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ECONOMICS OF PADDY RICE (*Oryza sativa* L.) PRODUCTION UNDER DIFFERENT NITROGEN FERTILIZER PLACEMENT IN TALATA MAFARA, NIGERIA

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ABSTRACT

Rice is one of the main staple food crops and its demand is rapidly increasing in Nigeria. Nitrogen (N) fertilizer is one of the key inputs in rice production, associated with widespread N deficiency. This study examined the economics of rice production under different N-fertilizer placement at various rates. The experiment was conducted at the Institute for Agricultural Research (IAR) Station, Talata Mafara to estimate the appropriate form and level of N-fertilizer application that will produce the most profitable yield in a dryland savanna. The study involved the use of Urea Super Granule (USG) and Granular Urea (GU) at different rates (0, 45.1, 72.2, 117.3 kg N/ha) with three varieties of rice (FARO 55, FARO 57 and FARO 52) as test crops. The experimental design adopted was Randomized Complete Block Design (RCBD) replicated thrice. Data were collected on growth and yield parameters; plant height, number of leaves, number of tillers, number of panicles, total biomass, straw yield, grain yield and 1,000 grain weight. All data collected were subjected to analysis of variance (ANOVA) using the mixed model procedure of statistical analysis system (SAS). Differences between treatment means were compared using Duncan Multiple Range Test (DMRT). Results from the trial showed that application of USG and GU at different rates were statistically similar but different with the control. Economic analysis of rice production revealed that application of USG at 117.3 kg N/ha on FARO 57 produced the highest gross margin of ₦254,267.15 k/ha and a profit of ₦2.54 k per naira invested. The study recommends that the deep placement of N fertilizer (USG) method should be adopted in conjunction with FARO 57 or FARO 52 for optimum productivity of rice in the study area.

Keywords: Economics, Northern Nigeria, N-fertilizer placement, Paddy yield, Talata Mafara,

INTRODUCTION

Rice (*Oryza sativa L.)* is the main food crop consumed by about 140 million Nigerians with over 2 million hectare of land devoted to its production (NAERLS and NFRA, 2009). About 5 million metric tons of rice is consumed in Nigeria and over 80% is imported costing the country a huge amount of money (Onu *et al.,* 2015). This rising increase in rice demand is largely due to rapid population growth, increased urbanization and people's preference for rice as a convenient food (FAO, 2003).

It has been discovered that average rice yields in West Africa is low and this is partly due to low soil-nutrient availability (Balasubramanian *et al*., 2007). In addition, poor-resource rice farmers in Africa are still relying on traditional technology with low use of modern inputs such as improved seeds (Lenis Saweda *et al*., 2014).

Nitrogen (N) fertilizer plays a vital role in the production of newly introduced improved rice varieties. Nigerian savanna soils are generally low in organic carbon with widespread deficiency in N (Olaleye *et al*., 2008). Unfortunately, there is low N use efficiency in rice ecosystem due to NH_3 volatilization, de-nitrification, runoff and leaching (Hasanuzzaman *et al*., 2009). The nature and magnitude of N loss largely depends on the sources and methods of N fertilizer application.

Urea is the most widely used source of N fertilizer globally including Nigeria and the conventional granular urea (GU) is a fast releasing nitrogen fertilizer which is usually broadcasted in splits that could cause considerable loss through ammonia volatilization, immobilization, de-nitrification and surface run off (Jena *et al.,* 2003). On the other hand, deep placement of N fertilizer is an alternative for increasing the N use efficiency of rice apart from minimizing the adverse effects of nitrogenous fertilizers on the environment (Bautista *et al*., 2001).

Due to aforementioned problems in the fertilizer usage and its associated increasing cost; the use of N efficient genotypes in conjunction with use appropriate method of placement is an important complementary strategy in improving rice yield and reducing cost of production. It therefore, becomes imperative to investigate the response of newly developed improved rice varieties commonly grown in the northern savanna, to different forms of urea fertilizer and modes of its placement on the rice field. This study was conducted to determine the appropriate N fertilizer forms and level in conjunction with rice varieties that will give optimum yield in the study area.

MATERIALS AND METHODS

The Study Area

The trials were conducted during the 2012 and 2013 cropping seasons (irrigated) at the Irrigation Research Station, Institute for Agricultural Research (IAR), Talata Mafara (12.6219^0 – 12.6223^0N, 006.0252^0 – 006.0255^0E and 305 m above sea level). Talata Mafara is located in the Sudan Savannah Ecological Zone of Nigeria under Sokoto Rima River Basin Development Authority. The area usually received about 660 mm of rainfall annually between the months of May and September, the rest of the period being dry (October to April). The monthly mean maximum air temperature during the dry period varies between 26 and 36^0C, while the monthly minimum is between 12 and 19^0C.

Treatments and experimental design

The treatments consisted of two factors. Factor one was the rice varieties {FARO 55 (NERICA 1), FARO 57 (TOX 4004) and FARO 52 (WITA 4)}, while factor two consisted of USG at 45.1 kg N ha^{-1} (1.8 g), 72.2 kg N ha^{-1} (2.7 g); and 117.3 kg N ha^{-1} (4.5 g); and GU at 45.08 kg N ha^{-1}, 72.22 kg N ha^{-1} and 117.30 kg N ha^{-1}. The Granular Urea (GU) was applied in two equal halves (at 2 weeks after transplanting and at panicle initiation). A control, unfertilized plot was also included. The experiments were laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times.

Agronomic Practices

The land was ploughed, harrowed and leveled manually. After land preparation, the field was dyked into basins of 3 x 3 m (9 m^2) each, as the plot size. The blocks were separated by an alley of 2 m and the plots were demarcated with high bunds of 20 cm so as to minimize lateral movement of fertilizer nitrogen from one plot to another, in-addition to conservation of water within the plot.

Pre-planting soil sampling: The soil samples were collected using auger at a depth of 0 – 20 cm. The samples collected were bulked to obtain a composite sample (20 cores for each of the three replicates), air-dried, crushed, screened through a 2-mm sieve and stored for soil characterization.

Nurseries and Transplanting of Seedlings: Nurseries were raised by drilling each rice variety (35 kg/ha) on a 4 x 4 m plot. NPK 15-15-15 fertilizer (80 kg/ha) was applied to the soil immediately after planting. Each plot was watered regularly to maintain optimum moisture using furrow irrigation method. The seedlings raised in the nurseries for three weeks were later transplanted at 2 seedlings per hill and at a spacing of 0.2 × 0.2 m to give a total population of 500, 000 plants ha^{-1}.

Fertilizer Application: Each plot received basal application of 50 kg P_20_5 ha^{-1} and 40 kg K_2O during land preparation. These fertilizer rates were based on the recommendations of FMARD (2012). Each capsule of USG (1.8 g, 2.7 g) and addition of (1.8 + 2.7) = 4.5 g size) was inserted between four hills of rice one week after transplanting (1WAT). The granular urea (GU) was applied in two equal halves (at 1 week after transplanting and at panicle initiation) by broadcasting. Irrigation was carried out using furrow method at 3 days intervals.

Harvesting: Harvesting was made at maturity (when the entire plants have turned golden brown and rachilla have dried). Harvesting was done with the help of a sickle at ground level. The total above ground biomass was bounded in heaves, dried for three days before threshing. The harvested net plots were threshed, winnowed and sun-dried, and the clean grains weighed per plot and were later expressed in kilogram per hectare.

Laboratory Analytical Procedures

Soil pH was determined in both water and 0.01M $CaCl_2$ solution using a 1:2.5 soil solution ratio with a glass electrode pH meter. The particle size distribution was determined by the hydrometer method (Gee and Or, 2002). Organic carbon was determined by the Walkley-Black wet oxidation method as described by Nelson and Sommers (1982). Total N was determined by macro-Kjeldahl oxidation method as modified by Bremner and Mulvaney (1982). Available phosphorus was extracted by the Bray-1 method as modified by Frank *et al.* (1998). Soil exchangeable potassium (K) was determined using flame photometry after extraction with ammonium acetate (Anderson and Ingram, 1993) while Calcium (Ca) and Magnesium (Mg) were determined by EDTA titration method.

Data Collection and Analysis

The following data were collected on growth and yield parameters; plant height, number of leaves, number of tillers, number of panicles, total biomass, straw yield, grain yield and 1,000 grain weight.

The data collected (plant and soil) were subjected to analysis of variance (ANOVA) using the mixed model procedure of SAS (Littell *et al.*, 1996). Differences between treatment means were compared using Duncan Multiple Range Test (DMRT). Data on costs and returns from paddy production were obtained during the trials; and results obtained were used to estimate which of the treatment combinations was profitable using gross margin and return per naira invested analysis (Mohammed, 2011). Gross margin analysis (GM) and return per naira invested (RPNI) employed were as expressed in the following equations:

$$GM = TR – TVC, TR = Yr * Pr \text{ and } RPNI = GM/TVC$$

Where:

GM = Gross margin (₦/ha)
TR = Total revenue (₦/ha)
TVC = Total variable cost (₦/ha)
RPNI = return per naira invested (₦)
Yr = Output of rice crop (kg/ha)
Pr = Unit price of rice (₦/kg)

$$\text{and } TVC = \sum_{i-j}^{n} P_i X_i$$

Where:

P_i = unit price of the i^{th} input (₦/kg) and Xi = quantity of the i^{th} input (/ha)

The cost incurred (₦/ha) for the inputs such as land preparation, seeds, fertilizers, irrigation, herbicides and labour were noted and recorded.

RESULTS AND DISCUSSION

Soil Characteristics of the Study Site

Initial physical and chemical properties of the experimental soils during 2012 and 2013 cropping seasons (irrigation) were presented in Table 1. The soil has a sandy loam texture and was generally low in clay content (80 – 120 gkg^{-1}). The soil reaction (pH) in water was moderately to slightly acidic (5.9 – 6.1). The soil is generally low in organic carbon content (1.38 – 2.42 gkg^{-1}), total N (0.35 – 0.84 gkg^{-1}) and available phosphorus (5.43 – 7.28 $mgkg^{-1}$). The exchangeable bases were also low: potassium (0.28 – 0.31 c mol kg^{-1}), calcium (2.8 – 3.2 c molkg^{-1}), magnesium (0.83 – 0.86 c mol kg^{-1}), sodium (0.22 – 0.32 c molkg^{-1}) and the CEC values were 3.5 – 4.2 c mol kg^{-1} indicating low fertility status based on FMARD (2012) rating. The low level of organic carbon is associated with sandy nature of the soil as presented in Table 1 which would enhance rapid leaching of basic cations; this is in line with Enwezor *et al.* (1989) who pointed out that this could accounted for low value of CEC. Furthermore, the low content of the soil nutrients indicate possibility of a good response to applied nutrients.

Table 1: Initial physical and chemical properties of soils at experimental location, Talata Mafara in 2012 and 2013 cropping seasons

Soil Properties	2012	2013
Physical properties:		
Bulk density (Mg cm^{-3})	1.23	1.17
Particle size distribution (g kg^{-1}):		
Clay	120	80
Silt	180	160
Sand	700	760
Textural class (USDA)	Sandy Loam	Sandy Loam
Chemical properties:		
pH water	5.90	6.10
pH $CaCl_2$	4.80	5.80
E.C (dS m^{-1})	0.42	0.39
Organic carbon (g kg^{-1})	2.42	1.38
Total Nitrogen (g kg^{-1})	0.84	0.35
Available phosphorus (mg kg^{-1})	5.43	7.28
Exchangeable bases (cmol kg^{-1}):		
K^+	0.31	0.28
Ca^{++}	3.20	2.80
Mg^{++}	0.86	0.83
Na^+	0.32	0.22
Exchangeable acidity	0.10	0.10
CEC	4.2	3.5

Source: Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria

Effect of Different N- fertilizers Placement on Grain Yield (t/ha)

The effect of N-fertilizer on grain yield of three rice varieties in 2012, 2013 and combined is presented in Table 2. From the combined analysis of the two years under investigation, results from the trial showed that application of USG and GU at different rates were statistically similar but different with the control with 33 to 37% increase over the control. This is in line with the findings of Tarfa and Kiger, 2013 who reported yield increase of 38% by the application of USG over the farmer's practice.

The varietal response showed that FARO 52 had the highest grain yield (4.97 t/ha) but statistically similar with FARO 57, while the least (2.19 t/ha) grain yield was obtained with FARO 55. The probable reason of these varietal differences is the genetic make-up of the variety which is primarily influenced by heredity. This result corroborates the findings of Bhowmick and Nayak (2000) who stated that effective tillers varied due to variety.

Significant interaction between N-fertilizer management and rice variety was observed only in 2013 as noted in Table 2.

Table 2: Effects of N-fertilizers, rates and variety on Grain yield (t/ha) of rice at Talata Mafara in 2012, 2013 cropping seasons and combin

Treatments Nitrogen (N) kg/ha	2012	2013	Combined	% Increase over control
Control	3.28[b]	2.08[c]	2.68[b]	-
USG (1.8 g)	4.66[a]	3.77[ab]	4.22[a]	36.49
USG (2.7 g)	4.39[a]	3.97[ab]	4.18[a]	35.89
USG (4.5 g)	4.43[a]	4.19[a]	4.22[a]	36.49
GU at 45.1	5.22[a]	3.42[ab]	4.32[a]	37.96
GU at 72.2	5.05[a]	3.08[b]	4.06[a]	33.99
GU at 117.3	4.25[ab]	4.17[a]	4.16[a]	35.58
S.E ±	0.341	0.289	0.397	
Variety (V)				
FARO 55	2.47[c]	2.09[c]	2.19[b]	
FARO 57	5.86[a]	3.16[b]	4.69[a]	
FARO 52	5.12[b]	4.78[a]	4.97[a]	
S.E ±	0.209	0.178	0.243	
Interaction				
N x V	NS	*	NS	

Means followed by the same letter(s) within the same column and treatment group are not significantly different at 5% level of probability using DNMRT. * = significant at 5% level of probability. NS = not significant. USG = Urea Super Granules, GU = Granular Urea

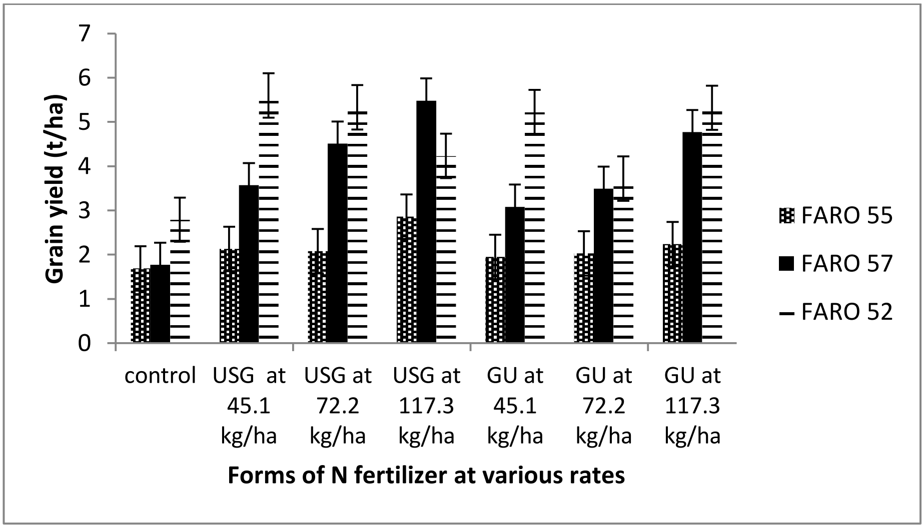

Figure 1: Interaction of N-form of fertilizer, rate and rice variety on grain yield (t/ha)

Analysis of Production Cost and Returns

The cost involved in the production of rice under different forms of N fertilizer in this study was majorly in the variable cost and this was due to the difference in level of fertilizer applied to the treatment apart from the methods of placement involved. The amount of N fertilizer applied varied per treatment and hence resulted in differences in total variable cost (TVC). Application of GU at 117.3 kg/ha gave the highest TVC of ₦105,250.00/ha while the control treatment had the least (₦79,750.00/ha) TVC with relatively low yield due to non-application of fertilizer in the treatment as presented in Table 3. This is similar to the findings of Daudu *et al*. (2014) who recorded average production cost of ₦81,600.00/ha but lower than the value of ₦265,481.50/ha reported by Tarfa and Kiger, 2013 for lowland rice in some parts of northern Nigeria. It could be observed that the different level and forms of fertilizer had significant effect on the paddy yield.

The revenue realized from the sale of paddy rice as presented in Table 3 showed that application of USG at 117.3 kg N/ha on FARO 57 had the highest (₦354,552.15/ha) revenue and non-application of fertilizer on FARO 55 had the lowest (₦87,710.41/ha) revenue. This value is lower compared to the findings of Tarfa and Kiger, 2013 where application of USG generated ₦447,051/ha while farmer's practice produced revenue of ₦267, 847/ha.

Economic Analysis of Paddy Yield

The result of gross margin (₦/ha) and return per naira invested (₦) on investment of growing three rice varieties using USG and GU is presented in Table 3. Results showed that non-application of N-fertilizer to either of the rice varieties (FARO 55, FARO 57 or FARO 52) resulted in gross margins of ₦7,960.41k/ha, ₦117,561.26k/ha and ₦121,723.26k/ha with profit of ₦0.10k, ₦1.47k and ₦1.53k respectively.

Production of paddy rice using USG at 117.3 kg N/ha on FARO 57 was the most profitable with highest gross margin of ₦254,267.15 k/ha and a profit of ₦2.54 k per naira invested. This was closely followed by the application of USG at 45.1 kg N/ha on FARO 52 with a gross margin of ₦251,533.48 k/ha and a return of ₦2.35 k per naira invested. Again, the rice production with least gross margin of ₦7,960.41 k/ha and a profit of ₦0.10 k per naira invested was FARO 55 with no N-fertilizer as presented in Table 3.

The results showed that the gross revenue or income, gross margin and return per naira invested were highly influenced by fertilizer application. The return per naira invested indicates the benefit-cost ratio and was greater than 1.0 in most of the applied fertilizer rates except with the FARO 55 where the grain yield was low and consequently led to lower gross margin (Table 3). The total cost of production increased as the rate of fertilizer increased up to 117.3 kg ha^{-1} for both GU and USG respectively (Table 3). The TVC varied from 79,750.00 to 100,285.00 (₦/ha) which is an indication of 24% and 20% differences between unfertilized and fertilized crops with GU at 117.3 kg N/ha and USG at 117.3 kg N/ha respectively. This finding corroborates the report of Daudu *et al.* (2014) who observed profitability of ₦93,780.00 - ₦264,420.00 with a return of ₦1.15k - ₦3.24k per naira invested in rice production in the northern Nigeria.

Results obtained in this study showed that regardless of variety used, application of N- fertilizers (USG and GU) up to 117.3 kg N/ha increased the grain yield. The results of the economic analysis of rice production showed that the applications of USG at 117.3 kg N/ha on FARO 57 gave the highest gross margin of ₦254,267.15 k with a profit of ₦2.54 k per naira invested. The higher profitability observed in the application of USG to all varieties of rice resulted from higher yield and low total variable cost especially the labour on fertilizer application and fertilizer cost incurred on the USG fertilizer options; thereby reducing the cost of fertilization. In addition, there was a substantial difference between the yields of paddy rice under different N- fertilizer regimes which can be attributed to differences in absorption of nutrients by the rice varieties differently and availability of the nutrients which differs for each treatment. On the other hand, the cost incurred on fertilizing GU was relatively higher due to labour cost incurred on fertilizer application at two (2) splits per growing season.

Table 3: Economic analysis on investment of growing three rice varieties using Urea Super Granules (USG) and Granular Urea (GU) at Talata Mafara

Treatment Fertilizer (N) Management	Rice Variety	Yield (t/ha)	Gross Revenue (₦/ha)	Total Variable Cost (₦/ha)	Gross Margin (₦/ha)	Return per naira invested (₦)
Control	FARO 55	1.46	87,710.41	79,750.00	7,960.41	0.10
USG at 45.1	FARO 55	2.05	123,070.09	88,285.00	34,785.09	0.39
USG at 72.2	FARO 55	2.29	137,407.72	90,950.00	46,457.72	0.51
USG at117.3	FARO 55	3.47	209,122.33	100,285.00	108,837.33	1.09
GU at 45.1	FARO 55	2.23	133,600.26	90,650.00	42,950.26	0.47
GU at 72.2	FARO 55	2.64	158,359.04	94,050.00	64,309.04	0.68
GU at 117.3	FARO 55	3.05	184,157.65	105,250.00	78,907.65	0.75
Control	FARO 57	3.23	197,311.26	79,750.00	117,561.26	1.47
USG at 45.1	FARO 57	4.91	297,204.81	88,285.00	208,919.81	2.37
USG at 72.2	FARO 57	5.42	327,206.96	90,950.00	236,256.96	2.60
USG at117.3	FARO 57	5.89	354,552.15	100,285.00	254,267.15	2.54
GU at 45.1	FARO 57	4.68	284,189.26	90,650.00	193,539.26	2.14
GU at 72.2	FARO 57	4.79	289,861.00	94,050.00	195,811.00	2.08
GU at 117.3	FARO 57	5.45	329,028.30	105,250.00	223,778.30	2.13
Control	FARO 52	3.35	201,473.26	79,750.00	121,723.26	1.53
USG at 45.1	FARO 52	5.66	339,818.48	88,285.00	251,533.48	2.45
USG at 72.2	FARO 52	4.86	290,454.89	90,950.00	199,504.89	2.19
USG at117.3	FARO 52	4.78	287,446.67	100,285.00	187,161.67	1.87
GU at 45.1	FARO 52	5.18	312,006.42	90,650.00	221,356.42	2.44
GU at 72.2	FARO 52	5.03	304,500.37	94,050.00	210,450.37	2.24
GU at 117.3	FARO 52	5.73	344,339.44	105,250.00	239,089.44	2.27

USG = Urea Super Granules, GU = Granular Urea. Calculation of total revenue is based on ₦ 6,000 per bag (100 kg) of paddy rice at the farm gate price. Assumption for economic analysis: Exchange rate, US $1= ₦ 160 at the time of experiment (2012 – 2013).

CONCLUSION

It can be deduced from this experiment that paddy yield varies with the forms and level of N -fertilizer applied to each treatment. It was found that application of USG at 117.3 kg N ha^{-1} on FARO 57 produced the highest grain yield of 5.89 t/ha with gross margin (₦254,267.15 k/ha) as well as profit (₦2.54 k) per naira invested. The deep placement of N fertilizer should be adopted so as to facilitate efficient utilization of N-fertilizer by the rice crop. This practice is therefore recommended within the scope of the study to the small and large-scale farmers in the study area.

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