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Original Research Article

Influence of Integrated Nitrogen-Nutrient Sources on Lowland Rice Varieties' Yield and Yield Components in a Derived Savannah Ecology

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ABSTRACT

The limited Nitrogen availability in most Nigerian soils is why poor rice yields are observed. The cost of inorganic fertilizers, especially in the post-COVID-19 era, tends to increase. Systems of Rice Intensification (SRI) principles utilize integrated nutrient management systems for growing lowland rice in order to reduce the negative effects of climate change. This study focused on evaluating the effects of six different nutrient source combinations on the development of NERICA (New Rice for Africa) L-34 and ARICA (Advanced Rice Varieties for Africa) 3 in Abeokuta Nigeria, between the years of 2017 and 2019. The treatment arrangements were split-plot, randomized complete block design, and triple replication. The nutrient sources and varieties were allocated a subplot and the main plot. The data pertaining to rice yield and its constituent parts were subjected to a two-way Analysis of Variance. In 2017, NERICA L-34 outperformed ARICA 3 in terms of grain yield. The longest panicle, heaviest panicle, and largest grain yield in 2018 were generated by combining 25 kg N per hectare (inorganic) and 75 kg N per hectare (organic). The most grains per panicle were observed by combining 25 kg N per hectare (inorganic) and 75 kg N per hectare (organic). The study concluded that enhancing the 1000 grain-weight and grain yield of ARICA 3 and NERICA L-34 by combining 25 kg N per hectare (inorganic) and 75 kg N per hectare (organic) is advantageous.

Keywords: Inorganic, organic, lowland rice, yield components, grain weight,. .

Introduction

High-yielding varieties were developed as part of the Green Revolution to meet the growing demand for grain over the past few decades.[1] Low-yielding traditional varieties, inadequate nutrition, planting at the wrong seedling density, and inappropriate population contribute to low productivity.[2] Poor germination, uneven crop stands, the usage of traditional rice varieties with low yields, and poor nutrition are only a few of the issues restricting local rice production.[3] Globally, 4.32 million hectares (ha) of rice are harvested, with an average annual yield of 8.342 million metric tons and 1.93 tons per hectare.[4] Around 66% of the difference between existing and prospective harvest rates could be attributed to inadequate and improper nitrogen fertilizer application.[5] The appropriate management of fertilizer application involves integrating the utilization of chemical, organic, and bio-fertilizers. Furthermore, it enhances the chemical, biological, and physical features of the soil, enhancing and maintaining soil production. The persistent utilization of synthetic fertilizers, coupled with a deficiency in the practical understanding of their application among rice farmers in Nigeria, leads to soil nutrient imbalances and environmental harm.[6]

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Due to the drawbacks of chemical fertilizers and their expensive costs, organic fertilizers are now used more frequently as a source of nutrients. Nevertheless, relying solely on organic fertilizer for paddy fields reduces nitrogen levels during the mid-tillering stage of rice growth, leading to decreased crop yields. This highlights the importance of integrated nutrition management strategies for successful rice production.[7] Consequently, organic manures and synthetic fertilizers promoted stable plant growth by addressing nutrient deficiencies at the primary, secondary, and micronutrients. They also enhanced the efficiency of nutrient application and improved soil conditions, thereby reducing environmental risks.[8] Combining natural compost with synthetic fertilizers is essential to enhance both crop yield and the overall quality of the soil.[9] The Africa Rice Center developed the inter-specific hybrid rice variety known as NERICA to increase African rice cultivars.[10] ARICA 3 has significantly high grain quality and is appropriate to be developed in Nigeria under its ecological circumstances.[11] According to the West Africa *Rice* Development Association (WARDA), NERICA L-34 is an early-maturing variety with a high yield advantage.[12] There is little empirical evidence of how actual fertilizer use rates compare, despite the widely held belief that increased use of inorganic fertilizers is necessary for sustained crop yield and growth in sub-Saharan Africa.[13] Hence, it is imperative to explore the impact of integrated nitrogen sources on the production of lowland rice cultivars in Nigeria's derived savannah environment.

Lowland Rice Varieties

Yield and nutrient absorption vary among different types of rice plants categorized as early, medium, late, and single-season, owing to factors such as temperature, rice genetic variations, and the management of nutrients.[14] The grain head increased from 75 to 400 grains per head.[15] This variety has early maturation (within 80–100 days, 50–70 days

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earlier than farmer's varieties). It also possesses resilience against local challenges like blasts, stem borers, and termites. Additionally, it offers a significant yield increase, potentially reaching up to 6 tons per hectare in favorable conditions. Furthermore, it boasts a higher protein content and a delightful taste.[16] It has a shorter phenological phase than the existing local cultivars, making it suitable for double cropping, and it is high in protein at 25%.[17] A new generation of improved, high-yielding rice varieties known as ARICA has genetic material that consistently outperforms other rice varieties that farmers can choose from.[18] It has a shorter cooking time, high milling recovery, low chalkiness, and good grain quality.[19,20]

Significance of Nitrogen on Rice

Most rice is grown in regions where there is little access to nitrogen.[21] The insufficient nitrogen supply with a dosage of 100 kg of N per hectare may explain the limited development of crop yield-related traits.[22] The variety of growth models presently at our disposal for explaining how nitrogen availability and climatic elements influence rice yield can be enhanced by incorporating details relating to the physiological nature of the crop's reaction to nitrogen supply. Such improved models can better simulate the dynamics of the crop-soil system and furnish valuable data for model validation.[23] Nitrogen is transferred from the leaves and stems to the grain.[24] Suboptimal nitrogen management, which reduces grain filling, may cause a low harvest index.[25] According to Xie *et al*.,[26] rice plants without applied nitrogen had lower total dry matter and grain yields than plants with applied nitrogen.

An excess of nitrogen may result in an overproduction of tillers, leading to increased tiller loss, inadequate grain formation, diminished panicle size, and ultimately a decrease in grain production.[27] The number of ineffective tillers can rise as a result of resource competition between the main stem and tillers and a higher risk of lodging. Through contention between the tillers and primary stem and an increased likelihood of lodging, excessive tiller production can increase the number of unproductive tillers.[28] Adjusting nitrogen levels to fulfill crop needs led to higher nitrogen uptake and reduced nitrogen wastage.[29] The overuse of synthetic fertilizers has resulted to soil toxicity from the accumulation of harmful heavy metals, causing detrimental effects on the well-being of rice crops and the soil.[30] In the pre-flowering and ripening stages, it plays a role in carbohydrates in the grain and the stems and leaf sheaths.[31] After consistently applying organic manure for three years to low-fertility soil, rice yield, and nitrogen availability increased.[32] The reduction in dry matter and growth-related features (such as tiller quantity and Soil Plant Analysis Development (SPAD) value) suggests that the decrease in nutrition can be attributed to nitrogen immobilization.[33] Selecting the appropriate fertilizer, determining the right time, method, and amount for its application are vital elements in minimizing nitrogen loss from the soil.[34]

System of Rice Intensification (SRI)

Young, single seedlings are transplanted, and this reduces transplanting shock while promoting faster tiller development along with enormous tillering under the favorable conditions provided by SRI management.[35] Cultivated rice using the SRI display increased enzymatic activity,[36] elevated cytokinin levels,[37] enhanced transfer of xylem fluids,[38] greater oxygen-dependent activity of microbes,[39] and improved nutrient absorption,[40] due to more excellent root development in addition to the oxygenated state of the soil. Cultivated rice using the SRI approach absorbed a more significant amount of essential nutrients than the roots of traditionally farmed plants, leading to increased SRI crop yields.[41]

Effect of Climate Change on Rice Productivity

Given that modern high-yield rice strains cannot withstand increased temperatures, drought, and higher salinity levels, all of which are predicted to occur oftentimes in the years to come, climate change could adversely affect rice production.[42]

Effects of Organic Manure on Developmental Variables

The most significant growth factors that have the potential to provide a direct indication of grain output are indices of leaf area, productive leaves, and volume of dry matter output.[43] Due to its greater quantity, poultry dung is an input for increasing rice yield.[44] Similar to how poultry manure helped rice plants grow and produce more quickly, it also made it easier for the plants to absorb more nutrients.[45] Poultry manure may have improved rice production's soil quality and grain yield.[46]

Concept of Integrated Nutrient Management (INM)

Instead of solely focusing on yield-scaled profit, by employing these methods, farmers are motivated to prioritize long-range planning and take into account the environmental consequences..[47] The coordinated utilization of compound compost and fertilizer is significant for harvest yield.[48] The expansion had an impact on grain yield, highlighting the significant role of nitrogen application in the rice production system.[49] However, integrated nutrient management relies heavily on organic manures, particularly Farm Yard Manure (FYM).[50] As a result, soil fertility increases through integrated resource management.[51] Not only did this soil have good health, but it also met the requirements for micronutrients and provided macronutrients.[52] The combination of organic fertilizers and synthetic nutrients enhanced growth and yield consistency via treating elementary, secondary, and micronutrient deficiencies, increasing the effectiveness of administered nitrogen, and promoting favorable soil conditions that reduce environmental risks.[8] Using both organic manures and inorganic fertilizers together is essential to ensure the soil receives the full amount of nutrients for plant life in a form that is easily accessible as well as to promote soil quality.[53] According to a comprehensive literature review, INM surpasses traditional approaches in terms of enhancing crop yields, improving water and nutrient utilization efficiency, increasing economic gains for farmers, enhancing grain quality, promoting soil health, and ensuring sustainability.[54] The sustainable enhancement of the productivity of the soil and rice harvest was achieved by boosting the soil's efficiency through the combined utilization of inorganic and organic fertilizers. This approach prompted the augmentation of the leaf area index, the number of filled spikelets, and enhanced nutrient absorption and utilization..[55] When organic manures and inorganic fertilizers are used together, nitrogen losses are reduced, soil nitrogen is conserved by generating organic-mineral complexes, and rice plants have constant access to nitrogen, resulting in higher yields.[56] The harvest index demonstrates the division of photosynthetic energy between grain and vegetative plant portions (many panicles).[57]

Effects of inorganic manure on developmental variables

The panicle number, biomass data, flowering date, maturity, and expected output for maximum productivity were all true.[58] Nitrogen applications in the field have led to an increase in grain output, grains quantity per panicle, tiller quantity, overall dry matter, shoot dry matter, and the mass of a thousand grains.[59]

Yield Components

One of the most significant agronomic characteristics that directly affect rice grain yield is the panicle's architecture.[60] The grain yield exhibited a notable quadratic response to the application of nitrogen fertilizer.[61] The grain yield, a genetically determined characteristic that impacts panicle density, is influenced by environmental conditions.[62]

Materials and Methods

Overview of the Study Area

In the rainy seasons of 2017, 2018, and 2019, three different field experiments were conducted in the inland valley known as FADAMA, located at the Teaching and Research Farms of the Federal University of Agriculture in Abeokuta (FUNAAB), situated at Latitude 07 15'N to 07 30'N and Longitude 3 28'E to 3 54'E, specifically in Alabata. The location sat at an altitude of 83.10 meters relative to sea level, offering a tropical climate and receiving an annual precipitation exceeding 1300 millimeters. The agroecological zone experiences a bimodal pattern of rainfall distribution, ensuring that there is consistently

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sufficient moisture to facilitate crop growth during the initial phase of the growing season. After five (5) years of grassland flora, the field was cropped with rice.

Planting Materials
ARICA-3: Better grain quality, a higher milling recovery, less chalkiness, and a shorter cooking time all contribute to a 30% higher yield than NERICA L-19 (FARO 60).
NERICA L-34 (FARO 61): Maturing quickly (in less than 90 – 100 days), showing resistance to lodging, pests, and diseases, while also delivering increased yield and higher protein levels.
Both were sourced from Africa Rice Centre, Moniya, Ibadan. These varieties were chosen for this study because they are lowland rice varieties and they perform three times better than upland rice varieties in terms of yield from the same portion of the field.

Fertilizers
The Department of Plant Physiology and Crop Production supplied the NPK 15: 15: 15 inorganic fertilizers (NPK 15: 15: 15 Golden Fertilizer is a granular fertilizer that contains 15% Nitrogen, 15% Phosphorus, and 15% Potassium). The organic fertilizer, referred to as cured poultry manure, was sourced from the chicken layer facility at the Federal University of Agriculture, Abeokuta (FUNAAB).

Experimental treatments and design
The study involved a split plot design incorporated within a randomized complete block (RCB) structure with three replications. The experimental factors under investigation were different types of varieties and nutrient sources, with varieties allocated to the main plots and nutrient sources to the sub-plots.
Varieties (Main Plot)
V1 — ARICA 3
V2 — NERICA L-34

Nutrient sources of N (Sub-plot)
N1- 100 kg N per hectare (inorganic)
N2 - 75 kg N per hectare (inorganic) + 25 kg N per hectare (organic)
N3 - 50 kg N per hectare (inorganic) + 50 kg N per hectare (organic)
N4 - 25 kg N per hectare (inorganic) + 75 kg N per hectare (organic)
N5 - 100 kg N per hectare (organic)
N6 – Control (no organic; no inorganic)

Land Preparation and Experimental Plot Size
The selected field was a sandy loam soil that had effective drainage, and was cleared by hand to prepare it for optimal root growth. The entire land area measured 33.5 meters by 26.5 meters. Afterward, the field was marked out with pegs. Each individual plot was 5 meters by 4 meters, totaling 20 square meters, with a 0.5-meter gap between each replicate and a 1-meter margin inside each plot. During the pegging procedure, the fields were divided using pegs. On the following specific dates: May 23, 2017, April 18, 2018, and April 22, 2019, rice seedlings from the ARICA 3 and NERICA L–34 cultivars were transplanted one seedling per hill. They were placed at a depth of 3 cm and spaced 20 cm × 20 cm apart. Each plot had a population density of 500 plants, and there was a total of 250,000 plants per hectare.

Data Collection
Utilizing techniques pioneered by the International Rice Research Institute (IRRI), information on the specified parameters was collected from ten identified plants in the experimental plot when they reached physiological maturity. The oven dry weights and destructive samples for dry weights were divided.

Reproductive Variables
Panicle length (cm): The length of ten (10) randomly chosen panicles was assessed by using a tape measure to calculate the range from the panicle's neck to its tip, and then recorded in centimeters.
Panicle weight (g): Ten panicles per plot were chosen at random and their weights were measured in grams using a sensitive weighing scale.
Number of grains per panicle: The grains of ten (10) randomly selected panicles from a 0.5 m × 0.5 m quadrant placed on each plot were dried, threshed, counted and recorded. The counted grains were divided by ten and recorded.
Number of panicles per metre square: This measurement was obtained using a one-meter square section, where we tallied the quantity of panicles within the square, then processed and weighed them.
Panicle bearing tiller rate (PBTR):

$$\text{(number of panicle m} - 2) \times 100\ /\ \text{number of maximum tillers m} - 2) \text{ (equation 1)}$$

Panicle fertility (%):

$$\text{Number of filled grains} \times 100/\text{number of unfilled grains(equation 2)}$$

1000 grain weight (g): This involved the process of counting 1000 threshed grains and measuring their weight using a sensitive weighing scale (model number**:** Digital Food Scale-1; Manufacturer**:** AGM; Country of Origin**:** China) expressed in grams per plot.
Harvest index (%): This was the grain weight divided by the above ground biomass multiplied by 100 expressed in percentage per plot.
Grain yield (kg ha^{-1}): The threshed grains of each rice varieties per net plot which were weighed and then extrapolated to determine the grain yield ha^{-1}.
Reproductive Coefficient (RC): is the ratio of harvest per unit area to seed per unit area multiplied by 100 using equation 3

$$RC = \text{Harvest per unit area} \times 100/\text{Seed per unit area} \quad \text{(equation 3)}$$

Production Efficiency (%):
This was calculated by dividing the total grain production (ha) with total duration (days)

$$\text{Production Efficiency (\%)} = \text{total grain production (ha)} / \text{total duration (days) (equation 4)}$$

Conversion of Milled Rice (kg):
Paddy rice was converted by multiplying the yield / ha with 0.76

$$\text{Conversion of Milled Rice (kg)} = \text{yield / ha} \times 0.76 \quad \text{(equation 5)}$$

Data Analysis
The gathered data were subjected to mixed model Analysis of Variance (ANOVA), and the treatment means that showed statistical significance were distinguished using Duncan's Multiple Range Test (DMRT) at 5% probability level ($p \leq 0.05$). All discrete data were transformed before analysis. GenStat 12th edition was the statistical software program used.

Results and Discussion

Effects of integrated nutrient sources of N on lowland rice varieties in 2017, 2018, and 2019
According to Table 1, Integrated N nutrient sources significantly affected the number of days it took for panicle extrusion, and for 50% flowering in 2018, and 2019; also had significant effect on the tillering duration in 2017. Varieties significantly affected the days to 50% flowering in 2017, and 2018 (Table 1). The interaction between varieties and Integrated nitrogen nutrition sources significantly affected the number of days to 50% flowering in 2018 (Figure 1). Tillering ability is one of the most significant characteristics of rice,[64] because it directly affects the formation of panicles, which is thought to be a key component of high and early tillering capacity for maximum grain output.[65] In general, applying a combination of organic and inorganic N resulted in a faster panicle extrusion. According to Table 2, Integrated N nutrient sources significantly affected the length of panicle in 2018 and number of panicles per meter squared in 2017 and 2018. Varieties significantly affected the quantity of grains found in each panicle in 2019 (Table 2). Applying a combination of 25 kg N ha^{-1} (organic) and 75 kg N ha^{-1} (inorganic) resulted in the longest panicles. Applying a combination of 25 kg N ha^{-1} (inorganic) and 75 kg N ha^{-1} (organic) resulted in the highest number of grains per panicle. In general, applying a combination of organic and inorganic N resulted in a higher number of panicles per meter squared. High quantity of N fertilizers applied improved the rate of translocation of nitrogen from culms to leaves which led to

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production of photosynthates that enhanced further translocation of nutrients for development of panicles. According to Table 3, Integrated N nutrient sources significantly affected weight of 1000 grains and panicle weight in 2018, and number of days to yield accrual in 2017. Varieties significantly affected the weight of 1000 grains in both 2017 and 2018, harvest index in 2019, and number of days to yield accrual in 2018 (Table 3). The interaction between varieties and Integrated nitrogen nutrition sources significantly affected the number of grains per panicle in 2018 (Figure 2). Applying 75 kg N ha^{-1} (organic) and 25 kg N ha^{-1} (inorganic) resulted in the heaviest 1000-grain weight. In this study, higher yield components, such as grain and straw yields, were identified when compared to the control, which was also in agreement with the findings of Akhtar *et al*.,.[63] Integrated N nutrient sources did not significantly affect the harvest index in any of the three years studied. Applying 25 kg N ha^{-1} (inorganic) + 75 kg N ha^{-1} (organic) delayed yield accrual. Compared to chemical fertilizers alone, rice saw higher nitrogen use efficiencies with mixtures of organic and inorganic fertilizers.[67] Applying 25 kg N ha^{-1} (organic) and 75 kg N ha^{-1} (inorganic) resulted in the heaviest panicles. According to Table 4, Integrated N nutrient sources significantly affected the grain yield in 2018. Varieties significantly affected the grain yield in 2017 (Table 4). Applying 25 kg N ha^{-1} (inorganic) plus 75 kg N ha^{-1} (organic) resulted in the highest grain yield. The greatest number of tillers were produced in NERICA L-34, which helped suppress weed interference and lessen competition for water, nutrients, and space—all of which are crucial for growth and yield—and hence provided the maximum grain output.[66] Overall, the results of this study suggest that integrated nutrient sources of N can have a positive impact on the growth and development of lowland rice varieties. In particular, applying a combination of organic and inorganic N resulted in faster panicle extrusion and flowering, longer panicles, more grains per panicle, more panicles per meter squared, heavier 1000-grain weight, and higher grain yield. Using inorganic fertilizer affected the physical conditions of the soil, reduced the amount of organic matter, and failed to maintain the desired physiological characteristics and yield of rice over time.[46] According to Slafer *et al.,*[68] the physiological efficiency of N decreases as N levels rise.

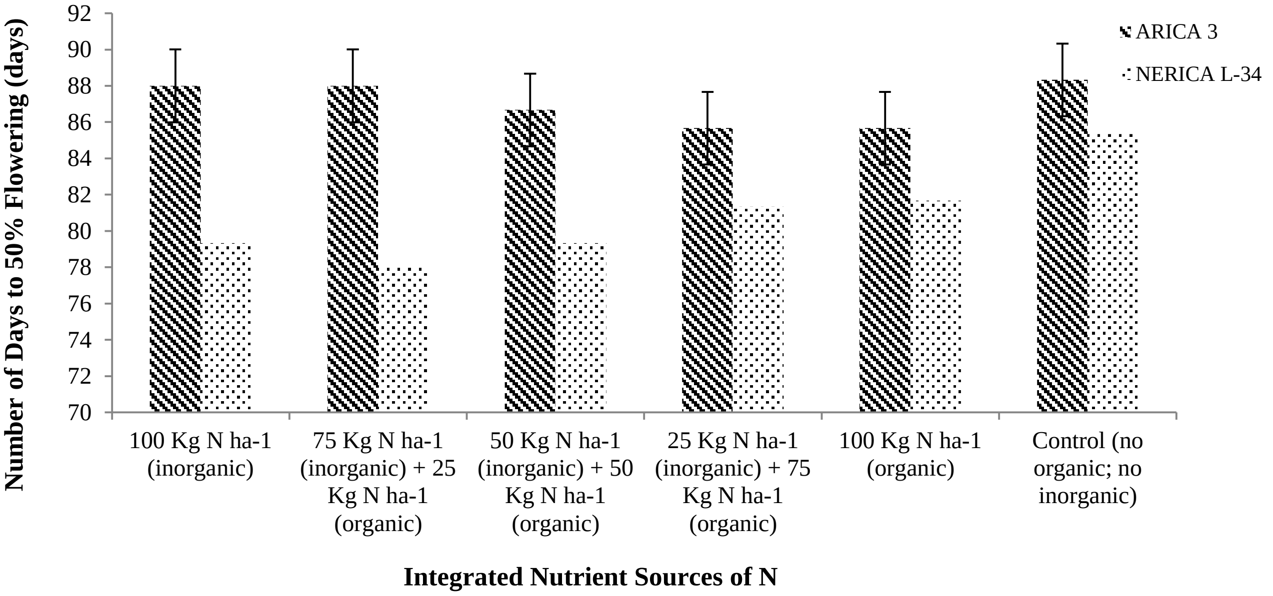

Figure 1: Variety × integrated nutrient sources of N effects on number of days to 50% flowering (days) in 2018
I = Standard Error of Difference at p≤0.05

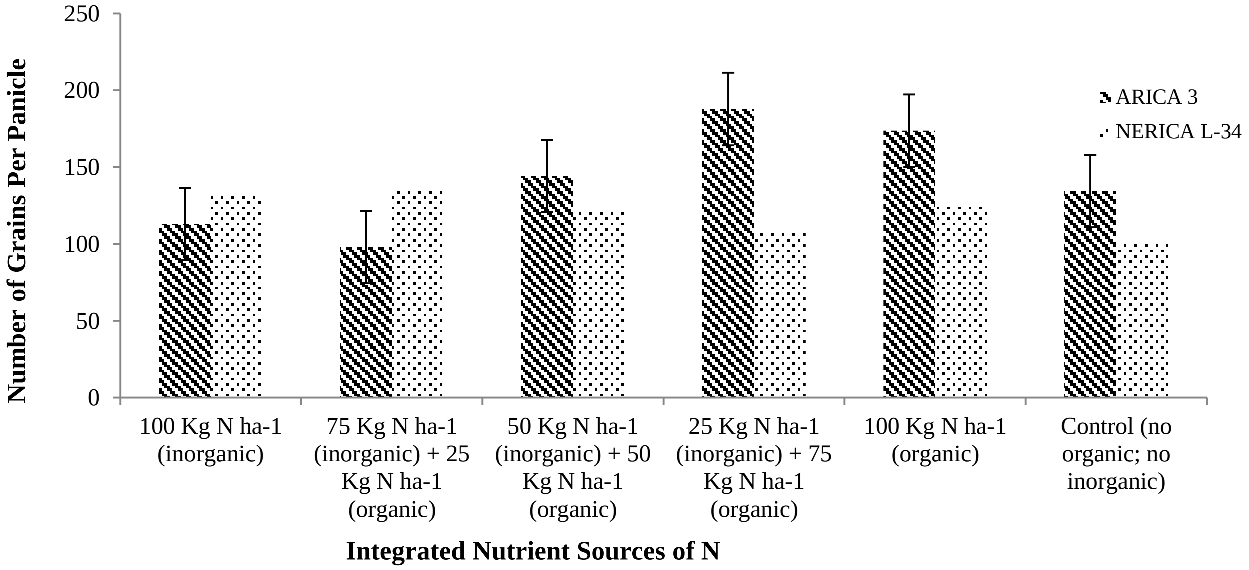

Figure 2: Variety × integrated nutrient sources of N effects on number of grains per panicle in 2018
I = Standard Error of Difference at p≤0.05

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Table 1: Effects of integrated nutrient sources of N on days to panicle extrusion (days), days to 50% flowering (days) and tillering duration (days) of lowland rice varieties in 2017, 2018 and 2019 in a derived savannah

Treatment	Days to Panicle Extrusion (days)			Days to 50%Flowering (days)			Tillering Duration (days)		
Varieties (V)	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**
ARICA 3	80.00	87.06	88.39	94.33a	102.61a	102.08	71.59	67.70	74.70
NERICA L-34	78.22	80.83	80.00	83.94b	87.28b	87.44	69.74	73.90	74.80
SED± (p≤0.05)	NS	NS	NS	7.29*	6.66**	NS	NS	NS	NS
Nutrient Sources (N)									
100 kg N ha^{-1} (inorganic)	81.17	83.67b	86.00ab	90.67	95.00b	94.17abc	75.56a	70.00	72.30
75 kg N ha^{-1} (inorganic) + 25 kg N ha^{-1} (organic)	78.83	83.00b	81.00b	87.67	92.83b	92.75bc	68.44bc	65.30	72.30
50 kg N ha^{-1} (inorganic) + 50 kg N ha^{-1} (organic)	78.50	83.00b	82.83b	88.83	92.83b	96.00ab	70.78abc	65.30	72.30
25 kg N ha^{-1} (inorganic) + 75 kg N ha^{-1} (organic)	77.83	83.50b	83.33b	90.00	94.67b	95.67abc	73.11ab	79.30	67.70
100 kg N ha^{-1} (organic)	78.83	83.67b	82.50b	88.67	93.67b	92.67c	70.78abc	65.30	70.00
Control (no organic; no inorganic)	79.50	86.83a	89.50a	89.00	100.67a	97.33a	65.33d	79.30	93.70
SED± (p≤0.05)	NS	1.02**	2.30*	NS	0.98**	1.45*	2.97*	NS	NS
V × N (p≤0.05)	NS	2.42**	NS	NS	2.00**	NS	NS	NS	NS

SED± - Standard Error of Difference, WAP – Weeks after Planting, * - Significant at p≤0.05, ** - Significant at p≤0.01, NS – Not Significant, Means with the same letter (s) in the same column are not significantly different at p≤ 0.05

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Table 2: Effects of integrated nutrient sources of N on panicle length (cm), number of grains per panicle and panicles per meter squared of lowland rice varieties in 2017, 2018 and 2019 in a derived savannah

Treatment	**Panicle Length (cm)**			**Number of Grains Per Panicle**			**Panicles Per Meter Squared**		
Varieties (V)	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**
ARICA 3	26.73	25.19	26.91	141.80	92.90	107.10a	215.90	186.40	78.80
NERICA L-34	26.65	23.69	26.25	120.20	94.40	94.10b	238.70	203.50	63.70
SED± ($p\leq0.05$)	NS	NS	NS	NS	NS	13.14*	NS	NS	NS
Nutrient Sources (N)									
100 kg N ha^{-1} (inorganic)	26.72	22.26b	26.15	122.10	91.30	105.10	230.80a	255.80a	79.30
75 kg N ha^{-1} (inorganic) + 25 kg N ha^{-1} (organic)	26.69	24.97a	27.24	116.50	90.30	99.40	218.10ab	207.80a	66.50
50 kg N ha^{-1} (inorganic) + 50 kg N ha^{-1} (organic)	26.42	25.67a	28.46	132.80	85.40	97.90	243.00a	224.90a	63.70
25 kg N ha^{-1} (inorganic) + 75 kg N ha^{-1} (organic)	26.97	26.94a	26.17	148.00	102.40	94.90	236.10a	197.50a	54.70
100 kg N ha^{-1} (organic)	27.56	25.48a	26.01	149.2	90.80	96.60	233.00a	177.80a	61.30
Control (no organic; no inorganic)	25.80	21.31b	25.46	117.4	101.60	109.70	202.80c	105.80b	102.20
SED± ($p\leq0.05$)	NS	1.20**	NS	NS	NS	NS	12.10*	34.25**	NS
V × N ($p\leq0.05$)	NS	NS	NS	23.56*	NS	NS	NS	NS	NS

SED± - Standard Error of Difference, * - Significant at $p\leq0.05$, ** - Significant at $p\leq0.01$, NS – Not Significant, Means with the same letter (s) in the same column are not significantly different at $p\leq 0.05$

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Table 3: Effects of integrated nutrient sources of N on 1000 grain weight (g), harvest index (%), days to accrual of yield (days) and panicle weight (g) of lowland rice varieties in 2017, 2018 and 2019 in a derived savannah

Treatment	**1000 Grain Weight (g)**			**Harvest Index (%)**			**Days to Accrual of Yield (days)**			**Panicle Weight (g)**		
Varieties (V)	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**
ARICA 3	26.92b	27.98b	28.80	36.80	30.7	46.9a	23.82	21.55a	13.69	16.60	14.88	18.85
NERICA L-34	30.86a	29.95a	27.01	47.30	31.1	16.8b	24.50	20.40b	7.44	19.97	14.93	19.70
SED± ($p \leq 0.05$)	2.02*	2.61*	NS	NS	NS	10.12**	NS	0.62*	NS	NS	NS	NS
Nutrient Sources (N)												
100 kg N ha^{-1} (inorganic)	29.40	27.87b	33.08	39.60	37.70	36.30	24.00c	20.33	8.17	16.52	11.99b	18.33
75 kg N ha^{-1} (inorganic) + 25 kg N ha^{-1} (organic)	28.10	30.93a	26.23	32.50	30.10	28.70	25.56a	20.19	11.75	16.37	14.83ab	20.34
50 kg N ha^{-1} (inorganic) + 50 kg N ha^{-1} (organic)	29.08	28.90ab	27.15	49.40	34.20	38.90	24.39ab	21.09	13.17	18.64	15.08ab	21.66
25 kg N ha^{-1} (inorganic) + 75 kg N ha^{-1} (organic)	29.43	29.99ab	26.80	48.00	27.80	47.10	23.56c	20.73	12.33	20.20	19.52a	18.74
100 kg N ha^{-1} (organic)	28.68	28.26b	27.28	47.70	45.50	49.20	23.94c	21.56	10.17	22.10	16.24ab	17.89
Control (no organic; no inorganic)	28.65	27.84b	26.88	35.00	9.90	40.10	23.53c	21.95	7.83	15.87	11.80b	18.68
SED± ($p \leq 0.05$)	NS	1.14*	NS	NS	NS	NS	0.57*	NS	NS	NS	2.33*	NS
V × N ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

SED± - Standard Error of Difference, * - Significant at $p \leq 0.05$, ** - Significant at $p \leq 0.01$, NS – Not Significant, Means with the same letter (s) in the same column are not significantly different at $p \leq 0.05$

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Table 4: Effects of integrated nutrient sources of N on grain yield (kg ha^{-1}) of lowland rice varieties in 2017, 2018 and 2019 in a derived savannah

Treatment	**Grain Yield (kg ha^{-1})**		
Varieties (V)	**2017**	**2018**	**2019**
ARICA 3	3572b	3858	7344
NERICA L-34	4010a	3039	5675
SED± (p≤0.05)	89.0*	NS	NS
Nutrient Sources (N)			
100 kg N ha^{-1} (inorganic)	3646	3019b	4738
75 kg N ha^{-1} (inorganic) + 25 kg N ha^{-1} (organic)	3722	3511ab	7365
50 kg N ha^{-1} (inorganic) + 50 kg N ha^{-1} (organic)	3827	4337ab	7455
25 kg N ha^{-1} (inorganic) + 75 kg N ha^{-1} (organic)	3843	4842a	7316
100 kg N ha^{-1} (organic)	3995	3421ab	6150
Control (no organic; no inorganic)	3711	1562c	6033
SED± (p≤0.05)	NS	695**	NS
V × N (p≤0.05)	NS	NS	NS

SED± - Standard Error of Difference, WAP – Weeks after Planting, * - Significant at p≤0.05, ** - Significant at p≤0.01, NS – Not Significant, Means with the same letter (s) in the same column are not significantly different at p≤ 0.05

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Conclusion

This study found that NERICA L-34 outperformed ARICA 3 in terms of physiological maturity, yield accrual, and 50% flowering in 2017 and 2018. When compared to when other nitrogen sources were used in 2018 and 2019, the application of 75 kg N ha^{-1} (inorganic) + 25 kg N ha^{-1} (organic) accelerated the attainment of physiological maturity, panicle extrusion, and the accrual of yield by rice plants. Furthermore, the 1000 grain weight and grain yield of rice plant NERICA L-34 were higher compared to ARICA 3 in 2017 and 2018. However, the longest, heaviest panicles and best grain yield were obtained in 2018 when 25 kg N ha^{-1} (inorganic) + 75 kg N ha^{-1} (organic) was applied in contrast to other integrated nitrogen sources.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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