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RICE RESPONSE TO NITROGEN FERTILIZER ON THREE WETLAND SOILS IN ADO-EKITI, NIGERIA

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ABSTRACT

Field experiment was conducted on three wetland soils during the 2011 late growing season at Ekiti State University Teaching and Research Farm to investigate the response of wetland rice to four rates of N (0, ST, 100 and 150 kg N/ha). The results obtained from the study showed that, nitrogen fertilizer application had significant (P<0.05) effect on rice dry matter, number of tillers, number of particles and grain yields. The use of 150 kg Nha^{-1} produced the maximum number of tillers/ M^{2} (29) at site 3 than all other treatments. Significantly, higher dry matter accumulation (0.60 and 0.55 kg/ m-^{2}) was obtained on plots treated with 150 and 100 kg N ha^{-2} respectively. The best economic rice yield (4.39 t ha^{-1}) was obtained using fertilizer rate based on soil test at site 1. The recovery by rice of labeled ^{15}N was much higher using the soil test fertilizer application rate in site 3 while it was higher using 100 kg N ha^{-1} in sites 1 and 3. Results obtained for nitrogen fertilizer use efficiency (NFUE) in sites 1 and 3 showed that when input (fertilizer) is properly managed, rice grown on wetland soils usually make use of higher proportion of N applied. The economic analysis of rice production showed that site 1 using soil test fertilizer application rate gave the highest net farm income of USD 5244.20 per hectare.

Keywords: Rice, N fertilizer, Wetland soils, Ado-Ekiti, NUE.

INTRODUCTION

Rice is the staple food for nearly half of the world's population, most of who live in developing countries. The crop occupies one-third of the world's total area planted to cereals and provides 35 – 60 % of the calories consumed by 2.7 billion people (Guerra *et al*., 1998).

Fertilizer management issue in rice production is drawing attention among farmers, especially under current climate change situation. Efficient fertilizer management under environment-friendly condition is crucial to increase rice production worldwide. Appropriate amount of fertilizers applied onto soils reduced greenhouse gas emissions, $N0_3$ leaching and eutrophication (Fasina, 2011a).

Nitrogen is normally a key factor in achieving optimum lowland rice grain yields (Fageria *et al.*,1997). It is, however, one of the most expensive inputs and if used improperly, can pollute the ground water. About 78 % of the world's rice is grown under rainfed lowland conditions (IRRI, 1997). Soils under these conditions are saturated, flooded, anaerobic and N. use efficiency is low. Under these situations, increasing rice yield per unit area through use of appropriate N management practices has become an essential component of modern rice production technology.

Fertilizer N use efficiency of lowland rice is relatively low due to loss of applied N through leaching, volatilization and denitrification in the soil flood water system (Peng *et al.*,1996). For example, in a study in farmers' field in the Phillipines, Cassman *et al.* (1993), reported that only 30-49 % of the applied N was accounted for by increased above ground N accumulation. Recovery efficiencies of 30-50 % of applied N are typical in field experiments at research stations for lowland rice in the tropics (De Datta 1986). Fageria and Baligar (2001), obtained an average nitrogen use efficiency of 58 kg of grain per kg N utilized by rice. They discovered that Nitrogen use efficiency decreased with increasing N rates.

The annual rice production in Nigeria is about 4 million metric tones and in-spite of the production, Nigeria has emerged as a major importer of rice using about N155 billion and N350 billion to import rice in 2010 and 2011 respectively, (Fasina 2011b). This is because, rice production in the country is characterized by low yield due to lack of efficient fertilizer application, cultivation of low yielding varieties and problem of soil fertility, caused as a result of climate change and poor management of wetland soils. One of the management options available to mitigate against the effects of climate change on wetland rice fields is to properly monitor the utilization and timing of the use of Nitrogen fertilizers on wetland rice field (Amoloja 2011). Nuclear techniques, especially stable isotope tracers like ^{15}N can be used to quantify N fertilizer use efficiency on wetland rice fields. Selection of the most appropriate rate of N fertilizer is one of the management practices that can affect both economic viability of crop production and impact of agriculture on the environment. There is need to evolve the optimum rate of N fertilizer that will result in maximal economic yield. Further, proper timing in combination with adequate rate of N application is crucial to minimize N losses and improve N use efficiency.

The objectives of the current study were:

i. To determine wetland rice response to N fertilization
ii. To evaluate N uptake and use efficiency under different N rates
iii. To appraise the economic effect of N fertilizer levels imposed.

MATERIALS AND METHODS

The experiment was conducted at three sites within the Teaching and Research Farm of Ekiti State University, Nigeria. The characteristics of the selected sites are given in Table 1. The experiment was conducted during the late growing season of October, 2010 – March, 2011.

The three wetland sites were mapped using rigid grid method of soil survey. Profile pits (3) were dug and described. Soil samples were collected and analysed following IITA (1979) methods of Laboratory analysis.

The soils were classified into taxonomic units using USDA (2006). Surface soil samples were collected for fertility evaluation studies from the three sites.

Field Experimentation

The IAEA technique/method for measuring N 15 on rice field was adopted where the use of labeled material was employed as tracers for quantitative determination of the fate of specific nutrient elements in a specific component or the whole soil plant system.

The Randomized Complete Block Design was used. There were 4 treatments (F1-0, F-2 ST, F3-100 kg/ha, F4-150 kg/ha – Urea) replicated three times at each of the three wetland sites. The ST – is the fertilizer rate applied based on the native fertility of the soil (soil test value). For site 1 it was 0.18 %N (40.02kg/plot/Urea), site 2- 0.29 % N (18.63 kg/plot/Urea and site 3

– 0.13 % (65.33 kg/plot/Urea). The ^{15}N enrichment levels were 1 for 100 kg N/ha and 1.5 for 150 kgN/ha.

Each wetland site was cleared manually which was the practice of the Farmers. Rice seedlings were raised in a seedling nursery adjacent to the experimental plot. The transplanting of rice seedlings was done uniformly on the same day at each of the wetland site. Two seedlings were transplanted normally per hill using an intra and inter-row spacing of 20 cm x 20 cm. Isotope plots were $1m^2$ within main plots. With 4 variety of rice was used. Soil samples were collected from each of the wetland site to determine routine soil properties.

Nitrogen fertilizer (Urea) was applied at the rate of 100 kg N/ha, 150 kg N/ha while the rate for soil test plots were 0. 18 % N (40.02 kg N/plot) for site 2, 0. 29 % N (18.63 kg/plot) for site 3- 0.13 % N (65.38 kg N/plot). The control plot (0 kg N/ha) received no fertilizer throughout the experimental period. ^{15}N was applied following IAEA procedure using the different enrichment levels. The crop was harvested after maturity using a sickle by cutting the rice plants above ground level. The panicles were then threshed and winnowed in the air to remove the chaff and obtain clean rice paddy grains.

Data Collection

The data collected were on the following parameters.

1. Plant height (10, 12 and 14 weeks after planting)
2. No of panicles (14 wk.)
3. No of tillers (8wk, 10 and 12 weeks)
4. No of days to 50 % flowering
5. Fresh weight of shoot (kg)
6. Dry matter weight (kg/plot)
7. Grain yield (t/ha)

All data collected were subjected to analysis of variance and the treatments were separated by Duncan Multiple Range Test (DMRT).

Fertilizer Nitrogen Use efficiency (FNUE) N15 measurements and Calculations

Fertilizer use efficiency is a quantitative measure of the actual uptake of fertilizer nutrient by the plant in relation to the amount of nutrient added to the soil as fertilizer. A common form of expression of fertilizer use efficiency is plant recovery or "Coefficient of utilization" of the added fertilizer. This is shown in equation (1) below:

$$\%\ \text{utilization of added fertilizer} = \frac{\text{Amounting of nutrient in the plant derived from the fertilizer}}{\text{Amount of nutrient applied as fertilizer}} \quad \text{(Eqn ----1)}$$

In isotopic – aided fertilizer experiments, a labeled fertilizer is added to the soil and the amount of fertilizer nutrient that a plant has taken up is determined. In this way, different practice (placement, timing, source etc.) can be studied.

The first parameter to be determined when studying the fertilizer uptake by a crop by means of the isotope techniques is the fraction of the nutrient in the plant derived from the (labelled) fertilizer i.e. fdff. often this fraction is expressed as a percentage i.e.

$$\%\ dff = fdff \times 100 \quad \text{------ (Eqn 2)}$$

The procedure followed in the calculation of this fraction in this study and other derived parameters for nitrogen using ^{15}N labelled materials is given below:

In summary, for this present field experiment with ^{15}N, the following basic primary data were recorded for each plot.

1. Dry matter (D.M) yield for the whole plant.
2. Total N concentration (% N in dry matter) of the whole plant. This was done by using Kjedahl 1 method.
3. Plant % ^{15}N abundance, which is analyzed by emission spectrometry.
4. Fertilizer % ^{15}N abundance.
5. N^{15} labelled fertilizer (s) used and N rates of application.

Calculations for Experiments with ^{15}N

% ^{15}N abundance is transformed into atom % N^{15} excess by subtracting the natural abundance (0.3663 atom % N) from the % N abundance of the sample. Afterwards the following calculations were made.

$$\%\ N\ dff = \frac{\text{atom \% } ^{15}N \text{ excess plant}}{\text{Atom \% } ^{15}N \text{ excess fertilizer}} \times 100/1 \quad \text{– (Eqn 3)}$$

Dry matter yield per unit area:

$$\text{DM yield (kg/ha)} = \frac{\text{FW (kg)}}{\text{area harvested}} \times \frac{10000/m^2/\text{ha}}{(m^2)} \times \frac{\text{SDW kg}}{\text{SFW(kg)}} \quad \text{– (Eqn4)}$$

Where FW is fresh weight per area harvested and SDW and SFN are sub-sample dry and fresh weight respectively.

$$\text{N yield (kg/ha)} = \text{DM yield } \frac{(\text{kg/ha} \times \%\ N}{100} \quad \text{- (Eqn5)}$$

$$\text{Fertilizer N yield (kg/ha)} = \text{N yield } \frac{(\text{kg/ha}) \times \%\ N\ dff}{100} \quad \text{- (Eqn 6)}$$

$$\%\ \text{fertilizer N utilization} = \frac{\text{Fertilizer N yield}}{\text{Rate of N application}} \times \frac{100}{1} \quad \text{- (Eqn 7)}$$

Economic Analysis of Rice Production in wetland sites

The Economic analysis of rice production was done to determine the most profitable treatments and wetland location for rice production. Economic indicators calculated and used were Gross income: total fixed cost, Total variable cost, Total cost (TC), Gross Margin (GM), Net farm income, Fixed Ratio, Gross ratio and Operating ratio.

1. Gross Margin = Gross income – Total variable cost
2. $\text{Operating Ratio} = \frac{\text{Operating expenses (VC)}}{\text{Gross income (TR)}}$
3. $\text{Gross Ratio} = \frac{\text{Total cost (Total expenses)}}{\text{Gross income}}$
4. $\text{Fixed Ratio} = \frac{TFC}{TC}$
5. Net Farm income = GM - TFC =Gross Margin – Total Fixed Cost

RESULTS AND DISCUSSION

Soil Fertility and Salinity Evaluation of Wetland Sites

The results of the soil physical and chemical properties of the three wetland sites are given in Table 2. Site 1 is neutral in soil pH (7.2), has a moderate organic matter (2.48 %), low total N (0.18 %) level, low P (4.20 mg/(kg) adequate K, Na, Ca and Mg. The soil texture is clay loam. Depth to water table at the peak of dry season was 100 cm, site 2 is also neutral l (7.3) in pH, has high Soil organic matter (3.68%), high total N (0.29 %), low P (3.81 mg/kg), moderate/adequate in K, Na, Ca and Mg levels. The soil texture is clay. Depth to water able at the peak of dry season was 86 cm. Site 3 is also neutral (6.7) in soil pH, has low organic matter (1.75 %), low total N (0.13 %), low P (2.35 mg/ka), with moderate/adequate levels of Na, Mg and Ca and low level of K (0.10 cm/kg). The soil texture is clay loam and depth to water table was 30 cm during the peak of the dry season.

Table 1: Site Characteristics of Three selected Experimental Wetland sites in Ado-Ekiti, Nigeria.

Site characteristics	Site 1	Site 2	Site 3
- Soil type (USDA)	Typic Endoaquent	Fluvaquentic Endoaquent	Typic Endoaquept
-Climate	Tropical Humid	Tropical humid	Tropical Humid
Coordinates	N 07^0 42.619^1 E005^0 14.8311	N 07^0 42.408^2 E 005^0 15.072	N 07^0 35.362^1 E 005^0 40.1241
-Vegetation slope	2-3%	2-3%	Mainly fallow from rice cultivation and vegetables
-Elevation	1269 feet	1330 feet	
-Landuse	Agriculture (Rice, vegetable, Fallow)	Mainly Fallow from rice cultivation	

Table 2. Chemical and Physical Properties of three Wetland locations in Nigeria

Soil Properties	Site 1	Site 2	Site 3
pH	7.2	7.3	6.7
Organic matter %	2.48	3.68	1.75
EC ds/m	3.5	3.5	3.4
Total N % (kg/ha)	0.18	0.29	0.13
Available P (mg/kg)	4.20	2.81	2.35
K (cmol kg^{-1})	0.17	0.20	0.10
Na (cmol kg^{-1})	0.10	0.14	0.11
Ca (cmol kg^{-1})	1.80	2.90	2.30
Mg (cmol kg^{-1})	1.10	1.70	1.50
Sand %	42	28	46
Clay %	35	51	35
Silt %	23	21	19
Depth to water table (cm)	100	86	30
Soil textural class	Clay loam	Clay	Clay loam

Using the critical levels of 0.2 % total/N, 3 % organic matter site 2 can be said to be fertile while site 1 and 3 will respond to fertilizer application because of their low levels of total N (0.18 % and 0.13% respectively. Site 2 may not likely benefit from fertilizer application because of the high level of total N (0.29 %).

Evaluation of Nitrogen Fertilizer on yield and yield Components of Rice

The results of the influence of Nitrogen Fertilizer on yield and yield components of rice are shown in Tables 3 to 9. The Nitrogen Fertilizer treatments had significant (P<0.05) effect on all the parameters studied. It was found that application of N fertilizer increased plant height significantly but maximum plant height (102.11cm and 102.56 cm) was obtained on plots where 100 kg N/ha and 150 kg N/ha were applied and the lowest on Control plots at site 2 (60.66 cm). The increase in plant height in response to application of N fertilizer is probably due to enhanced availability of Nitrogen which enhanced more leaf resulting in higher photo assimilates and thereby resulted in more dry matter accumulation. These results are supported by the findings of Mandal (1992).

No of days to 50 % flowering (Table 4) was also influenced significantly (P<0.05) as the highest influence (98.37) was obtained at site 1 on plots that received 150 kg N/ha. Nitrogen fertilizer application increased significantly no of tillers/m^2 (Table 7) in rice at harvest. The use of 150 kg N/ha produced maximum number of tillers/m^2 (29.33) at site 3 than all other treatments. Number of tillers per unit area is the most important component of yield. The more the number of tillers, especially fertile tillers, the more will be the yield. More number of tillers/m^2 in 150 kg N/ha plot might be due to the more availability of Nitrogen that played a vital role in cell division. These results are in agreement with the findings of Rajput *et al*. (1988). Also, according to Yoshida (1972), as the amount of Nitrogen absorbed by the crop increases, there is an increase in the number of tillers per square meter.

Dry matter accumulation increased significantly with N-fertilizer application in rice (Table 8). Significantly highest dry matter accumulation (0.60 and 0.55) was obtained on plots that received 150 kg N/ha and 100 kg N/ha respectively (Table 9). This result is expected since vegetative growth resulting from higher photosynthetic activities is well known to be influenced by nitrogen application.

Table 3: Effects of Plant Height (cm) at 14 weeks after Planting

Treatment	Site 1	Site 2	Site 3
O	71.00d	60.66c	81.00c
ST	74.78c	67.44b	97.44b
F100	80.00b	74.67a	102.11a
F150	82.45a	74.67a	102.56a
LSD	2.25	2.62	4.30

Table 4: Effects of Nitrogen Fertilizer on No. of days to 50% flowering

Treatment	Site 1	Site 2	Site 3
O	95.00	88.33b	92.67b
ST	97.67a	89.33b	92.33b
F100	97.67a	89.33b	92.00b
F150	98.33a	91.67a	94.67a
LSD	1.65	1.60	1.59

Table 5: Effects of Nitrogen Fertilizer on Plant Panicles at 14 weeks

Treatment	Site 1	Site 2	Site 3
O	15.00c	15.00c	14.8c
ST	18.45b	19.33b	19.22b
F100	20.89a	23.44a	22.89a
F150	21.00a	22.89a	21.11a
LSD	1.69	1.72	2.48

Table 6: Effects of Nitrogen Fertilizer on No. of Tillers at 14 weeks after plant

Treatment	Site 1	Site 2	Site 3
O	17.78b	19.33c	24.22d
ST	17.67b	24.56b	23.56c
F100	18.55a	24.22b	26.67b
F150	18.89a	25.45a	29.33a
LSD	3.81	1.36	4.62

Table 7: Effects of Nitrogen Fertilizer on fresh weight of shoot (kg)

Treatment	Site 1	Site 2	Site 3
O	1.23d	0.57c	1.28c
ST	1.70c	0.75b	1.87b
F100	1.97b	0.80a	2.03ab
F150	2.17a	0.80a	2.27a
LSD	1.69	0.004	0.34

Table 8: Effects of Nitrogen Fertilizer on dry matter weight (kg)

Treatment	Site 1	Site 2	Site 3
O	0.32	0.10b	0.33c
ST	0.42c	0.16a	0.42bc
F100	0.55b	0.18a	0.47ab
F150	0.60a	0.81a	0.55a
LSD	0.05	0.03	0.12

Table 9: Effects of Nitrogen Fertilizer on grain yield (t/ha)

Treatment	Site 1	Site 2	Site 3
O	2.67b	1.55b	2.31c
ST	4.39a	1.94a	3.05a
F100	3.94a	2.22a	3.22a
F150	4.45a	2.22a	3.05a
LSD	1.09	0.13	0.41

In general, dry matter accumulation increased at slow rate up to 30 days after transplanting and thereafter increased at faster rate up to harvest. The highest dry matter of Nitrogen treated plots/plants could be connected with the positive effect of Nitrogen in some important physiological processes. The difference was statistically significant. Significantly, lowest dry matter accumulation (0.10 kg) was obtained from the control treated plot at site 2 (Table 8). The yield data (Table 9) revealed a positive response to N fertilizer treatment. The pooled data of yield (Table 9) revealed that rice crop responded significantly to 100 kg N/ha and 150 kg N/ha at sites 1 and 3 better than site 2. This is expected because the total N % level at sites 1 and 3 are below the critical levels (0.2 %) of Nitrogen recommended for rice production in Nigeria (Fasina 2003) to show response while the nitrogen site of 2 (0..29 %) was above the critical level of Nitrogen recommended. Plots treated with 150 kg N/ha and 100 kg N/ha gave the highest yield of 4.45 tons/ha and 3.94 tons/ha at site 1 but these yield results were not significantly different from each other (Table 9). It would be better to apply 100 kg N/ha since an additional 50 kg N/ha did not bring in any appreciable significant increase in rice yield.

There is a very close relationship between soil fertility evaluation and the result obtained for rice yield. It is obvious that 100 kg N/ha or fertilizer rate base on Soil test is optimum for rice production on these three wetland soils.

NITROGEN UPTAKE AND USE EFFICIENCY – ^{15}N STUDIES

The pattern of N uptake in dry water of the wetland sites under the different N rates and the NUE is presented in Table 10. Significant ($P< 0.05$) higher dry matter yields were obtained from two sites (1 and 3) when urea was applied at 150 kg N/ha. The values for grain yield was also high with 150 kg N/ha application than 100 kg N/ha in sites 1 and 2 but were not statistically significant. Increase in N uptake is related to dry matter production and grain yield (Table 10). Similar responses of rice crop to N uptake have been reported by Guindo *et al.* (1994), during different stages of development. The results obtained in this study showed that dry matter as well as grain yield depend on N accumulation in rice plant.

The recovery by rice of ^{15}N urea applied at 100 kg N/ha and 150 kg N/ha is shown in Table 10. The recovery by rice of ^{15}N labeled was much higher at 150 kg in sites 1 and 2; while the recovery by rice of ^{15}N urea applied was higher using 100 kg N/ha in site 3. This is expected because the total nitrogen for each of the sites differed (Table 2). The total nitrogen obtained for sites 1, 2 and 3 were 0.18 %, 0.29 % and 0.13 % respectively.

This must have been one of the reasons why there were differences in FNUE values obtained for the three wetland sites. In site 2, total nitrogen was 0.29 % obtained for the three wetland sites. In site 2, total nitrogen was 0.29 %. This value was higher than the recommended critical value (0.2%) for rice production in Nigeria (FPPD 1989). Basically, there was no response by the crop to fertilizer application because of the high native nitrogen and organic matter (Table 2).

The FUE - ^{15}N values measured in this study are comparable to those reported (43.3 to 63.8 %) for soil with low fertility (Asagie *et al.* 2007). These values are higher than those reported for upland crop (Ghoneim *et al*., 2006) and may vary depending on the crop and soil type.

The percentage of N recovery varies with soil properties, methods, amounts and timing of fertilizer application and other management practices. It usually ranges from 30 to 50 % in the tropics. Studies conducted in the Southern USA on the influence that different application timings and N management strategies have on N use efficiency in rice showed recovery at maturity of 17 to 61 % of the applied N (Norman *et a.,l* 1989). Singh and Mirayanas, (1998), reported a N recovery efficiency of 37 % in 20 lowland rice genotypes. Our results are within this limit of studies reported here (12.13 % to 57 %). The low N recovery efficiency in lowland rice may be related to N losses from soil via nitrification – denitrification, NH_3 volatization, or leaching (Craswell and Vic, 1979). The efficiency of utilization for grain production in the tropics is about 50 kg grain per kg N absorbed, and this efficiency appears to be almost constant regardless of the rice yields achieved (Yoshida 1981).

The FUE of the wetland sites at 100 kg N/ha were 55 %, 33 % and 52.9 % of the applied N in sites 1, 2, and 3 while the FUE of urea using 150 kg N/ha were 56.9 %, 36 % and 45.3 % of applied N on sites 1, 2, and 3. The higher N use efficiency in site 3 can be attributed to the considerably low soil fertility (Table 3) obtained at that site. The unaccounted portion of the inorganic ^{15}N was potentially lost through NH_3 volatilization.

An important reason for the low and average efficiency in sites 1 and 2 is the loss of the applied fertilizer from the soil – plant system. The data obtained (Table 10) from ^{15}N experiment in site 3 show that when input (fertilizer) is properly managed, rice grown on wetland sites usually make effective use of higher proportion of N applied from isotopic dilution method.

Table 10: Rice Yield and Nitrogen Uptake from Urea on three Wetland Soils in Nigeria.

Sites	Soil Total N %	Urea (kg N/ha)	Dmyield (t/ha)	Total N Yield (kg/ha)%	Urea Ndff%	Urea FNUE%	Grain yield t/ha	Salinity level ds/m	Net Farm Income (US Dollars)
1.	0.18	100	11.60b	125.85	44.05	55.44	3.94a	3.5	4575.30
		150	12.06a	130.20	43.69	56.88	4.45a		5218.00
2.	0.29	100	5.16a	63.38	52.75	33.43	2.22a	3.5	2282.00
		150	5.16a	77.32	69.27	35.70	2.22a		2244.67
3.	0.13	100	13.53b	155.50	47.91	74.50	3.22a	3.4	3615.30
		150	16.81a	170.84	39.78	45.31	3.50a		3951.30

Table 11: Economic Analysis of Rice Production on three Wetland Soils in Nigeria

Soil Type/ Site	Fertilizer Treatments KgN/ha	Grain yield t/ha	Gross income (N)	Total Fixed Cost (N)	Total Variable Cost (N)	Total Cost (TC) (N)
1	T_1 (0)	2.67	534,000	52,500	38,000	90,500
	T_2 (st)	4.39	878,000	52,500	38,870.20	91,370.24
	T_3 (100)	3.94	788,000	52,500	49,200	101,200
	T_4 (150)	4.45	890,000	52,500	54,800	106,800
2	T_1 (0)	1.55	310,000	52,500	38,000	90,500
	T_2 (st)	1.94	388,000	52,500	39,402.80	91,902.80
	T_3 (100)	2.22	444,000	52,500	49,200	101,200
	T_4 (150)	2.22	444,000	52,500	54,800	106,800
3	T_1 (0)	2.31	462,000	52,500	38,000	90,500
	T_2 (st)	3.05	610,000	52,500	38,870	91,370.24
	T_3 (100)	3.22	644,000	52,500	49,200	101,200
	T_4 (150)	3.50	700,000	52,500	54,800	106,800

Site 1

Net farm income, T_1 (0) = ₦409,500.00
T_2(ST) = ₦786,629.76
T_3(100) = ₦686,300.00
T_4(150) = ₦782,700.00

With the adequate knowledge of the native Nitrogen in the soil through soil test, the farmer can apply the right quantity needed in the soil to supplement what is deficient, and then in this case the farmer will avoid wastage and will not also pollute the soil. With this kind of information T_2 (Soil test fertilizer application rate) is recommended. But if the farmer could not lay his land on information on soil test value of Nitrogen of the area, then he can go for T_4 (150 kg N/ha).

This is because the farmer will earn over N96,000 more for the one extra bag of fertilizer he applied when compared with T_3 (100 kgN/ha). The Gross margin of N835,200/ha obtained for T_4 was higher than that of T_3 N738,800 (Table I0). The order of preference of recommendation for Site I is as follows T_2 (ST) > T_4(150)> T_3(100) > T_1 (0) T_1(0).

Economic Analysis of Rice Production

The Economic analysis of rice production of the three wetland sites is presented in (Table 11). Site 1 using 150 kg N/ha fertilizer application gave the highest yield of 4.45 t/ha but did not resulted in the highest Net farm income to the farmer. The soil test fertilizer treatment in Site 1 gave the highest Net farm income of ₦786, 629.76 (5244.20 US Dollars per hectare). This suggested that Site 1 using soil test fertilizer application rate has the best rice output of rice production. Total fixed cost did not vary between the sites. The highest total variable cost of N54,800 was incurred under 150 kg N/ha fertilizer treatment for Sites 1 and 3 (Table I2). The economic analysis for each site is hereby given below:

Site 1

Net farm income,	T_1 (0)	=	₦409,500.00
	T_2(ST)	=	₦786,629.76
	T_3(100)	=	₦686,300.00
	T_4(150)	=	₦782,700.00

With the adequate knowledge of the native Nitrogen in the soil through soil test, the farmer can apply the right quantity needed in the soil to supplement what is deficient, and then in this case the farmer will avoid wastage and will not also pollute the soil. With this kind of information, T_2 (Soil test fertilizer application rate) is recommended. But if the farmer could not lay his land on information on soil test value of Nitrogen of the area, then he can go for T_4 (150 kg N/ha).

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Site 2

Here, T_4 (150 kg/ha) is least recommended as the extra one bag of fertilizer applied resulted in a lower Net farm income of N336,700 (2244.67 US Dollars). Considering the Gross income and the Net farm income of T_2 (ST) and T_3 (100), T_2 (ST) is recommended as less than ½ bag of fertilizer was applied at soil test level. The difference in the Net farm Income does not justify the difference in the quantity of fertilizer applied in T_3. However, if soil test value on Nitrogen is not available, the farmer can go for T_3. The order of Preference of recommendation for this is given below.

T_2(ST) > T_3(100) > T_1(0) > T_4(150)

Site 3

Here also the T_2 (ST) is the most preferred. From Table 11 when comparing T_2, T_3 and T_4 that the extra quantity of fertilizer applied when one used T_3 and T_4 does not reflect in the Net farm income generated. When one compared T_3 and T_4, T_4 (150 kg N/ha) is preferred as the extra bag of fertilizer applied resulted in a difference of more than ₦50,000 in net farm income. The order of preference is given as:

T_2 (ST) > T_4(150) > T_3(100) > T_1(0)

In all the sites T_2 (ST) is the most preferred fertilizer application rate provided farmers have adequate information on soil test value of Nitrogen of their soils. The best economic rice yield (4.39 t/ha) was obtained using fertilizer rate based on soil test at Site 1.

CONCLUSION

The N rates applied in this experiment significantly influenced plant height, number of days to 50 % flowering, number of panicles, number of tillers, fresh weight of shoot, dry matter and grain yield of rice on three wetland soils in Ado-Ekiti, Ekiti State, Nigeria. The best economic yield of 4.39 t/ha of rice was obtained on a Typic Endoaquept soil using fertilizer application based on the soil test. N Recovery of rice of ^{15}N labeled was much higher using the soil test fertilizer application rate in site 3 (Typic Endoaquept). Results obtained for NFUE in sites 1 and 3 show that when input (fertilizer) is properly managed, rice grown on wetland soils usually make use of higher proportion of N applied.

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