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Response of Upland New Rice for Africa (NERICA) to Nitrogen Fertilization in the Guinea Savannah Agro-ecological Zone

Martey Abraham [a*], Richard Osei [b], Isaac Kodzo Amegbor [c++] and Israel K. Dzomeku [a]

[a] University for Development Studies, Tamale, Ghana.
[b] Gansu Agricultural University, China.
[c] Maize Breeder Maize Improvement Programme, CSIR - Savanna Agricultural Research Institute, Tamale, Ghana.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The trial was conducted during the cropping season of 2020 June to November on the upland field of the Savanna Agricultural Research Institute (SARI), at Nyankpala near Tamale in the Northern Region of Ghana. The objective was to establish the response of Upland New Rice for Africa (NERICA) to nitrogen fertilization in the Guinea Savannah Agroecological Zone. Two upland NERICAs were used. A 2×2×5 factorial experiment was laid out in Randomized Complete Block Design (RCBD) in three replications. The Phosphorus and Nitrogen fertilizers rates were 0, 60 kg

[++] Research Scientist;
**Corresponding author: E-mail: marteyabraham48@gmail.com;*

P/ha and 0, 30, 60, and 120 kg N/ha respectively. There were significant differences ($p< 0.05$) in the effect of P and N levels on plant height, number of tillers, panicle weight, and straw weight. Combined application of 60kg P/ha and 60kg N/ha increased the grain yield of upland NERICAs. The upland NERICA in the savannah zone should get 60 kg N/ha in addition to 60 kg P/ha for the best grain production.

Keywords: NERICA; nitrogen; phosphorous; savannah; yield.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple crops for maintaining both global food security and the lives of millions of people in Sub-Saharan Africa [1]. Upland rice varieties are especially important in the Guinea Savannah Agroecological Zone since agriculture is a major aspect of the region's economy and social [2]. Among these, the New Rice for Africa (NERICA) initiative offers a viable way to improve rice yield, deal with food scarcity, and guarantee the robustness of agricultural systems [3].

In West Africa, rice is a staple crop that is mostly farmed on modest family farms that typically cover less than two hectares [4]. The proportional rise in demand for rice is quicker in this region than anyplace else in the world [5] because of the region's 4% annual population growth, growing wages, and a shift in consumer preferences toward rice, particularly in urban areas [6]. Upland rice is currently the primary food source for about 100 million people [7].

The West Africa Rice Development Association (WARDA) created the interspecific cultivar known as "New Rice for Africa," or "NERICA," to increase the production of African rice cultivars. Approximately 240 million individuals rely on rice as their main dietary source of energy and protein, however, the bulk of this rice is imported for $1 billion. According to Arouna et al. [1], self-sufficiency in rice production will enhance food security and promote economic growth in West Africa.

The availability of vital nutrients, with nitrogen being a major element influencing plant development and grain output, is one important factor determining rice productivity [8]. A long-standing agricultural technique that has a big influence on crop growth and total yield outcomes is nitrogen fertilizer [9]. Research and investigation are still needed to determine how certain rice varieties particularly upland varieties like NERICA respond to nitrogen fertilization under the peculiar agroecological circumstances of the Guinea Savannah Zone.

Although NERICA is suited to its environment and provides grains that fulfill local demands, many upland farmers plant native rice that does not react well to modern management approaches [10]. In rice farming, chemical fertilizer is still a cost-effective substitute for the labor-intensive process of producing organic fertilizer [11]. As applied nitrogen levels rise, so do the dry matter and protein percentage of grains and the contents of methionine and tryptophan in seeds [12]. The production of cereals is thought to be severely limited in nitrogen, particularly in savanna uplands where leaching, continual cropping, volatilization of nitrogen fertilizers, and other factors contribute to this. It has been suggested that upland NERICA in Ghana's savanna upland agroecological zones combine 30 kg N/ha and 60 kg P/ha to maximize output [13]. In order to maximize the grain output of upland savanna, Ofoso [14] additionally suggested 30-kilogram N/ha for NERICA 1 and 90 kg N/ha for NERICA 2, together with 60 kg P/ha. Though upland rice cultivation is a significant aspect of agriculture in this region, yields are poor because of the limited availability of proper nitrogen recommendations for these novel cultivars. Therefore, the research evaluated the response of NERICA to nitrogen fertilization in the Guinea Savannah Agroecological Zone and ascertained the precise nitrogen requirements of these upland NERICA.

2. MATERIALS AND METHODS

2.1 Site Description and Location

The trial was conducted during the cropping season of 2020 June to November on the upland field of the Savanna Agricultural Research Institute (SARI), at Nyankpala near Tamale in the Northern Region of Ghana. The trial was conducted under rain-fed conditions; a monomodal rainfall pattern. Nyankpala lies at an altitude of 183m, latitude of 09˚ 25', and longitude of 0˚ 58 of the equators. Monomodal rainfall pattern with a mean annual rainfall of 991mm evenly distributed from April to

November with peaks in August and September. Mean temperature distribution of monthly minimum of 23.4°C and maximum of 34.5°C with a minimum relative humidity of 46% and maximum of 76.8%.

2.2 Experimental Design

A 2×2×5 factorial experiment was laid out in Randomized Complete Block Design (RCBD) in three replications. The first factor of the experiment was two varieties of NERICAS (1 and 2), the second factor of the experiment was two levels of phosphorus fertilizer (0 and 60 kg P/ha), and the final factor was five levels of nitrogen fertilizer (0, 30, 60, 90, and 120 kg N/ha).

2.3 Land Preparation

The land was left to weedy fallow during the dry season before the trial. The trial field was ploughed at the onset of the rainy season to a depth of about 15-18 cm and was harrowed. The field was laid into sixty plots of equal size with the help of field pegs. The plot size was 3×5 m making a net plot size of 15 m².

2.4 Source of Seeds and Planting

The seed for the trial was obtained from the Savanna Agricultural Research Institute (SARI). The reason for the seed selection was to select viable seeds for the trial. Planting was done by seed drilling 20 cm between rows and 20 cm within rows on 7/07/2020.

2.5 Weed Management

Integrated Weed Management (IWM) was used to check weeds on the various plots. (Chemical usage; both pre and post-emergence herbicides, cultural methods; hand weeding). The first-hand weeding was done two weeks after germination and the second-hand weeding was done when weeds were observed to be present in the plots.

2.6 Fertilizer Application

The N fertilizer (urea) was applied at five levels; 0, 30, 60, 90, and 120 N kg/ha. The various levels of fertilizer were calculated to suit the trial plot size of 15 m². The N fertilizer was split and applied at 3 WAP and the second half was top-dressed at 6WAP. The fertilizer was dibbled since N was volatile. Two levels of Phosphorus (triple supper phosphate); 0 and 60 kg P/ha were applied. Fixed potassium was applied at the rate of 45 kg/ha to all the plots.

2.7 Data Collection

2.7.1 Gravimetric soil moisture content

Soils were scooped from the trial field of about 5 cm with a core soil sampler to the brim. The soils were oven-dried at a temperature of 105 ˚C for 48 hours to determine the Gravimetric Moisture Content (GMC).

$$GMC = \frac{Wet\ weight - dry\ weight \times 100}{Dry\ weight} \quad \text{Eqn. (1)}$$

2.7.2 Plant stand

At 14 DAP the total number of viable seeds that emerged per hill were counted leaving non-viable and ingeminated hills. The total percentage of plant stands is calculated as

$$\frac{Counted\ hills \times 100}{Expected\ total\ hill} \quad \text{Eqn. (2)}$$

2.7.3 Plant height

Five plants per hill were randomly selected and tagged and their heights were taken or measured using meter rule. Plant heights were taken at intervals of weeks; (3, 6, 9, and 12 WAP) to determine the mean height of the plant.

2.7.4 Tiller count

The 2×2 hill method was used to select five plants per hill per plot to count the tiller numbers. 2×2 hill method means; 10 plants /m².

2.7.5 Effective tiller number

Effective tiller number count was taken using the 2×2 hill (10plants/m²) method on each plot and the mean effective panicles were recorded. Effective tillers were counted at 13 WAP where most of the tillers have shown productive panicles.

2.7.6 Panicle weight

The panicle that is the head of the rice was harvested per net plot and weighed.

2.7.7 Straw weight

The straw that was left after harvesting the panicle was later harvested per net plot and weight recorded.

2.7.8 Grain moisture content

The grain moisture content was determined by using the standard grain of 15g per plot.

2.7.9 Grain yield

The grain weight was determined based on 14% moisture content using the formula below;

$$Grain\ yield = \frac{(100-A)\times W}{86} \quad \text{Eqn. (3)}$$

A = moisture content of grain at weighing
W = weight of grain in kg/ha

2.7.10 1000 seed weight

A thousand seeds from the paddy from each plot were counted with the aid of the rice seed counter and were weighed to obtain a thousand seed weights per each weighed grain.

2.7.11 Data analysis

The data obtained was subjected to analysis of variance i.e. ANOVA by using Genstat Discovery. Means were separated using the Least Significant Difference (LSD) at 5%. Further analysis was done, including correlation analysis, and simple linear regression analysis.

3. RESULTS AND DISCUSSION

3.1 Gravimetric Moisture Content

The gravimetric moisture content was high during the growing season and it was a result of a high evenly distributed rainfall pattern during the experiment period. (Fig. 1). The highest soil moisture content was recorded at 6WAP. These results indicated a rise of 15% in the first 6 weeks after planting after which there was a decrease of 13% at 9 WAP. Again, there was a slight decrease of 3% of soil moisture content at 12 WAP during the latter part of the growing period where panicles had already initiated.

3.2 Plant Height

The second-order interactions did not significantly ($p>0.05$) affect plant height at 3 and 6 WAP (Fig. 2.) but the main effect of nitrogen significantly ($p > 0.05$) increased plant height with NERICA 1 recorded 92.17 cm and NERICA 2 recorded 92.83 cm at 9 and NERICA 1 recorded 105.00 cm and NERICA 2 recorded 107.0 cm at12 WAP, respectively, (Fig. 3 and 4). According to WARDA [15], the development of NERICA 1 and 2 was stimulated by a mixture of nitrogen and phosphorus. The application of 120 kg N/ha to NERICA types resulted in a 4-day delay in maturity when compared to a zero N fertilizer treatment. Ofoso [14] also discovered comparable outcomes during the 2009 study. At 12 WAP, NERICA 1 reached its maximum height with an application of 30 kg N/ha, whereas NERICA 2 likewise maintained its maximum height with the application of 120 kg N/ha. For NERICA 1 and 2, phosphorus at 60 kg P/ha also increased plant height.

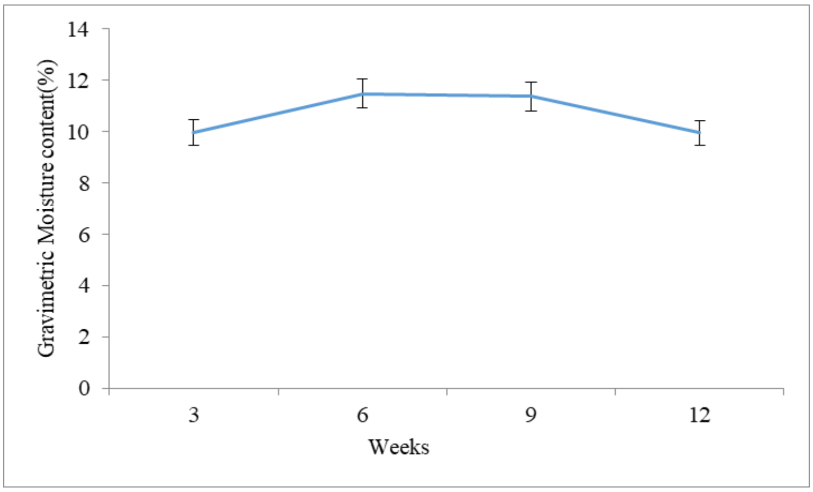

Fig. 1. Gravimetric moisture content of soil up to 12 WAP during the 2020 cropping period, Bars represent LSD

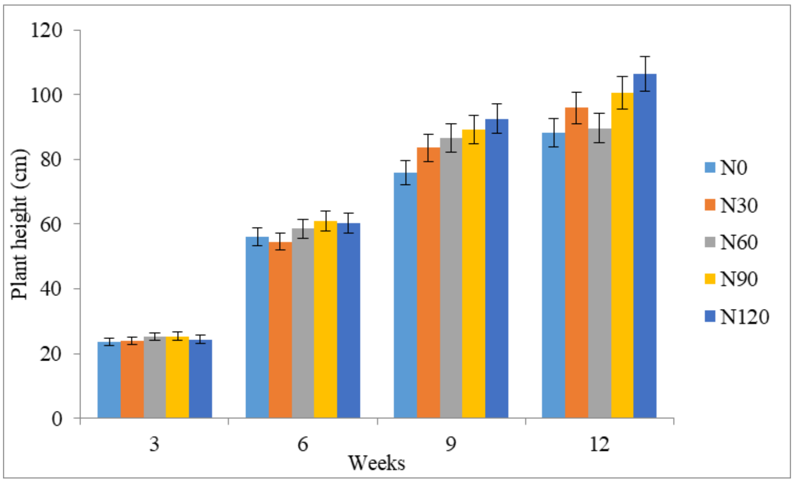

Fig. 2. Effect of nitrogen on plant height, 3-12 WAP over the means of two levels of phosphorus. Bars represent SED

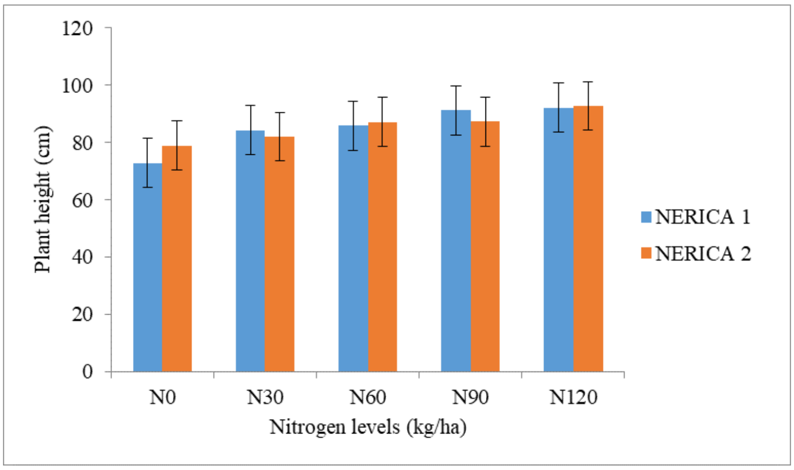

Fig. 3. Effect of nitrogen on plant height of NERICA 1 and 2 over the means of two levels of phosphorus at 9 WAP. Bars represent SED

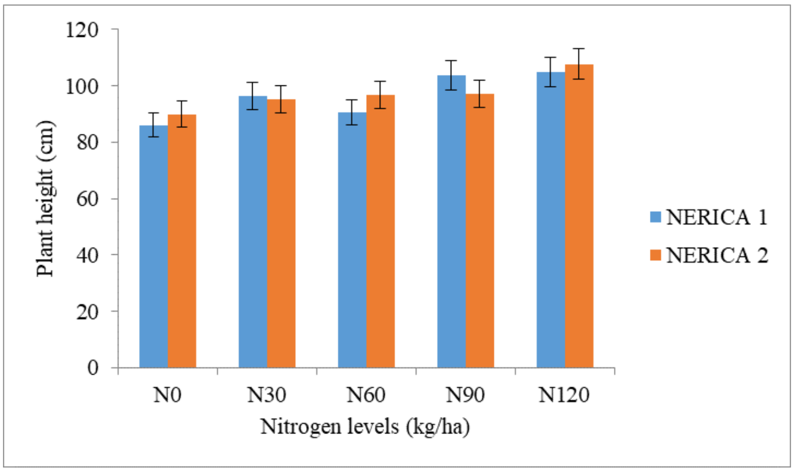

Fig. 4. Effect of nitrogen on plant height of NERICA 1 and 2 over the mean of two Levels of phosphorus at 12 WAP. Bars represent SED

3.3 Tiller Number

The main effect of nitrogen was significant ($p < 0.01$) on tiller number. Application of phosphorus at 60 kg/ha also enhanced tillering on both NERICAs (Figs. 5 and 6). In NERICA 1 and 2, the number of tillers increased significantly with nitrogen application up to 60 kg N /ha. Gandebe et al. [16] reported that the development of tillers is inhibited when N is deficient, and increasing the supply of N to a plant that is grown individually increases the number of tillers per plant. Apaseku and Dowbe [17] also found in their studies that the application of nitrogen and phosphorus at the rate of 120 kg N/ha and 26 kg P/ha increased the number of tillers of NERICA.

3.4 Effective Tiller Number

Second-order interactions of N × P × variety significantly ($p<0.05$) influenced the effective tillers. The main effect of nitrogen significantly ($p< 0.01$) influenced effective tiller numbers. (Fig. 7) and also phosphorus at 60 kg/ha enhanced effective tiller numbers of both NERICAs (Fig. 8). NERICA 1 and 2 were better tilled by applying 60 kg P/ha, as stated by Shultana et al. [18].

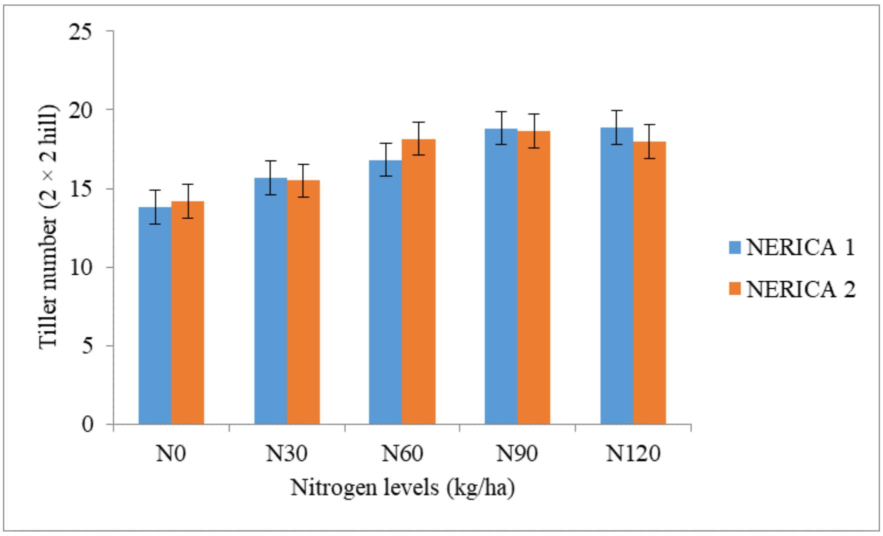

Fig. 5. The effect of nitrogen on tiller number. The results are a mean of two phosphorus levels. Bars represent SED

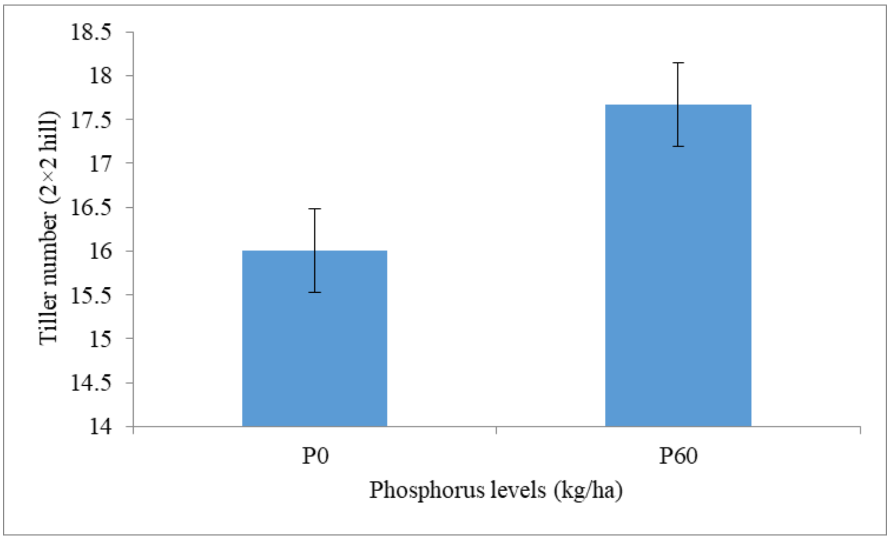

Fig. 6. Effect of phosphorus on tiller number of NERICA 1 and 2. The results are a mean of five levels of nitrogen. Bars represent SED

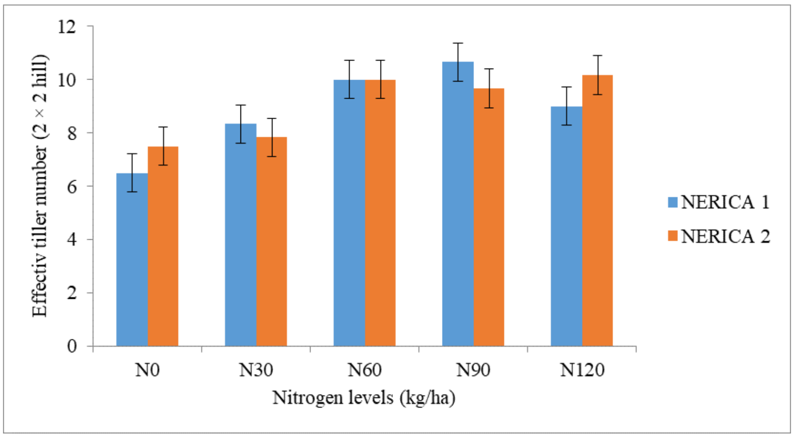

Fig. 7. Effect of nitrogen on effective tiller numbers over the mean of 2 levels of phosphorus. Bars indicate SED

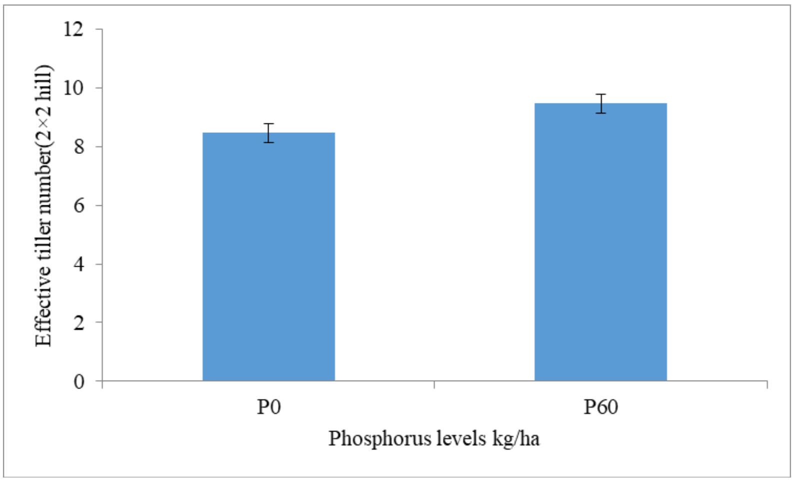

Fig. 8. Effects of phosphorus on effective tiller numbers over 5 levels of nitrogen. Bars indicate SED

3.5 Panicle Weight

The first-order interactions of nitrogen × phosphorus, nitrogen × variety, and phosphorus and variety did not significantly ($p>0.05$) determine panicle weight but only the main effect of N significantly ($p<0.05$) increased panicle weight of the NERICAs. (Fig. 9). Panicle weight of NERICA 1 and 2 responded to nitrogen application significantly such 60 kg N/ha was optimum to promote the panicle weight of both NERICAs. This finding supports the findings of Okegbade et al. [19] that the application of 60 kg N/ha to NERICA rice increased panicle weight.

3.6 Straw Weight

The first-order interaction of phosphorus × variety and the main effect of nitrogen significantly ($p<0.05$) increased the straw weight of the NERICA (Fig. 10). Nitrogen had a major influence on straw weight, with the maximum straw weight being produced at 120 kg N/ha. However, 90 kg N/ha also produced similar findings, with 60 kg N/ha being the optimal value; this might be due to vegetative development. This finding might validate the significance of nitrogen for rice crop growth when combined with phosphorus treatment [17].

3.7 Grain Yield

Second-order interactions of nitrogen × phosphorus × variety and first-order interactions did not significantly ($p<0.05$) influence grain yield but the main effect of nitrogen significantly ($p<0.05$) influenced grain yield such that both NERICA grain yield was optimized at 60 kg N/ha but 120 kg N/ha also gave the highest grain yield for both NERICA (Fig. 11). Both NERICAs responded to P at 60 kg/ha as compared with 0kg/ P/ha (Fig. 12). Although each NERICA seems to react differentially to nitrogen treatment, in general, 60 kg N/ha seemed to be the ideal amount for NERICA. Bekere et al. [20] reported similar results. Economic efficiency should be considered while managing fertilizer. Alam et al. [21] also discovered comparable outcomes, indicating that upland rice benefited most from 40–60 kg of applied N/ha. According to Ssenyonga and Yoshiaki [22], 2-3 t of rice may need to be harvested per ha in West Africa for the first crop to need 20–40 kg N/ha. The outcomes of this experiment are comparable to this. When compared to 0 kg P/ha, the grain yield rose similarly for both NERICAs to 60 kg P/ha. This finding is consistent with the findings of Kaizzi et al. [23], who found that the grain yield of upland rice increased considerably to 66 kg P/ha.

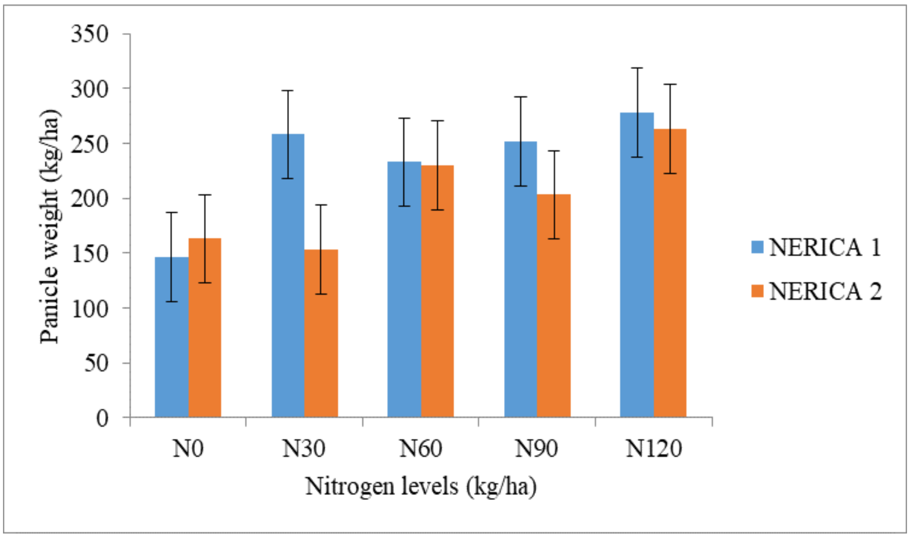

Fig. 9. Effects of nitrogen on panicle weight of NERICA 1 and 2 over means of 2 levels of phosphorus. Bars represent SED

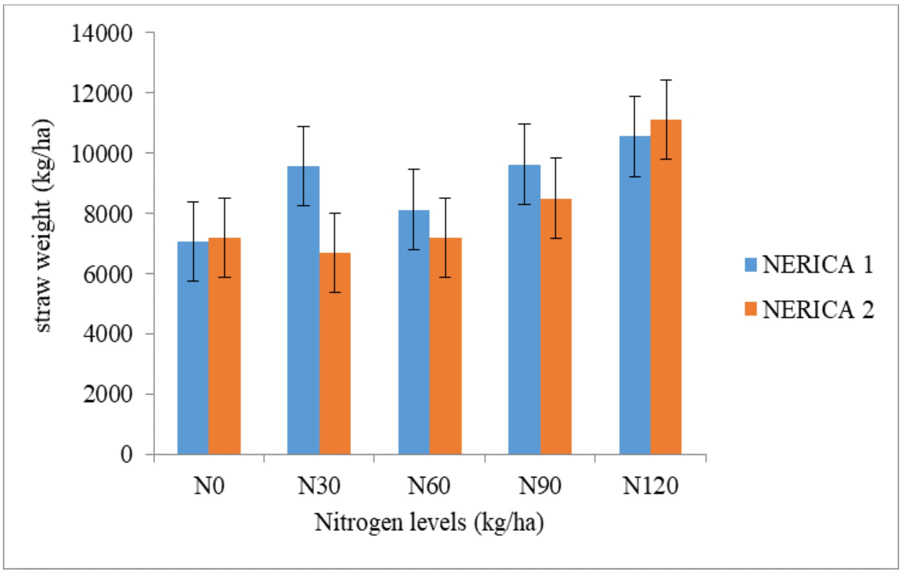

Fig. 10. Effects of nitrogen on the straw weight of both NERICA 1 and 2. The results are the mean of 2 levels of phosphorus. Bars represent SED

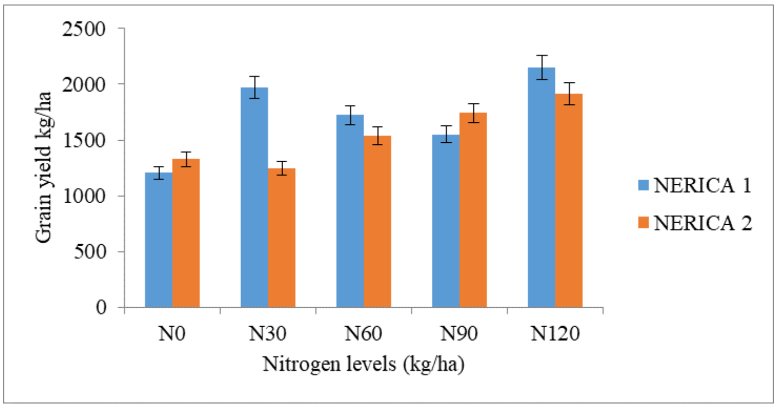

Fig. 11. Nitrogen and cultivar effects on grain yield of NERICA 1 and 2 over the mean of 2 levels of phosphorus. Bars represent SED

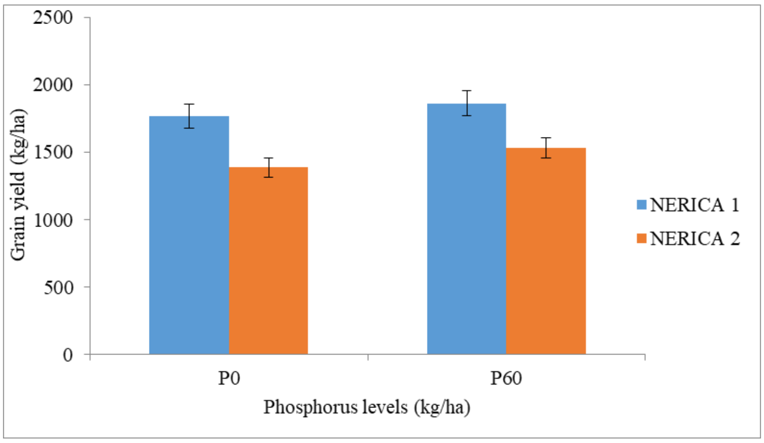

Fig. 12. Phosphorus and cultivar effects on grain yield over 5 levels of nitrogen. Bars represent SED

4. CONCLUSION

From the study, it can be concluded that application nitrogen and phosphorus significantly increase plant height, tiller number, effective tiller number, panicle weight, and straw weight. Moreover, combined application of 60kg P/ha and 60kg N/ha increased the grain yield of upland NERICAs. The upland NERICA in the savannah zone should get 60 kg N/ha in addition to 60 kg P/ha for the best grain production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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