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EFFECT OF NITROGEN FERTILIZER (UREA) ON SOIL ACIDITY INDICES UNDERLOWLAND RICE CULTIVATION IN YOLA, NIGERIA

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Abstract

The experiment was conducted for two years to determine the effect of N fertilizer application rates (0, 50, 100 and 150 kg/ha on grain yield, pH, calcium (Ca), magnesium (Mg), base and acidity saturation of the soil in FARO 44 lowland rice cultivation. Grain yield was significantly (P= 0.05) affected by the N fertilizer rates; it increased linearly with N rates. The grain yield increased was by 41.59, 66.21 and 79.87% for 50, 100 and 150 kg ha^{-1} N rates respectively as compared to control. pH, Ca, Mg and base saturations decreased with increased in N rates compared to the control. Acidity saturation increased with increasing N rates. The acidity saturation increased was by 3.57, 4.92 and 6.68% for 50, 100 and 150 kg ha^{-1} N rates respectively as compared to control. In order to sustain the soil, regular monitoring and adoption of management practices such as split application of fertilizers, incorporation of organic matter and soil conservation measures to control erosion and leaching of base cations that minimizes soil acidification processes should be imbibed in lowland rice cultivation in Adamawa state, Nigeria.

Keywords: Nitrogen fertilizer, acidity, indices, rice

INTRODUCTION

Globallyabout 76% of rice is produced from an irrigated lowland system and nitrogen is usually the most yield-limiting nutrient in lowland production system. Intensive agricultural production systems have increased the use of nitrogen (N) fertilizer in an effort to produce and sustain high crop yields (Fageria *et al.*, 2003). Soil acidification is one of the serious environmental problems in the world which was originally a slow natural process; however, human activities have dramatically accelerated the process in recent decades. One of the artificial factors is unreasonable agricultural practices such as improper and excessive continuous application of nitrogen fertilizer which considerably aggravate soil acidification (Wang *et al.*, 2010). Although crop productivity can be enhanced by N fertilization, this with other management practices may strongly interact and impact soil properties differently (Russell *et al*., 2006). N fertilization has been found to decrease exchangeable calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^{+}) levels, and cation exchange capacity (CEC) of the soils (Barak e*t al.*, 1997).

The pH of the soil is a valuable diagnostic measurement that indicates whether soil is acidic (pH 1 to 6.5), neutral (pH 7), or alkaline (pH 8.5 to 14). The pH is an indication of the concentration of hydrogen ions (H^{+}) in the soil solution and as the concentration increases they become more active and the soil becomes acidic. At pH 5.5 aluminium tends to dissolve into free ion and dominate the soil solution and compete very successfully with other cations for negative charges, in this regard the basic cations are displaced and leached out leaving the soil acidic (Harter, 2007). Three processes are largely responsible for soil acidification: leaching away of bases (Na^{+}, Ca^{++}, Mg^{++}, K^{+}), removal of bases by crops and repeated application of acid forming fertilizers, such as ammonium sulfate, urea, etc. Savanna soils been highly weathered, high in low activity clay and low in organic matter content, with continuous cultivation that warrants major nutrient uptakes by the crops and regular application of nitrogenous fertilizers are prone to acidification. The objective of the study was to assess the impact of nitrogen fertilizer (Urea) rates on soil acidity indices under irrigated lowland rice cultivation.

MATERIALS AND METHODS

The study area lies within the Northern Guinea Savannah zone of Nigeria, (9^{o} 23' N, 12^{o} 46' E and 152m above sea level). The experiments were carried out at the Lake Geriyo Irrigation scheme site, West of River Benue and North of Jimeta-Yola town, the Capital of Adamawa State, Nigeria during the 2011 and 2012 dry seasons. The major sources of the irrigation water are Benue River, Geriyo Lake and some drilled tube wells, The area is underlain by the Bima sandstone and recent river alluvium (Ishaku, 2011) and characterized by an average annual rainfall of 900– 1000mm. Mean daily air temperatures (minimum and maximum) rangesfrom 18 - 40^{o} C. The wind speed ranges from 88km/day in October to 284km/day in March. The humidity may be as low as between 10 - 20% during the dry season and 80% in August (Adebayo and Nwagboso, 2005). The field experiment carried out for two yearsconsisted of four nitrogen rates 0, 50, 100 and 150kg N ha^{-1} urea fertilizer (46% N) with 3 replicates in a randomized complete block design (RCBD).

FARO 44 lowland rice variety sourced from the Adamawa state skilled acquisition training center, Yola south LGA were sown in the nursery and transplanted to the field permanent 30 days after sowing (DAS) at a spacing of 20cm x 20cm andfour days irrigation interval was maintained throughout the growth period of the crop. After crop harvest the second year soil samples were taken at 0–20 cm depth from each plot for physico-chemical analysis using standard procedures and methods as described by Ryan *et al*. (2001). The soil particles size distribution was determined by the hydrometer method. The soil bulk density was determined from undisturbed soil samples in the field using core samplers (Cassel, 1982). Soil pH was determined potentiometrically in a 1:1 (Soil: Water) suspension and 0.01M $CaCl_2$. The electrical conductivity was measured with EC meter using the same 1:1 soil-water suspension. The organic carbon content was determined using potassium dichromate wet-oxidation method. Total Nitrogen in the soil was measured by wet digestion using the kjeldahl and distillation procedure. Available phosphorus was determined by Bray No. 1 method. Exchangeable bases were extracted in neutral 1N ammonium acetate (NH_40Ac). Calcium and Magnesium were determined by atomic absorption spectrophotometry while, sodiumand potassium by flame photometer. Exchangeable acidity was determined by displacement with I N KCL and titration of the extract with 0.025 N NaOH solution using phenolphthalein indicator. The effective cation exchange capacity was by summation of the exchangeable bases and acidity. Base saturation was calculated by dividing the sum of the exchangeable bases by the CEC (soil) expressed as a percentage. The relative grain yield and soil acidity indices were calculated following expressions described in Fageria*et al.* (2010) as: Relative grain yield (%) = (Grain yield at a determined N rate/ Maximum grain yield at a determined N rate) × 100

Ca saturation (%) = (Ca^{2+} / CEC) × 100, where CEC is cation exchange capacity in $cmol_c\ kg^{-1}$ = [sum of (Ca^{2+} , Mg^{2+} , K^+ , H^+ , Al^{3+})]

Mg saturation (%) = (Mg^{2+} / CEC) × 100

Base saturation (%) = [sum of (Ca^{2+}, Mg^{2+}, K^+) / (CEC)] × 100

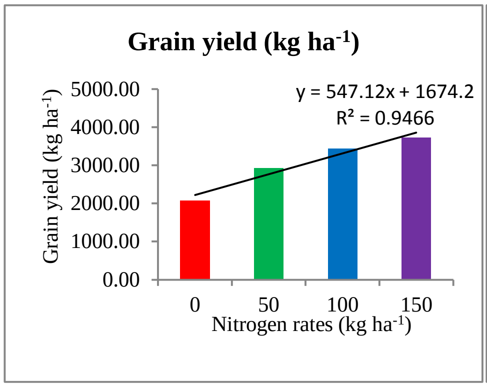
Acidity saturation (%) = (H^+ + Al^{3+} /CEC) × 100

RESULTS AND DISCUSSION

The initial soil properties of the study area (Table 1) showed that the soil is clay loam in texture, slightly acidic (pH 6.10) considered to be suitable for most crop production (Brady and Weil, 2007) but need to be monitored, while nitrogen, organic carbon, phosphorus and exchangeable bases were low (Esu, 1991). This could be explained by the inherent low fertility status associated with savanna soils known to be characterized by low activity clay, low level of organic matter, nitrogen, phosphorus, potassium and exchangeable bases (Osundare, 2008).

The rice grain yield was significantly influenced by the N-rates showing an increasing trend with increase in N levels (Figure 1). This result was in conformity with the findings of Fageria*et al*. (2010) who reported that grain yield expressed as relative grain yield was significantly increased by urea fertilization. The grain yield increased as compared to control was by 41.59, 66.21 and 79.87% for 50, 100 and 150 kg ha^{-1} N rates as compared to control whilepH decreased with increased in N levels from control to 50, 100 and 150kgN ha^{-1} respectively by 1.79, 3.41 and 4.72% (Figure 2).

Naturally, soil acidity develops gradually over time as part of the soil development process and other natural phenomena (Obiri-Nyarko, 2012). This indicates that increase use of nitrogenous fertilizer will continue to decrease the pH level (increase acidity) if proper and best management practices were not adopted. The soil pH directly affects nutrient availability,because as the pH decreases some of the vital nutrients such as P, Ca and Mg are made unavailable in the soil solution for plant uptake (Obiri-Nyarko, 2012; Brady and Weil, 2007).



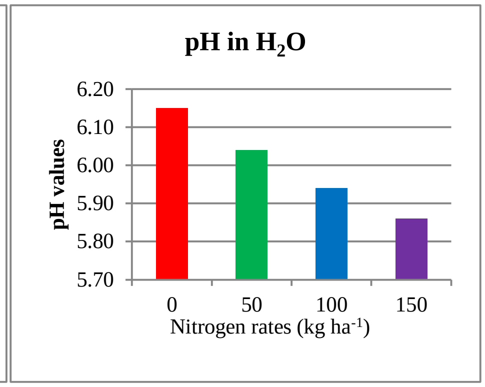
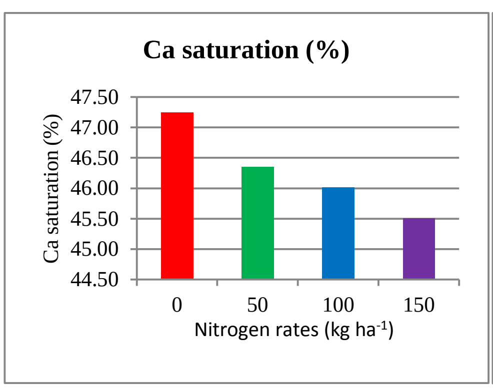


Figure 1: Effect of N-rates on relative grain yield of rice Figure 2: Effect of N-rates on soil pH

Ca and Mg saturation decreased with increasing N rates (Figures 3 and 4). The Ca saturation decreased by 1.88, 2.58 and 3.66% while Mg saturation decreased by 2.22, 1.64 and 2.45% for 50, 100 and 150 kg ha^{-1} N rates respectively. The decrease in Ca and Mg saturation at greater N rates may be associated with increase in acidity at greater N rates and decrease in concentration of these elements. An increase in acidity decreases the concentrations of Ca and Mg in Brazilian Inceptisols (Fageria and Baligar, 1999; Fageria*et al*., 2010).



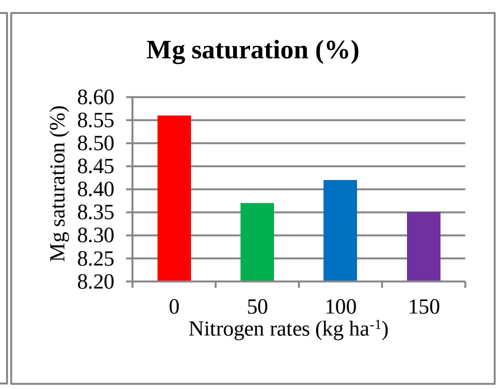


Figure 3: Effect of N-rates on Ca-saturation Figure 4: Effect of N-rates on Mg-saturation

Base saturation is an important soil acidity index for predicting fertility behavior of tropical soils (Fageria and Baligar 2001). Base saturation decreased linearly with increasing N rates by N fertilizer (Figure 5). The decrease in base saturation was by 1.50, 1.80 and 2.47% for 50, 100 and 150 kg ha^{-1} N rates respectively as compared to the control treatment. The acidity saturation increased linearly with the increasing N rates (Figure 6). The acidity saturation increased was by 3.57, 4.92 and 6.68% for 50, 100 and 150 kg ha^{-1} N rates as compared to control. The increase in acidity saturation was associated with a decrease in base saturation with increasing N rates. Another reason for increase of these acidity indices was due to a decrease in pH with increasing N rates (Fageria*et al*., 2010).Soil acidity has been shown to have detrimental effects on plant by affecting nutrients availability and plant growth and development (Obiri-Nyarko, 2012). Some best management practices (BMPs) can be adopted to ameliorate and sustain the soils from been acidic. These may include application of organic matter, crop rotation, inter-cropping cereals with leguminous crops, conservation tillage to minimize loss of base cations to leaching and runoff. Other nitrogen management practices should be considered are selection of fertilizers that contribute little or no acidity (nitrates over aluminium sources), avoid applying too much fertilizer, adopt split applications instead of once or use slow-release fertilizer and monitoring of soil regularly through soil test.

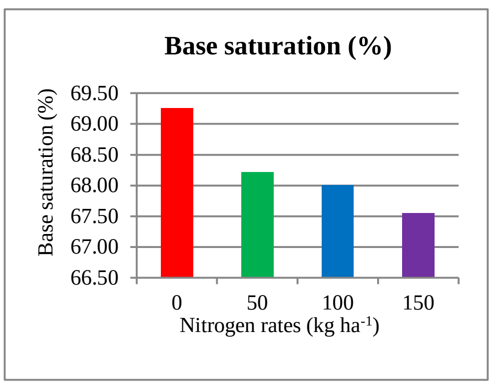


Figure 5: Effect of N-rates on base saturation

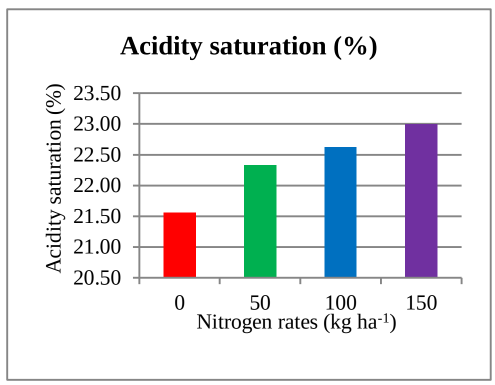


Figure 6: Effect of N-rates on acidity saturation

CONCLUSION

The grain yield and acidity saturation of the soil increased significantly with increased in N application rates, while the pH, Calcium, Magnesium and base saturations of the soil showed decreasing trend with the increased in N application rates. Therefore, in order tosustain the soils from been acidic, acidity indices should be monitored regularlyand adopt some best management practices such as split application of fertilizers, incorporation of organic matter and soil conservation measures to control erosion and minimize loss of base cations.

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Table 1: Initial physical and chemical properties of the soil of the experimental site at 0 – 20cm depth before the application of N treatments

Properties	**Value**
Sand (g kg^{-1})	393.7
Silt (g kg^{-1})	241.3
Clay (g kg^{-1})	365
Textural class	Clay Loam
Bulk density (g cm^{-3})	1.53
Basic Infiltration rate (m hr^{-1})	0.44
pH (Water)	6.1
pH (0.01M $CaCl_2$)	5.63
Electric Conductivity (dS m^{-1})	1.82
Organic Carbon (g kg^{-1})	6.4
Organic Matter (g kg^{-1})	11.01
Total Nitrogen (g kg^{-1})	0.08
Available Phosphorus (mg kg^{-1})	2.04
Calcium (Ca^{2+})	2.25
Magnesium (Mg^{2+})	0.3
Sodium (Na^{+})	0.14
Potassium (K^{+})	0.24
Base Saturation (%)	78.24
EA ($cmol_c kg^{-1}$)	0.84
ECEC ($cmol_c kg^{-1}$)	3.86

EA =Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity