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Morphological characterization of Katarni rice (*Oryza sativa* L.) derived backcross population for yield and its contributing traits

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ABSTRACT

The aim of backcross breeding is the introgression of a certain trait of interest in a popular variety from a suitable donor variety. Morphological characterization of backcross derived line is a crucial step in backcross breeding programme. Present investigation was framed for the morphological characterization of advance backcross population, developed to introgress semi-dwarf and early maturing traits of Rajendra Sweta and BPT5204 into the background of tall, late maturing scented Katarni rice. The results indicated a significant decrease in the plant height and days of 50 % flowering in the backcross derived lines with respect to Katarni rice. Higher values of phenotypic coefficient of variation (PCV) than the genotypic coefficient of variation (GCV) for all character indicated environmental influence in the development of all characters. High heritability with high genetic advance as percent of mean was observed for 1000 grain weight and plant height. Highly significant and positive correlation with yield per plant was exhibited by traits like 1000 grain weight and leaf aroma. Result of path coefficient analysis indicated direct positive effect of characters like L/B ratio, kernel length and 1000 grain weight on grain yield per plant.

Key words: *BPT5204, early maturity, Katarni, Rajendra Sweta, semi-dwarf*

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than 2.7 billions people (Tannidi et al., 2016) around world and about 32- 59% of the dietary energy and 25-44% of the dietary protein is obtained from rice in more than 39 countries (Prabhu et al., 2017). Its chromosome no. is 24 and genome size is 389 Mb (IRGSP 2005) which is the smallest genome among the cultivated crop and hence called as a model plant. India is a top grower as well as exporter of Basmati rice which is known for its aroma, cooking and grain type. According to Nagaraju et al., 2002, the aromatic Basmati lies on separate group between *indica* and *japonica* in which the traditional Basmati and evolved Basmati varieties represent a major component of the Basmati gene pool of the Indian subcontinent. Katarni is a non-basmati traditional aromatic rice cultivar of Bhagalpur district of Bihar. This rice is one of the famous fine grained aromatic rices of India which is renowned for its unique aroma, special grain and cooking qualities. Its flowering occurs between end of October to beginning of November and matures in the month of December. It is 140 to 160 cm (Smriti et al., 2016) in height. In view of uniqueness, Katarni rice is granted geographical indication in April, 2018 (Geographical Indication no. 553; Certificate number: 312 dated 26-06-2016; source: http://ipindiaservices.gov.in/GirPublic/Application/Details/553) by the office of Intellectual Properties Rights, Govt. of India. However, the available Katarni is poor yielder (25-30 t/ha), weak strawed, traditionally tall type and late maturing. Due to photoperiod sensitivity, its flowering is delayed considerably under long-day treatments. It commonly suffers from the problem of lodging due to its very tall stature (Kumar et al., 2018). Hence, there is need to develop dwarf and high yielding and medium maturing Katarni rice with good grain cooking qualities. For this, crossing was made between tall Katarni with two semi-dwarf, medium maturing rice

varieties namely, Rajendra Sweta and BPT5204 to introgress the sd1 gene into Katarni and simultaneously reducing its maturity duration. The present study deals with the morphological characterization of backcrossed derived lines of these crosses along with the parental lines *i.e*., Katarni, Rajendra Sweta and BPT5204 for identifying suitable genotypes to develop a high yielding variety. Each segregating populations of Katarni x R. Sweta and Katarni x BPT5204 generated from selfing and back crossing of the selected plants were phenotyped for yield and other morphological traits. Information on the phenotypic data of different generations was subjected to analysis of heritability parameters, correlation and path coefficient and their effect on grain yield per plant was assessed.

MATERIALS AND METHODS

The present study comprises of evaluation of BC_1F_4, BC_2F_3 families of Katarni x R. Sweta and BC_1F_3 of Katarni x BPT5204 population having fragrant (fgr) gene from the recurrent parent Katarni (Kumar et al., 2018) and introgressed ***sd1*** gene from high yielding, early maturing and semi-dwarf donor parents R. Sweta and BPT5204. In successive generations of backcrossing, the plants were selected on the basis of semi-dwarf plant height and early maturity followed by PCR screening through gene specific makers for fragrance (*fgr*) and semi-dwarfing (sd1) gene. The selected 18 families of BC_1F_4 and 10 families of BC_2F_3 generation in Katarni x R. Sweta and 9 families of BC_1F_3 generation in Katarni x BPT5204 were planted in RBD in two replications with all three parents Katarni, R. Sweta and BPT5204 in 20 x 20 cm spacing. The investigation was carried out in field of Rice section, Bihar Agricultural University, Sabour, Bhagalpur, Bihar in *kharif* season of 2018.

Statistical analysis was done by using mean value of all the observations of the families planted in two replications. The observation were recorded in two sets (i) Pre-harvest, *viz*., plant height (PH), days to 50 % flowering (DOF 50 %), number of tillers (NT), panicle length (PL), flag leaf length (FL) and leaf aroma (LA) (ii) Post-harvest, *viz*., 1000 grain weight (GW), kernel length (KL), kernel breadth (KB), L/B ratio (L/B), grain yield per plant (GYP) and grain aroma (GA). Grain and leaf aroma was determined by 1.7% KOH sensory method (Sood and Siddiq, 1978). The tested samples were scored 0 for absence of aroma, 1 for mild aroma, 2 for strong aroma and 3 for very strong aroma. Evaluation of aroma in the samples was carried out by the smell through a panel of three individuals. Phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) was calculated by using formula given by Johnson et al. (1955). Heritability and genetic advance as percentage of mean was estimated by using formula given by Lush (1940), and categorized by Johnson et al., 1955. Correlation coefficient was calculated by the method given by Johnson et al. (1955) and Al - jibouri et al., (1958) and its significance was decided by using test of significance given by Fisher and Yates (1971). Path coefficient was calculated by formula established by Dewey and Lu (1959) and its direct and indirect effect was estimated by relation given by Lenka and Mishra (1973). The statistical analysis was done using INDOSTAT software.

Table 1. Morphological traits of 37 entries in backcross derived progenies of Katarni x R. Sweta and Katarni x BPT5204.

Traits	Range	Katarni	Rajendra Sweta	BPT 5204	Mean±S.D.	C.V.	C.D. at 5%
Plant height (cm)	77-123	165	110	98	105±13.7	6.3	13.5
Days to 50% flowering	101-129	128	111	107	118±8.5	2.1	5.1
Number of tillers	8-18	12	14	12	13±2.7	16.5	4.3
Panicle length(cm)	18-26	23	22	22	22±1.8	5.7	2.5
Flag leaf length(cm)	20-33	26	29	25	26±3.0	7.1	3.8
1000 grain wt(gm)	10-28	12	12	15	14±3.1	8.8	2.5
Kernel length(mm)	6-10	7.40	7.82	7.78	7.69±0.6	4.4	0.7
Kernel breadth(mm)	1-2	1.49	1.51	1.63	1.63±0.09	4.6	0.2
L/B ratio	4-5	5	5	5	5±0.3	4.9	0.5
Grain yield / plant (gm)	7-29	16.40	20.80	25.60	19±4.6	18.2	7.0
Grain aroma	0-3	3	0	0	1±0.7	57.4	1.4
Leaf aroma	0-3	3	0	1	1±0.8	68.7	1.7

RESULTS AND DISCUSSION

Range and mean of different phenotypic traits of 37 backcross families of Katarni x R. Sweta and Katarni x BPT5204 and three checks Katarni, R. Sweta and BPT5204 has been shown in Table 1. Plant height ranged from 77 to 123 cm which is much below the height of recurrent parent Katarni (165 cm). The days for attaining 50 % flowering ranged between 101 to 129 days with a mean value of 118 days indicating the shifting of maturity period of the backcross families towards donor parental range (107-111 days). Entry number KRS-16, KRS-19, KBPT-2 and KBT-9 for number of tillers, KRS-10 and KRS-20 for panicle length, KRS-23 for flag leaf length and KRS-10 for 1000 grain weight were found to be significantly superior to the recurrent parent Katarni. Entry number KRS-10 was found to be significantly superior to Katarni for kernel length, kernel breadth and L/B ratio. Grain yield per plant ranged from 7 to 29 g with a mean value of 19 g. With respect to Grain yield per plant, entry number KRS-14 (28.20 gms) and KRS-18 (28.60 gms) were found to be significantly superior to all checks. No entry scored superior to Katarni (aroma score 3) with respect to grain aroma while entry number KRS-2 scored 3 for leaf aroma test through 1.7% KOH sensory method. On the basis of reduced plant height, flowering duration and high grain yield/plant, line no. KRS-2, KRS-7 and KRS-17 in BC_1F_4 generation of Katarni X R. Sweta and line no. KBT-2 and KBT-8 in BC_1F_3 generation of Katarni X BPT5204 were selected (Table 2). These lines also retained desirable traits of Katarni like aroma score of 1.5 to 3 and L/B ration between 4.43 to 4.79.

Analysis of variance for yield and quality traits (Table 3) indicated a considerable variation among the Katarni derived progenies. The broad sense heritability for all 13 quantitative characters was maximum for days to 50 % flowering (92 %) and minimum for leaf aroma (29 %). High heritability were also observed high in characters like 1000 grain wt. (86 %), plant height (79 %), kernel length (73 %), flag leaf length (67 %), and panicle length (63 %). Moderate heritability was observed in characters like grain yield per plant (57 %), L/B ratio (55 %), number of tillers (55 %), kernel breadth (50%), and grain aroma (45 %). Low heritability was observed for leaf aroma. Genetic advance for all 13 quantitative characters ranged from 0.11 (kernel breadth) to 23.75 (plant height). Value of genetic advance for for days to 50 % flowering was 16.82, for flag leaf length was 4.54, for number of tillers was 3.54, for panicle length was 2.62, for 1000 grain wt. was 5.70, for kernel length was 0.98, for grain aroma was 0.82, for leaf aroma was 0.60, for L/B ratio was 0.40 and for grain yield per plant, it was 6.21.The value of genetic advance as % of mean was maximum for grain aroma (70.91) and minimum for kernel breadth (6.69) (Table 3).

The value of phenotypic correlation coefficient (Table 4) revealed asignificant and positive correlation of yield per plant with 1000 grain weight and leaf aroma. Besides this, days to 50 % flowering had positive significant correlation with no. of tillers (0.401) per plant. Positive significant correlation was also found between

Table 2. Mean performance of the selected entries for 12 characters.

Character	Line No.				
	KRS-2	KRS -7	KRS -17	KBPT -2	KBPT -8
Plant height (cm)	98.1	107.1	100	88	103.5
Days of 50 % flowering	112	122.5	126.5	126.5	118
Number of tillers	14	9	13.5	17.5	13
Panicle length (cm)	22.6	23.7	19.3	19.9	20.8
Flag leaf length (cm)	23.5	26.6	26.5	22.6	30.8
1000 grain wt (gm)	19.2	15.5	12.25	15.8	14.8
Kernel length (mm)	8.66	8.19	7.22	7.93	7.48
Kernel breadth (mm)	1.81	1.73	1.62	1.67	1.69
L/B ratio	4.79	4.72	4.47	4.78	4.43
Grain yield / plant (gm)	17.6	21.8	19.8	22	9.6
Grain aroma	2	2	2	2	2
Leaf aroma	3	1.5	2	2	2.5

Table 3. Analysis of variance for 13 morphological traits in backcross derived families of Katarni x R. Sweta and Katarni x BPT5204.

Sl. no.	Character	Mean sum square			GCV	PCV	h^2 (Bs) in %	GA % of mean
		Replication	Treatment	Error				
1	Plant height (cm)	205.440	380.377**	44.33	12.33	13.86	79	22.60
2	Days of first flowering	0.112	205.894**	11.522	9.01	9.53	89	17.55
3	Days of 50 % flowering	9.112	151.486**	6.368	7.20	7.51	92	14.23
4	Number of tillers	32.512	15.299**	4.486	18.15	24.55	55	27.64
5	Panicle length (cm)	0.032	6.676**	1.531	7.39	9.34	63	12.06
6	Flag leaf length (cm)	5.100	18.001**	3.545	10.51	12.39	67	17.13
7	1000 grain wt	6.844	19.386**	1.510	21.35	23.08	86	40.68
8	Kernel length	0.016	0.732**	0.113	7.23	8.45	73	12.74
9	Kernel breadth	0.003	0.016**	0.005	4.58	6.47	50	6.69
10	L/B ratio	0.000	0.192**	0.054	5.51	7.39	55	8.45
11	Grain yield (gm/plant)	1.378	43.530**	11.809	21.05	27.80	57	32.83
12	Leaf aroma	0.200	1.333*	0.738	51.54	77.17	45	70.91
13	Grain aroma	2.111	1.163**	0.445	43.63	81.42	29	48.61

Note: * and **: significant at 5 % and 1 % level of significance, respectively.

panicle length and flag leaf length (0.355), 1000 grain weight (0.313), kernel length (0.422) and L/B ratio (0.338).

By the study of correlation coefficient, the relation between two variables can be determined, whereas path co-efficient study separates the correlation effect into direct and indirect effect for other attributes (Dewey and Lu, 1959). It gives an idea about the direct selection of trait, and its component trait that contribute towards the yield. The results of various causes influencing yield per plant (direct and indirect effect) are shown in Table 5. L/B ratio (0.981), kernel length (0.663) and 1000 grain wt (0.490) had high direct positive effect on grain yield. Number of tillers (0.109) had low positive effect on grain yield. Days to 1st flowering (0.048) had negligible effect on grain yield. Lenka and Mishra (1973) reported rating of the direct and indirect effect ranging from 0.30-1.00 as high and above 1.00 as very high. In this study the values of the direct and positive effect for the above characters were ranging from 0.36 - 2.32. Hence, the contribution of the above characters to grain yield per plant is evidently high to very high hence, they can potentially help for direct selection for increased yield. Similar types of results were also reported by Hossain et al. (2015) and Devi et al. (2017). Chakraborty et al. (2010) for thousand grain weight, Agahi et al. (2007) for number of tillers.

Table 4. Phenotypic correlation between different pair of traits in advanced backcross generation BC_1F_4, BC_2F_3, of Katarni x R. Sweta and BC_1F_3 of Katarni x BPT5204.

Character	DOFF	DOF 50%	NT	PL	FL	1000 GW	KL	KB	L/B	YP	GA	LA
PH	-0.01	-0.08	-0.19	0.43**	0.30**	0.17	0.15	0.02	0.17	-0.05	0.04	0.13
DOFF		0.86**	0.24*	-0.15	-0.08	-0.22*	-0.23	-0.16	-0.12	-0.15	0.12	0.02
DOF 50%			0.40**	-0.18	-0.10	-0.26*	-0.25	-0.23 *	-0.08	-0.17	0.23*	0.01
NT				-0.12	-0.40**	0.08	0.09	-0.10	0.19	0.16	-0.02	-0.14
PL					0.35**	0.31**	0.42**	0.14	0.33 **	0.01	-0.12	-0.13
FL						0.08	-0.06	0.18	-0.24 *	-0.15	-0.10	0.03
1000 GW							0.74 **	0.70**	0.21	0.27*	-0.17	-0.10
KL								0.51**	0.66**	0.16	-0.17	-0.17
KB									-0.29 **	0.04	-0.08	0.07
L/B ratio										0.15	-0.11	-0.259*
YP											-0.21	-0.31**
GA												0.40**

** Significant at 1 % level, * Significant at 5 % level.

Table 5. Path analysis showing direct and indirect effects of different traits on yield in advanced backcross generation BC_1F_4, BC_2F_3, of Katarni x R.Sweta and BC_1F_3 of Katarni x BPT5204.

Character	DOFF	DOF 50%	NT	PL	FL	1000 GW	KL	KB	L/B	YP	GA	Leaf Aroma
PH (cm)	-0.042	0.001	0.004	0.008	-0.018	-0.013	-0.007	-0.006	-0.001	-0.007	-0.002	-0.005
DOF 50 %	0.019	-0.196	-0.226	-0.091	0.042	0.024	0.060	0.058	0.053	0.020	-0.053	-0.002
NT	-0.021	0.026	0.044	0.109	-0.014	-0.044	0.010	0.011	-0.012	0.021	-0.003	-0.016
PL (cm)	-0.008	0.003	0.003	0.002	-0.018	-0.006	-0.006	-0.008	-0.003	-0.006	0.002	0.002
FL (cm)	-0.037	0.011	0.013	0.048	-0.042	-0.119	-0.010	0.008	-0.022	0.029	0.013	-0.004
1000 GW	0.085	-0.108	-0.131	0.043	0.154	0.040	0.490	0.363	0.344	0.105	-0.086	-0.051
KL (mm)	-0.202	0.304	0.332	-0.129	-0.547	0.085	-0.959	-1.294	-0.672	-0.859	0.223	0.220
KB (mm)	0.014	-0.109	-0.156	-0.070	0.096	0.124	0.465	0.345	0.663	-0.193	-0.058	0.052
L/B ratio	0.169	-0.126	-0.085	0.193	0.332	-0.237	0.209	0.651	-0.285	0.981	-0.112	-0.254
YP (gms)	-0.002	-0.006	-0.011	0.001	0.006	0.005	0.008	0.008	0.004	0.005	-0.047	-0.019
Grain aroma (GA)	-0.031	-0.007	-0.002	0.034	0.031	-0.007	0.025	0.040	-0.019	0.062	-0.097	-0.238

Plant height (PH), Days to 50 % flowering (DOF 50 %), Number of tillers (NT), Panicle length (PL), Flag leaf length (FL), 1000 grain weight (1000 GW), Kernel length (KL), Kernel breadth (KB), L/B ratio (L/B), Grain yield per plant (YP).

Estimation of phenotypic variance component of heritability depends on the population type. In an immortal or permanent population such as double haploids (DHs) and recombinant inbred lines (RILs), it can be estimated using family based phenotyping in multi-environment trials while in mortal or temporary segregating population, phenotypic variances can only be estimated by using representative individuals for each traits (Xu et al., 2017). Presence of considerable variation of entries for each trait in the present study may be due to mortality of the backcross generation in each cross and the remaining homozygosity can be achieved in successive selfing of the backcross progenies.

For achieving desired improvement for a particular character, high heritability should be accompanied by high genetic advance (Johnson, 1955). It is very difficult to evaluate whether observed variability is highly heritable or not. Crop improvement in rice depends on the magnitude of genetic variability and the extent to which the desirable genes are heritable. Moreover, knowledge of heritability is essential for selection based improvement as it indicates the extent of transmissibility of a character into future generations. Value heritability for a particular character alone cannot drive a smooth force of selection; it's always coupled with genetic advances as % of mean (Sabesan et al., 2009; Ullah et al., 2011). In the present study, the gap between PCV and GCV was more for characters like grain aroma and leaf aroma which indicated that these characters was highly influenced by environment. However high GCV coupled with high PCV were observed for characters like number of tillers, 1000 grain weight, grain yield per plant, grain aroma and leaf aroma. High value of GCV of these characters indicated that there is considerable amount of genetic variation and there is scope of improvement of these characters through selection (Pandey et al., 2010; Tiwari et al., 2011). The genetic advance as percentage of mean along with heritability provides clear picture regarding effectiveness of selection for improving the plant characters. High heritability with high genetic advance as % of mean was observed for 1000 grain wt. (40.68) and plant height (22.60). These traits were less influenced by environment hence selection of these traits may be rewarding. High heritability with moderate genetic advance as % of mean was observed for traits like days of 1st flowering (17.55), flag leaf length (17.13), days to 50% flowering (14.23), kernel length (12.74) and panicle length (12.06). This result was also in accordance with Lal and Chauhan (2011) and Prabhu et al. (2017). Moderate heritability with high genetic advance as % of mean was observed for grain aroma (70.91), grain yield per plants (32.83) and numbers of tillers (27.64). These traits were more influenced by environment and selection of these train were ineffective. Moderate heritability with low genetic advance as % of mean

was observed for L/B ratio (8.45) and kernel breadth (6.69). Low heritability with high genetic advance as % of mean was observed for leaf aroma (48.16). It is indication of the predominance of epistasis and dominant gene action (non - additive gene action) and selection for such traits may not be rewarding (Nandarajan and Gunasekaran, 2005). Selection of one character may be affected positively and negatively by other characters which is measured by correlation coefficient and its value gives the idea about the simultaneous improvement of correlated characters. From the results, it is evident that if the genotype is selected which possesses more 1000 grain weight and leaf aroma will contribute to increased yield. This was also in confirmation with the findings of Anbanandan et al. (2009), Sabesan et al., (2009), Jayasudha and Sharma (2010), Selvaraj et al. (2011b), Augustina et al. (2013) and Minnie et al. (2013).

There are few reports of assessment of morphological traits for yield and attributing traits when the segregating population is about to reach the immortality (Balakrishnan et al., 2016; Srichant et al., 2019). Phenotypic study gave an idea on the nature of gene action, variability and extent of correlation of different morphological traits with yield. The main objective of gene introgression through backcrossing programme is the retention of background of recurrent parent in the derived lines with introgressed gene. The selected lines in the present study will be evaluated for yield and quality parameters in further selfing generations to develop semi-dwarf, early maturing and high yielding Katarni lines.

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