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Variations in agronomic characteristics of irrigated rice varieties: Lessons from participatory trials in South Eastern Tanzania

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Abstract

The agronomic characteristics of thirteen improved rice varieties were compared with farmers' own varieties, in two villages of South-Eastern Tanzania. The aim was to provide farmers with new varieties and to try out the idea of shortening the process of releasing new varieties. The variation between the varieties could be reduced to three principal component axes (PCA) representing 83% of the original variation in the first village and 76% in the second village. These PCA correspond to structural plant characteristics, grain characteristics and yield. The differences in structural characteristics and grain characteristics were statistically significant, while this was not the case for the differences in yield. Nevertheless, farmers were quick at selecting varieties with many tillers and high grain qualities. If the conventional procedure for releasing varieties would have been followed, it is unlikely that breeders would have retained these varieties.Making varieties, or promising lines, available to farmers at an early stage not only shortens the release process but also ensures that farmers get varieties suiting their needs.

Key words: Rice, variety release, agronomic characteristics, participatory trials

Introduction

Rice (*Oryza sativa* L.) is one of Tanzania's most popular staple foods, regularly consumed by 60% of the population[1]. Tanzania ranks second after Madagascar as a major rice producer in Eastern and Southern Africa. According to Kanyeka et al.[2], about 90% of the crop in Tanzania is cultivated on smallholdings of 0.5 to 2.0 ha, with average yields ranging between 1.5 and 2.1 t ha^{-1}. It is estimated that in 1998, rice was grown on over 655,000 ha with a production of 849,100 tons[3]. In South-Eastern Tanzania[4], rice ranks third in importance for food security after maize (*Zea mays* L.) and cassava (*Manihot esculenta* Crantz). It is also an important local source of income for some farmers; though cashew nut (*Anacardium occidentale* L.) and sesame (*Sesamum indicum* L.) are the main cash crops. Farmers prefer varieties with long and slender, translucent and aromatic grains. These are tall, photoperiod sensitive, late maturing (up to 6 months) and low yielding (average yield approximately 1.5 t ha^{-1}). Farmers usually plant rice at the end of December or early January. As most farmers grow long duration varieties, harvesting begins at the end of May and continues to the end of June, thus coinciding with the commencement of the dry season. When farmers can irrigate, they may transplant as late as March. As these varieties are influenced by day length, delayed planting results in shorter season with no change in harvest date but results in yield reduction[5]. As in many other countries, the current variety release system in Tanzania requires that varieties are tested on station for not less than three seasons. Thereafter, promising varieties are tested on-farm. From on-station testing to the release of a variety takes more than six cropping seasons. This long process hampers the availability of new improved rice varieties.

Farmers' participation in the selection of varieties at an earlier stage could shorten the process. This approach has been adopted in other parts of the world, as it was realized that low-resource farmers were not benefiting from centralized plant breeding programmes[6]. The practical aim of the study was to provide farmers with new improved varieties and to try out the idea of shortening the procedure of releasing varieties by testing them in a participatory way. In the course of this, we assessed the agronomic performance of both new and farmers' varieties in farmers' fields. This led to a better understanding of the agronomic characteristics, which matter to farmers of South-Eastern Tanzania.

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Materials and Methods

The study was conducted in two villages, selected to represent two typical valley systems of South-Eastern Tanzania. Annual average rainfall ranges from 810 to 1090 mm; rainfall is uni-modal with a dry season from the end of May to mid December. Temperature ranges from 21.7 to 30.5°C. Kitere, the first village is located at 10°20'28" South and 39°41'33" East in Mtwara region. The valley has a seasonal stream and soils are predominantly Vertisols[7]. Farmers use water from an artesian well to irrigate. In this village the study was conducted during two rainy seasons and two dry seasons (2000-2001). Kinyope, the second village, is located at 9°58'57" South and 39°23'50" East in Lindi region. The valley has a perennial stream and soils are predominantly Fluvisols[8]. Farmers make small dams to divert water from the river for supplementary irrigation rice during the rainy season. Here, the study was conducted during three rainy seasons (2000-2002).

Experimental design: Eight cultivars (Agulha, Kihogo Red Selection No. 7, Naro fupi, Subarimati, Supa Utafiti, Rangimbili, TXD-85, TXD-88) and five lines (TXD-213, TXD-220, TXD-275, TXD-282, TXD-299, TXD-306) were provided by the Rice Research Institutes of Dakawa and Ifakara in Tanzania. Except for Agulha originating from Mozambique and Subarimati from India, all the materials were developed in Tanzania. These had been bred for the characteristics of early to medium maturity, long translu-

cent aromatic grains and potential for high yielding. In Kitere, the new materials and three farmers' varieties (Dakawa, Tunduru and Supa Kitere) were tested in the wet season in plots of 4 x 4 m gross and 3.2 x 3.2 m net. Eight out of the thirteen new materials which are not photoperiod sensitive namely Subarimati, TXD-306, TXD-88, TXD-220, TXD-282, TXD-213, TXD-299 and Naro Fupi were compared with farmers' variety Dakawa during the dry season in plots of 3.8 x 3.6 m gross and 3.0 x 2.8 m net. In Kinyope, the new materials and one farmers' variety (Supa Kinyope) were tested in plots of 4.3 x 2.7 m gross and 3.5 x1.9 m net. The trials were laid out in a Complete Randomised Block Design with three replications.

Trial management: Four weeks old seedlings were transplanted in bunded and puddled fields. A spacing of 20 cm between rows and 20 cm between hills to reflect farmers' practice was used. Two seedlings per hill were transplanted. In Kitere, Triple Super Phosphate was applied prior to transplanting at a rate of 65 kg P_2O_5 ha^{-1}. Nitrogen (urea) was broadcast at a rate of 60 kg N ha^{-1} in two splits; at maximum tillering and at panicle initiation stages. Fertilisers were not applied in Kinyope as farmers do not use them. The trials were irrigated, weeded and birds were kept away. Harvesting was done when plant straws and leaves were changing from greenish to orange by cutting the panicles from the net area of each plot separately. Also, straws from the net area of each plot were harvested separately, tied in a bundle and left in the field to dry and measured.

Data collection: The total number of tillers, number of panicles, panicle length, plant height, grain yield, weight of dry straws and dry panicles were determined per plot. Grain samples were taken to determine their grain weight, grain width and length. The harvest index is calculated as grain yield divided by the total of straw weight and grain yield. All field observations were made with the involvement of the collaborating farmers. After the first season, farmers were allowed to choose varieties to test in their own fields.

Data analysis: Variation of the agronomic characteristics between the varieties was analysed with principal component analysis, with VARIMAX rotation, using SPSS[9]. This was done on the average values of each of the characteristics and on the data of the two villages separately. The varieties Dakawa and Tunduru - from Kitere - were disregarded such that the results from the two villages would be comparable. Pearson correlation coefficients were calculated between the principal components extracted from these two data sets, to check whether they represent the same underlying source of variation. Differences between varieties were checked with multivariate analysis of variance, with the Duncan post hoc test, using SPSS.

Results

The variation in the agronomic characteristics of the varieties in Kitere can be reduced to three principal component axes (PCA), representing 83% of the original variation. The first PCA represents characteristics of the plant structure, such as number of tillers, number of panicles, panicle length and plant height; the second PCA is characterised by the grain shape (Fig 1a). The third PCA is characterised by yield and grain weight, though these two are negatively correlated. The varieties can be grouped accordingly, for example. Subarimati and TXD-306 have many panicles and many tillers, while Kihogo and Supa Utafiti have few; similarly it can be seen that Agulha and Supa Utafiti have longer grains, while TXD-88 and TXD-220 have shorter grains (Fig 1a). In Fig 1b it can also be seen that TXD-282 and TXD-299 have relatively high yields, while Rangimbili and TXD-220 have relatively low yields.

From the data set of Kinyope, the first three PCA represents 76% of the original variation. The first PCA is determined by yield and number of panicles, and negatively correlated to this, by grain weight and grain length/width ratio (Fig 1c). This PCA is well correlated with the third PCA of Kitere ($R = 0.75$; $P < 0.01$). The second PCA from Kinyope represents characteristics of the plant structure, similarly as the first PCA of Kitere ($R = 0.87$; $P < 0.01$). The third PCA of Kinyope is mainly determined by the number of tillers and width of the grains (Fig 1d). It is only weakly correlated with the third PCA of Kitere ($R = 0.59$; $P = 0.06$). The average values on the agronomic characteristics and the F-test of the effects of the varieties are presented in Table 1. In both villages differences between varieties were only significant for "structural characteristics" or "grain characteristics". No significant differences between the varieties were detected in terms of yield. Although overall average yields is slightly higher in Kitere than in Kinyope, this difference is statistically not significant ($F = 1.2$; $P = 0.28$). The differences in number of tillers, between the two villages, are statistically significant ($F = 17.1$; $P < 0.001$). In line with the observations made from the PCA, the Duncan post hoc test allows to distinguish between the varieties in terms of number of tillers and grain length (Table 2a and 2b).

Discussion

Although from the principal component analysis, the varieties come out as quite distinct, no statistically significant differences can be made in-terms of yield. Significant differences are only found for characteristics related to plant structure and grain shape. The lack of significant differences in yield between varieties may be due to a narrow genetic base of the tested material. It could also be due to the fact that the trials were conducted under farmers' conditions, with low levels of inputs. With higher levels of inputs, differences possibly could be more pronounced. The higher variability in yields from Kinyope is reflected in its high score for yield on the first PCA and could be due to higher variability in soils and water availability. The negative correlation found between total yield and grain weight may seem counter intuitive. However, if the number of seeds per plant makes is genetically predetermined, it may be that plants producing more seeds could have a total higher yield but would invest less in each individual seed, resulting in a lower weight per seed. Despite the fact that no significant differences were found in terms of yield between the varieties, farmers were quick at selecting and adopting some of the varieties. Farmers in Kitere as well as in Kinyope liked TXD-220 because of its high milling qualities. Farmers of Kitere also liked TXD-306 because they claim that high number of tillers leads to higher yields; moreover its long grains give it a high market value. Although the principal component analysis indicates that yield is only weakly correlated with the number of tillers, it is conceivable that varieties with more tillers are less sensitive to weeds and pests. These two varieties are also appreciated for their

Table 1. Average values of the agronomic characteristics and F-tests of the effect of 16 varieties in Kitere village and 14 varieties in Kinyope village.

	Kitere			Kinyope		
Agronomic characteristics	**Mean**	**F**	**Sig.**	**Mean**	**F**	**Sig.**
Yield (kg ha^{-1})	3246	0.54	ns*	3081	0.40	ns
No of tillers per hill	9.3	4.02	<0.001	6.5	2.78	0.01
No of panicles per hill	7.4	3.45	<0.001	5.0	1.99	ns
Productive tillers (%)	79	1.15	ns	92	1.25	ns
Panicle length (cm)	22	1.49	ns	21	2.66	0.01
Plant height (cm)	108	11.71	<0.001	115	5.95	<0.001
Harvest Index	44	0.74	ns	45	5.34	<0.001
Grain weight (g/1000 seeds)	30	8.68	<0.001	31	12.01	<0.001
Grain length (mm)	9.5	9.02	<0.001	9.5	1.88	ns
Grain width (mm)	2.0	1.08	ns	2.0	0.57	ns
Grain length/width ratio	4.8	3.18	<0.001	4.7	0.55	ns

*ns = not significant ($P > 0.05$)

Table 2a Average number of tillers and grain length of 16 varieties in Kitere village

Variety	n	No of Tillers		Grain length (mm)	
Tunduru	3	7.4	a*	10.5	f
Rangimbili	3	7.4	a	10.6	f
Supa Utafiti	3	7.5	a	10.4	ef
Kihogo	3	7.7	ab	9.4	ab
TXD-213	6	7.8	ab	9.4	ab
TXD-299	6	8.3	abc	9.2	ab
Supa Kitere	3	8.5	abc	9.6	abc
TXD-220	6	8.9	abc	9.7	abcd
Agulha	3	9.0	abc	10.1	def
Naro Fupi	6	9.4	abc	9.3	ab
TXD-88	6	10.0	abc	9.2	a
TXD-282	6	10.2	bcd	9.5	ab
TXD-85	3	10.5	cd	10.0	cde
Dakawa	6	10.5	cd	9.5	abc
Subarimati	6	10.7	cd	9.7	bcd
TXD-306	6	12.3	d	10.0	cde

* different letters indicate significant differences between varieties ($P < 0.05$)

Table 2b Average number of tillers and grain length of 14 varieties in Kinyope village

Variety	n	No of Tillers		Grain length (mm)	
Supa Utafiti	3	4.6	a*	10.0	c
TXD-213	3	5.7	ab	9.1	a
Rangimbili	3	5.9	abc	9.8	bc
Supa Kinyope	3	6.2	abc	9.4	abd
Kihogo	3	6.2	abc	9.2	ab
TXD-220	3	6.4	abc	9.2	ab
Naro Fupi	3	6.5	abc	9.3	ab
TXD-88	3	6.5	abc	9.1	a
Agulha	3	6.5	abc	9.3	abc
TXD-299	3	7.2	bcd	9.1	a
TXD-85	3	7.3	bcd	9.6	abc
TXD-282	3	7.3	bcd	9.6	abc
Subarimati	3	8.2	cd	9.2	ab
TXD-306	3	9.4	d	9.4	abc

* different letters indicate significant differences between varieties ($P < 0.05$)

short duration to mature which makes them suitable for growing in the dry season. If the selection had been done without the participation of farmers, researchers might have disregarded these varieties, as they tend to give more importance to yield. Maurya et al.[10], working on rice in India and Sperling et al.[11], working on beans in Rwanda made similar observations.

Conclusions

This study has shown that varieties which breeders deemed ready for testing on-farm do not perform better than the local varieties, under farmers' conditions in South Eastern Tanzania. Nevertheless, the varieties differed in terms of plant structure and grain characteristics. Farmers appreciated these differences and were quick at selecting varieties either with many tillers or with good milling and grain qualities. If the conventional procedure of releasing varieties would be adhered to, chances are slim that breeders would have retained these varieties. Making varieties, or promising lines, available to farmers at an earlier stage would shorten the release process and farmers would be more likely to get varieties suiting their needs.

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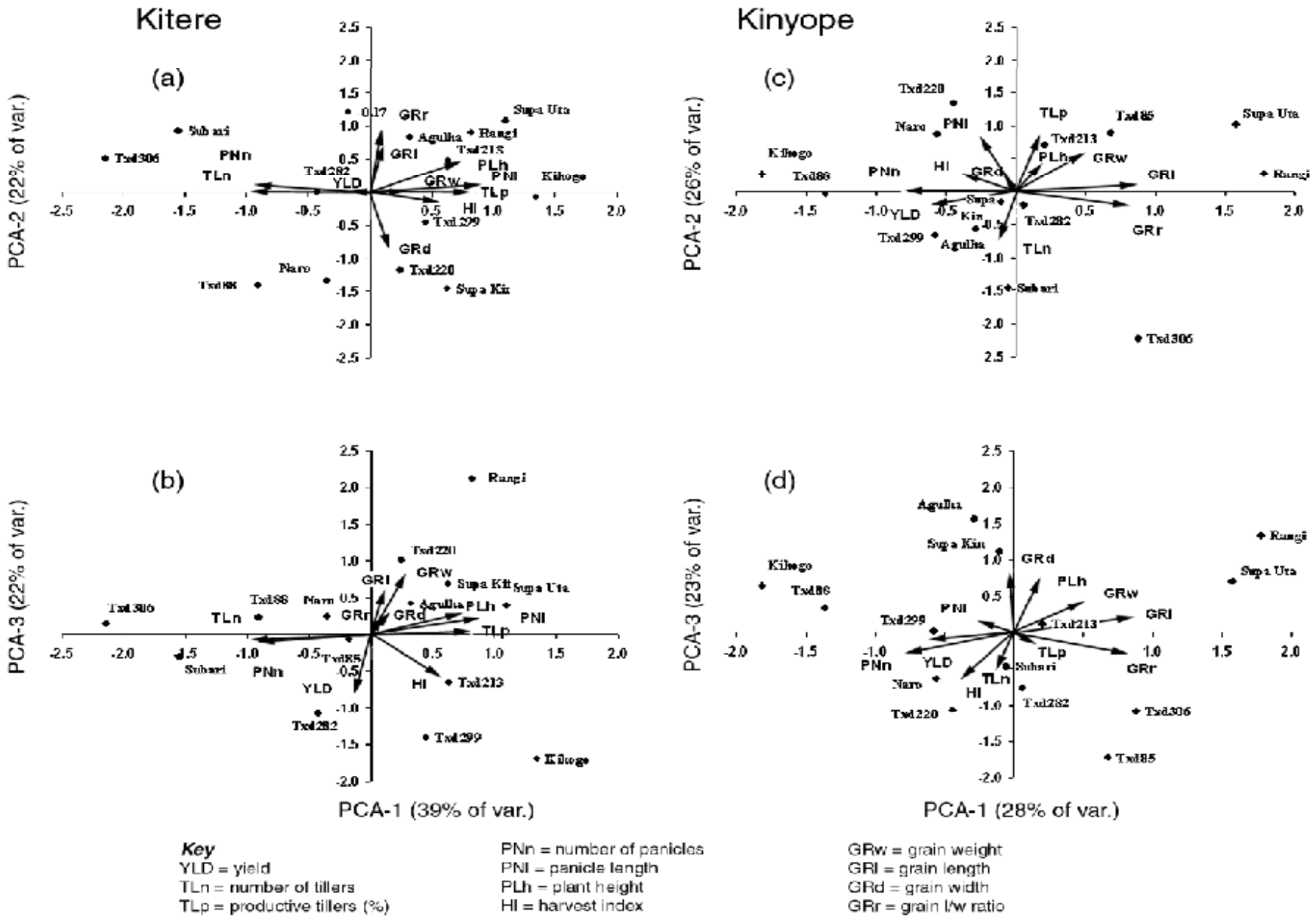

Figure 1 Bi-plots of agronomic characteristics of 14 rice varieties in two villages of South Eastern Tanzania. The vectors are the characteristics; the dots are the varieties.

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