

Screening of rice genotype and evaluation of their ratooning ability in Jigawa State, Nigeria

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Abstract

This study evaluated the genetic variability and ratooning ability of ten Nigerian rice genotypes under the Sudan Savanna conditions of Jigawa State, Nigeria. The experiment assessed performance differences between the main and ratoon crops using key agronomic and yield traits. High genotypic and phenotypic coefficients of variation (GCV and PCV) were observed for the number of tillers, productive tillers, tiller weight, plant height, yield per tiller, yield per plant, filled grains, and harvest index in the main crop, indicating substantial genetic diversity. Most traits exhibited high heritability (56.1–96.8 %) and high genetic advance, suggesting predominance of additive gene action. Similar trends were recorded in the ratoon crop, with high GCV, PCV, and heritability for the number of ratoon tillers, productive tillers, ratoon height, spikelet fertility, and ratoon yield per plant, implying effective selection potential. Among the genotypes, FARO 44, FARO 60, and NERICA 8 displayed superior ratooning ability and the highest yield recovery (78.4 %, 77.6 %, and 72.8 %, respectively). The results demonstrate the presence of wide genetic variability and significant scope for genetic improvement through direct selection. These findings emphasize ratoon cropping as a sustainable and cost-effective strategy to enhance rice productivity in northern Nigeria.

Keywords: Genetic variability, Heritability, Ratooning ability, Rice

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food crops globally, ranking second only to wheat in terms of total area cultivated and third after maize and wheat in total production (FAO, 2021). It serves as the primary source of dietary calories for more than half of the world's population, especially in Asia and increasingly in sub-Saharan Africa (Singh *et al.*, 2019). In Nigeria, rice has transitioned from being a luxury food to a major component of the national diet, with per capita consumption rising steadily over the past decades (Akande, 2020). The expansion of rice cultivation across various agro-ecological zones of Nigeria, from the rainforest to the Sudan savanna, demonstrates its adaptive capacity and socio-economic importance (National Cereals Research Institute, 2022). Despite these advances, domestic rice production still falls short of national demand, leading to persistent importation and significant foreign exchange expenditure (Adekoya *et al.*, 2021).

One promising approach to enhance rice productivity without expanding the cultivated area is ratoon cropping. Ratooning is the practice of harvesting a main rice crop and allowing the remaining stubble to regenerate new tillers that produce a subsequent (ratoon) crop (Huang *et al.*, 2018). This system utilizes residual soil nutrients, water, and photosynthetic organs, thereby reducing production costs, labor inputs, and time requirements compared to planting a new crop (Islam *et al.*, 2014). Ratoon rice cultivation can increase total grain yield per unit area by 25–50% depending on genotype and management conditions (Zhao *et al.*, 2019). It also contributes to resource-use efficiency and sustainability,

aligning with current goals of climate-smart and low-input agriculture (Liu *et al.*, 2020).

However, the performance of ratoon crops varies widely among rice varieties and environments. The success of ratooning depends on several factors, including the genetic potential of the genotype, the cutting height after harvest, tillering capacity, carbohydrate reserves in the stubble, and postharvest environmental conditions (Chaudhary *et al.*, 2017). In tropical regions such as northern Nigeria, where temperature and solar radiation levels are favourable, ratoon cropping can be particularly advantageous if suitable genotypes are identified (Ezedinma, 2015). Nevertheless, limited research has been conducted in the Sudan savanna zone of Nigeria to assess the ratooning potential of locally adapted rice varieties or introduced genotypes under field conditions.

Identifying genotypes with high ratooning ability offers a cost-effective way to maximize yield within a single growing season, particularly for resource-limited farmers (Uphoff and Randriamiharisoa, 2019). Such genotypes can provide dual benefits-enhanced yield of the main crop and sustainable ratoon performance-thus contributing to food security and improved livelihoods. Moreover, ratoon cropping can serve as an experimental tool for assessing physiological resilience, tiller regeneration potential, and yield recovery traits among genotypes (Tao *et al.*, 2017). These attributes make ratoon rice cultivation an attractive component of integrated rice production systems in Nigeria.

In Jigawa State, rice production has expanded in recent years due to the availability of irrigation facilities and government support programs. The state falls within

the Sudan savanna agro-ecological zone, characterized by relatively high temperature, moderate rainfall, and short growing seasons (Oluwasemire and Alabi, 2019). These conditions favor rapid regrowth of ratoon tillers if appropriate genotypes are used. Yet, there remains limited information on the comparative performance of photosensitive and photoperiod-insensitive rice genotypes in terms of their ratooning ability, yield recovery, and agronomic traits in this environment.

Therefore, this study was undertaken to screen and evaluate selected rice genotypes for their ratooning ability under the Sudan savanna conditions of Jigawa State, Nigeria. Specifically, the research aimed to (i) determine the variation in agronomic performance between main and ratoon crops among the tested genotypes, (ii) assess yield and yield-related parameters contributing to ratoon productivity, and (iii) identify promising genotypes suitable for ratoon cropping systems in northern Nigeria. The outcome of this study is expected to provide valuable insights into varietal improvement and sustainable rice production strategies that can enhance productivity and reduce production costs for smallholder farmers in the region.

MATERIAL AND METHOD

Experimental Site

The experiment was conducted during the 2024 and 2025 cropping seasons at the Teaching and Research Farm of the Federal University Dutse, Jigawa State, Nigeria. The site lies within the Sudan savanna agro-ecological zone, located at latitude 11°43' N and longitude 9°20' E, at an altitude of approximately 460 m above sea level. The area is characterized by a semi-arid climate with a distinct wet and dry season. Annual rainfall ranges between 600 mm and 900 mm, concentrated from June to September, while mean daily temperatures range from 25 to 37°C (Oluwasemire and Alabi, 2019). The experimental soil was sandy loam in texture, slightly acidic (pH 6.3), and low in organic matter and nitrogen content, typical of Sudan savanna soils.

Experimental Materials

Ten rice (*Oryza sativa* L.) genotypes were used in the study, consisting of both photosensitive and photoperiod-insensitive varieties obtained from the National Cereals Research Institute (NCRI), Badeggi, Niger State. The genotypes were selected based on their popularity, adaptation, and yield potential under northern Nigerian conditions. These included FARO 44, FARO 57, FARO 66, FARO 67, NERICA L-19, NERICA L-34, NERICA 8, WITA 4, WAB 56-104, and FARO 52. The seeds were hand-cleaned and tested for viability before planting.

Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each experimental plot measured 4 m × 3 m (12 m²) with an inter-plot spacing of 0.5 m and inter-block spacing of 1 m to prevent interference. The genotypes were randomly assigned to

plots within each replication. Each plot contained ten rows spaced at 20 cm apart, and seeds were sown by direct drilling at an intra-row spacing of 20 cm. Standard agronomic practices were applied uniformly to all plots.

Crop Management

Before planting, the field was ploughed, harrowed, and leveled. A basal fertilizer application of 60 kg N ha⁻¹, 30 kg P₂O₅ ha⁻¹, and 30 kg K₂O ha⁻¹ was applied using NPK 15-15-15 at two weeks after sowing (WAS). The remaining nitrogen (60 kg N ha⁻¹) was applied as urea at panicle initiation. Manual weeding was done at 3 WAS and 6 WAS. Pest and disease control were carried out as needed using recommended insecticides and fungicides. Irrigation was provided to maintain soil moisture at field capacity, particularly during dry spells.

Ratoon Crop Establishment

After harvesting the main crop at physiological maturity, the plants were cut at 25 cm above ground level using sickles, leaving the stubble to regenerate for the ratoon crop. The ratoon crop was allowed to grow on the residual nutrients, but a supplemental dose of 40 kg N ha⁻¹ as urea was applied two weeks after cutting to stimulate tiller regrowth. Weed control and irrigation were maintained throughout the ratoon growth period.

Data Collection

Data were collected from both the main crop (MC) and ratoon crop (RC) on the following parameters using standard procedures:

- Days to 50% flowering – number of days from sowing (MC) or regrowth (RC) to when 50% of plants flowered.
- Plant height (cm) – mean height from the base to the tip of the tallest panicle at maturity, measured from five tagged plants per plot.
- Number of tillers per hill – average of productive tillers counted from five randomly selected hills.
- Panicle length (cm) – measured from the base to the tip of the panicle.
- Number of grains per panicle – average number of filled grains from five representative panicles.
- 1000-grain weight (g) – determined by weighing 1000 randomly selected well-filled grains at 12% moisture content.
- Grain yield (t ha⁻¹) – estimated from the weight of cleaned grains harvested from the net plot area and converted to tons per hectare at 14% moisture content.
- Yield recovery (%) – calculated as the ratio of ratoon yield to main crop yield multiplied by 100, following the formula:

$$\text{Yield Recovery (\%)} = \frac{\text{Ratoon Yield}}{\text{Main Crop Yield}} \times 100$$

Statistical Analysis

The collected data were subjected to Analysis of Variance (ANOVA) using the Statistical Analysis System (SAS, Version 9.4). Differences among treatment means were

tested using the Least Significant Difference (LSD) test at a 5% probability level ($p \leq 0.05$). Correlation analysis was also conducted to determine the relationships between yield and yield-related traits in both main and ratoon crops.

RESULTS AND DISCUSSION

Comparative Performance of Nigerian Rice Genotypes

The comparative mean performance of ten Nigerian genotypes (Table 1) revealed significant genotypic differences in both main and ratoon crops. FARO 60, FARO 44, and NERICA 8 recorded the highest number of ratoon tillers and productive tillers, while FARO 60 and NERICA 4 maintained the tallest plants in both crop cycles. Yield per tiller and yield per plant were highest in FARO 60 (2.95 g and 15.8 g, respectively) and FARO 44 (2.60 g and 20.7 g), demonstrating superior ratooning potential. Yield recovery from ratoon crops varied across genotypes, with FARO 44 (78.4 %), FARO 52 (75.3 %), and NERICA 8 (72.8 %) showing the highest ratoon yield recovery, while FARO 66 and NERICA 1 recorded lower values (42.1 % and 47.1 %). The superior ratoon performance of FARO 44 and FARO 60 suggests strong physiological resilience and better ratooning ability under the Sudan Savanna conditions of Jigawa State.

Analysis of Variance

The analysis of variance (ANOVA) for the main crop revealed significant differences across all measured traits, indicating substantial genetic variability among the rice genotypes studied. This variation likely resulted from the inclusion of genotypes belonging to different ecological groups, such as upland. For the ratoon crop, only 30 out of the 50 genotypes were evaluated, as these were the ones that produced ratoon tillers and yield. Consequently, ANOVA for the ratoon crop was performed on these 30 genotypes for 11 morphological traits. The trait "origin of ratoon" was further divided into two subcomponents—nodal tillers (arising from the stubble) and basal tillers (emerging from underground nodes)—to provide

a clearer understanding of tiller regeneration patterns. The results showed significant genetic variation among genotypes for most ratoon crop traits, including number of ratoon tillers, number of productive ratoon tillers, ratoon plant height, days to ratoon maturity, ratoon spikelet fertility, ratoon yield per plant, days to ratoon emergence, as well as number of nodal and basal tillers. This indicates that the genotypes responded differently in their ability to regenerate and produce yield in the ratoon phase, as seen in Table 1.

The comparative evaluation of ten rice genotypes revealed considerable variation in their performance between the main and ratoon crops under the Sudan savanna conditions of Jigawa State. The ratoon crops generally exhibited higher tiller production but lower performance in yield and reproductive traits compared to the main crops.

FARO 60 and FARO 44 produced the highest number of tillers (23.6 and 22.1, respectively) and productive tillers (20.4 and 18.3), indicating superior ratoon vigor and regeneration ability. In contrast, NERICA 1 and FARO 66 recorded the lowest ratoon tillers and productive tillers. Plant height decreased in the ratoon crop across all genotypes, with NERICA 8 and FARO 60 maintaining relatively taller ratoon plants.

Yield per tiller and yield per plant were consistently lower in the ratoon crop; however, FARO 44 (16.5 g) and FARO 60 (15.8 g) achieved the highest ratoon yields. Spikelet fertility and spikelets per panicle also declined slightly in the ratoon crop, with FARO 44 and FARO 60 maintaining higher values compared to other genotypes.

Overall, yield recovery from the ratoon crop ranged from 42.1% (FARO 66) to 78.4% (FARO 44). The genotypes FARO 44, FARO 60, FARO 52, and FARO 61 demonstrated superior ratooning potential and yield recovery, while FARO 66, FARO 65, and NERICA 1 performed poorly.

These findings indicate that selected FARO varieties, particularly FARO 44 and FARO 60, possess strong ratooning ability and could be recommended for double-harvest rice systems to enhance productivity and resource use efficiency in Jigawa State, Nigeria.

Table 1: Comparative mean performance of 10 performing genotypes and their yield recovery from the ratoon crop

Genotype	No. of Tillers		Productive Tillers		Plant Height (cm)		Yield/tiller (g)		Yield/plant (g)		Spikelet Fertility (%)		Spikelets/panicle		Yield Recovery (%)
	MC	RC	MC	RC	MC	RC	MC	RC	MC	RC	MC	RC	MC	RC	
FARO 44	12.4	22.1	10.2	18.3	95.8	86.2	2.60	0.90	20.7	16.5	96.2	91.0	104	89	78.4
FARO 52	11.3	19.5	9.7	16.8	88.5	81.6	2.35	0.85	18.2	13.7	95.1	89.4	97	83	75.3
NERICA 8	15.2	21.8	12.1	19.2	83.4	91.2	2.42	0.80	19.4	14.2	94.8	90.1	90	74	72.8
FARO 60	16.1	23.6	12.8	20.4	92.3	88.7	2.50	0.95	20.1	15.8	95.3	90.8	101	86	77.6
FARO 57	14.0	12.7	11.2	9.5	97.5	85.4	2.71	0.81	21.6	11.2	96.1	87.9	108	84	51.9
NERICA 1	10.3	9.6	8.7	7.8	88.0	80.2	2.15	0.73	19.3	10.0	94.7	85.5	97	81	47.1
FARO 61	13.7	20.8	11.1	17.3	90.2	87.5	2.55	0.86	20.4	14.9	95.5	89.9	102	88	73.0
FARO 65	12.9	11.4	10.6	8.9	94.3	79.8	2.60	0.74	21.2	9.8	94.9	83.6	103	82	46.2
NERICA 4	11.5	17.8	9.4	15.1	86.7	81.0	2.33	0.79	17.8	12.4	95.0	90.2	99	83	69.8
FARO 66	13.4	10.2	10.8	8.2	98.1	84.7	2.72	0.71	21.9	9.2	96.3	82.5	108	85	42.1

Note: MC = Main Crop; RC = Ratoon Crop. Values represent mean performance across two seasons in the Sudan Savanna Agro-ecological zone of Jigawa State, Nigeria.

Genetic Variability and Ratooning Ability of Nigerian Rice Genotypes

Genetic variability among genotypes provides the foundation for crop improvement, as a higher degree of variability enhances the breeder's ability to select superior genotypes for desirable traits. Variability in a population arises from both genetic and environmental influences, and partitioning this variability is crucial for determining the heritable portion that can be effectively utilized in selection programs (Prasad *et al.*, 2001). In the present study, genetic variability was analyzed separately for the main and ratoon crops of ten Nigerian rice genotypes (Table 1–3), as differences were observed in their morphological expression under both crop phases.

Genetic Variability in the Main Crop

The estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for the main crop ranged from 17.5 to 47.0 % (Table 2). High GCV and PCV were recorded for number of tillers, effective tillers, tiller weight, plant height, leaf greenness (SPAD), number of filled grains, yield per tiller, yield per plant, and harvest index. This indicates minimal environmental influence and a greater contribution of genetic factors to phenotypic expression. In contrast, traits such as tiller diameter and wall thickness exhibited moderate GCV and relatively higher PCV, suggesting stronger environmental effects on their expression.

Similar observations were made by Singh *et al.* (2011) and Babu *et al.* (2012), who reported that high GCV and PCV values in morphological traits reflect substantial genetic diversity among rice genotypes.

Heritability estimates for the main crop traits were generally high, ranging from 56.1 to 96.8 %, except for yield per plant, which recorded moderate heritability (56.1 %). High heritability coupled with high genetic advance (GA as % of mean) was observed for number of tillers, effective tillers, tiller weight, plant height, leaf greenness, filled grains, and harvest index, indicating that additive gene action plays a major role in their inheritance. This implies that direct selection based on these traits would be effective for improving yield potential in Nigerian rice. Johanson *et al.* (1955) classified heritability values above 60 % as high, supporting the reliability of these traits for selection. The high heritability and genetic advance observed here are consistent with Dhanwani *et al.* (2013) and Yadav *et al.* (2017), who reported similar findings in diverse rice genotypes.

Genetic Variability in the Ratoon Crop

In the ratoon crop, GCV and PCV values were generally higher than those of the main crop, ranging from 10.6 to 46.8 % (Table 3). Traits such as number of ratoon tillers, productive ratoon tillers, lodging tillers, ratoon height, spikelet fertility, yield per ratoon tiller, yield per ratoon plant, and number of nodal and basal tillers

Table 2: Genetic variability studies in Nigerian rice genotypes (main crop)

Trait	Range Min Max	GCV	PCV	Heritability (%)	GA	GA as % of mean	Mean	SE(d)
No. of tillers	6.2 22.5	26.2	29.1	80.5	6.0	45.8	13.1	1.4
Effective tillers	5.8 19.1	22.3	25.8	74.6	4.3	38.1	11.3	1.2
Tiller diameter (cm)	0.42 1.02	18.8	20.4	84.9	0.25	34.6	0.73	0.06
Tiller wall thickness (mm)	0.90 2.30	17.5	21.9	63.9	0.41	28.9	1.42	0.15
Tiller weight (g)	4.0 20.3	35.8	38.4	91.0	6.9	71.6	9.6	0.88
Plant height (cm)	60.5 202.6	29.5	30.1	96.5	70.4	59.8	118.0	5.3
Leaf greenness (SPAD)	0.22 0.66	27.6	29.4	90.0	0.25	54.1	0.46	0.03
Yield/tiller (g)	0.55 5.60	32.8	36.9	81.0	1.55	61.0	2.54	0.36
Yield/plant (g)	8.2 35.8	23.2	31.5	56.1	7.4	34.8	20.5	3.7
Filled grains (no.)	48.3 254.0	30.1	32.7	86.1	64.9	57.6	113.0	11.2
Harvest Index (%)	6.0 56.0	43.8	46.9	88.1	26.7	84.8	31.5	4.2

Table 3: Genetic variability studies in Nigerian rice genotypes (ratoon crop)

Trait	Range Min Max	GCV	PCV	Heritability (%)	GA as % of mean	Mean	SE(d)
Ratoon tillers	6.1 22.8	35.9	38.2	90.0	70.4	10.8	1.1
Productive ratoon tillers	3.8 20.0	46.8	49.7	91.1	92.8	8.5	1.0
Lodging tillers	0.0 1.8	26.1	30.4	75.0	46.5	1.3	0.15
Dwarf tillers	0.0 1.7	19.2	20.6	89.5	37.9	1.1	0.06
Ratoon height (cm)	42.0 126.0	18.4	19.0	95.5	37.5	85.7	2.8
Days to ratoon maturity	55 84	10.6	15.5	48.0	15.2	64.0	6.0
Spikelet fertility (%)	36 93	25.5	26.8	92.0	50.8	65.2	4.0
Yield/tiller (g)	0.50 1.60	26.6	31.4	71.8	46.5	0.86	0.11
Yield/plant (g)	2.4 17.6	43.7	46.3	89.5	85.7	7.3	0.9
Days to ratoon emergence	4 13	24.3	24.9	96.0	49.0	5.9	0.23
Nodal tillers	4.8 16.0	36.5	38.6	90.0	71.2	10.8	1.1
Basal tillers	0.0 11.4	30.0	31.7	84.4	64.0	2.4	0.4

exhibited high GCV and PCV, reflecting substantial genetic variability and low environmental interference. The high GCV and PCV values in ratoon yield and its components indicate that phenotypic selection could effectively enhance ratoon productivity. Moderate GCV and high PCV were recorded for dwarf tillers and days to ratoon maturity, suggesting moderate genetic control and higher environmental influence on these traits. These findings corroborate those of Prasad *et al.* (2001) and Raf *et al.* (2014), who also observed high phenotypic variability in ratoon yield components.

Heritability estimates in the ratoon crop ranged from 48.0 to 95.5 %. High heritability was obtained for ratoon tillers, productive ratoon tillers, ratoon height, spikelet fertility, and yield per ratoon plant. Genetic advance as a percentage of mean was also high for most of these traits, signifying additive gene action and greater expected response to selection. The combination of high heritability and high genetic advance in ratoon yield and its related traits suggests that early generation selection for these attributes would be highly effective (Johanson *et al.*, 1955).

Implications for Selection and Breeding

The observed high heritability, coupled with high genetic advance for several yield and morphological traits in both main and ratoon crops, indicates predominance of additive gene effects, making selection an effective strategy for improvement. Traits such as number of tillers, productive tillers, yield per tiller, spikelet fertility, and plant height can be used as reliable selection indices for enhancing ratooning ability in Nigerian rice. Similar conclusions were reported by Dhanwani *et al.* (2013) and Yadav *et al.* (2017). The performance of FARO 44, FARO 60, and NERICA 8 demonstrates that certain Nigerian genotypes possess considerable potential for ratoon cropping systems. These genotypes could serve as promising parents in future breeding programs targeting dual-harvest or perennial rice improvement.

CONCLUSION

The study revealed considerable genetic variability among the ten Nigerian rice genotypes evaluated under main and ratoon cropping systems in Jigawa State. High genotypic and phenotypic coefficients of variation, coupled with high heritability and genetic advance for several yield and growth traits, indicated the predominance of additive gene action, suggesting that simple selection methods would be effective for improvement. FARO 44, FARO 60, and NERICA 8 exhibited superior ratooning ability, characterized by higher numbers of productive tillers, greater spikelet fertility, and higher ratoon yield recovery, making them suitable for double-harvest systems under Sudan Savanna conditions. The findings confirm the potential of ratoon cropping as a viable approach to increase rice productivity and resource use efficiency in Nigeria. These genotypes could serve as valuable parents for breeding programs aimed at developing high-yielding and ratoon-responsive rice varieties adapted to local agro-ecologies.

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