program, and helps the selection of a desirable breeding method. Heritability and genetic advance are important selection parameters, and selection success is a reflectance of selection response. To estimate selection effect, genetic advance, heritability and selection success in rice, a study was conducted on 4 generations, including 2 parents, BC_1 and BC_1S_1 populations. After development of BC_1 population, one plant (BC_1-#4) was selected based on its desirable performance, particularly in heading date and seven other morphological traits. BC_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_1S_1 population compared to BC_1 population showed advance only for heading date, plant height, tiller number and grain yield. Estimation of degree of dominance (d) revealed prevalence of additive genetic effects in controlling panicle weight, hundred seed weight, weight of filled seeds per panicle, plant height and heading date, and prevalence of non-additive effects in controlling grain yield. 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 (ΔG_e) was obtained for tiller number (49.4%), followed by grain yield (43.5%) and plant height (35.5%), while the highest real genetic advance (ΔG_r) 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 selection of progenies with early maturity and semi-dwarfism in early segregating generations, while they suggested preference of heterosis for improvement of grain yield.

Key words: Rice, selection, heritability, response.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops worldwide. Breeding 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. 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 [2].

Heritability values have been variable depending upon the genetic nature of genotypes for different studied characters. Vivek et al. [14] 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 [6] evaluated 16 rice genotypes alongwith 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. Ahmadikhah [1] noted highest heritability and genetic advance for 1000-seed weight and plant height. The association of high heritability with high genetic advance was observed for plant height and grain yield per plant by Mahto et al. [5]. Swati and Ramesh [12] reported high heritability for grain yield while moderate heritability for flag leaf area and plant height. Hosseini et al. [4] observed 61 percent broad sense heritability for grain yield in rice. Saleem et al. [9] 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 [2]. Bisne et al. [2] 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 in this research were to estimate the improvement rate in mean performance of some important traits in response to selection, to estimate the genetic advance and real selection success, and to study the important genetic parameters in rice.

MATERIAL AND METHODS

Plant material

Two parental lines of rice, Neda (P_1) and Sadri (P_2), were crossed in 2007 to produce F_1 generation. 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_1 plant was selected based on some desirable morphological characters, particularly early maturation, shorter height and longer panicle. The selefed seeds of this plant (BC_1S_1) were sown next year (spring 2010). Each generation was sown in three replications with crop spacing of 35cm x 35cm. For each parent 30 plants were analyzed, however for two BC_1 and BC_1S_1 generations, 25 and 78 plants were analyzed, respectively.

Studied traits

Eight important quantitative traits including heading date (HD; days from germination to flower 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.

Studied genetic parameters

Some important parameters were evaluated on plants of each generation (P_1, P_2, F_1, BC_1 and BC_1S_1) including mean, coefficient of variation (C.V), phenotypic variance (V_P), environmental variance (V_E), genetic variance (V_G), broad-sense heritability (h^2_b), narrow-sense heritability (h^2_n) and genetic advance due selection (ΔG). Data were analyzed using GLM procedure and subsequent univariate tests in spss 11 software. Means of studied generations were compared using Duncan multiple test, and graphs were drawn in excel spreadsheet. Mean square of experimental error (EMS) in ANOVA table was considered as environmental variance (V_E).

Degree of dominance (d) was calculated as

$$d = (V_D / V_A)^{0.5}$$

where, V_A and V_D are additive and dominance genetic variances, respectively. Broad-sense heritability (h^2_b) and narrow-sense heritability (h^2_n) were calculated as

$$h^2_b = V_G / V_P \text{ and } h^2_n = R / D$$

Where, V_G is genetic variance, V_P is phenotypic variance, R is selection response and D is differential of selection. Expected genetic advance and real genetic advance due selection were calculated as

$$\Delta G_e = k\, h^2_n\, (V_P)^{0.5} \text{ and } \Delta G_r = R / GM$$

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

Variance analysis (ANOVA)

Result of variance analysis on 4 generations is shown in table 1. As seen, all eight traits significantly differed in studied generations, indicating that selection had significant effect on mean performance of studied traits. Highest coefficient of variation (C.V) belonged to grain yield (13.09%), followed by tiller number (8.77%), while plant height and heading date had the least C.V (~1.9%).

Table 1. Analysis of variance (ANOVA) on different traits

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	10.387	0.948	11.732	0.033	0.177	0.182	298.225
Grand mean	79.4	87	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

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

Selection effect on mean performance of studied generations

BC_1 generation

This generation consisted from 25 plants developed by backcrossing Sadri/Neda to Neda. Mean performance of different traits for two parents and generations after F_1 is shown in table 2. As seen, BC_1 population mean 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 rest 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_1 generation in most other studied traits, too (Table 2; Figure 1) and hence, BC_1S_1 generation was developed from its self-pollination.

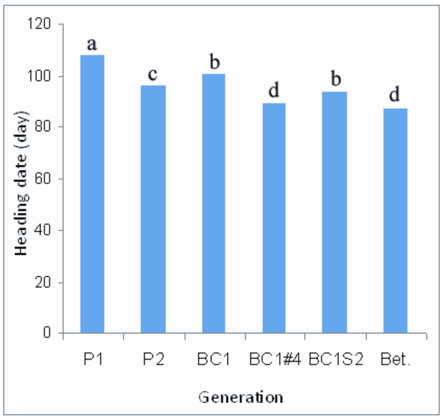
Table 2. Mean performance of studied generations

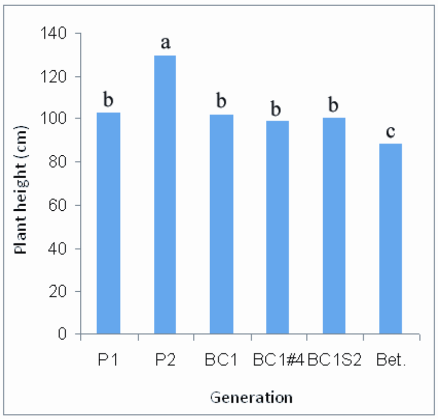
	P_1	P_2	Mid-parents	BC_1	BC_1#4	BC_1S_1	Better plants in BC_1S_1	S.E
HD	107.4	96.1	101.8	100.2	89	93.4	87	1.631
PLH	102.8	129.2	116.0	102	99	100	88	1.732
PL	26.4	30.5	28.45	28.1	29	28.5	33.5	0.523
TN	25	13.9	19. 5	28.8	31	29.9	53	1.841
HSW	2.76	2.55	2.66	2.89	2.91	2.9	3.55	0.098
PW	4.38	3.89	4.14	4.82	4.88	4.85	6.91	0.226
WFS	4.21	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	211.77	9.282

BC_1S_1 generation

This generation consisted from 78 plants. As seen in table 2, mean performance of BC_1S_1 population compared to BC_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 rest traits did not observed further progress compared to BC_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 before generations including two parents, indicating possibility for continuing selection to obtain partial supper rice lines (each harboring one or more desirable traits). Such lines had an improved performance even compared to better BC_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 rest traits was considerable over selected BC_1#4 plant (Table 2; Figure 1).





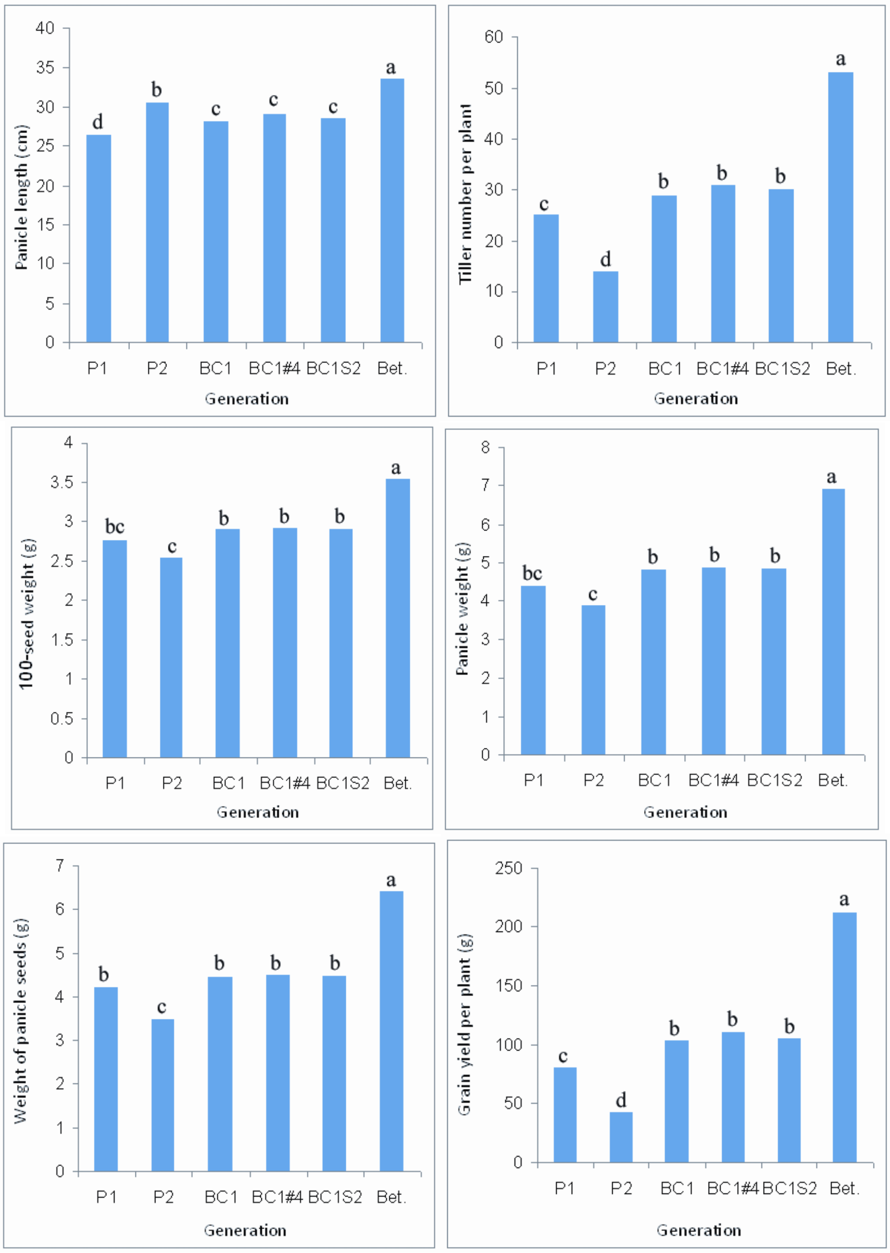


Figure 1. Comparison of mean performance of studied generations in different traits. Means with common letters have no significant differences. Bet., better single plants in BC_1S_1.

Degree of dominance, heritability and genetic advance

Some important genetic parameters of 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 one, 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). Above results shows that improvement of most studied traits is possible via selection in segregating populations, while for grain yield breeders must rely on heterosis vigor.

It seems that half traits have a high degree of general heritability (h^2_b). Four traits viz. 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. Actual heritability can be equalized to specific heritability when many generations (parents, F_1, F_2, BC_1, BC_2 etc) are not available to breeders. Therefore, with availability of two non-segregating generations (two parents) and two segregating sequential generations (such as BC_1 and BC_1S_1 in this research), it is possible to obtain selection response and differential of selection and hence, one can easily calculate narrow-sense heritability using their values. Values of selection response, differential of selection and h^2_n 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^2_n (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. High expected genetic advance (ΔG_e) was obtained for tiller number (49.4%), followed by grain yield (43.5%) and plant height (35.5%) (Table 3). Similar findings were also reported by Regina et al. [8], Vanniarajan et al. [13], Shivani and Reddy [11], Iftekharuddaula et al. [7], Gannamani [3] and Sao [10].

The highest real genetic advance (ΔG_r) was obtained for heading date (-8.5%) and tiller number (5.4%) followed by grain yield (4.3%), while for remained traits value of ΔG_r 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) because selection caused obtaining half of the expected genetic advance for this trait and gave the promise for further advance in few next generations.

Table 3. Important genetic parameters of eight studied traits of rice

	HD (day)	PLH (cm)	PL (cm)	TN	HSW (g)	PW (g)	WFS (g)	Yield (g hill^{-1})
V_E	9.204	10.387	0.948	11.732	0.033	0.177	0.182	298.225
V_G	99.161	482.946	6.853	78.962	0.0917	0.453	0.419	1118.091
V_P	108.365	493.3328	7.801	90.694	0.12475	0.63025	0.6015	1416.316
h^2_b	0.915	0.979	0.878	0.871	0.735	0.719	0.697	0.789
R	-6.8	-2.03	0.47	1.064	0.01	0.03	0.03	2.84
D	-11.0	-3.0	0.93	2.167	0.02	0.06	0.06	7.68
h^2_n	0.607	0.675	0.507	0.491	0.554	0.565	0.484	0.37
V_A	65.815	333.105	3.954	44.542	0.069	0.356	0.291	523.982
V_D	33.346	149.841	2.899	34.420	0.023	0.097	0.128	594.109
d	0.712	0.671	0.856	0.879	0.573	0.523	0.664	1.065
ΔG_e (%)	0.164	0.355	0.128	0.494	0.182	0.257	0.232	0.435
ΔG_r (%)	0.085[a]	0.023[a]	0.021	0.054	0.004	0.009	0.008	0.043
Selection success (%)	0.518	0.065	0.164	0.109	0.022	0.035	0.034	0.099

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

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