JJEES

JJEES (2019) 10 (4): 204-214
ISSN 1995-6681

Jordan Journal of Earth and Environmental Sciences

Nitrogen Mineralization Kinetics in some Tropical Soils Amended with Ashed and Un-ashed Animal Manures

Toyin Olowoboko[1*], Jamiu Azeez[1], Olanrewaju Olujimi[2], Oluwatoyin Babalola[1]

[1]Federal University of Agriculture Abeokuta, Department of Soil Science and Land Management, Nigeria
[2]Federal University of Agriculture Abeokuta, Department of Environmental Management and Toxicology, Nigeria

Received 19 March 2019; Accepted 23 July 2019

Abstract

This study is carried out to evaluate mineral nitrogen release of three animal manure ashes and dried animal manures by kinetic models under incubation, screen-house, and field conditions. Soils were treated with dried manures and manure ashes of cattle, goat, and poultry and NPK 15-15-15 at 120kg N ha^{-1} after which the amended soil mixtures were taken fortnightly and analyzed for mineral nitrogen. The incorporation of manure ashes increased mineral N in the incubation experiment; there was a significant increase of 184%, 245%, 53%, and 65% in the screen-house and field experiments respectively with the cattle manure ash amendment compared to the control and dried manure. Mineral N release was in the following order: screen-house experiment > incubation experiment > field experiment. The first and second order was fit for N release only from the goat manure ash in the incubation and screen-house experiments. The relationship between N kinetics and time was polynomial.

Keywords: Nitrogen mineralization, nutrient release kinetics, rate order, recycled manure.

1. Introduction

Land application of animal manure seems to be an effective option in terms of management and disposal. It is considered as a valuable nutrient source when applied to the soil at rates and proportion to agronomic practices. Animal manure has been reported to significantly increase the soil physical properties such as soil aggregation, infiltration, and water holding capacity (Gilley and Risse, 2000) as well as the chemical properties including the cation exchange capacity and the soil buffering potential (Tisdale et al., 1993). Major nutrients like nitrogen and phosphorus have been recovered by the manure input to the soil. Despite all this importance of animal manure, its use is still limited due to bulkiness, nutrient heterogeneity, weed seed content, and low surface area; hence the recycling of manures becomes important. The incineration of animal manure is effective in reducing the volume and in concentrating the fertilizer nutrients. Thermal energy, which can be used for heating animal houses and electricity generation, is produced by incineration (Teppei et al., 2012). Beneficial uses of animal manure ash include its use in land application as an agricultural fertilizer, or a liming agent and a partial substitute for Portland cement in the cement and concrete industries (Demeyer et al., 2001). Furthermore, the nutrient-rich ash has the potential to increase the concentration of extractable plant nutrients in the amended soils. The calcium-rich alkaline ash from the poultry manure (Codling et al., 2002; Yusiharni et al., 2007) increases the pH of acidic soils and may increase the yield of barley, grass, white clover, rice, carrots, onions, beans, tomatoes, and wheat. Alkaline ash may, however, decrease the bioavailability of P, potassium (K), magnesium (Mg), copper (Cu), and iron (Fe) in soil (Yang et al., 2007).

The immediate impact of organic waste application is relevant to the availability of nitrogen to the subsequent crop, because of mineralization–immobilization processes (Hadas et al., 2004). However, the release of nutrients from the added organic substrate has proven to be difficult to predict, and this is to say that farmers often take inadequate account of the nutrient supply provided by various organic amendments (Domburg et al., 2000). The proportion of mineral N released from an added material may become part of the mineralized N pool; it may be immobilized by microbes and hence become part of a microbial biomass pool, or may be denitrified and lost as either nitrous oxide or dinitrogen (Calderon et al., 2005). Most recommendations on manure N application are blanket, with the assumption that N release is the same for all manures even though a large variability in manure qualities between manures from the same animal species has been reported (Chadwick et al., 2000). Abbasi et al. (2007) worked on the mineralization of three organic manures as nitrogen sources in a soil incubated under laboratory conditions. Teppei et al. (2012) worked on the chemical characteristics of ashes from cattle, swine, and poultry manure. Paulo et al. (2010) worked on the phosphorus availability and early corn growth response in soils amended with turkey manure ash. Information on the amount of N mineralized under incubation, screen-house, and field conditions in soils amended with animal manure ash and dried animal manure is not available.

Measuring the amount of mineral N (NH_4^+ + NO_3^-) released during a specified period under uniform conditions is an assessment of the mineralization potential of a soil or any organic substrate (Abbasi et al., 2003). Several approaches have been used to evaluate the N mineralization kinetics as

* Corresponding author e-mail: rachy_blare26@yahoo.com

indicators of N availability over time. Stanford and Smith (1972) proposed calculating the amount of N mineralized directly, while single exponential models have been successfully applied to describe N mineralization by relating the N_0 from a single compartment with the incubation time (Wang et al., 2003; Camargo et al., 2004; Pereira et al., 2005). In an incubation experiment Stanford and Smith (1972) estimated the N mineralization potential (N_0) and the rate constant (k) of the kinetic equation to be a first order using a logarithmic function. Smith et al. (1980) improved the model and reported that a nonlinear least-squares equation gave a more accurate estimation of k and N_0.

Azeez and Van Averbeke (2010) used the first order, second order, and power function model developed by Dang et al. (1994) for abiotic system to test the data on nitrogen mineralization kinetics of three animal manures. It was reported that the model did not capture the N kinetics, and the relationship between the amount of N release and time was not linear but polynomial to the power of three. The inconsistencies in the N mineralization kinetics could be attributed to the different systems used for testing the models. Hence, there is a need for re-evaluation of the model used by Azeez and Van Averbeke (2010) in order to acquire concrete information on the N kinetics of systems involving dried manures and manure ashes. This study is aimed at determining the mineral N release kinetics of three animal manure ashes and dried animal manures in incubation, screen-house and field experiments. It also evaluates the data by kinetic models. Moreover, it is aimed at determining the percentage of mineral N released and the effect of animal manure ashes, and dried animal manures on mineral N in the amended soils.

2. Materials and Methods

2.1 Soil, Manure Collection and Analysis

The top soil samples (0-20 cm) were collected from four locations, which were chosen based on parent material (two locations from basement complex (Alabata, Osiele) and the other two from a sedimentary parent material (Itori and Papalanto)) in Ogun state in a forest transitional ecological zone. The soils were air-dried to constant weight at room temperature and sieved with a 2 mm mesh sieve. The cattle, goat, and poultry manures were collected from the Federal University of Agriculture, Alabata (FUNAAB) farm, and were air-dried to produce dried manures. Part of the dried manures were burnt in an open space at a temperature range of 320^0C - 450^0C to produce manure ash. Olowoboko et al. (2018) have reported the properties of the soils, dried manures and manure ashes used. Mineral N was calculated as the sum of nitrate nitrogen and ammonium nitrogen analyzed with (UV-3200 PCS spectrophotometer) according to Cataldo et al. (1975).

2.2 Treatments

The experiments were replicated three times with eight treatments which included no amendment (control), amendments with dry cattle manure (CMD), dry goat manure (GMD), dry poultry manure (PMD), cattle manure ash (CMA), goat manure ash (GMA), poultry manure ash (PMA), and NPK 15-15-15 applied at 120 kg N ha^{-1}.

2.3 Incubation Experiment

This experiment was laid in a completely randomized design, and four soils (Alabata, Osiele, Itori and Papalanto) were used in this experiment. One hundred grams of air-dried soil were dispensed into a 200g capacity plastic. Treatments (CON, CMD, CMA, GMD, GMA, PMD, PMA, NPK) were applied into the plastics accordingly and mixed thoroughly. The soil and amendment mixture were watered to a field capacity and kept in a dark cupboard for fifty-six days (eight weeks). Temperature of the incubation cupboard was determined daily with a thermometer, and an average temperature of 27.5^0C was recorded. The soil samples taken at 1, 14, 28, 42, and 56 days of incubation were analyzed for mineral N using the aforementioned methodology.

2.4 Screen-house Experiment

This experiment was laid in a completely randomized design and two soils (Alabata and Papalanto) were used for the experiment. The two soils used in this experiment were chosen based on the results of N-release pattern from the incubation experiment. One soil was chosen from each of the two parent materials. Five kilograms of soil were dispensed into 5L capacity buckets with dried-manure treatments (CMD, GMD, PMD) applied before planting, and the soil samples in the pots were watered. Maize seeds (BR-9928-DMR-SR-Y) were sown (three seeds per bucket), and after two weeks, manure ash (CMA, GMA and PMA) and NPK treatments were applied. The plants were thinned to one plant per pot after two weeks. The plants were watered when required and monitored in the screen-house for seventy days (ten weeks). The soil samples taken at 1, 14, 28, 42, 56, and 70 days were analyzed for mineral N using the aforementioned methodology.

2.5 Field Experiment

This experiment was laid in a randomized complete block design, and FUNAAB soil (Alabata) was used for the experiment which was carried out at the Teaching and Research Farms, Federal University of Agriculture, Abeokuta Ogun state Nigeria. Manure manure treatments (CMD, GMD, and PMD) were applied manually two weeks before planting. Manure- ashe treatments (CMA, GMA, and PMA) and NPK treatment were applied two weeks after planting. Maize seeds were sown at a spacing of 25 cm by 75 cm. Soil samples were taken at 1, 14, 28, 42, 56 and 70 days weeks, and were analyzed for mineral N using the aforementioned methodology.

2.6 Calculations

The percentage of total N released from an applied N source at time t was calculated as:

$$(\%N\ rel)\ N\,source = [(N\ (rel)Nsource / N_0(Nsource)]*\ 100.$$

where N(rel)Nsource is the amount of mineral N released from N source, N_0 is the total N in applied N sources.

The Mineral N release kinetics was estimated with first order, second order, and power function equations that were described by Dang et al. (1994) and reported by Azeez and Van Averbeke (2010).

First order:

$$\ln Qt = \ln Qe - k_1 t \quad \text{......eqn 1}$$

Second order:

$$1/Qt = 1/Qe + k_2 t \quad \text{......eqn 2}$$

Power function:

$Qt = at^b$ ……………………………....eqn 3

k_1, first-order rate constant (day^{-1})

k_2, second-order rate constant ((mg N kg^{-1})$^{-1}$)

a, initial N release rate constant (mg N kg^{-1} day^{-1})

b, release rate coefficient ((mg N kg^{-1})$^{-1}$)

Qt (mg N kg_1) is the amount of mineral N released after t days; Qe (mg N kg^{-1}) is the

amount of mineral N released at equilibrium. N in the equations refers to mineral N (NH_4^+–N + NO_3^-–N).

2.7 Statistical Analysis

Data collected were analyzed for their variance with the software package SAS (1999). Treatment effect and timing effects were determined using LSD at 5% level of probability.

3. Results and Discussion

3.1 Soil and Amendment (Dried manures and Manure ash) Characteristics

Soil and manure characteristics have been discussed in Olowoboko et al., (2018) who reported that the pH of soils used for the experiment ranged from 7.63 in Itori to 6.07 in FUNAAB. Total N in the FUNAAB soil was 0.25%; followed by 0.23% in Itori, 0.21% in Alabata, 0.19% in Osiele, and 0.18% Papalanto. The value of total organic carbon was highest in Osiele (55.9 g kg^{-1}), and lowest in Itori (43.7 g kg^{-1}). All the experimental soils are loamy sandy except the soil from Papalanto which is sandy in texture. The pH values of the dried manures and manure ashes ranged from 10.90 in GMA to 8.20 in DPM. pH values of the manure ashes were in the order of GMA > PMA > CMA while the pH of the dried manures were in the order of DGM > DCM > DPM. There was no significant difference in the values of total organic carbon (TOC) for the dried manures and manure ashes except for poultry manure ash which had 33% lower TOC as compared with its dried manure. No significant reduction in total organic carbon and nitrogen of the manures was noticed after burning at 320–450 °C. The total nitrogen of the manures did not significantly differ from that of the manure ashes; this shows that the incineration of the manure at this temperature did not lead to a significant loss of nitrogen. Dried poultry manure had the highest total nitrogen value followed by dried goat manure and dried cattle manure. Total organic carbon was in the order of GMA > DGM > CMA > DPM > DCM > PMA.

3.2 Mineral N Changes with Applied Amendment

The incorporation of manure ashes increased mineral N (mineral N) in comparison with dried manures during the incubation, screen-house, and field experiments. This could be attributed to the fact that a proportion of the organic N content has been converted to the inorganic form through the incineration of manures, and hence the mineral N content of the manure ashes were higher at incorporation. Additionally, this could be attributed to differences in the particle size of the dried manures and manure ashes. Particle size plays a major role in N mineralization as it affects the surface area of the N source and contact with microorganisms (Abbasi et al., 2007). Nitrogen mineralization and immobilization vary as a function of the availability of organic carbon (Van kessel et al., 2000). Table 1 shows the effect of amendment on the soil mineral N in the incubation experiment. At incorporation, a significant increase in mineral N was observed at the first day of incubation with PMA, a 164% increase in mineral N was recorded compared to its dried manure. Not all other amendments, except the NPK and PMA, differed from the control soil. On the 14th day of incubation, the highest and lowest mineral N values were observed with CMA and GMD respectively. CMA was able to increase the soil mineral N more than all other amendments; only a significant increase of 109% was found when compared to GMD.

Table 1. Effect of amendments on mineral N with incubation time

Amendments	………………………………. Mineral N (mgkg^{-1}) ……………………………….				
	1day	14days	28days	42days	56days
Soil only (CON)	166.71b	249.82a	163.6abc	151.2ab	217.77d
Dried cattle manure (CMD)	146.48b	225.63ab	199.24ab	223.51ab	420.49abc
Cattle manure ash (CMA)	166.99b	262.94a	203.93ab	117.39ab	486.23ab
Dried goat manure (GMD)	180.83b	125.51b	87.84c	151.26ab	252.83d
Goat manure ash (GMA)	157.18b	173.98ab	241.18ab	232.64ab	469.99ab
Dried poultry manure (PMD)	176.82b	203.11ab	157.06bc	172.84b	322.89bcd
Poultry manure ash (PMA)	465.96a	237.89a	249.05ab	248.21ab	385.88abcd
NPK	372.91a	167.50ab	279.19a	323.11a	506.21a

Means with the same letters are not significantly different at p≤0.05

Manure ashes and NPK were similar in terms of effect on mineral N at 28 days of incubation. Although the control soil did not differ from all the amendments except GMD, mineral N in the control soil was lower than that observed for all manure ashes and NPK-amended soils. This is expected since organic manures contain a higher concentration of total N compared to the control soil. This could be attributed to the more labile organic N compounds and the higher level of microbial activity in the soils amended with the manure ashes. The single application of goat and poultry manure ashes allowed mineral N to significantly increase by 175% and 59% compared to the dried manures. On day 42, there was no significant difference in the mineral N of manure ash-amended soil and the soil amended with dried manures even though an increase was observed following the application of manure ashes. The highest mineral N was observed with NPK at 114%, and the lowest value was observed with GMD. The control soil did not differ from the soil amended with GMD on the 56th day of incubation. Abbasi et al. (2007) observed a significant difference among different manures and soils on days 10, 20, 55, 90, and 120, whereas a non-significant difference was observed on days 0, 30, 40, and 70 in a 120-day incubation experiment using three organic manures. However, significant increases were observed for mineral N in soils amended with manure ashes in comparison to the soils amended with their dried manures, a

16%, 86%, and 20% increases in mineral N were observed for CMA, GMA and PMA. Mineral N was similar for NPK, CMA, GMA and PMA at the end of the incubation experiment. The similarities observed in the mineral N release of NPK, CMA, GMA and PMA at the mid, and at the end of the experiment could be attributed to similar nutrient characteristics of these amendment i.e. they contained some proportions of mineral N before being incorporated into the soils.

The effect of amendment on the mineral N in the screen house experiment is shown in Table 2. The highest mineral N was recorded after the application of PMD on day one of the experiment. This is expected since dried manures were incorporated into the soil before day one (before planting), while the manure ashes were incorporated into the soil on day one (at planting). Mineralization of N from the applied organic source had commenced in the soils amended with dried manures compared to the manure ash-amended soil. Poultry manure showed a greater potential for N mineralization, according to the results obtained by Cordovil et al. (2005) in an incubation experiment. Mineral N in the manure ash-amended soil was lower than that in the dried manure-amended soil. All amendments except PMD and CMD did not differ significantly from the control soil, while significant increases of 56% and 79% in mineral N were observed with CMD and PMD respectively compared to their manure ashes. On day 14, mineral N increased with the application of manure ashes in comparison to the dried manures. Manure ashes are thermal products of the dried manure subjected to heat. They are expected to contain more mineral N, so their ability to increase the mineral N of the soil even at incorporation is normal since they were incorporated on the 14th day. The incorporation of CMA increased mineral N significantly by 52% compared to the control; however, mineral N for the dried manure did not differ. There was no significant difference in the control soil and the amended soil on day 28, and the amendment effect was not significant even though increases in mineral N were observed with the cattle and poultry manure ashes. The non-significance of the amendment effect could be a result of the temporary loss of mineral N from the soil or by the plant uptake of mineral N for physiological growth. On day 42, the amendment effect was only significant with NPK, and manure ashes and dried manures did not significantly differ from each other and the control soil. The single application of the cattle manure ash allowed a significant increase of 184% and 245% compared to the control and the dried manure on day 56. Dried poultry manure increased mineral N by 85% compared to the poultry manure ash. The PMA, NPK, CMD did not show any difference from the control. At the end of the experiment, mineral N did not differ following all amendments and even the control.

Table 2. Effect of amendments on mineral N in the screen-house experiment

Amendments	……………………… Mineral N ($mgkg^{-1}$) ………………………					
	1day	14days	28days	42days	56days	70days
Soil only (CON)	470.8c	1178.3bc	627.2a	424.6b	614.1b	1290.1a
Dried cattle manure (CMD)	1065.56b	2495.5abc	665.0a	250.6b	506.4b	1932.2a
Cattle manure ash (CMA)	468.1c	3803.6a	1048.8a	262.1b	1746.0a	1281.4a
Dried goat manure (GMD)	418.5c	1952.9abc	556.2a	293.5b	1480.4a	965.3a
Goat manure ash (GMA)	448.5c	547.6c	471.6a	528.4b	1782.9a	1035.8a
Dried poultry manure (PMD)	2092.8a	2331.6abc	1000.4a	297.6b	1519.0a	2302.8a
Poultry manure ash (PMA)	430.6c	3084.0ab	1351.5a	732.3b	818.8b	1091.2a
NPK	501.8bc	3698.2a	599.3a	1357.9a	325.7b	821.5a

Means with the same letters are not significantly different at $p \leq 0.05$

The highest and lowest mineral N values were observed with PMA and control respectively on day one of the field experiment (Table 3). PMA increased mineral N by 142% and 267% compared to its dried manure and control respectively. The faster mineralization of N from PMA as a result of the lower carbon nitrogen ratio could have been the rationale for its significant effect at the onset of the field experiment. However, other manure ashes were similar to their dried manures. The GMD-amended soil did not differ from the control soil. Mineral N increased drastically in the NPK-amended soil on the 14th day in comparison to other amendments and the control; a significant increase of 1077% above the control was recorded. The majority of the N contained in NPK is in the mineral form, since it is an inorganic fertilizer, and has the capacity to supply N immediately for plant use. In addition, the fact that it was incorporated on the 14th day is the justification for the drastic effect.

Table 3. Effect of amendment on mineralized N in field experiment

Amendments	………………………Mineral N ($mgkg^{-1}$) ………………………					
	1day	14days	28days	42days	56days	70days
Soil only (CON)	79.57b	231.02b	70.37b	142.34ab	44.87a	154.17bc
Dried cattle manure (CMD)	190.81ab	251.22b	92.56b	107.74b	110.2b	142.91bc
Cattle manure ash (CMA)	143.76ab	73.08b	174.96ab	227.20a	292.8ab	235.19a
Dried goat manure (GMD)	117.75b	198.38b	120.76ab	190.51ab	195.7ab	150.61bc
Goat manure ash (GMA)	159.58ab	75.20b	275.45a	167.94ab	125.3ab	173.59abc
Dried poultry manure (PMD)	120.52b	208.52b	181.49ab	141.50ab	440.1ab	109.95c
Poultry manure ash (PMA)	292.04a	190.20b	161.93ab	150.47ab	291.8ab	139.83bc
NPK	184.30ab	2720.57a	279.86a	104.99b	199.2ab	189.16ab

Means with the same letters are not significantly different at $p \leq 0.05$

A similar response was observed on the 28th day, and the highest mineral N observed with NPK did not differ from that observed with GMA. On day 42, the lowest mineral N was observed in NPK-amended soil. The leaching and immobilization of mineral N is the rationale for the lowest N observed in NPK-amended soil on day 42, since all N is in the inorganic form. Adeniyan et al. (2011) reported that the nutrients released from the NPK fertilizer were only for a short period of time because the leaching of nutrients may be higher in the soil treated with NPK fertilizer than the soil treated with organic manures. GMA and PMA did not differ from their dried manure while CMA differed in mineral N from its dried manure by 111%. On day 56, no amendment difference was observed in terms of mineral N, and the values of mineral N in the amended soil were similar to those observed in the control soil. However, at the end of the experiment, CMA encouraged the highest mineral N compared to the control and other amendments except NPK and GMA. Manure ashes increased mineral N when compared to their dried manures. The incorporation of CMA into the soil increased mineral N by 53% and 65% compared to the control and CMD respectively. CMD, GMD, and PMD did not differ, while CMA and GMA showed similar results.

3.3 Amendment Effect on Mineral N across Time and Mineral N Dynamics across Amendments

Table 4 shows the concentration of mineral N across time in the incubation, screen-house, and field experiments. Mineral N release was similar with NPK, PMA, and CMA amendments during the incubation experiment. This is observable since the incubation experiment was a controlled experiment and changes in the pattern of N release were solely due to the soil environment and amendment characteristics. Lower values of mineral N were recorded for the dried manures compared with the manure ashes, while the control did not significantly differ from the GMD amendment. Dried goat manure contained more carbon than any of the amendments, which may have caused the observed immobilization of mineral N in its amended soil. Azeez and Van Averbeke (2010) also confirmed the lowest value of mineralized N for goat manure, and reported a marginal increase in mineral N for the cattle and poultry manures. Higher ratios of 10%, 60%, and 54% of mineral N were recorded for CMA, GMA and PMA in comparison with CMD, GMD and PMD. The values reported here are higher compared to N mineralization reported by Abbasi et al. (2007). The reason for this disparity in values may be attributed to the lower N rate of 200mg/kg used by the author. However, in the screen-house experiment, there was no significant difference in the amendments. Also, the amendment effect was not significant compared to the control. NPK was able to release the highest mineral N, which was significantly different from other amendments and even the control although the release of mineral N was higher with CMA and PMA compared to their dried manures. The similarities observed in the screen-house and field experiments can be attributed to plant factors, and the non-significance of the amendment effect may be attributed to several factors in addition to the soil and amendment characteristics.

Table 4. Amendment effect on mineral N across time

Amendments	Incubation	Screen-house Mineral N	Field ($mgkg^{-1}$)
Soil only (CON)	189.85de	1114.4a	187.7b
Dried cattle manure (CMD)	243.07cd	1281.6a	149.2b
Cattle manure ash (CMA)	267.50abc	1393.3a	191.2b
Dried goat manure (GMD)	159.65e	1039.5a	162.3b
Goat manure ash (GMA)	254.98bcd	977.8a	162.3b
Dried poultry manure (PMD)	206.55cde	1515.0a	200.4b
Poultry manure ash (PMA)	317.40ab	1186.2a	204.4b
NPK	329.78a	1366.4a	6130a

The dynamics of mineral N release across amendment for the three experiments is presented in Table 5. In the incubation experiment, after the incorporation of the amendments into the soils, mineral N decreased with the increasing of time up to day 28, after which it increased again till the end of the experiment. The initial proliferation of microbes, as a result of the increased reproductive rates which led to a high competition for nutrients and the subsequent trapping of nutrients in the soil, could have led to the immobilization of mineral N observed at the onset of the experiment.

Table 5. Timing effect on mineral N across amendments

Time	Incubation	Screen-house Mineral N	Field ($mgkg^{-1}$)
1day	229.23b	950.1cde	161.0b
14days	205.80b	2387.2a	493.5a
28days	197.65b	790.0de	169.7b
42days	215.03b	518.4e	154.1b
56days	382.78a	1099.1bcd	263.0b
70days	--------	1340.0bc	161.9b

Means with the same letters are not significantly different at $p \leq 0.05$

Azeez and Van Averbeke (2010) observed that the immobilization of mineral N occurred on day 10 in the incubation experiment. Significantly, a higher mineral N release was observed on the 56th day i.e., the end of the experiment. This is attributed to the decomposition of microbial mass and release of the initially-immobilized nutrients on the days earlier than the 56th day. This is consistent with the findings of Azeez and Van Averbeke (2010) who reported that the highest uptake of N by crops should be expected around day 55 following the manure application.

Using three organic manures in a mineralization experiment, Abbasi et al. (2007) reported that the release of mineral N from organic pools increased over time, and that a significant difference was noticed in the later stages of the incubation experiment. The value of 382.78mgkg^{-1} mineral N recorded the highest increase at 67% compared to the lowest value of 197.65mgkg^{-1} on the 28th day of the experiment. Mineralization reached a maximum value at the end of the incubation experiment. This could have happened because mineralization in the manures was gradual, and it reached a maximum when the conditions were favorable in the soils.

However, in the screen house experiment, mineral N was low immediately after the incorporation of the amendments into the soils, after which a drastic increase of 151% was observed on the 14th day of the experiment. After day 14 of the experiment, mineral N dropped by a significant decrease of 66% on the 28th day up to day 42 after which it increased again by 112% on the 56th day up until the end of the experiment. However, after the incorporation of the amendments into the soils in the field experiment, mineral N increased significantly by 206% on the 14th day, after which it decreased again by 65% on the 28th day up to the 42nd day. On day 56, mineral N increased, though this was not significant and at the end of the experiment, mineral N value was low and similar to that observed at the incorporation stage. The highest mineral N was recorded on day 14, and the values observed on other days were significantly lower. It can be concluded that the mineralization pattern could be affected by the type of environment i.e being controlled or uncontrolled. Utmost N release was observed on the 14th day for the screen-house and field experiments. This means that the application of manure, weeks before planting, as is recommended in some agronomy manuals, may cause a substantial loss of mineralized N, and hence, encourage ground water pollution. The erratic pattern, observed in N release across time, may be attributed to the proliferation and death of microbes leading to a distortion in the N release. Additionally, the data provided were according to the soils and amendment types, which is the reason for the patterns observed.

3.4 Nitrogen Mineralization Kinetics

Tables 6, 7, and 8 show the parameters estimates of the equations used to describe mineral N kinetics in the control soil, soils amended with dried manures or manure ashes, and NPK-amended soils. The R^2 was used as the criteria to determine the best fit. Table 6 shows that the first order, second order, and power function were only able to capture the release of N from CMD and GMA, while for the other amendments, the R^2 was very low. The first order constant K_1 was positive for all amendments and the second order was negative for all the amendments with the highest found in GMA and CMD. The wide variation in mineralization rate constant (k) of the dried manures and manure ashes may be attributed to the differences in amendment characteristics. The ability of the first order model and the second order model to capture the release of N in the control soil was zero. For the power function, GMA and CMD also had the highest R^2 and release rate coefficient (b), although the initial N release per day was highest in PMA. This could be due to the lower C:N ratio of PMA which mineralized faster than other amendments, the reason behind the highest N release per day.

Table 6. Estimated kinetic model parameters for mineral N in the incubation experiment

	First order		Second order		Power function		
	K^1 (× 10^{-1})	R^2	K^2 (× 10^{-4})	R^2	a	b (× 10^{-1})	R^2
Soil only (CON)	0	0	-0.01	0	176.6	0.19	0.021
Dried cattle manure (CMD)	0.15	0.748	-0.6	0.775	138.8	1.79	0.579
Cattle manure ash (CMA)	0.09	0.155	-0.2	0.042	165	1.02	0.099
Dried goat manure (GMD)	0.06	0.117	-0.3	0.064	156.2	0.1	0.003
Goat manure ash (GMA)	0.17	0.839	-0.7	0.909	138.8	1.9	0.523
Dried poultry manure (PMD)	0.07	0.335	-0.3	0.282	167.7	0.62	0.126
Poultry manure ash (PMA)	0.02	0.029	-0.5	0.014	415.6	1.1	0.346
NPK	0.09	0.241	-0.3	0.198	299.5	0.12	0.002

However, in the screen-house experiment (Table 7), the first-order model captured a bit of the N release from GMA and PMD, and the second-order model captured N release from GMA, while the power-function model was unable to capture N release from any of the amendments. The first-order rate constant was highest in GMA, while in other amendments and control soil, $K_1$was very low. The second-order rate constant K was very low in all of the amendments with negative values recorded for CMA, GMD and GMA. For the power-function model, the initial release rate constant was highest in PMD, while negative values of release rate coefficient were observed for the control, CMD, PMD, and NPK. The second-order model and the power-function model were unable to capture any N release in all of the amendments in the field experiment (Table 8). Moreover, amongst all the amendments and control, only the first-order model captured the release of N from CMA. The first-order model was positive and low for all amendments except NPK which showed the highest value. The second-order constant K_2 was very low for all amendments with negative values recorded for GMD, GMA, and PMD. The first-order, second-order and power-function models were unable to capture a release of N from all amendments since the R^2, which was used as the criterion of fit, was very low. This is consistent with the findings of Azeez and Van Averbeke (2010) who used the same model and observed that the non-conformity of the data to the models may be ascribed to the inconsistent N release patterns, net mineralization, immobilization, and fixation. They also reported that the models have been developed for abiotic systems rather than microbial induced systems in soil conditions, which is reason behind the inadequacy of the models. This means that the release of N from NPK, dried manures, and manure ashes, except for GMA, was not linear. However, mineral N released from GMA in the incubation experiment follows a linear trend, which is observable from the R^2.

Table 7. Estimated mineral N kinetics model in the screen-house experiment

	First order		Second order		Power function		
	K^1 ($\times 10^{-2}$)	R^2	K^2 ($\times 10^{-4}$)	R^2	a	b	R^2
Soil only (CON)	0.7	0.133	0.08	0.099	1613	-0.2	0.376
Dried cattle manure (CMD)	0.5	0.029	0.1	0.041	1257	-0.12	0.049
Cattle manure ash (CMA)	0.2	0.005	-0.06	0.014	659.9	0.142	0.055
Dried goat manure (GMD)	0.5	0.038	-0.1	0.049	505.7	0.134	0.081
Goat manure ash (GMA)	1.6	0.577	-0.2	0.668	377.6	0.201	0.334
Dried poultry manure (PMD)	0.4	0.618	0.06	0.017	2095	-0.15	0.094
Poultry manure ash (PMA)	0	2E-05	0.08	0.084	637.2	0.157	0.14
NPK	1.5	0.238	0.2	0.221	1481	-0.14	0.074

Table 8. Parameters estimates for mineral N kinetics in the field experiment

	First order		Second order		Power function		
	K^1 ($\times 10^{-2}$)	R^2	K^2 ($\times 10^{-4}$)	R^2	a	b	R^2
Soil only (CON)	0.1	0.006	0.3	0.017	97.14	0.022	0.003
Dried cattle manure (CMD)	0.7	0.275	0.5	0.21	210	-0.13	0.305
Cattle manure ash (CMA)	1.4	0.554	0.9	0.417	109	0.156	0.25
Dried goat manure (GMD)	0.3	0.131	-0.2	0.163	123.1	0.081	0.284
Goat manure ash (GMA)	0.3	0.033	-0.3	0.067	140.1	0.025	0.009
Dried poultry manure (PMD)	0.3	0.026	-0.4	0.001	129.7	0.103	0.104
Poultry manure ash (PMA)	0.5	0.162	-0.3	0.203	278.6	-0.11	0.321
NPK	1.7	0.164	0.4	0.119	366.1	-0.88	0.012

Attempts which have been made to predict the nutrient value of manures, using their mineral N concentration at the time of application, are good approaches for preparing simple-nutrient budgets (Chambers et al., 1999). However, such approaches do not take account of mineralization and immobilization which follow the manure application to the field and ignore any potential changes in the rates of mineralization of the background organic matter (Abbasi et al., 2007). Mineral N release kinetics is shown in Figures 1, 2, and 3 for the incubation, screen-house, and field experiments, respectively. It can be concluded that the relationship between the N release kinetics and the number of days in the three experiments was not linear, and best was described by a polynomial raised to the power of three.

In Figure 1, it is observed that the kinetics of N release per time for GMA was not described by the polynomial raised to the power of three (Figure 1). The R^2 shows that about a 50%, 63%, 96%, 69%, 33%, 68% and 52% variation in the amount of N release per unit time was captured by the model for the control soil, CMD, CMA, GMD, PMD, PMA and NPK, respectively. Among the dried manures and manure ashes, only CMA had a polynomial relationship existing between the amount of N released and time. Figure 1 also shows that the pattern of N release was not the same for the dried manures, manure ashes and control. This may be ascribed to differences in the characteristics of the manures and manure ashes used for the experiments. Additionally, the variation in the mineralization pattern observed could be attributed to mineralization-immobilization turnover in the experiment. For CMA, CMD, PMD, and the control soil, there was an initial N release between day 0 and day 14 as a result of the initial wetting and drying of the soil. This was followed by a phase of constant release from day 14 to day 24 due to immobilization, and a slow decline between days 25 and 40, after which a final sharp increase in N release was observed from day 42 to day 56. The similarities in the pattern of N release per time for the dried manures may be attributed to the same carbon nitrogen ratio. This implies that for CMA, CMD, and PMD, the application of these manures should be synchronized with the N uptake i.e., they should be applied at planting so that the final sharp phase of N increase will correspond with the time of plants' utmost need for N (at taselling) to avoid a substantial loss of mineralized N. Gale and Gilmour (1986) reported that three phases of decomposition and mineralization occurred when broiler manure was incorporated into the soil. However, For GMD, a phase of rapid decline from day 0 to day 28, and a rapid increase from day 32 to day 56 was observed. For PMA, an increase-decrease pattern of N release was observed and for GMA, and a phase of steady increase in N on day 0 to day 28 followed by a decline, after which a sharp increase was observed on days 42 to 56.

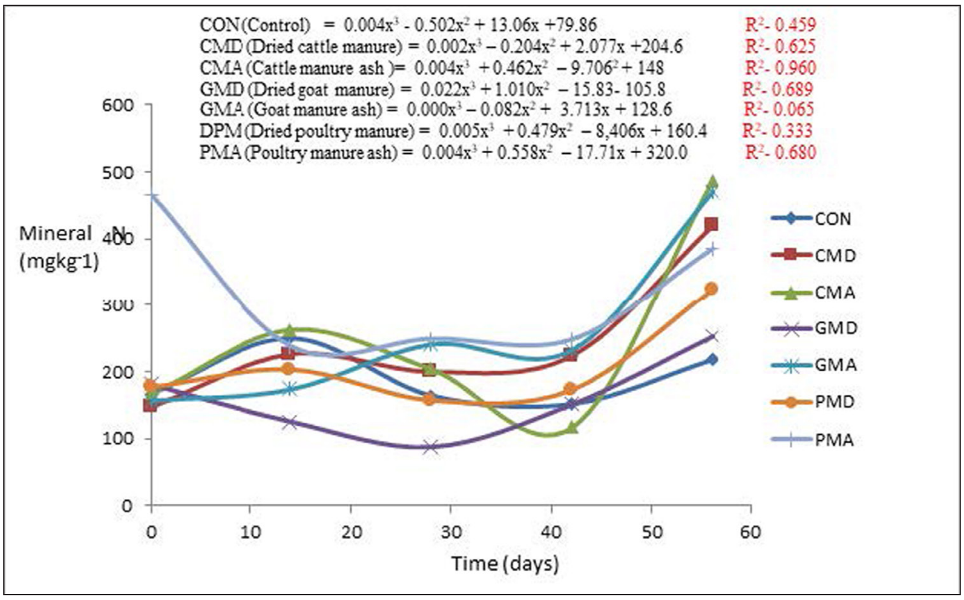

Figure 1. Nitrogen release kinetics in incubation experiment

However, in the screen house experiment (Figure 2), the relationship between N release kinetics and time was totally captured by the model for the control soil, since it was 100% fit for the data. This is because mineral N release from the control soil was solely curvilinear not linear. For CMD, CMA, GMD, GMA, PMD and PMA, the variation in the captured data were 79%, 34%, 14%, 61%, 77%, and 68% respectively. The phases of N release kinetics were similar for CMD, PMD and PMA. The reason for the similarities in CMD and PMD has been explained above. These amendments had a sharp increase in N release from day 0 to day 14 followed by an abrupt decrease in N on day 15 to day 42, and a final phase of rapid N release. The immobilization of mineral N occurring on day 15 to day 42 in CMD, PMD, and PMA could be attributed to the temporary loss of the released N by microbes, especially when the carbon in the amended soils increased at this point. This also means that on days 15 to 42, the plant N uptake will be very low, since most of the released N had been immobilized. The increased mineralization of N from these amendment at the final phase is advantageous for the plant, since these phases correspond to the phase of utmost N need for physiological processes such as tasselling.

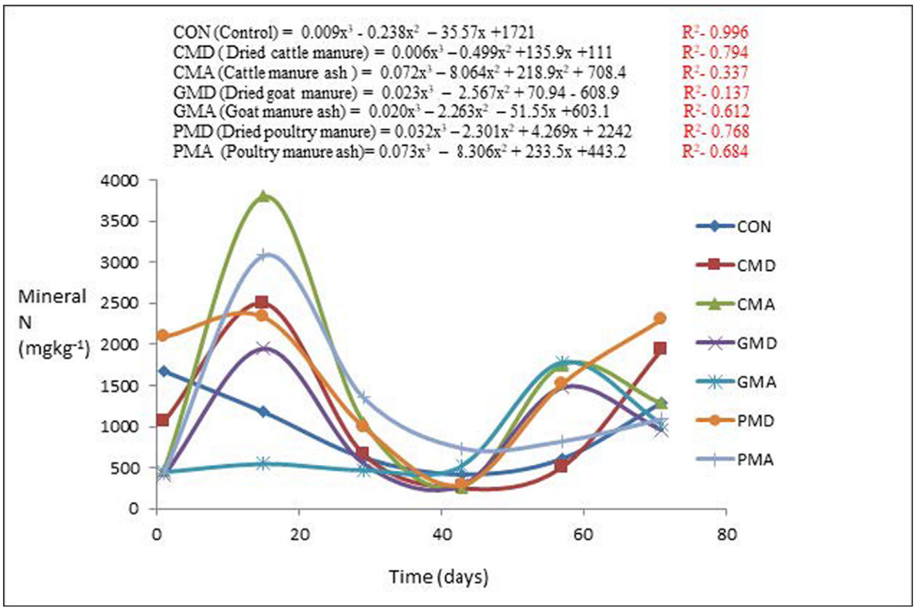

Figure 2. Nitrogen release kinetics in the screen-house experiment

The findings presented above is inconsistent with the findings of greenhouse studies by Mugwira and Mukurumbira (1984) who observed a depression in the yields in the first two weeks followed by a significant increase of plant growth after two weeks of being planted in manured pot. The non-conformity could be attributed to the differences in manure characteristics. Conversely, for the control soil, only two phases were observed in the N release per time which are: a phase of steady decrease from day 0 to day 42, and a steady increase from day 43 to day 70. For CMA and GMD, four phases were recorded as follows: an initial phase of sharp increase from day 0 to the 14th day, followed by a sharp decrease from the 15th day to the 42nd day, a steady increase from day 43 to day 56, and a final phase of constant decline in N. A similar pattern was observed for GMA only that the first and second phases were steady. The erratic pattern of N release observed with CMA and GMD could be due to death and growth of N mineralizing microbes, thereby causing the inconsistencies in the observed data.

The goodness of fit measured by the R^2 showed that a 86%, 99%, 98%, 98%, 95%, 100%, 95% variation in the data for the control, CMD, CMA, GMD, GMA, PMD and PMA respectively were captured by the model for the field experiment (Figure 3). This means that release of N across time from the amendments was curvilinear, but not linear, and could be attributed to the impacts of soil and environmental factors which could not be controlled on the field experiment. The phases of N release kinetics were similar for the control, and all the dried manures, and an erratic pattern of N release was observed during which N increased at one week, but decreased the succeeding week. The rationale for the erratic pattern of mineral N may be attributed to the proliferation and death of microbes thereby causing inconsistencies in the data. This is in agreement with the findings of Abbasi et al., 2007 who observed an inconsistency (an increase or decrease with time) in the pattern of total mineral N of three organic manures in an incubation experiment. However, three phases were observed for the manure ashes. For PMA, a steady decline from day 0 to day 42, followed by a phase of increase in N up to day 56, and a final phase in which N declined steadily. For CMA, a steady decline from day 0 to day 14 was followed by a steady increase till day 56, and a constant decrease from day 57 to day 70. For GMA, a steady decrease from day 0 to day 14 was followed by a steady increase from day 15 to day 28, and a final steady decline in N was observed.

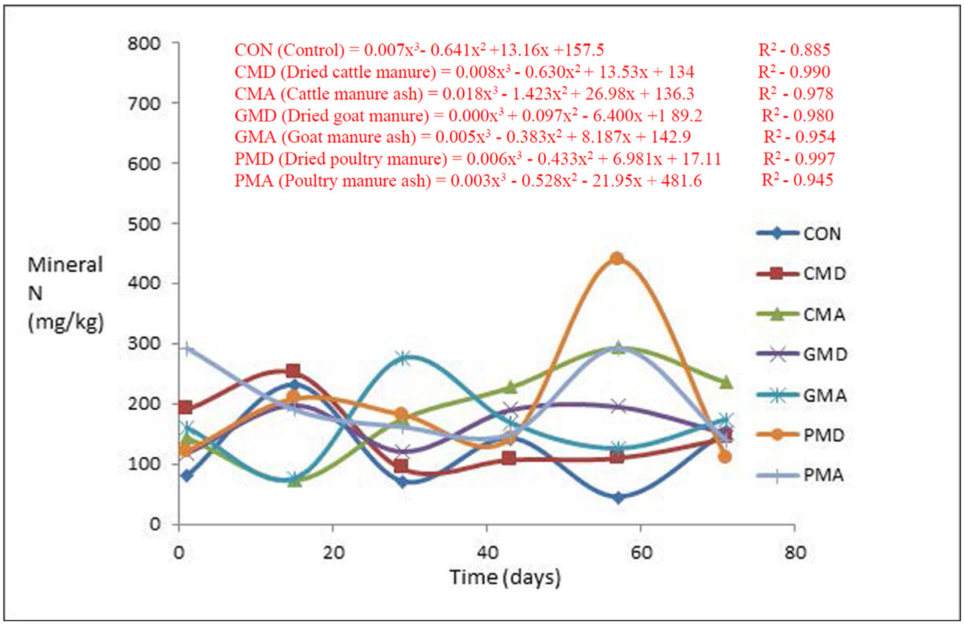

Figure 3. Nitrogen release kinetics in the field experiment

The percentage proportions of mineral N released from the applied organic amendments (dried manures and manure ashes) are presented on Figure 4. The release of mineral N was not the same for the three amendments in the three experiments. Mineral N released from the dried manures and manure ashes was in the order of: screen-house experiment > incubation experiment > field experiment. The highest amount of mineral N released from the applied organic sources in the screen-house experiment, compared to the incubation experiment, could be due to the temperature and the increased action of microorganisms in the rhizosphere favoring N release, and also because the pathway of N loss was not as wide as that in the field experiment. The rationale for this is that the mineral N released was subjected to losses that could be through plant uptake of N, immobilization, leaching, and volatilization in the field experiment. Plant uptake of N in the screen-house experiment is expected to be low compared to the field experiment, since it was a controlled experiment, and several factors responsible for the N loss could be controlled. The relatively low mineralization capacity of the manures and manure ashes in the incubation experiment could be attributed to changes in the soil which may have developed during incubation (Abbasi et al., 2007). In the incubation experiment, the mineral N release followed the order PMA > CMA > GMA > CMD > PMD > GMD. However, in the screen house experiment, the order was CMA > PMA > CMD > CMD > GMA > GMD. Moreover, a different order was observed in the field experiment as follows: PMA > CMA > GMA = PMD > CMD = GMD.

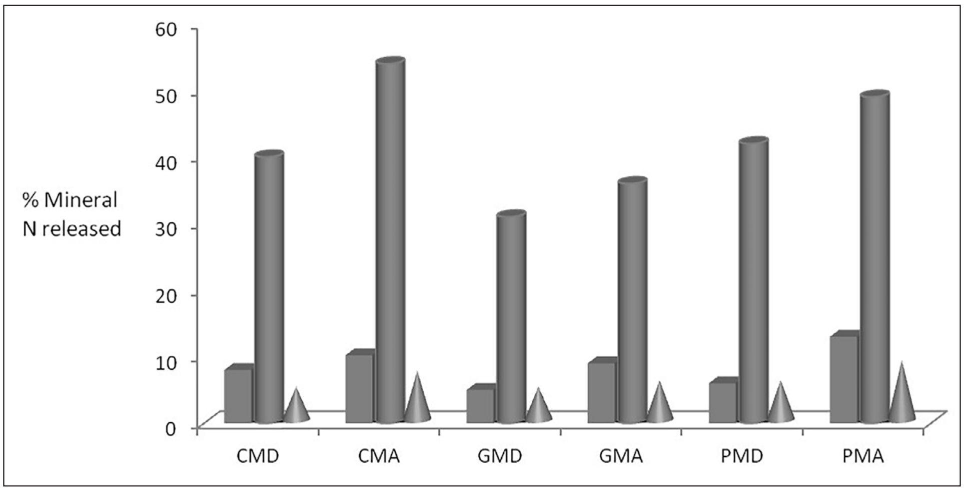

Figure 4. Percentage of mineral N released in the incubation, screen-house and field experiments.

4. Conclusions

The incorporation of manure ashes increased mineral N in comparison with dried manures in the experiments. Soil environment and amendment characteristics are important factors affecting mineral N release in incubation experiments, while plant factors coupled with the above factors are determinants of the amount of N released from screen-house and field experiments.

Mineralization reached a maximum on day 56 of the incubation experiment (end of the incubation experiment). Utmost N release was on day 14 for the screen-house and field-patterns. The application of manure to the soil, some weeks before planting, as recommended by some manuals, could cause a substantial loss of mineralized N, and hence encourage ground water pollution.

The first-order and second-order models were able to capture the release of N from only GMA amongst other amendments, while the power-function model was unfit for the data. Relationship between the N release kinetics and number of days in the experiments were not linear, and were best described by a cubic polynomial function. In the incubation experiment, the N release kinetics was not the same for the dried manures, manure ashes and the control, while similar phases of N release kinetics were observed for CMD, PMD, and PMA in the screen-house experiment, and an erratic pattern of N kinetics was observed with similar pattern for the control and the dried manures in the field experiment.

Mineral N released from dried manures and manure ashes was in the order of: screen-house experiment > incubation experiment > field experiment. However, PMA > CMA > GMA > CMD > PMD > GMD, CMA > PMA> CMD > CMD > GMA >GMD and PMA > CMA > GMA = PMD > CMD = GMD was observed in the incubation, screen-house and field experiments respectively.

Acknowledgement

The authors wish to acknowledge the Soils of Forest Islands in Africa (SOFIIA-FUNAAB) for their support in the laboratory analyses. SOFIIA is a collaborative research project funded through by the UK Government's Royal Society-DFID Africa Capacity Building Initiative. Opinions expressed and conclusions arrived at are those of the authors and are not necessarily to be attributed to the project.

References

Abbasi, M.K., Hina, M., Khalique, A., Khan, S.R. (2007). Mineralization of three organic manures used as nitrogen source in a soil incubated under laboratory conditions. Communication in Soil Science and Plant Analysis 38:1691-1711. https://doi.org/10.1080/00103620701435464.

Abbasi, M.K., Shah, Z., Adams, W.A. (2003). Effects of nitrification inhibitor nitrapyrin on the fate of nitrogen applied to a soil incubated under laboratory conditions. Journal of Plant nutrition and Soil Science 166: 513-518.

Adeniyan O.N., Ojo A. O., Akinbode, O. A., Adediran J.A. (2011) Comparative study of different organic manures and NPK fertilizer for improvement of soil chemical properties and dry matter yield of maize in two different soils. Journal of Soil Science and Environmental Management Vol. 2 (1), pp. 9-13.

Azeez, J.O., and Van Averbeke, W. (2010). Nitrogen mineralization potential of three animal manures applied on a sandy clay loam soil. Bioresource Technology 101: 5645–5651. doi:10.1016/j.biortech. 2010.01.119.

Calderon, F.J., MeCarty, G.W., Reeves, J.B. (2005). Analysis of manure and nitrogen mineralization during incubation. Biology Fertility and soils 41: 328-336.

Camargo, F.A.O., Gianello, C., Tedesco, M.J. (2004). Soil nitrogen availability evaluated by kinetic mineralization parameters. Communication in Soil Science and Plant Analysis 35: 1293-1307.

Cataldo, D.A., Haroon, M, Schrander, L.E.,Youngs, V.L. (1975). Rapid colorimeteric determination of nitrate in plant tissue by nitration of salicylic acid. Communication in Soil Science and Plant Analysis 6: 71-80 https://doi.org/10.1080/00103627509366547

Chambers, B.J., Lord, E.I., Nicholson, F.A., Smith, K.A. (1999). Predicting nitrogen availability and losses following application of organic manures to arable land. MANNER. Soil Use Management 15:137-143.

Chadwick, D.R., John, F, Pain, B.F., Chambers, B.J., Williams J.C. (2000). Plant uptake of nitrogen from the organic nitrogen fraction of animal manures. A laboratory experiment. Cambridge Journal Agriculture Science 134:159-168 https://doi.org/10.1017/s0021859699007510

Codling, E.E., Rufus, L.C., Sherwell, J. (2002). Poultry litter ash as a potential phosphorus source for agricultural crops. Journal of Environmental Quality 3: 954-961. doi: 10.2134/jeq2002.0954

Cordovil, C.M.D.S., Coutinho, J., Goss, M., Cabral, F. (2005). Potentially mineralisable nitrogen from organic materials applied to a sandy soil: fitting the one-pool exponential model. Soil Use Management 21: 65–72.

Dang, Y.P., Dalal, R.C., Edwards, D.G., Tiller, K.G. (1994). Kinetics of zinc desorption from Vertisols. American Journal of Soil Science Society 58:1392–1399.

Demeyer, A., Voundi Nkama, J.C., Verloo M.G. (2001). Characteristics of wood ash and influenceon soil properties and nutrient uptake: An overview. Bioresource Technology 77: 287–295.

Domburg, P., Edwards, A.C., Sinclair, A.H. (2000). A comparison of N and Pinputs to the soil from fertilizers and manures summarized at farm and catchment scale. Cambridge Journal of Agriculture Science 134:147-158.

Gale, P.M., and Gilmour, J.T. (1986). Carbon and nitrogen mineralization kinetics for poultry litter. Journal of Environmental Quality 15:423-426.

Gilley, J.E., and Risse, M. (2000). Runoff and soil loss as affected by the application of manure. Transaction ASAE, 43:1583- 1588.

Hadas, A., Kautsky, L., Mustafa, G., Kara, E.E. (2004). Rates of decomposition of plant residues and available nitrogen in soil, related to residue composition through simulation of carbon and nitrogen turnover. Soil Biology and Biochemistry 36:255–266.

Mugwira, L.M. and Mukurumbira, L.M. (1984). Comparative effectiveness of manure from communal areas and commercial feedlot as plant nutrient sources. Zimbabwe Journal of Agriculture 81: 241-250.

Olowoboko T.B., Azeez J.O., Olujimi O.O., Babalola, O.A. (2018). Availability and dynamics of organic carbon and nitrogen indices in some soils amended with animal manures and ashes. International Journal of Recycling of Organic Waste in Agriculture 7(4):287-304.

Paulo, P., Carl, R., Jeff, S., Michael, R. (2010). Phosphorus Availability and Early Corn Growth Response in Soil Amended with Turkey Manure Ash. Communication in Soil Science and Plant Analysis 41(11): 1369-1382.

Pereira, J., Muniz, J., Silva, C. (2005). Nonlinear models to predict nitrogenmineralization in an Oxisol. Science and Agriculture (Piracicaba, Braz.) 62: 395-400.

SAS Institute Inc. (1999). SAS/STAT® 9.1 user's guide. Cary, N.C.: SAS Institute Inc.

Smith, J.L., Schnabel, R.B., McNeal, B.L., Campbell, G.S. (1980). Potential errors in the first order model for estimating soil nitrogen mineralization potentials. American Society of Soil Science 44: 996-1000.

Stanford, G., and Smith, S.J. (1972). Nitrogen mineralization potential of soils. Proceeding of American Society of Soil Science 109: 190–196.

Teppei, K., Arata, K., Manabu, Y. (2012). The chemical characteristics of ashes from cattle, swine and poultry manure. Journal of Material Recycling and Waste Management https://doi.org/10.1007/s10163-012-0089-2

Tisdale, S.L., Nelson, W.L., Beaton, J.D., Havlin, J.L. (1993). Soil fertility and Fertilizers, 5th Edn.; Prentice Hall: Upper Saddle River, N.J.

Van Kessel, J.S., Reeves III, J.B., Meisinger, J.J., (2000). Nitrogen and carbon mineralization of potential manure components. J. Environ. Qual. 29, 1669–1677.

Wang, W.J., Smith, C.J., Chen, D. (2003).Towards a standardised procedure fordetermining the potentially mineralizable nitrogen of soil. Biology Fertility and Soils 37:362-374.

Yang, J., He, Z., Yang, Y., Stoffella, P., Yang, X.,Banks, D., Mishra, S. (2007). Use of amendments to reduce leaching loss of phosphorus and other nutrients from a sandy soil in Florida. Environmental Science and Pollution Research 14:266 269. doi:10.1065/espr2007.01.378

Yusiharni, B.E., Ziadi, H.,Gilkes, R.J. (2007). A laboratory and glasshouse evaluation of chicken litter ash, wood ash and iron smelting slag as liming agents and P fertilizers. Australian Journal of Soil Research 45:374–389. https://doi.org/10.1071/sr06136.