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DEVELOPMENT OF BASMATI RICE VARIETIES THROUGH THE USE OF INDUCED MUTATIONS AND RELATED TECHNIQUES

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Abstract

Several short stature (20-40 %), early flowering (7-21 days earlier) and long grain mutants/recombinants have been developed at NIAB through induced mutations and other breeding techniques in the traditional Basmati rice. The mutants with desired traits were hybridized with the traditional Basmati, which resulted in the derivation of desirable progenies showing good hybrid vigour. In the selected progenies of M_4 generation, mutants showed significant reduction in plant height (18.29-33.62 %). The mutant 39-1 which was short statured as compared to its counterparts, produced maximum productive tillers/plant (17.6) and outyielded along with some other mutants 15-2 and 15-3 as compared to their counterparts and checks. All the mutants possessed increased paddy length (10.00 mm-10.76 mm) and outclassed their respective parents exhibiting high L/W ratio. The recombinants exhibited improvement in grain yield due mainly to greater number of tillers per plant and increased spike fertility percentage. The physical grain quality parameters of paddy length, paddy width and their L/W ratio were also superior. From the yield trial, one of the mutants (EF-1-20-5-99) flowered 14 days earlier than the parent (Basmati-370) and standard Super Basmati and Basmati-2000 may be used in hybridization for the development of recombinants with even more desirable traits.

Introduction

In Pakistan, rice is cultivated on an area of about 2.52 million hectares with a production of 5.16 metric tons annually, giving an average yield of 2,050 kg per hectare (Anonymous, 2000). The importance of rice for our country is manifold as it is an agricultural commodity that adds 20 % foreign exchange to the national foreign exchange reserves (Anonymous, 2001). The demand for rice is continuously increasing due to unabated growth of population. Inorder to cope with the ever-increasing population, achieving self-sufficiency in rice production and maintaining price stability, new high yielding varieties with tolerance to biotic and abiotic stresses are needed.

Breeding for high yield, short stature and shorter duration is a common breeding objective throughout the world in all the cereal crops. In Pakistan, the introduction of short stature varieties of rice resulted in a substantial increase in rice production, yet due to their inferior grain quality did not suit the preferences of the consumer. Breeders, in Pakistan, have been trying to develop high yielding and early maturing Basmati varieties by incorporating genes for short stature, early maturity and higher yield potential from the newly released non-Basmati semi-dwarf varieties by keeping all the quality traits of traditional Basmati. Progress in this direction has been difficult and slow due to genetic differences between the varieties. So, keeping in view our national interest, the only alternative approach is to induce the desirable traits in the Basmati background and then utilize in cross breeding or direct release. Induced mutations have undoubtedly played a significant role in achieving useful mutations in rice (Mustafa *et al.*, 1997; Baloch *et al.*, 1999). In plant breeding, mutation has become an effective way of supplementing existing germplasm and improving cultivars (Micke *et al.*, 1990; Wen & Qw, 1996; Baloch *et al.*, 2001a,b). Most of the mutants are directly utilized, but an increasing number of cultivars are resulting from crossing of induced mutants (Krivolapov, 1987: Wang, 1991).

Several short stature, early maturing and extra long grain mutants/recombinants have been developed through the use of induced mutations and other related breeding techniques in the traditional Basmati rice at NIAB. Mutants with desired traits were hybridized with the traditional Basmati, which resulted in the desirable progenies showing a promise.

Materials and Methods

Pure and dry dormant paddy seed of Basmati-370 with 10-12 % moisture were exposed to different doses of gamma radiations of 200, 250 and 300 Gy. The M_1 generation was raised during 1999 by keeping a row distance of 10 cm. Main panicle from each M_1 plant was harvested at physiological maturity and seed was bulked dose-wise. From M_2 population, desirable mutants were isolated on the basis of early flowering, short stature, good plant type and other grain quality characteristics. These plants were assessed for stability of the selected traits in the M_3 and M_4 progeny rows. The untreated control was also planted after every 10^{th} M_3/M_4 progeny for comparison.

An extra long grain mutant *viz.* EL-30-2-1, developed earlier was crossed with commercial variety Super Basmati during 1998 with the aim of improving the grain quality. The desired recombinants were selected in the segregating populations. More than 500 single plant progenies in the F_4 generation were sown in early June during the year 2002 at NIAB, Faisalabad. Individual plant selection was based on plant height, productive tillers/plant, grain fertility, yield/plant and grain acceptability (grain physical parameters). The parents were also planted after every 10^{th} row of the recombinants for comparison.

In another trial, three mutants and their parents along with commercial varieties were planted in a yield trial during 2001-02. The experiment was laid out in randomized complete block design (RCBD) with three replications. Thirty days old seedlings were transplanted into a 1.60 x 2.60 (sq.m.) plot size. Recommended cultural practices and plant protection measures were applied. The data were collected on yield as well as yield components and physical parameters of the grain on five randomly selected plants of the middle rows excluding the border plants. The data thus collected were subjected to analysis of variance following Steel & Torrie (1980). The varietal means for each character were compared by using the Duncan's Multiple Range Test (DMRT).

Results and Discussions

Plant height, paddy yield, some yield components and physical parameters of grain for 12 mutants in M_4 generation and parents are presented in Table 1. The data revealed 18.3-33.6 % reduction in plant height, which showed that the genes controlling this trait can easily be mutated in rice by gamma rays. The mutant 39-1, which is short statured, also produced maximum productive tillers/plant (17.6). Regarding the paddy yield per

Table 1. Performance of mutants in M_4 generation (Derivative of Basmati-370) along with parent during the year 2002-03.

Progeny	Plant height (cm)	Productive tillers/plant	Fertility (%)	Yield/plant (g)	Paddy length (mm)	Paddy width (mm)	Length/width ratio
2-1	129.8 ± 7.85	11.60 ± 2.07	93.09 ± 2.16	22.28 ± 3.21	10.21 ± 0.10	2.14 ± 0.06	4.72 ± 0.16
15-2	109.8 ± 4.15	14.40 ± 1.67	92.70 ± 1.55	28.64 ± 3.75	10.16 ± 0.14	2.09 ± 0.08	4.86 ± 0.16
15-3	109.0 ± 4.06	12.80 ± 1.30	95.68 ± 1.09	27.28 ± 2.80	10.00 ± 0.12	2.05 ± 0.06	4.88 ± 0.12
39-1	107.4 ± 3.05	17.60 ± 2.07	89.40 ± 5.82	29.00 ± 4.94	10.34 ± 0.15	2.04 ± 0.04	5.06 ± 0.17
40-1	131.8 ± 3.11	12.20 ± 2.59	87.88 ± 8.31	23.96 ± 6.62	10.06 ± 0.15	2.04 ± 0.07	4.93 ± 0.17
52-1	114.4 ± 4.83	11.80 ± 0.84	90.79 ± 2.93	22.24 ± 2.37	10.09 ± 0.58	2.05 ± 0.04	4.92 ± 0.28
56-1	115.2 ± 1.79	14.20 ± 2.95	92.67 ± 2.98	20.96 ± 4.94	10.53 ± 0.35	1.96 ± 0.02	5.37 ± 0.21
56-2	119.8 ± 7.26	13.20 ± 3.42	86.75 ± 4.54	21.52 ± 4.22	10.76 ± 0.05	2.08 ± 0.06	5.18 ± 0.17
56-4	115.2 ± 4.82	16.00 ± 2.92	89.05 ± 5.89	25.44 ± 3.06	10.58 ± 0.20	2.04 ± 0.05	5.20 ± 0.19
59-1	115.6 ± 5.55	14.40 ± 1.82	96.37 ± 1.77	26.24 ± 2.36	10.43 ± 0.16	2.00 ± 0.06	5.20 ± 0.15
75-2	126.0 ± 3.24	17.40 ± 4.34	93.30 ± 2.99	30.94 ± 6.59	10.13 ± 0.23	2.03 ± 0.09	5.00 ± 0.25
119-1	132.2 ± 3.42	12.40 ± 0.55	91.93 ± 4.94	26.28 ± 3.49	10.13 ± 0.41	2.06 ± 0.04	4.92 ± 0.27
Basmati-370 (Parent)	161.0 ± 1.10	12.60 ± 3.78	98.02 ± 1.76	25.92 ± 4.18	9.56 ± 0.10	2.13 ± 0.05	4.49 ± 0.14

Table 2. Performance of progenies in F_4 generation (Super Basmati x EL-30-2-1) along with parents during the year 2002-03.

Progeny	Plant height (cm)	Productive tillers/plant	Fertility (%)	Yield/plant (g)	Paddy length (mm)	Paddy width (mm)	Length/width ratio
9-1	140.6 ± 4.4	14.00 ± 0.9	95.43 ± 0.9	22.4 ± 2.9	11.11 ± 0.29	2.02 ± 0.09	5.48 ± 0.25
9-3	137.0 ± 3.9	15.4 ± 2.5	96.79 ± 1.4	23.8 ± 2.8	11.34 ± 0.59	2.04 ± 0.06	5.54 ± 0.32
12-2	135.6 ± 3.8	17.60 ± 2.7	88.58 ± 6.9	29.9 ± 0.1	11.22 ± 0.41	2.01 ± 0.48	5.58 ± 0.18
45-1	134.4 ± 3.8	18.40 ± 2.2	88.41 ± 5.1	25.7 ± 4.1	12.22 ± 0.38	2.12 ± 0.04	5.76 ± 0.12
45-2	134.7 ± 3.3	14.26 ± 2.2	93.33 ± 2.5	21.7 ± 2.8	11.97 ± 0.71	2.20 ± 0.19	5.48 ± 0.48
73-3	138.5 ± 1.4	14.00 ± 2.1	94.74 ± 1.2	24.0 ± 3.6	11.80 ± 0.30	2.11 ± 0.06	5.61 ± 0.26
73-5	130.0 ± 2.3	16.00 ± 2.0	94.57 ± 1.9	26.3 ± 3.4	11.71 ± 0.39	2.17 ± 0.05	5.40 ± 0.20
90-2	124.0 ± 2.6	14.00 ± 1.9	89.93 ± 3.9	22.3 ± 4.2	11.12 ± 0.20	2.16 ± 0.08	5.16 ± 0.24
Super Basmati	115.2 ± 4.7	16.00 ± 1.4	94.25 ± 0.6	21.5 ± 1.6	10.32 ± 0.33	2.00 ± 0.06	5.15 ± 0.20
EL-30-2-1	139.8 ± 3.8	12.40 ± 1.6	75.00 ± 6.3	13.6 ± 1.8	13.67 ± 0.17	2.24 ± 0.14	6.13 ± 0.34

Table 3. Mean performance of induced mutants (derivatives of Basmati-370) as compared to parent and check varieties at NIAB, Faisalabad (2001-02).

Entry name	50 % Heading days	Plant height (cm)	Productive tillers/ plant	Panicle length (cm)	1000-seed weight (g)	Yield (Kgs/ha)	Length of raw rice (mm)	Length of cooked rice (mm)	Width of raw rice (mm)	Width of cooked rice (mm)	Elongation ratio
EF-1-20-5-99	109.0 ^{D}	150.3 ^{B}	16.1 ^{A}	32.0 ^{B}	20.13 ^{D}	4393 ^{A}	6.73 ^{C}	12.27 ^{D}	1.63 $^{N.S}$	2.07 $^{N.S}$	1.82 ^{C}
DM-1-20-7-99	121.7 ^{B}	113.4 ^{D}	16.1 ^{A}	28.5 ^{C}	21.73 ^{B}	4084 ^{BC}	7.23 ^{B}	14.00 ^{B}	1.63 $^{N.S}$	2.07 $^{N.S}$	1.92 ^{AB}
DM-1-30-3-99	121.7 ^{B}	114.9 ^{D}	17.1 ^{A}	29.4 ^{C}	22.67 ^{AB}	3903 ^{C}	7.53 ^{A}	13.87 ^{B}	1.63 $^{N.S}$	2.13 $^{N.S}$	1.84 ^{BC}
Super Basmati	121.0 ^{B}	117.6 ^{D}	16.5 ^{A}	28.8 ^{C}	20.53 ^{CD}	4346 ^{A}	7.33 ^{AB}	13.67 ^{B}	1.76 $^{N.S}$	2.20 $^{N.S}$	1.87 ^{BC}
Basmati-2000	122.7 ^{A}	138.8 ^{C}	12.1 ^{B}	33.3 ^{AB}	23.33 ^{A}	4459 ^{A}	7.27 ^{B}	14.53 ^{A}	1.70 $^{N.S}$	2.13 $^{N.S}$	1.99 ^{A}
Basmati-370 (Parent)	122.7 ^{C}	171.6 ^{A}	13.3 ^{B}	33.8 ^{A}	21.33 ^{B}	4247 ^{AB}	6.73 ^{C}	12.87 ^{C}	1.67 $^{N.S}$	2.20 $^{N.S}$	1.91 ^{B}

*Any two means sharing a letter in common are not statistically different at $P<0.01$

plant, four mutants 75-2, 39-1, 15-2 and 15-3 out-yielded all the mutants and checks. The results of physical parameters of the grain showed that all the mutants had increased paddy length than the parent. All the mutants out-classed their respective parents by possessing high paddy L/W ratio of the grain. Significant improvements in rice crop with the use of induced mutations have been reported in the literature for plant height (Hoang *et al.*, 1988), high yield potential (Sharma & Reddy, 1991) and improved grain quality (Narahari, 1979).

All the F_4 recombinants (Table 2) showed increased yield/plant (21.7 g to 29.9 g) than the parent Super Basmati (21.5 g). The progeny 45-1 had maximum productive tillers/plant followed by the progeny 12-2 (17.60) and both had almost the same plant height and fertility percentage. The progeny 12-2 expressed the highest yield per plant (29.9 g) followed by 73-5 (26.3 g) and 45-1 (25.7 g). All the progenies showed increase in paddy length and paddy L/W ratio over the Super Basmati. Roy & Arraudeau (1988) and Sison (1989) also reported improved grain fertility and grain length in F_4 generation.

The means for yield and yield components for different genotypes along with the parents and standards are shown in Table 3. Results indicated that the mean values for 50 % heading days ranged from 109.0-122.7. The mutant EF-1-20-5-99 was significantly different from all the other genotypes and took minimum number of days (109) for 50 % heading, whereas, parent Basmati-370 (122.7) and Basmati-2000 (123) took maximum number of days to heading followed by Super Basmati (121). Mean plant height ranged from 113.4 cm to 171.6 cm. The mutant DM-1-20-7-99 was observed to be the shortest (113.4 cm) followed by DM-1-30-3-99 (114.9 cm). Both the mutants were non-significant to Super Basmati but significant than the parent Basmati-370 (171.6 cm) and Basmati-2000 (138.8 cm). The mean value for productive tillers/plant varied from 12.1 to 17.1. Mutant DM-1-30-3-99 produced maximum number of tillers/plant (17.1) whereas, Basmati-2000 produced minimum (12.1). Mean panicle length ranged from 28.5 cm to 33.8 cm. The mean values for 1000-seed weight ranged from 20.13 g to 23.33 g. Basmati-2000 had the highest seed index (23.33 g), while the least was recorded in EF-1-20-5-99 (20.13 g). Both the dwarf mutants DM-1-20-7-99 (21.73 g) and DM-1-30-3-99 (22.67 g) were statistically different from Super Basmati (20.53 g) but non-significant with the parent Basmati-370 (21.33 g). The results showed that though the mutant EF-1-30-3-99 yielded 4393 kg/ha and was non-significant with the parent Basmati-370 and the commercial varieties Basmati-2000 and Super Basmati but flowered much earlier.

The mean values of different grain quality parameters of raw rice for some of the mutants along with parents and standards were found to be statistically significant. All the genotypes were non-significant for the characters *viz*. width of raw rice and width of cooked rice. The mean values for length of raw rice varied from 6.73 mm to 7.53 mm. The mutant DM-1-30-3-99 had the maximum raw rice length (7.53 mm). The statistical significance revealed that this mutant was non-significantly different from the Super Basmati but significantly different from the parent Basmati-370 and Basmati-2000. It is clear from the data that there is wide range of variation in the mean values of length of cooked rice that ranged from 12.27 mm to 14.53 mm. The highest cooked rice length was observed in Basmati-2000 (14.53 mm) followed by the dwarf mutant DM-1-20-7-99 (14.00 mm) but significantly different from the parent Basmati-370 and non-significant form the Super Basmati. The elongation ratio of cooked rice ranged from 1.82 to 1.99. Basmati-2000 showed the maximum elongation ratio (1.99) followed by DM-1-20-7-99 (1.92). The mutant DM-1-20-7-99 was non-significantly different from Basmati-2000, Super Basmati and DM-1-30-3-99 but significantly different from the parent Basmati-370. These results are in conformity with the findings for early maturity (Bari & Awan, 1974), short stature (Hu, 1991; Gravois & Helms, 1992; Takamure & Kinoshita, 1993), increase panicle length, fertile spikelets per panicle and L/W ratio (Sarawgi & Soni, 1993), yield and quality improvement (Baloch *et al.*, 2001a,b) and small grains and large grains (Chung *et al.*, 1990).

The present studies showed that a large number of mutants/recombinants derived from induced mutations may be used either directly or in cross breeding for the development of segregants possessing improved plant and grain quality characteristics.

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