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Comparison of Rice Yield among Farmer's Fertilizer Practices

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CNG: Interpretation of data and first draft
BOO: first draft and revised manuscript

Abstract

The study examined rice farmers' fertiliser purchasing behaviour and the impact of various fertiliser regimes on rice growth, yield, and grain nutrient content. Additionally, a field experiment using a randomised complete block design tested four treatments: no fertilizer *(control), NPK20:10:10 (farmer's practice), NPK20:10:10 + Single Superphosphate (SSP), and Urea + SSP. Results showed that while Urea + SSP improved growth metrics, NPK20:10:10+SSP achieved the highest grain yield (81 kg/plot) and 1000-seed weight (24.67 g), alongside elevated levels of iron and zinc, addressing both yield gaps and hidden hunger. These findings highlight the potential of phosphorus-enriched fertilizers to enhance productivity and nutritional outcomes in smallholder systems. The study underscores the importance of tailored, balanced fertilizer recommendations and sustainable interventions to address food security and malnutrition in Nigeria. Future research should explore these practices' scalability and long-term effects in diverse agrarian contexts.*

Introduction

Food security and malnutrition are pressing challenges in Nigeria, a country where a substantial portion of the population faces inadequate access to food and essential nutrients. United Nations World Food Programme (UNWFP, 2024) projects that about 33.1 million Nigerians will experience high levels of acute food insecurity during June-August 2025. According to the Integrated Food Security Phase Classification (IPC, 2024), nearly 5.4 million children in northern Nigeria are suffering from acute malnutrition. Addressing these challenges is vital to achieving Sustainable Development Goal 2 (UNDESA, 2023) and improving the health and well-being of Nigerians.

Rice (*Oryza sativa* L.), a staple food for over half of Nigeria's population, plays a pivotal role in addressing food insecurity. However, the country faces a significant rice yield gap, with current production levels unable to meet rising demand. Nigeria has become a major importer of rice, with import values exceeding $1.2 billion annually, and was expected to import about 2.3 million metric tonnes of rice in 2024 (USDA/GAIN, 2023). Bridging the rice yield gap through improved agronomic practices is therefore essential to reduce import dependency and ensure national food security.

One major factor contributing to the yield gap is the improper use of fertilizers by small-scale rice farmers, who dominate rice production in Nigeria (Iwuchukwu & Obazi, 2020; Iwuchukwu et al., 2022). Commonly used fertilizers, such as NPK 20:10:10, often fail to supply the balanced nutrients required for optimal rice growth and grain development. This nutrient imbalance reduces yields and compromises grain nutritional quality. Adding single superphosphate (SSP), a phosphorus-enriched fertilizer, to existing practices could address these issues. Phosphorus plays a critical role in root development, energy transfer, and grain formation, which are essential for both higher yields and improved grain quality (Chukwudi et al., 2024).

The addition of SSP to current fertilizer practices is hypothesized to improve rice yields and grain quality by addressing phosphorus deficiencies. Enhanced phosphorus availability promotes robust root systems and efficient nutrient uptake, leading to healthier plants capable of higher grain production (Chukwudi et al., 2024). Also, better nutrient partitioning during grain filling can increase the concentration of essential macronutrients and micronutrients in cereal grains (Chukwudi et al., 2022; Nwaobiala et al., 2022; Sun et al., 2023; Yan et al., 2020), potentially addressing both food security and hidden hunger.

To develop effective strategies for improving rice production and nutritional quality in Nigeria, it became necessary to evaluate how the current fertilizer practice of small-scale farmers compares with alternative nutrient management approaches that incorporate SSP. Understanding the benefits and trade-offs of these practices is crucial for making evidence-based recommendations that align with national food security and nutrition goals. The objective of this study is to assess the impact of different fertilizer practices on rice growth, yield, and grain nutritional quality. By comparing the farmer's traditional practice (*$NPK_{20:10:10}$*) with alternative treatments (*$NPK_{20:10:10}$ + SSP* and *Urea + SSP*), this study identified fertilizer regimes that can enhance rice productivity and contribute to improved nutritional outcomes.

Methodology

Experimental Design and Treatment Application

The field evaluation study employed a randomized complete block design with three replications. Four fertilizer treatments were tested, designed to compare the common farmer practice against alternative nutrient management strategies: (i) Control (no fertilizer), (ii) $NPK_{20:10:10}$ (farmer's practice), (iii) $NPK_{20:10:10}$ + SSP, and (iv) Urea + SSP. The field was manually prepared, and Faro 44, a popular rice variety cultivated in the region, was planted through the broadcasting methods. Standard agronomic practices, including irrigation, weeding, and pest management, were applied uniformly across all plots in a farmer's field in Omor, Ayamelum LGA Anambra State. This location is situated in the tropical rainforest agroecological zone, which is distinguished by bimodal rainfall patterns, with an annual precipitation of roughly 1500–2000 mm and average temperatures ranging from 25°C to 30°C.

Data Collection and Laboratory analysis

Data were collected on growth and yield parameters. Plant height, number of leaves, and number of tillers were measured at the end of the vegetative stage, while grain yield (kg/plot) and 1000-seed weight (g) were determined after harvest. The rice plants were harvested when fully ripe (3 months and 3 weeks), typically using the traditional method of hand cutting with the horticultural tool sickle. After harvesting, the rice plants were dried to reduce moisture content before threshing, which separated the grains from the stalks. Following threshing, winnowing was performed to separate the rice grains from the chaff and other debris by tossing the mixture in the air to let the wind blow away the lighter elements. The next step was milling, where the outer husk was removed to produce brown rice, and further milling removed the bran layer to produce white rice. Each treatment was harvested, processed, and packaged separately in preparation for laboratory analyses.

The protein (Method No. 978.04), fat (Method No. 930.09), fibre (Method No. 930.10), ash (Method No. 930.05), and moisture percentages of the proximate composition of the rice grains were analysed using the Association of Official Analytical Chemists (AOAC) methods (AOAC, 2023). The carbohydrate content was obtained by subtracting the sum values of protein, fat, fibre, ash, and moisture from 100. The samples used for ash determination were also utilized in the mineral determinations, encompassing the analysis of various elements such as iron (Fe), phosphorus (P), copper (Cu), manganese (Mn), and zinc (Zn), which were analysed using the atomic absorption spectrophotometric method. Metals, including calcium (Ca) and magnesium (Mg), were determined through EDTA titration. Sodium (Na) and potassium (K) were determined using a flame photometer following the AOAC official method (AOAC, 2005). All laboratory analyses were conducted in triplicate, each with its corresponding calibration curve and a blank sample.

Statistical Analysis

Rice growth, yield, and nutritional data were subjected to analysis of variance to determine the significance of treatment effects using GenStat 11th edition software. Mean separation was performed using the Duncan's Multiple Range Test at a 5% probability level, and treatment differences were denoted by distinct alphabets.

Ethical Considerations and Informed Consent

The experiment was conducted in collaboration with local rice farmers, ensuring alignment with traditional practices while introducing novel nutrient management strategies. Farmers' consent was obtained before the commencement of the study. Farmers were informed about the study objectives and their rights to withdraw from the study at any time they felt uncomfortable.

Results and Discussion

Growth and Yield Parameters

The growth and yield parameters of rice under different fertilizer treatments are summarized in Figure 1. Plant height was significantly affected by the treatments, with the highest mean (19.19 cm) recorded for *Urea* + *SSP*, which differed significantly from all other treatments (p < 0.05). This was followed by $NPK_{20:10:10}$ + *SSP* (16.88 cm) and $NPK_{20:10:10}$ (16.57 cm), while the control recorded the lowest plant height (12.54 cm). The number of leaves and number of tillers were also highest in the *Urea* + *SSP* treatment (7.8 and 3.2, respectively), which was significantly greater than other treatments. Among the fertilizers tested, the $NPK_{20:10:10}$ + *SSP* treatment resulted in intermediate values for both parameters (4.7 and 1.5, respectively), while the control showed the lowest performance in terms of the number of leaves (2.7) and number of tillers (1.0).

The observed differences in growth parameters among the fertilizer treatments underscore the importance of nutrient management in optimizing rice performance. The significantly greater plant height, number of leaves, and number of tillers recorded in the *Urea* + *SSP* treatment suggest that this combination provided a more favourable nutrient environment compared to the farmer's practice ($NPK_{20:10:10}$ alone). Nitrogen from urea likely supported vigorous vegetative growth through enhanced chlorophyll synthesis and photosynthetic efficiency, while phosphorus from SSP contributed to improved root development and energy transfer. These results align with earlier studies that demonstrated the synergistic effects of nitrogen and phosphorus on cereal crops' performance (Blandino et al., 2022; Li et al., 2023).

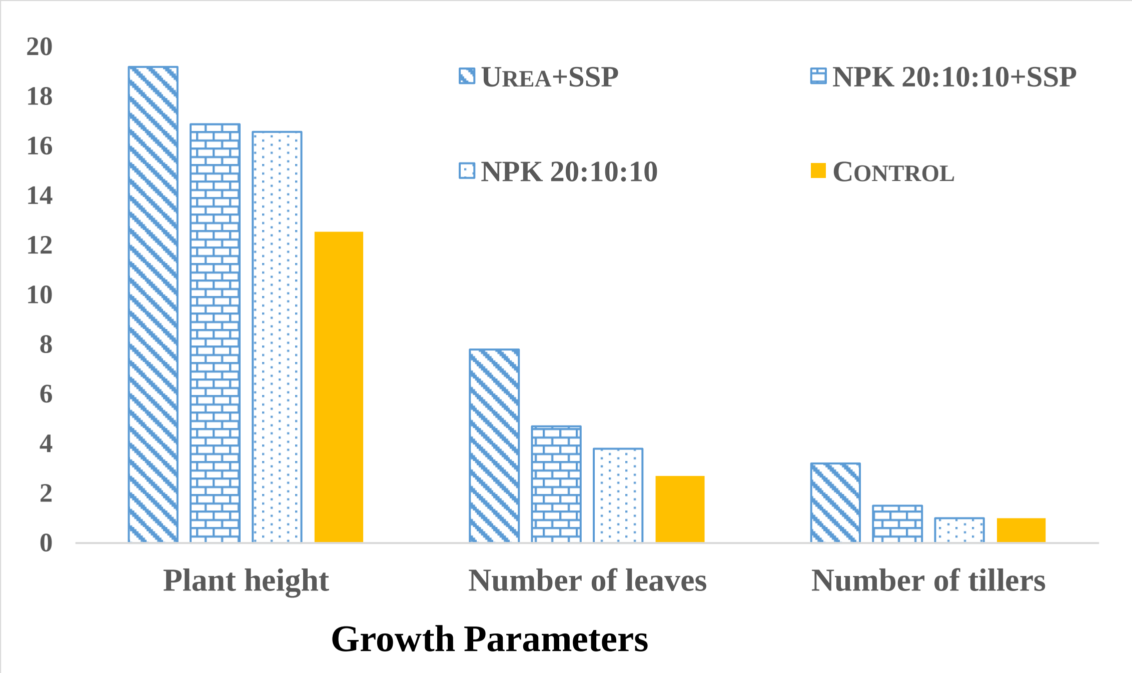

Figure 1: Growth response of Faro 44 to different fertilizer treatments

Grain weight per plot did not significantly differ among fertilizer treatments, with values ranging from 65.00 to 80.00 kg across treatments, except for the control, which recorded the lowest value of 50.00 kg (Figure 2). Similarly, the 1000-seed weight was highest under the $NPK_{20:10:10}$ + *SSP* treatment (24.67 g), followed by $NPK_{20:10:10}$ (23.00 g) and *Urea* + *SSP* (22.40 g). The control treatment exhibited the lowest 1000-seed weight (22.13 g).

The superior vegetative growth observed with *urea* + *SSP* did not translate into a proportionate increase in grain yield or 1000-seed weight. Compared to the farmer's practice, *urea* + *SSP* resulted in slightly lower 1000-seed weight (22.40 g vs. 23.00 g in $NPK_{20:10:10}$). This suggests a potential trade-off where excessive vegetative growth under *Urea* + *SSP* may have limited assimilate allocation to reproductive structures, resulting in suboptimal grain filling. Luxurious vegetative growth can reduce grain yield if it extends the vegetative phase, but it can also buffer against post-silking water and nitrogen stress in some cases (Hütsch & Schubert, 2023). By contrast, the addition of SSP to the farmer's practice ($NPK_{20:10:10}$ + *SSP*) enhanced both grain yield and 1000-seed weight (81.00 kg and 24.67 g, respectively). This indicates that supplementing the farmer's practice with phosphorus further optimized assimilate partitioning, ensuring better reproductive performance.

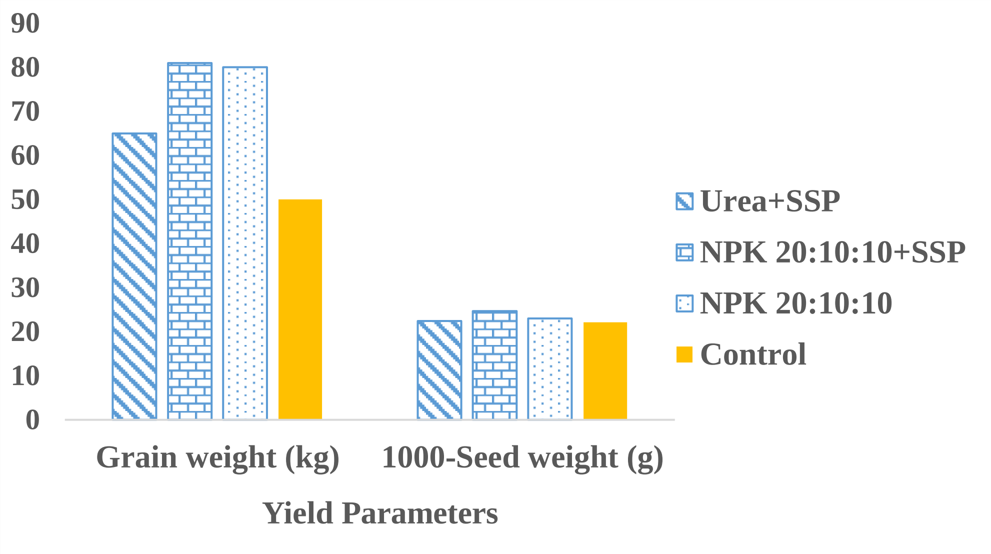

Figure 2. Yield response of Faro 44 to different fertilizer treatments

Proximate and Mineral Contents of Rice Grains

The proximate composition and mineral contents of the rice grains are presented in Table 1. The ash content was highest in rice treated with $NPK_{20:10:10}$ (1.25%), significantly different from other treatments (p < 0.05). In contrast, the lowest ash content (0.30%) was observed in $NPK_{20:10:10}$ + *SSP*. Carbohydrate content (CHO) was significantly higher in $NPK_{20:10:10}$ (80.25%) compared to other treatments, while *Urea + SSP* resulted in the lowest CHO content (78.65%). Fat content ranged from 1.00% to 1.35%, with the highest value recorded in $NPK_{20:10:10}$ + *SSP* and the lowest in both *Urea + SSP* and $NPK_{20:10:10}$. Treatments did not significantly affect fibre content, which ranged from 0.50% to 0.60% across treatments. The control recorded the highest moisture content (9.55%), comparable to other treatments except $NPK_{20:10:10}$ (7.50%).

Table 1: Influence of fertilizer treatment on proximate composition of Faro 44 rice

Treatment	Ash (%)	CHO (%)	Fats (%)	Fibre (%)	Moisture (%)	Protein (%)
Urea + SSP	0.50^{bc}	78.65^{b}	1.00^{b}	0.60^{a}	9.85^{a}	9.40^{a}
$NPK_{20:10:10}$ + SSP	0.30^{d}	79.04^{b}	1.35^{a}	0.50^{a}	9.55^{a}	9.23^{ab}
$NPK_{20:10:10}$	1.25^{a}	80.25^{a}	1.00^{b}	0.60^{a}	7.50^{b}	9.40^{a}
Control	0.75^{b}	79.29^{b}	1.10^{b}	0.50^{a}	9.55^{a}	8.80^{b}

Similar superscript alphabets in a column are not significantly different at 5% probability level

Table 2: Influence of fertilizer treatment on mineral content of Faro 44 rice

Treatment	Na (ppm)	Ca (ppm)	Mg (ppm)	K (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)
Urea + SSP	2.30^{a}	17.33^{b}	8.65^{a}	2.39^{a}	1.71^{ab}	0.32^{a}	0.03^{a}	0.09^{c}
$NPK_{20:10:10}$ + SSP	1.68^{ab}	15.33^{c}	7.36^{b}	0.85^{b}	1.46^{b}	0.30^{a}	0.00^{b}	0.16^{b}
$NPK_{20:10:10}$	2.23^{a}	22.00^{a}	8.57^{a}	0.15^{c}	1.83^{ab}	0.23^{b}	0.03^{a}	0.22^{a}
Control	1.41^{b}	16.00^{bc}	8.30^{a}	1.39^{b}	2.20^{a}	0.14^{b}	0.00^{b}	0.12^{bc}

Similar superscript alphabets in a column are not significantly different at 5% probability level

Regarding mineral content, Na, Ca, and Mg levels were highest in *$NPK_{20:10:10}$*, with values of 2.23 ppm, 22.00 ppm, and 8.57 ppm, respectively (Table 2). The *Urea + SSP* and control treatments exhibited lower concentrations for these minerals. Additionally, Zn and Cu were significantly affected by treatments, with the highest Zn (0.22 ppm) and Cu (0.23 ppm) levels recorded in *$NPK_{20:10:10}$*. The control treatment demonstrated lower concentrations of Fe (1.39 ppm), Zn (0.14 ppm), and Mn (0.12 ppm), while *$NPK_{20:10:10}$ + SSP* resulted in the highest Fe content (2.20 ppm).

The relationship between 1000-seed weight and grain nutrient composition also differed between treatments. The higher 1000-seed weight observed in *$NPK_{20:10:10}$ + SSP* was associated with a dilution effect, where increased carbohydrate storage led to relatively lower mineral concentrations. Conversely, the lower 1000-seed weight in *Urea + SSP* coincided with a concentration effect, resulting in higher mineral densities. These findings suggest that while the farmer's practice supported moderate grain filling, the addition of SSP either enhanced yield or contributed to mineral density shifts. Research has shown that nutrient distribution in cereal grains is influenced by the interplay between yield and nutrient accumulation (Chukwudi et al., 2022; Guo et al., 2020).

From a practical perspective, these results highlight the potential benefits of modifying the farmer's current fertilizer practice to improve both yield and grain nutritional quality. The farmer's practice (*$NPK_{20:10:10}$*) alone yielded acceptable grain weight (80.00 kg) and 1000-seed weight (23.00 g), but the addition of SSP further enhanced these metrics while maintaining adequate nutrient composition. Importantly, the elevated mineral concentrations under *Urea + SSP* indicate its potential to address hidden hunger, offering a strategy to increase micronutrient availability in rice grains, albeit with lower yield performance.

This study demonstrates the value of integrating balanced fertilizer regimes to simultaneously address food security and hidden hunger. While the farmer's practice provides a reasonable baseline, adding phosphorus-enriched fertilizers like SSP enhances both productivity and grain quality. These findings underscore the importance of evidence-based recommendations to improve nutrient management practices in smallholder farming systems. Future research should focus on the long-term economic and environmental sustainability of such interventions to ensure their practicality and adoption at the farm level.

Conclusion and Recommendations

This study highlights the significant impact of fertilizer type on rice growth, grain yield, and nutritional quality. The farmer's practice (*$NPK_{20:10:10}$*) demonstrated moderate productivity, while the addition of SSP (*$NPK_{20:10:10}$ + SSP*) enhanced both grain yield and 1000-seed weight, striking a balance between food security and nutritional quality. In contrast, *urea + SSP* promoted vigorous vegetative growth and higher mineral density but did not optimize grain yield, underscoring the trade-offs between vegetative growth and reproductive performance. These findings suggest that integrating phosphorus-enriched fertilizers, such as SSP, into existing farmer practices can enhance yield and grain nutrient quality, offering a pathway to address both food security and hidden hunger. Policymakers should prioritize the dissemination and subsidization of balanced fertilizer formulations, particularly for smallholder farmers, to ensure sustainable and equitable access to improved practices. Future research should focus on the long-term agronomic and economic viability of these fertilizer regimes, as well as their environmental impacts, to inform scalable interventions that support sustainable rice production and nutritional outcomes.

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