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SHORT COMMUNICATION

Genetic variability and yield performance evaluation of upland rice cultivars under agro-ecological conditions of Morogoro region, Tanzania

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ABSTRACT

This study evaluated genetic variability and yield performance of six upland rice cultivars (NERICA 01, 02, 04, 07, SARO 5, and WAB) under Morogoro's agro-ecological conditions in Tanzania. A randomized complete block design with three replications was used on plots measuring 2 m^2. Data collected included plant height, tiller number, panicle length, grain yield, and days to 50% flowering. Analysis of variance (ANOVA) was performed using GENSTAT software, and means were compared with Tukey-Kramer tests at $P \leq 0.05$. NERICA 7 showed the highest grain yield (2.4 kg/2 m^2) and tallest plants, while SARO 5 had the greatest tiller number but failed to flower. Early flowering NERICA 02 suits short rainfall areas but has a moderate yield. Grain yield positively correlated with panicle length and tillering capacity, key traits for breeding. The findings guide the selection of well-adapted upland rice genotypes to improve productivity and food security in Tanzanian rain-fed systems.

Keywords: genetic variability; grain yield; phenotypic traits; rice production; upland rice

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food crop for millions of people in sub-Saharan Africa, including Tanzania, where it serves as both a food security crop and a key source of income. In Tanzania, upland rice accounts for approximately 20% of the total rice production, particularly in areas where irrigation infrastructure is limited and rainfall is the primary water source (URT, 2021). The growing demand for rice, coupled with unreliable access to irrigated water, has led to increased interest among smallholder farmers in upland rice cultivation systems.

The introduction of New Rice for Africa (NERICA), a group of interspecific hybrids developed by crossing African rice (*Oryza glaberrima*) with Asian rice (*Oryza sativa*), represents a major breakthrough in enhancing upland rice production. NERICA varieties are designed to combine high yield potential with drought tolerance, early maturity, and better weed competitiveness—traits crucial for resource-constrained farmers (Saito et al., 2018). Their adaptability to upland environments has made them increasingly attractive to Tanzanian farmers, especially in regions such as Morogoro, where rainfall patterns support seasonal cultivation but water for irrigation remains scarce.

Despite the potential of NERICA varieties, the availability of site-specific agronomic information remains limited. Many farmers and extension officers lack adequate knowledge on best practices for upland rice production, including variety selection, soil fertility management, and weed control strategies (Mabaya et al., 2017). Furthermore, while NERICA have shown promising results in some parts of Africa, its performance varies significantly across different agro-ecological zones. Local evaluation is therefore essential to identify the most suitable varieties and management practices for specific environments such as Morogoro (Kebede et al., 2021; Issa et al., 2019).

Recent studies have also emphasized the importance of integrating local knowledge with improved agronomic practices to maximize the productivity of upland rice systems (Mabaya et al., 2017; Mwangi et al., 2020). Factors such as low soil fertility, poor seed quality, pest and disease pressure, and inadequate technical support continue to constrain upland rice performance in many parts of Africa (Meliyo et al., 2018; FAO, 2020). Thus, assessing the growth and yield performance of upland rice under specific local conditions is essential to inform policy, research, and extension services.

MATERIALS AND METHODS

Experimental site

A field experiment on upland rice variety performance was conducted at the Crop Museum of Sokoine University of Agriculture (SUA), located in Morogoro Region, eastern Tanzania. The site lies approximately 200 meters northwest of the Department of Crop Science and Horticulture. Geographically, the area is situated at an altitude of 525 meters above sea level, with coordinates at latitude 6° 52′ S and longitude 37° 35′ E. The region experiences a semi-humid tropical climate characterized by a bimodal rainfall pattern, with the long rainy season occurring from March to May and the short rains from October to December. The mean annual rainfall ranges between 600 mm and 1000 mm, while the average annual temperature fluctuates between 20°C and 30°C, supporting a wide range of rainfed agricultural activities (URT, 2021; Kimaro et al., 2019). The soil at the experimental site is predominantly sandy loam in texture, classified under the Oxisol soil order, locally referred to as Ferralsols. These soils are typically well-drained but inherently low in fertility due to high weathering and leaching, with moderately acidic pH values averaging around 5.16 (Msanya et al., 2020).

Experimental Plots Preparations

The experimental field was prepared through conventional tillage, beginning with tractor-based primary operations to ensure proper land leveling and soil breakdown. This was followed by secondary tillage using hand hoes and rakes to achieve a fine seedbed suitable for upland rice establishment. Planting was done manually, placing one seed per hill at a depth of 2.5 to 5 cm, in line with upland rice agronomic practices. Each upland rice cultivar was sown in well-defined plots arranged according to the experimental design. Di-Ammonium Phosphate (DAP) fertilizer was applied at planting through spot application to promote early root development and vigorous seedling growth. Post-planting management included manual irrigation using watering cans during dry periods, and regular weed control through hand weeding to reduce competition. Pest control measures were implemented to protect the rice seedlings from early-stage insect damage. Although pest pressure was generally low, appropriate chemical control measures were applied as needed to ensure uniform growth conditions across cultivars.

Experimental Design and Treatment Application

The experiment involved six upland rice cultivars as treatments: T1 = Saro 5, T2 = NERICA 1, T3 = NERICA 2, T4 = NERICA 4, T5 = NERICA 7, and T6 = WAB. The study was laid out in a Randomized Complete Block Design

(RCBD) with three replications to minimize field variability, following the procedure described by Gomez and Gomez (1984). Each experimental plot measured 6 m^2 (2 m × 3 m), and the total experimental area was 232.5 m^2 (15.5 m × 15 m). A plant spacing of 20 cm × 20 cm was used to establish optimal density for upland rice under rain-fed conditions. Each plot contained five rows with fifteen plants per row, totaling 75 plants per plot. The six treatments were randomly assigned within each replication using calculator-generated random numbers, ensuring unbiased distribution. This layout facilitated reliable comparison of varietal performance under uniform agronomic conditions typical of upland rice systems.

Data collection

The following data were collected: Number of tillers, plant Height, panicle length, days to 50% flowering and grain Yield.

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) to evaluate the significance of differences among treatments, following standard procedures by Gomez and Gomez (1984) and Kothari (2004). The analysis was conducted using GENSTAT Fourteenth Edition (VSN International, 2008). The key agronomic and yield-related variables analyzed included plant height, number of tillers per plant, days to 50% flowering, panicle length, number of grains per panicle, 1000-grain weight, and grain yield per plot. Where significant differences were detected, treatment means were separated using the Tukey – Kramer Multiple Comparison Test at a 5% probability level ($P < 0.05$) to determine statistically meaningful variations among the upland rice cultivars.

RESULTS AND DISCUSSION

Highly significant differences among upland rice genotypes for all evaluated traits demonstrated the presence of substantial genetic variability likely attributable to the diverse genetic origins of the material (local landraces, NERICA lines, and introduced cultivars). Such extensive variability aligns with similar findings in upland rice germplasm, where high genetic diversity was observed for traits like tiller number, panicle length, grain yield, and days to flowering attributes essential for harnessing selection gains (Akinola et al., 2019; Divya et al., 2018).

Considerable variation existed in plant height among genotypes both before and during flowering. NERICA 7 (112.8 cm) and WAB (108.1 cm) exhibited the tallest statures, while SARO 5 was notably shorter (68.9 cm). Taller plants can sometimes be disadvantageous due to lodging risk, but moderate stature in upland systems can favor drought avoidance in some environments (Fischer, 2022). Plant height showed a moderate-to-high heritability in rice, indicating that breeding efforts targeting ideal plant architecture could lead to effective improvements (Divya et al., 2018) on the number of tillers; SARO 5 produced the highest number of tillers (27.9) both before and after flowering, while WAB recorded the fewest. High tillering capacity correlates strongly with panicle number and eventual grain yield, as confirmed by several recent studies (Akinola et al., 2019; Kumar, 2020). However, extreme tillering without proportional panicle development may not always translate into yield gains, as unproductive tillers can divert resources. Notably, genetic correlations often show that fewer tillers are associated with heavier grains and better panicle filling in upland conditions.

Panicle length variation in panicle length reflected known genetic differences, with NERICA lines generally longer than SARO 5. Panicle length is strongly linked to grain yield because longer panicles can produce more spikelets (Akinola et al., 2019). Across rice germplasm, panicle length consistently shows high genotypic and phenotypic variability, making it a valuable trait for selection (Divya et al., 2018) There was significant variation in days to 50% flowering across genotypes ($P \leq 0.05$), with NERICA 02 being the earliest (63 days) and WAB the latest (88 days); SARO 5 did not flower under study conditions. Early-flowering cultivars like NERICA 02 are advantageous for drought escape, particularly in zones with truncated rainy seasons (Akinola et al., 2019; Ethiopian upland study, 2023). However, early maturity may restrict biomass accumulation and grain filling, leading to moderate yield levels (up to 2.4 t/ha in this study). Late-flowering cultivars can benefit from full-season moisture but are more vulnerable to terminal drought (Gebre, 2023; Massawe, 2020).

Grain yield is the ultimate agronomic trait reflecting the combined effects of genetic potential and environmental interactions. In this study, the grain yield per 2 m^2 plot varied significantly among upland rice cultivars, with NERICA 7 exhibiting the highest yield (2.4 kg/2 m^2), followed by NERICA 1 and NERICA 4, while

SARO 5 failed to produce any grain yield under the tested conditions. The superior yield of NERICA 7 is likely attributed to its optimal combination of agronomic traits such as moderate plant height, effective tillering, and longer panicle length, which collectively enhance photosynthate allocation to grain development. This is consistent with recent studies showing that grain yield in upland rice is strongly influenced by panicle characteristics and tiller productivity (Akinola et al., 2019; Divya et al., 2018). Moreover, other upland rice research indicates that longer panicles generally produce a higher number of spikelets and ultimately more grains per panicle (Rahayu et al., 2021; Nguyen et al., 2019; Santoso, 2020). Grain filling efficiency and panicle fertility are also crucial for achieving higher yields, as noted by Dao et al. (2020), who reported that improved sink capacity through panicle traits leads to better grain filling in rain-fed rice systems.

The low yield observed in SARO 5 suggests that some genotypes may not adapt well to specific upland agro-ecological conditions, possibly due to delayed or absent flowering and susceptibility to abiotic stresses like drought (Massawe, 2020). Early flowering cultivars, such as NERICA 02, although yielding moderately, have the advantage of escaping terminal drought through a shorter growth cycle (Girma et al., 2022). However, this often comes at the expense of lower biomass and grain yield compared to longer-duration varieties. Overall, the significant variability in grain yield observed underscores the importance of selecting cultivars with balanced phenotypic traits that optimize both yield potential and adaptation to upland rain-fed environments. This approach is critical to improving food security and livelihood in regions like Morogoro.

Table 1. Agronomic performance of upland rice cultivars under Morogoro conditions

Rice cultivars	Height length (cm)	Panicle length (cm)	Tillers number	Yield (kg)/2m^2	Days - 50% Flowering
NERICA01	96.07^b	24.35^b	14.27^a	1.700^e	85^b
NERICA02	112.87^c	25.19^b	12.20^a	1.500^c	63^c
SARO 05	68.89^a	0.00^a	27.87^b	0.000^a	0.00^a
NERICA07	93.47^b	25.43^b	13.67^a	2.400^f	78^b
NERICA04	94.15^b	24.80^b	13.00^a	1.600^d	75^b
WAB	108.13^c	24.88^b	11.73^a	1.300^b	88^b
Grand mean	95.6	20.77	15.46	1.4167	0.2nN
CV (%)	1.9	4.8	10.6	5.9	0.200
LSD	11.54	2.636	3.273	0.07427	0.0542
P-value (5%)	<.001	<.001	<.001	<.001	<.001

Note: Values with the same letter are not significantly different at $p \leq 0.05$ (Tukey–Kramer Multiple Comparison Test), while values with different letters indicate significant differences.

CONCLUSION

This study revealed significant genotypic differences among the six upland rice cultivars evaluated, indicating substantial genetic variability for key agronomic traits including plant height, number of tillers, panicle length, grain yield, and days to 50% flowering. NERICA 7 and WAB recorded the tallest plant heights, while SARO 5 showed superior tillering capacity but failed to flower under field conditions. NERICA 02 demonstrated early flowering and moderate yield, making it a suitable candidate for regions with short and erratic rainfall. Grain yield was highest in NERICA 7, which also exhibited favorable panicle traits. The variability observed highlights the potential for selecting high-performing genotypes suited to the agro-ecological conditions of Morogoro. These results underscore the relevance of trait-based selection in upland rice improvement for rain-fed systems in Tanzania. Based on the findings, NERICA 7 is recommended as a promising variety for upland rice cultivation in Morogoro due to its high yield potential, balanced maturity period, and desirable agronomic traits. NERICA 02 is also recommended for environments with shorter rainy seasons because of its early maturity, which could help avoid terminal drought. Breeding programs should focus on crossing genotypes with complementary traits, such as combining SARO 5's high tillering ability with NERICA 7's grain yield and panicle characteristics. Further multi-season and multi-location trials are encouraged to validate genotype stability across different ecological zones. Extension services should prioritize training farmers on the most promising varieties and their management practices to enhance adoption and productivity in upland rice systems.

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AUTHORS CONTRIBUTIONS

Patrick Cleophace Mpombeye was responsible for conceptualization, methodology, data collection, formal analysis, writing the original draft, and coordinating the manuscript. Andrea Malima Kigeso provided field supervision, technical expertise on rice production, validation of findings, and reviewed and edited the manuscript. Mayunga Sylvester Ezekiel handled data curation, statistical analysis, visualization, and contributed to manuscript review and editing. Susan Nchimbi Msolla provided supervision, guidance on study design, critically revised the manuscript for important intellectual content. All authors have read and approved the final manuscript.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

ETHICAL APPROVAL

This research was conducted in accordance with institutional, national, and international ethical standards. All experimental procedures involving field trials were reviewed and approved by the Department of Crop Science and Horticulture, Sokoine University of Agriculture. The study involved no human or animal subjects. Before fieldwork, informed verbal consent was obtained from all participating farmers and farm managers for access to the fields and for conducting intercrop trials. The study did not involve the collection of any personal data or sensitive information. All data collected was anonymized and used solely for academic and scientific purposes.

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Funding was not involved in this study.

AVAILABILITY OF DATA AND MATERIALS

All datasets analyzed and described during the present study are available from the corresponding author upon reasonable request.

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