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Growth and yield responses of selected rice (*Oryza Sativa L.*) varieties to nitrogen fertilization in Southern Nigeria

[1] William Ubi, *[2] Godwin Michael Ubi, [3] Martina W Ubi, [1] Thomas Okweche

[1] Department of Science and Technology, National Open University of Nigeria, Calabar Study Centre, Nigeria.
[2] Department of Genetics and Biotechnology. University of Calabar, Nigeria.
[3] Cross River State Agricultural Development Programme CRADP, Calabar, Nigeria.

Abstract

Field experiments were carried out in 2013 and 2014 at Iwuru, Cross River State, in Southern Nigeria to determine the effect of nitrogen fertilizer on the growth and yield of three rice varieties. The experiment was laid out in a randomized complete block design fitted in a 3x4 split-plot, replicated three times. The results showed that the application of 90kgha^{-1} significantly (p<0.05) produced higher agronomic parameters (plant height, number of leaves per sucker, weight per tiller and leaf area), compared with nil fertilizer. The application of 90kgha^{-1} had higher values of agronomic parameters than the application of either 60 or 120kgha^{-1} under similar experimental conditions. There was 18.3% unit drop in grain yield when fertilizer rate was increased from 90 to 120kgha^{-1}, indicating that grain yields obtained by applying 90kgha^{-1} were significantly, higher than values obtained from the application of 120kgha^{-1}. Varietal differences were significant (p<0.05). The varieties had their maximum yield where 90kgha^{-1} was applied. Faro 15 at the application of 90kgha^{-1} had higher values than nil application and these values were significantly (p<0.05) higher than values obtained from either the application of 60kgha^{-1} or that of 120kgha^{-1} under the same experimental conditions. These results are discussed in light of nitrogen fertilizer effect on the growth and yield of rice.

Keywords: Nitrogen fertilization, rice growth and yield, varietal response

1. Introduction

Rice (*Oryza sativa L.*) is a widely cultivated crop in the world and can be found in almost every market all over Africa. Rice can be grown in both swamp and upland. The one grown in the swamp is commonly called swamp rice, while the one grown on the upland is called upland rice. Rice has a high starch content and varying amount of protein and carbohydrate with oil and vitamins occurring in the tissues of the grain (Schipper, 2000) [19]. Rice has contributed immensely to the economic development of many countries in the world including countries like: China, Thailand, Philipines, USA, Indonesia and India (Olaniyi, 2007) [19]. The differences in the maturation periods when planted at different dates are governed by the correct level of fertilizer application. One of the major causes of low yield in rice in Nigeria is the inadequate information on the application rate of inorganic fertilizer especially nitrogen fertilizer (FAO, 2005). Several experiments on crops have generally indicated yield increase due to fertilizer application (FAO, 1975; Chang, 1976 and CRRI, 1954) [8, 10]. Although, there are some co-operative rice farmers in Nigeria, but the bulk of production is from individual farmers. Most of these individual farmers in Nigeria produce at very low levels compared with their counterparts in other regions of the world. It was in consideration of the low production level and the high demand of the grains within and outside Nigeria, that this study was carried out to examine the effect of nitrogen fertilizer application on the yield and yield attributes of three varieties of rice commonly grown in Cross River State, Southern Nigeria.

2. Materials and Methods

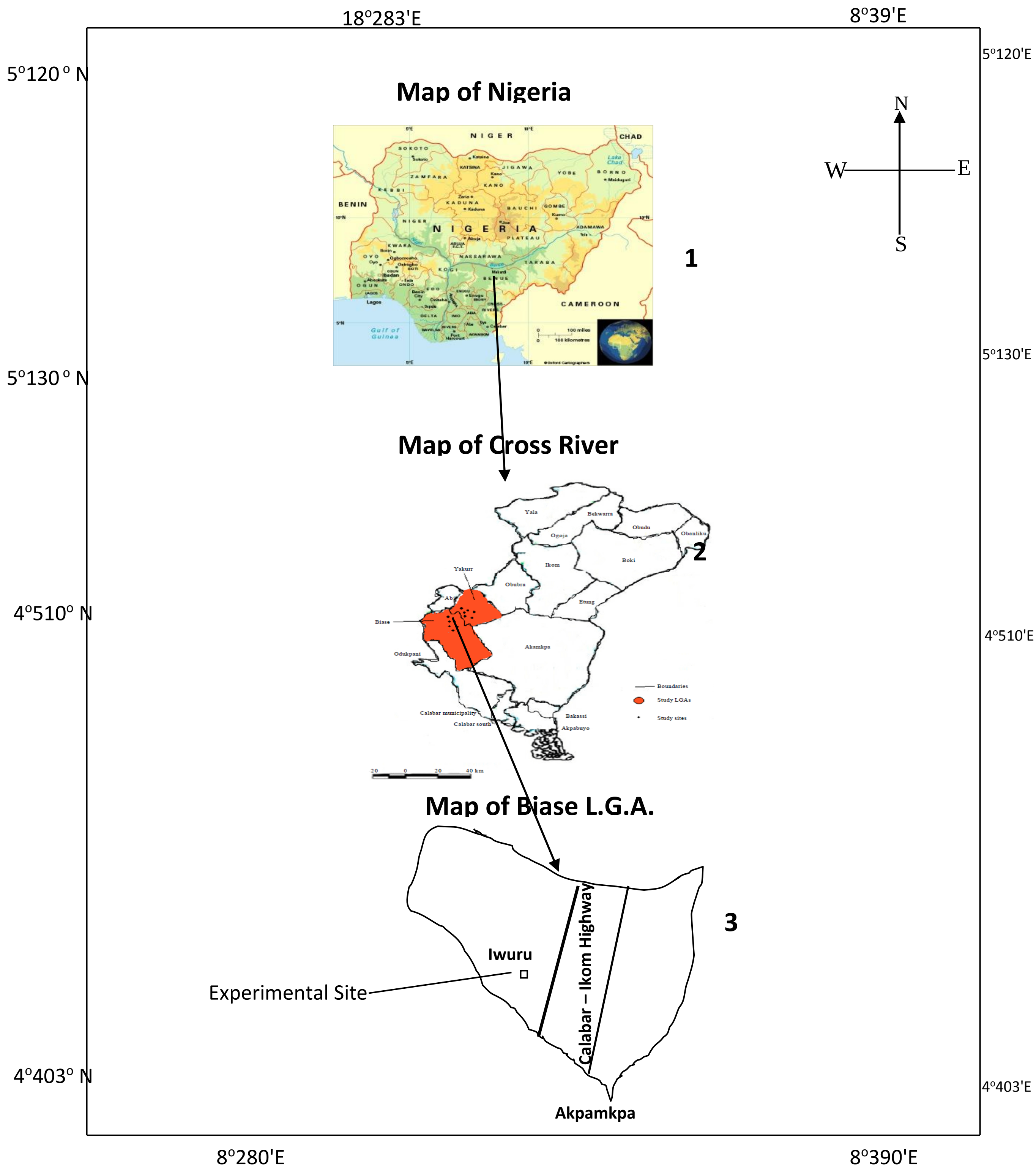
Field experiments were carried out at Iwuru in Biase, Cross River State, Southern Nigeria during the 2013 and 2014 growing seasons. The experiments were designed to study the effect of nitrogen fertilizer on yield and yield attributes of three varieties of rice. The experimental site lies between 8°14'N and 8°20'E longitude, 5°14'N and 5°18'E latitude with a rainfall of over 2,000mm in the rainforest vegetation. The mean daily minimum and maximum temperatures vary from 21°C to 24°C and 27°C to 32°C respectively. Relative humidity varies from 82 to 79% (Eshiet, 1994) [11]. The source of planting materials was International institute of Tropical Agriculture (IITA) Ibadan.

2.1 Experimental Site

In terms of land use, the area was previously cropped with maize and cassava followed by a three year fallow in which guinea grass (*Panicum maxima* S112) was the dominant fallow species. The site was cleared and allowed to dry for some days, then gathered together, removed and leveled.

2.2 Experimental Design

A randomized complete block design, (RCBD) was used fitted into a 3x4 split-plot, replicated three times. The main plot was the rice varieties while the sub-plot was the nitrogen fertilizer levels. Unit plot size was 3x4m (12m^2) with 1 and 0.5m pathway between each replication and the plots respectively. A sampling area of 2^{2}m was marked out for random sampling of agronomic parameters.



Maps showing experimental site

2.3 Experimental Treatments

The experimental materials used include:

1. Levels of nitrogen fertilizer 0, 60, 90 and 120kgha^{-1} (designated N_1, N_2, N_3 and N_4). At the beginning of the experiment, the soil was treated with 325.5kgPha^{-1}, P_2O_5 (single super phosphate) and K_2O (muriate of potash) because P and K were low in the soil prior to the trial, (Table 1). The four rates of nitrogen fertilizer, used were: (0, 60, 90 and 120kgha^{-1}) and were applied as per treatment in two equal splits doses at two and four weeks after sowing by broadcasting.
2. Planting materials: Three varieties of rice used were
   a. Faro 12
   b. Faro 15
   c. Faro 44.

The rice seedlings were transplanted into the field from the nursery at 3-4 weeks old. Weeding was done as at when due, and the periphery was well kept against rodents and other grass eating animals. Data collected were plant height, weight per filler, number of leaves, number of fillers, leaf area (LA), root weight and grain yield.

2.4 Soil Sampling

Soil samples were collected at the depth of 0-30cm (cm), air – dried in the laboratory, ground and sieved through 2mm sieve before analysis. Soil pH was measured using the pH meter 1:1 soil to water ratio. Particle size distribution was determined by the hydrometer method (Bonyoucos, 1951). The percentage organic carbon was determined by the Walkey Black wet oxidation method (Walkey and Black, 1934) while percent total nitrogen (N) was determined by the micro Kieldahl method (Jackson, 1962). Organic matter was determined by multiplying the percent organic carbon with a factor of 1.724. Available P was extracted by the Bray-1 method and determined colorimetrically (Bray and Kurtz, 1945) [7]. Exchangeable bases were displaced by $NH4^+$ from neutral normal NH_4 OAC solution as described by Jackson (1958). Calcium (Ca) and Magnesium (Mg) were determined by the Atomic Absorption Spectrophotometer (AAS), Potassium (K) and Sodium (Na) were determined by flame emission photometry. Cation Exchange Capacity (CEC) was determined by the neutral normal NH_4 OAC Saturation method. Base saturation was calculated with reference to the NH_4 OAC, CEC, Exchangeable acidity was extracted with IMKCL and determined by filtration with Na oH solution.

Statistical Analysis

All the data collected were subjected to analysis of variance (ANOVA) and means compared using Fisher's least significant difference at 0.05 probability level.

3. Results and Discussion

3.1 Characteristics of the soil used for the experiment

The results of the analysis of the soil used for the experiments are presented in Table 1, in which the particle size distribution had the following results: sand 84 (gkg^{-1}), silt as 285gkg^{-1} and clay as 168gkg^{-1}. The soil pH was 5.8, organic carbon content was 5.18%, CEC was 1.82$cmolkg^{-1}$ while total N and available P were 0.08% and 8.35mg/kg^{-1} respectively. The texture of the soil was dandy loam. The total N and available P were very low compared with critical level of 0.1% for N and a range of 10-12$mgkg^{-1}$ for available (Udo, 1977) [28] obtained for soils in Southern Nigeria (Lal, 1994) [18]. Using the critical levels of 0.16-0.20 $cmolkg^{-1}$ exchangeable K was low (Agboola and Obigbesan, 1974) [2].

Table 1: Physico-chemical properties of the soil before the experiment

Soil properties	Values
pH (H_2O)	5.8
Organic carbon (%)	5.8%
Total N (%)	0.08%
Available P (mg/kg)	8.35($mgkg^{-1}$)
Exch.bases ($cmolkg^{-1}$)	0.76
K	0.15 ($cmolkg^{-1}$)
Ca	0.50
Mg	0.07
Na	0.04
CEC ($cmolkg^{-1}$)	1.82 ($cmolkg^{-1}$)
Base saturation (%)	13.5 (%)
Sand (gkg^{-1})	84 (gkg^{-1})
Silt (gkg^{-1})	285 (gkg^{-1})
Clay (gkg^{-1})	168 (kg^{-1})
Textural class	Sandy loam

3.2 Effect of N fertilizer application on plant height (cm)

Plant height is among the important growth components directly linked with the productive potential of plant in terms of folder, grains and tiller production. An optimum plant height is assumed to be positively correlated with dry matter yield. The effect of N fertilizer application on the height of three rice varieties is presented in Table 2.

Table 2: Effect of N fertilization rates on growth characters of three rice varieties

Treatments	Plant Height (cm) Varieties				Total Number of leaves/tiller Varieties			
	Faro 12	Faro 15	Faro 44	Total	Faro 12	Faro 15	Faro 44	Total
0 (N_1)	18.3	19.2	18.1	18.5	8.4	7.8	6.2	6.8
60 (N_2)	26.4	27.3	24.3	26.0	7.3	8.1	7.4	7.6
90 (N_3)	34.0	36.4	32.5	34.3	8.6	9.4	8.2	8.7
120 (N_4)	31.1	32.6	30.2	31.4	7.2	8.1	7.0	7.4
Mean	27.5	28.9	26.3		7.4	8.4	7.2	
LSD (0.05)	3.2*	3.5*	3.0*		1.2*	1.4*	1.2*	

* Significant ($P<0.05$). SE ± 0.25
CV = 10%

Table 3: Effect of N fertilization rates on leaf area (LA) and root weight of three rice varieties

Treatments	Plant Height (cm) Varieties				Total Number of leaves/tiller Varieties			
	Faro 12	**Faro 15**	**Faro 44**	**Total**	**Faro 12**	**Faro 15**	**Faro 44**	**Total**
0 (N_1)	54.0	60.3	56.4	56.9	0.032	0.041	0.033	0.035
60 (N_2)	71.2	88.4	73.2	27.7	0.056	0.088	0.068	0.071
90 (N_3)	114.6	132.2	113.1	13.6	0.104	0.285	0.106	0.165
120 (N_4)	96.4	108.6	97.5	100.8	0.114	0.164	0.112	0.168
Mean	84.1	97.4	85.1		0.076	0.095	0.079	
LSD (0.05)	18.7*	25.2*	23.0*		0.02*	0.03*	0.02*	

* Significant ($P<0.05$). SE ± 12.54
CV = 17%

Table 4: Effect on N-fertilizer rates on grain yield of rice

Treatment	Yields ($tonsha^{-1}$) Varieties			
	Faro 12	**Faro 15**	**Faro 44**	**Total**
0 (N_1)	3.6	4.6	3.7	3.9
60 (N_2)	4.9	5.8	4.3	5.0
90 (N_3)	6.1	8.9	6.3	7.1
120 (N_4)	5.4	7.6	5.0	6.0
Mean	5.0	6.7	4.8	-
LSD (0.05)	1.2*	1.3*	1.2*	-

SE ± 8.35; * significant ($P<0.05$).
CV = 6%

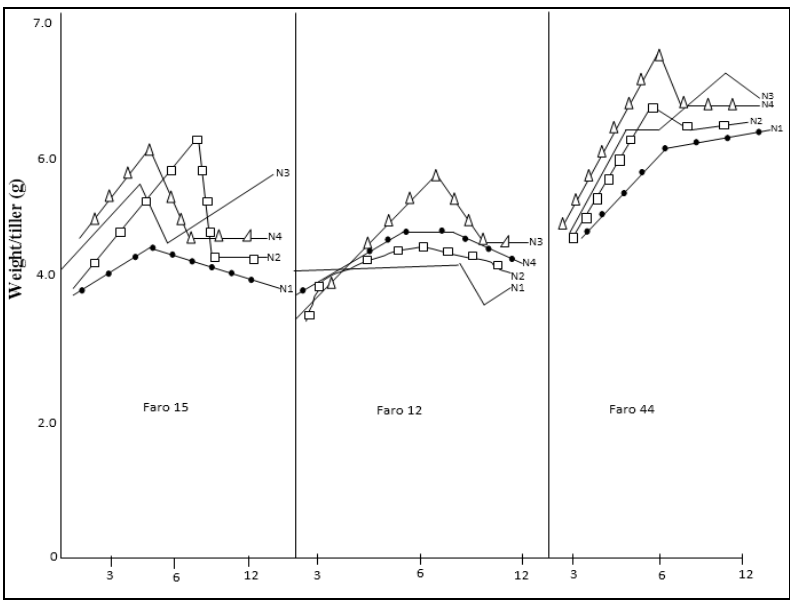


Fig 1: Age (weeks)

Table 5: Analysis of Variance

Source of variation	DF	MS	F
Reps	2	0.1762	0.217NS
Tillers	2	34.8988	42.7262**
Error (a)	4	0.8168	
Total	8	-	-
Sub-plot	3	2.6035	3.9039*
Variety x N interaction	6	0.8473	1.2705NS
Variety error B	18	0.669	
Grand total	35	*$p<0.05$	

The application of nitrogen fertilizer tended to increase plant height significantly ($p<0.05$). Increasing N-application from $60kgha^{-1}$ N to $90kgha^{-1}$ N significantly ($p<0.05$) increased plant height and the number of leaves compared with nil application. There was 31.9% unit increase $\left(\frac{34.3-26.0}{26.0}\times 100\right)$ in plant height when nitrogen fertilizer was increased from $60kgha^{-1}$ to $90kgha^{-1}$. Equally, there was 14.5% $\left(\frac{8.7-7.6}{7.6}\times 100\right)$ unit increase in number of leaves per tiller when N fertilizer was increased from $60kgha^{-1}$ to $90kgha^{-1}$. Varietal differences in terms of plant height and number of leaves per tiller was significant ($p<0.05$) taking the mean of each variety, Faro 15 recorded the highest mean values of tiller height and number of leaves per tiller

28.9cm and 8.4 respectively, compared with nil-application and these values were significantly ($p<0.05$) higher than all other values of other varieties given similar experimental condition (Table 3). The effect of nitrogen application on grain yield of three rice varieties showed that Faro 15 had the highest yield of 6.7 tons ha^{-1} which was significantly ($p<0.05$) higher than mean values of either Faro 12 or Faro 44 under similar experimental conditions (Ubi, 2004; Olaniyi, 2007) [23, 24, 19]. The application of $90kgha^{-1}$ tended to produce more grain yield on the average compared with nil, and these values were significantly ($p<0.05$) higher than all other values of either $60kgha^{-1}$ or $120kgha^{-1}$. This is cost effective for the farmer because less money will be needed to purchase fertilizer. Rice varieties were taller in those plants that received $90kgha^{-1}$ than those that received either $120kgha^{-1}$ or lower rate of $60kgha^{-1}$, the $90kgha^{-1}$ which induced plant height; number of leaves, leaf area and root weight. This is in agreement with the findings of FMANR (1990); Ajari *et al.* (2002); Akinfasoye and Nwanguma (2005); Awe *et al.* (2006); Ubi *et al.* (2006); Ubi and Osodeke (2007).

The results of nitrogen fertilizer rates on yield of three rice varieties is presented in Table 4 in which the application of $90kgha^{-1}$ on the average produced 7.1 metric tons ha^{-1} of grains compared with nil fertilizer, and this value was significantly ($p<0.05$) higher than all other values from either the application of $60kgha^{-1}$ or $120kgha^{-1}$, under similar experimental condition. There was 42% $\left(\frac{7.1-5.0}{5.0}\times\frac{100}{1}\right)$ unit increase in grain yield when nitrogen fertilizer rate was increased from 60 to $90kgha^{-1}$ and 18.3% $\left(\frac{7.1-6.0}{6.0}\times\frac{100}{1}\right)$ unit drop in grain yield when nitrogen fertilizer was increased from $90kgha^{-1}$ to $120kgha^{-1}$, given similar experimental condition. These results were earlier reported (Tindall, 1983; Akintunde *et al.*, 2000; Smith *et al.*, 2001; Ubi and Omaliko, 2004; Ubi *et al.*, 2005) [4, 21, 23, 27]. Fig. 1 illustrates the weight per tiller of the three rice varieties in which the weights of tillers were significantly ($p<0.05$) influenced by nitrogen application. Varietal differences in terms of weight per tiller were glaring but each of the varieties had their maximum weight per tiller where $90kgha^{-1}$ was applied at the 6th week of planting, which of course continued to drop, up to the 12th week. This drop has established that the photosynthetic activities tended to slow down with an over-riding of flower initiation in which much less of nitrogen was required (Queen-sland, 1964).

The analysis of variance on the grain yield showed that there was significant difference at 0.1% level among the varieties (Table 4). Farmers intending to go into commercial production are encouraged from this result to grow Faro 15 for better economic returns. Equally, the application of $90kgha^{-1}$ tended to have greater effect on the three cultivars especially, Faro 15 which of course is more cost effective than the higher level of 120 $kgha^{-1}$.

4. Conclusion

The relative performance of each of the rice varieties was glaring, giving each of them the opportunity to perform best at the optimum fertilizer rate of $90kgha^{-1}$ throughout the study period. However, this level of nutrient would obtain similar or better yields of grains in the potential rice production in Southern Nigeria, can only be ascertained by further research. At the beginning of the study, P and K were also incorporated into the soil as to establish a healthy crop (Christic, 1964) [9]. The phosphorus promotes a strong root system which is basic to rapid early growth of primary shoots. Variety Faro 15 has perfused tillering habit with broader leaves than Faro 12 and Faro 44, which exposed this cultivar to photosynthetic activities leading to higher values of growth parameters. Thus Faro 15, with good growth habit and yield at the application of $90kgha^{-1}$ and good management can produce optimum yield in Southern Nigeria.

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