Variation and Inter-relationship Between Yield and Some Agronomic Characters in Induced Rice (*Oryza sativa* L.) mutants

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Abstract

A high yielding, locally adapted cultivar "Salama" of rice (Oryza sativa L.) which was recommended for cultivation in Tanzania since 1978 was irradiated with gamma rays using two doses (170 & 210 grays) from Cobalt 60 (^{60}C0) in order to shorten the plant height. Twenty three mutant lines in M_5 and M_6 generations plus two controls were sown in a Randomised complete Block Design (RCBD) and replicated three times at the Sokoine University of Agriculture (SUA) farm in Morogoro, Tanzania. The objective of the study was to estimate genetic parameters and the association of various traits with yield. The combined analysis over two years was used to estimate genetic variances, heritability and expected genetic gain from selection. The data generated were also used to perform correlation and path coefficient analysis. Analysis of variance revealed significant differences among the tested genotypes for all the characters tested. Significant Genotype X Year interactions were observed for all the characters except number of tillers per plant and 1000 grain weight. High genotype coefficient of variation, heritability estimates and expected genetic advance were recorded for plant height, number of tillers per plant and 1000 grain weight. Correlation and path coefficient analysis revealed that days to 50% flowering and number of panicles per square metre were important characters that influenced yield.

Key words: Agronomic characters, mutants, *Oryza sativa*, rice varietal improvement, yield.

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereals in the world. It is one of the major field crops in sub-Saharan Africa with an estimated cultivated area of about 6.8 million hectares (Jones, 1999). In East, Central and Southern Africa (ECSA) region, Tanzania is the second largest producer after Malagasy (IRRI, 1994).

There is a considerable potential for increasing grain yield and expanding the area under rice in Tanzania. Annual rice production is about 800,000 tons from an estimated total area of 548,000 tons (Ministry of Agriculture & Cooperation, 1998). The average yield is estimated at 1.5 - 2.0 ton per hectare.

Rice breeders in Tanzania have been using various breeding methods such as introduction and selection, hybridization and mutation breeding to develop improved rice varieties (Monyo & Kanyeka, 1978, Luzi-Kihupi, 1998). The introduction of modern semi dwarf varieties has not been successful in Tanzania due to poor grain quality of these varieties as compared to the local varieties. Farmers still grow locally adapted varieties, many of which are photoperiod - sensitive, late maturing, tall and weak -statured (Kanyeka *et al.*, 1994, Kihupi *et al.*, 1996). These traditional cultivars, however, have superior grain quality though they perform poorly under high input management.

The need to have a wide range of genotypes to select from, together with the hope of introducing one or two desired genes to our traditional cultivars without drastically changing

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their grain quality, prompted utilization of induced mutation breeding to complement the conventional breeding. The aim of the rice breeding programme at the Sokoine University of Agriculture is to develop varieties that perform better than farmers' traditional cultivars. The developed varieties should combine good plant type and acceptable grain quality. Mutagenesis is an effective tool for improving specific characters of the existing cultivars particularly plant height, maturity and grain characteristics. Successful use of mutations has been reported in several rice improvement programmes (Mahadevappa *et al.*, 1983, Mikaelsen, 1980, Rutger, 1983 and Rutger *et al.*, 1986).

This present study was undertaken to determine the genetic parameters for yield and its components and to assess genetic x environment interaction of selected characters in rice mutants. These mutants were derived from irradiating "*Salama*" variety with gamma rays in 1994 with the aim of reducing its plant height and maturation period. The study also aimed at estimating the direct and indirect contribution of various components towards yield. The results obtained may be useful in planning a more efficient breeding programme (Grevois and McNew, 1993).

Materials and Methods

Dry seeds of '*Salama*' cultivar were irradiated with 170 and 210 Gray (gy) gamma rays from cobalt 60 (^{60}CO) gamma source at the International Atomic Energy Agency (IAEA) Seibersdorf Laboratory, near Vienna, Austria in May, 1994. The irradiated seeds and control were sown in July 16, 1994 at the Sokoine University of Agriculture (SUA) Crop Museum. The M_1, primary panicles were harvested, and panicle fertility determined and M_2 seeds planted as M_2 panicle - to - row progenies. About 70 panicles were selected per dose (treatment). The M_2 plants were selected using plant height, early maturity and grain types as the selection criteria, and harvested individually. About 80 plants were selected per treatment and advanced to M_3 and subsequently to M_4 pedigree nurseries.

In 1998 and 1999, twenty three M_5 and M_6 lines, respectively were sown in replicated trials at SUA. These lines plus two control varieties including the original variety "*Salama*" were sown under upland conditions using a Randomised Complete Block Design with three replications. The plot size used was 2m x 2m in which the plants were spaced at 20cm x 20cm. Nitrogen fertilizer was applied in the form of urea at the rate of 100kg N/ha in three split applications; at planting, tillering and panicle initiation stages. Phosphorus was applied at planting at the rate of 50kg P_2O_5/ha. Data collected included plant height, days to 50% flowering, panicle length, number of panicles per square metre, 1000 grain weight and grain yield per plot. All the data were collected in accordance with Gomez (1972). The data collected were subjected to the analysis of variance using MSTATC computer package (Michigan State University, 1990). From the combined analysis of variance table of individual traits, estimates of error phenotypic, genotypic and genotype x environment variances for different characters were computed following the procedure described by Johnson *et al.*, (1955) and Kaul (1973).

Genotypic and phenotypic coefficient of variations were estimated by the formula adopted by Kaul and Garg (1979), that is dividing the square root of the genotypic and phenotypic variance respectively by the population mean and multiplying by 100. Heritability estimates in the broad sense (Line basis) for various traits were calculated by using the formula proposed by Hanson *et al.*, (1956). Expected genetic advance was estimated by the formula given by Johnson *et al.*, (1975).

From the data collected, simple correlation analysis was performed using MSTAT C (Michigan State University, 1990). Partitioning of direct and indirect effects was carried out using path coefficient analysis as outlined by Dewey and Lu (1959).

Results

There were highly significant differences among the genotypes for all the characters tested In both years non-significant difference were observed for days to 50% flowering, panicle length and 1000 grain weight. With the exception of number of tillers per plant and 1000 grain weight, all the other characters showed highly significant genotype X years interactions.

Table 1: Estimates of Error mean squares from ANOVA table

	Error Mean Square			
Character	Genotype	Year	GxY	Error
Yield (kg/ha)	285203.92	3381282.31***	9865.286***	33005.906
Plant Height (cm)	2154.298***	2449.75**	130.406***	23.318
Days to 50% Flow	155.69***	173.603^{ns}	15.449***	2.442
No.of Tillers/plant	3.66**	139.105***	0.98^{ns}	0.588
No.of Panicle/Sq.m	1205.36***	65644.815***	412.54***	284.725
Panicle Legth (cm)	6.435***	0.477^{ns}	3.00***	1.277
1000 grain wt. (G)	66.609***	0.05^{ns}	5.742^{ns}	4.112

*** $P< 0.001$

ns =Non significant

Table 2: Variance Components of various traits

Chacter	δ^2g	δ^2gy	δ^2e	δ^2ph
Grain yield	31189.1	21686.46	164908.67	47780.3
Plant Height	337.3	35.70	38.65	355.79
Days to 50% Flowering	23.37	4.40	2.12	25.60
No.of Tillers/plant	0.45	0.13	2.23	0.55
No.of Panicles/Sq.m	48.80	209.27	1066.23	171.21
Panicle length	0.57	0.57	0	0.86
1000 grain weight	10.14	0.54	0	10.41

δ^2g = genetypic variance
δ^2gy = genotype x year variance
δ^2e = Error variance
δ^2ph = phenotypic variance

The estimates of variance components are given in Table 2. Genotypic variances were observed to be higher than variances due to Genotype X year interactions except for days to 50% flowering and number of panicles per square metre (Table 2).

The estimates of genetic coefficient of variation, expected genetic advance, broad sense heritability are presented in Table 3. The genotypic and phenotypic coefficient of variations were numerically higher for the plant height and 1000 grain weight, while the reverse was observed for number of tillers per plant and number of panicles per plant (Table 3). The two variations were almost similar for all the remaining traits. Heritability estimates were higher for 1000 grain weight (97.4%) and lowest for number of panicles per square metre (28.5%). Plant height, number of tillers per plant and 1000 grain weight had high expected genetic advance while panicle length exhibited the lowest value (Table 3).

Table 3: Genotypic Phenotypic coeffient of variation, Heritability and Expected genetic advance (EGA)

Character	Mean	Genontypic Coeff. Var.	Phanotypic Coeff. var.	H^2 (%)	EGA (of Mean)
Grain yield	4293	4.11	5.09	65.30	6.85
Plant Height	119.3	15.39	15.84	94.48	30.88
Days to 50% Flowering	96	5.04	5.48	91.29	9.91
No.of Tillers/plant	7	9.58	11.21	81.50	17.82
No.of Panicles/Sq.m	133	5.25	9.84	28.50	5.78
Panicle length	23.2	3.26	3.99	66.28	5.46
1000 grain weight	27.2	11.58	11.73	97.4	23.80

Analysis of correlation coefficient revealed that grain yield was positively correlated with days to 50% flowering, number of panicles per square metre, number of tillers per plant and panicle length. A negative correlation was observed between yield and 1000 grain weight. Highly signif icant positive correlation was recorded between number of tillers per plant and number of panicles per square metre and between plant height and 1000 grain weight. Days to 50% flowering was negatively correlated with 1000 grain yield (Table 4). Days to 50% flowering and number of panicles per square metre exhibited high direct effect on yield (Table 5). Although all the other characters had positive direct effect on yield, their magnitude was low.

Table 4: Simple correction coefficients of some rice parameters (Pooled data of 2 years)

	Days to 50% low	Plant height	No.of tillers/plant	Panicles/ sq.m	Panicle length	1000 grain wt	Grain yield
Days to 50%	1.000						
Flowering Plant Height	-0.468**	1.000					
No.of	0.350**	-0.080	1.000				
Tillers/Plant/Panicles	0.505**	-0.113	0.660**	1.000			
Sq.Metre Panicle Length	0.247	0.145	-.094	0.149	1.000		
1000 Grain weight	-0.598	0.603	-0.244	-0.324**	0.105	1.000	
Grain Yield	0.527	-0.104	0.418**	0.551**	0.236	-0.253*	1.000

**:P< 0.01
*:P<0.05

Table 5: Path conefficients showing direct and indirect effects of various traits on grain yield

	Days to 50% flow	Plant height	No.of Tillers/plant	Panicles/ sq.m	Panicle length	1000 grain wt
Days to 50% Flow	0.387	-0.039	0.031	0.157	0.017	-0.026
Plant Height	-0.181	0.083	-0.007	-0.035	0.101	0.026
No.of Tillers/Plant	0.135	-0.007	0.088	-0.205	0.006	-0.010
No.Panicles/Sq.M	0.195	-0.009	0.058	0.310	0.010	-0.014
Panicle Length	0.096	0.012	0.008	0.046	0.069	0.005
1000 grain wt	-0.231	0.050	-0.021	-0.100	0.007	0.043

Residual effects = 0.769

Discussion

Genetic variability in rice can be generated by either hybridization or mutation. The use of induced mutations in rice improvement has been reported by many workers (Maluszynski *et al.*, 1986).

The results from this study revealed the presence of considerable variability in all the characters studied. This indicated that mutagenesis created a lot of useful variation from which selection could be effected. Induced variation on native rice were also reported by Rutger *et al.*, (1976); Mikaelsen (1980) and Rutger (1983). Year differences were not significant for days to 50% flowering, panicle length and 1000 grain weight which showed that these characters will not change much in different years and are relatively stable.

The total genetic variance estimates were higher than their respective environmental variance for characters; plant height, days to 50% flowering, panicle lengths and 1000 grain weight, while the reverse was true for grain yield, number of tillers per plant and number of panicles per square metre. This showed that considerable genetic variability was available in the tested lines for improvement of the crop in the traits with higher genetic variability than those with low genetic variability. Conversely, the high G x Y interaction variance for grain yield and number of panicles per square metre indicated that for these traits estimates would vary from year/season to another. This underscores the importance of evaluating the breeding lines for more than one season or year. Panicle length and 1000 grains weight showed no environmental effects. The latter also showed non-significant G x Y interaction, indicating that 1000 grain weight of rice does not change in various environment. Grain weight of rice has high heritability estimate and is usually fixed early in the breeding programme.

The genotypic coefficient of variation was numerically very low indicating that the range of genetic variability existent in the traits was relatively low. However, the estimates of heritability which determines the heritable portion of variation was highest for the traits 1000 grain weight and plant height and lowest for number of panicles per square metre. A Similar trend was obtained by Kihupi and Doto (1989). From the result it is evident that plant height, 1000 grain weight and days to 50% flowering are highly heritable characters. These traits also had high expected genetic advance indicating that these traits could be improved upon through selection.

Yield is a complex character involving several related characters. Plant breeders have recognised the importance of the association of these components and yield and their implication in designing and evaluating a breeding programme. In this study, yield was positively correlated with days to 50% flowering, number of panicles per square metre, while it was negatively correlated with 1000 grain weight. A significant positive correlation between rice yield and number of panicles per square metre was also obtained by Sarathe *et al.*, (1969) and Luzi-Kihupi (1998).

Days to 50% flowering, number of tillers per plant and number of panicles per square metre were found to have positive influences on yield. Although the number of panicles per square metre had direct effect on yield, it exhibited low heritability estimate compare to the other two traits. Therefore, this trait can not be effectively used as a selection criterion for yield.

Days to 50% flowering, plant height, number of tillers per plant and 1000 grain weight which exhibited high genotypic coefficient of variation and high heritability estimates could offer scope for selection and genetic progress should be expected. However, number of tillers per plant and 1000 grain weight which showed non significant G x Y interactions should be given more weight in selection for yield in earlier generations. Attention should be given to the negative correlation between these two characters if simultaneous selection of the two traits is desired in order to increase grain yield.

Conclusion

Through mutation breeding, it was possible to generate heritable variation by irradiating an upland rice variety "Salama". Significant genotype x year interactions were observed for all the traits studies except number of tillers per plant and 1000 grain weight, plant height and days to 50% flowering. Number of tillers per plant and 1000 grains weight were found to be highly heritable characters. However, number of tillers per plant and 1000 grain weight could be useful as selection criteria in earlier generation since these characters are not affected by year differences and have high heritability estimates.

Acknowledgements

The author sincerely thanks the International Atomic Energy Agency (IAEA) for financial support. The help of the field staff of the Rice breeding project in the Department of Crop Science and Production is highly acknowledged.

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