Journal of Stress Physiology & Biochemistry, Vol. 20, No. 1, 2024, pp. 111-116 ISSN 1997-0838

ORIGINAL ARTICLE

OPEN ACCESS

Characterization of Induced Mutants in Short Grain Aromatic non-basmati Rice Badshabhog

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Received November 2, 2023

An experiment was conducted to evaluate the agronomic performance of advance generation 28 mutant families in the M_4 generation. The mutant families were derived following pedigree method by treating aromatic short grain non-basmati land race Badshabhog with 200, 300, 400Gy doses of gamma rays. The mutant families retained the aroma of mother and were 10-15 days earlier. Agronomic performance reveals that height of many families was reduced which will render plants to be lodging resistant and responsive to higher doses of fertilizer. Some of the families have desirable mutant characters *viz.* flag leaf, panicle exsertion, panicle number and test weight. Majority of the families have reduction in panicle length, spikelet and grain number, spikelet fertility and grain yield which may be improved through gene cleaning. Segregation patterns of the mutant characters indicated that mutations are recessive and micromutations in nature. Appearance of multiple mutant characters in a plant may not be due to true mutations for all such characters, but may be due to pleiotropic effects of mutant genes. The mutants may be used directly and/or indirectly in recombination breeding programme for their beneficial mutant characters through Mutant × Parent and Mutant × Mutant crosses.

Key words: Aromatic rice, non-basmati, induced mutants, agro-botanical characters

Aromatic rice is grown almost in all rice growing areas of India. Outside the traditional basmati growing region of India, location specific age-old aromatic landraces are grown. Such aromatic landraces are tall *indica* photo-sensitive low yielding type with the kernel characters non-conforming to the standard of basmati rice traded in the international market. However, these aromatic non-basmati rices are popular among farmers. Badshabhog is such aromatic short grain non-basmati rice grown in different pockets of southern parts of West Bengal. Improvement in plant type through gamma ray induced mutation of Badshabhog resulted in identification of a number of short height mutants with alteration in a number of agro-morphic characters in the M_3 generation. The present study was aimed at evaluating the performance of some mutant families in the M_4 generation for their potential use in breeding aromatic rice.

MATERIALS AND METHODS

The experimental material used in the present investigation comprised 28 mutant families belonging to the M_4 generation along with their mother Badshabhog. The procedure of induction of mutations has been reported elsewhere (Kant and Chakraborty, 2021). Pedigree method was followed onwards the M_2 generation. The nomenclature of the mutants were as follows: Mut, followed by a number to represent the dose in gray/100, followed by a number in parenthesis to represent the M_2 family, followed by a number indicating plant number selected in the M_3 generation. Superscript indicates morphologically near-similar plant apparently differing mainly in one character. Seeds harvested from such selected M_3 plant were used to raise M_4 family for conducting the experiment. The number of families in different doses are in 200Gy: five families (2+1+1+1), in 300Gy: fifteen families (1+8+6) and in 400Gy: eight families (2+1+3+2) (Values greater than one in the parenthesis represent number of sister families derived from a segregating population in the M_3 generation).

The field experiment was conducted in a randomized complete block design (RCBD) with 3 replications during the *kharif* (warm wet) seasons of 2019 (July-December) at Agriculture Farm of Palli-Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan. The farm is situated under sub-humid, subtropical, lateritic belt of West Bengal at 23° 39' N latitude and 87° 42' E longitude with an average altitude of 58.9 meters above mean sea level. The seeds of each family were sown in the nursery bed with the onset of monsoon. Thirty-day-old seedlings were transplanted under puddled field condition, with a basal fertilizer dose 60:30:30 kg N: P: K per hectare. Single seedling was transplanted in each hill. Each plot consisted of five rows of three-meter long with inter- and intra-row spacing of 20 cm and 15 cm, respectively. Standard cultural practices were followed for raising a healthy crop. Ten plants in each plot were selected randomly for recording observations for plant height, flag leaf area, panicle exsertion, total effective tiller plant^{-1}, main panicle length, total spikelets and grains panicle^{-1}, fertility(%), test weight and grain yield. Data were analysed following Gomez and Gomez (1983).

RESULTS AND DISCUSSION

The analysis of variance of twenty nine families (Table 1) for ten quantitative characters *viz.,* plant height, flag leaf area, panicle exertion, effective tiller, main panicle length, total spikelet per panicle, filled grains per panicle, spikelet fertility (%), test (1000-grain) weight and grain yield per plant revealed the mean squares due to families for all the above characters are highly significant which indicated existence of genetic variability among the experimental materials. The mean performances of twenty nine families for ten characters (Table 2) are as follows:

Plant height: Plant height varied from 86.97cm [Mut3(102)38^2] to 164.27 cm [Mut4(48)22] with a grand mean of 131.91cm**.** Some short stature mutant families Mut2(381)32, Mut3(102)36^1, Mut3(102)36^2, Mut3(102)38^1, Mut3(102)38^2, Mut3(102)39^1, Mut3(102)39^2, Mut4(33)25, Mut4(33)26 resistant to lodging could be utilized directly subject to their yield performance or indirectly in cross-breeding programme to develop semi-dwarf high yielding variety.

Flag leaf area: The range of this character is varied from 7.66 cm^2 [Mut3(102)39^1] to 23.37cm^2 [Mut4(100)7] with a grand mean of 16.49 cm^2. Some mutant families Mut2(207)2, Mut2(267)24, Mut3(58)9, Mut3(58)10, Mut3(58)27, Mut4(33)26, Mut4(47)6, Mut4(48)20, Mut4(100)6 and Mut4(100)7 were having higher flag leaf area than mother family Badshabhog. Some mutant families were on par with mother family Badshabhog, while thirteen families had less flag leaf area. Wide variation in this character is due to mutational changes in the genetic system(s) associated with determining the flag leaf length and/or its breadth. Flag leaf plays important role in source-sink relationship. The mutant families having desirable flag leaf area are important for increasing grain yield in rice.

Panicle exsertion: This character varied from 4.53 cm in Mut4(47)6 to 20.17 cm in Mut4(100)6 with a grand mean of 11.26 cm. Panicle exsertion in Mut3(58)3, Mut3(58)10, Mut4(48)20, Mut4(48)22, Mut4(100)6 was more than the mother variety Badshabhog. Some mutant families were on par with mother family, while sixteen mutant families had less exssertion than Badshabhog. Exsertion of panicle is due to differential length of first (top) internode and flag leaf sheath. The wide difference in exertion is due mainly to variation in the length of panicle bearing first internode which is longest among all internodes. Mutational treatment affecting plant height, although causes proportional changes in the length of almost all internodes, causes drastic changes usually in the first internode, while leaf sheathes are nearly unaffected. Complete exsertion of panicle is highly desirable, but long exsertion, particularly in tall *indica* rice leads to lodging susceptibility when panicle gains weight on grain filling.

Effective Tiller: The number of productive tillers per plant were found to be lowest 9.33 in Badshabhog (control) and highest 33.17 in mutant family Mut3(102)36[2] with a general mean of 17.70 tillers per plant. All the mutant families having more number of total effective tiller $plant^{-1}$ than mother family Badshabhog except Mut4(48)20 which was on par with Badshabhog. Mutant families having greater number of total effective tiller $plant^{-1}$ are desirable if yield per panicle is not affected to such an extent so as to reduce productivity per unit area.

Main Panicle Length: The mutant family Mut3(102)39[2] and parent family (control) exhibited lowest (13.33 cm) and highest (29 cm) panicle lengths, respectively with a grand mean of 23.17 cm. Two mutant families Mut3(58)3, Mut4(48)22 were having panicle length on par with mother family. Rest mutant families showed main panicle length less than mother. Drastic reduction in panicle length will reduce grain yield per panicle which is common in mutants. Therefore, reduction in panicle length, unless compensated with panicle density (grain number per unit panicle length), will have reduced seed yield.

Total Spikelet $panicle^{-1}$: Wide range of variability was obtained for total number of spikelets $panicle^{-1}$ ranging from 47.39 [Mut3(102)39[2]] to 281.22 [Badshabhog] with a grand mean of 142.57. Unfortunately, all the mutant families had less number of total spikelets per panicle than mother family Badshabhog. This indicated no compensation through panicle density. Therefore, the mutants carried the harmful effect for sink number.

Filled grain $panicle^{-1}$: Wide range of variability was obtained for total number of filled grain $panicle^{-1}$ ranging from 32.26 [Mut3(102)39[1]] to 246.78 [Badshabhog (parent family)] with a grand mean of 108.56. In this case all the mutant families were of lower value for filled grain per panicle than mother family Badshabhog. This will have a direct bearing on seed yield unless compensated by sink size.

Spikelet fertility (%): The range of variation for this character varied from 60.38 to 88.16 with a grand mean of 74.84. The maximum fertility percentage was recorded 88.16 in Badshabhog (control) and the minimum fertility percentage was recorded 60.38 in mutant family Mut3(102)38[1]. Some mutant families having fertility (%) on par with mother family were Mut2(267)24, Mut2(381)32, Mut3(58)3, Mut3(58)9, Mut4(48)22 and Mut4(100)7. All other mutant families were of lesser fertility (%) than mother family. Reduction in spikelet fertility is very common harmful effect associated with mutational events. Therefore, elimination of such lethal genes through gene cleaning is very important for improvement in performance of the mutants.

Table 1. Analysis of variance (mean squares) for ten quantitative characters in rice

Source	d.f.	Plant Height (cm)	Flag Leaf Area (cm^2)	Panicle Exsertion (cm)	Total Effective Tiller	Main Panicle Length (cm)	Spikelet Number per Panicle	Grain Number per Panicle	Spikelet Fertility (%)	Test Weight (g)	Grain Yield (g)
Replication	2	18.18	3.08	5.39	2.59	0.36	88.31	72.31	10.53	0.16	10.14
Genotypes	28	1810.31''	67.47**	48.18**	12.47**	61.59**	9295.19**	6712.04**	58.94**	4.01**	34.51**
Error	56	18.40	3.61	2.13	7.70	1.20	166.96	106.07	5.44	0.38	5.08

*, ** Significant at P= 0.05 and P= 0.01, respectively

Table 2. Mean performance of twenty eight mutant families and their mother Badshabhog for ten quantitative character in rice

Name		Plant Height (cm)	Flag Leaf Area (cm^2)	Panicle Exsertion	Total Effec-tive Tiller	Main Panicle length(cm)	Number of Spikelet per panicle	Number of Grain per panicle	Spikelet Fertility (%)	Test Weight (%)	Grain Yield (gm)
Badshabhog		163.00	18.65	14.87	9.33	29.00	281.22	246.78	88.16 (70.07)	10.31	22.30
Mut2(30)17		136.82^{c}	16.33^{c}	11.91^{c}	12.30^{a}	25.10^{c}	169.71^{c}	126.03^{c}	74.26 (59.52)^{c}	11.73^{a}	15.06^{c}
Mut2(30)18		135.10^{c}	14.71^{c}	11.05^{c}	10.77^{a}	24.76^{c}	150.63^{c}	109.24^{c}	72.51 (58.39)^{c}	10.44^{b}	12.54^{c}
Mut2(207)2		134.14^{c}	19.23^{a}	5.80^{c}	16.50^{a}	24.53^{c}	181.40^{c}	114.54^{c}	63.05 (52.59)^{c}	11.45^{a}	17.24^{c}
Mut2(267)24		136.46^{c}	19.42^{a}	11.43^{c}	10.97^{a}	25.11^{c}	158.59^{c}	121.06^{c}	76.30 (60.88)^{b}	10.49^{b}	14.85^{c}
Mut2(381)32		123.88^{c}	17.03^{c}	5.67^{c}	12.95^{a}	22.87^{c}	153.42^{c}	125.57^{c}	81.87(64.81)^{b}	10.84^{b}	14.64^{c}
Mut3(30)4		150.28^{c}	17.67^{b}	14.16^{b}	12.97^{a}	25.19^{c}	200.40^{c}	131.19^{c}	65.46 (54.01)^{c}	9.20^{c}	13.47^{c}
Mut3(58)3		160.43^{b}	15.99^{c}	17.15^{a}	15.53^{a}	27.66^{b}	172.37^{c}	140.02^{c}	84.37 (64.46)^{b}	11.89^{a}	20.94^{b}
Mut3(58)8		108.57^{c}	14.14^{c}	13.77^{b}	25.80^{a}	18.60^{c}	49.37^{c}	34.73^{c}	70.35 (57.06)^{c}	11.51^{a}	8.42^{c}
Mut3(58)9		155.23^{c}	21.16^{a}	12.95^{c}	11.57^{a}	26.14^{c}	186.01^{c}	151.07^{c}	81.23 (64.34)^{b}	11.01^{a}	17.90^{c}
Mut3(58)10		159.22^{c}	19.41^{a}	15.04^{a}	13.60^{a}	26.72^{c}	155.65^{c}	124.22^{c}	79.95 (63.45)^{c}	11.27^{a}	19.89^{c}
Mut3(58)11		134.82^{c}	17.56^{b}	11.27^{c}	11.61^{a}	25.22^{c}	163.43^{c}	121.69^{c}	74.44 (59.64)^{c}	10.51^{b}	14.06^{c}
Mut3(58)12		137.21^{c}	16.41^{c}	12.17^{c}	10.13^{a}	25.13^{c}	154.87^{c}	117.79^{c}	75.99(60.67)^{c}	10.25^{b}	12.81^{c}
Mut3(58)13		137.11^{c}	17.15^{c}	12.56^{c}	12.47^{a}	25.19^{c}	160.21^{c}	122.10^{c}	76.21(60.83)^{c}	10.92^{b}	14.04^{c}
Mut3(58)27		142.42^{c}	19.77^{a}	10.48^{c}	12.57^{a}	25.21^{c}	155.33^{c}	117.62^{c}	75.59(60.44)^{c}	11.44^{a}	15.41^{c}
Mut3(102)36^{1}		92.81^{c}	9.26^{c}	6.85^{c}	27.43^{a}	18.61^{c}	51.80^{c}	37.60^{c}	72.52 (58.39)^{c}	10.82^{b}	10.04^{c}
Mut3(102)36^{2}		94.28^{c}	7.69^{c}	9.17^{c}	33.17^{a}	17.77^{c}	53.61^{c}	32.33^{c}	61.07 (51.51)^{c}	12.68^{a}	12.42^{c}
Mut3(102)38^{1}		96.43^{c}	9.92^{c}	7.78^{c}	22.10^{a}	18.13^{c}	82.48^{c}	49.86^{c}	60.38 (51.03)^{c}	12.90^{a}	11.44^{c}
Mut3(102)38^{2}		86.97^{c}	7.84^{c}	8.89^{c}	21.60^{a}	16.57^{c}	64.49^{c}	47.93^{c}	74.32 (59.57)^{c}	14.76^{a}	12.41^{c}
Mut3(102)39^{1}		89.55^{c}	7.66^{c}	7.89^{c}	27.20^{a}	17.22^{c}	49.68^{c}	32.26^{c}	65.48 (54.06)^{c}	10.83^{b}	9.05^{c}
Mut3(102)39^{2}		89.40^{c}	8.13^{c}	7.33^{c}	25.33^{a}	13.33^{c}	47.39^{c}	33.62^{c}	70.94 (57.41)^{c}	11.17^{a}	9.01^{c}
Mut4(33)25		128.42^{c}	20.30^{a}	11.06^{c}	15.75^{a}	23.29^{c}	188.24^{c}	139.86^{c}	74.18 (59.53)^{c}	8.49^{c}	18.03^{c}
Mut4(33)26		129.70^{c}	19.75^{a}	12.77^{c}	11.23^{a}	23.87^{c}	139.47^{c}	104.39^{c}	74.85 (59.96)^{c}	10.29^{b}	12.45^{c}
Mut4(47)6		138.92^{c}	22.14^{a}	4.53^{c}	11.73^{a}	24.00^{c}	147.46^{c}	116.02^{c}	78.70 (62.58)^{c}	10.39^{b}	12.02^{c}
Mut4(48)19		135.40^{c}	16.73^{c}	9.82^{c}	11.93^{a}	25.37^{c}	162.25^{c}	127.85^{c}	78.79 (62.59)^{c}	10.60^{b}	13.84^{c}
Mut4(48)20		161.09^{b}	22.55^{a}	16.04^{a}	9.87^{b}	26.33^{c}	190.27^{c}	147.64^{c}	77.40 (61.64)^{c}	11.35^{a}	15.49^{c}
Mut4(48)22		164.27^{a}	17.57^{b}	18.49^{a}	11.40^{a}	27.58^{b}	158.73^{c}	128.75^{c}	81.10 (64.24)^{b}	10.18^{b}	14.90^{c}
Mut4(100)6		157.12^{c}	20.88^{a}	20.17^{a}	12.50^{a}	25.11^{c}	153.86^{c}	119.66^{c}	77.68 (61.83) ^{c}	10.44^{b}	16.46^{c}
Mut4(100)7		146.35^{c}	23.27^{a}	5.53^{c}	14.37^{a}	24.50^{c}	152.23^{c}	126.93^{c}	83.39 (65.96) ^{b}	9.90^{c}	13.84^{c}
Range	Max	164.27	23.27	20.17	33.17	29.00	281.22	246.78	88.17 (70.07)	14.76	22.30
	Min	86.97	7.66	4.53	9.33	13.33	47.39	32.26	60.38 (51.03)	8.49	8.42
GM		131.91	16.49	11.26	15.67	23.17	142.57	108.56	74.84 (60.05)	10.96	14.30
CV		3.25	11.53	12.98	17.70	4.73	9.06	9.48	10.35 (3.88)	5.69	15.76
CD (5%)		7.00	3.10	2.38	4.53	1.78	21.10	16.80	3.80	1.00	3.68
CD (1%)		9.31	4.12	3.16	6.02	2.37	28.06	22.34	5.05	1.33	4.89

Here superscript 'a' exceeding mother, 'b' on par with mother and 'c' lower than mother. Values in parenthesis indicates arc sin transformation.

Test (1000-grain) weight: The grand mean of 1000-grain weight was 10.96 g and among all the mutant families Mut3(102)38^{2} recorded the highest 1000-grain weight and was superior to all the mutant family tested and Mut4(33)25 expressed lowest 1000 grain weight (8.49g). Eleven mutant families showing higher test weight than mother family Badshabhog, twelve mutant families on par with mother family and three mutant families from higher doses of radiation had lower test weight than mother family. Mutant families having test weight higher than or at par with the mother variety are important.

Grain yield Plant^{-1}: Yield per plant varied from 8.42g to 22.30g with a grand mean of 14.30 g. Parent family (Badshabhog) had highest yield per plant and mutant family Mut3(58)8 has minimum yield per plant. Mutant family Mut3(58)3 showed on par with mother family. All other mutant families were low yielder than the mother family. However, Mut2(207)2 had short stature and considerable yield.

From the values of coefficient of variation, it was observed variability was highest in effective tillers plant^{-1}, followed by grain yield plant^{-1}, panicle exsertion, flag leaf area, filled grains panicle^{-1} and spikelets panicle^{-1}. Considerable amount of variability for tillers per plant (Selvaraj *et al*., 2011; Sharma *et al*., 2014; Riadi *et al*., 2018; Kumari *et al*., 2019), grain yield plant^{-1}(Sharma *et al*., 2014; Riadi *et al*., 2018), panicle exertion (Sameera *et al*., 2016), flag leaf area (Pratap *et al*., 2012), fertility percent (Kumari *et al*., 2019), filled grain panicle^{-1}(Pandey *et al*., 2012; Sharma *et al*., 2014; Riadi *et al*., 2018) has earlier been reported.

Performance of induced mutants of aromatic non-basmati rice has earlier been reported (Kole and Chakraborty, 2007; Kole *et al.*, 2012, Hasib *et al.* 2019). The mutants were identified in the M_2 generation, indicating mutational events as recessive in nature. Segregation pattern indicated the mutational changes are due to micromutaions (Kole *et al.,* 2007). Changes in multiple characters in a family may be due to pleiotropic effects of mutant genes (Kole, 2007)

All the mutant families were early flowering by 10-15 days compared to the mother variety and retained the characteristic aroma of Badshabhog. The overall performance of the mutant families indicates that Mut2(207)2, Mut4(33)25, Mut2(30)17 and Mut3(58)27 can be tested under different agronomic management for judging their potential for direct use. The other mutants Mut3(58)11, Mut3(102)38[2] and Mut4(48)19 could be utilized indirectly in recombination breeding programme for their beneficial mutant characters through Mutant × Parent and Mutant × Mutant crosses.

CONFLICTS OF INTEREST

The authors declare that they have no potential conflicts of interest.

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