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Organic amendment and soil moisture of an ultisol: effects on nitrogen mineralization

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Abstract

This study was conducted to assess nitrogen (ammonium nitrogen: NH_4-N and nitrate nitrogen: NO_3-N) mineralization of an ultisol amended with different rates of cow dung (CD) and soil moisture regimes (water holding capacity: WHC). The Ultisol soils were sampled at 0-30 cm depth from cassava cultivated land beside Faculty of Agriculture, Kogi State University Anyigba, Nigeria. The soils were sieved, each pot filled with 5 kg each, and treatments applied under controlled environment in complete randomized design replicated three times. Treatments were composed of TA50 (15g CD @50 % WHC), TA100 (15g CD @ 100 % WHC), TB50 (30g CD @50 % WHC), TB100 (30g CD @ 100 % WHC), TC50 (45g CD @50 % WHC), TC100 (45g CD @ 100 % WHC), Control50 (5kg soil @ 50% WHC), and Control100 (5kg soil @ 100% WHC). During the 70 days incubation period, water treatments were applied every 2 weeks while NH_4-N and NO_3-N were measured at 35 and 70 days after mineralization (D.A.M.). The results showed that pots treated with TC100 had highest NH_4-N (797.9 and 875.2 mg/kg at 35 and 70 D.A.M. respectively) and highest NO_3 -N (72745 and 3010 mg/kg at 35 and 70 D.A.M. respectively). However, at 70 D.A.M., there was no significant difference in NH_4-N and NO_3-N concentrations of pots treated with TB50, TB100, and TC100. The results indicate that nitrogen mineralization is influenced by high moisture regime and the rate of organic amendment applied.

Keywords: Mineralization; Nitrogen; Soil Moisture; Nitrate; Ammonium.

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1.0 Introduction

In the past years, inorganic fertilizers were advocated for crop production to ameliorate the soil's low inherent fertility in the tropics. In addition to being expensive and scarce, inorganic fertilizers are often associated with leaching, accumulation of toxic wastes, soil acidity and nutrient imbalance (Ano & Agwu 2005). Organic fertilizers represent a source of nutrient for plants (Powlson *et al.,* 2011). Their decomposition is responsible for the nutrient release, for example, animal by-products are rich in protein, and they offer a good source of N for the plant (Gaskell & Smith, 2007). Soil organic matter (SOM) decomposition and N mineralization is the process of transforming undissolved organic N into dissolved inorganic N (NH_4+ and NO_3-); the process is influenced by soil temperature, soil moisture, vegetation litter, quantity and quality of organic matter, microbial metabolism and soil management practices (Wang *et al*., 2009; Liu *et al*., 2010; Abera *et al.,* 2012; Li *et al.,* 2014).

Laboratory incubations under controlled conditions can separate the effects of temperature and moisture on N mineralization, however, with diverse soil nutrient contents, controlling factor level settings and sampling frequencies, different studies have provided inconsistent responses (Li *et al.,* 2014). To eliminate the effect of soil nutrient changes, many studies used disturbed soil samples. In previous research, the net N mineralization rate has been acknowledged to be positively related to temperature during incubation (Zaman *et al*., 2004; Wu *et al*., 2007). However, some studies had shown that the net N mineralization rate was positively related to soil moisture (Zhang *et al*., 2008; Chen *et al*., 2012), while others had suggested that the N mineralization rate decreased when the moisture level was beyond an optimal condition (Wu *et al*., 2007; Zou *et al*., 2010). Even less information is available regarding the combined effects of these two factors on N mineralization processes (Guntinas *et al*., 2012); therefore, a thorough explanation of the mineralization mechanism is limited. To apply manure or compost to fulfil the nutritional requirement of a crop, knowledge of the rate of application and mineralization rate influenced by soil moisture regime and temperature application is needed. Therefore, this study was conducted to assess the effect of the rate of application of organic manure and soil moisture regime on N mineralization (ammonium nitrogen: NH_{4+} - N and nitrate nitrogen: NO_{3-} - N). Other objectives were:

i. To examine soil moisture regime's effect on soil NH_{4+}

- N and NO_3- - N. mineralization.

ii. To evaluate the cow dung application rate's effect on the mineralization of NH_4^+ - N and NO_3^- - N.

2.0. Materials and Method

2.1. Study Location

Pot experiments were conducted in the laboratory complex, Faculty of Agriculture, Kogi State University (KSU) Anyigba located between latitude 7°15' and 7°29' N of the equator and longitude 7°11' and 7°32' E of Greenwich meridian. The study area has a distinct rainy and dry season, and it has an average temperature of 31°C and an annual rainfall of 1496 mm (Amhahkian *et al*., 2010).

2.2. Treatment and experimental design

The cow dung was sourced from K.S.U.'s livestock farm. A total of 24 pots filled with 5 kg of soil each were used for the experiment. Cow dung treatment was mixed with the weighed soils before filling each pot. The treatments consisted of cow dung manure applied at the rate of 15 g/pot, 30 g/pot, 45 g/pot and the control pots (Table 1). The experimental design was Complete Randomized Design (C.R.D.) with treatments replicated three (3) times. The moisture regime was at 50 % and 100 % water holding capacity (W.H.C.). The water holding capacity was derived from the values of the gravimetric moisture content (GMC). The GMC was determined by weighing core soil samples from the field to get the fresh weight (W2) and then oven-dried at 1050C for 24 hours to determine the dry weight (W3). These values were then used to calculate the GMC (θg) of the soil as follows;

Gravimetric moisture content =

$$\frac{\text{mass of water (g/g)}}{\text{Mass of oven-dried soil}}$$

$$\% \, Moisture = \frac{W2-W3}{W2-W1} \, X \, 100$$

Where;
W1= initial weight of the empty core
W2= weight of the core with the sample before drying
W3= weight of the core with the sample after drying

The moisture regime of 50 % and 100 % W.H.C. used in this study were 50% and 100 % GMC that was determined. Moisture treatment (addition of deionized water) was after mixing the varying quantities of cow dung with the soils in the pots. The potted samples were weighed, and subsequently, moisture treatment was done at every 2 weeks. Daily morning and evening temperature were recorded for 70 days using a room thermometer.

2.2. Soil Preparation and Analysis

The soil used for the experiment were collected from Faculty of Agriculture, Kogi State University (K.S.U.), beside Centre for Atmospheric Research, Anyigba Kogi State. The soils were prepared (crushed, air dried, and sieved through 2mm sieve) for 35 and 70 days. Soil NH_4+ - N and NO_3- - N of the samples were analyzed. However, as outlined in previous studies (Abbasi and Adams, 2000; Abbasi et al., 2001; Abbasi and Khizar, 2012; Abbasi & Khaliq, 2016), the determination of NO_3- - N will require values of total mineral nitrogen (T.M.N.) and NH_4+ - N which was pointed out as steam distillation and titration method of Keeney and Nelson (1982). The T.M.N. and NH4+–N were analyzed in the laboratory by extracting soil samples with 200 ml of 2 M KCl (Abbasi & Khaliq, 2016) - this involved 1-hour shaking of soil samples with 200 ml of 2 M KCl followed by filtration using Whatman's No. 40 filter paper. The NO_3- - N was then derived by subtracting NH_4+–N from T.M.N.

Table 1: Treatments and their meaning

Treatment	Meaning
TA50	15 g of cow dung/5kg soil at 50 % water holding capacity
TA100	15 g of cow dung/5kg soil at 50 % water holding capacity
TB50	30 g of cow dung/5kg soil at 50 % water holding capacity
TB100	30 g of cow dung/5kg soil at 100 % water holding capacity
TC50	45 g of cow dung/5kg soil at 50 % water holding capacity
TC100	45 g of cow dung/5kg soil at 100 % water holding capacity
Control50	5 kg soil with no cow dung at 50 % water holding capacity
Control100	5 kg soil with no cow dung at 100 % water holding capacity

2.3. Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) and using GENSTAT Discovery Software. Significant means were separated using Duncan Multiple Range Test (DMRT).

3.0. Results and Discussion

3.1. Results

3.1.1 Interactive Effect of Cow Dung Rate and Soil Moisture Regime on the Mineralization of Ammonium Nitrogen (NH_4+ - N)

Table 2 shows the interactive effect of cow dung rate and soil moisture regime on ammonium nitrogen's mineralization**.** At 35 days after treatment application, TC100 gave the highest NH_4+ - N (797.9 mg/kg) followed by TA100 (759.3 mg/kg), TB100 (765.8 mg/kg) and TC50 (746.5 mg/kg) which are not significantly different. Similarly TA50 (701.4 mg/kg) TB50 (701.4 mg/kg) and control100 showed no significant difference. On the other hand, Control50 had the lowest (669.2 mg/kg) NH_4+ - N.

At 70 days after treatment application Treatments, TB50 (830.1), TB100 (849.4 mg/kg), and TC100 (875.2 mg/kg) gave the highest value NH_4+ - N. Similarly, TA100 (823.7 mg/kg), TB50 (830.1 mg/kg), TB100 (849.4 mg/kg), TC50 (810.8 mg/kg) and Control100 (823.7 mg/kg), showed no significant difference followed by TA50 (752.9 mg/kg) while Control50 had the lowest (662.8 mg/kg) NH_4+ - N.

3.2. Interactive Effect of Cow Dung Rate and Soil Moisture Regime on the Mineralization of Nitrate Nitrogen (NO_3^- - N)

At 35 days after treatment application, TC100 gave the highest (2745 mg/kg) NO_3^--N. Treatments TA100, TB100, and TC50 were not significantly different with values of 2611, 2634, and 2568 mg/kg respectively (Table 3). Also, lowest with no significant difference in NO_3^- - N were TB50 (2391 mg/kg), Control50 (2302 mg/kg) and Control100 (2346 mg/kg).

At 70 days after treatment application, there was no significant difference in NO_3^--N levels of TB50 (2878 mg/kg), TB100 (2922 mg/kg), TC50 (2789 mg/kg). Likewise treat-

Table 2: Interactive Effect of Cow Dung Rate and Soil Moisture Regime on the Mineralization of Ammonium Nitrogen (NH4+ - N)

Treatment	Ammonium Nitrogen (mg/kg) at 35 Days after Treatment Application	Ammonium Nitrogen (mg/kg) at 70 Days after Treatment Application
TA 50	701.4c	752.9c
TA 100	759.3b	823.7b
TB 50	701.4c	830.1ab
TB 100	765.8b	849.4ab
TC 50	746.5b	810.8b
TC 100	797.9a	875.2a
Control 50	669.2d	662.8d
Control 100	682.1c	823.7b

Note: Means with different letters in a column are statistically significant.

TA50 = 15 g of cow dung/5kg soil at 50 % water holding capacity(WHC), TA100 = 15 g of cow dung/5kg soil at 50 % WHC, TB50 = 30 g of cow dung/5kg soil at 50 % WHC, TB100 = 30 g of cow dung/5kg soil at 100 % WHC, TC50 = 45 g of cow dung/5kg soil at 50 % WHC, TC100 = 45 g of cow dung/5kg soil at 100 % WHC, Control50 = 5 kg soil with no cow dung at 50 % WHC.

ments TA100 (2833 mg/kg), TB50 (2878 mg/kg), TB100 (2922 mg/kg), TC50 (2789 mg/kg) and control 100 (2833 mg/kg) were also not significantly different. Control50 recorded the lowest (2278 mg/kg) NO_3^--N.

4.0. Discussion

Interactive Effect of Cow Dung Rate and Soil Moisture Regime on the Mineralization of Ammonium Nitrogen and Nitrate Nitrogen

The results from this study revealed that increased rate of cow dung application and soil moisture resulted in a higher rate of soil N (ammonium N and nitrate N) mineralization. This was evident at 35 days after treatment application where TC100 (45 g of cow dung at 100 % W.H.C.) had the highest mineralization rate. The results from this study support the report of Walters *et al.* (1992) that moisture influences mineralization of nitrogen in three major ways; moisture stress inhibits microbial growth directly, high moisture content decreases aeration and microbial growth, and cycles of wetting and drying tend to increase the amount of available substrate. At high moisture contents, biological activity and decomposition rates are decreased through lack of oxygen; thus, under anaerobic conditions, decomposition depends on anaerobic bacteria. Furthermore, Mazzarino *et al.* (1991) reported a positive correlation between mineralization and soil moisture.

Table 3: Interactive Effect of Cow Dung Rate and Soil Moisture Regime on the Mineralization of Nitrate Nitrogen (NO3- - N)

Treatment	Nitrate Nitrogen (mg/kg) at 35 Days after Treatment Application	Nitrate Nitrogen (mg/kg) at 70 Days after Treatment Application
TA 50	2413c	2590c
TA 100	2611b	2833b
TB 50	2391cd	2878ab
TB 100	2634b	2922ab
TC 50	2568b	2789b
TC 100	2745a	3010a
Control 50	2302d	2278d
Control 100	2346cd	2833b

Note: Means with different letters in a column are statistically significant.

TA50 = 15 g of cow dung/5kg soil at 50 % water holding capacity(WHC), TA100 = 15 g of cow dung/5kg soil at 50 % WHC, TB50 = 30 g of cow dung/5kg soil at 50 % WHC, TB100 = 30 g of cow dung/5kg soil at 100 % WHC, TC50 = 45 g of cow dung/5kg soil at 50 % WHC, TC100 = 45 g of cow dung/5kg soil at 100 % WHC, Control50 = 5 kg soil with no cow dung at 50 % WHC.

Conversely, increased levels of soil moisture regime and cow dung application rate to an extent did not result in much variations in soil N mineralization at 70 days after treatment application. Depending on the quality of the organic materials used, mineralization is rapid within a few weeks of incorporation, for high-quality materials or is slow and spread over several weeks for low-quality materials. Thus time is a function of quality. Rubaduka *et al.* (1993) working with woody legume prunings, found that at least 59 % of the total nitrogen was released within two weeks of incorporation.

5.0. Summary And Conclusions

This study was conducted to evaluate the effect of the rate of cow dung application and soil moisture regime on N mineralization (ammonium nitrogen: NH_{4+} - N and nitrate nitrogen: NO_{3-} - N). Pot experiments were conducted in the laboratory complex, Faculty of Agriculture, K.S.U. Anyigba. The treatments consisted of cow dung manure applied at 15 g/pot, 30 g/pot, 45 g/pot and the control pots. The moisture regime was at 50 % W.H.C. and 100 % W.H.C. The experimental design was Complete Randomized Design (C.R.D.) with treatments replicated three (3) times. The data collected were subjected to analysis of variance (ANOVA) and using GENSTAT Discovery

Software. Significant means were separated using Duncan Multiple Range Test (DMRT).

The results from this study revealed that increased rate of cow dung application and soil moisture resulted in a higher rate of soil N (ammonium N and nitrate N) mineralization. This was evident at 35 days after treatment application where TC100 (45 g of cow dung at 100 % W.H.C.) had the highest mineralization rate. Conversely, increased levels of soil moisture regime and cow dung application rate to an extent did not result in much variations in soil N mineralization at 70 days after treatment application. Findings from this study are based on the controlled environment in potted experiments. A further experiment involving field trials is suggested. Besides, comparative analysis of the mineralization rate of different organic fertilizers such as poultry droppings, goat manure, and plant waste in laboratory and field trials is suggested.

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