Development of improved mutants from the traditional medium-grain variety EEA-404

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Interest in short- and medium-grain varieties has increased in Uruguay, where only a reduced area of those cultivars was grown in the past, and the traditional variety EEA-404 has been the most popular of them, obtaining premium prices in special markets. However, EEA-404 has several undesirable agronomic traits and the purpose of this work was to use mutation techniques to reduce its plant height and growth duration.

Seeds were irradiated in 1994 with 250 and 350 Gy. In 1994-95, 1,000 M_1 plants were grown and high sterility was observed. One panicle per plant was collected and 1,000 M_2 headrows were grown in 1995-96. Selection was done based on agronomic traits and the M_3 and M_4 lines were grown in individual rows in 1996-97 and 1997-98. A total of 118 lines were selected and tested in replicated trials in 1998-99.

Radiation treatment induced important variability in plant height, growth duration, pubescence, and grain shape. The parental variety required 100 days to heading and the M_3 lines ranged from 80 to 110 d. Plant height of EEA-404 was 1.22 m and M_3 lines ranged from 0.64 to 1.36 m. Several mutants with improved plant type and good grain quality yielded higher than the parental variety and check cultivars.

Rice is a major crop in Uruguay, where 200,000 ha of irrigated long-grain rice are grown and 90% of the production is exported. Average yield is 6.2 t ha^{-1} and the main long-grain varieties have an indica or japonica background. Only a reduced area of short- or medium-grain cultivars has been grown and local breeding work has focused on developing high-yielding long-grain cultivars with improved grain quality and cold tolerance during the reproductive phase. However, interest in short- and medium-grain varieties, to be exported to special markets, has increased in recent years and a crossing program to develop adapted cultivars with this grain type has begun.

Only an area of medium- or short-grain varieties was grown in the past, and the traditional medium-grain variety EEA-404 has been the most popular of them, obtaining premium prices in special markets. This old Brazilian variety has large and bold grains, with low amylose content and low gelatinization temperature. However, EEA-404 has several undesirable agronomic traits and lower yield potential than improved long-grain cultivars. It is lodging-susceptible (plant height 1.4 m), long-season, and cold-susceptible and its grain and leaves are pubescent. Introduced short-grain cultivars grown in Uruguay, such as Sasanishiki and Koshihikari, have received high scores in sensory tests in Japan, but they have also shown lodging, limited yield potential, and poor adaptation to mechanized harvest (Pérez and Blanco 1995).

Induced mutations in rice have been widely used for semidwarfness and earliness, in many cases without greatly modifying the desirable genetic background of the parental variety (Maluszynski 1998, Rutger 1992, Deus et al 1996, Tisseli Filho et al 1996). The purpose of this work was to use mutation techniques to develop improved mutants from the traditional variety EEA-404. This work is part of the activities conducted under a research contract with the International Atomic Energy Agency (IAEA).

Materials and methods

Seeds were irradiated with Gamma rays at the Centro de Investigación Nuclear (CIN), Montevideo, in 1994, with 250 and 350 Gy. The populations were managed in the following way:

- M_1: 1,000 M_1 plants were grown in 1994-95 and high sterility was observed. One panicle per plant was collected.
- M_2: 1,000 headrows were grown in 1995-96. In general, the population showed severe lodging and 360 panicles from 66 rows were selected, based on agronomic traits.
- M_3: 360 M_3 lines were grown in individual rows in 1996-97 and heading date and plant height were recorded. At harvest, the selected lines were not bulked because some of them still showed some degree of variability. A total of 337 panicles were selected from 115 M_3 lines.
- M_4: 337 M_4 lines were grown in individual rows in 1997-98 and plant height, heading date, grain shape, lodging, leaf angle, and pubescence were recorded. A total of 118 lines with desirable traits were selected for yield and grain quality testing.
- M_5: 118 lines were evaluated in replicated trials in 1998-99.

The 118 M_5 lines were tested in two trials with two replications, with a randomized complete block design, to determine grain yield, milling and cooking quality, plant height, days to heading, lodging, and grain shape. Plots had 6 rows of 3.5 m and 0.20 m between rows. Parental variety EEA-404, short-grain varieties Koshihikari, Sasanishiki, and S-201, and high-yielding long-grain cultivar INIA Tacuarí were used as checks. Experiments 1 and 2 were seeded 28 October and 4 November 1998, re-

spectively. Heavy rains after planting and low temperatures resulted in a nonuniform stand in experiment 1 and only results from experiment 2 are reported here.

Results and discussion

M_3 generation

M_3 lines from parental variety EEA-404 showed high variability in growth duration, plant height, pubescence, and grain shape. The parental variety required 100 d to heading and the M_3 lines ranged from 80 to 110 d. About 34.5% of the M_3 lines required less than 95 d to heading and 44% required from 96 to 100 d (Fig. 1).

Plant height of EEA-404 was 1.22 m and M_3 lines ranged from 0.64 to 1.36 m, 88% of them being shorter than 1.2 m and 28% shorter than 1 m (Fig. 2). Thirty semidwarf M_4 lines were backcrossed to the parental variety to recover the parental grain type and populations can be used for genetic studies of dwarf genes involved. The parental variety EEA-404 is pubescent but several M_3 lines were glabrous. In M_4, 62.5% of the selected lines were glabrous. Glabrous mutants were also obtained in previous work on indica variety BR(IRGA)409, one of them being used as a parent in the cross from which the commercial variety INIA Cuaró was selected (Blanco et al 1997). The M_3 lines also showed variability in grain shape, from medium to short grain type. The parental grain type was difficult to recover and it was probably related to the dose of mutagenic treatment applied (250–350 Gy), which, according to the sterility observed in M_1, was too high for a parental variety.

Field testing of M_5 lines

The mean grain yield of experiment 2 was 6.3 t ha^{-1} and significant differences among cultivars were found for all variables tested (Table 1). Maximum and minimum yields

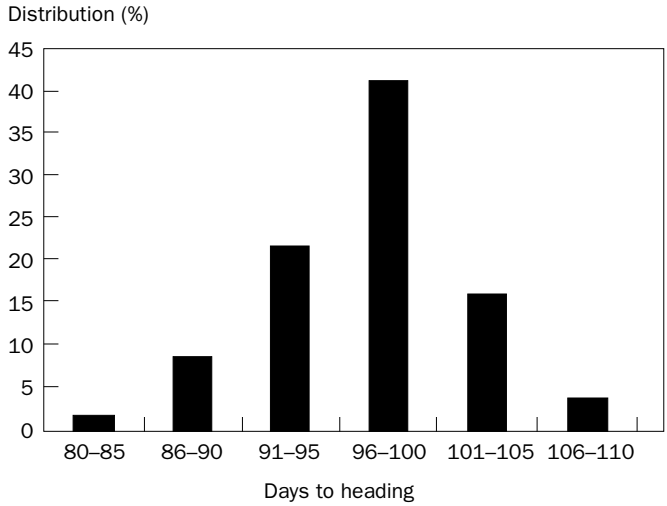

Fig. 1. Days to heading for M_3 lines.

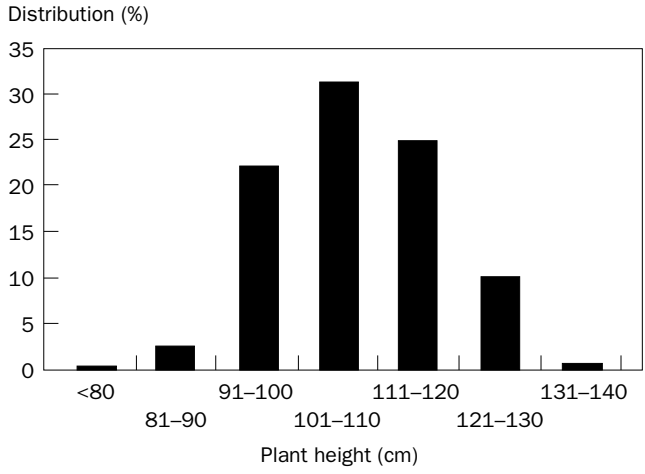

Fig. 2. Plant height of M_3 lines.

Table 1. Mean, range of variation, and statistical analysis of selected variables.

Item[a]	Grain yield (t ha^{-1})	Whole kernels (%)	Chalkiness (%)	Plant height (m)	Heading (d)
Mean	6.3	52.2	8.2	0.98	106
Maximum	8.4	70.4	25.1	1.29	127
Minimum	2.7	23.1	0.5	0.81	92
EEA-404	2.7	61.7	1.7	1.29	108
CV%	11.6	14.1	15.0	5.2	1.2
LSD 0.05	1.46	14.76	4.627	0.109	2.638

[a]CV = coefficient of variation. LSD = least significant difference.

were 8.4 and 2.7 t ha^{-1}, the latter corresponding to the parental variety. This low yield was linked to the high sterility observed in the parental variety as a result of the unusually low temperatures registered during the reproductive phase in the 1998-99 crop season. The long-term yield of EEA-404 was 5.8 t ha^{-1}. The parental variety had a plant height of 1.29 m and 108 d to heading and the mutants ranged from 1.21 to 0.81 m and from 127 to 92 d, respectively, for both variables (Tables 1 and 2). All mutants except one were significantly shorter than the parental variety, but only 17 required less days to heading. There was a strong negative correlation between days to heading and yield ($r^2 = -0.451$, $P = 0.0001$), which may be related to the low temperatures registered in the season as was mentioned above. Some milling variables, such as whole kernel % and chalkiness %, also showed high variability, ranging from 70.4% to 23.1% and from 25.1% to 0.5%, respectively (Table 1).

The mean performance of the best-yielding mutants and check varieties is shown in Table 2. A group of eight mutants had grain yields significantly higher than that of Sasanishiki, which has been the best adapted introduced short-grain variety. The mean yield of those mutants was 34% higher than that of Sasanishiki. The mean plant height of the best-yielding mutants (0.99 m) was average for the experiment, but their mean growth duration (100 d to heading) was 6 d shorter than the overall mean. The amylose content of EEA-404 and Koshihikari was normal, but Sasanishiki and S-201 showed higher values than usual, along with the long-grain check INIA Tacuarí, which may be because of an interaction caused by temperature.

Some of the eight best-yielding mutants showed poor milling yields or high chalkiness, but others combined high yield potential with good milling and grain appearance. The amylose content of those mutants was similar to that of the parental variety, with the exception of one that showed very low amylose (Table 3). Six of them were pubescent and three had grain type similar to that of the parental variety. Weather conditions during maturity and harvest were good and the lodging-suscep-

Table 2. Performance of check varieties and mean of best-yielding mutants.

Cultivar	Grain yield (t ha^{-1})		Whole kernels (%)	Chalkiness (%)	Plant height (m)	Heading (d)	Amylose (%)	Lodging[a]
8 lines > yield[b]	8.1	134	53.6	11.0	0.99	100	18.5	1
EEA-404	2.7	45	61.7	1.7	1.29	108	21.2	3
Koshihikari	6.4	106	59.7	6.2	0.92	98	18.8	4
Sasanishiki	6.0	100	61.5	7.5	0.86	97	23.1	2
S-201	5.7	95	63.2	1.6	0.92	107	23.9	1
INIA Tacuarí	7.1	117	58.1	5.6	0.81	93	28.6	4

[a]Lodging: 1 = no lodging, 9 = all plants lodged. [b]Significantly higher than Sasanishiki.

Table 3. Performance of best-yielding mutants (significantly higher than Sasanishiki) and the parental variety.

No.	Grain yield[a] (t ha^{-1})	Whole kernels (%)	Chalkiness (%)	Plant height (m)	Heading (d)	Amylose (%)	Lodging
56	8.4 +	44.3 –	8.8 +	0.92 –	101 –	21.5	1
42	8.3 +	56.3	11.3 +	1.02 –	101 –	17.6	1
21	8.1 +	59.7	3.4	1.07 –	107	19.2	1
48	8.1 +	51.0	25.1 +	0.94 –	98 –	20.0	1
55	8.1 +	31.2 –	21.2 +	0.84 –	97 –	23.1	1
41	8.0 +	56.4	7.4 +	1.21	92 –	17.6	1
22	7.9 +	64.3	5.6	1.03 –	103 –	20.0	1
36	7.7 +	66.0	5.4	0.94 –	105	9.1	1
EEA-404	2.7 +	61.7	1.7	1.29	108	21.2	3

[a]+ and – signs indicate significant differences with EEA-404.

tible check varieties showed only moderate lodging (3–4 on the 1 to 9 scale, INGER-IRRI 1996), whereas the best mutants showed no lodging at all (1 on the 1 to 9 scale, Tables 2 and 3).

Conclusions

The mutagenic treatment was highly effective in reducing plant height in the parental variety EEA-404, but important variation was also observed in growth duration, pubescence of grain and leaves, milling and cooking quality, and grain shape. Several high-yielding mutants with desirable agronomic traits were selected and will be tested next season in more advanced trials.

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Notes

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Citation: Hill JE, Hardy B, editors. 2002. Second temperate rice conference. Proceedings of the Second Temperate Rice Conference, 13-17 June 1999, Sacramento, California, USA. Los Baños (Philippines): International Rice Research Institute. 714 p.