



IMPACT OF NITROGEN SOURCES ON THE PERFORMANCE OF LOWLAND RAINFED RICE AT EDOZHIGI IN THE SOUTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT

Field trials were conducted at Edozhigi, in the southern Guinea savanna of Nigeria during the 2020 and 2021 cropping seasons to determine the response of lowland rainfed rice to two Nitrogen sources (urea super granule (USG) and granular urea (GU)). There treatments consisted of five levels of USG (80, 90, 100, 110, 120 kg N ha⁻¹) and six levels of GU (40, 80, 90, 100, 110, 120 kg N ha⁻¹) and a control (0). The 12 treatments were laid out in a randomised complete block (RCBD) with three replicates. Result of the physical and chemical analysis of soil of the experimental field revealed that, soil had sandy clay loam texture with slightly acidic soil reaction. The soil organic carbon, total N, available P, exchangeable cationic nutrients were all low in the soil which make the soil to have low fertility. Result of the study indicated that, plant growth and maturity period were not significantly affected by the application of N. The result further shows a significant response to application of USG, but not to GU. The highest paddy yield of 4.53 Mg ha⁻¹ was recorded for USG at 90 kg N ha⁻¹ which was significantly higher than that of the control and the GU treatments, but statistically similar to most of the other USG treatments. The USG is recommended as a source of N for the enhancement of the paddy yield.

Keywords: Lowland, Nitrogen, Performance, Rice and Savanna

INTRODUCTION

In Nigeria, rice (*Oryza sativa* L.) is a leading food staple whose consumption has continued to increase with population growth, urbanization, changes in consumption habits and shift in consumer preference. This is due to its ease of preparation compared to other traditional foods thereby reducing the task of food preparation and fits more easily into urban life and styles of rich, urban poor and rural population alike (Nguezet *et al.*, 2011). Nitrogen is generally the most deficient nutrient required for proper growth and development of rice crop (Rakesh *et al.*, 2020). It is an essential plant nutrient being a component of amino acids, nucleic acids, nucleotides, chlorophyll, enzymes and hormones (Brady and Weil, 2010). Optimum rates of N in photosynthetic processes promotes rapid plant growth and improves grain yield and grain quality through higher tillering, leaf area development, grain formation, grain filling and protein synthesis (Ahmad *et al.*, 2009; Massignam *et al.*, 2009).

In Nigeria, more than 70 % of total rice area is under rainfed lowland rice cultivation (Ehirim *et al.*, 2023). This ecology is said to contribute between 43 to 45 % of national rice production (Oko *et al.*, 2012). Though there are various factors affecting paddy production across various rice clusters, effective nutrient management especially N; method and type of application are key to boosting nutrient efficiency, food security and optimize farming investments. It is for this reason that most rice farmers are still small-scale farmers adopting

traditional production methods and facing the challenges of poor returns to scale (Nwike and Ugwumba, 2015).

Fertilizer Deep Placement (FDP) also known as Urea Deep Placement (UDP) is used to describe the application of urea super granule (USG) which is effective in addressing N loss by releasing the N slowly preventing it from being leached from the soil. The application of USG as a source of N has proven to be a fertilizer technology that achieved average yield increase of 18 %, while reducing N fertilizer use by about one-third (IFDC, 2012). Few documented studies carried out on USG have shown increase of 20-30 % of rice yields over traditional farmers practice of broadcast application of other N sources (Tarfa and Kiger, 2013; IFDC, 2012). However, these few studies focused only on the rate of application of USG under lowland irrigated rice, but not under rainfed condition with little studies on the optimum rate of application of USG in rainfed lowland rice. Therefore, this study was conducted in two seasons under rainfed condition to determine the impact of N sources on the performance of lowland rainfed rice as to ascertain the efficacy of slow-release N source to boost paddy production in the moist savanna of Nigeria with the objective to determine the effect of N sources on yield and yield component of rainfed lowland rice.

MATERIALS AND METHODS

The Study Area

The study was conducted at Edozhigi (longitude 09° 05.673' N and latitude E 005° 50.971' E) in Gbako Local Government Area of Niger State in the southern Guinea savanna of Nigeria during the 2020 and 2021 rainy seasons. The climate of the area is sub-humid, and the rainfall pattern is mono modal with mean annual rainfall of about 1300 mm, occurring during the rainy season starting in March and ending in October and the dry season starting in November and ending in March. The rainfall data during the period of study is shown in Fig 1. The site is in the middle Niger Valley characterized by extensive flat to very undulating lowlands of River Niger and filled with Cretaceous and Tertiary rocks over which the river has been at. The vegetation is isoberlina – hyperrhema woodland savanna. The soil was developed from weathered tertiary knipe sandstones and are very deep, red Dystic Nitosols with coarse surface and subsoil on the uplands and poorly drained grey soils (Dystric Flvisols) in the valleys (Ojanuga, 2006).

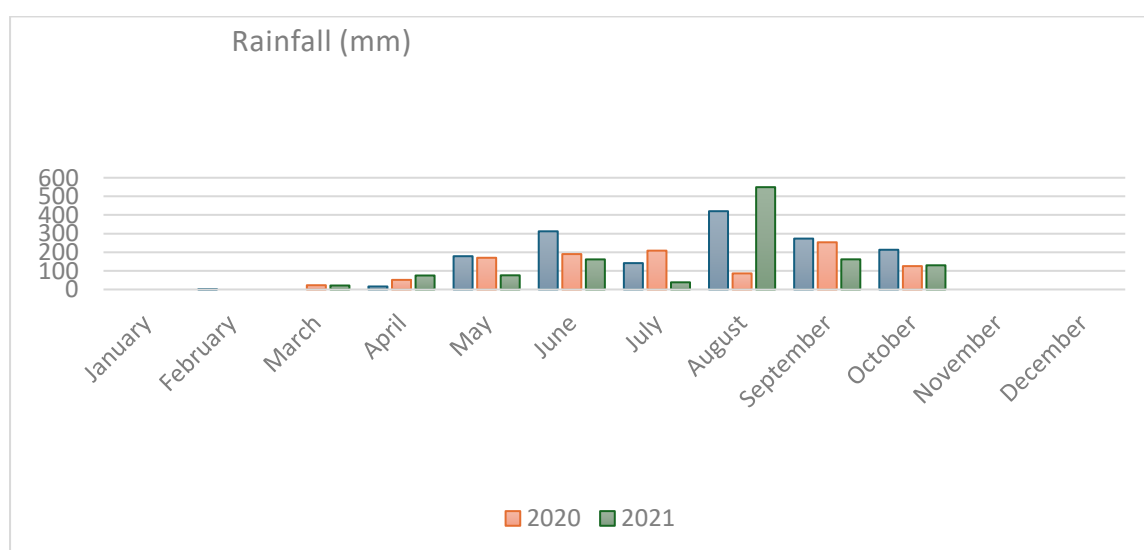


Figure 1: Monthly rainfall distribution at Edozhigi during the period of the study



Treatments and Experimental Design

The treatments consisted of two N sources; granular urea (GU) at six N levels (40, 80, 90, 100, 110, 120 kg N ha⁻¹) and USG at five N levels (80, 90, 100, 110, and 120 kg N ha⁻¹) and an absolute control to give a total of 12 treatments and laid out in a randomized complete block design (RCBD) with three replicates to give a total of 36 plots. The plot sizes were 3 m × 3 m (9 m²).

Agronomic Practices

Nurseries were established near experiment field with Faro 44 rice variety. Two seedlings per hill were transplanted at 21 days after being raised in the nursery to each plot on the field at a spacing of 0.2 m x 0.2 m to obtain a plant population of 500,000 stands per hectare. All plots received a basal application of 40 kg ha⁻¹ of P and K. Phosphorus was supplied by single superphosphate fertilizer, while potassium was supplied by muriate of potash fertilizer. The N levels were all applied in split form and by broadcast except USG. In plots requiring GU as N source, one-third was applied as basal, while the remaining two-thirds was applied at panicle initiation stage. In plots requiring USG as a source of N, a briquette granule of USG was deeply placed in between four hills at a depth of 5 – 7 cm at one (1) week after transplanting (WAT).

Soil Sampling and Analysis

Surface soil (0 – 20 cm) samples were collected with auger from ten points along three diagonal transects from the study site. Samples from each transect were bulked together to give three composite samples which were used to characterize the field before land preparation. The composite soil samples for characterization of the field were air-dried, crushed gently, passed through 2 mm sieve and taken to the laboratory for physical and chemical analysis using standard method as described by IITA (2015). Briefly, particle size analysis was determined by the hydrometer method. Soil pH was measured in a 1:2.5 soil to water with a glass electrode pH meter. Organic carbon was determined by Walkley - Black wet oxidization method. Total nitrogen was determined by micro Kjeldahl method. Available P was determined calorimetrically after Bray P1 extraction. Exchangeable bases were extracted with neutral 1N NH₄OAC solution. Na and K in the leachate were determined by flame photometry, and Ca and Mg by Na-EDTA titration. Exchangeable acidity was extracted with 1.0 N KCl. Effective cation exchange capacity (ECEC) was obtained by summation of the exchangeable cations and the exchangeable acidity.

Growth and Yield Data Collection

A total of 10 hills were selected randomly and tagged from each plot and used to collect data on number of tillers and panicles. Paddy yield (Mg ha⁻¹) was determined by harvesting from a quadrant of 1 m × 1 m (1 m²), threshed, winnowed and weighed.

Data Analysis

The general Linear Model Procedure of Statistical Tool for Agricultural Research (STAR) version 2.0.1 software was used for statistical analysis of the data including analysis of variance (ANOVA) and means where significant, were separated using Tukey's Honest Significant Difference (HSD) Test at 5 % level of probability, unless otherwise stated.



RESULTS AND DISCUSSION

Physical and Chemical Properties of Soil of the Experimental Site

The initial physical and chemical properties of the soils of the study site are shown in Table 1. The result indicated that, sand was dominant but with a relatively high amount of clay which indicates sandy clay loam texture. The dominance of sand contents in Northern Nigerian soils is because of sorting of materials by clay eluviation surface wind erosion (Voncir *et al.*, 2008; Malgwi *et al.*, 2000). The sandy nature of the soil allows for tillage of the soil, even at high moisture content with less damage to the structure of the soil (Adeboye *et al.*, 2020). The soil has a slightly acidic reaction, implying that nearly all plant nutrients are available in optimum amount. The pH range of 6.0 to 7.0 is the most suitable for the release of many plant nutrients for uptake and optimum growth and development of most plants (Tan, 2000).

The soil organic carbon, total N and Phosphorus (P) were all low in the soil. This is in line with the result of Chude *et al.* (2011). The low content of soil organic carbon implies low reserves of soil organic matter which is responsible for low N and P in the soil. Soil organic matter which is the major source of N and usually P in the soil (Brady and Weil, 2010). The low organic carbon with consequent low N and P is characteristics of savanna soils, due partly to rapid decomposition of tropical climates which makes it difficult to build-up soil fertility (Andr en *et al.*, 2007). The relatively low N compared to organic carbon will lead to stabilization of N in the soil and minimize it via nitrification coupled to nitrate leaching and denitrification due to high microbial N use efficiency (Zhang *et al.*, 2019).

The exchangeable cationic plant nutrients: Ca^{2+} , Mg^{2+} , K^{+} , and Na are all rated low. This is in conformity with the report of Chude *et al.* (2011). The low content of these cationic nutrients reflects the low organic matter content in the soil. The result of this findings lend support from that of Brady and Weil (2010) that organic matter in tropical soils is the main source of negative charges that these nutrients are absorbed to which prevents them from being leached down the soil profile beyond the root zone. The exchangeable acidity was $0.10 \text{ cmol kg}^{-1}$ is rated low. The soil is thus low in potential acidity will not contribute to the active acidity may not constitute toxicity to crops or have an adverse effect on root development. High amount of aluminium is toxic to roots and causes swelling of the roots thereby impeding their ability to absorb water and nutrients from the soil (Brady and Weil, 2010).

Table 1: Means of initial soil properties prior to land preparation in 2020 rainy Season

Parameters	Values
Physical properties:	
Particle size distribution (g kg ⁻¹):	
Sand	598
Silt	160
Clay	242
Textural class	Sandy clay loam
Chemical properties:	
pH in H ₂ O (1:2.5)	6.7
Organic Carbon (g kg ⁻¹)	3.24
Total Nitrogen (g kg ⁻¹)	0.49
Available P (mg kg ⁻¹)	7
Exchangeable Bases (cmol kg⁻¹):	
Ca ²⁺	4.20
Mg ²⁺	0.57
K ⁺	0.24
Na ⁺	0.54
Exchangeable Acidity (cmol kg ⁻¹)	0.10
Effective cation exchange capacity (cmol kg ⁻¹)	5.55

Effects of Nitrogen Sources on Growth Parameters and Yield

Nitrogen sources had a significant effect on the number of tillers at panicle initiation, panicle number and paddy yield in both seasons as shown in Table 2. Over the two seasons, at panicle initiation growth stage, 100 GU, 110 GU and 120 USG kg ha⁻¹ recorded the highest number of tillers which were significantly ($p < 0.05$) different from that of the other treatments. There was no clear trend of the effects of the two N sources on the number of tillers and panicles, as the control produced similar or a greater number of both parameters than some of the fertilizer treatments. However, the higher rates of both USG and GU produced significantly ($p < 0.05$) higher number of tillers and panicles compared to the control. These results suggest that higher rate of N is needed to enhance production of tillers and panicles as reported by Tsukru *et al.* (2023). High N rate of greater than 120 kg ha⁻¹ have been reported to increase the growth parameters of improved rice varieties by some workers (Apagu *et al.*, 2023; Fagade and Ojo, 2006).

The paddy yield ranged from 3.17 to 4.53 Mg ha⁻¹. This is higher than the average yield ranging between 1 and 2.5 Mg ha⁻¹ but lower than the potential yield of 5 to 6 Mg ha⁻¹ reported for the country (Cadoni and Angelucci, 2013). The highest yield of 4.53 Mg ha⁻¹ was obtained with USG at 90 kg ha⁻¹ which was significantly higher compared to that recorded for the control and the GU treatments. Almost all the USG treatments, except the 120 kg N ha⁻¹ produced significantly higher yield than the GU treatments. The application of slow-release fertilizer has been reported to significantly increase yield by over 7 % relative to other N sources at the same N rate (Ding *et al.*, 2018). This result is consistent with previous studies concluding that the application of USG increased paddy yield by 20-30 % compared to application of other N sources (Tarfa and Kiger, 2013). Deep placement of N fertilizer as espoused by USG application technology had positive effect on yield (Rea *et al.*, 2019).

Table 2: Effects of nitrogen sources on number of tillers, panicles and paddy yield in both seasons at Edozhigi

Treatment (kg N ha ⁻¹)	Number of tillers			Panicle number			Paddy yield (Mg ha ⁻¹)		
	Year		Combined analysis	Year		Combined analysis	Year		Combined analysis
	2020	2021		2020	2021		2020	2021	
0 (Control)	136.00 ^c	250.00 ^c	174.00 ^b	188.00 ^{de}	105.00 ^d	146.00 ^{de}	3.17 ^e	3.73 ^{ab}	3.40 ^{de}
40 (GU)	148.00 ^{abc}	231.00 ^{cd}	177.00 ^b	192.00 ^{cde}	110.00 ^{cd}	151.00 ^{de}	3.10 ^e	3.20 ^{bc}	3.17 ^e
80 (GU)	157.00 ^{ab}	281.00 ^{bc}	164.00 ^c	206.00 ^b	132.00 ^{ab}	169.00 ^b	3.47 ^{cde}	3.70 ^{ab}	3.60 ^{cde}
90 (GU)	150.00 ^{abc}	259.00 ^c	163.00 ^c	234.00 ^a	127.00 ^b	181.00 ^a	4.37 ^{abc}	2.57 ^c	3.50 ^{de}
100 (GU)	163.00 ^a	289.00 ^b	186.00 ^a	206.00 ^b	132.00 ^{ab}	169.00 ^b	3.67 ^{bcde}	3.60 ^{ab}	3.63 ^{cde}
110 (GU)	157.00 ^{ab}	250.00 ^c	186.00 ^a	204.00 ^{bc}	133.00 ^{ab}	168.00 ^b	4.33 ^{abcd}	3.30 ^b	3.87 ^{bcd}
120 (GU)	134.00 ^c	239.00 ^{cd}	175.00 ^b	194.00 ^{bcd}	139.00 ^a	167.00 ^b	3.30 ^{de}	3.83 ^{ab}	3.60 ^{cde}
80 (USG)	137.00 ^c	254.00 ^c	175.00 ^b	194.00 ^{bcd}	110.00 ^{cd}	152.00 ^d	4.77 ^a	3.57 ^b	4.20 ^{abc}
90 (USG)	139.00 ^c	298.00 ^b	176.00 ^b	181.00 ^e	109.00 ^{cd}	145.00 ^e	4.67 ^{ab}	4.30 ^a	4.53 ^a
100 (USG)	141.00 ^{bc}	296.00 ^b	177.00 ^b	204.00 ^b	113.00 ^c	159.00 ^c	5.03 ^a	3.70 ^{ab}	4.40 ^{ab}
110 (USG)	138.00 ^c	294.00 ^b	174.00 ^b	204.00 ^b	134.00 ^{ab}	169.00 ^b	4.70 ^{ab}	3.73 ^{ab}	4.23 ^{abc}
120 (USG)	165.00 ^c	319 ^a	178.00 ^{ab}	202.00 ^{bc}	134.00 ^{ab}	168.00 ^b	3.67 ^{bcde}	3.77 ^{ab}	3.77 ^{bcde}
SE ±	5.03	1.21	2.63	2.21	2.07	1.83	0.12	0.07	0.07

Means with the same superscript within a set of treatment column are not significantly different at $p < 0.05$. GU – Granular urea USG = Urea super granule SE± = Standard error

CONCLUSION AND RECOMMENDATIONS

The study had determined the impacts of urea super granules (USG) and granular urea (GU) as sources of nitrogen on the performance of rainfed lowland rice. The soil of the site is low in fertility especially in terms of soil organic carbon, total N, available P and the exchangeable cationic nutrients. The USG as a source of N recorded higher paddy yield than GU as a source of N. The USG as a source of N seems to be a better source of N than GU and therefore recommended for the study area at 80 kg N ha⁻¹ to obtain optimum paddy yield.

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