Performance of Early Maturing Mutants Derived from "Supa" Rice (*Oryza sativa L.*) cultivar

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Abstract

Supa rice (Oryza sativa L.) cultivar which is very popular in Tanzania was sent for irradiation at the Seibersdorf Laboratory, Vienna, Austria in 1994. The dry seeds were irradiated with gamma rays using three doses (170, 210 and 240Gy) from Cobalt 60 (^{60}CO) in order shorten the plant height and maturity period. From the resulting mutant populations originating from modified single seed descent method, five very early maturing lines plus the original cultivar were evaluated in replicated trials at two sites (SUA and Dakawa) in 1999. The trial was laid in a Randomised Complete Block Design replicated three times. The data generated include plants height, days to 50% flowering, panicle length, number of productive tillers per plant, 1000 grain weight, percent filled grains per panicle and grain yield. The mutants and the parent were also screened for grain quality characteristics. The data collected were subjected to the Analysis of Variance and correlation analysis using MSTAT-C. Path coefficient analysis was also performed to determine the cause - effect relationship. The analysis of variance revealed that there were significant differences between the mutants and their parent for all the characters tested except 1000 grains weight and panicle weight. The mutants flowered up to 24 days earlier than the parent. Further analysis revealed that grain yield was positively correlated with percent filled grains per panicle. Days to 50% flowering and 1000 grain weight exerted negative direct effect on yield. Changes in grain quality were also observed emphasizing the importance of conducting cooking and taste panel tests.

Key words: Early maturity, grain quality, rice mutants, *Oryza sativa*, path coefficient

Introduction

Rice (*Oryza sativa* L.) is a staple food in many countries of Africa and constitutes a major part of the diet in many others (Oteng and Sant' Anna, 1999). In sub–Saharan Africa it is estimated that the cultivated area is 6.8 million hectares (Jones, 1999).

Tanzania, the second largest rice producer after Malagasy (IRRI, 1994) produces about 800,000 tons of rice from an estimated area of 548,100 hectares (Ministry of Agriculture and Co-operative, 1989). The average yield estimated at 1.5-2.0 tons per hectare is far below the average for Africa which is estimated at 2.1 tons/ha. The average yield in Africa is 49 percent below the world average (3.4 tons/ha) (Oteng and Sant' Anna, 1999). In Tanzania, most of rice (74%) is grown by small -scale farmers under rainfed lowland conditions. Upland rice comprises about 20% and irrigated rice constitutes about 6% of the total area under rice (Kanyeka *et al.*, 1994).

Major constraints that limit rice production in Tanzania have been summarized by Monyo and Kanyeka, (1978), Kihupi and Pillai (1989). These include poor weed management, pests and diseases, lack of improved varieties with acceptable grain quality, inadequate fertilizer and soil amendments, inadequate soil and water management and unavailability of inputs. Farmers still grow specifically adapted local varieties many of which are photoperiod – sensitive, late maturing, tall and weak–statured.

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Mutagenesis, or induced mutation, is an effective tool for improving specific characters of existing cultivars, specifically plant height, maturity and certain grain characteristics such as grain appearance, protein and amylose content (Mikaelsen *et al.*, 1971, Mahadevappa *et al.*, 1983, Maluszynski *et al.*, 1986, Gangelharan & Misra, 1975). Successful use of mutagenesis has been reported in earlier rice improvement programmes (Mahedevappa *et al.*, 1983, Singh and Sinha, 1986). There are examples in rice breeding where induced mutants have not only been released directly as improved cultivars but have been used specifically as donor parents in standard breeding programmes (Maluszynski *et al.*, 1986).

Mutagenesis was employed in the rice breeding programme at the Sokoine University of Agriculture in order to reduce the plant height and maturation period of the popular indigenous cultivars while maintaining the good qualities of the parents. The present study was undertaken to evaluate the performance of five early maturing mutants which are resistant to Rice Yellow Mottle Virus.

Materials and Methods

Dry seeds of "supa" cultivar were irradiated with 170, 210 and 240 Gray (Gy) gamma rays from cobalt 60 (^{60}C0) at the International Atomic Energy Agency (IAEA) Seibersdorf Laboratory, near Vienna, Austria in May, 1994. The irradiated seeds and control were sown in July, 1994 at the Sokoine University of Agriculture Crop Museum field.

The M_1 primary panicles were harvested, panicle fertility determined and M_2 seeds planted as M_2 panicle – to – progeny rows. About 70 panicles were selected per dose (treatment). The M_2 plants were selected using Single Seed-Descent (SSD) method whereby, one seed was randomly selected from M_2 plant to raise the M_3 generation. In 1995, the M_4 plants were selected individually, and their seeds were planted as progeny rows. The M_4 generation consisted of 39 progeny rows of which 7 came from 170 Gy treatment, 18 from 210 Gy treatment and 14 from 240 Gy treatment. The selected lines were screened for rice mottle virus (RYMV) disease.

From M_4 lines, five early maturing lines, which were also found to be resistant to RYMV disease, were selected and evaluated in observation nursery in 1997. These early maturing line were subsequently advanced to M_6 generation in 1998.

In 1999, the five early maturing, RYMV resistant lines plus the original cultivar (parent) were grown in replicated trials at two sites; SUA and Dakawa Agro-Scientific Research Centre. The Design used was Randomised Complete Block Design with three replications. The plot size was 3m x 2m in which the plants were spaced at 20cm x 20cm. Urea fertilizer was applied at a rate of 100kg N/ha in three split applications; at planting, tillering and panicle initiation stages. Phosphorus in the form of Triple Super Phosphate was applied at 50kg P_2O_5/ha at planting time.

Data collected included plant height, days to 50% flowering, panicle length, number of productive tillers per plant, 1000 grain weight, percent filled grains per panicle and grain yield. All the data were collected in accordance with Gomez (1972). The data were subjected to the analysis of variance using MSTAT C (Michigan State University, 1990). From the data collected, simple correlation analysis was performed. To partition the direct and indirect effects, path coefficient analysis was carried out following the method outlined by Wright (1921) and adopted by Dewey and Lu (1959).

Apart from Agronomic data, grain quality analysis was done to determine the grain appearance, cooking and eating quality according to procedures outlined by Jennings *et al.*, 1978. The parameters which were measured included grain length, shape, gelatinization temperature, amylose content, gel consistency and aroma.

Results

From the pooled data of the two sites, all the characters except panicle length, panicle weight and grain weight showed significant differences (Table 1). Days to 50% flowering of the mutants were reduced to between 22 – 24 days as compared to the parent. All the mutants except mutant SSD 35 significantly out yielded the parent. The highest yielding mutant being SSD 3 which yielded a mean of 5296 kg/ha for the two locations.

Table 1: Agronomic Characteristics of Supa Mutants and their parent (Mean of 2 locations)

Parent/ Mutant	Treat-ment	Yield (kg/ha)	Days to 50% Flow	Plant Height (cm)	No. of Pani-cles/Sq.m	Panicle length (cm)	Panicle weight (g)	1000 grain wt (g)	% filled grains/ panicles
SSD1	170Gy	4816^{b}	71^{bc}	118.3^{a}	160.7	21.9^{c}	4.3	32.9	82.2^{ab}
SSD3	170Gy	5296^{a}	72^{b}	122.0^{ab}	167.2	23.9^{ab}	4.6	32.5	81.2^{ab}
SSD5	170Gy	4655^{b}	72^{bc}	120.0^{b}	163.7	23.9^{ab}	4.4	31.9	79.7^{b}
SDD7	170Gy	3799^{b}	72^{bc}	121.1^{ab}	168.3	23.7^{ab}	4.7	31.9	83.4^{ab}
SSD 35	170Gy	2956^{c}	70^{c}	120.0^{b}	146.5	24.9^{a}	4.7	34.7	84.5^{a}
Supa	Control	2935^{d}	94^{a}	122.1^{a}	184.3	23.5^{bc}	4.1	32.1	71.2^{c}
Mean		4556	75	120.6	165.1	23.5	4.4	32.7	80.4
Sx (+/-)		150	0.53	12.77	9.97	0.54	0.17	0.4	1.23
CV (%)		8.43	1.73	5.63	14.8	5.62	3.1	3.1	3.76

Means followed by the same letter are not significantly different by Duncans Multiple range test ($P \leq 0.05$)

Table 2 summarizes the mean square estimates of the selected characters for the two locations. The genotype mean square was very highly significant for the traits days to 50% flowering, 1000 grain weight, number of filled grains per panicle and grain yield/plot. The location mean square was significant for most of the characters except panicle length, 1000 grain weight, percent filled grains and grain yield/plot. The interaction due to genotype and environment was significant only for panicle length, panicle weight, percent filled grains and grain yield per plot, while G X E was non – significant for the rest of the characters.

Simple correlation coefficient analysis revealed that grain yield was positively correlated with percent filled grains per panicle and negatively correlated with days to 50% flowering (Table 3). The other correlations with

Table2: Estimates of Mean Square values of various characters

Character	Genotype (G)	Location (L)	GXL	Error
Days to 50% Flowering	504.8***	58.78***	2.75^{ns}	33.78
Plant Height	12.35^{ns}	7148.70***	44.39^{ns}	46.18
No. of tiller/plant	4.49^{ns}	30.25*	4.18^{ns}	1.92
No. of panicles/sq.m	902.78^{ns}	9344.44**	1122.78^{ns}	597.21
Panicle length	5.95*	4.99^{ns}	9.58**	1.75
Panicle weight	0.39^{ns}	13.44**X	0.90**	0.17
1000 grain weight	6.66***	0.87^{ns}	1.558^{ns}	0.98
No. of filled grains/panicle	1675.87^{ns}	1099002.78***	1838.13^{s}	3601.2
% filled grains/panicle	139.57***	85.25^{ns}	160.28***	9.119
Grain Yield/Plot	1546010.51***	233611.1^{ns}	404120.81***	48399.88

ns=not significant

*=significant ($P < 0.05$)

**=significant ($P < 0.01$)

***=significant ($P < 0.001$)

Table 3: Simple correlation coefficients of various characters of the mutants and the parent (n = 36)

	Days to 50% Flowing (DF)	Plant Height (PH)	No. of productive tillers/plant (PT)	Panicle length (PL)	Panicle weight (PW)	1000 grain wt (GW)	% Filled grains (FG)	Grain Yield/ Plant (GY)
DF	1.000							
PH	0.198	1.000						
PT	0.064	-0.402**	1.000					
PL	-0.134	0.282	-0.181	1.000				
PW	-0.099	0.768**	-0.384**	0.479**	1.000			
GW	-0.194	0.084	-0.215	-0.014	0.140	1.000		
FG	0.633**	-0.319**	-0.175	0.114	-0.077	0.040	1.000	
GY	-0.658**	-0.146	0.157	0.142	0.016	-0.223	0.398**	1.00

**=Significant ($P \leq 0.01$)

Very highly significant correlation was observed between panicle weight and plant height (r = 0.768). However, number of productive tillers/plant and plant height was negatively correlated. Other interesting correlations were between percent filled grains per panicle and days to 50% flowering (r = 0.633) and between percent filled grains and plant height (r = 0.319). Similarly, number of productive tillers was negatively correlated with plant height (r = 0.402) yield were not significant though positive (No. of productive tillers / plant, panicle length and panicle weight) and negative for plant height and 1000 grain weight.

On partitioning the correlation coefficient analysis, it was revealed that days to 50% flowering and 1000 grain weight exerted negative direct influence on yield, while percent filled grains per panicle exerted positive effect on yield (Table 4).

Table 4: Path coefficient showing Direct (Bold) and Indirect effects of various traits on yield

	Days to 50% Flowing (DF)	Plant Height (PH)	No. of Productive tillers/plant (PT)	Panicle length (PL)	Panicle weight (PW)	1000 grains (GW)	% Filled grains/panicle (FG)
DF	**-0.780**	0.032	0.011	-0.008	0.007	0.077	0.024
PH	-0.154	**0.163**	-0.066	0.016	-0.056	-0.033	0.012
PT	-0.050	-0.066	**0.165**	-0.010	0.028	0.085	0.007
PL	0.105	0.046	-0.030	**0.057**	-0.035	0.006	-0.044
PW	0.077	0.125	-0.063	0.027	**-0.073**	-0.055	0.003
GW	0.151	0.014	-0.035	-0.001	-0.010	**-0.395**	-0.002
FG	0.494	-0.054	0.025	0.006	0.006	-0.016	**0.398**

Residual effects ('P')=0.610.

The grain quality of the tested genotypes is presented in Table 5. Grain quality of the parent was affected to some extent by mutagenesis as exhibited by the parameters evaluated. The hull colour of the mutants was the same as the parent except for SSD 35, which was brown. The grain length of SSD 35 was the highest (8.4mm) followed by Supa (8.0 mm). The other mutants ranged from 6.7-7.8 mm long. The grain shape of most mutants was medium while SSD 35 was slender. Mutant SSD1 and Supa exhibited translucent grains while the other mutants showed some degree of chalkiness.

For amylose content, which determines the cooking and eating quality of rice, mutant SSD 3 and SSD 7 exhibited low amylose content while SSD 5, SSD 35 and Supa had intermediate amylose content. SSD 1 exhibited high amylose content (Table 5). Gel consistency of all the genotypes was soft (>50). None of the mutant was asaromatic as the parent Supa, however, SSD 3, SSD 5 and SSD 7 exhibited slight aroma.

Table 5: Grain Quality Characteristics of Supa Mutants and their parent

Parent/ Mutant	Hull colour	Kernel length (cm)	Length/ width	Shape	Opacity (% chalkiness)	Gelatinization temp.	Amylose content (%)	Gel Consistency	Aroma
SSD1	Gold	7.8	2.97	Medium	Trans.	High	29.5	Med.	None
SSD3	Gold	6.8	2.44	Medium	10%	High	18.3	Soft	Slight
SSD5	Gold	6.7	2.35	Medium	10%	High	22.1	Soft	Slight
SDD7	Gold	7.3	2.88	Medium	10%	High	14.7	Soft	Slight
SSD 35	Brown	8.4	3.10	Slender	10%	Int.	22.7	Soft	None
Supa	Gold	8.0	2.87	Medium	Trans.	Low	25.8	Soft	Aromatic

Trans =Translucent
Int. = Intermediate

Discussion

The use of mutation techniques in crop improvement has been well recognized in many crops. Rice breeders worldwide made good use of this technology to generate variation and produce some of the leading rice varieties (Maluszynski *et al.*, 1986). Some of these varieties have been direct descendants of the induced mutants, while many were developed by crossing the selected mutants with the established rice varieties.

From the data presented, it is clear that mutagenensis reduced the maturity period of the original cultivar for up to 24 days. This is a significant improvement on this trait. Wang (1991) also reported that one of the prominent mutant varieties of rice in china, Yuan feng Zao, was developed through gamma irradiation and this variety matures approximately 45 days earlier than the parent variety IR8 and still has a high yield potential.

Short duration varieties (105-115 days) are excellent for input economy. Because they grow rapidly during the vegetative phase, they are thus more competitive with weeds, weed control costs are reduced and they utilize less irrigation water, thus lowering the production costs (Khush, 1995). The five mutants evaluated in this study are of short duration (105 days), since it takes 30 days from flowering to maturity. These mutants will be useful in drought prone rainfed lowland areas which have short, monomodal rainfall pattern or in areas with bimodal rainfall pattern where two crops can be grown.

With regards to G x E interaction, the variation due to this component was important for panicle length, panicle weight, percent filled grain per panicle and grain yield. The results thus indicated that for the characters with significant G x E interaction, performance of the genotypes will vary with locations. Thus selection for the said traits should be done in a particular location where the varieties will be recommended for release.

The dependence of grain yield on other agronomic traits has been reported for many crops (Robinson *et al.*, 1951), Johnson *et al.*, 1955, Gravois and McNew 1993. In the present study, yield was significantly positively correlated with percent filled grain per panicle and negatively with days to 50% flowering and 1000 grain weight. Negative correlation between yield and days to 50% flowering was also reported in earlier study (Luzi-Kihupi, 1998). Panicle weight was positively correlated with plant height and panicle length. This indicated that tall plants tend to have larger and longer panicles.

Partioning of correlations into direct and indirect effects revealed that percent filled grains per panicle is an important character in increasing yield, since it had the highest direct effect on yield. Positive direct effect of percent filled grains/panicle have been reported by other workers (Gravois and Helms, 1992, Saini & Gagneja, 1975). Days to 50% flowering has negative correlation with yield and also exerted strong negative direct effect on yield. Negative effect of days to maturity on yield can be explained by the fact that short duration plants (less than 100 days) grown under normal field conditions usually does not permit the production of sufficient leaf area to result in the production of a large number of panicles with well filled grains. Thus the longer the growth period of a variety, the greater is the total plant weight (De Datta, 1981). The percent filled grains per panicle had significant positive correlation with yield and positive direct effect. This trait can be a useful criterion to use when selecting for yield during the early generations.

In Tanzania, most consumers prefer long or medium long and slender grains. Cooking quality is determined largely by the amylose content and gelatinization temperature of the rice starch. Consumers in Tanzania prefer varieties with intermediate amylose content and intermediate gelatinization temperature, which cook moist and fluffy. The mutants which were evaluated in this study had low gelatinization temperature and low to high amylose content. Mutants SSD 5 and SSD 35 stand a good chance of being accepted by the consumers. These lines which have intermediate amylose content and soft gel consistence are likely to cook moist and fluffy and therefore have good cooking qualities.

Conclusion

From the data presented it can be concluded that mutagenesis reduced the maturity period of cultivar 'Supa" by up to 24 days. The mutant lines exhibited higher yield potential and disease resistance than the original variety. However, the grain quality of most of the mutants was changed as compared to the parent. Further evaluation especially in terms of cooking and taste panel tests is required before any of the mutants can be recommended for release as a new variety.

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