# INTERACTION EFFECTS OF NITROGEN, PHOSPHORUS, AND ZINC FERTILIZATION ON GROWTH, YIELD, AND NUTRIENT CONTENTS OF LOWLAND RICE VARIETIES

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**Abstract**. This study explored the effects of nitrogen, phosphorus, and zinc fertilization on two lowland rice varieties, NERICA L-34 and ARICA-3, in a screenhouse experiment at the Federal University of Agriculture, Abeokuta, Nigeria. Two levels each of nitrogen (0 and 120 kg ha-1), phosphorus (0 and 60 kg ha-1), and zinc (0 and 10 kg ha-1) were applied. Results indicated that the (N120 P60 Zn10) treatment produced the highest panicle weight (28.3g), grains per panicle (202.2), and 1000 grain weight (27.1g), leading to superior grain yield, dry weight, and harvest index. ARICA-3 showed the best panicle weight under specific treatments, while NERICA L-34 achieved the highest grain yield with other nutrient combinations. The study highlights the need for tailored nutrient management based on varietal responses and genetic factors to enhance rice productivity and address nutrient deficiencies.

**Keywords**: Grain yield, Harvest index, Nutrient, Rice, Screen-house

## INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple crops worldwide, providing a primary food source for over half of the world's population. Rice is a member of the Poaceae family and is believed to have originated in the river valleys of China and Southeast Asia (Zhang *et al.*, 2014). It is also a major staple crop with more than 50 kg of rice being consumed per capita per year worldwide (FAO, 2021). Rice, a grain cereal, is an important source of nutrition for the world human population, providing more than 20% of the calories consumed worldwide (Kenmore, 2003). It has the second-highest production worldwide, after maize (Mohanty *et al.*, 2013).

Soil fertility in Nigeria has progressively declined because of increased pressure on land resources arising from rapid population expansion, forcing farmers to adopt continuous cropping while fertilizer use is low (Ekeleme *et al.*, 2008). In nutrient management, fertilizer plays a greater role mainly owing to its increased need for higher productivity and maintaining soil nutrient reserve on account of nutrient mining practices. Nutrient mining can occur as a result of imbalanced and inadequate use of nutrients, high yield of crops and intensive crop rotation such as rice-wheat leads to more removal and negative balance of those nutrients in the soil which were not added to meet crop demand (Chand and Pavithra 2015).

The human body needs micronutrients for proper growth and development and to maintain good health (Maret 2017; Palanog *et al.*, 2019). However, deficiencies in these elements and associated health risks are commonly reported in all age groups in the developing world (Caulfeld *et al.*, 2006). An estimated one-third of the global population suffers from micronutrient malnutrition, mainly because of the large dependence on cereal staples for daily nutritional needs without access to a diversified diet and supplementation (Ritchie *et al*. 2018).

The urgent need to address micronutrient malnutrition has been widely recognized globally; (Hanieh *et al*. 2020). Among the micronutrients, zinc (Zn) is most essential for vital organs, enzymatic activity, tissue growth and development, cognitive function and immunity. There is therefore a need for a regular daily supply of Zn in the required quantity to have healthy and productive populations (Prasad *et al*. 2014; Chasapis *et al*. 2020). However, an estimated two billion people suffer from Zn deficiency-related health consequences and most of them are resource-poor urban and rural dwellers (Rampa *et al*. 2020).

The yield of rice in Nigeria has been dramatically reduced by low soil productivity which is the capacity of a soil to produce a certain yield of crops or other plants under a defined set of management practices (Wilfred, 2006). Soil fertility is lost mainly because of environmental factors such as erosion which is prevalent in Sub-Saharan Africa as a result of the heavy downpour of rainfall and deforestation (Obalum *et al.*, 2012). This has made the application of soil amendments like fertilizer a must for optimum output. While there is extensive work on N.P.K application in rice production, little has been done in determining its interaction with Zn an essential micronutrient of great importance in rice production, which has necessitated this study. Thus, there is a need to determine the effects of N, P, and Zn on the growth and yield of lowland rice varieties.

## MATERIALS AND METHODS

The experiment was carried out at the college of plant sciences and crop production screen house of the Federal University of Agriculture, Abeokuta (FUNAAB). Coordinates: (7.2437° N, 3.3433° E), altitude of 146m (479 feet) above sea level. Soil was loamy sand (Typic Ustochrept), in texture with a mechanical composition (Bouyoucos 1962) of 79.3% sand, 18.9% silt and 1.9% clay. The experimental soils had 0.864% organic C (Walkley and Black 1934), 0.221% alkaline permanganate-oxidizable N (Subbiah and Asija 1956), 18.95 mg/kg available P (Olsen’s method) (Jackson 1973), 0.528 cmol/kg N ammonium acetate exchangeable K (Hanway and Heidel 1952), and 2.81 mg/kg available zinc (Zn) (Lindsay and Norvell 1978). The pH of the soil was 6.89 (1:2.5 soil and water ratio) (Elico pH meter, Piper 1950) (Table 1). The experiment was conducted in pots in completely randomized design with two rice varieties (NERICA L-34 and ARICA-3) and eight nutrient application rates. These eight treatments comprised of Control, N120 P0 Zn0, N120 P60 Zn0, N120 P60 Zn10, N120 P0 Zn10, N0 P0 Zn10, N0 P60 Zn10 and N0 P60 Zn0. All fertilizer was applied at 14 days after transplanting (DAT) according to the treatment details. Each treatment was replicated three times. Each pot containing 7 kg soil was planted with one seedling of rice after applying water to bring soil moisture suitable for sowing operation. Anaerobic condition was maintained throughout the crop growth in both rice varieties. The following data were collected pre-harvest at 70 DAT:

Chlorophyll content: the amount of chlorophyll in the leaves was determined using a SPATHE LEAF CHL PLUS chlorophyll meter (131 - 50 ver 1.0). To determine the chlorophyll content of each leaf of the tagged plant, the leaves were positioned at the reading point of the chlorophyll meter. Plant height: the plant height was measured by using a meter rule and was taken by measuring from the base of the plant to the tip of the longest leaf. Number of tillers per pot: the number of tillers in a pot was counted and recorded. Panicle weight: harvested panicle was weighed using a sensitive weighing scale in a laboratory. Total dry weight: the straw were oven-dried and the weight was measured using a sensitive scale in a laboratory

Panicle length: Panicle length was measured using a tape rule. Number of grain per panicle: the number of grains per panicle was counted. Grain weight: the weight of harvested grain was measured using a sensitive weighing scale in a laboratory. 1000 grain weight: the weight of 1000 grains was measured using a sensitive weighing scale in a laboratory. The N concentration was determined by Kjeldahl method and P and K concentration by wet di-acid digestion method using spectrophotometer and flame photometer, respectively. Zn concentration was determined by atomic absorption spectrophotometer. Data collected were subjected to Analysis of Variance (ANOVA) and the means of significant treatment were separated using LSD at 5% probability level ($P \leq 0.05$). The statistical package used is GENSTAT 12th edition.

Table 1

Physical and chemical properties of the soil of the experimental site before planting

| Soil properties | |
|---|---|
| pH | 6.89 |
| %N | 0.22 |
| %Organic carbon | 0.86 |
| %Organic matter | 1.49 |
| Available phosphorus | 18.95 mg/kg |
| Na | 0.32 cmol/kg |
| K | 0.53 cmol/kg |
| Ca | 0.32 cmol/kg |
| Mg | 0.36 cmol/kg |
| Exchangeable acidity | 0.40 cmol/kg |
| sand | 79.20% |
| Clay | 1.90% |
| Silt | 18.90% |
| Fe | 12.57 mg/kg |
| Zn | 16.10 mg/kg |
| Cu | 2.81 mg/kg |
| Mn | 1.83 mg/kg |
| ECEC | 1.93 cmol/kg |

## RESULTS AND DISCUSSIONS

### Growth Attributes

Variety had no significant influence on plant height, number of leaf and number of tillers at 70 DAT and at harvesting. Plant height, number of leaf and number of tillers were significantly influenced by nutrient at 70 DAT and at harvest (Table 2). Application of N120, P60 and Zn10 produced the tallest plant compared to other treatments and control. Also at 70 DAT and at harvest, application of N120, P60 and Zn0 resulted in taller plants than other treatments and control except the tallest. Similar number of leaf was observed on the pots treated with N120, P60 and Zn10 as well as N120, P60 and Zn0 which was significantly higher than N0, P0 and Zn10, N0, P60 and Zn0 and the control at 70 DAT and at harvest.

At 70 DAT, application of N120, P60 and Zn10, and N120, P60 and Zn0 produced similar number of tillers and significantly higher than other treatments and control. At harvest, highest number of tillers was observed on the plot treated with N120, P60 and Zn10. (Table 2). Also at harvest, similar number of tillers were observed with application of N120, P60 and Zn0, and N120, P0 and Zn10 and was significantly higher than all other treatments and the control. All growth attributes studied was strongly influenced by N application, leading to significantly higher values of growth attributes than rest N-omitted treatments and same was reflected in all yield-attributing characters. Among the N-applied treatments, higher values for all growth and yield attributing characters were found in the treatments containing application of N, P and Zn which was followed by treatments having N and P application and N and Zn application.

Table 2

Effects of lowland rice varieties and nutrient application rates on rice growth attributes.

| Treatment | Plant height (cm) | | Number of leaf | | Number of tillers | |
|---|---|---|---|---|---|---|
| | 70 DAT | At harvest | 70 DAT | At harvest | 70 DAT | At harvest |
| Varieties (V) | | | | | | |
| NERICA L-34 | 104.7 | 124.7 | 10.4 | 11.6 | 6.2 | 6.6 |
| ARICA-3 | 104.4 | 125.6 | 11.8 | 13.3 | 5.9 | 6.6 |
| LSD ($p<0.05$) | ns | ns | ns | ns | ns | ns |
| Nutrients (N) | | | | | | |
| Control | 100.1 | 113.0 | 7.8 | 7.8 | 4.0 | 4.0 |
| N120, P0, Zn0 | 101.9 | 125.7 | 11.3 | 12.5 | 6.5 | 7.0 |
| N120, P60, Zn0 | 111.0 | 133.9 | 13.8 | 14.8 | 8.0 | 8.0 |
| N120, P60, Zn10 | 124.8 | 140.2 | 13.8 | 17.3 | 8.0 | 9.8 |
| N120, P0, Zn10 | 104.5 | 130.7 | 12.8 | 15.0 | 7.0 | 8.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| N0, P0, Z10 | 99.3 | 115.8 | 9.8 | 10.0 | 5.0 | 5.0 |
| N0, P60, Zn10 | 96.2 | 121.0 | 10.0 | 12.0 | 5.0 | 6.0 |
| N0, P60, Zn0 | 98.5 | 120.8 | 9.5 | 10.0 | 4.8 | 5.0 |
| LSD (p<0.05) | 5.10 | 4.76 | 2.97 | 3.16 | 0.44 | 0.60 |
| V x N | ns | 6.76 | ns | ns | 0.60 | ns |

ARICA-3 with the application of N120, P60 and Zn10 produced the tallest plant statistically not significant from the height of NERICA L-34 with the application of N120, P60 and Zn10. Also, application of N120, P60 and Zn10 irrespective of rice variety produced significantly taller rice plants than the control, N0, P0 and Zn10 irrespective of rice variety (Figure 1). In Figure 2, NERICA L-34 treated with N120, P60 and Zn0 produced the tallest rice plants, while the shortest plants were observed on the control plots irrespective of the variety. Generally, application of N fertilizer produced taller rice plants and when N is not applied.

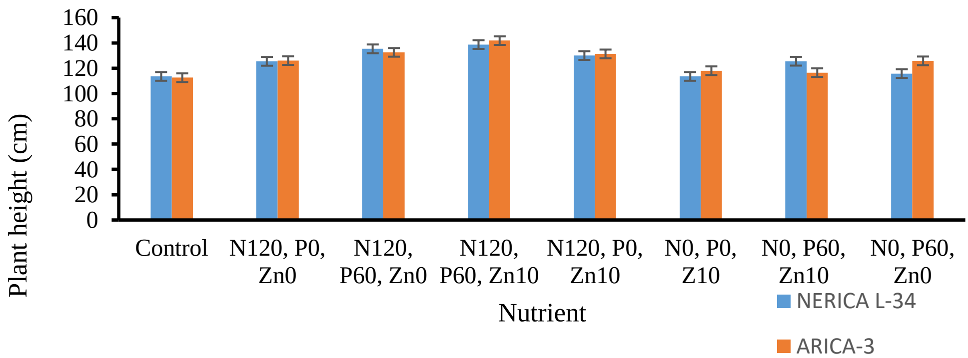


Fig. 1. Interaction of lowland rice varieties and nutrient application rate on plant height (cm) at harvest

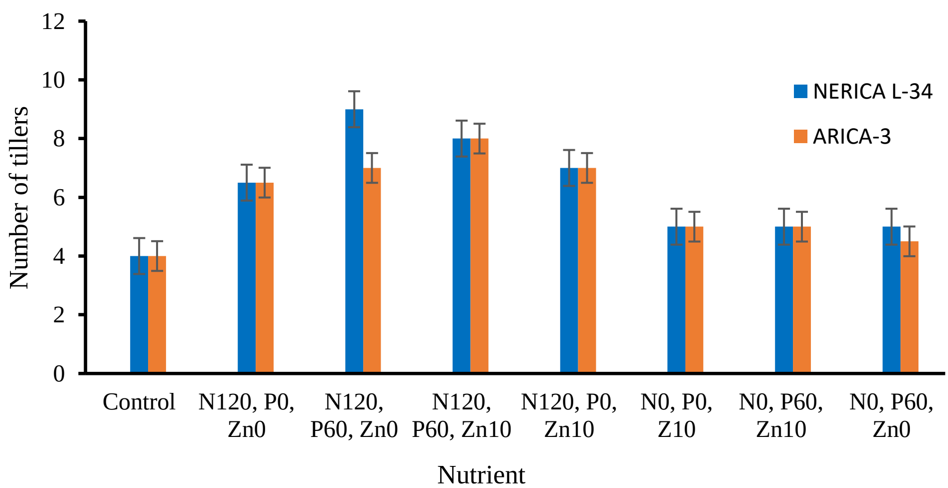


Fig. 2. Interaction of lowland rice varieties and nutrient application rate on number of tillers

**Yield and Yield Attributes**

Variety had no significant influence on the yield attributes (Table 3). However, application of nutrients significantly influenced the yield attributes. The highest and lowest panicle weight, number of grain per panicle, panicle length and 1000 grain weight was observed with the application of N120, P60 and Zn10, and control, respectively (Table 3). Grain yield, total dry weight and harvest index differed significantly among N-applied treatments (Table 4). Highest grain yield was observed on the pot treated with N120, P60 and Zn10 which was statistically significant than all other treatments applied and control. Furthermore, application of N120, P60 and Zn10 and N120, P60 Zn0 produced similar total dry weight which was significantly higher than other treatments applied. It was observed that pots with no N application produced similar harvest index which was significantly higher than those pots treated with N irrespective of other P and Zn (Table 4).

The highest panicle weight was observed in ARICA-3 treated with N120, P60 and Zn10, while the lowest values were recorded on the control irrespective of the rice varieties (Figure 3). However, in Figure 4, NERICA L-34 produced the highest grain yield with the application of N120, P60 and Zn10, while the lowest values were recorded on the controls.

Table 3

Effects of lowland rice varieties and nutrient application rate on lowland rice yield attributes.

| Treatment | Panicle weight (g) | Number of grain per panicle | Panicle length (cm) | 1000 grain weight (g) |
|---|---|---|---|---|
| Varieties (V) | | | | |
| NERICA L-34 | 19.9 | 132.5 | 25.5 | 24.0 |
| ARICA-3 | 20.0 | 130.4 | 25.4 | 24.2 |
| LSD (p<0.05) | ns | ns | ns | ns |
| Nutrients (N) | | | | |
| Control | 13.6 | 95.0 | 22.2 | 18.5 |
| N120, P0, Zn0 | 20.6 | 125.2 | 25.8 | 25.4 |
| N120, P60, Zn0 | 24.5 | 150.5 | 27.6 | 28.0 |
| N120, P60, Zn10 | 28.3 | 202.2 | 28.7 | 29.5 |
| N120, P0, Zn10 | 21.7 | 134.0 | 26.4 | 27.1 |
| N0, P0, Z10 | 17.3 | 117.2 | 24.8 | 21.0 |
| N0, P60, Zn10 | 16.9 | 111.2 | 24.2 | 21.5 |
| N0, P60, Zn0 | 16.7 | 116.2 | 24.1 | 21.5 |

| | | | | |
|---|---|---|---|---|
| LSD (p<0.05) | 1.55 | 11.67 | 0.94 | 1.48 |
| V x N | 2.27 | ns | ns | ns |

Table 4

Effects of lowland rice varieties and nutrient application rate on grain yield, total dry weight and harvest index

| Treatment | Grain yield (g/plant) | Total dry weight (g) | Harvest Index |
|---|---|---|---|
| Varieties (V) | | | |
| NERICA L-34 | 23.7 | 72.4 | 26.8 |
| ARICA-3 | 22.2 | 68.1 | 24.8 |
| LSD (p<0.05) | ns | ns | ns |
| Nutrients (N) | | | |
| Control | 15.6 | 34.5 | 36.1 |
| N120, P0, Zn0 | 23.5 | 56.4 | 21.9 |
| N120, P60, Zn0 | 26.1 | 106.7 | 14.4 |
| N120, P60, Zn10 | 33.9 | 120.1 | 14.8 |
| N120, P0, Zn10 | 24.0 | 65.3 | 17.8 |
| N0, P0, Z10 | 20.9 | 57.4 | 36.9 |
| N0, P60, Zn10 | 20.4 | 62.9 | 36.1 |
| N0, P60, Zn0 | 19.2 | 58.6 | 28.1 |
| LSD (p<0.05) | 1.92 | 22.51 | 7.23 |
| V x N | 2.94 | ns | ns |

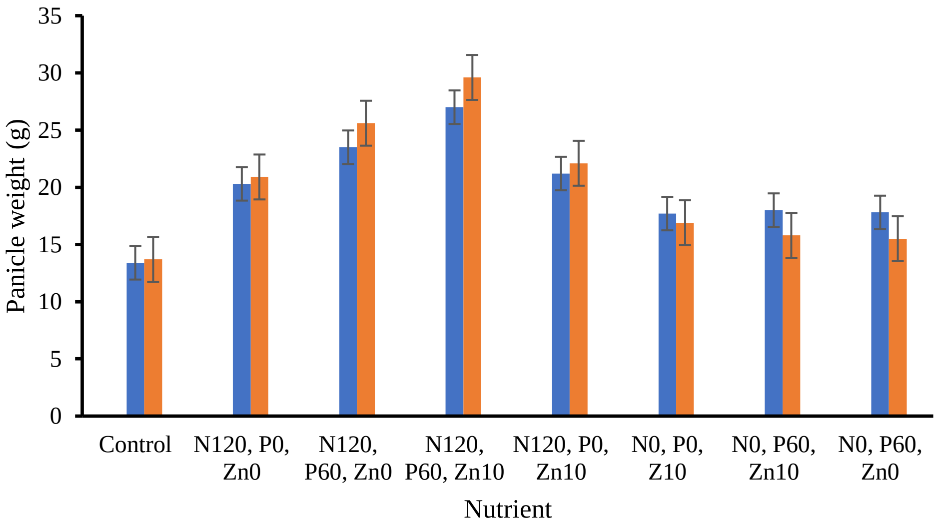


Fig. 3. Interaction of lowland rice varieties and nutrient application rate on panicle weight (g)

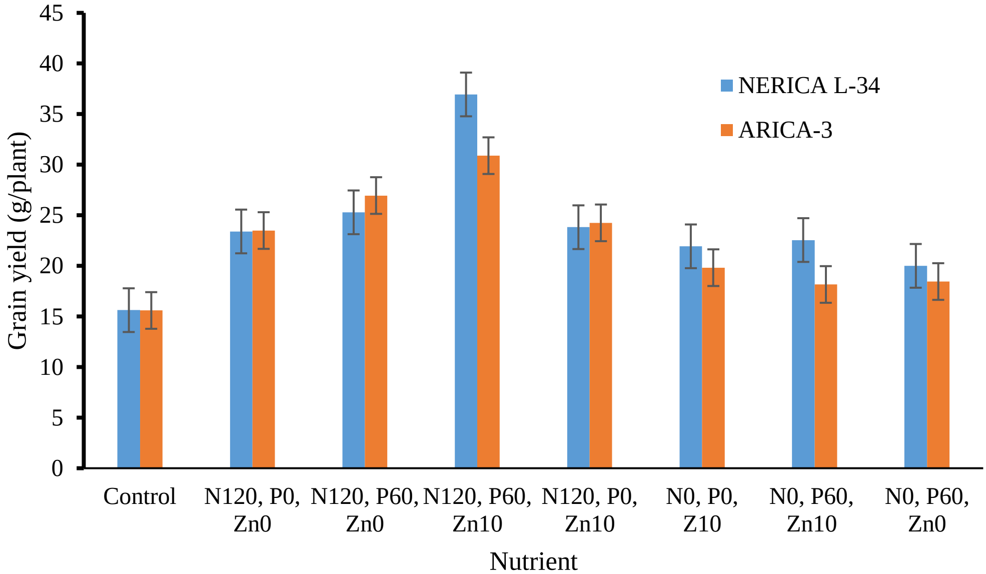


Fig. 4. Interaction of lowland rice varieties and nutrient application rate on grain yield

***Nutrients Uptake.***

Rice variety had significant effect on P and Zn uptake with ARICA-3 having higher values than NERICA L-34 (Table 5). Application of N120 P60 Zn10 resulted in maximum N and P uptake, which was significantly higher than N120 P0 Zn10, N0 P0 Zn10, N0 P60 Zn10, N0 P60 Zn0 (Table 5). The highest Zn uptake was recorded with application of N120 P60 Zn10, the lowest uptake was recorded with application of N0 P60 Zn0. Generally application of Zn based fertilizers resulted in significantly higher Zn uptake than zero application of Zn (Table 5).

Table 5

Effects N, P and Zn treatment combination on nutrient uptake in grain

| Varieties | %N | P mg | Zn |
|---|---|---|---|
| NERICA L-34 | 3.79 | 0.16 | 1.77 |
| ARICA-3 | 4.06 | 0.18 | 1.90 |
| LSD | ns | 0.004 | 0.021 |
| | | | |
| Nutrients (N) | | | |
| Control | 3.88 | 0.18 | 1.92 |
| N120, P0, Zn0 | 3.87 | 0.17 | 1.82 |
| N120, P60, Zn0 | 3.96 | 0.17 | 1.69 |
| N120, P60, Zn10 | 4.23 | 0.18 | 2.00 |

| | | | |
|---|---|---|---|
| N120, P0, Zn10 | 3.73 | 0.16 | 1.82 |
| N0, P0, Zn10 | 3.76 | 0.17 | 1.89 |
| N0, P60, Zn10 | 3.75 | 0.17 | 1.94 |
| N0, P60, Zn0 | 4.11 | 0.17 | 1.59 |
| LSD | 0.243 | 0.007 | 0.042 |
| V x F | 0.687 | 0.010 | 0.060 |

## DISCUSSION

### Growth Attributes

The findings of this study revealed that the variety of rice did not have a significant influence on plant height, number of leaves, and number of tillers at 70 days after transplanting (DAT) and at harvest. This suggests that the genetic variation among the tested varieties did not play a major role in determining these growth attributes. However, the application of nutrients had a significant impact on plant height, leaf number, and tiller number at both 70 DAT and harvest. This finding supports previous research, which suggested that different rice varieties may respond similarly to specific nutrient treatments in terms of plant height (Huang et al., 2016).

Among the nutrient treatments, the application of N120, P60, and Zn10 resulted in the tallest plants compared to other treatments and the control. This indicates that nitrogen, phosphorus, and zinc are essential nutrients for promoting vertical growth in rice plants. Similar results were reported by previous studies (Smith, 2021; Johnson and Brown, 2019), further supporting the importance of these nutrients in enhancing plant height. Furthermore, the number of leaves was significantly higher in pots treated with N120, P60 and Zn10, N120 and P60, N120 and Zn10, and N120 compared to other treatments and the control group at 70 DAT. This demonstrates that the combined application of nitrogen, phosphorus, and zinc positively influenced leaf development. Similar findings were reported by other researchers (Johnson et al., 2020; Brown et al., 2018), indicating that these nutrients play a crucial role in vegetative growth. Higher number of leaves and tillers with application of N fertilizers compared to the control could be attributed to availability of right nutrition and in right proportion as a result of the fertilizer applied. This suggests that these nutrient treatments sustained leaf production throughout the growth period, leading to a higher leaf count at harvest. These results are consistent with previous studies emphasizing the positive effects of nutrient application on leaf development (Chen et al., 2017; Wang and Li, 2016). Liu *et al*., 2018; Zhang *et al*., 2014; Li *et al*., 2019; Zhang and Yang, 2015 also reported more tiller in rice with application of fertilizers

All growth attributes studied in this research were strongly influenced by nitrogen application, leading to significantly higher values compared to the N-omitted treatments. This indicates the pivotal role of nitrogen in promoting overall growth and development in rice plants. These findings align with numerous studies highlighting the importance of nitrogen in crop production (Li and Zhang, 2019; Xu et al., 2017).

**Yield Attributes**

Application of nutrients had a significant impact on yield parameters. The application of N120, P60, and Zn10 resulted in maximum panicle weight, number of grains per panicle, panicle length, and 1000-grain weight compared to other treatments, including the control plot. This indicates that the combined application of nitrogen, phosphorus, and zinc positively influenced yield-related characteristics. These results are in agreement with previous studies emphasizing the role of these nutrients in enhancing rice yield (Huang et al., 2019; Jiang et al., 2016).

Grain yield, total dry weight, and harvest index also differed significantly among the N-applied treatments. The highest grain yield was observed in the pots treated with N120, P60, and Zn10. This suggests that the combined application of nitrogen, phosphorus, and zinc had a substantial positive effect on grain yield. Similar results have been reported in previous studies highlighting the importance of these nutrients in maximizing grain production (Luo et al., 2020; Zhou et al., 2018). Furthermore, Kumar et al., 2018 and Hussain et al., 2021 also reported that the combination of N and P or N and Zn applications also showed notable improvements in yield attributes, albeit to a lesser extent than the complete N, P, and Zn treatment. Application of nitrogen and phosphorus had been reported to enhance to growth of rice, thereby resulting in higher biomass (Yu et al., 2015; Chen et al., 2014).

Although variety did not significantly influence the yield attributes, panicle weight was significantly higher in ARICA-3 treated with N120, P60, and Zn10 compared to all treatments with NERICA L-34. However, NERICA L-34 produced the highest grain yield with the application of N120, P60, and Zn10, which was significantly different from other treatment combinations. This indicates that while ARICA-3 exhibited a higher panicle weight, NERICA L-34 demonstrated superior grain yield under specific nutrient treatments. These results highlight the importance of considering both variety and nutrient management for optimizing yield in rice cultivation. However, previous research has highlighted the impact of variety on yield potential and response to nutrient management (Anandan et al., 2019). The present results indicate that NERICA L-34 produced higher grain yield when treated with N120, P60, and Zn10 compared to other treatment combinations.

The study revealed significant differences in phosphorus (P) and zinc (Zn) uptake between rice varieties, with ARICA-3 exhibiting higher levels compared to NERICA L-34 (Table 5). This underscores the influence of genetic variability on nutrient uptake efficiency in rice plants (Impa et al., 2013). Furthermore, fertilizer treatments significantly affected nitrogen (N), phosphorus (P), and zinc (Zn) uptake. The combination of N120 P60 Zn10 resulted in the highest N and P uptake, indicating the importance of balanced fertilization practices for optimal nutrient absorption (Cakmak, 2008). Interestingly, the highest Zn uptake was observed when all nutrients were applied at optimal levels (N120 P60 Zn10), emphasizing the synergistic effects of combined nutrient application on Zn uptake. Conversely, the lowest Zn uptake was recorded in treatments with no phosphorus application (N0 P60 Zn0), highlighting the role of phosphorus in facilitating Zn absorption by rice plants. Notably, Zn-based fertilizers significantly enhanced Zn uptake compared to treatments with zero Zn application, underscoring the importance of Zn fertilization in addressing potential deficiencies and promoting overall rice growth and yield (Impa et al., 2013; Cakmak, 2008).

## CONCLUSIONS

In conclusion, the results of this study indicate that variety had no significant influence on plant height, leaf number, and tiller number, whereas nutrient application significantly affected these growth attributes. The combined application of nitrogen, phosphorus, and zinc (N120, P60, and Zn10) resulted in the tallest plants and highest yield attributes, including panicle weight, grain yield, and total dry weight. The three mineral elements (Nitrogen, Phosphorus and Zinc) played a crucial role in influencing all growth and yield parameters studied, and therefore recommended for optimum yield in rice production. Furthermore, ARICA-3 and NERICA L-34 demonstrated differential responses to nutrient treatments, emphasizing the importance of considering both genetic factors and nutrient management for optimizing rice yield.

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