CARIBBEAN FOOD CROPS SOCIETY

50

Fiftieth Annual Meeting 2014

St. Thomas, United States Virgin Islands
Volume L

PROCEEDINGS

OF THE

50TH ANNUAL MEETING

Caribbean Food Crops Society
50TH Annual Meeting
July 7 – July 11, 2014

Sugar Bay Resort and Spa Hotel
St. Thomas, United States Virgin Islands

Edited by
Thomas W. Zimmmerman, Stafford M.A. Crossman,
Errol Chichester and Wilfredo Colón

Published by the Caribbean Food Crops Society

ISSN 95-07-0410

Copies of this publication may be obtained from:

CFCS Treasurer
Agricultural Experiment Station
Jardín Botánico Sur
1193 Calle Guayacán
San Juan, Puerto Rico 00936-1118

Proceedings of the Caribbean Food Crops Society. 50:49-57. 2014

Animal Science and Agronomy/Soil

NITROGEN MINERALIZATION OF AGOUTI (*Dasyprocta leporina*) MANURE APPLIED TO FOUR TROPICAL SOILS

Gaius Eudoxie and Lincoln Ashby, Department of Food Production, University of the West Indies, St. Augustine, Trinidad and Tobago, West Indies.

Abstract: Assessing nitrogen (N) mineralization potential of manure is an important precursor for ensuring nutrient use efficiency. N mineralization of agouti and cattle manure was assessed after application to four contrasting soils, incubated for 35 days. Total Kjeldahl nitrogen (TKN) fluctuated over the incubation period and was affected by both soil and manure type. Mineralization was greater in agouti versus cattle manure, with the latter showing immobilization between sampling days 3 and 14. TKN was greatest in Princes Town soil. Ammonium (NH_4^+) content fluctuated similarly to TKN. Values were significantly higher in the strongly acid soils. Nitrate (NO_3^-) content decreased with time, stabilising at values just below 50 mg/kg. For the first two sampling times, agouti manure contained significantly higher values compared to cattle manure. Agouti manure can be applied as a soil amendment with consideration of the N supplying potential.

INTRODUCTION

The regional livestock industry is under increasing pressure to improve the management of waste and increase the efficiency of nutrient use. Soil application of manures has remained an important traditional control point that not only increases soil organic matter content and quality (Burger and Venterea, 2008) but also reduces soil degradation and environmental pollution when applied at appropriate rates related to crop requirements. This practice has increased with greater concern over the misuse of inorganic fertilisers and trends towards improving soil quality through sustainable practices (Hartz et al., 2000). Application rates of animal manures have been generalized based on decay rates (mineralization models) based on trials conducted mostly in temperate regions and rarely are nitrogen (N) content of the manures determined and mineralization assessed under humid, hot conditions. Burger and Venterea (2007) indicated that accurate estimates of plant available N and phosphorus (P) are needed to maximise the benefit to the crop and minimize undesirable losses of these nutrients. Eghball (2000) stated that N mineralization increased with increasing temperature under conditions found in agricultural soils. This is important in the tropics as at present rates, greater amounts of available N may be present over the growing season due to increase mineralization.

Whilst ammonium (NH_4^+) and nitrate (NO_3^-) are readily available for plant uptake from manures, mineralization determines the time dependent continual release of these inorganic N forms. Manures vary widely in nutrient quality, depending on animal species, age, feed and feeding pattern, management system and sex (Azeez et al., 2009). Differences in manure composition influences N transformation processes when applied to soil. Ehgball et al. (2002) showed a range from 18-55 % of organic N mineralized within one year after application for composted manure and poultry manure respectively. The wide range in potential N availability necessitates assessment of specific animal manures in lieu of soil application. The Agouti (*Dasyprocta leporina*) is a neotropical rodent. Locally, the high demand for its meat has directed research efforts towards domestication. Intensive rearing of these animals must include appropriate systems of waste management. It is germane that N mineralization potential be assessed to allow for proper use and disposal of this manure through soil application. Although practical constraints limit scaling up results from laboratory incubation-based mineralization studies to field application, such studies are important for comparison and understanding of the mechanisms and factors affecting N mineralization.

In addition to animal related factors matrix effects also determine the rate of release of inorganic N from applied manure. Van Kessel and Reeves III (2002) reported that a series of studies showed a range from 0-60 % organic N mineralized from cow manure. Chae and Tabatabai (1998) concluded that net N mineralized from manure depended on soil chemical and physical properties, but failed to elucidate the associated properties. Limited research has reported on the effects of soil properties on N mineralization. Burger and Venterea (2007) stated that declines in inorganic N occurring immediately after manure application to soil have been attributed to N loss processes. Nitrogen losses as high as 39% of manure N via denitrification have been reported (Calderon et al., 2005). The diverse nature of the soils of Trinidad (Roopnarine et al., 2012) will compound any generalization of application rates for animal manures. The main objectives of this study were to determine the mineralization rate of Agouti manure applied to contrasting soils and further to comparatively evaluate N mineralization from agouti relative to cattle manure.

MATERIALS AND METHODS

Manures and Soils

Laboratory incubations were performed comparing two manure types. Cattle manure was collected from storage areas where animal were confined with straw bedding assessable to the cattle. Agouti manure was collected from storage pits below animal confinement cages. Surface samples (0-30cm) were collected for four contrasting soils series; Piarco, River Estate, Princes Town and Talparo. Soils and manures were prepared by air drying, followed by crushing to pass a 2 mm sieve. Subsamples were analysed for pH, EC, TKN, total organic carbon (TOC), available P, K and particle size distribution for the soils. TKN was determined by acid digestion of 0.3 g and 1.05 g of dried milled manure and soil samples respectively, followed by Kjeldahl steam distillation (Bremner, 1966). TOC was tested using (Nelson and Sommers, 1996) loss on ignition and Walkley and Black wet oxidation for manure and soils respectively. Available P was extracted using $NaHCO_3$ following the Ascorbic Acid method (Kuo, 1996) and determined using a UV Mini 1240 (Shimadzu Corporation, Japan), while K was determined on the Digital Flame Model 2655-00 (Cole Parmer Instrument Company, USA) after NH_4OAc extraction (Helmke and Sparks, 1996). Electric conductivity (EC) was measured using a hand held conductivity/ TDS/ Temperature/ RS232C meter and pH using the IQ 150 pH meter at a solid to water ratio of 1:1 and 2.5: 1. Soil available N (NH_4^+ and NO_3^-) was extracted with 2M KCl (Mulvaney, 1996) followed by steam distillation utilizing Rapidstill II Labconco distillation unit. Clay content of soil samples was determined by the hydrometer method following Gee and Or (2002).

Soil Incubation

Triplicate samples of 4.5 kg of soil were mixed with either manure at a rate equivalent to 25 t/ha and then transferred into 3.78 L perforated plastic containers. Samples were watered to field capacity, covered and incubated in a closed ventilated room at 30°C for 35 days. A total of 24 experimental units were used for the incubation. Samples for all treatments were taken using a core auger capable of sampling the entire depth of the container, at different times (i.e. 1, 2, 3, 7, 14, 21, 28 and 35 days). Samples were analysed for nitrate (NO_3^-), NH_4^+ and TKN, as described previously.

Analysis

All data were subjected to repeated measures analysis of variance (ANOVA) using Genstat statistical software. Significant treatment means were separated using least significant differences (LSDs) values at 5 % level of probability.

RESULTS AND DISCUSSION

The soil series showed a wide variability in physical and chemical characteristics. Clay content ranged from 11.2 for Piarco to 75.7 % for Talparo (Table 1). Talparo and Princes Town series have been classified as Vertisols with expanding mineralogy, whilst Piarco and River Estate are classified as an Ultisol and Inceptisol respectively (Smith, 1983). The soils ranged from strongly acid to neutral, with the neutral soil having the highest TOC and TKN contents. Inorganic N was similar across all soils, values typical of tropical soils (Eudoxie, 2010) and indicative of quick N turnover and transformations. Wide variation in soil properties was important for elucidating the properties affecting N mineralization from manures.

Chemical characteristics of the manures differed, supporting the claim that manure quality varies in relation to animal type, age, diet and management (Chadwick et al., 2000). Cattle manure had a lower pH (alkaline) but higher EC compared to agouti manure (Table 1). TOC and TKN were lower in cattle manure, whilst the C:N ratios were similar. The C:N ratios (>25) suggest that mineralization would be slow and dependent on availability of native soil and manure inorganic N. Azeez et al., (2010) stated that immobilization of applied nutrients was likely from cattle and goat manures with C:N ratios of 10.3 and 11.3 respectively. This implies that immobilization would be the dominant N process in this study. However, the decomposition of organic substrates is also conditioned by the content of labile C and inorganic N.

Manure Mineralization in Soils

Figure 1 shows the combinatory effects of soil series and manure type on TKN. Variation in TKN is reflective of changes in organic N and inversely related to mineralization. For both manures across all soils TKN content fluctuated over the incubation period. Patterns were similar among cattle amended soils, whilst greater variability was observed in soils receiving agouti manure. TKN increased and decreased at different times among the soils. Princes Town recorded significantly higher TKN contents at days 3 and 7, whilst Talparo had a significantly lower content at day 21. The fluctuating trend suggests equilibrium shifts between mineralization and immobilization, with periods of increased TKN representative of immobilization. This is interesting as immobilization occurred immediately after application for cattle manure across all soils, whilst it took 21 days before immobilization was observed in agouti amended soils with the exception of Princes Town, which showed immobilization at day 3. The C:N ratios were similar for both manures but the content of C and N was greater in agouti manure. Agouti manure was able to supply available N for an extended period indicating the potential for use in cropping systems. Similar fluctuating trends were noted by Azeez et al. (2010) who attributed it to microbial population and C:N ratio. Notably the C:N ratios across the three manures used in their study was very similar and in the low range (10). It is suggested that C:N ratio plays a secondary role as values in our study were three times greater, in the range associated with immobilization. Availability of inorganic N and labile C moderates mineralization-immobilization dynamics. Abbasi et al. (2007) inferred that the higher C content of manures increases the energy and food supply to the microbes. This in turn stimulates their activity consuming more available N than the mineralization process releases.

Princes Town soil across both manures maintained the greater amount of organic N, implying lowest mineralization. Eudoxie (2010) reported highest immobilization for this soil among a similar range of tropical soils and alluded to the higher carbon content of this soil. Barret and Burke (2000) hypothesized that soils with higher organic matter content and wide soil C:N ratios may immobilize more N than soils with less SOM because of a limitation of reduced C substrate to microbial metabolism.

Inorganic N

NH_4^+ content decreased over the incubation period, stabilising at about 15 mg/kg for both manures (Figure 2). NH_4^+ content was significantly ($P < 0.05$) higher for agouti compared to cattle manure for all sampling times except days 7 and 35. NH_4^+ content was lowest after 28 DOI. Burger and Venterea (2007) reported similar results for incubation of four different manure types. Consistent with TKN trends, agouti manure sustained a greater amount of NH_4^+, indicating greater mineralization. Contrastingly, Piarco soil showed the greater content of NH_4^+. The corresponding low TKN values for this soil indicate greater mineralization. River Estate soil showed significantly lower NH_4^+ content over time relative to Piarco although TKN values were similar. This may be related to greater nitrification of NH_4^+ in the former soil associated probably with pH and enhanced microbial populations. Lower levels of microbial activity associated with low soil organic C, coarse texture and acidity allowed for a longer period of NH_4^+ availability in Piarco soil.

Agouti manure significantly ($P < 0.05$) increased the content of NH_4^+ in Talparo soil relative to cattle manure (Figure 3). This value was also significantly greater than all other soil×manure interactions except agouti amended Piarco soil. Piarco and Talparo soils are strongly acid, which could affect microbial activity. Eudoxie (2010) showed lowest nitrification and immobilization in these soils, which is also supported by the TKN data. Curtin et al. (1998) reported that liming of acid soils stimulated mineralization of C and N. Cheng et al., (2013) investigating gross mineralization in contrasting forest and grassland soils reported that the increase in soil pH significantly stimulated gross mineralization, while the opposite occurred for soil acidification.

Liming of acidic soils may stimulate N mineralization and subsequently nitrification, increasing the content and availability of inorganic N.

Nitrification was affected solely by manure type and varied significantly over the incubation period. After 1 DOI, NO_3^- content was 20 fold greater in agouti amended soils (Figure 4). The decreasing trend stabilized at values < 50 mg/kg from day 3, indicating loss or utilization of NO_3^- from soils. The high content of NO_3^- in agouti treated soil is related to native inorganic N in the manure and greater gross N mineralization. The rapid decline in NO_3^- concentration after application is of concern as continued supply of inorganic N may be interrupted. Additionally, dependent on soil properties loss pathways such as leaching and denitrification may pose environmental concerns. Azeez et al. (2010) reported net decreases in nitrification within 30 DOI for goat, cattle and poultry manure, all with significantly lower C:N ratios than manures used in this study. However, the authors showed that at 40 DOI, net nitrification increased for all manures. The incubation duration for this study did not exceed 40 DOI, but a similar fate can be anticipated.

CONCLUSION

Agouti manure differed in its physical and chemical properties compared to cattle manure and resulted in separate mineralization kinetics across different soils. Greater amounts of organic N were mineralized for agouti amended treatments, the extent modified by soil series. Princes Town series (pH 7.07) showed increased immobilization. Inorganic N forms (NH_4^+ and NO_3^-) generally decreased over time being affected by manure type. Agouti manure started with a greater content but at 35 DOI was similar to cattle manure. Use of agouti manure can follow similar recommendations to cattle manure with consideration for the higher content of organic and inorganic N and C.

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Table 1 Selected properties of manures and soils used in the study.

	Manure		Soil			
Property	Agouti	Cattle	Piarco	Princes Town	River Estate	Talparo
Clay (%)			11.2	61.8	32.3	75.7
pH	8.42	7.1	4.21	7.07	5.59	4.37
EC (dS/m)	5.33	7.91				
OC (%)	47.5	34.3	0.86	2.1	1.26	0.69
TKN (%)	1.63	1.08	0.08	0.22	0.14	0.1
C:N	29	32	11	10	9	7
NH4+ (mg/kg)			27.6	33	49.1	35.9

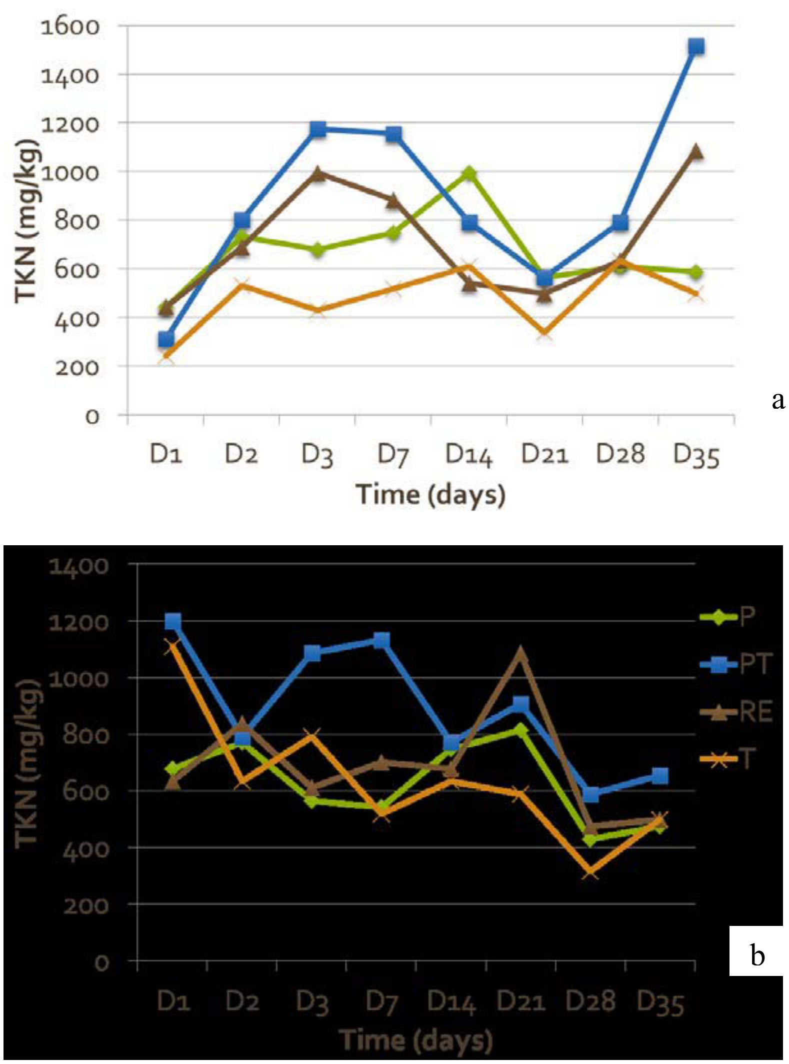

Figure 1 Combinatory effect of soil series and cattle (a) or agouti (b) manure on TKN content of samples incubated for 35 days

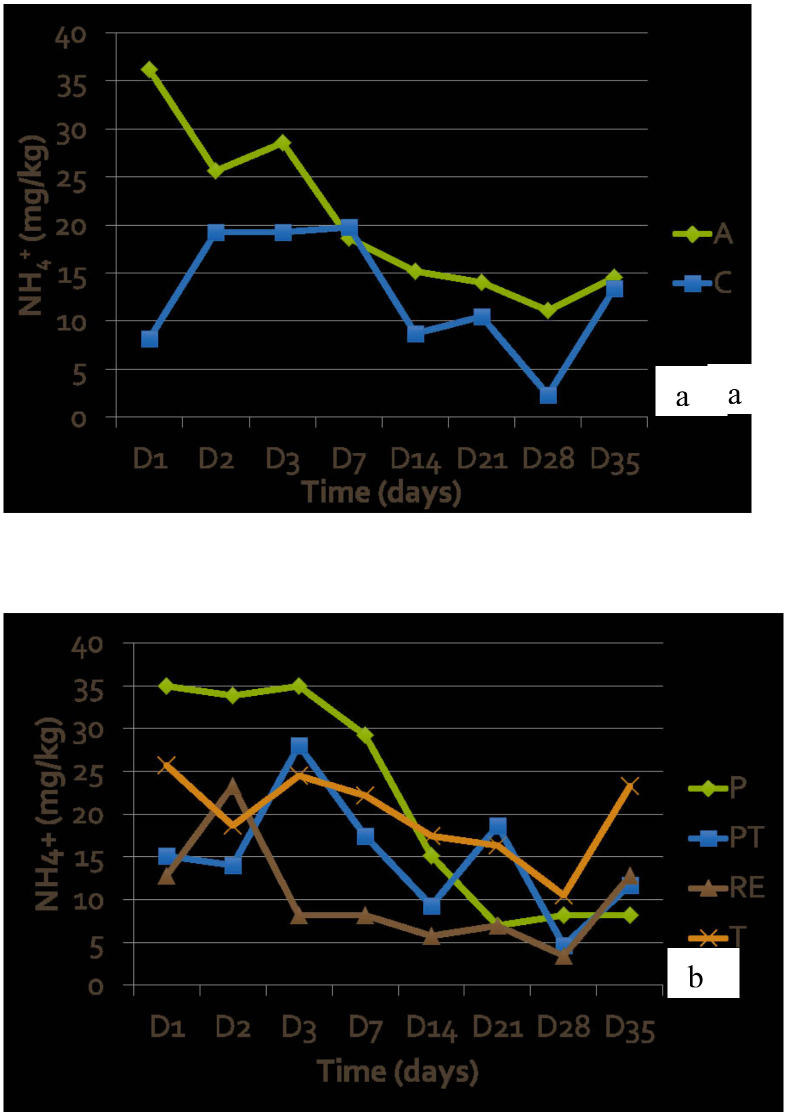

Figure 2 Main effects of manure type (a) and soil series (b) on NH4* content of samples incubated for 35 days

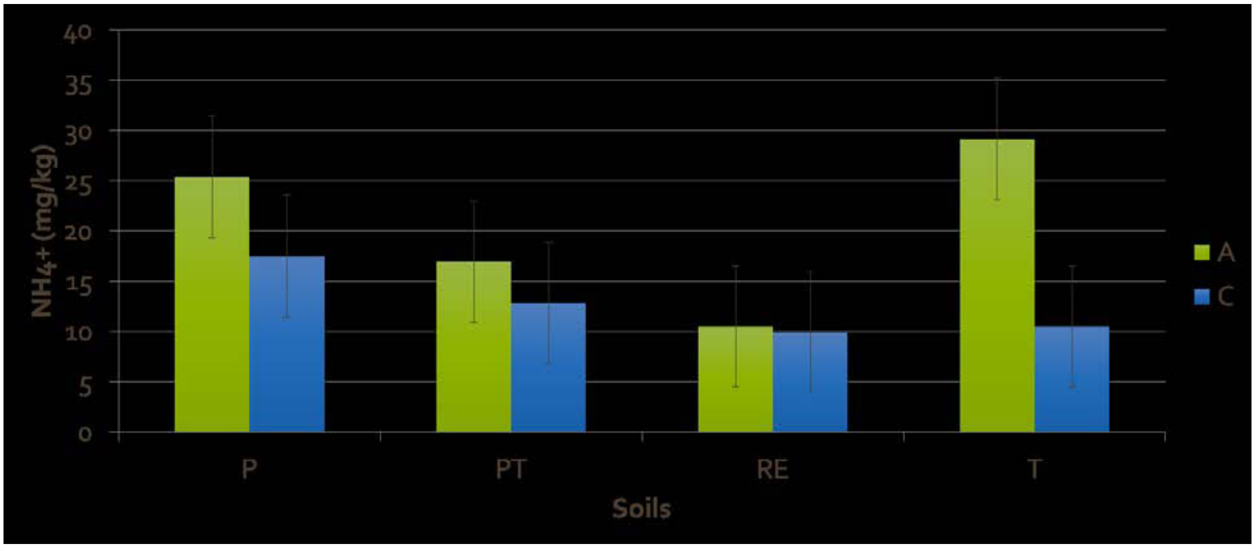

Figure 3 Interaction effect between manure type and soil series on NH4+ content

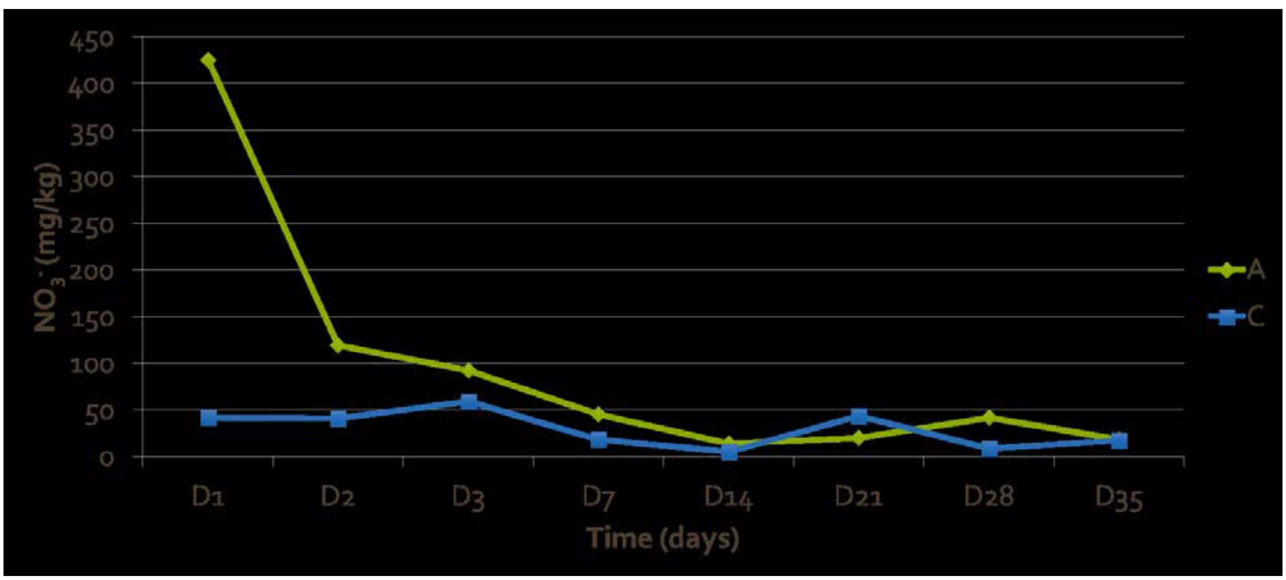

Figure 4 Main effect of manure type on NO3- content of samples incubated over 35 days.