J Plant Mol Breed (2020) 8(1): 57-67
DOI: 10.22058/JPMB.2022.122358.1204

RESEARCH ARTICLE

Roshan, a new released mutant aromatic rice variety with high yield and early maturity

Ghorbanali Nematzadeh[1,2*], Morteza Oladi[1], Ammar Afkhami Ghadi[1.3], Ammar Gholizadeh Ghara[2], Farhad Bagheri[1], Mojtaba Aghajani Ghara[1], Maryam Emami Ghara[1], Alireza Babaii[4], Masud Rahimi[5], Camran Mozafari[5], Reza Vojdan[1], Amir Ziyai[1], Ahmad Esfandiyari[1]

[1] Genetics and Agricultural Biotechnology Institute of Tabarestan, Sari Agricultural Sciences and Natural Resources University, Sari, Iran.

[2] Department of Plant breeding, Sari Agricultural Sciences and Natural Resources University, Sari, Iran.

[3] Department of Genetic and plant breeding, Imam Khomeini International University, Qazvin, Iran.

[4] Shaheed Forouzandeh Applied Science and Technology Center of Agricultural Jihad in Mazandaran, Iran.

[5] Nuclear Agriculture Research Center, Nuclear Science and Technology Research Institute, Atomic Energy Organization of Iran, Tehran, Iran.

ABSTRACT: Mutation breeding could be an efficient procedure for improvement of grain yield and quality characteristics in rice. A rice mutation breeding program was conducted at the Genetics and Agricultural Biotechnology Institute of Tabarestan (GABIT) research field during 2010-2018 using five varieties (Sang Tarom, Tarom Chaloci, Nemat, Khazar, and Sepidrood). These varieties were treated with Gama ray at 200 Gray by the Atomic Energy Organization of Iran (AEOI). The mutated plants were evaluated for the agronomic characteristics in seven generations (M2-M9). Eventually, eleven M9 pure promising lines were selected and evaluated for the agro-morphological and molecular as well as grain quality characteristics. The results showed that a line (M9-P10-37-1-1-1-1-1-1-1) derived from Nemat variety has the desired characteristics of high yield (8.23 ton/ha) and early maturity (123.67 days). Additionally, it possesses good physicochemical quality such as amylose content (AC=18.4%), gel consistency (GC=98 mm), gelatinization temperature (GT= 5.42), and aromatic scent confirming by *fgr* gene marker with 257bp length. The grain yield and quality test indicated that the line M9-P10-37-1-1-1-1-1-1-1 has 12.51% more yield compared Shiroodi and 47.97% compared Tarom Hashemi, with a comparable quality. This line was registered as the 'Roshan' variety.

KEYWORDS: Aroma, Improved rice variety, Mutation breeding, *Oryza sativa* L.

INTRODUCTION

Rice is a second important crop in Iran and it's cooking and eating quality plays a significant requirement for the consumers. Therefore, the introduction of high-yielding, as well as high-quality rice varieties which are early maturity, are the most important breeding objectives in our institute (GABIT). The mutation breeding procedures are used as the alternatives to traditional and molecular breeding methods, especially where the genetic variation is limited.

*Corresponding author (✉):gh.nematzadeh@gmail.com
Received: 1 March 2020 / Revised: 9 May 2022
Accepted: 10 May 2022

Mutation breeding can be used to improve traits such as yield, qualities, and resistance to biotic and abiotic stresses. To date, many improved varieties in different crops at the world wide have been released either with chemical or physical mutagenesis (9). Mutation breeding is one of the most important methods for development of varieties with some novel attributes such as early maturity and semi dwarf status (12). China with 638 mutant rice varieties is the first rank followed by India with 272 and Japan with 233 are the leading countries in employing mutation breeding in rice (22). Generally, a higher application of physical mutagenesis agents (89%) than chemical agents are evident. Furthermore, among the physical against, 64% related to gamma ray, 22% to the X ray and the rest belonged to the other physical agent (1, 32). Some researcher reported, application of higher doses of gamma ray (300 gry) is better for increasing tiller numbers per plant in rice varieties (10), and 200 gray is efficient for early maturity (11) and reducing plant height (29).

The three rice varieties obtained via gamma-ray of basmati rice, including Basmati 370, Pousa Basmati, and Pakistani Basmati, which having high-yield, non-loading, long panicle, with the ideal properties of grain quality are a few examples of mutant varieties (28). Some others researcher used EMS mutagenesis for reducing plant height (14) and Azide Sodium for increasing grain weight (15). Arefii and Norozi successfully used gamma ray on Tarom Mahalli, Mosa Tarom (local Variety) and Amol3 (improved Variety), and eventually released a MT- 44- 7-7 line with 4830 (kg/ha) yield (3). Furthermore, physicochemical properties and nutritional quality of rice germplasm have been intensively investigated (17, 18, 4). Meanwhile the integration of classical and molecular methods revealed more stringent for the screening of aromatic and non-aromatic scent lines (35). Borba *et al.* reported a marker (RM190) that has a significant association with amylose content in rice (5). The objective of this project was to improve a high yield variety that also possessed the desired physicochemical properties including aromatic scent using a mutation breeding program.

MATERIALS AND METHODS

Five rice verities including local (Sang Tarom, Tarom Chaloci) and improved varieties (Nemat, Sepidrood, and Khazar) used for physical gamma ray treatment through AEIO, then treated seeds cultivated at experimental field of Genetics and Agricultural Biotechnology Institute of Tabarestan (GABIT), Sari Agricultural Sciences and Natural Resources University (SANRU) in year 2010. The M_1 seeds along with wild-type varieties (untreated seeds), were hereafter named as maternal parents grown in a nursery at year 2010. After 30 days the M_1 and the maternal seedlings were transplanted in the main field for further evaluation. All the agronomic practices were carried out according to the region practices. At the end, the seeds of the main panicle were harvested at the maturity time. The evaluation of the succeeding generations (M_2-M_7) was conducted using a modified method based on the pedigree during 2011 to 2017 (Figure 1).

Morphological evaluation (M7)

The eleven superior M_7 lines (Table 1) selected and planted together with 3 check varieties (Tarom Hashemi local aromatic, Shiroodi and Nemat (23), high yield improved varieties). A Randomized Complete Block Design (RCBD) with three replications was used for the advanced yield trials (AYT). Soaking, transplanting (25 × 25) and agronomic practices were done according to the practices of local farmers. Most important morphological traits such as days to maturity, number of fertile tiller (no), plant height (cm), panicle length (cm), number of grain per panicle (no), number of filled grain per panicle (no), 1000 grain weight (gr), grain yield (gr.m^{-2}) were evaluated (13).

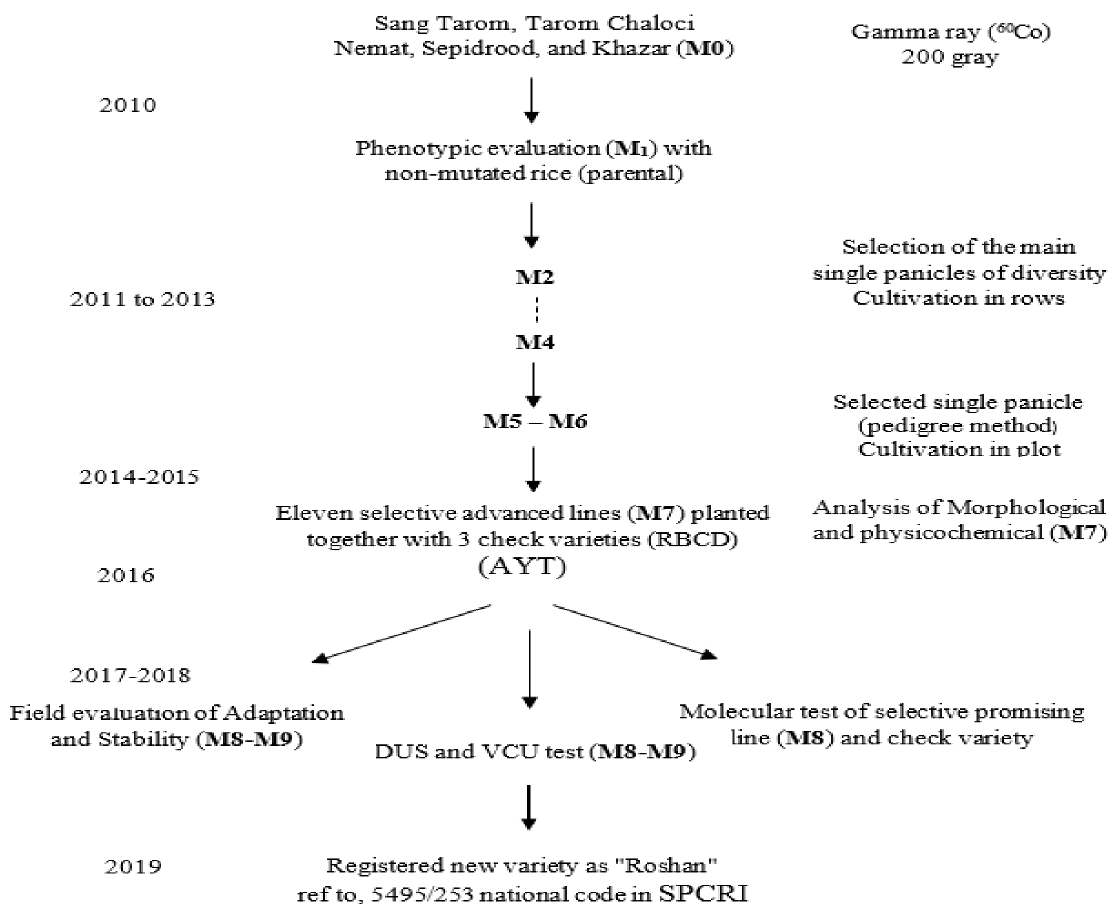

Figure 1. The whole mutation breeding scheme of the registered and released new mutant variety as "Roshan".

Table 1. The entry code of eleven M7 mutant lines, including check varieties, used for further agronomical tests.

NO.*	Genotype code	NO.	Genotype code
1	M7-P1-4-1-1-1-1-1-1-1	8	M7-P10-37-1-1-1-1-1-1-1
2	M7-P6-1-1-1-1-1-1-1-1	9	M7-P11-6-1-1-1-1-1-1-1
3	M7-P10-2-2-1-1-1-1-1-1	10	M7-P11-6-2-3-1-1-1-1-1
4	M7-P10-5-4-4-1-1-1-1-1	11	M7-P18-1-4-3-3-1-1-1-1
5	M7-P10-5-4-5-1-1-1-1-1	12	Tarom Hashemi
6	M7-P10-6-4-1-1-1-1-1-1	13	Shiroodi
7	M7-P10-6-4-6-1-1-1-1-1	14	Nemat

*: Number of genotypes, M7: 7th mutant generation, P1: Sange Tarom, P6: Tarom Chaloosi, P10: Nemat, P11: Sepidrood, P18: Khazar, Tarom hashemi (local control), Shiroodi (Improved control), Nemat (Mutant parent).

Table 2. Molecular markers correlated with aroma and qualities traits genes of studied rice genotypes.

Marker ID	Marker type	Chromosom location	Sequence 5' → 3'	Reference
FGR	SNP	8	ttgtttggagcttgctgatg agtgctttacaaagtcccgc	[6]
IFAP, INSP, ESP and EAP	SNP		cataggagcagctgaaatatatacc ctggtaaaaagattatggcttca	
RM190	SSR	6	gctacaaatagccacccacacc aacacaagcagagaagtgaagc	[2]
RM510	SSR	6	aaccggattagtttctcgcc tgaggacgacgagcagattc	[34]

Physicochemical properties (M7)

Physicochemical characteristics used were brewers rice (%), milling (%), grain length before cooking (mm), grain length after cooking (mm), elongation after cooking (mm). Furthermore, amylose content (%) was measured using Juliano and Villareal methods (16), Gelatinization Temperature (GT) using Little *et al*. (19). Gel Consistency (GC) was determined using Cagampang and coworkers methods (7). The study of aroma in grains was done according to the Sood and Siddiq sensory methods (33) and finally, the head rice, was evaluated at the GABIT grain quality lab (Table 2).

Molecular testing (M8)

Molecular analysis was done only for aromatic gene and cooking quality genes using three SSR primers, Including RM190 for quality cooking, RM510 for GC, and SNP of *fgr* for aroma (Table 2). Fresh leaves (M8) of the selected promising line (M8-P10-37-1-1-1-1-1-1-1) along with aromatic and non-aromatic control varieties (Tarom Hashemi, Nemat, and Sange Tarom) were used for DNA extraction using CTAB method (36). SSR-PCR was performed according to Bradbury *et al*. (6) with the modification. SNP-PCR was performed using the mixture of 2.0 µl of 10X reaction buffer (with 20 mM Mg^{2+}), 0.2 µl of 10 mM dNTPs mix, 0.25 µl of *taq* DNA Polymerase, 5 µl of DNA template, 0.4 µl of each primer EAP, and ESP, 0.5 µl of primer INSP and 0.5 µl of IFAP. The total volume of the PCR reaction mixture was 20 µl and amplification was carried out using a thermal cycler. Cycling conditions were performed for 4 min at 94 ˚C, followed by 35 cycles of 30 s at 94 ˚C, 30 s at 53 ˚C and 1 min at 72 ˚C concluded with the final extension of 7 min at 72 ˚C. Electrophoresis in 1.8% agarose gel and staining in ethidium bromide was done to analyze PCR products.

Supplementary experiments

The selected promising lines of M8 and M9 (2017-2018) were grown in 40 farmer's fields in Mazandaran province for further field tests. Meanwhile (for two years), DUS and VCU tests were conducted for a selected promising line with its parent and check varieties through the SPCRI description (2017-2018) (Figure 1).

Data analysis

Data analysis was performed using SPSS software version 16. Mean comparison was conducted using Duncan's method at the 5% probability level. A dendrogram was produced by cluster analysis of the agronomic and physicochemical traits of mutant genotypes including check varieties using the Ward method.

RESULTS AND DISCUSSION

Morphological characteristics (M7)

The analysis of variance in advanced yield trials (AYT) indicated, the significant differences of all morphological traits at a 1% level of probability (Table 3).

The mean comparison of different traits (Table 4) has shown that, the M7-P1-4-1-1-1-1-1-1-1 line was the earliest maturity (average 123.67 days of sowing to harvest; means 123 up to 126.67 days to maturity).

Table 3. Variance analysis of morphological traits related to 11 promising lines (M7) and 3 control varieties.

S.O.V	df	No. Days to maturity	No. Fertile tiller	Plant Height	Panicle length	No. Grain panicle	No. filled grain Panicle	1000 weight Grain	Grain yield	Head rice
		Ms								
Genotype	13	79.5**	25.6**	925.0**	29.3**	3562.7**	2413.9**	14.4**	3267266**	185.7**
Block	2	0.16	0.13	0.43	0.18	19.10	30.78	0.04	52.21	0.04
Error	26	0.14	0.83	7.13	0.74	5.93	13.00	0.24	2541.41	0.021

**: Significant at 0.01 Probability level

Table 4. The average grain yield and others agronomic important traits of the studied mutant rice genotypes and check varieties**.**

Rice genotypes	No. Days to maturity	No. Fertile tiller	Plant Height (cm)	Panicle length (cm)	No. Grain.panicl[1]	No. filled grain.panicle[1-]	1000 Grain weight (g)	Grain yield
1	118.67 i	10.67 f	140.23 b	27.10 ef	85.57 j	79.80 g	23.62 c	4.27 j
2	124.33 f	11.12 e	100.07 g	24.63 gh	67.20 k	62.33 h	28.04 a	5.77 g
3	126.67 c	13.03 d	105.41 ef	22.50 i	150.60 d	129.40 b	23.92 c	6.19 f
4	124 f	15.08 c	100.94 fg	26.03 gh	145.33 ef	125.27 bc	25 b	6.80 d
5	126 d	12.15 de	100.66 fg	27.21 ef	168.07 bc	129.53 b	25.18 b	6.61 e
6	125 e	11.92 de	94.22 h	28.30 de	140.40 g	106.47 de	23.58 c	5.77 g
7	125 e	15.25 c	103.94 efg	32.16 ab	149 de	101 e	25.05 b	6.66 e
8	123.67 f	18.75 a	119.70 d	32.53 a	193.23 a	175.10 a	24.17 c	8.23 a
9	125.67 e	16.75 bc	103.33 efg	27.63 e	128.63 h	84.87 fg	23.46 c	5.73 g
10	124 f	18.67 a	107.05 e	30.87 bc	143.60 g	101.07 e	28.69 a	6.88 d
11	123 g	16 .25 bc	87.55 i	24.23 h	146.27 ef	82.80 fg	21.86 d	5.52 h
Tarom Hashemi	120 h	10.67 e	148.04 a	26 fg	100.80 i	88.30 f	21.71 d	4.70 i
Shiroodi	130 b	17.33 ab	123.25 cd	29.56 cd	170.93 b	122 .70 c	25.26 b	7.31 b
Nemat	140.67 a	16.33 bc	126.67 c	31.67 ab	165.67 c	108.33 d	28.33 a	6.98 c

Means in each column, followed by similar letter(s) are not significantly different at 5% probability level, using Duncan´s Multiple Range Test.

This trait is one of the most important traits of rice cultivation for the Northern part of Iran, due to early season rainfall and third generation of stem borer pest. The highest number of fertile tillers (18.75) is related to M7-P10-37-1-1-1-1-1-1 line. On the other hand, the high-yielding cultivars such as Shiroodi and Nemat have on average about 16 fertile tillers per plant. The longest panicle length belonged to M7-P10-37-1-1-1-1-1-1 line with 32.53 cm, which was longer than its Nemat parent variety (31.67 cm). The highest total number of grains per panicle and number of filled grains per panicle also belonged to this line, which is two-fold greater than the local check variety (Tarom Hashemi) (Table 4). The grain yield of the new improved line (M7-P10-37-1-1-1-1-1-1) was 8.23 ton/ha, which was greater than Shiroodi (7.31 ton/ha), Nemat (6.98 ton/ha) and Tarom Hashemi (4.70 ton/ha). Nuruzzaman *et al.* (24) reported that the high yield of mutant line's (11.8 to 33.02 gr per plant) comparing to the classical and parental normal line's yield (6.15 to 9.97 gr per plant). Graphical comparison of grain yield among new mutant lines and check varieties are shown in Figure 2. In this comparison, the M7-P10-37-1-1-1-1-1-1 has shown 12.51 percent yield more than Shiroodi, 17.96 percent comparing to the Nemat (the maternal parent) and 74.97 percent comparing to the local aromatic check variety (Tarom Hashemi). Sen *et al*. reported that, the new released mutant line entitled CR Boro Dhan-2, a high yield mutant variety (6.1 t/ha) of China 45, with medium maturity and tolerant to cold stress at the seedling stage (30). Analysis of variance for

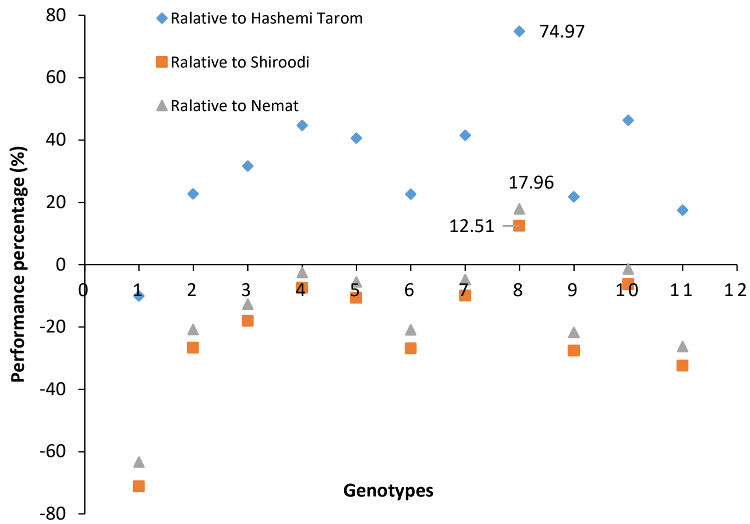

Figure 2. Yield graphic comparison between, the mutant genotypes and control varieties.

physicochemical properties indicated that, the significant differences between the genotypes for all traits (Table 5).

Physicochemical properties (M7)

Mean comparison of physicochemical characteristics is shown in Table 6; The best head rice (66.20%), including highest milling rate (73.96%) is belonged to the M7-P10-2-2-1-1-1-1-1-1, the longest grain belongs to line M7-P11-6-2-3-1-1-1-1-1 with 8.03 mm length, and the grain elongation refers to M7-P10-5-4-4-1-1-1-1-1 with 13.5 mm length, (5.62 mm elongation). Cooking test showed the best aroma scent which was comparable to the quality control variety (Tarom Hashemi) belonged to the M7-P1-4-1-1-1-1-1-1-1, M7-P10-6-4-1-1-1-1-1-1 and M7-P10-37-1-1-1-1-1-1-1 lines. All mutant promising lines indicated the desirable GC (87-98 mm) and the soft gel (3-7). Similar to our observation, Shehata *et al.* reported the development of quality and aromatic scent variation in a mutation breeding program (21). Patnaik *et al.* treated the Pusa Basmati variety, in order to enhance its yield via mutation breeding, and finally introduced Poorna Bhog new variety with 4.5-5 ton/ha yield (27). Usually the high-yield variety, is accompanied by a lack of the aromatic and fluffy characteristics, the type has no preference by Iranian consumers (26).

Cluster analysis of morphological traits of genotypes has shown, three main groups (Figure 3a); the maximum members (7 lines) related to group II or high yield varieties (50%). M7-P11-6-2-3-1-1-1-1-1 and M7-P10-37-1-1-1-1-1-1-1 as well as two improved check varieties (Nemat and Shiroodi) are located in group III. These results pointed to the close genetic relationship of new mutant lines with two high yield varieties. The effects of gamma ray on genetic and morphological diversity of some rice varieties analyzed via cluster analysis; The results, demonstrated that the vast diversity comparing to the local varieties (Tarom Hashemi and Sange-Jo) and some improved varieties (Nemat, Fajr and Jelodar) (25). Cluster analysis of physicochemical traits of genotypes has shown, four main groups (Figure 3b); Furthermore, the quality characteristics cluster has shown that, M7-P10-6-4-1-1-1-1-1-1, M7-P1-4-1-1-1-1-1-1-1 and M7-P10-37-1-1-1-1-1-1-1), as well as aromatic check variety (Tarom Hashemi) located in the same group. It means that those mutant lines have cooking and eating characteristics with the same aromatic attribute as local varieties.

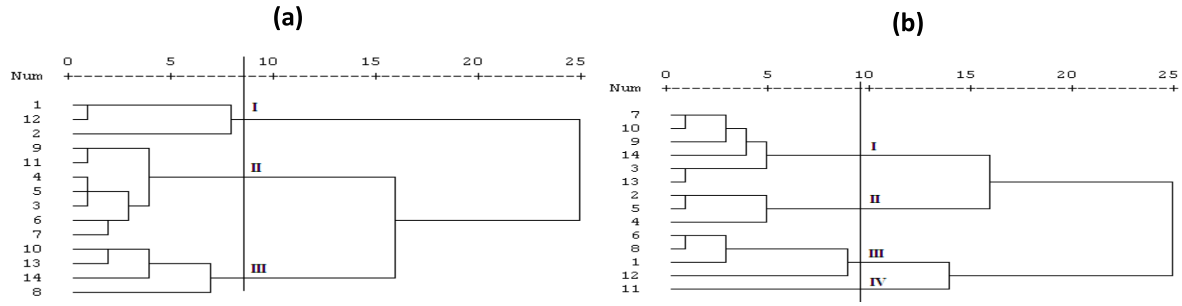

Figure 3. Dendrogram of morphological (a) and physiological (b) cluster analysis of mutant genotypes including check varieties using Ward method for grain yield, agronomy and physicochemical traits.

Ultimately, line M7-P10-37-1-1-1-1-1-1-1 with desirable morphological and physicochemical characteristics such as early maturity (123.67), number of tillers plant (18.75), panicle length (32.53 cm), total grain per panicle (193), grain yield (8.23 tons/ha), GT (5.42), GC (98 mm), AC (18.4%), same aromatic sent such as local aromatic variety (Tarom Hashemi), was selected to be released.

Table 5. Variance analysis of physicochemical traits related to 11 promising lines (M7) and 3 control varieties.

S.O.V	df	BR	M	L	L+	Ar	GT	GC (mm)	AC (%)	E
		Ms								
Genotype	13	162.37**	72.29**	0.75**	2.84**	0.71**	7.01**	235.81**	13.94**	1.44**
Block	2	0.12	0.36	0.53	1.01	0.02	0.01	103.07	0.33	1.80
Error	26	0.05	0.06	0.10	0.35	0.101	0.00	25.61	0.32	0.42

BR: brewers rice, M: Milling rate (%), L: Grain length before cooking, L+: Grain length after cooking.

**: Significant at 0.01 Probability level

Table 6. Mean Comparison of physicochemical traits for studied mutant lines including check varieties.

Rice genotypes	HR (%)	BR (%)	M (%)	L (mm)	L+ (mm)	Ar	GT	GC (mm)	AC (%)	E (mm)
1	54.49 i	16.33 e	70.82 c	7.18 d-g	11d-f	3 a	3.33 h	87 b	19.1 e	3.82
2	47.23 k	23.66 b	70.89 c	7.37 c-f	12.23 bc	2.67	4.5 g	97 a	19.1 e	4.86
3	66.20 a	7.76 i	73.96 a	7.68 b-e	12.26 bc	2 cd	6.5 c	93.33	23 bc	4.58
4	56.73 h	16.77 d	73.50 b	7.82 bc	13.50 a	2.33	7 a	97 a	23 bc	5.68 a
5	46.31 k	27.60 a	73.91 ab	7.28 c-f	11.50 b-e	2 cd	6.5 c	93.67	20.9 d	4.22
6	58.49 f	11.46 g	69.95 d	7.69 b-e	11.67 bcd	3 a	6.75 b	95 ab	21.1 d	3.98
7	57.21 g	6.20 i	63.41 i	7.42 b-f	12 bcd	2 cd	6.75 b	88.67	22.79	4.58
8	63.73 b	5.08 ik	69.80 d	7.33 b-f	10.53 e-g	3 a	5.42 e	98 a	18.4 e	3.21 c
9	54.63 i	8.21 h	62.84 i	7.79 bcd	11.50 b-e	1.67 d	3.25 h	88.33	21.11	3.71
10	52.25 i	12.49 f	64.74 h	8.03 b	12.55 ab	2 cd	6.5 c	94.33	21.2 d	4.51
11	37.32 m	19.58 c	56.90 k	6.82 fg	9.83 g	2.67	3 i	98 a	17.3 f	3.01 c
Tarom Hashemi	62.11 d	6.25 i	68.37 e	6.57 bcd	10.33 fg	3 a	3.25 h	67 d	22.85	3.68
Shiroodi	62.85 c	4.68 l	67.53 f	7.16 efg	11.33 c-f	2 cd	4.75 f	94.67	24 ab	4.18
Nemat	59.51 e	5.77 k	65.28 g	8.61 a	12.33bc	2 cd	6 d	77 c	24.2 a	3.73

Ar: Aroma, GT: Gelatinization temperature, GC: Gel consistency, AC: Amylose content and E: Elongation after cooking.

Molecular testing (M8)

The results of the molecular analysis with aroma gene (*fgr* marker) for the selected line (M8-P10-37-1-1-1-1-1-1-1) indicated that it has the same aromatic gene's band (257 bp) as Tarom Hashemi and Sang Tarom local aromatic varieties (Figure 4a). Yeap *et al*. (35) was confident in the efficacy of molecular markers analysis integrated with sensory methods, using aromatic bands (257 bp) for Gharib and Sadri genotypes. Furthermore, in the current study the use of RM190 and RM510 primers also showed that selected promising line M8-P10-37-1-1-1-1-1-1-1 possessed the same band similar as qualitative control cultivars (Figures 4b, c).

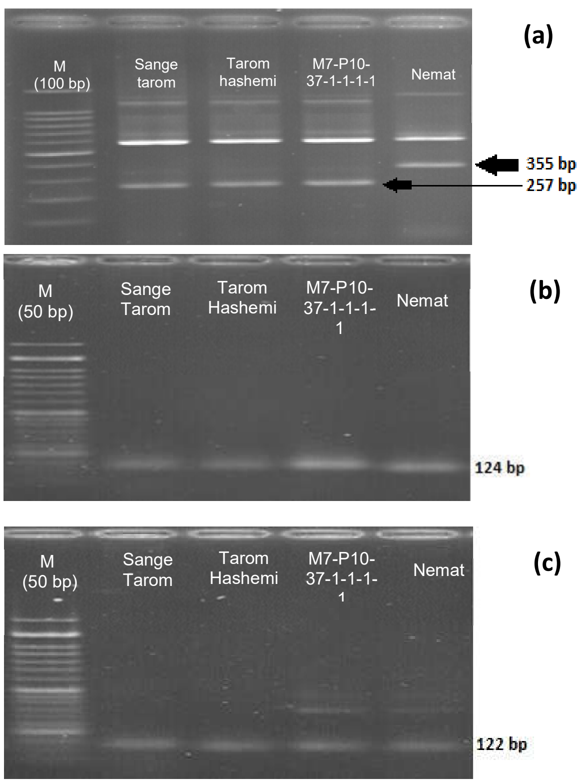

Figure 4. The locus of aroma gene marker (*fgr*) of P10-37-1-1-1-1-1-1-1 (a), RM 190 of P10-37-1-1-1-1-1-1-1 (b) and P10-37-1-1-1-1-1-1-1 (c), Sang Tarom, Tarom Hashemi, and Nemat.

Finally, based on tests of advanced yield trial, physiological, molecular, DUS, and VCU field observations. the line M9-P10-37-1-1-1-1-1-1-1 was recognized as the best candidate for releasing as a new variety. So that this line was registered as "Roshan" variety in Seed and Plant Certification and Registration Institute (SPCRI), ref to, 5495/253 national code, dated 02/12/2019. The agronomical and physicochemical characteristics of 'Roshan' variety is summarized in Table 7.

Table 7. Agronomic and physicochemical characteristics of Roshan new rice varieties based on tests of DUS and VCU in two years and also field observations

Traits	Feature
Maturity (Mat)	**123.67 days**
Plant Height (Ht)	**119.7 cm**
No. tiller	**18.75 No**
Panicle Exsertion (Exs)	**Well exserted**
Awning (An)	**Absent**
Panicle Length (PnL)	**32.53 mm**
1000-grain Weight (GW)	**24.17 gr**
Grain.panicle^{-1}	**175.1 No**
Unfilled grain panicle^{-1}	**15**
Grain yield	**8.23 Ton/ha**
Grain Length (GrL)	**11.32 mm**
Brown Rice Length (Len)	**7.33 mm**
Brown Rice Width (BrW)	**1.55 mm**
Chalkiness of Endosperm (Clk)	**None**
Rice Length After cooking	**10.53 mm**
Gelatinization temperature (GT)	**5.42**
Gel consistency (GC)	**98 mm**
Amylase content (AC)	**18.4%**
Aroma	**Good**
Tolerance to Stem Borers	**Moderate***
Tolerance to Leaf folder	**Moderate***
Tolerance to blast	**Resistant***
Tolerance to Blight Disease	**moderate***

Observation in field at VCU and DUS.

ACKNOWLEDGEMENTS

Hereby we have highly appreciated the director of GABIT and SANRU, for the financial support of this project and Iran Atomic Organization (IAO) for seed treatment with Gamma rays. Also, thanks go to the SPCRI for conducting Supplementary experiments.

REFERENCES

[1] Ahloowalia, B.S., Maluszynski, M. and Nichterlein, K. 2004. Impact of mutation-derived varieties. Euphytica, 135, 187–204.

[2] Akagi, H., Yokozeki, Y., Inagaki, A., Fujimura, T. 1996. Microsatellite DNA markers for rice chromosomes. Theor Appl Genet 93: 1071-1077.

[3] Arefii, H. and Norozi, M. 2008. Introduced two new rice varieties through mutation (gamma rays), Rice Research Institute. Department of Mazandaran, 1:2-10.

[4] Bao, J., Ying, Y., Xu, Y., Zhou, X., Yan, S. and Pang, Y., 2020. Variation in physicochemical properties and nutritional quality in chalky mutants derived from an indica rice. Journal of Cereal Science, 91, p.102899.

[5] Borba, T.C.D.O., Brondani, R.P.V., Breseghello, F., Coelho, A.S.G., Mendonça, J.A., Rangel, P.H.N. and Brondani, C., 2010. Association mapping for yield and grain quality traits in rice (*Oryza sativa* L.). Genetics and Molecular Biology, 33(3), pp.515-524.

[6] Bradbury, L.M., Henry, RJ., Jin, Q., Reinke R.F., and Waters, D.L. 2005. A perfect marker for fragrance genotyping in rice. Molecular Breeding. 16(4):279–283.

[7] Cagampang, G.B., Perez, C.M. and Juliano, B.O. 1973. A gel consistency test for eating quality of rice. J. Sci. Food. Agric, 24: 1589–1594.

[8] FAO/IAEA-MVD. 2019. Food and agriculture organization of the United Nations/International atomic energy agency – mutant variety database. Available online: https://mvd.iaea.org/

[9] Gulfishan, M., Bhat, T.A. and Oves, M. 2015. Mutants as a Genetic Resource for Future Crop Improvement. In Advances in Plant Breeding Strategies: Breeding, Biotechnology and Molecular Tools, 95-112.

[10] Harding, S.S., Johnson, S.D., Taylor, D.R., Dixon C.A. and Turay, M.Y. 2012. Effect of Gamma Rays on Seed Germination, Seedling Height, Survival Percentage and Tiller Production in Some Rice Varieties Cultivated in Sierra Leone. American Journal of Experimental Agriculture, 2(2): 247-255.

[11] Haris, A., Abdullah, B., Subaedah, A. and Jusoff, K., 2013. Gamma ray radiation mutant rice on local aged dwarf. Middle-East Journal of Scientific Research, 15(8): 1160-1164

[12] IAEA. 2013. Plant Mutation Reports. International Atomic Energy Agency. Vienna International Centre, PO Box 100. A-1400 Vienna. Austria, 3:1- 52.

[13] IRRI. 2013. Standard Evaluation System for rice. 5th edition. P. o. Box 933, 1099. International Rice Research Institute. Manila, Philippine. 65 pp.

[14] Jeng, T.L., Tseng, T.H., Wang, C.S., Chen C.L. and Sung, G.M. 2003. Starch biosynthesizing enzymes in developing grains of rice cultivar Tainung 67 and its sodium azid-induce rice mutant. Field Crops Research, 84: 261-269.

[15] Jeng, T.L., Tseng, T.H., Wang, C.S., Cheng, C.L. and Sung, J.M. 2006. Yield and grain uniformation in contrasting rice gene type's suitable for different growth environments. Field Crop Research, 99: 59-66.

[16] Juliano, B.O. and Villareal, C.P. 1993. Grain quality evaluation of world rice. International Rice Research Institute, Manila, the Philippines.

[17] Kong, X., Sun, X., Xu, F., Umemoto, T., Chen, H. and Bao, J. 2014. Morphological and physicochemical properties of two starch mutants induced from a high amylose indica rice by gamma irradiation. Starch-Stärke, 66(1-2), pp.157-165.

[18] Li, K., Bao, J., Corke, H. and Sun, M. 2017. Genotypic diversity and environmental stability of starch physicochemical properties in the USDA rice mini-core collection. Food Chemistry, 221, pp.1186-1196.

[19] Little, R.R., Hilder, G.B., Dawson, E.H. and Elsie, H. 1958. Differential effect of dilute alkali on 25 varieties of milled white rice. Cereal Chem, 35: 111–126.

[20] Lo, S.F., Fan, M.J., Hsing, Y.I., Chen, L.J., Chen, S., Wen, I.C., Liu, Y.L., Chen, K.T., Jiang, M.J., Lin, M.K. and Rao, M.Y., 2016. Genetic resources offer efficient tools for rice functional genomics research. Plant, cell & environment, 39(5), pp.998-1013.

[21] Majd, F., Rahimi, M. and Rezazadeh, M. 2002. Evolving of mutant lines resistant to lodging, and high yield in rice by induce mutation using Gamma ray (physical mutagen). Journal of Nuclear Science and Technology, 26: 37-43.

[22] Nakagawa, H. 2009. Induced mutations in plant breeding and biological researches in Japan. In: Q.Y. Shu (ed.), Induced Plant Mutations in the Genomics Era. Food and Agriculture Organization of the United Nations, Rome, pp51-58

[23] Nematzadeh, G., Arefi, H.A. Amani, R. and Mani, R. 1997. Release of a new variety of Rice Namely "Nemat" with

superiority in Yield and Quality, Iranian Journal of Agricultural Sciences, 28 (4): 79-86.

[24] Nuruzzaman, M., Hassan, L., Begum, S.N. and Huda, M.M. 2016. Morphological characterization and assessment of genetic parameters of NERICA mutant rice lines under rainfed condition. Asian Journal of Medical and Biological Research, 2(4): 532-540.

[25] Oladi, M., Nematzadeh, G.A., Hashemi, S.H., Gholizadeh, A., Afkhami Ghadi, A. and Rezaei, M. 2014. Screening of Rice Promising Lines from multiple cross using agro-morphological Traits. Journal of Crop Breeding, 6:14. 15-26.

[26] Oladi, M., Nematzadeh, G.A., Rahimi, M., Afkhami Ghadi, A., Gholizadeh Ghara, A., Mozafari, K. and Ziaee A. 2015. The effects of gamma ray on genetic and morphological diversity of some rice varieties. Journal of Nuclear Science and Technology. Atomic Energy Organization of Iran, 73: 80-87.

[27] Patnaik, A., Rao, G.J.N. and Choudhury, D. 2013. Poorna Bhog, a High Yielding Mutant of Rice. Plant Mutation Reports, 3: 1. 48-45

[28] Rao, G.J.N., A. Patnaik, and D. Chaudhary. 2012. Genetic improvement of Basmati rice through mutation breeding. In: Shu, Q. Y., B.P. Forster and H. Nakagawa (Eds). Plant Mutation Breeding and Biotechnology. CABI publications.

[29] Sasikala, R. and Kalaiyarasi, R. 2010. Sensitivity of rice varieties to gamma irradiation. Electron J Plant Breed, 1(4):885–889.

[30] Sen, P., Rao, G.J.N., Subudhi, S.C. and Mishra, R.N. 2013. Development CR Boro Dhan-2, a High Yielding Mutant of Rice for Boro Situation. Plant Mutation Reports, 3: 1. 49-51.

[31] Shehata SM, Ammar MH, Abdelkalik AF, Zayed BA. 2009. Morphological, molecular and biochemical evaluation of Egyptian jasmine rice variety and its M5 derived mutants. Afr J Biotechnol 8(22): 6110-6116.

[32] Shu, Q.Y. and Lagoda, P.J.L. 2007. Mutation techniques for gene discovery and crop improvement. Mol Plant Breed, 5:193–195.

[33] Sood, B.C, and Siddiq, E.A. 1978. A rapid technique for scent determination in rice. Indian Journal of Genetics and Plant Breeding. 38(2):268–275.

[34] Temnykh, S., DeClerck, G., Lukashova, A., Lipovich, L., Cartinhour, S. and McCouch, S., 2001. Computational and experimental analysis of microsatellites in rice (*Oryza sativa* L.): frequency, length variation, transposon associations, and genetic marker potential. Genome research, 11(8), pp.1441-1452.

[35] Yeap, H.Y., Faruq, G., Zakaria, H.P. and Harikrishna, J.A., 2013. The efficacy of molecular markers analysis with integration of sensory methods in detection of aroma in rice. The Scientific World Journal. doi: 10.1155/2013/569268.

[36] Yesmin, N., Elias, S.M., Rahman, M., Haque, T., Mahbub Hasan, A.K.M. and Seraj, Z.I., 2014. Unique genotypic differences discovered among indigenous Bangladeshi rice landraces. International journal of genomics, 2014.

.

روشن، رقم جدید برنج موتانت معطر با عملکرد بالا و زودرس

قربانعلی نعمت‌زاده[۱،۲]، مرتضی اولادی[۱]، عمار افخمی قادی[۱،۳]، عمار قلیزاده قرا[۲]، فرهاد باقری[۱]، مجتبی آقاجانی قرا[۱]، مریم امامی قرا[۱]، علیرضا بابائی[۴]، مسعود رحیمی[۵]، کامران مظفری[۵]، رضا وجدان[۱]، احمد اسفندیاری[۱]

[۱] پژوهشکده ژنتیک و زیست‌فناوری کشاورزی طبرستان، دانشگاه علوم کشاورزی و منابع طبیعی ساری. سلری، ایران.

[۲] گروه اصلاح نباتات، دانشگاه علوم کشاورزی و منابع طبیعی ساری. سلری، ایران.

[۳] گروه ژنتیک و به‌نژادی گیاهی، دانشگاه بین‌المللی امام خمینی (ره)، قزوین، ایران.

[۴] مرکز آموزش علمی - کاربردی جهاد کشاورزی مازندران، ایران.

[۵] مرکز تحقیقات کشاورزی هسته‌ای، پژوهشگاه علوم و فنون هسته‌ای، سازمان انرژی اتمی کشور، تهران، ایران.

*نویسنده مسئول: gh.nematzadeh@gmail.com

چکیده

اصلاح موتاسیونی بعنوان روشی نوین برای بهبود گیاهان زراعی و دستیابی به عملکرد بالا با حفظ خصوصیات کیفی است. در این پژوهش از برنامه اصلاح موتاسیونی با پرتودهی اشعه گاما بر روی چند رقم برنج (ارقام محلی و اصلاح‌شده شامل ارقام سنگ طارم، طارم چالوسی، نعمت، سپیدرود و خزر) در مزرعه پژوهشی پژوهشکده ژنتیک و زیست‌فناوری کشاورزی طبرستان از سال ۱۳۸۹ تا ۱۳۹۷ شمسی استفاده گردید. بذور پنج رقم برنج با اشعه گاما و با دز ۲۰۰ گری در پژوهشکده هسته‌ای سازمان انرژی اتمی کشور تیماردهی شده و سپس نسل‌های در حال تفکیک (M2-M9) طی مدت ۷ سال کشت و صفات زراعی از طریق روش شجره‌ای ارزیابی شدند. در نهایت ۱۱ لاین امیدبخش انتخابی در نسل نهم موتانت در قالب طرح بلوک‌های کامل تصادفی با سه تکرار برای آزمون‌های تکمیلی مورد ارزیابی قرار گرفتند. نتایج نشان داد که لاین M9-P10-37-1-1-1-1-1-1-1 (از موتانت نعمت) دارای عملکرد بالا (۸/۲۳ تن در هکتار)، زودرس (۱۲۳/۶۷ روز)، همراه با خصوصیات فیزیکوشیمیایی مطلوب (AC=۱۸/۴ GC =۹۸ و GT=۵/۴۲) و عطر و طعم مناسب (تایید شده با نشانگر *fgr* با طول باند ۲۵۷bp) می‌باشد. مقایسه میانگین عملکردها نشان داد که، لاین M9-P10-37-1-1-1-1-1-1-1 در مقایسه با رقم شیرودی ۱۲/۵۱ درصد و نسبت به طارم هاشمی ۴۷/۹۷ درصد افزایش عملکرد داشته و همزمان از کیفیت مناسبی (مشابه خصوصیات فیزیکوشیمیایی و عطر ارقام محلی) برخوردار می‌باشد. این لاین موتانت جدید در مؤسسه ثبت و گواهی بذر و نهال بعنوان رقم روشن ثبت و تجاری‌سازی گردید.

واژهای کلیدی: اصلاح موتاسیونی، ارقام برنج اصلاح‌شده، معطر، *Oryza sativa* L.