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PLANT TYPE IMPROVEMENT OF INDIGENOUS RICE CULTIVARS THROUGH INDUCED MUTATIONS

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Abstract

A high yielding, locally adapted cultivar 'Afaa Mwanza 1/159' of rice (*Oryza sativa* L.) which is tall and late in maturity, was irradiated with gamma rays at doses of 170, 210 and 250 Gy to shorten plant height and time of maturity. Twelve mutants were selected, and evaluated for yield performance in field trials from M_6 to M_9 generations. All the mutants were shorter in plant height, and gave higher mean yield than the parent. Correlation coefficient analysis showed that the number of productive tillers, number of panicles per square meter and grain filling in the panicle were important characters which influenced yield. On the other hand, panicle length had negative influence on yield. Cv. 'Supa India' and 'Salama' were also irradiated with doses of 170, 210, 240 Gy gamma rays. Analysis of M_2 populations of these cultivars indicated that mutagenesis created a lot of variation in plant height, maturity, spikelet fertility and panicle length. The induced variation shall be useful in selecting desired plant types.

1. INTRODUCTION

Rice is the staple food for approximately half of the world's population. It is predominantly a food crop in developing countries, which during 1987-89 produced and consumed 95% of the world output of rice, and accounted for nearly 80% of its trade [2]. Rice is an important crop in Tanzania. It has been estimated that about 60% of the population eat some rice [7]. Tanzania is the largest rice producer in Southern Africa Development Community (SADC) region. Yields of rice are disappointingly low in the developing tropical areas where most of the rice is grown. In Tanzania, for example average yield is estimated between 1.5 to 2.1 tons per ha [8] as compared to the average yields of more than 5 t/ha in the temperate countries, such as USA, Japan, Korea and Australia.

Since the inception of the International Rice Research Institute (IRRI) in 1962, it became evident that probably the most important single reason for the low yield of rice in the tropics was that the typical tropical rice plant is tall and leafy [1]. Plants with such characteristics are able to compete reasonably well with weeds, and produce fair grain yields under the prevailing conditions of low-inputs. However, when the modern methods of rice production, such as the use of adequate fertilizer (especially N), the adoption of good weed, insect and water control practices are applied, tropical varieties grow excessively tall, produce long droopy leaves, and tend to lodge. This led the plant breeders at IRRI to develop short-statured, high-yielding plant types with erect leaves, which resulted in a major breakthrough to increase rice yields. The plant breeders were able to shorten the plant from the traditional height of about 180 cm to 100 cm. They made the leaves short and upright, so that the water ran off quickly, and sunlight penetrated the lower leaves.

A major factor limiting rice production in Tanzania is the lack of lodging resistant, nitrogen responsive, high yielding varieties. Farmers still grow traditional varieties which are tall, and prone to lodging, when nitrogen is applied. The popularity of these cultivars lies in their superior grain quality and performance under high risk and poor management conditions. These varieties have long maturation period, and are not suitable in areas with marginal rainfall, since most of the rice grown is rainfed.

Mutagenesis is an effective tool for improving specific characters of existing varieties. Successful use of induced mutations to improve varieties has been reported by many workers [14, 11, 10]. The characters which have been successfully improved are plant height, maturity period and grain characteristics. A large number of short-statured mutants of local varieties have been produced in many countries [9, 15, 16]. Some of the semi-dwarf mutants are allelic and others are non-allelic to the semi-dwarfing gene of 'Deo-geo-woo-gen' (DGWG) [3, 10]. The mutation breeding programme at the Sokoine University of Agriculture (SUA) was aimed at reducing plant height and maturation period of the popular high yielding indigenous cultivars while maintaining the good qualities of the parents.

2. MATERIALS AND METHODS

2.1. 'Afaa Mwanza 1/159'

Dry seeds of cv. 'Afaa Mwanza 1/159' were sent for irradiation to the IAEA Laboratory, Seibersdorf (near Vienna) in 1987. The seeds were irradiated with gamma ray doses of 170, 210 and 250 Gy from a ^{60}CO source. The irradiated seeds and controls were sown in a field in Tanzania. The M_2 was raised from single M_1 plants, and grown as panicle-to-row progenies. Dwarf and semi-dwarf variants were selected among the M_2 population. In the subsequent generations, variants were selected on the basis of plant height, short growth duration and yielding ability. The selected variants were advanced to subsequent generations.

During 1992-1994, twelve mutants from M_6, M_7 and M_8 generations were evaluated for yield in replicated trials at the farm of Sokoine University of Agriculture (SUA), Morogoro, Tanzania. The design used was complete randomized block design with three replications. The plot size was 5 m x 2 m in which the plants were spaced 20 cm x 20 cm. Fertilizer was applied at a rate of 100 kg/ha in three split doses at planting, tillering and panicle initiation. M_9 generation was evaluated using the same design, spacing and cultural management at five sites at Morogoro, Dakawa, Ilonga, Ruvu and Katrin. However, the plot size was 5 m x 3 m.

Various characters, including plant height, days to 50% flowering, panicle length, number of panicles per square meter, 1000-grain weight, grain yield, grain appearance as well as biochemical properties were studied, and data were subjected to analysis of variance, according to the method of Gomez and Gomez [4].

2.2. 'Supa India' and 'Salama' Cultivars

Dry seed of the above cultivars were irradiated with 170, 210, 240 Gy gamma rays from ^{60}CO in Seibersdorf, in May, 1994. The irradiated seed and controls were sown on July 16, 1994 at SUA Crop Museum. The M_1 panicles were harvested, and planted as M_2 panicle-to-row progeny. Data on days to 50% flowering, number of tillers per plant, plant height and spikelet fertility were recorded. The M_2 plants were selected using plant height, early maturity and grain type as the selection criteria, and harvested individually.

3. RESULTS AND DISCUSSION

3.1. 'Afaa Mwanza 1/159'

The performance of the selected mutants for three years at SUA, Morogoro is presented in Tables I and II. The overall mean performance of mutants obtained from irradiation with 170 Gy and 210 Gy was higher than that of the parent for the three years of study. There was a highly significant difference between year and genotype x year interactions. During 1994, yields were higher than the other years. The low yield in 1995 likely resulted from floods when the crop was still at tillering stage.

TABLE I. GRAIN YIELD OF MUTANTS AND THEIR PARENT (SUA, MOROGORO)

Entry No.	Description	Yield (ton/ha) 1993	1994	1995	Mean
1	Afaa Mwanza 210Gy	5.45	6.24	3.44	5.04
2	"	3.74	6.18	2.59	4.17
3	"	2.45	6.36	3.05	3.95
5	"	2.86	6.08	2.22	3.72
6	"	3.15	6.14	2.25	3.85
7	"	2.29	6.09	3.17	3.85
4	Afaa Mwanza 170Gy	4.53	5.32	2.17	4.01
9	"	3.64	5.36	2.45	3.82
12	"	3.73	6.28	1.85	3.95
13	"	3.48	5.16	2.48	3.71
Control	Afaa Mwanza	3.31	4.76	2.56	3.54
CV%		4.6	14.0	16.96	

During all years, plant height of the variants was shorter than that of the parent. The mean plant height of the variants ranged from 86.5 to 95.8 cm, as compared to 140.2 cm of the parent. The mean number of days to 50% flowering were less for the mutants than the parent (Table II). The year 1994 was favourable in terms of rainfall, and the trial was planted early during the rainy season. That may explain the higher yield and taller plant growth 1994 as compared to the other years. In summary, mutagenesis reduced plant height of the parent variety. The results suggest that it was possible to select mutants that combined short culm, earliness, and high yield potential. Reduction in plant height through induced mutations has been reported [11, 15, 10]. A number of semi-dwarf rice mutants have been released in various countries during the past years [3, 12, 13].

TABLE II. PLANT HEIGHT AND DAYS TO 50% FLOWERING OF MUTANTS AND THEIR PARENT (SUA, MOROGORO)

Entry No.	Mutagen/dose	Plant Height 1993	1994	1995	Mean	Days to 50% Flowering 1993	1994	1995	Mean
1	Afaa Mwanza 210Gy	84.7	111.2	84.3	93.7	105	99	88	97
2	"	85.6	113.0	88.9	95.8	118	91	90	100
3	"	85.6	113.0	87.4	95.3	107	93	92	97
5	"	85.6	109.1	87.6	94.1	102	93	80	93
6	"	84.3	96.3	79.0	86.5	111	87	89	96
7	"	82.4	104.9	88.9	92.1	110	94	97	100
4	Afaa Mwanza 170 Gy	80.7	114.9	82.3	92.5	108	86	79	91
9	"	82.4	103.6	82.1	89.4	118	91	86	98
12	"	84.4	115.7	78.9	93.0	99	89	87	92
13	"	82.8	112.2	81.5	92.2	104	90	94	96
Control	Afaa Mwanza	115.2	183.2	122.2	140.2	115	99	96	103
CV%		4.4	5.1	5.3	3.3	2.2	4.4		

The grain yield of M_9 generation at three locations is presented in Table III. There was a highly significant variation for locations and genotype x location interaction. A number of mutants out-yielded the parent variety. Mutant No. 1 was the highest yielder followed by No 12; Mutant No. 6 yielded the lowest.

The correlation coefficient analysis for M_9 at Morogoro is presented in Table IV. Grain yield per plot was positively correlated with the number of effective tillers per plant,

TABLE III. GRAIN YIELD OF MUTANTS AND THEIR PARENT GROWN IN THREE LOCATIONS

Entry No.	Description	Yield (tons/ha) Morogoro	Dakawa	Ilonga	Mean
1	Afaa Mwanza 210Gy	3.44	4.84	3.50	3.93
2	"	2.59	4.23	2.43	3.08
3	"	3.05	4.23	1.86	3.05
5	"	2.22	4.10	3.09	3.14
6	"	2.25	4.40	3.08	3.24
7	"	3.17	3.73	3.02	3.31
4	"	2.18	3.83	3.29	2.77
9	"	2.47	3.63	2.84	2.98
12	"	1.85	4.73	3.26	3.28
13	"	2.48	4.60	2.95	3.34
Control	Afaa Mwanza	2.56	3.77	3.45	3.26
"	Supa India	2.48	2.43	2.53	2.48
Sx		±0.250	±0.333	±0.314	
CV%		16.96	14.54	11.07	

number of panicles per square meter and percentage of filled grains per plant. Grain yield was negatively correlated to panicle length. Number of panicles per unit area has been reported to be positively associated with grain yield in rice [6, 5]. The positive correlation of grain yield and number of panicles per unit area indicates that the improvement of this character in the test population would be effective in increasing yield.

TABLE IV. CORRELATION COEFFICIENT BETWEEN YIELD, YIELD COMPONENTS AND GROWTH PARAMETERS OF M_9 MUTANTS (n = 36) (SUA, MOROGORO)

	No. of tillers/ plants	Days to 50% Fl	No. of panicles /sq. m.	Plant Height	Panicle length	1000-grain wt	% filled grains	Yield/ plot
No. of tillers/plant	1.00							
Days to 50% Fl	0.395	1.00						
No. of panicles/ sq. m.	0.583	0.310	1.00					
Plant Height	-0.235	0.045	-0.281	1.000				
Panicle length	-0.378	-0.250	-0.413	0.662	1000			
1000 grain wt.	-0.582	-0.519	-0.598	0.441	0.612	1.000		
% filled grains	0.270	0.142	-0.078	0.310	0.045	0.092	1.000	
Yield/plot	0.412	0.262	0.403	0.093	-0.432	-0.294	0.296	1.000

Evaluation of grain appearance is present in Table V. Most mutants had medium and long grain, while Mutant No. 13 had extra-long kernels. All the mutants showed some amount of endosperm opacity, except Mutant No. 13, which had translucent grains.

The eating and cooking qualities were determined by amylose content, gel consistency and gelatinization temperature, and aroma. All mutants, except Mutant No. 9 and their parent had intermediate amylose content (Table VI). Variation in gel consistency, gelatinization temperature and aroma was observed. Mutant No. 13, which had extra long grains, translucent endosperm, intermediate amylose content, soft gel consistency and low to intermediate gelatinization temperature, stands a good chance of acceptance by consumers in Tanzania. Mutants Nos. 1 and 2 which had high yield potential (Tables I & II) have acceptable cooking quality but their grains have more opacity.

This study has demonstrated that semi-dwarf mutants, induced with gamma irradiation, combined high yield potential with earliness and acceptable grain quality. Preliminary multi-location trials have identified Mutant No. 1 to be higher yielding than the rest. The average performance of mutants at SUA for three seasons have indicated that Mutant Nos. 1, 2, 3, 4 and 12 have a high yield potential.

TABLE V. PHYSICAL GRAIN CHARACTERISTICS OF RICE GENOTYPES

Radiation dose	Entry No.	Variety	Length (mm)	Size Category	Length/ width	Description	Opacity Chalkiness	Description
170 Gy	4	Afaa Mwanza	7.09	Long	2.53	Medium	< 10	Small
	8	"	6.55	Medium	2.58	Medium	< 10	Small
	9	"	7.00	Long	2.80	Medium	< 10	Small
	10	"	6.58	Medium	2.63	Medium	10-20	Medium
	12	"	7.24	Long	2.60	Medium	> 20	Large
	13	"	7.73	Extra-long	3.00	Medium	no chalkiness	Trans.
210 Gy	1	"	6.27	Medium	2.26	Medium	10-20	Medium
	2	"	6.30	Medium	2.18	Medium	10-20	Medium
	3	"	6.33	Medium	2.22	Medium	> 20	Large
	5	"	6.67	Long	2.50	Medium	> 20	Large
	6	"	6.96	Long	3.03	Slender	< 10	Small
	7	"	6.40	Medium	2.41	Slender	10-20	Medium
Control		Afaa Mwanza	6.83	Long	2.72	Medium	no chalkiness	Trans.
"	Supa India		8.12	Extra Long	3.11	Slender	"	Trans.

TABLE VI. PHYSICO-CHEMICAL CHARACTERISTICS OF SOME RICE GENOTYPES

Radiation dose	Entry No.	Variety	Amylose content		Aroma	Gel		Gelatinization Temp.	
			%	Description		Consistency	Description	Temp.	Description
170 Gy	4	Afaa Mwanza	19.46	Int.	Slight	51.5	Med.	< 69	Low
	8		22.20	Int.	Mod.	50.1	Med.	70-74	Int
	9		19.36	Low	No aroma	90.0	Soft	74-75	H/Int
	10		22.08	Int.	Mod.	50.0	Med.	70-74	Int
	12		22.08	Int	Mod.	83.0	Soft	70-74	Int
	13		21.85	Int	Strong	96.0	Soft	< 69	Low
210 Gy	1		22.91	Int	No aroma	95.0	Soft	< 69	Low
	2		21.85	Int	No aroma	99.0	Soft	70-74	Int
	3		21.64	Int	Slight	99.0	Soft	70-74	Int
	5		22.67	Int	Slight	90.0	Soft	70-74	Int
	6		22.43	Int	Slight	79.0	Med/soft	70-74	Int
	7		23.07	Int	Slight	88.0	Soft	70-74	Int
Control		Afaa Mwanza	22.78	Int	Mod.	45.0	Med.	70-74	Int
		Supa India	23.93	Int	Strong	28.5	Hard	< 69	Low

3.2. 'Supa India' and 'Salama'

Primary panicles of each M_1 plant were harvested individually, and spikelet fertility was determined by dividing the total number of grains by the number of filled grains in a panicle. The results (Tables VII & VIII) indicated that there was a reduction in spikelet fertility of M_1 plants as compared to the control. There were some difference between the two cultivars. Spikelet fertility decreased as dose rate increased, except for cv. 'Supa India' which had a higher mean value with 240 Gy than at the lower doses.

TABLE VII. SPIKELET FERTILITY (%) IN M_1 GENERATION OF CV. 'SUPA INDIA' TREATED WITH GAMMA RAYS - 1994 DRY SEASON

Dose (Gy)	No. of plants	X±SD	Range
170	70	52.83±20.64	10.6 - 84.0
210	50	52.43±16.08	24.2 - 81.2
240	93	55.15±16.70	19.0 - 85.5
Control	34	66.46±16.95	31.3 - 87.6

TABLE VIII. SPIKELET FERTILITY (%) IN M_2 GENERATION OF CV. 'SALAMA' TREATED WITH GAMMA RAYS - 1994 DRY SEASON

Dose (Gy)	No. of Plants	X±SD	Range
170 Gy	79	52.40±24.78	7.4 - 91.8
210 Gy	64	50.92±18.86	13.4 - 88.0
Control	10	58.75±22.35	26.6 - 87.8

In M_2, plant height, days to 50% flowering and panicles length were studied. There was a significant reduction in plant height (Table IX). The reduction in plant height increased with the dose. However, the reduction in the progeny of cv. 'Supa India' treated with 210 Gy was more than with 240 Gy. This could be attributed to Yellow Mottle Virus disease which affected plants from treatment with 210 Gy.

TABLE IX. EFFECT OF MUTAGEN AND DOSE RATE ON PLANT HEIGHT (cm) OF M_2 POPULATIONS

		'Supa India'			'Salama'		
Mutagen	Dose rate	Range	Mean±SD	CV	Range	Mean±SD	CV
Gamma rays	170 Gy	79-113	107.8±12.9	12.0	87-172	141.7±19.9	14.1
"	210 Gy	55-118	88.4±13.9	26.3	86-167	135.2±16.2	11.9
"	240 Gy	80-158	114.1±15.4	16.5			
	Control	120-141	125.0±13.4	10.7	120-170	152.0±12.2	8.4

The number of days to flower were less in the respective control populations than in the treated materials (Table X). However, the wide variation in this trait in the M_2 population indicated that it was possible to select mutants for desired maturity period. Generally, cv. 'Salama' and its mutants flowered earlier than cv. 'Supa India' and its mutants; this could be because cv. 'Salama' is an upland cultivar and has been selected for earliness.

TABLE X. EFFECT OF GAMMA RAY DOSE ON DAYS TO 50% FLOWERING IN M_2 POPULATIONS OF RICE CULTIVARS

Dose rate	cv. 'Supa India'			cv. 'Salama'		
	Range	Mean±SD	CV	Range	Mean±SD	CV
170 Gy	107-131	121±3.0	13.9	81-111	98.2±10.6	10.8
210 Gy	114-131	119±3.1	5.8	88-113	98.6±8.2	8.3
240 Gy	110-139	123±7.4	8.0			
Control	107-123	115±5.1	3.9	80-85	83.0±3.1	13.3

The effect of irradiation on panicle length is shown in Table XI. There was no significant difference between different doses; however, the parents had higher values for this trait than the treated materials, suggesting that mutagenesis generally reduced panicle length. The effect of mutagenesis on spikelet fertility is shown in Table XII. The mean value for this trait was higher in the progeny than the parents. There was a wide variation in spikelet fertility in all treatments. Since spikelet fertility is an important yield component, it would be possible to select desirable mutants in the subsequent generations. This study has indicated that mutagenesis created a wide variation in plant height, maturity, spikelet fertility and panicle length. Therefore, plants with desired characteristics could be selected in the subsequent generations. Pronounced changes in plant height and tillering ability observed in the treated populations suggested that improved plant types are induced by mutagenic treatment.

TABLE XI. EFFECT OF MUTAGEN AND DOSE RATE ON PANICLE LENGTH (cm) OF M_2 POPULATIONS OF RICE CULTIVARS

Mutagen	Dose rate	cv. 'Supa India'			cv. 'Salama'		
		Range	Mean±SD	CV	Range	Mean±SD	CV
Gamma rays	170 Gy	15-34	21.2±3.0	13.9	17-26	22.2±1.8	8.2
"	210 Gy	13-26	20.1±2.9	5.5	17-28	22.8±2.3	10.3
"	240 Gy	14-29	22.8±2.6	2.8			
	Control	19-29	23.6±2.6	19.7	18-30	23.0±1.7	2.0

TABLE XII. EFFECT OF MUTAGEN AND DOSE RATE ON SPIKELET FERTILITY OF M_2 POPULATIONS

Mutagen	Dose rate	'Supa India'			'Salama'		
		Range	Mean±SD	CV	Range	Mean±SD	CV
Gamma rays	170Gy	7.7 - 48.6	22.7±11.2	49.6	5.9 - 61.5	30.3±12.5	41.5
"	210Gy	15.4 - 43.6	25.3±7.9	31.5	12.0 - 64.2	29.2±13.2	45.4
"	240Gy	9.1 - 43.4	21.5±7.1	32.9			
	Control	3.8 - 24.2	15.4±6.2	40.1	11.1 - 45.6	27.6±9.5	34.3

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