Paper 31

[Accueil] [Remonter] [Intro 1] [Paper 2] [Paper 3] [Paper 4] [Paper 5] [Paper 6] [Paper 7] [Paper 8] [Paper 9] [Paper 10] [Paper 11] [Paper 12] [Paper 13] [Paper 14] [Paper 15] [Paper 16] [Paper 17] [Paper 18] [Paper 19] [Paper 20] [Paper 21] [Paper 22] [Paper 23] [Paper 24] [Paper 25] [Paper 26] [Paper 27] [Paper 28] [Paper 29] [Paper 30] [Paper 31] [Paper 32] [Paper 33] [Paper 34] [Paper 35] [Paper 36] [Paper 37] [Paper 38] [Paper 39] [Paper 40] [Paper 41] [Paper 42]

Results obtained in rice breeding (Oryza sativa L.) by induced mutation methods

Authors :

ALIONTE Gheorghe
ALIONTE Eliana
Research Institute for cereals & Technical Rice Research Station
Bulev. Marasti 61, Sect. 1 - 71331 Bucarest - ROMANIA
Tel : +17 00 55 40
Fax:+ 131 10 722

Abstract

Utilisation of induced mutation method in rice breeding resulted, in a relative short period, in the registration of the new variety Olteniþa (38/79 mutant from Krasnodar 424, a variety grown over 80% from crop area before 1986).

Some other mutant lines with large genetic variability and promising for breeding process were obtained.

Seeds of variety Krasnodar 424 were treated with different mutagen agents, in doses of 20 and 40 kR, the most efficient being X and gamma rays. As a result of repeated individual selection, 23 induced mutants were selected from different generations and analysed for favourable agronomic traits.

All mutant lines differed from the variety of the origin in terms of internode length, form, position and size of flag leaf, culm thickness and plant height.

In some short or semi-short culm mutants, significant improvement in lodging was achieved as compared to Krasnodar 424.

Important differences in panicle form and size, number of seeds per panicle, fertility rate, seed form and size and thousand kernel weight were, also, registered.

Vegetation period, the most important limiting climate factor for rice in Romania, was shortened in some mutants with up to 11 days as compared to the check. Significant differences in yielding ability and seed quality were recorded.

Keywords

- kR, mutants, Oryza sativa, rice
- Romania

Introduction

Utilisation of induced mutations in plant breeding has been a problem widely discussed world-wide for many years. This topic may be discussed objectively due to the fact that many successful results achieved in this field have been communicated recently and a high number of mutants have been registered as varieties. Thus, in 1994, Sigurbiornsson and Micke published a list of 98 varieties in different crops being of mutant origin, out of which 13 were in rice. In 1980, over 30 mutant rice varieties were registered and in 1994, from a total of 826 mutants obtained in cereals, a number of approximately 322 were in rice (FAO - AEIA Report, 1994).

As Marie (1962) pointed out, induction of artificial mutations - as a modern methods of cultivated plant breeding - successfully competed against sexual crossing method. Some authors even consider that the utilisation of mutations in plant breeding of certain species is a better method than crossing and in some circumstances is the only solution (Futsuhara et al., 1967; Kaul et al., 1980; Rutger et al., 1976).Used in combination with other breeding methods, it may render good results (Hu, 1972; Michaelsen, 1980; Okuno and Kawai, 1978).

The problem of the effectiveness of the breeding method by mutations is questioned also at present by numerous authors. Critics to this method base their disapproving attitude on the fact that most mutations created have a more reduced vitality and consequently they are less competitive as compared to their initial forms.

Supporters of this method reveal the fact that from the total induced mutations, a sufficient large number of mutants with a better or at least equal vitality as compared to that of initial forms could be obtained by selection. Furthermore, they consider that mutants with a more reduced productivity or vitality could be important in breeding programs, either by direct utilisation in production or as initial breeding material, if they express a new trait, capable of compensating yield decrease.

In order to obtain and use artificial mutations in plant breeding, various method are being applied depending on the mutagen agent, plant species, the action of modifying factors and particularly on selection application (Nicaolae, 1978; Michaelsen, 1980; Konzak et al., 1985).

Releasing varieties of a short or semi-short culm, resistant to lodging, is a target which rice breeders are concerned with (Okuno and Kavai, 1978). Precocity, by either maintaining or increasing yielding capacity, represents a main objective in breeding by induced mutations (Rutger, 1982). Thus, Japonica Koshihikari R 151 type of mutant was intensively used in Japan in the breeding process, resulting in registration of Fujihikari rice variety (Hato, 1980), with a high seed quality.

In Romania rice breeding by this method was initiated in 1979 and was materialised in 1992, when Olteniþa rice variety was registered (mutant 38/79). The new variety ripens 7-9 days earlier than parent variety Krasnodar 424, have a short culm and a good yielding capacity.

The paper presents the results achieved in the experiments carried out at Research Institute for Cereals and Industrial Crops-Fundulea - Rice Laboratory Chirnogi, where induced mutations in rice were used for the first time in Romania. The aim of research have been the releasing of short and semi-short-culm types of rice, resistant to lodging, adequate for mechanical harvesting, early ripening and with high yielding ability. Krasnodar 424 variety was used as initial material due to its good ecological plasticity and high yielding ability, Krasnodar 424 is very little resistant to lodging.

Material and methods

Rice seeds (Oryza sativa L.) of Krasnodar 424 variety (Japonica type) were submitted to treatments with various physical and chemical mutagen agents, in 1979 and 1987 at the Centre of Nuclear Physics, Mãgurele, Bucharest.

Krasnodar 424 was released by the Institute for Rice Breeding in Krasnodar (Russia) in 1961 and has been cultivated in Romania since 1964. It has a height of 125 cm, a vegetation period of 125-130 days (semi-late), and a high yielding potential but it is poorly resistant to lodging. The seed submitted to treatments had 14% moisture.

In 1979 cycle the following mutagens were used :

- irradiation treatments, with X ray in doses of : 0, 15, 20 and 25 kR; gamma ray (60Co) in doses of : 0, 20, 25, 30, 35 and 40 kR; thermal neutrons in doses of 5 x $10^{12}/cm^2$ and 10 x $10^{12}/cm^2$;
- chemical treatments with ethyl-methane sulphonate (EMS) in doses of 0.4% x 10 h and 0.6% x 12 h.

In 1987 cycle only gamma rays were used, in doses of : 20, 25; 30 and 40 kR.

For both treatment cycles (1979 and 1987), about 2 000 seeds were used for each dose separately.

The treated material was sown in plots located at a distance of 10 m from other rice plots. It is known that the rate of cross fertilisation in rice under the climatic conditions of Romania, is very low, even at short distances (less than 1 m).

Approximately 65-70% of the seeds treated produced plants which reached maturity. Each mature plant was separately harvested and sampled. More than 2500 plants were obtained at each cycle.

For a sound choice an individualisation of M_2 generation plants, as well as, in order to make correct observation, seeds from individual panicles were planted in seedbeds specially created and irrigated. At 3-4 leaf phase, plants representing a panicle were transplanted into a row with a length of 1.5 m, 40 cm apart 25 cm between plants on the row.

Table 1. Selection efficiency in different mutant segregating generations in rice

Years of mutant generations						
1979 (1987)-M1	1980(1988)-M2		1981 (1989)-M3		1982 (1990)-M4	
Plants harvested	Number of transplanted plants	Number of mutants selected/ Panicle number	Number of panicles sown	Number of mutants selected/ Panicle number	Number of panicles sown	Number of mutants selected/ Panicle number
2500 (2300)	80.000 (60.000)	95/664 (60/420)	664 (420)	60/175 (55/165)	175 (165)	(30/23)

The number of plants selected in generation M_2 is shown in Table 1. In the stage of panicle formation, short and medium-culm plants were sampled separately for each individual treatment. A total number of 95 plants with 664 panicles, respectively 60 plants with 420 panicles were selected. The plants selected from each population were sown in 1981 and 1989, respectively (generation M_3), each panicle per one row of 1.5 m length and 40 cm apart.

Varieties used as checks were Krasnodar 424 (parent variety) and Bega (for precocity).

In the years 1981 and 1991, respectively, two short-culm mutants (70 - 80 cm) were crossed with Krasnodar 424 parent variety.

Segregation observations for culm height were made in generation F_2 of these crosses.

Results and discussion

In the case of both treatment cycles, up to generation M_4 a different number of mutant plants was selected (Table 1), so that finally a number of 30, respectively 23 mutants were separately selected. The rest of segregating material was observed, in parallel, in the common breeding nursery, by continuing to use the individual selection method, repeated annually.

Efficiency in obtaining useful mutants

Table 2. Vegetation period and grain yield potential in mutants obtained from Krasnodar 424 variety (1979 cycle)

Mutant	Irradiation dose (kR)	Vegetation period (days)	Yield (kg/ha)	%	Difference from Krasnodar 424 (kg/ha)
M 38/79	20 gamma rays	118	7500	121.4	1400***
M 30/79	40 gamma rays	124	7400	121.3	1300***
M 40/79	40 gamma rays	122	7400	121.3	1300***
M 19/79	25 gamma rays	122	7100	116.3	1000***
M 50/79	35 gamma rays	122	7100	116.3	1000***
M 31/79	40 gamma rays	121	7100	116.3	1000***
M 43/79	40 gamma rays	122	7000	114.8	900***
M 57/79	35 gamma rays	118	6900	113.1	800***
M 3/79	25 gamma rays	128	6800	111.4	700***
M 32/79	40 gamma rays	122	6800	111.4	700***
M 37/79	40 gamma rays	120	6700	109.8	600***
M 60/79	40 gamma rays	119	6550	107.3	550***
M 47/79	20 gamma rays	122	6300	103.2	200**
M 26/79	25 gamma rays	122	6300	103.2	200
M 15/79	25 gamma rays	122	6300	103.2	200**
M 11/79	25 gamma rays	129	6300	103.2	200**
M 5/79	25 gamma rays	122	6300	103.2	200**
M 32/79	40 gamma rays	120	6200	101.6	100
M 29/79	25 gamma rays	122	6100	100.0	0
Krasnodar 424	non - irradiated	125	6100	100.0	-
Bega	non - irradiated	118	5900	96.7	-200**
M 59/79	25 X rays	115	5700	93.3	-400***
M 69/79	EMS 0.4 x 10 h	115	5700	93.3	-400***
M 67/79	EMS 0.4 x 10 h	115	5700	93.3	-400***
M 66/79	EMS 0.40 x 0.10 h	115	5200	85.2	-900***

, * - significant for P<0.01 and P<0.001, respectively.

Short height, semi-short height and precocity were the main criteria for selection in generation M_2 (Table 1). Attention was also granted to detect mutants with modifications in the leaf form and size, position of the flag leaf, culm thickness, form, position and size of panicle, seed size, form and aspect.

In treatment cycle applied in 1979 (Table 2) the best results were achieved with treatment with gamma radiation, in doses of 20-40 kR. In terms of height, precocity and yield, two mutants in the dose of 20 kR, seven mutants in the dose of 25 kR, two mutants in the dose of 35 kR and seven mutants in the dose of 40 kR gamma rays, were considered useful mutants.

The treatments with X rays and thermal neutrons, were less efficient and resulted each in one mutant, earlier and with short culms (in the doses of 20 kR and 10 x 1012/cm^2, respectively). In the case of EMS chemical treatments early mutants were selected at the dose of 0.4% x 10 h.

Since gamma rays gave the best results, they were used as mutation agent in 1987 treatment. Two mutants were selected in the dose of 20 kR, eight mutants in the dose of 30 kR, six mutants in the dose of 35 kR and three mutants in the dose of 40 kR (Table 3).

Performances of selected mutant lines with special emphasis on precocity and plant height

In M_2 generation preliminary tests, attention was paid mainly to select short-culm (75-90 cm length) early mutants and to maintain yielding capacity at the level of the parent variety.

Table 3. Vegetation period and grain yield potential of perspective mutant lines obtained from Krasnodar 424 variety.

Mutant variety	Irradiation dose (kR)	Vegetation period (days)	Difference from the check (± days)	Grain yield (kg/ha)	Difference from the check (kg/ha)
M 231//79	35 gamma rays	125	0	9800	3400***
M 300/87	20 gamma rays	127	+2	9600	3200***
M 217/79	25 gamma rays	123	-2	8800	2400***
M 214/79	35 gamma rays	127	+2	8500	2100**
M 210/79	35 gamma rays	117	-8	8400	2000**
M 216/79	40 gamma rays	125	0	8300	1900**
M 358/87	30 gamma rays	128	+3	8000	1600*
M 212/79	35 gamma rays	131	+6	7900	1500*
M 355/87	30 gamma rays	123	-2	7700	1300*
M 37 x M 43	35 gamma rays	123	-2	7700	1300*
M 220/79	30 gamma rays	125	0	7600	1200
M 354/87	30 gamma rays	117	-8	7600	1200
M 353/87	30 gamma rays	115	-10	7300	900
M 38 (Olteniþa)	40 gamma rays	115	-10	7200	800
M 402/87	40 gamma rays	119	-6	7200	800
M 218/79	35 gamma rays	119	-6	7200	800
M 351/87	30 gamma rays	117	-8	7000	600
M 357/87	30 gamma rays	119	-6	6700	300
M 219/79	35 gamma rays	123	-2	6700	300
M 30/87	20 gamma rays	117	-8	6700	300
M 312/87	30 gamma rays	113	-12	6600	200
2M 15/79	25 X rays	123	-2	6500	100
Krasnodar 424	Non- irradiated	125	-	6400	-
M 356/87	30 gamma rays	123	-2	6400	0
M 401/87	40 gamma rays	117	-8	6200	-200

*,**,*** - significant for $P<0.05$, $P<0.01$, $P<0.001$, respectively.

Data in Table 4 show a great variation in plant height and increased resistance to lodging. Mutants with a greater height as compared to the check (+9.3 cm) but a thick culm (Ø=9.1 mm), which usually have a large tillering capacity and better lodging resistance were obtained. Unfortunately this type accumulates a greater quantity of vegetation mass - an undesirable trait for mechanised harvesting.

Mutants with a height much shorter than the check (-38.7 cm) were selected. Although a negative correlation between yield and culm height was communicated by some authors, height reduction did not negatively influence yielding capacity in some of these mutants. Mutants such as M 300/87, M 213/79, M 217/79, etc., with a height of 80 - 90 cm, had better resistance to lodging, superior yield and shorter vegetation period as compared to the checks (Tables 3 and 4).

Table 4. The effect of induced mutations on internode length, plant height and lodging resistance

Mutant	Irradiation dose (kR)	Culm diameter (diff.from check) (mm)	Internode length (difference from check[1]) (cm) I 1	I 2	I 3	I 4	I 5	I 6	Plant height (diff.from check (cm)	Lodging resistance[2]
M 301/87	20 gamma rays	0.2***	+1.1	3.3*	7.2***	-0.3	2.6	-	-15.3***	2-3
M 300/87	20 gamma rays	0.5	+12.1***	11.4***	7.2***	1.0	1.4	-	-37.0***	1
M 351/87	30 gamma rays	-2.2***	+0.3	2.5	2.5*	1.0	0.8	-	-8.1**	3-4
M 358/87	30 gamma rays	-1.1	+1.9	7.0***	3.2**	-3.0	3.4	-	-9.5**	3-4
M 352/87	30 gamma rays	0.9	+8.2***	5.2***	1.9	-2.6	0.9	-	-18.1***	2-3
M 356/87	30 gamma rays	1.4*	+13.8***	10.8***	6.9***	-1.7	4.1*	3.3	-29.6***	3
M 354/87	30 gamma rays	1.5**	+13.1***	10.3***	4.8***	-1.3	1.5	-	-31.6***	1
M 355/87	30 gamma rays	2.2***	+7.8***	7.7***	3.7**	-0.4	2.7	2.0	-20.6***	1
M 357/87	30 gamma rays	-0.3	-1.6*	3.66	0.7	-0.3	3.0	0.6	-2.0	4
M 353/87	30 gamma rays	0.7	+6.8***	6.3***	-1.1	-3.0	2.5	-	-11.6***	4
M 402/87	40 gamma rays	2.7***	+8.6***	7.2***	1.6	-3.0	4.7*	3.4	-13.1***	2-3
M 401/87	40 gamma rays	1.6**	+13.3***	11.0***	3.4**	-3.1	5.6**	3.0	-22.8***	2
M 217/79	25 gamma rays	2.2***	+10.4***	9.1*	-0.5	-4.9**	5.1**	4.3	-10.5***	3-4
M 218/79	25 gamma rays	2.4***	+1.1	1.6	-1.7	-4.2**	3.6	1.8	+6.9*	3-4
M 210/79	25 gamma rays	-1.4*	+9.4***	5.6***	0.5	-7.4***	4.2*	2.3	-38.6***	2
M 215/79	35 gamma rays	1.4*	+18.9***	12.6***	6.4***	-2.4	3.2	2.2	-7.0*	3
M 212/79	35 gamma rays	2.7***	-2.8	-1.2	-1.8	-1.1	1.7	2.9/0.8	+9.3**	3-4
M 220/79	35 gamma rays	1.5*	+4.6*	-2.4	3.2**	-2.1	3.1	0.3	-13.9***	3-4
M 219/79	35 gamma rays	-0.5	+17.1***	11.5***	6.6***	-2.3	3.5	-	-38.6***	1-2
M 214/79	35 gamma rays	0.2	+16.4***	12.0***	6.5***	-2.8	5.3**	2.4/0.4	-38.7***	1-2
M 213/79	35 gamma rays	-0.4	+11.2***	9.8***	5.8***	0.1	3.7	0.3	-31.1***	1-2
M 216/79	40 gamma rays	0.7	+2.3	8.4***	4.6***	0.4	2.7	1.6	-15.8***	2
M37xM47	-	2.2***	+4.3*	8.4***	3.5**	0.1	3.3	-	-13.9***	3
M 38 (Olteniþa)	35 gamma rays	-1.2*	+10.0***	5.6***	4.8***	-4.1**	-1.4**	-	-31.0***	3-4
Kr.424 (check)	Non-irradiated	6.7	34.5	27.7	20.8	9.3	2.1	-	117.0	7-8

*, **, *** - significant for P<0.05, P<0.01 and P<0.001 respectively

[1] I1 - the first top internode; [2] Score 1 - very resistant/ Score 9 - very susceptible

Our results confirmed the positive achievements communicated by many researchers such as : Nisimura and Kurakami (1959), Wettstein (1954), Kawai et al. (1961, 1968), Futsuhara et al. (1967), Konishi (1968), Kawai (1978), Okuno and Kawai (1978).

Thus, a large part of our induced short-culm mutants presented simultaneous changes in several agronomic traits. Gottschalk (1968) showed that many mutants which had been interpreted as a result of the action of pleiotropic genes proved to be simultaneously induced mutation in close loci, during the mutagenic treatments. Okuno and Kawai (1978) concluded that phenotypic changes observed in long-culm mutants were the result of a simple genetic change. Such simultaneous changes of some traits are considered to be due to the pleiotropic effect of "long-culm" mutant genes or the simultaneous action of mutant genes induced in close loci, responsible for morphological traits.

The length and internode number highly varied in mutants as compared to the parent check variety Krasnodar 424. This confirm the results of many research (Gustafsson et al., 1960; Konishi, 1968; Persson et al., 1979; Marishima and Oka, 1968), who showed that rice short-culm mutants may be classified into two groups : apical and basal (in our case M 213/79 and respectively, M 300/87) to which, according to Okuno and Kawai (1978), a third group may be added, the one of multiple nodes (for example : $M_2$14/79 with seven visible nodes).

In our experiments we observed that resistance to lodging (Table 4) visibly increased in mutant lines with basal extension of the culm and visibly increased number of nodes. Additionally, mutants with short and semi-short height had a frailer culm than the check, making mechanised harvesting easier.

Panicle length (Tables 4 and 5), decreased in all mutants studied with up to 9.0 cm (M 215/70) as compared to parent check variety Krasnodar 424. Modifications of panicle form and position occurred and most mutants showed a dense or semi-dense, erect or semi-erect panicle, as compared to check variety, which has a lax and bent panicle.

Although shorter than check, the panicles of a large part of the selected mutants had a superior density as they produced an increased number of ramifications and seeds per panicle.

Table 5. The effect of induced mutations on length, number of seed, fertility rate, weight and form of panicle

Mutant variety	Irradiation dose (kR)	Panicle length (difference from check) (cm)	Number of seeds / panicle (differences from check)	Fertility (difference from check) (%)	Panicle weight	Panicle type
M 301/87	20 gamma rays	-12.1***	-33.2	3.4	3.12	lax
M 300/87	20 gamma rays	-12.8***	-35.6	-13.3**	3.37	dense
M 351/87	30 gamma rays	-9.1***	-59.4***	1.0	2.77	semi-lax
M 358/87	30 gamma rays	-10.2***	-29.2***	-28.9***	2.62	dense
M 352/87	30 gamma rays	-11.7***	2.8	0.6	3.95	dense
M 356/87	30 gamma rays	-11.4***	22.0	-9.2*	4.04	dense
M 354/87	30 gamma rays	-13.0***	16.0	-5.9	3.83	dense
M 355/87	30 gamma rays	-10.8***	0.8	4.2	4.41	dense
M 357/87	30 gamma rays	-8.3***	-47.0*	3.1	2.92	lax
M 357/87	30 gamma rays	-10.0***	4.2	0.1	3.96	dense
M 402/87	40 gamma rays	-12.8***	30.4	14.0***	3.95	dense
M 401/87	40 gamma rays	-12.5***	90.0***	-20.8	4.26	dense
M 217/79	25 X rays	-11.0***	60.0**	-7.3	5.24	semi-dense
M 218/79	25 X rays	-7.1***	52.4*	-3.1	5.60	semi-dense
M 215/79	25 X rays	-9.3***	21.6	-3.1	6.23	lax
M 210/79	35 gamma rays	-15.4***	-42.0*	-0.2	3.33	semi-dense
M 212/79	35 gamma rays	-6.4***	78.4***	-18.6***	5.23	semi-dense
M 220/79	35 gamma rays	-9.7***	13.3	1.6	4.19	lax
M 219/79	35 gamma rays	-15.3***	-44.8*	-0.3	3.04	semi-dense
M 214/79	35 gamma rays	-15.3***	-20.6	-6.0	3.37	dense
M 213/79	35 gamma rays	-14.5***	-34.8	-0.9	2.78	lax
M 216/79	40 gamma rays	-10.2***	-40.2	-8.8*	2.56	dense
M 37 x M 43	non-irradiated	-10.4***	39.6	-12.9**	4.85	lax
M 38	non-irradiated	-11.9***	14.5	5.5	3.80	semi-dense
Krasnodar 424 (check)	non-irradiateds	28.9	148.6	95.2	4.80	lax

*, **, *** - significant for P<0.05, P<0.01 and P<0.001 respectively

Generally lower fertility percentage were recorded in mutants with tight panicles but the number seed was not significantly affected (e.g. M 400/87 which at a fertility rate of only 62.4% produced 90 seeds more than the check variety Krasnodar 424). Mutants such as M 352/87, M 353/87, M 355/87 had both tight panicle and high fertility (over 90%) (Table 5).

Modifications in the position of the flag leaf occurred. In the check variety, the flag leaf is located laterally, in a horizontal or a little bent position, with implications plant population, while in some mutants (M 300/87; M 352/87; M 213/79) the position of the flag leaf is erect or semi-erect, similar to the modern varieties of intensive type.

Changes in the date of flowering and maturity represent also important objectives for the climate conditions in Romania. Precocity, accordingly to most researchers, may be easily induced by mutations. Thus, Michaelsen (1980) showed that a shortening of the growing duration up to 30 days, without negatively affecting the yield was possible in rice. The author pointed out that, although many major genes influenced the flowering and maturity period in rice, and most of the early mutants showed a recessive monogenic heredity.

Some of our mutants had a shorter period of vegetation though their yielding ability was similar or even superior to the parent variety Krasnodar 424, M 352/87 was earlier than the check with 11 days and had a yielding potential similar to Krasnodar 424 , M 210/79 earlier with 7 days give significantly larger grain yield than the check; M 213/79 with a vegetation period equal to the check proved to be the highest yielding and had improved agronomic traits such as plant height, lodging resistance, etc. (Table 3).

Table 6. The effect of induced mutations on 1000 kernel weight and seed length / width ratio

Mutant variety	Irradiation dose (kR)	1000 K. weight (differences from check) (g)	Seed length (L)	Seed width (l)	L/l
M 301/87	20 gamma rays	0.9	7.0	3.6	1.94
M 300/87	20 gamma rays	11.0***	7.9	3.9	2.02
M 351/87	30 gamma rays	6.1***	7.8	4.0	1.95
M 358/87	30 gamma rays	-5.8	8.6	3.2	2.68
M 352/87	30 gamma rays	0.7	6.6	3.9	1.69
M 356/87	30 gamma rays	1.3	8.0	3.8	2.10
M 354/87	30 gamma rays	-0.4	7.6	3.6	2.11
M 355/87	30 gamma rays	3.3**	7.2	3.9	1.85
M 357/87	30 gamma rays	2.9**	7.8	3.7	2.10
M 350/87	30 gamma rays	0.7	7.3	3.6	2.02
M 402/87	40 gamma rays	0.9	7.9	3.6	2.19
M 401/87	40 gamma rays	-2.3	7.9	3.9	2.02
M 217/79	25 X rays	2.6	7.8	4.0	1.95
M 218/79	25 X rays	4.2***	7.6	3.6	2.11
M 215/79	25 X rays	8.7***	10.1	3.6	2.80
M 210/79	35 gamma rays	6.7***	8.5	3.6	2.36
M 212/79	35 gamma rays	4.7***	8.5	3.9	2.18
M 220/79	35 gamma rays	0.2	7.8	3.8	2.05
M 219/79	35 gamma rays	4.6***	8.2	3.5	2.34
M 214/79	35 gamma rays	3.5	8.1	3.4	2.38
M 213/79	35 gamma rays	-0.5	8.0	3.6	2.22
M 216/79	40 gamma rays	1.0	8.2	3.9	2.10
M 37 x M 43	gamma rays	5.4***	8.5	3.8	2.24
M 38 (Oltenipa)	35 gamma rays	-1.7	6.3	3.8	1.65
Krasnodar 424 (check)	non-irradiated	28.0	6.8	3.4	2.00

, * - significant for P<0.01 and P<0.001, respectively

Kernel characteristics were also affected by mutations, as significant differences were recorded in seed form and size (Table 6). Deviations of the length / width ratio (as compared to 2.0 in the check variety characterised as a semi-round type) were observed. For instance, the 2.80 ratio of the M 215/70 mutant is very close to that of the varieties belonging to the group with long seeds (>3.0). Furthermore M 352/87 mutant, with a ratio of 1.69 could be included in the group of varieties with round seeds.

As Hag et al., 1973; Bhaqwat et al., 1979 indicated, in many cases, yield increases were accompanied of an increasing of protein content under normal fertilisation conditions. Data from Table 7 show that high variations in 1000 kernel weight and processing productivity (whole seed) were found as compared to the check variety Krasnodar 424. Additionally, protein content increases along with decreases of the starch content were observed, comparatively to the check, in a large number of mutants (M 358/8; $M_3$51/87; $M_3$55/87; etc.)

Short culm heredity

Short culm mutants 52/79 and 352/87 were crossed with the untreated check, Krasnodar 424 (tall plant type).

Table 7. The effect of induced mutations on seed quality

Mutant	Irradiation dose (kR)	Processing efficiency (whole grain)	Content	
			Protein %	Starch %
M 301/87	20 gamma rays	70.0	8.58	78.3
M 300/87	20 gamma rays	71.2	8.75	80.2
M 351/87	30 gamma rays	75.6	9.60	70.6
M 358/87	30 gamma rays	69.5	10.10	70.5
M 352/87	30 gamma rays	73.0	8.60	69.6
M 356/87	30 gamma rays	70.3	8.20	67.5
M 354/87	30 gamma rays	71.4	9.21	62.1
M 355/87	30 gamma rays	77.2	9.65	72.1
M 357/87	30 gamma rays	70.1	9.49	69.9
M 350/87	30 gamma rays	72.0	8.60	69.5
M 402/87	40 gamma rays	70.3	8.11	65.3
M 401/87	40 gamma rays	75.0	8.80	64.4
M 217/79	25 X rays	69.1	9.50	68.3
M 218/79	25 X rays	76.4	9.62	73.6
M 215/79	25 X rays	67.2	9.10	64.8
M 210/79	35 gamma rays	69.7	8.95	69.6
M 212/79	35 gamma rays	72.9	8.10	83.4
M 220/79	35 gamma rays	71.3	8.73	81.3
M 219/79	35 gamma rays	73.5	9.50	79.6
M 214/79	35 gamma rays	72.0	8.32	78.4
M 213/79	35 gamma rays	75.1	9.20	71.2
M 216/79	40 gamma rays	66.6	9.40	67.2
M 37 x M 43	gamma rays	72.0	8.88	79.3
M 38 (Olteniþa)	35 gamma rays	74.0	8.24	76.6
Krasnodar 424 (check)	non-irradiated	70.0	8.62	82.6

Segregation ratio in F_2 generation was of 3: 1 (three high and one short) and F_3 generation offspring was classified into dwarf and high plants. Data confirmed that in the case of 52/79 and 352/87 mutants, short culm was controlled by one single recessive gene.

Conclusion

Treatments with mutagen agents in rice demonstrated the possibilities to obtain short or semi-short culm mutants, resistant to lodging, early and productive.

Irradiation of biological material in rice proved to be an effective method to induce short and early maturity in rice, in doses of 20 - 40 kR, (Krasnodar 424 variety). Gamma rays was the most effective irradiation source in order to produce mutations.

Among the short-culm, early and productive mutants obtained in the first experiments in 1979, the mutant 38/79 was registered as Olteniþa variety in 1991. Some other mutants such as 213/79, 217/79, 214/79, 210/79 (1979 irradiation) and 300/87, 358/87 and 356/87 (1987 irradiation) proved to be superior to the parent variety concerning important agronomic traits and yielding ability.

Positive results were achieved in seed quality, by increasing processing efficiency, protein content and decreasing the starch content (M 38/79, 358/87 etc.).

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Home

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