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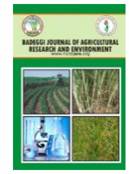

Research Article

NPK Fertilizer Application for Enhanced Productivity of FARO 44 Lowland Rice in Guinea Savanna Zone of Nigeria

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Abstract
A field study was conducted to assess the effects of different rates of NPK fertilizer on the performance of FARO 44 lowland rice at two sites in Yaba and Gada Biyu in the southern guinea savanna of Nigeria in 2019 cropping season. At both sites, the experiment was laid out in a randomized complete block design (RBCD) with three replicates. The treatments were five NPK (20:10:10) fertilizer levels (0,100,200,300 and 400kg/ha). Data collected were subjected to analysis of variance (ANOVA) using the GenStat (2011) statistical package. Means were separated using Least Significant Difference (LSD) at 5% probability level. The meteorological data from both locations recorded unimodal rainfall distribution but the soil at Yaba was a clay soil with high organic matter, nitrogen, phosphorus, calcium and magnesium contents, while the soil at Gada Biyu had low nitrogen, phosphorus and potassium contents. NPK fertilizer significantly increased rice plant height, number of tillers per plant, number of leaves per plant, panicle length, panicle weight, number of grains per panicle and 1000-grain weight in the two sites. Grain yield also followed a linear response to NPK fertilization up to 400kg/ha. Grain yield at Yaba was 21.6% significantly higher than the yield at Gada Biyu which had lower soil fertility than the former. Therefore, to optimize the growth and yield of FARO 44 lowland rice, applying NPK fertilizer at 400kg/ha could be recommended for farmers.

Keywords: *Enhanced, FARO 44, Guinea Savanna, Lowland, NPK fertilizer, Productivity.*

Introduction
Rice (*Oryza sativa* L.) is a staple food crop for over half of the world's population, with a 60% potential increase in its demand by 2025 in order to meet up with the ever-growing population (Fageria 2003). Nigeria is the largest producer of rice in West Africa (FAO, 2020), with approximately 40% of the country's total rice output emanating from the Guinea Savanna zone of Nigeria (Adebiyi *et al.*, 2021). The zone is characterized by predominantly loamy to clayey soil and often exhibit deficiencies in essential nutrients, particularly nitrogen. High rainfall can exacerbate nitrogen leaching, further reducing the availability of this critical nutrient for rice plants (Fageria and Baligar, 2005; Choudhury and Kennedy, 2005). Among the varieties of rice cultivated in this zone is FARO 44 also known as Sippi. It is a lowland early maturing (110 –120 days) and high yielding variety, tolerant to some stresses, resistant to blast, long grain (Dontsop *et al.*, 2011), highly adaptable to the soils of the guinea savanna, and good response to fertilizer application (Oladimeji *et al.*, 2018).

Soil fertility and nutrient availability are critical factors influencing rice productivity, and the use of fertilizers is essential for maintaining soil fertility and ensuring optimal yields (Dobermann *et al.*, 2002). Nitrogen, Phosphorus, and

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Potassium (NPK) fertilizers are the most widely used fertilizers in rice production, playing critical roles in plant nutrition and soil fertility management (Fageria *et al.*, 2010). Nitrogen is crucial for vegetative growth and biomass production, phosphorus is necessary for root development and energy transfer, and potassium is important for enzyme activation and disease resistance (Marschner, 2012). However, excessive or inadequate application of NPK fertilizers can lead to reduced productivity, environmental degradation, and economic losses (Ladha *et al.*, 2005), hence the need for a balanced application of these nutrients through NPK fertilizers aimed at maximizing rice yields (Witt *et al.*, 2007).

Optimizing the application of NPK fertilizers involves understanding the specific nutrient requirements of FARO 44 rice and the environmental dynamics of the Guinea Savanna zone. This is crucial because the precision in timing, placement, and the ratio of NPK fertilizers can significantly enhance nutrient uptake and improve yield outcomes of FARO 44 lowland rice in the Guinea Savanna zone, ensuring sustainable rice production and food security (Chuan *et al.*, 2013). Despite the importance of NPK fertilizers, there is limited information on the optimal application rates for FARO 44 lowland rice in this region (Oladimeji *et al.*, 2018). This knowledge gap necessitates research to determine the effects of varying NPK fertilizer rates on the growth and yield of FARO 44 lowland rice, identifying the optimal application rates for improved productivity and sustainability in the region.

Materials and Methods

The study was conducted in 2019 cropping season at two locations: Yaba in Abaji Area Council and Gada Biyu in Kwali Area Council within the Federal Capital Territory (FCT), Abuja, in the Southern Guinea Savanna Zone of Nigeria. Abuja is situated between latitudes 8° 25' and 9° 25' North and longitudes 6° 45' and 7° 45' East. The region experiences a six-month dry season from November to April and a six-month rainy season from May to October, with an average annual rainfall of 1,350 mm and temperatures ranging from 30.4°C to 35.1°C (Balogun, 2001). The vegetation is characterized as a Southern Guinea Savanna biome, with scattered deciduous trees among grasses (Aondoakaa, 2012). The map of the study area is presented in Figure 1. The rice seed (FARO 44 also known as Sippi) was obtained from Africa Rice Centre, International Institute of Tropical Agriculture (IITA), Ibadan.

Before the trial, the sites in Yaba and Gada Biyu were cleared of existing vegetation using non-selective herbicide glyphosate at 4lml/ha. Stones and roots were removed and uprooted respectively. Ploughing and harrowing were done using an MF 375 tractor. Bunds were constructed around the field to prevent water runoff and aid in water management. Before ploughing, soil samples were obtained from representative parts of the study sites with auger to a depth of 0-20cm, and taken to the laboratory to determine the physical and chemical properties of the soil. The percentage of sand, silt and clay was determined using Bouyoucos method (Bouyoucos, 1996). Soil pH was measured in 1:2.5 soil/water ratio with pH meter (Udo *et al*., 2009). Organic carbon was determined by Walkley and Black method (Nelson and Sommers, 1982). Organic matter content was determined by multiplying total carbon by 1.724. Total nitrogen was determined by microkjeldahl method (Bremner, 1996). Available Phosphorus was obtained by Bray-II method (Bray and Kurtz, 1945). Exchangeable cations (Ca, Mg, K, and Na) were extracted with one normal neutral ammonium acetate solution as described by Thomas (1982) and exchangeable K and Mg were read using atomic absorption spectrophotometer (AAS).

The nursery was ploughed, and raised nursery bed measuring 5m x 2m ($10m^2$) was prepared. Seeds were hydro-primed (soaked in water) for 12hrs and afterwards, sown in the nursery beds by broadcasting at a seed rate of 30kg/ha. A thin film of water was maintained for two days and thereafter it was drained off. Compound fertilizer NPK (20:10:10) was applied to the nursery beds at 200kg/ha during the nursery stage, after sowing and initial water management but before the seedlings were transplanted into the field. The seedlings were transplanted 3 weeks after sowing at 2 seedlings per stand and a spacing of 20 cm x 20 cm. This gave a plant population of 500, 000 plants/ha. The field was flooded with water to a depth of 5-7cm before seedlings were carefully uprooted from the nursery bed and transplanted into the field. After transplanting, a shallow layer of water (2-5cm) was maintained in the field to provide moisture and suppress weed growth.

At each site the treatments were arranged in a randomized complete block design (RBCD) measuring 10m x 5m ($50m^2$). The treatment consists of 5 NPK fertilizer rates (0, 100, 200, 300, and 400kg/ha), with three replications, with each replication representing a block. Seedlings were transplanted into field plots prepared with different NPK rates (0, 100, 200, 300, and 400 kg/ha) applied through broadcast method, followed by light incorporation into the soil.
Non-selective herbicide (glyphosate at 4lml/ha) and selective post emergence (Bispyribac sodium 10% at 400ml/ha) herbicides were applied to the field before land preparation and 7 days after transplanting respectively to control weeds. Manual hand picking of weeds (roguing) was done at 4 weeks after transplanting (WAT), and scarecrows were used to control birds at flowering.

At 4, 6 and 8 weeks after transplanting (WAT), data on growth parameters were taken. Plant height was measured using a measuring tape as distance from the base of ten randomly selected plants (ground level) to the tip of the leaves when raised vertically up divided by the number of sampled plants. The number of tillers (secondary or lateral shoots) per plant was obtained by counting number of tillers from ten plants (5 tagged hills) divided by the number of sampled plants. The number of leaves per plant was obtained by counting the number of leaves from ten plants divided by the number of sampled plants.

Data on grain yield and yield components were taken at physiological maturity when the grains had turned brown. Ten panicles were randomly selected from the ten tagged plants and the length was measured from the neck node to the tip of the upper most spikelet and the average length recorded; their mean weight taken using Novo SF400-C3 electronic weighing scale. Ten panicles were randomly selected and threshed to determine the mean number of grains per panicle. 1000 randomly selected grains after threshing the panicle per plot were weighed to obtain the weight. The panicles per plot were harvested, threshed, and combined with grains from the ten tagged plants and used to estimate the yield in tons per hectare after sun drying to a 13 % moisture content using digital moisture meter.
Data collected were subjected to analysis of variance (ANOVA) using the GenStat (2011) statistical package. Means were separated using Least Significant Difference (LSD) at 5% probability level.

Results and Discussion

The soil at Yaba was a clay soil with high organic matter, nitrogen, phosphorus, calcium and magnesium contents, while the potassium level was close to the critical value reported by Fairhurst (2012) (Table 1). This resulted in a better performance of the rice in Yaba than at Gida Biyu as rice grew taller and produced greater number of tillers and leaves as well as higher grain yield in Yaba than Gada Biyu. The soil at Gada Biyu was sandy loam with low nitrogen, phosphorus and potassium contents. Both locations were characterized by unimodal rainfall distribution as presented in Figure 2. The total annual rainfall was 1423.9mm at Yaba and 1548.5mm at Gada Biyu. At both sites the bulk of the rains fell within the period of May and September. The mean minimum and maximum temperatures at Yaba were 22.2^{o}C and 33.8^{o}C respectively, while the minimum and maximum temperatures at of Gada Biyu were 24.1^{o}C and 36.7^{o}C respectively, showing higher temperature values in Gada Biyu. The lower rice growth and yield in Gada Biyu could be attributed to the higher rainfall that probably caused more cloudy days and leaching of nutrients in the sandy loam soil as well as the higher temperatures that resulted in the loss of nutrients (nitrogen) through volatilization. A previous study conducted in the savannas of Nigeria reported by Kamara *et al* (2010) attributed the variations in rice yields between locations to differences in rainfall amount and distribution.

Table 2 shows the result of various rates of NPK fertilizer on the plant height at different week after transplant at the two sites under study. According to Fageria and Baligar, (2005), plant height is a key indicator of overall plant health and vigor, influenced significantly by nutrient availability, particularly nitrogen (N), phosphorus (P), and potassium (K). These macronutrients play distinct yet interconnected roles in plant growth, contributing to various physiological processes that collectively impact plant height (Dobermann and Fairhurst, 2000). The result obtained showed that the plant height significantly ($P<0.05$) increased as the rate of NPK application increased at both sites. A numerical increase in plant height was also observed as the plant aged. Similar results were reported by Singh *et al.* (2001), and Bello *et al*. (2004). The result obtained in this present study is consistent with the report of Marschner, (2012), that adequate nitrogen availability promotes vigorous vegetative growth as nitrogen stimulates cell division and elongation, resulting in the development of taller plants with more robust foliage.

The effect of NPK fertilizer on number of tillers at different weeks after transplant is presented in Table 3. Tillering is a crucial determinant of rice yield potential as it directly influences the number of panicles, and subsequently, the grain yield (Fageria, 2003). A numerical and statistical ($P<0.05$) increase in the number of tillers was observed as the rate of NPK application increased at the two sites under study. The number of tillers also increased with maturity of the rice plant. The study by Mahajan *et al*. (2012) found that higher rates of NPK fertilizer application resulted in a significant increase in the number of tillers in dry-seeded rice. Saha and Mondal, (2017) also demonstrated in their research that higher levels of NPK fertilizer application led to a substantial increase in the number of tillers per plant in rice. These results support the publication of Fageria, (2003) that adequate nitrogen leads to greater biomass accumulation, and phosphorus also influences the metabolic processes that are essential during the early growth stages, promoting vigorous tiller initiation (Dobermann and Fairhurst, 2000).

The application of NPK fertilizers plays a crucial role in enhancing the vegetative growth of rice plants, including the production of leaves. Leaves are essential for photosynthesis, and their number directly impacts the plant's ability to generate energy and grow effectively (Fageria *et al*., 2010). The effect of application of NPK fertilizer at various rate on the number of leaves is shown in Table 4. There was a progressive statistical ($P<0.05$) increase in the number of leaves produced with increase in the rate of fertilizer application and with maturity of the rice plant at Yaba and Gdad Biyu. Similar results were reported by Fageria and Baligar, (2005) in their study where they discussed how the combined application of NPK fertilizers enhances overall plant growth, including leaf number and leaf area index. Chaturvedi, (2005**)** also indicated in his study that higher nitrogen application rates, along with adequate phosphorus and potassium, resulted in a significant increase in the number of leaves in hybrid rice. Studies have shown that rice plants with sufficient nitrogen supply develop more leaves and larger leaf areas compared to nitrogen-deficient plants (Fageria and Baligar, 2005).

The effect of NPK fertilizer on the yield and yield components of rice is in Table 5. Panicle length is a critical determinant of rice yield as it affects the number of spikelets and consequently, the grain yield (Saha and Mondal, 2017). This study observed that increasing the application rate from 200 to 300kg/ha resulted in no significant ($P>0.05$) increase in the panicle length, however a significant ($P<0.05$) increase was recorded when the application rate increased to 400kg/ha at both sites. This agrees with the study of Thakur *et al.* (2011), who demonstrated that increased nitrogen and phosphorus levels significantly enhanced panicle length in both direct-seeded and transplanted rice conditions.

Panicle weight is a critical determinant of rice yield, as heavier panicles typically contain more grains, leading to higher productivity. The panicle weight obtained in this study significantly ($P<0.05$) increased when the NPK fertilizer rate was increased from 100 to 200kg/ha. Increasing the application rate from 200 to 400kg/ha resulted in no further significant increase in the panicle weight of the rice. This agrees with the study of Singh *et al*. (2002), whose study indicated that beyond a certain threshold, additional nitrogen did not enhance panicle weight and could negatively impact yield due to excessive vegetative growth and reduced efficiency in nutrient utilization. Saha and Mondal, (2017) however reported a substantial increase in the panicle weight when

NPK application rate increased. Increasing the application rate from 0 to 300kg/ha yielded a significant (P<0.0.5) increase in the number of rice grains obtained, however further increase to 400kg/ha yielded no significant (P>0.05) increase in the number of grains at both sites. Similar response trend was observed in the 1000 grain weight of rice. Islam *et al.* (2007) indicated that balanced NPK application enhances the number of grains per panicle by promoting healthy panicle development and reducing lodging risk.

At both Yaba and Gada Biyu sites, grain yield followed similar pattern, and increased significantly with each successive increment in NPK fertilizer rates. When totaled across both sites, NPK fertilizer at 400kg/ha had the highest grain yield of 5.59t/ha, and this was greater than the yield from 0, 100, 200, and 300kg/ha NPK rates by 69.77%, 60.82%, 36.44% and 26.12% respectively. This supports the report of Peng *et al.* (2006) who found that balanced NPK fertilization significantly increased rice yield in irrigated systems in China. They reported that higher nitrogen application rates, combined with adequate phosphorus and potassium, enhanced vegetative growth, photosynthetic capacity, and grain filling, leading to higher yields. The study of Koutroubas and Ntanos, (2003) was however contradictory as they documented that excessive nitrogen application could lead to reduced rice yields due to increased vegetative growth at the expense of reproductive development. They also reported in a similar study that excessive nitrogen also increased the risk of lodging and pest infestations, which negatively impacted yield.
The optimum grain yields of 3.08t/ha at Yaba and 2.51t/ha at Gada Biyu obtained when 400kg/ha NPK was applied were 63.31% and 77.69% respectively higher than the yields from unfertilized plants (0kg/ha NPK). This suggests a higher yield response to fertilizer at Gada Biyu, where the soil had lower fertility, which is consistent with Fairhurst's (2012) observation that crops exhibit a significant response to fertilizer on nutrient-deficient soils.

Conclusion

The results of this study have demonstrated the significant effects of different rates of NPK fertilizer on the growth and yield of rice under Yaba and Gada Biyu conditions in the southern guinea savanna zone of Nigeria. The results showed that increases in NPK fertilizer rates were accompanied by corresponding significant increase in plant height, number of tillers, number of leaves, panicle length, number of grains per panicle, 1000-grain weight and grain yield. Optimum grain yields were realized at Yaba and Gada Biyu sites when NPK at 400kg/ha was applied and is recommended for farmers at both locations in the southern guinea savanna of Nigeria.

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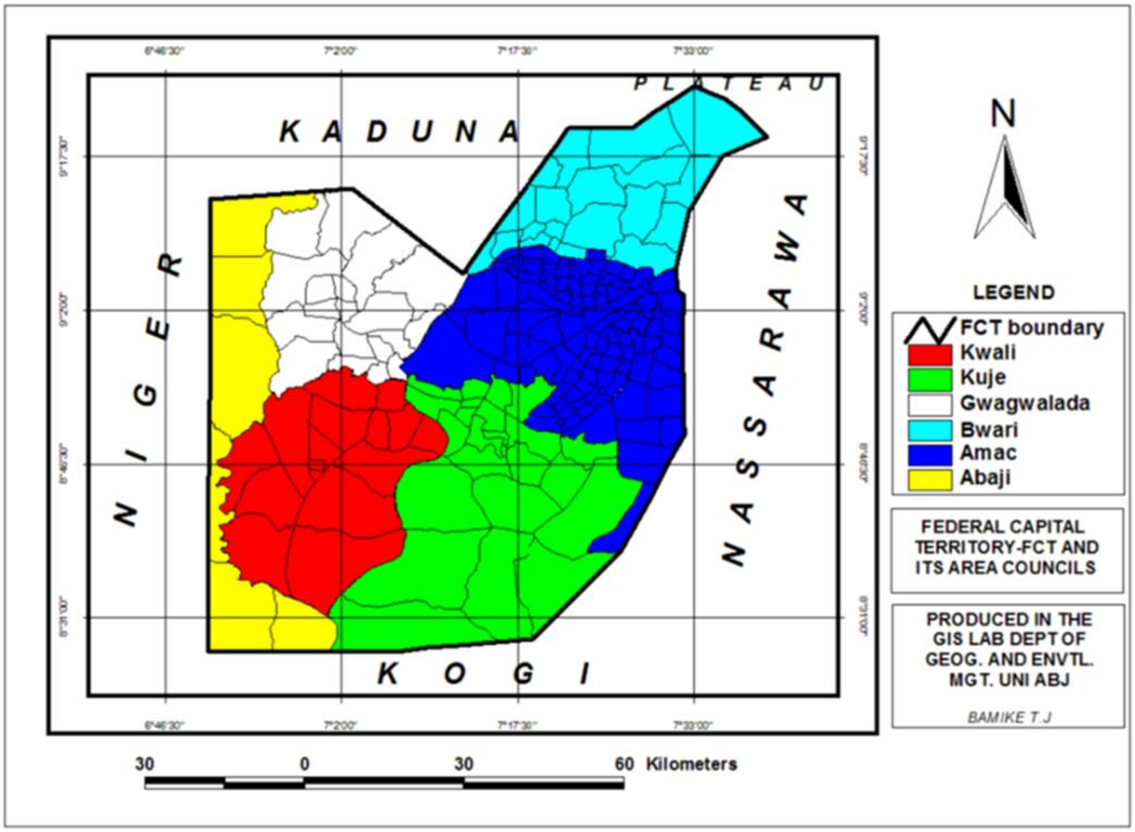

Figure 1: Map of the Study Area. Source: (Aondoakaa, 2012)

Table1: Soil Physical and Chemical Properties in Yaba and Gada Biyu, FCT, Southern Guinea Savanna

Soil properties	Yaba	Gada Biyu
Physical Properties		
Sand (%)	32.4	71.4
Silt (%)	26.8	13.8
Clay (%)	40.8	14.8
Textural class	Clay	Sandyloam
Chemical Properties		
PH (1:2.5 H_2O)	4.7	5.3
OM (%)	37.4	2.7

Total N (%)	0.29	0.13
Available P (mg/kg)	19.2	14.6
K (Cmol/kg)	0.19	0.15
Ca (Cmol/kg)	8.0	4.6
Mg (Cmol/kg)	4.2	2.6
Na (Cmol/kg)	0.24	0.13
Ea (Cmol/kg)	2.80	0.64
ECEC (Cmol/kg)	15.3	8.1
BS (Cmol/kg)	81.5	92.1

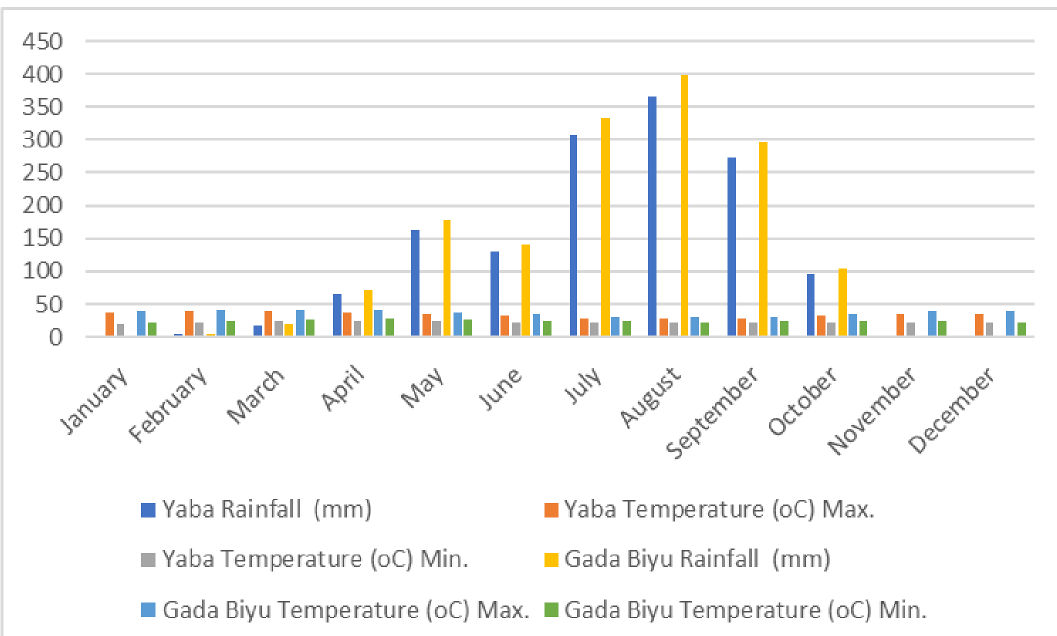

Figure 2: Meteorological Data on Rainfall and Temperature in Yaba and Gada Biyu, FCT, Southern Guinea Savanna

Table 2: Effect of NPK Fertilizer on Plant Height (cm) at Different Weeks After Transplanting in Yaba and Gada Biyu in 2019 Cropping Season

	Yaba			Gada Biyu		
	Weeks after Transplanting					
NPK (Kg/ha)	4	6	8	4	6	8
0	27.60[d]	33.11[e]	45.54[e]	26.39[d]	31.89[e]	44.31[e]
100	35.15[c]	38.60[d]	50.53[d]	33.94[c]	37.38[d]	49.31[d]
200	41.19[b]	45.30[c]	53.74[c]	39.98[b]	44.08[c]	52.52[c]
300	42.06[b]	52.44[b]	56.41[b]	40.85[b]	51.22[b]	55.19[b]
400	44.70[a]	58.87[a]	70.53[a]	43.49[a]	57.65[a]	69.31[a]
LSD	1.65	4.72	0.75	1.03	4.32	0.83

abc Mean values with different superscripts within a column differed significantly (P<0.05); LSD= Least Significant Difference.

Table 3: Effect of NPK Fertilizer on Number of Tillers at Different Weeks After Transplanting in Yaba and Gada Biyu in 2019 Cropping Season

	Yaba			Gada Biyu		
	Weeks after Transplanting					
NPK (Kg/ha)	4	6	8	4	6	8
0	1.82[e]	3.08[e]	4.93[e]	1.58[e]	2.82[e]	4.16[e]
100	2.26[d]	4.18[d]	5.77[d]	2.00[d]	3.92[d]	5.00[d]
200	2.88[c]	5.16[c]	7.18[c]	2.62[c]	4.90[c]	6.41[c]
300	4.69[b]	5.94[b]	7.98[b]	4.44[b]	5.68[b]	7.21[b]
400	5.56[a]	7.27[a]	10.82[a]	5.30[a]	7.01[a]	10.05[a]
LSD	0.12	0.15	0.45	0.12	0.15	0.45

abc Mean values with different superscripts within a column differed significantly (P<0.05); LSD= Least Significant Difference.

Table 4: Effect of NPK Fertilizer on Number of Leaves at Different Weeks After Transplanting in Yaba and Gada Biyu in 2019 Cropping Season

	Yaba			Gada Biyu		
	Weeks after Transplanting					
NPK (Kg/ha)	4	6	8	4	6	8
0	3.72[e]	5.63[e]	8.04[e]	3.51[e]	5.40[e]	7.88[e]
100	4.51[d]	7.61[d]	10.01[d]	4.28[d]	7.38[d]	9.78[d]
200	5.35[c]	9.08[c]	11.57[c]	5.12[c]	8.85[c]	11.34[c]
300	8.34[b]	12.26[b]	18.05[b]	8.11[b]	12.03[b]	17.82[b]
400	13.14[a]	19.91[a]	27.66[a]	12.91[a]	19.68[a]	27.43[a]
LSD	0.54	0.30	0.52	0.53	0.30	0.53

abc Mean values with different superscripts within a column differed significantly (P<0.05); LSD= Least Significant Difference.

Table 5: Effect of NPK Fertilizer on Yield and Yield Component at Yaba and Gada Biyu in 2019 Cropping Season

Components / NPK (kg/ha)	Yaba					Gada Biyu				
	Panicle Lgth (cm)	Panicle Wgt (kg/ha)	No of Grains (kg/ha)	1000 weight (g)	Grain Yield (t/ha)	Panicle Lgth (cm)	Panicle Wgt (kg/ha)	No of Grains (kg/ha)	1000 weight (g)	Grain Yield (t/ha)
0	6.02^d	5.19^c	195.5^c	26.50^c	1.13^d	5.55^d	4.58^c	177.3^c	25.79^c	0.56^d
100	10.25^c	5.57^b	275.6^b	27.48^b	1.38^c	9.78^c	6.87^b	257.4^b	26.71^b	0.81^c
200	11.77^b	7.68^a	276.8^b	27.74^b	2.06^c	11.30^b	7.02^a	258.6^b	26.97^b	1.49^c
300	12.33^b	8.32^a	295.9^a	28.13^a	2.35^b	11.86^b	7.60^a	277.7^a	27.36^a	1.78^b
400	14.16^a	8.42^a	293.4^a	28.70^a	3.08^a	13.69^a	7.65^a	275.1^a	27.93^a	2.51^a
LSD	0.86	0.79	10.7	0.76	0.16	0.86	0.65	10.7	0.76	0.16

abc Mean values with different superscripts within a column differed significantly (P<0.05); LSD= Least Significant Difference.