

# Dynamics of soil nitrogen availability indices in a sandy clay loam soil amended with animal manures

Habeebah Adewunmi Saka<sup>1</sup> · Jamiu Oladipupo Azeez<sup>1</sup> · Joy Nwakaego Odedina<sup>1</sup> · Shade John Akinsete<sup>1</sup>

Received: 7 July 2016 / Accepted: 22 April 2017 / Published online: 29 April 2017  
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## Abstract

**Purpose** Transformation of nitrogen (N) from different manure sources to available forms to promote food security in context of rising climate change is vital. Effect of manure (types, nutrients, high rates and application time) on soil N transformation requires further investigation. This study evaluated effects of three animal manures on soil N mineralization of sandy clay loam.

**Methods** A 22-week field study in a Randomized Complete Block Design (three replicates) was conducted using dried Cattle, Goat and Poultry Manures (CGPM), applied at 5, 10, 20, 40, 60, 80, 120 and 150 t ha<sup>-1</sup> once at onset of the study. Also, N<sub>15</sub>P<sub>15</sub>K<sub>15</sub> (0.4 t ha<sup>-1</sup>) was incorporated in three splits of 2, 8 and 14 weeks after incorporation (WAI) of manures as reference. Soil NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N were determined bi-weekly.

**Results** The results showed N release peaked at 10 WAI with highest NH<sub>4</sub><sup>+</sup>-N (830, 400, 253 mg kg<sup>-1</sup>) and NO<sub>3</sub><sup>-</sup>-N (316, 398, 250 mg kg<sup>-1</sup>) at 150, 60 and 60 t ha<sup>-1</sup> for CGPM, respectively. Initial rapid N release phase occurred at 0–4 WAI, NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N increased averagely by 182, 183, 139% and 131, 175, 144% for CGPM, respectively. Declines occurred at 8, 14 and 22 WAI but reduction observed at 22 WAI tripled 8 and 14 WAI.

**Conclusions** Application of NPK and all the manures provided highest soil NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N at 12 WAI. High rates of CGPM were not injurious to these soil properties; hence this has implication for N to maximize plants uptake as well as decrease losses to environment.

**Keywords** Animal manures · Rates · NPK fertilizer and nitrogen mineralization

## Introduction

Agricultural growth as a result of population increase had contributed to intensification of land cultivation; this causes severe soil fertility depletion. However, losses of nutrients in the soil have been replenished through the use of animal manures (Ramsasa 2010). Hence, the potential of animal manure use in soil replenishment has received the global attention. Currently, to many soil fertility difficulties, animal manures offer an affordable and readily available solution (Spore 2006) and are important source of Ca, Mg, S and micronutrients (Gomez-Brandon et al. 2013); they contain low and highly variable amounts of N, P and K. Aside from being source of plant nutrients, the physical properties of soil are also improved (Akanni and Ojeniyi 2008). However, the use of animal manures can pose a major problem of excess nitrate in soil (Azeez and Van Averbeke 2010b; Navarro Pedreno et al. 1996). The difficulty in the prediction of manure nutrients to plants is due to turnover processes and losses in manures (Azeez and Van Averbeke 2010a; Sorenson 2001). Therefore, incorporation of animal manures to supply nitrogen in proper dose at the proper time without posing any injury to soil and plants is very important in soil replenishment to support crop productivity. Hence, in order to predict the net mineralization of nitrogen in animal manures, transformation of nitrogen from organic into inorganic form and immobilization processes need to be understood. These processes are mediated through microbial activities and naturally, they are biochemical (Vel and Swamam 2013; Bartholomew 1965). Large variability in manure qualities

✉ Habeebah Adewunmi Saka  
sakahabeebah.staad@gmail.com

<sup>1</sup> Federal University of Agriculture Abeokuta, Abeokuta, Nigeria

(Chadwick et al. 2000) or types had posed difficulties for researchers in concluding on a specific rate of manure to support development of different crops. The consequence of these led to differences in the recommendations of 60 t ha<sup>-1</sup> of cattle kraal manure for *Corchorus olitorius* L. (Masarirambi et al. 2012b), goat manure rate of 20 t ha<sup>-1</sup> for sweet maize (Uwah and Eyo 2014); and poultry manure at the levels of 60 t ha<sup>-1</sup> (Masarirambi et al. 2012a) and 30 t ha<sup>-1</sup> (Enujeke et al. 2013) for lettuce and maize yield, respectively.

Animal manures at proper application time, adequate rates and proper nutrient contents when expanding the uses of organic matter in place of inorganic fertilizers for nitrogen mineralization to meet crop N requirement without adverse problem on soil, crop and the environment need to be investigated. This necessitated the study to (1) examine the release patterns of NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N from different rates of three animal manures and recommended inorganic fertilizer rate to soil, (2) evaluate the potential rates of mineralization of the three animal manures on soil and (3) determine the influence of high application rates of the three animal manures on soil.

## Materials and methods

### Location of the experiment

This research was conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria, located between latitude 7°12' N and longitude 3°20' E (FUNAAB 2013). Irregularities of rainfall occurred during the period of the study (Table 1).

### Experimental design

The experiment was a randomized complete block design (RCBD) with three replicates. Cattle, goat and poultry

manures were applied at the rates of 5, 10, 20, 40, 60, 80, 120 and 150 t ha<sup>-1</sup> separately; these were used to test the pattern of manure mineralization irrespective of the rates, to test the manure-induced soil factors that affect plant growth and also evaluate the residual effect of manure rates on soil properties. NPK 15–15–15 fertilizer was used as check for each manure treatment and applied at the rate of 400 kg ha<sup>-1</sup> (Schippers 2000). Starting from 2 weeks after incorporation of manures but a day after application of NPK fertilizer, soil samples were collected at every 2-week intervals from the net portion of each bed at a depth of 0–15 cm with the exception of 6 and 16 WAI due to rainfall failure. The samples were air dried, prepared for laboratory analysis and analyzed for NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N.

### Soil and manures analyses

Initial soil sample and those collected bi-weekly were analyzed using the following methods. Soil EC and pH were extracted with 1:2 soil:water ratio and measured potentiometrically using HANNA 215 electrical conductivity meter (Richards 1954) and glass pH meter electrodes (HANNA pHep), respectively, (Van Reeuwijk 1993). The NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N were extracted in 2 Molar K<sub>2</sub>SO<sub>4</sub> and determined colorimetrically using the method of Okalebo et al. (1993). Available P was extracted by Bray P-1 extraction (Bray and Kurtz 1965), obtained colorimetrically (Murphy and Riley 1962). Exchangeable bases were extracted with 1 N Ammonium-acetate solution in 1:10 soil solution ratio, K<sup>+</sup> and Na<sup>+</sup> were analyzed with flame photometer, while Ca<sup>2+</sup> and Mg<sup>2+</sup> with Atomic Absorption Spectrophotometer (AAS) (Anderson and Ingram 1993). Organic carbon (OC) content was determined by Walkley–Black method (Nelson and Sommers 1990) and particle size by hydrometer method (Bouyoucos 1965).

The cattle, goat and poultry manures used were digested with nitric per chloric acid (2:1) (Watanabe et al. 2013; Silva and Queirós 2002). The digests were analyzed for

**Table 1** Agrometeorological data for the period of the experiment

	2 WAI	4 WAI	6 WAI	8 WAI	10 WAI	12 WAI	14 WAI	16 WAI	18 WAI	20 WAI	22 WAI
Agrometeorological data for the period of the experiment											
Rainfall (mm)	119.4	33.3	8.8	15.1	62.5	147.8	3.5	NA	87.3	35.6	43.1
Mean Temp./day (°C)	27.9	28.1	26.9	27.5	47.3	54.6	39.1	24.9	26.1	26	26.9
Soil Temp./day (°C) (20 cm)	28.7	28.9	28.1	29.9	27.3	26.8	36.3	27.4	26.2	27.9	27.4
Average RH/day (%)	79.8	77.6	73.6	73.1	81.1	89.1	80.6	80.6	80.9	84.1	77.5
Mean sunshine (h/day)	5.5	6.7	5.2	5.4	3.7	2.7	2.9	3.4	3.1	4.1	5.2
Evaporation/day (mm)	3.1	4	3	2.9	1.5	NA	0.8	3.2	2.5	2.8	3.4

Source: Federal University of Agriculture, Abeokuta AGROMET STATION, May–October, 2013

WAI weeks after incorporation of manures, Soil temperature at the depth of 20 cm, NA not available, Temp. temperature, mm millimeter, RH relative humidity

macronutrients and micronutrients using standard procedures (Kaira and Maynard 1991; Cater 1993). Distilled water was used for extraction to determine the electrical conductivity and pH of the manures.

### Statistical analysis

Data collected were subjected to Analysis of Variance (ANOVA) using SAS (1999). Duncan Multiple Range Test at 5% level of probability was used to determine differences in the treatment rates means and also to show the significance effects on parameters measured in relation to the control.

## Results

### Agrometeorological data for the experimental period

Agrometeorological average data for rainfall, relative humidity, mean temperature, soil temperature, mean sunshine hour and evaporation at 2-week intervals during the experiment were presented in Table 1.

### Soil characteristics

The result revealed that the soil used for the research had EC value of 0.69 dS m<sup>-1</sup>, pH of 7.6 and total N value of 0.8 g kg<sup>-1</sup>. The NH<sub>4</sub><sup>+</sup>-N, NO<sub>3</sub><sup>-</sup>-N, OC and available P values were 0.013, 0.014, 14.2 g kg<sup>-1</sup> and 7.5 mg kg<sup>-1</sup>, respectively. Exchangeable bases; K<sup>+</sup>, Na<sup>+</sup>, Ca<sup>2+</sup> and Mg<sup>2+</sup> had the values of (0.42, 0.82, 10.96 and 1.34) cmol<sup>+</sup> kg<sup>-1</sup>, respectively. The carbon to nitrogen ratio (C: N) was 11.83. The micro-nutrients; Mn<sup>2+</sup>, Fe<sup>2+</sup>, Cu<sup>2+</sup> and Zn<sup>2+</sup> had the values of (55.1, 9.85, 1.2 and 5.1) mg kg<sup>-1</sup>, respectively. The percentages of sand, silt and clay were 770, 68 and 162 g kg<sup>-1</sup>, respectively.

### Manures characteristics

The EC values of the cattle, goat and poultry manures were 12.4, 8.8 and 16.4 dS m<sup>-1</sup>, respectively, while the pH values of the cattle, goat and poultry manures were 7.9, 7.7 and 7.8, respectively. The equivalent amount of total N, NH<sub>4</sub><sup>+</sup>-N, NO<sub>3</sub><sup>-</sup>-N, P, K, Na, Ca, Mg and OC in cattle manure added to the soil between the rates of 5–150 t ha<sup>-1</sup> were 225.5–6765, 2.1–63, 2.2–66, 16–480, 37–1110, 46.5–1395, 148–4440, 47.5–1425 and 894–26,820 kg, respectively. However, addition of goat manure between the rates of 5 and 150 t ha<sup>-1</sup> is equivalent to adding total N, NH<sub>4</sub><sup>+</sup>-N, NO<sub>3</sub><sup>-</sup>-N, P, K, Na, Ca, Mg and OC of 241–7230, 1.6–48, 1.8–54, 3.5–105, 18.5–555, 23–690,

90.5–2715, 50–1500 and 1115–33,450 kg, respectively, to the soil. Hence, the equivalent amount of total N, NH<sub>4</sub><sup>+</sup>-N, NO<sub>3</sub><sup>-</sup>-N, P, K, Na, Ca, Mg and OC in the poultry manure applied to the soil at the rates ranged from 5 to 150 t ha<sup>-1</sup> estimated to the amount of 139–4170, 7.4–220.5, 7.5–223.5, 81–2430, 19.5–585, 24.5–735, 88.5–2655, 26.5–795 and 296.5–8895.0 kg, respectively (Tables 2, 3, 4).

### Effect of cattle, goat and poultry manures on soil NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N (mg kg<sup>-1</sup>)

#### *Effect of cattle manure on soil NH<sub>4</sub><sup>+</sup>-N (mg kg<sup>-1</sup>)*

Table 5 reveals that at 2 WAI, soil applied with cattle manure rate of 60 t ha<sup>-1</sup> gave highest value of 62.06 mg kg<sup>-1</sup> in NH<sub>4</sub><sup>+</sup>-N and lowest of 27.69 mg kg<sup>-1</sup> at 80 t ha<sup>-1</sup> by 171 and 21%, respectively, above the control, whereas percentage decreases of 13, 9 and 0.04% were recorded in soil with cattle manure rates of 120, 150 t ha<sup>-1</sup> and NPK, respectively. But there were no significant differences in control and the amendment rates at 4 WAI. While at 8 WAI, soil with cattle manure rate of 120 t ha<sup>-1</sup> had NH<sub>4</sub><sup>+</sup>-N of 51.66 mg kg<sup>-1</sup> with the highest increase of 98%, soil applied with 20 t ha<sup>-1</sup> of cattle manure had 36.50 mg kg<sup>-1</sup> of NH<sub>4</sub><sup>+</sup>-N with the lowest increase of 40% in relation to control. The soil with cattle manure rate of 150 t ha<sup>-1</sup> gave highest NH<sub>4</sub><sup>+</sup>-N value of 830.4 mg kg<sup>-1</sup> by 636% but 5 t ha<sup>-1</sup> resulted in the least value of 221.4 mg kg<sup>-1</sup> by 96% relative to control at 10 WAI. However, the amendment rates were not significantly different from control soil at 12 WAI. At 14 WAI, highest increase of 61% and lowest increase of 14% above the control were obtained from soil applied with cattle manure rates of 150 and 40 t ha<sup>-1</sup> with NH<sub>4</sub><sup>+</sup>-N values of 29.32 and 20.88 mg kg<sup>-1</sup>, respectively. While 5, 10, 20 t ha<sup>-1</sup> and NPK decreased by 38, 29, 31 and 72%, respectively relative to control. At 18 WAI, soil with cattle manure rate of 150 t ha<sup>-1</sup> with NH<sub>4</sub><sup>+</sup>-N value of 86.55 mg kg<sup>-1</sup> recorded the highest increase of 290%, but 10 t ha<sup>-1</sup> had 23.33 mg kg<sup>-1</sup> and recorded the least increase of 5% over the control, while 5 t ha<sup>-1</sup> with 21.11 mg kg<sup>-1</sup> of NH<sub>4</sub><sup>+</sup>-N decreased by 5%. At 20 WAI, soil with cattle manure rate of 150 t ha<sup>-1</sup> gave 49.53 mg kg<sup>-1</sup> of NH<sub>4</sub><sup>+</sup>-N and had the highest increase of 111% while the rate of 5 t ha<sup>-1</sup> had 25.03 mg kg<sup>-1</sup> of NH<sub>4</sub><sup>+</sup>-N and recorded the lowest increase of 7% relative to control. But the rate of 60 t ha<sup>-1</sup> with NH<sub>4</sub><sup>+</sup>-N value of 5.26 mg kg<sup>-1</sup> recorded the highest increase of 149%, while 20 t ha<sup>-1</sup> and 120 t ha<sup>-1</sup> with NH<sub>4</sub><sup>+</sup>-N value of 2.99 mg kg<sup>-1</sup> each had the least increase of 42% compared to control at 22 WAI. However, the level of soil NH<sub>4</sub><sup>+</sup>-N decreased in relation to the corresponding rates at 20 WAI.



**Table 2** Equivalent amount of nutrients present in cattle manure rates added to the soil

Rates (t ha <sup>-1</sup> )	Total N	NH <sub>4</sub> <sup>+</sup> -N	NO <sub>3</sub> <sup>-</sup> -N	P	K	Na	Ca	Mg	OC
Cattle manure nutrients (kg)									
5	225.5	2.1	2.2	16.0	37.0	46.5	148.0	47.5	894.0
10	451.0	4.2	4.4	32.0	74.0	93.0	296.0	95.0	1788.0
20	902.0	8.4	8.8	64.0	148.0	186.0	592.0	190.0	3576.0
40	1804.0	16.8	17.6	128.0	296.0	372.0	1184.0	380.0	7152.0
60	2706.0	25.2	26.4	192.0	444.0	558.0	1776.0	570.0	10,728.0
80	3608.0	33.6	35.2	256.0	592.0	744.0	2368.0	760.0	14,304.0
120	5412.0	50.4	52.8	384.0	888.0	1116.0	3552.0	1140.0	21,456.0
150	6765.0	63.0	66.0	480.0	1110.0	1395.0	4440.0	1425.0	26,820.0

Total N total nitrogen, K total potassium, NH<sub>4</sub><sup>+</sup>-N ammonium–nitrogen, Na total sodium, NO<sub>3</sub><sup>-</sup>-N nitrate–nitrogen, Ca total calcium, P total phosphorus, Mg total magnesium, OC organic carbon

**Table 3** Equivalent amount of nutrients present in goat manure rates added to the soil

Rates (t ha <sup>-1</sup> )	Total N	NH <sub>4</sub> <sup>+</sup> -N	NO <sub>3</sub> <sup>-</sup> -N	P	K	Na	Ca	Mg	OC
Goat manure nutrients (kg)									
5	241.0	1.6	1.8	3.5	18.5	23.0	90.5	50.0	1115.0
10	482.0	3.2	3.6	7.0	37.0	46.0	181.0	100.0	2230.0
20	964.0	6.4	7.2	14.0	74.0	92.0	362.0	200.0	4460.0
40	1928.0	12.6	14.4	28.0	148.0	184.0	724.0	400.0	8920.0
60	2892.0	19.2	21.6	42.0	222.0	276.0	1086.0	600.0	13,380.0
80	3856.0	25.1	28.8	56.0	296.0	368.0	1448.0	800.0	17,840.0
120	5784.0	38.4	43.2	84.0	444.0	552.0	2172.0	1200.0	26,760.0
150	7230.0	48.0	54.0	105.0	555.0	690.0	2715.0	1500.0	33,450.0

Total N total nitrogen, K total potassium, NH<sub>4</sub><sup>+</sup>-N ammonium–nitrogen, Na total sodium, NO<sub>3</sub><sup>-</sup>-N nitrate–nitrogen, Ca total calcium, P total phosphorus, Mg total magnesium, OC organic carbon

**Table 4** Equivalent amount of nutrients present in poultry manure rates added to the soil

Rates (t ha <sup>-1</sup> )	Total N	NH <sub>4</sub> <sup>+</sup> -N	NO <sub>3</sub> <sup>-</sup> -N	P	K	Na	Ca	Mg	OC
Poultry manure nutrients (kg)									
5	139.0	7.4	7.5	81.0	19.5	24.5	88.5	26.5	296.5
10	278.0	14.7	14.9	162.0	39.0	49.0	177.0	53.0	593.0
20	556.0	29.4	29.8	324.0	78.0	98.0	354.0	106.0	1186.0
40	1112.0	58.9	59.6	648.0	156.0	196.0	708.0	212.0	2372.0
60	1668.0	88.2	89.4	972.0	234.0	294.0	1062.0	318.0	3558.0
80	2224.0	117.6	119.2	1296.0	312.0	392.0	1416.0	424.0	4744.0
120	3336.0	176.4	178.8	1944.0	468.0	588.0	2124.0	636.0	7116.0
150	4170.0	220.5	223.5	2430.0	585.0	735.0	2655.0	795.0	8895.0

Total N total nitrogen, K total potassium, NH<sub>4</sub><sup>+</sup>-N ammonium–nitrogen, Na total sodium, NO<sub>3</sub><sup>-</sup>-N nitrate–nitrogen, Ca total calcium, P total phosphorus, Mg total magnesium, OC organic carbon

### Effect of goat manure on soil NH<sub>4</sub><sup>+</sup>-N

Table 6 showed that aside the soil applied with goat manure rate of 150 t ha<sup>-1</sup> that was significantly higher by 114% with NH<sub>4</sub><sup>+</sup>-N of 48.27 mg kg<sup>-1</sup> at 2 WAI, soil with other amendment rates were not statistically different from control. The soil with goat amendment rates followed similar trend as cattle treatment at 4 WAI. The soil NH<sub>4</sub><sup>+</sup>-

N increased in comparison with the corresponding rates at 2 WAI. At 8 WAI, soil with goat manure rate of 150 t ha<sup>-1</sup> gave NH<sub>4</sub><sup>+</sup>-N value of 44.17 mg kg<sup>-1</sup> and recorded the highest increase of 53% while 20 t ha<sup>-1</sup> had NH<sub>4</sub><sup>+</sup>-N value of 34.60 mg kg<sup>-1</sup> and with the least increase of 20% above the control. But reductions of 18 and 28% were obtained from 5 to 10 t ha<sup>-1</sup>, respectively. The level of NH<sub>4</sub><sup>+</sup>-N increased relative to corresponding rates at 4

**Table 5** Influence of cattle manure rates and NPK fertilizer ( $\text{t ha}^{-1}$ ) on mean soil  $\text{NH}_4^+-\text{N}$  ( $\text{mg kg}^{-1}$ ) at 2 weeks intervals

Rates ( $\text{t ha}^{-1}$ )	Means of bi-weekly analyses of soil $\text{NH}_4^+-\text{N}$ ( $\text{mg kg}^{-1}$ ) with applied cattle manure									
	2 WAI	4 WAI	8 WAI	10 WAI	12 WAI	14 WAI	18 WAI	20 WAI	22 WAI	
0	22.88 <sup>b</sup>	68.11 <sup>a</sup>	26.10 <sup>c</sup>	112.90 <sup>f</sup>	79.90 <sup>a</sup>	18.24 <sup>bc</sup>	22.19 <sup>g</sup>	23.50 <sup>f</sup>	2.11 <sup>e</sup>	
5	21.60 <sup>b</sup>	69.31 <sup>a</sup>	38.30 <sup>b</sup>	221.40 <sup>d</sup>	93.50 <sup>a</sup>	11.31 <sup>5de</sup>	21.11 <sup>g</sup>	25.03 <sup>e</sup>	3.81 <sup>c</sup>	
10	31.96 <sup>b</sup>	74.26 <sup>a</sup>	47.40 <sup>bc</sup>	270.30 <sup>c</sup>	118.80 <sup>a</sup>	14.43 <sup>cd</sup>	23.33 <sup>f</sup>	26.69 <sup>d</sup>	4.81 <sup>b</sup>	
20	29.61 <sup>b</sup>	78.80 <sup>a</sup>	36.50 <sup>bc</sup>	246.80 <sup>d</sup>	133.60 <sup>a</sup>	12.63 <sup>cde</sup>	24.44 <sup>f</sup>	25.06 <sup>d</sup>	2.99 <sup>d</sup>	
40	37.45 <sup>ab</sup>	75.52 <sup>a</sup>	38.29 <sup>bc</sup>	246.90 <sup>d</sup>	121.00 <sup>a</sup>	20.88 <sup>b</sup>	26.61 <sup>f</sup>	38.14 <sup>c</sup>	3.53 <sup>c</sup>	
60	62.06 <sup>a</sup>	71.32 <sup>a</sup>	49.10 <sup>bc</sup>	219.20 <sup>e</sup>	107.90 <sup>a</sup>	23.94 <sup>b</sup>	36.66 <sup>e</sup>	39.53 <sup>c</sup>	5.26 <sup>a</sup>	
80	27.69 <sup>b</sup>	73.13 <sup>a</sup>	49.10 <sup>bc</sup>	202.30 <sup>d</sup>	122.60 <sup>a</sup>	22.67 <sup>b</sup>	42.16 <sup>d</sup>	40.00 <sup>c</sup>	3.49 <sup>c</sup>	
120	20.03 <sup>b</sup>	88.39 <sup>a</sup>	51.66 <sup>a</sup>	408.60 <sup>b</sup>	142.40 <sup>a</sup>	25.20 <sup>ab</sup>	66.58 <sup>b</sup>	40.59 <sup>c</sup>	2.99 <sup>d</sup>	
150	20.79 <sup>b</sup>	75.35 <sup>a</sup>	40.50 <sup>bc</sup>	830.40 <sup>a</sup>	149.90 <sup>a</sup>	29.32 <sup>a</sup>	86.55 <sup>a</sup>	49.53 <sup>a</sup>	3.39 <sup>c</sup>	
0.4	22.87 <sup>b</sup>	73.25 <sup>a</sup>	37.90 <sup>bc</sup>	270.40 <sup>c</sup>	149.40 <sup>a</sup>	5.2 <sup>e</sup>	50.30 <sup>c</sup>	46.52 <sup>b</sup>	3.59 <sup>c</sup>	

Means followed by the same letter(s) within the same columns do not differ significantly at  $P < 0.05$  according to Duncan multiple range test  
WAI weeks after incorporation of manures

**Table 6** Influence of goat manure rates and NPK fertilizer ( $\text{t ha}^{-1}$ ) on mean soil  $\text{NH}_4^+-\text{N}$  ( $\text{mg kg}^{-1}$ ) at 2 weeks intervals

Rates ( $\text{t ha}^{-1}$ )	Means of bi-weekly analyses of soil $\text{NH}_4^+-\text{N}$ ( $\text{mg kg}^{-1}$ ) with applied goat manure									
	2 WAI	4 WAI	8 WAI	10 WAI	12 WAI	14 WAI	18 WAI	20 WAI	22 WAI	
0	22.54 <sup>b</sup>	66.92 <sup>a</sup>	28.93 <sup>d</sup>	100.10 <sup>i</sup>	76.70 <sup>a</sup>	18.52 <sup>b</sup>	22.19 <sup>j</sup>	23.35 <sup>f</sup>	2.07 <sup>c</sup>	
5	20.89 <sup>b</sup>	67.43 <sup>a</sup>	23.85 <sup>d</sup>	232.10 <sup>g</sup>	85.00 <sup>a</sup>	13.09 <sup>cd</sup>	26.63 <sup>i</sup>	24.45 <sup>e</sup>	3.04 <sup>c</sup>	
10	21.50 <sup>b</sup>	75.99 <sup>a</sup>	20.75 <sup>e</sup>	225.70 <sup>h</sup>	93.50 <sup>a</sup>	16.12 <sup>bc</sup>	37.73 <sup>h</sup>	24.45 <sup>e</sup>	3.29 <sup>c</sup>	
20	25.77 <sup>b</sup>	77.00 <sup>a</sup>	34.60 <sup>c</sup>	234.00 <sup>f</sup>	95.00 <sup>a</sup>	19.57 <sup>ab</sup>	47.71 <sup>g</sup>	29.79 <sup>d</sup>	3.95 <sup>c</sup>	
40	27.57 <sup>ab</sup>	70.55 <sup>a</sup>	39.46 <sup>b</sup>	308.70 <sup>c</sup>	111.10 <sup>a</sup>	19.51 <sup>ab</sup>	49.93 <sup>f</sup>	30.89 <sup>d</sup>	3.28 <sup>c</sup>	
60	27.75 <sup>b</sup>	77.68 <sup>a</sup>	37.87 <sup>b</sup>	400.30 <sup>a</sup>	112.20 <sup>a</sup>	18.67 <sup>b</sup>	68.80 <sup>d</sup>	30.89 <sup>d</sup>	4.12 <sup>b</sup>	
80	27.98 <sup>b</sup>	80.27 <sup>a</sup>	37.58 <sup>b</sup>	298.00 <sup>d</sup>	134.60 <sup>a</sup>	19.42 <sup>ab</sup>	72.12 <sup>c</sup>	40.00 <sup>c</sup>	4.28 <sup>b</sup>	
120	30.74 <sup>b</sup>	74.52 <sup>a</sup>	34.80 <sup>c</sup>	374.60 <sup>b</sup>	123.50 <sup>a</sup>	18.94 <sup>b</sup>	79.62 <sup>b</sup>	47.76 <sup>a</sup>	4.99 <sup>a</sup>	
150	48.27 <sup>a</sup>	92.08 <sup>a</sup>	44.17 <sup>a</sup>	308.70 <sup>c</sup>	141.30 <sup>a</sup>	22.88 <sup>a</sup>	88.77 <sup>a</sup>	43.35 <sup>c</sup>	3.69 <sup>c</sup>	
0.4	23.98 <sup>b</sup>	72.70 <sup>a</sup>	37.14 <sup>b</sup>	241.32 <sup>e</sup>	145.50 <sup>a</sup>	5.49 <sup>e</sup>	54.00 <sup>e</sup>	46.52 <sup>b</sup>	3.78 <sup>c</sup>	

Means followed by the same letter(s) within the same columns do not differ significantly at  $P < 0.05$  according to Duncan multiple range test  
WAI weeks after incorporation of manures

WAI. The soil applied with goat manure rate of  $60 \text{ t ha}^{-1}$  resulted in  $\text{NH}_4^+-\text{N}$  value of  $400.3 \text{ mg kg}^{-1}$  with highest increase of 300% while  $10 \text{ t ha}^{-1}$  had  $225 \text{ mg kg}^{-1}$  and recorded the least increase of 126% relative to control at 10 WAI. But 12 WAI followed the same trend as soil applied with cattle amendment. Furthermore, soil  $\text{NH}_4^+-\text{N}$  decreased in comparison with the corresponding rates at 10 WAI. Highest increase of 24% was recorded from soil with goat manure rate of  $150 \text{ t ha}^{-1}$  which had  $\text{NH}_4^+-\text{N}$  value of  $22.88 \text{ mg kg}^{-1}$  at 14 WAI. The soil with rate of  $60 \text{ t ha}^{-1}$  resulted in  $18.67 \text{ mg kg}^{-1}$  and gave the lowest increase of 1% more than the control. However, 5, 10  $\text{t ha}^{-1}$  and NPK reduced by 29, 13 and 70%, respectively. The level of soil  $\text{NH}_4^+-\text{N}$  decreased in relation to the corresponding rates at 12 WAI. However, soil applied with goat manure rate of  $150 \text{ t ha}^{-1}$  had highest  $\text{NH}_4^+-\text{N}$

value of  $88.77 \text{ mg kg}^{-1}$  by 300% while  $5 \text{ t ha}^{-1}$  resulted in  $26.63 \text{ mg kg}^{-1}$  and recorded the least increase of 20% at 18 WAI, compared with control. At 20 WAI, soil with goat manure rate of  $120 \text{ t ha}^{-1}$  recorded  $\text{NH}_4^+-\text{N}$  value of  $47.76 \text{ mg kg}^{-1}$  and had the highest increase of 105%. But the soil with goat manure rate of 5 and 10  $\text{t ha}^{-1}$  with the  $\text{NH}_4^+-\text{N}$  value of  $24.45 \text{ mg kg}^{-1}$  each recorded the lowest increase of 5%. However, there was a decrease in soil  $\text{NH}_4^+-\text{N}$  level in relation to the corresponding rates at 18 WAI. Consequently, the soil with goat manure rate of  $120 \text{ t ha}^{-1}$  which gave  $\text{NH}_4^+-\text{N}$  value of  $4.99 \text{ mg kg}^{-1}$  recorded the highest increase of 141% at 22 WAI while  $5 \text{ t ha}^{-1}$  resulted in  $3.04 \text{ mg kg}^{-1}$  with the least increase of 47% relative to control. There were decreases in soil  $\text{NH}_4^+-\text{N}$  level compared with the corresponding rates at 20 WAI.

### Effect of poultry manure on soil $\text{NH}_4^+\text{-N}$

At 2 WAI, soil applied with poultry manure rate of  $60 \text{ t ha}^{-1}$  gave  $\text{NH}_4^+\text{-N}$  value of  $50.86 \text{ mg kg}^{-1}$  and recorded the highest increase of 153%. The rate of  $10 \text{ t ha}^{-1}$  had soil  $\text{NH}_4^+\text{-N}$  value of  $20.18 \text{ mg kg}^{-1}$  and had the least increment of 0.5% more than the control. But the values at 4 WAI followed similar trend with soil on which cattle and goat manures were incorporated. The soil  $\text{NH}_4^+\text{-N}$  increased compared to the corresponding rates at 2 WAI. Meanwhile, soil applied with poultry manure rate of  $150 \text{ t ha}^{-1}$  recorded highest soil  $\text{NH}_4^+\text{-N}$  value of  $47.85 \text{ mg kg}^{-1}$  by 90% at 8 WAI. However, soil on which NPK was added with  $\text{NH}_4^+\text{-N}$  value of  $37.21 \text{ mg kg}^{-1}$  recorded the least increase of 47% over the control. The level of soil  $\text{NH}_4^+\text{-N}$  decreased in relation to the corresponding rates at 4 WAI. More so, soil with poultry manure rate of  $60 \text{ t ha}^{-1}$  resulted in  $253.4 \text{ mg kg}^{-1}$  of  $\text{NH}_4^+\text{-N}$  and had the highest increase of 138%, while the rate of  $5 \text{ t ha}^{-1}$  with soil  $\text{NH}_4^+\text{-N}$  value of  $110.7 \text{ mg kg}^{-1}$  recorded the least increase of 4% relative to control at 10 WAI. The soil applied with poultry amendment rates were not different significantly from control at 12 WAI but soil  $\text{NH}_4^+\text{-N}$  level decreased relative to corresponding rates at 10 WAI. At 14 WAI, soil with poultry manure rate of  $150 \text{ t ha}^{-1}$  had  $\text{NH}_4^+\text{-N}$  value of  $28.06 \text{ mg kg}^{-1}$  and recorded the highest increase of 49% but  $40 \text{ t ha}^{-1}$  resulted in  $19.86 \text{ mg kg}^{-1}$  of  $\text{NH}_4^+\text{-N}$  with lowest increase of 6% more than the control. However, at 14 WAI the level of soil  $\text{NH}_4^+\text{-N}$  decreased in relation to the corresponding rates at 12 WAI. At 18 WAI, soil with poultry manure rate of  $150 \text{ t ha}^{-1}$  gave highest  $\text{NH}_4^+\text{-N}$  value of  $73.23 \text{ mg kg}^{-1}$  by 230% increase while  $5 \text{ t ha}^{-1}$  had least  $\text{NH}_4^+\text{-N}$  value

of  $23.27 \text{ mg kg}^{-1}$  by 5% increase compared with control, whereas,  $80 \text{ t ha}^{-1}$  resulted in soil  $\text{NH}_4^+\text{-N}$  value of  $52.44 \text{ mg kg}^{-1}$  and had the highest increase of 127% more than the control at 20 WAI while  $20 \text{ t ha}^{-1}$  with soil  $\text{NH}_4^+\text{-N}$  value of  $27.41 \text{ mg kg}^{-1}$  recorded the least increase of 19%. At 22 WAI, soil with poultry manure at the rate of  $150 \text{ t ha}^{-1}$  with  $\text{NH}_4^+\text{-N}$  value of  $4.45 \text{ mg kg}^{-1}$  recorded the highest increase of 119% while  $5 \text{ t ha}^{-1}$  gave soil  $\text{NH}_4^+\text{-N}$  value of  $2.08 \text{ mg kg}^{-1}$  and recorded the least increase of 3% above the control. In addition, soil  $\text{NH}_4^+\text{-N}$  values decreased in comparison with the corresponding rates at 20 WAI, Table 7.

### Effect of cattle manure on soil $\text{NO}_3^-\text{-N}$

The soil applied with cattle manure rate of  $60 \text{ t ha}^{-1}$  resulted in  $\text{NO}_3^-\text{-N}$  value of  $54.09 \text{ mg kg}^{-1}$  at 2 WAI by 119% while the soil with NPK had the  $\text{NO}_3^-\text{-N}$  value of  $25.98 \text{ mg kg}^{-1}$  and recorded the least increase of 5% more than the control. The 4 WAI was in line with soil  $\text{NH}_4^+\text{-N}$  but the soil  $\text{NO}_3^-\text{-N}$  values increased compared with the corresponding rates at 2 WAI. However, at 8 WAI, soil with cattle manure at the rate of  $120 \text{ t ha}^{-1}$  gave  $\text{NO}_3^-\text{-N}$  value of  $50.42 \text{ mg kg}^{-1}$  with highest increase of 117% but  $10 \text{ t ha}^{-1}$  with soil  $\text{NO}_3^-\text{-N}$  value of  $25.56 \text{ mg kg}^{-1}$  recorded the least increase of 10% in relation to control. However, the soil  $\text{NO}_3^-\text{-N}$  values reduced in comparison with the corresponding rates at 4 WAI, Table 8. Moreover, soil with cattle manure rate of  $150 \text{ t ha}^{-1}$  with soil  $\text{NO}_3^-\text{-N}$  of  $316.68 \text{ mg kg}^{-1}$  resulted in highest increase of 201% at 10 WAI while  $5 \text{ t ha}^{-1}$  with  $133.78 \text{ mg kg}^{-1}$  had the least increase of 27% in relation to control. At 12 WAI,  $80 \text{ t ha}^{-1}$  with soil  $\text{NO}_3^-\text{-N}$  value of  $139.60 \text{ mg kg}^{-1}$

**Table 7** Influence of poultry manure rates and NPK fertilizer ( $\text{t ha}^{-1}$ ) on mean soil  $\text{NH}_4^+\text{-N}$  ( $\text{mg kg}^{-1}$ ) at 2 weeks intervals

Rates ( $\text{t ha}^{-1}$ )	Means of bi-weekly analyses of soil $\text{NH}_4^+\text{-N}$ ( $\text{mg kg}^{-1}$ ) with applied poultry manure									
	2 WAI	4 WAI	8 WAI	10 WAI	12 WAI	14 WAI	18 WAI	20 WAI	22 WAI	
0	20.08 <sup>b</sup>	67.22 <sup>a</sup>	25.25 <sup>d</sup>	106.50 <sup>i</sup>	71.50 <sup>b</sup>	18.79 <sup>b</sup>	22.19 <sup>j</sup>	23.13 <sup>g</sup>	2.03 <sup>e</sup>	
5	19.94 <sup>b</sup>	79.79 <sup>a</sup>	23.50 <sup>d</sup>	110.72 <sup>h</sup>	99.17 <sup>ab</sup>	12.89 <sup>cd</sup>	23.27 <sup>i</sup>	28.60 <sup>e</sup>	2.08 <sup>e</sup>	
10	20.18 <sup>b</sup>	77.08 <sup>a</sup>	24.72 <sup>d</sup>	244.86 <sup>b</sup>	120.20 <sup>ab</sup>	15.29 <sup>bcd</sup>	28.82 <sup>h</sup>	28.60 <sup>e</sup>	2.64 <sup>d</sup>	
20	29.40 <sup>ab</sup>	76.61 <sup>a</sup>	23.57 <sup>d</sup>	219.16 <sup>d</sup>	127.43 <sup>ab</sup>	16.54 <sup>bc</sup>	32.18 <sup>g</sup>	27.41 <sup>f</sup>	2.89 <sup>cd</sup>	
40	34.26 <sup>ab</sup>	74.74 <sup>a</sup>	35.25 <sup>c</sup>	217.03 <sup>e</sup>	121.00 <sup>ab</sup>	19.86 <sup>b</sup>	35.51 <sup>f</sup>	27.44 <sup>f</sup>	3.01 <sup>c</sup>	
60	50.86 <sup>a</sup>	71.19 <sup>a</sup>	47.35 <sup>a</sup>	253.37 <sup>a</sup>	144.01 <sup>a</sup>	20.45 <sup>b</sup>	45.59 <sup>d</sup>	33.23 <sup>d</sup>	2.23 <sup>de</sup>	
80	41.82 <sup>ab</sup>	80.70 <sup>a</sup>	43.37 <sup>b</sup>	227.75 <sup>c</sup>	156.33 <sup>a</sup>	21.95 <sup>ab</sup>	38.84 <sup>e</sup>	52.44 <sup>a</sup>	2.44 <sup>d</sup>	
120	46.06 <sup>a</sup>	87.39 <sup>a</sup>	46.43 <sup>a</sup>	212.78 <sup>f</sup>	140.80 <sup>a</sup>	26.54 <sup>a</sup>	65.55 <sup>b</sup>	48.97 <sup>b</sup>	3.28 <sup>b</sup>	
150	43.58 <sup>ab</sup>	75.44 <sup>a</sup>	47.85 <sup>a</sup>	200.07 <sup>g</sup>	153.40 <sup>a</sup>	28.11 <sup>a</sup>	73.23 <sup>a</sup>	47.44 <sup>c</sup>	4.45 <sup>a</sup>	
0.4	21.75 <sup>b</sup>	72.98 <sup>a</sup>	37.21 <sup>c</sup>	212.24 <sup>f</sup>	144.50 <sup>a</sup>	5.88 <sup>e</sup>	57.70 <sup>c</sup>	46.52 <sup>c</sup>	3.02 <sup>c</sup>	

Means followed by the same letter(s) within the same columns do not differ significantly at  $P < 0.05$  according to Duncan multiple range test WAI weeks after incorporation of manures



**Table 8** Influence of cattle manure rates and NPK fertilizer ( $\text{t ha}^{-1}$ ) on mean soil  $\text{NO}_3^-$ -N ( $\text{mg kg}^{-1}$ ) at 2 weeks intervals

Rates ( $\text{t ha}^{-1}$ )	Means of bi-weekly analyses of soil $\text{NO}_3^-$ -N ( $\text{mg kg}^{-1}$ ) with applied cattle manure									
	2 WAI	4 WAI	8 WAI	10 WAI	12 WAI	14 WAI	18 WAI	20 WAI	22 WAI	
0	24.75 <sup>b</sup>	68.70 <sup>a</sup>	23.28 <sup>d</sup>	105.07 <sup>f</sup>	91.70 <sup>b</sup>	20.09 <sup>bc</sup>	28.25 <sup>g</sup>	20.00 <sup>j</sup>	3.18 <sup>d</sup>	
5	21.81 <sup>b</sup>	75.61 <sup>a</sup>	29.17 <sup>b</sup>	133.78 <sup>ef</sup>	97.70 <sup>b</sup>	12.68 <sup>d</sup>	31.40 <sup>fg</sup>	29.24 <sup>h</sup>	4.50 <sup>c</sup>	
10	35.95 <sup>ab</sup>	75.63 <sup>a</sup>	25.56 <sup>cd</sup>	179.56 <sup>d</sup>	99.28 <sup>b</sup>	13.89 <sup>d</sup>	38.51 <sup>f</sup>	28.74 <sup>i</sup>	6.58 <sup>a</sup>	
20	31.29 <sup>b</sup>	71.55 <sup>a</sup>	26.00 <sup>cd</sup>	151.61 <sup>e</sup>	133.95 <sup>a</sup>	14.76 <sup>d</sup>	42.41 <sup>e</sup>	30.00 <sup>g</sup>	3.99 <sup>c</sup>	
40	40.31 <sup>ab</sup>	73.86 <sup>a</sup>	27.24 <sup>cd</sup>	140.80 <sup>e</sup>	126.00 <sup>a</sup>	18.76 <sup>cd</sup>	45.31 <sup>d</sup>	37.66 <sup>c</sup>	4.64 <sup>c</sup>	
60	54.09 <sup>a</sup>	69.75 <sup>a</sup>	48.69 <sup>ab</sup>	148.78 <sup>e</sup>	108.30 <sup>ab</sup>	24.78 <sup>c</sup>	48.39 <sup>b</sup>	38.95 <sup>d</sup>	6.58 <sup>a</sup>	
80	30.96 <sup>b</sup>	76.65 <sup>a</sup>	47.09 <sup>ab</sup>	206.51 <sup>c</sup>	139.60 <sup>a</sup>	24.28 <sup>c</sup>	58.26 <sup>a</sup>	40.00 <sup>b</sup>	3.96 <sup>c</sup>	
120	22.78 <sup>b</sup>	83.65 <sup>a</sup>	50.42 <sup>a</sup>	208.28 <sup>c</sup>	135.60 <sup>a</sup>	26.42 <sup>a</sup>	58.28 <sup>a</sup>	37.31 <sup>f</sup>	3.31 <sup>d</sup>	
150	24.70 <sup>b</sup>	81.01 <sup>a</sup>	45.74 <sup>ab</sup>	316.68 <sup>a</sup>	123.40 <sup>a</sup>	25.74 <sup>b</sup>	54.19 <sup>ab</sup>	39.27 <sup>c</sup>	5.20 <sup>b</sup>	
0.4	25.98 <sup>b</sup>	82.56 <sup>a</sup>	26.91 <sup>cd</sup>	267.77 <sup>b</sup>	145.50 <sup>a</sup>	10.76 <sup>e</sup>	46.82 <sup>fg</sup>	43.28 <sup>a</sup>	4.38 <sup>c</sup>	

Means followed by the same letter(s) within the same columns do not differ significantly at  $P < 0.05$  according to Duncan multiple range test  
WAI weeks after incorporation of manures

gave highest increase of 52% but  $5 \text{ t ha}^{-1}$  had soil  $\text{NO}_3^-$ -N value of  $97.70 \text{ mg kg}^{-1}$  and had lowest increase of 7% relative to control. However, soil  $\text{NO}_3^-$ -N decreased relative to the corresponding rates at 10 WAI. The soil with cattle manure rate of  $120 \text{ t ha}^{-1}$  gave highest  $\text{NO}_3^-$ -N value of  $26.42 \text{ mg kg}^{-1}$  by 32% at 14 WAI while  $80 \text{ t ha}^{-1}$  with the value of  $24.28 \text{ mg kg}^{-1}$  resulted in least increase of 21% relative to control. But in comparison with the corresponding rates at 10 WAI, soil  $\text{NO}_3^-$ -N decreased, Table 8. At 18 WAI, soil applied with cattle manure at the rate of  $120 \text{ t ha}^{-1}$  gave  $\text{NO}_3^-$ -N value of  $58.28 \text{ mg kg}^{-1}$  by 106%, but  $5 \text{ t ha}^{-1}$  with  $\text{NO}_3^-$ -N value of  $31.4 \text{ mg kg}^{-1}$  recorded the least increase of 11%, relative to control. Consequently, at 20 WAI, soil applied with NPK had  $\text{NO}_3^-$ -N value of  $43.28 \text{ mg kg}^{-1}$  and recorded the greatest increment in soil  $\text{NO}_3^-$ -N by 116% followed by  $80 \text{ t ha}^{-1}$  with  $\text{NO}_3^-$ -N value of  $40.00 \text{ mg kg}^{-1}$  that had 100% increases, while  $10 \text{ t ha}^{-1}$  with soil  $\text{NO}_3^-$ -N value of  $29.24 \text{ mg kg}^{-1}$  had the lowest increase of 44% more than control. There was a decrease in soil  $\text{NO}_3^-$ -N for cattle treated soil at 20 WAI compared to the corresponding rates at 18 WAI. However, at 22 WAI, soil applied with cattle manure rates of 10 and  $60 \text{ t ha}^{-1}$  with the same  $\text{NO}_3^-$ -N value of  $6.58 \text{ mg kg}^{-1}$  gave the highest increase of 107% while  $150 \text{ t ha}^{-1}$  with  $\text{NO}_3^-$ -N value of  $3.31 \text{ mg kg}^{-1}$  gave the least increase of 4% in comparison with control. The soil  $\text{NO}_3^-$ -N decreased in relation to the corresponding rates at 20 WAI.

#### Effect of goat manure on soil $\text{NO}_3^-$ -N

At 2 WAI, soil applied with goat manure rate of  $150 \text{ t ha}^{-1}$  had  $\text{NO}_3^-$ -N value of  $50.29 \text{ mg kg}^{-1}$  which recorded the highest increase of 133% while  $5 \text{ t ha}^{-1}$  with soil  $\text{NO}_3^-$ -N value of  $23.13 \text{ mg kg}^{-1}$  recorded the least increase of 7%

relative to control. At 4 WAI, the trend was in line with cattle manure treated soil as  $\text{NH}_4^+$ -N. However, there were increases of soil  $\text{NO}_3^-$ -N compared with the corresponding rates at 2 WAI. At 8 WAI, goat manure rate of  $40 \text{ t ha}^{-1}$  with  $\text{NO}_3^-$ -N value of  $45.22 \text{ mg kg}^{-1}$  recorded the highest increase of 102% but  $10 \text{ t ha}^{-1}$  with  $\text{NO}_3^-$ -N value of  $24.95 \text{ mg kg}^{-1}$  recorded the least increase of 11% above the control. In comparison of 8 WAI values with the corresponding rates at 4 WAI, soil  $\text{NO}_3^-$ -N decreased. The soil with goat manure rate of  $60 \text{ t ha}^{-1}$  which had  $\text{NO}_3^-$ -N value of  $398.54 \text{ mg kg}^{-1}$  recorded highest increase of 293%,  $5 \text{ t ha}^{-1}$  gave  $\text{NO}_3^-$ -N value of  $227.02 \text{ mg kg}^{-1}$  with the least increase of 124% in relation to control at 10 WAI. However, at 12 WAI,  $80 \text{ t ha}^{-1}$  resulted in soil  $\text{NO}_3^-$ -N value of  $137.85 \text{ mg kg}^{-1}$  and had highest increase of 51% but  $5 \text{ t ha}^{-1}$  with soil  $\text{NO}_3^-$ -N value of  $100.70 \text{ mg kg}^{-1}$  had lowest increase of 11% more than the control. The result revealed that soil  $\text{NO}_3^-$ -N decreased compared to the corresponding rates at 10 WAI. More so, at 14 WAI,  $150 \text{ t ha}^{-1}$  with soil  $\text{NO}_3^-$ -N value of  $23.22 \text{ mg kg}^{-1}$  was significantly higher while other goat manure treated soil rates decreased in soil  $\text{NO}_3^-$ -N compared with control. Consequently, the soil  $\text{NO}_3^-$ -N decreased relative to corresponding rates at 12 WAI. The soil applied with goat manure at the rate of  $150 \text{ t ha}^{-1}$  had  $\text{NO}_3^-$ -N value of  $82 \text{ mg kg}^{-1}$  and highest increase of 183%. The least increase of 4% was recorded from  $5 \text{ t ha}^{-1}$  with soil  $\text{NO}_3^-$ -N value of  $30 \text{ mg kg}^{-1}$  compared with control, at 18 WAI, while  $120 \text{ t ha}^{-1}$  with soil  $\text{NO}_3^-$ -N value of  $44.69 \text{ mg kg}^{-1}$  resulted in highest increment of 111% at 20 WAI. But  $5 \text{ t ha}^{-1}$  gave  $28.75 \text{ mg kg}^{-1}$  of  $\text{NO}_3^-$ -N and recorded lowest increase of 36% in relation to control. In comparison with the corresponding rates at 18 WAI, there were decreases in soil  $\text{NO}_3^-$ -N level. At 22 WAI, soil with goat manure rate of  $120 \text{ t ha}^{-1}$  had  $\text{NO}_3^-$ -

**Table 9** Influence of goat manure rates and NPK fertilizer ( $\text{t ha}^{-1}$ ) on mean soil  $\text{NO}_3^- \text{--N}$  ( $\text{mg kg}^{-1}$ ) at 2 weeks intervals

Rates ( $\text{t ha}^{-1}$ )	Means of bi-weekly analyses of soil $\text{NO}_3^- \text{--N}$ ( $\text{mg kg}^{-1}$ ) with applied goat manure									
	2 WAI	4 WAI	8 WAI	10 WAI	12 WAI	14 WAI	18 WAI	20 WAI	22 WAI	
0	21.61 <sup>b</sup>	70.33 <sup>a</sup>	22.39 <sup>d</sup>	101.35 <sup>f</sup>	91.10 <sup>d</sup>	19.00 <sup>ab</sup>	29.00 <sup>i</sup>	21.22 <sup>g</sup>	3.26 <sup>d</sup>	
5	23.13 <sup>b</sup>	78.52 <sup>a</sup>	25.49 <sup>bcd</sup>	227.02 <sup>e</sup>	100.70 <sup>d</sup>	14.68 <sup>cde</sup>	30.00 <sup>h</sup>	28.75 <sup>f</sup>	3.34 <sup>d</sup>	
10	35.21 <sup>ab</sup>	70.40 <sup>a</sup>	24.95 <sup>cd</sup>	232.24 <sup>c</sup>	114.10 <sup>b</sup>	15.92 <sup>cde</sup>	31.00 <sup>g</sup>	30.00 <sup>e</sup>	4.27 <sup>c</sup>	
20	30.42 <sup>ab</sup>	81.69 <sup>a</sup>	28.25 <sup>c</sup>	270.24 <sup>d</sup>	112.10 <sup>bc</sup>	18.14 <sup>bcd</sup>	49.00 <sup>d</sup>	30.08 <sup>e</sup>	5.34 <sup>b</sup>	
40	27.64 <sup>b</sup>	74.28 <sup>a</sup>	45.22 <sup>a</sup>	309.51 <sup>b</sup>	113.50 <sup>bc</sup>	19.25 <sup>ab</sup>	36.00 <sup>f</sup>	33.55 <sup>d</sup>	5.55 <sup>b</sup>	
60	27.11 <sup>b</sup>	83.51 <sup>a</sup>	33.84 <sup>b</sup>	398.54 <sup>a</sup>	115.80 <sup>b</sup>	18.95 <sup>bc</sup>	72.00 <sup>b</sup>	41.76 <sup>c</sup>	5.34 <sup>b</sup>	
80	24.49 <sup>b</sup>	83.83 <sup>a</sup>	28.46 <sup>c</sup>	313.51 <sup>c</sup>	137.80 <sup>a</sup>	19.85 <sup>ab</sup>	70.00 <sup>c</sup>	40.00 <sup>c</sup>	5.41 <sup>b</sup>	
120	34.26 <sup>ab</sup>	80.55 <sup>a</sup>	31.81 <sup>bc</sup>	317.41 <sup>c</sup>	132.70 <sup>b</sup>	17.56 <sup>bcd</sup>	72.00 <sup>b</sup>	44.69 <sup>a</sup>	5.79 <sup>a</sup>	
150	50.29 <sup>a</sup>	84.04 <sup>a</sup>	31.47 <sup>bc</sup>	374.18 <sup>b</sup>	117.80 <sup>b</sup>	23.22 <sup>a</sup>	82.00 <sup>a</sup>	40.77 <sup>c</sup>	5.51 <sup>b</sup>	
0.4	26.32 <sup>b</sup>	78.15 <sup>a</sup>	27.59 <sup>c</sup>	261.51 <sup>d</sup>	141.05 <sup>a</sup>	10.82 <sup>e</sup>	46.68 <sup>e</sup>	42.22 <sup>b</sup>	4.53 <sup>c</sup>	

Means followed by the same letter(s) within the same columns do not differ significantly at  $P < 0.05$  according to Duncan multiple range test  
WAI weeks after incorporation of manures

**Table 10** Influence of poultry manure rates and NPK fertilizer ( $\text{t ha}^{-1}$ ) on mean soil  $\text{NO}_3^- \text{--N}$  ( $\text{mg kg}^{-1}$ ) at 2 weeks intervals

Rates ( $\text{t ha}^{-1}$ )	Mean of bi-weekly analyses of soil $\text{NO}_3^- \text{--N}$ ( $\text{mg kg}^{-1}$ ) with applied poultry manure									
	2 WAI	4 WAI	8 WAI	10 WAI	12 WAI	14 WAI	18 WAI	20 WAI	22 WAI	
0	22.59 <sup>d</sup>	68.51 <sup>a</sup>	22.46 <sup>d</sup>	104.19 <sup>f</sup>	91.40 <sup>g</sup>	19.11 <sup>b</sup>	28.18 <sup>j</sup>	20.28 <sup>j</sup>	3.19 <sup>a</sup>	
5	22.38 <sup>d</sup>	72.95 <sup>a</sup>	24.23 <sup>cd</sup>	114.46 <sup>f</sup>	99.49 <sup>f</sup>	12.08 <sup>e</sup>	30.42 <sup>i</sup>	30.00 <sup>i</sup>	5.59 <sup>a</sup>	
10	23.54 <sup>d</sup>	82.25 <sup>a</sup>	24.88 <sup>cd</sup>	239.48 <sup>b</sup>	145.95 <sup>bc</sup>	12.12 <sup>d</sup>	30.96 <sup>h</sup>	30.48 <sup>h</sup>	4.16 <sup>a</sup>	
20	28.91 <sup>bcd</sup>	76.99 <sup>a</sup>	23.94 <sup>c</sup>	230.91 <sup>b</sup>	123.60 <sup>de</sup>	13.79 <sup>d</sup>	35.63 <sup>g</sup>	38.77 <sup>f</sup>	4.12 <sup>a</sup>	
40	46.00 <sup>abc</sup>	68.69 <sup>a</sup>	25.55 <sup>c</sup>	240.08 <sup>b</sup>	131.15 <sup>d</sup>	17.87 <sup>cd</sup>	37.37 <sup>f</sup>	42.08 <sup>e</sup>	3.55 <sup>a</sup>	
60	51.22 <sup>a</sup>	65.63 <sup>a</sup>	24.98 <sup>cd</sup>	250.14 <sup>a</sup>	144.35 <sup>c</sup>	16.50 <sup>cd</sup>	44.12 <sup>d</sup>	49.64 <sup>c</sup>	2.96 <sup>a</sup>	
80	43.11 <sup>abcd</sup>	77.76 <sup>a</sup>	28.96 <sup>b</sup>	228.89 <sup>c</sup>	153.75 <sup>a</sup>	16.28 <sup>cd</sup>	40.22 <sup>e</sup>	56.38 <sup>a</sup>	3.18 <sup>a</sup>	
120	47.37 <sup>ab</sup>	84.95 <sup>a</sup>	35.42 <sup>a</sup>	217.42 <sup>d</sup>	121.90 <sup>e</sup>	17.19 <sup>cd</sup>	46.55 <sup>a</sup>	54.19 <sup>b</sup>	4.73 <sup>a</sup>	
150	37.65 <sup>abcd</sup>	75.35 <sup>a</sup>	28.05 <sup>b</sup>	211.43 <sup>e</sup>	145.95 <sup>bc</sup>	25.87 <sup>a</sup>	45.66 <sup>b</sup>	31.32 <sup>g</sup>	2.37 <sup>a</sup>	
0.4	24.76 <sup>cd</sup>	84.32 <sup>a</sup>	28.96 <sup>b</sup>	261.76 <sup>a</sup>	145.40 <sup>bc</sup>	10.34 <sup>f</sup>	45.23 <sup>c</sup>	42.81 <sup>d</sup>	4.35 <sup>a</sup>	

Means followed by the same letter(s) within the same columns do not differ significantly at  $P < 0.05$  according to Duncan multiple range test  
WAI weeks after incorporation of manures

N value of  $5.79 \text{ mg kg}^{-1}$  and gave highest increase of 78% but  $5 \text{ t ha}^{-1}$  with  $\text{NO}_3^- \text{--N}$  value of  $3.34 \text{ mg kg}^{-1}$  recorded least increase of 3% more than the control. The values also decreased compared to corresponding rates at 20 WAI, Table 9.

#### Effect of poultry manure on soil $\text{NO}_3^- \text{--N}$

Table 10 presented that at 2 WAI, soil applied with poultry manure rate of  $60 \text{ t ha}^{-1}$  had  $\text{NO}_3^- \text{--N}$  value of  $51.22 \text{ mg kg}^{-1}$  and recorded the highest increase of 127%. The rate of  $10 \text{ t ha}^{-1}$  gave  $\text{NO}_3^- \text{--N}$  value of  $23.54 \text{ mg kg}^{-1}$  and recorded the least increase of 7% more than the control. The 4 WAI was also similar to others above. The soil with poultry manure rate of  $120 \text{ t ha}^{-1}$  with the value of  $35.42 \text{ mg kg}^{-1}$  recorded the highest

increase of 59% in soil  $\text{NO}_3^- \text{--N}$  while  $20 \text{ t ha}^{-1}$  with  $\text{NO}_3^- \text{--N}$  value of  $23.74 \text{ mg kg}^{-1}$  had the least increase of 7% relative to control at 8 WAI. Soil  $\text{NO}_3^- \text{--N}$  decreased in comparison with the corresponding rates at 4 WAI. Furthermore, soil applied with NPK gave highest  $\text{NO}_3^- \text{--N}$  value of  $261.76 \text{ mg kg}^{-1}$  with increment of 151% while  $5 \text{ t ha}^{-1}$  with  $\text{NO}_3^- \text{--N}$  value of  $114.46 \text{ mg kg}^{-1}$  presented least increase of 10% compared with control at 10 WAI. However, soil with poultry manure rate of  $80 \text{ t ha}^{-1}$  with  $153.75 \text{ mg kg}^{-1}$  of  $\text{NO}_3^- \text{--N}$  resulted to highest increment of 68% but  $5 \text{ t ha}^{-1}$  with  $\text{NO}_3^- \text{--N}$  value of  $99.49 \text{ mg kg}^{-1}$  had lowest increase of 9% relative to control at 12 WAI. There were decrements at 12 WAI in relation to the corresponding rates at 10 WAI. More so, soil with poultry manure rate of  $150 \text{ t ha}^{-1}$  recorded  $\text{NO}_3^- \text{--N}$  value of  $25.87 \text{ mg kg}^{-1}$  and gave the highest increase of 35% at 14



WAI. But soil  $\text{NO}_3^-$ -N decreased in relation to the corresponding rates at 12 WAI. The rate of  $120 \text{ t ha}^{-1}$  recorded highest  $\text{NO}_3^-$ -N value of  $46.55 \text{ mg kg}^{-1}$  by 62% and the least increase of 8% was recorded from  $5 \text{ t ha}^{-1}$  with  $\text{NO}_3^-$ -N value of  $30.42 \text{ mg kg}^{-1}$  relative to control, at 18 WAI. Consequently, at 20 WAI,  $80 \text{ t ha}^{-1}$  presented soil  $\text{NO}_3^-$ -N value of  $56.38 \text{ mg kg}^{-1}$  and this resulted in highest increment of 178% while  $5 \text{ t ha}^{-1}$  had  $\text{NO}_3^-$ -N value of  $30 \text{ mg kg}^{-1}$  by 88% over the control. Increments in relation to 18 WAI were erratic. At 22 WAI, the rates of soil amended with poultry manure were not significantly different from control but  $\text{NO}_3^-$ -N level reduced when compared to the corresponding rates at 20 WAI.

## Discussion

### Soil characteristics

The soil used for the research was sandy clay loam (USDA 2010), slightly saline (LAS 2014), and slightly alkaline (Pam and Brian 2007) and these could support plant performances. More so, the soil was deficient in total nitrogen (McBride 2015; USDA-SCS 1974) and had low available P content (ENDMEMO 2015; Mallarino 2000) which could retard crop development. It contained moderate OC (McBride 2015; USDA-SCS 1974), exchangeable  $\text{K}^+$  and  $\text{Mg}^{2+}$  (Pam and Brian 2007); these were optimal for performance of the crop. The high exchangeable  $\text{Na}^+$  and  $\text{Ca}^{2+}$  contents (Pam and Brian 2007) could be attributed to the decomposition of the organic matter content of the soil due to high temperature, evaporation rate, sunshine hours/day and low rainfall during the research. This confirmed the studies of some researchers (Davidson and Jannsens 2006; Friedlingstein et al. 2006). The  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N contents were low and C: N ratio was considered normal (Hill 2001) and could be as a result of low rainfall during this period. The copper, iron and zinc contents were very high (Enwezor et al. 1989).

### Manure characteristics

The EC of the three manures applied were very strongly saline (LAS 2014). This could be as a result of high concentration of cationic salts in the manures. More so, the highest EC value of poultry manure compared with the cattle and goat manures support the findings of Azeez and Van Averbeke (2010a, b) and could be attributed to the highest  $\text{NH}_4^+$ -N,  $\text{NO}_3^-$ -N and total P contents in poultry manure compared to others. The pH of the pure goat and poultry manures was considered mildly alkaline, whereas that of cattle manure was moderately alkaline (Pam and Brian 2007). This would allow for nutrients availability in

the soil after mineralization. It was observed from the result that cattle manure had the highest total K, Na and Ca over the goat and poultry manures. However, goat manure was higher in total N, Mg and OC in relative to cattle and poultry manures. Very low value of total P in goat manure could be a result of the nutrient concentrations of the feed given to the animals. This is because they were fed with elephant grasses and wheat offal under intensive system although the nutrient contents of the feed were not measured. Equivalent amount of total N contents present in goat manure applied was higher than cattle and poultry manures. High P content in poultry manure could also contribute to the yield quality of crops at lower rates than cattle and goat manures. Cattle manure recorded highest equivalent amount of pH, total K, Na and Ca than goat and poultry manures; this could be attributed to the higher EC value in cattle manure than goat manure and confirmed the report of Monica (2013). Highest contents of total N, Mg and OC in goat manure compared with cattle and poultry manures suggested the reason for lowest value of EC in goat manure applied during the studies. This is because Mg was the only salt forming cation that was highest in goat manure. Highest total N could be a result of N level in the feed given to the goat animals, although the nutrient contents of the feed were not determined.

### Manure mineralization processes in the soil

Incorporation of cattle, goat and poultry manures increased the concentration of  $\text{NH}_4^+$ -N; this supports the findings of Sajal and Abul Kashem (2014) and  $\text{NO}_3^-$ -N depending on the rates (Eghball et al. 2002) compared with control. However, the low values of  $\text{NH}_4^+$ -N between 0 and 8 WAI of the manures could be attributed to conversion of  $\text{NH}_4^+$ -N to  $\text{NO}_3^-$ -N as supported in the study of (Hoskins 2015) that, between 2 and 4 weeks,  $\text{NH}_4^+$ -N converted relatively quickly to  $\text{NO}_3^-$ -N in a soil applied with broiler manure. However, mineralization of organic N into inorganic form of  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N occurred between 8 and 14 WAI of manures. Consequently, the low  $\text{NH}_4^+$ -N between 18 and 22 WAI could be attributed to ammonia volatilization (Meissinger and Jokela 2000) while low  $\text{NO}_3^-$ -N contents between 18 and 22 WAI could be attributed to leaching (Tom 2002; Marco et al. 2002) and plant root uptake. The low  $\text{NO}_3^-$ -N contents in soil applied with NPK fertilizer at 18 WAI compared with 8 and 14 WAI could be attributed to acidic properties of NPK fertilizer, since acidity reduces soil microbial activity and this would in turn reduce nutrient mineralization (Xu et al. 2002).

Mineralization of  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N contents occurred in the soil with the maximum values at 10 WAI for cattle, goat and poultry manures but was contrary to the results of Azeez and Van Averbeke (2010b) that sharp

increase in N release was at 120 days; and (Ayeni 2011; Ayeni and Adeleye 2011), that release of poultry manure nutrients proportion is between 1 and 2 months of incubation. The variability of mineralization processes could be attributed to microbial activities as suggested by Vinten et al. (2002); and climatic variations. Hence, the turnover processes and losses have influence on availability of nutrients in manures; this is why the prediction of manure nutrients to plants is problematic (Azeez and Van Averbeke 2010b; Sorenson 2001).

Very low N mineralization at 14 WAI compared to 12 WAI could be attributed to very low rainfall during this period. This corroborated the report of Jonathan (2006) that in dry soils, N mineralization is low because soil micro-organism activity is limited by water availability. More so, low  $\text{NH}_4^+$ -N suggested to be as a result of volatilization of  $\text{NH}_3$  as this is favored by warm temperature wet soils under drying conditions (Tom 2002; James 2001). While low  $\text{NO}_3^-$ -N could be as a result of leaching that might have occurred at 12 WAI due to very high rainfall at this period, this also corroborated the work of Tom (2002) that  $\text{NO}_3^-$  in the soil can be lost through percolation of water below the active root zone.

Across weeks after incorporation of the three manures, application rates of  $20 \text{ t ha}^{-1}$  for cattle,  $40 \text{ t ha}^{-1}$  for goat and poultry manure at the rate of  $10 \text{ t ha}^{-1}$  were not widely significantly different when compared to higher rates. Therefore, addition of manures more than these rates to the soil could lead to wastage as these did not increase the amount of  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N in the soil sequentially according to this study. Although the high rates of cattle, goat and poultry manures were significantly higher relative to lower rates in this research, these suggested not to be encouraged as the increments were not regular across the weeks after manure application. The irregularity could be attributed to volatilization (Meissinger and Jokela 2000) and leaching (Tom 2002; Marco et al. 2002) of the  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N in the soil, respectively.

During this work, NPK fertilizer applied was able to supply equal amount of  $\text{NH}_4^+$ -N to the soil when compared with  $10 \text{ t ha}^{-1}$  of cattle manure treatment between 2 and 12 WAI. But goat manure treated soil at  $60 \text{ t ha}^{-1}$  supplied equal amount of  $\text{NH}_4^+$ -N compared to NPK fertilizer between 2 and 8 WAI, while  $40 \text{ t ha}^{-1}$  of poultry manure was able to supply equal amount of  $\text{NH}_4^+$ -N to the soil compared to NPK fertilizer at  $0.4 \text{ t ha}^{-1}$  between 2 and 8 WAI. This suggested that cattle, goat and poultry manures incorporated to the soil at 10, 60 and  $40 \text{ t ha}^{-1}$ , respectively, supplied equal amount of  $\text{NH}_4^+$ -N compared to NPK fertilizer at  $0.4 \text{ t ha}^{-1}$  within 6 weeks. The low  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N contents of the soils applied with NPK fertilizer at 14 WAI compared with cattle, goat and manure treated soils rates could be attributed to acidic properties of NPK fertilizer. This corroborated the study

results of Xu et al. (2002) that acidity reduces soil microbial activity resulting in reduced nutrient mineralization. This could also be attributed to depletion of soil organic matter as a result of synthetic fertilization (Jonathan 2006).

## Conclusion and recommendation

Generally, addition of NPK 15–15–15 fertilizer, cattle, goat and poultry manures improved the soil  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N compared with control. The  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N contents of the soil between 2 and 8 WAI increased with the application of cattle, goat and poultry manures. However, between 8 and 14 WAI mineralization of  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N occurred but peak values were obtained at 10 WAI irrespective of the manures types and rates. Finally, the effect of cattle, goat and poultry manures on  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N decreased between 18 and 22 WAI.

To increase soil  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N for optimum production of crops yield, application of cattle, goat and poultry manures is recommended. It is recommended that application rate of  $20 \text{ t ha}^{-1}$  for cattle,  $40 \text{ t ha}^{-1}$  for goat and poultry manure at the rate of  $10 \text{ t ha}^{-1}$  would provide optimum and improve the soil nutrients level which will be retained in the soil for longer period. To improve soil with low N contents, poultry manure is recommended. Meanwhile, addition of cattle, goat and poultry manures to supply  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N to the soil with regard to sowing dates is recommended to be 2 WAI as this would allow equilibration of the manures with the soil prior to planting, while incorporation of these three manures for crop needs is recommended to be 8 WAI.

**Acknowledgements** The assistance of people that contributed to the success of this research is gratefully appreciated while the expressions, views and conclusions attained are for the authors.

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## References

- Akanni DI, Ojeniyi SO (2008) Residual effect of goat and poultry manures on soil properties nutrient content and yield of amaranthus in southwestern Nigeria. *Res J Agric* 2(2):44–47
- Ayeni LS (2011) Integrated plant nutrition management: a panacea for sustainable crop production in Nigeria. *Int J Soil Sci* 6:19–24
- Ayeni LS, Adeleye EO (2011) Soil nutrient status and nutrient interactions as influenced by agro wastes and mineral fertilizer in an incubation study in the South—west Nigeria. *Int J Soil Sci* 6:60–68. doi:10.3923/ijss.2011.60.68

- Azeez JO, Van Averbeke W (2010a) Fate of manure phosphorus in a weathered sandy clay loam soil amended with three animal manures. *Biores Technol* 101:6584–6588. doi:10.1016/j.biortech.2010.03.073
- Azeez JO, Van Averbeke W (2010b) Nitrogen mineralization potential of three animal manures applied on a sandy clay loam soil. *Biores Technol* 101:5645–5651. doi:10.1016/j.biortech.2010.01.119
- Bartholomow WW (1965) Mineralization and immobilization of nitrogen in the decomposition of plant and animal residues. In: Bartholomow WW, Clark FE (eds) *Soil nitrogen*. American Society of Agronomy, Madison, pp 285–306
- Bouyoucos GH (1965) A calibration of the hydrometer method for testing mechanical analysis of soils. *Agric J* 43:434–438
- Bray RH, Kurtz LT (1965) Determination of total organic and available forms of phosphorus in soil. *Soil Sci* 59:225–624
- Cater MR (1993) *Soil sampling and methods of analysis*. Canadian Society of Soil Science, Ontario
- Chadwick DR, John F, Pain BF, Chambers BJ, Williams JC (2000) Plant uptake of nitrogen from the organic nitrogen fraction of animal manures: a laboratory experiment. *J Agric Sci Camb* 134:159–168
- Eghball B, Wienhold BJ, Gilley JE, Eigenberg RA (2002) Mineralization of manure nutrients. *J Soil Water Conserv* 57(6):470–473
- ENDMEMO (2015) Conversion of part per million to milligram per kilogram. Complete concentration percentage unit conversions. (Online). <http://www.endmemo.com/sco>
- Enujeke EC, Ojeifo IM, Nnaji GU (2013) Residual effects of organic manure and inorganic fertilizer on maize grain weight and some soil properties in Asaba Area of Delta State. ISSN 2250–3579. *Int J Adv Bio Res* 3(3):433–442
- Enwezor WO, Udo EJ, Usoroh NJ, Ayotade KA, Adepetu JA, Chude VO, Udegbe GJ (1989) *Fertilizer use and management practices for crop in Nigeria* (eds). Federal Ministry of Water Resources and Rural Development (FMAWRRF) Lagos, pp 52–56
- FUNAAB (2013) Record of daily agrometeorological observation. Department of Water Resources Management and Agrometeorology. College of Environmental Management. Federal University of Agriculture, Abeokuta, pp 1–12
- Gomez-Brandon M, Fernandez-Delgado MJ, Domiguez J, Insam H (2013) Animal manures: recycling and management technologies. *INTECH Open Sci*. doi:10.5772/53454
- Hill laboratories (2001) *Soil tests and interpretation*. Technical Notes. <http://www.hill-laboratories.com>, vol 4, 3196, p 9
- Hoskins B (2015) Nutrient content, availability, and release rates from natural fertilizers. University of Maine. [http://www.newengladvfc.org/2015\\_conference/2](http://www.newengladvfc.org/2015_conference/2), pp 1–3
- James JC (2001) Nitrogen in soil and fertilizer. First Published in the: *Science Turfgrass Foundation News* 8(1):6–10
- Jonathan D (2006) Nitrogen mineralization potential in important agricultural soils of Hawaii, i. Cooperative extension service. *Soil Crop Managt* 15:1–5
- Kaira YP, Maynard DC (1991) *Method manual for forest soil and plant analysis*. For. Can., Northwest Reg., North. For. Cent., Edmonton, Alberta Inf. Rep. NOR-X-319
- LAS (2014) soluble salts or electrical conductivity of soils and green house media. Litchfield Analytical Services, pp 1–2
- Mallarino A (2000) *Soil testing and available phosphorus*. Integrated crop management. LOWA State University. University Extension, pp 164–166
- Marco J, Vlado K, Hrvoje P, Jasna S, Mitra R (2002) Influences of Nitrogen fertilizer and irrigation on nitrogen leaching. In proceedings of the second international conference on sustainable agriculture for food, energy and industry, pp 1641–1647
- Masarirambi MT, Dlamini P, Wahome PK, Oseni TO (2012a) Effects of chicken manure on growth, yield and quality of lettuce (*Lactuca sativa* L.) “Taina” under a lath house in a semi-arid sub-tropical environment. *American- Eurasian. J Agric Environ Sci* 12(3):399–406
- Masarirambi MT, Sibandze N, Wahome PK, Oseni TO (2012b) Effects of kraal manure application rates on growth and yield of wild okra (*Corchorus olitorius* L.) in a sub-tropical environment. Accepted: November, 29, 2011. ISSN: 2041–3890. *Asian J Agric Sci* 4(1):89–95
- McBride C (2015) How to calculate percentages in grams. Demand Media
- Meissinger JJ, Jokela WE (2000) Ammonium volatilization from dairy and poultry manure. Natural Resource, Agriculture, and Engineering Service. <http://www.nraes.org>, pp 1–2
- Monica ZB (2013) *Water and soil characterization. pH and electrical conductivity*. Microbial life. Educational Research. Montana State University, Bozeman, pp 1–5
- Murphy J, Riley JP (1962) A modified single solution method for determination of phosphate in natural waters. *Anal Chem* 27:31–36
- Navarro Pedreno J, Moral R, Gomez I, Mataix J (1996) Reducing nitrogen losses by decreasing mineral fertilization in horticultural crops in eastern Spain. *Agric Ecosyst Environ* 59:217–221
- Okalebo JR, Gathua KW, Woomer PL (1993) *Laboratory methods of soil and plant analysis. A working manual*. Soil Science Society of East Africa (SSSEA). Technical Publication 1
- Pam H and Brian M (2007) Interpreting soil test results. What Do all the numbers mean? Pam Hazelton and NSW Department of Natural Resources, pp 1–66
- Ramsasa C (2010) How to replenish the nutrients in the soil of your garden. *Ezine Article*. <http://EzineArticles.com>
- Sajal R, Abul Kashem M (2014) Effects of organic manures in changes of some soil properties at different incubation periods. *Open J. Soil Sci.* 4(3):81–86. doi:10.4236/ojss.2014.43011
- Schippers RR (2000) African indigenous vegetables—an overview of the cultivated species, pp 103–118
- Silva DJ, Queiróz AC (2002) *Análise de alimentos: métodos químicos e biológicos*, 3 (ed) Vicoso: Imprensa Universitária/UFV
- Sorenson P (2001) Short-term nitrogen transformations in soil amended with animal manure. *Soil Biol Biochem* 33:1211–1216
- Spore (2006) Issue 123, June 2006, p 13
- Tom D (2002) *Nitrogen Sources*. University of Nebraska Lincoln Extension. 402. Available through: 441–7180. <http://Lancaster.uni.edu>, p 288
- USDA (2010) Soil texture calculator. United State Development of Agriculture Natural Resources Conservation Service Soils. <http://www.nrcs.usda.gov/wps>
- USDA–SCS (1974) *Total nitrogen and organic carbon ratings and interpretation*. Interpretation Guides for Evaluating Analytical Data. USDA–SCS
- Uwah DF, Eyo VE (2014) Effects of number and rate of goat manure application on soil properties, growth and yield of sweet maize (*Zea mays* L. *saccharata* strut). *Sustainable Agriculture Research*; ISSN 1927-050X. Accepted: September 2, 2014. doi:10.5539/sar.v3n4p75
- Van Reeuwijk LP (1993) Procedure for soil analysis. International Soil Reference and Information Centre Technical paper, pp 9
- Vel AM, Swamam TP (2013) Nitrogen release pattern from organic manures applied to an acid soil. *J Agric Sci* 5(6):174–184. ISSN 1916–9760. doi:10.5539/jas.v5n6p174
- Vinten A, Whitmore AP, Bloem J, Howard R, Wright F (2002) Factor affecting nitrogen immobilization or mineralization kinetics for cellulose-, glucose-, and straw amended sandy soils. *Biol Fert Soils* 36:190–199
- Watanabe PH, Thomas MC, Pascoal LAF, Ruiz, US, Daniel E, Amorim AB (2013) Manure production and mineral excretion in faeces of gilts fed ractopamine. *Acta Scientiarum. Animal*



Sciences. Maringa. Received on September 19, 2012. Accepted on December 14, 2012, v35n3, 267–272. <http://www.redalyc.org/articulo.oa?id=303128706007>; <http://www.ehow.com/how>, pp 1–6

Xu RK, Coventry DR, Farhoodi A, Schultz JE (2002) Soil acidification as influenced by crop rotations, stubble management, and application of nitrogenous fertiliser, Tarlee, South Australia. *Aust J Soil Res* 40:483–496

