Assessment of nitrogen mineralization of organic materials on sands of Central Vietnam: incubation experiments

Hoang Thi Thai Hoa[1], Tran Thi Anh Tuyet[1], Do Dinh Thuc[1], Surender Mann[2], Richard Bell[2]

[1] Hue University- Hue College of Agriculture and Forestry, 102 Phung Hung street, Hue city, Thua Thien Hue province, Vietnam, 530000, http://www.huaf.edu.vn, hoangthithaihoa@huaf.edu.vn
[2] School of Veterinary and Life Sciences, Murdoch University, Murdoch WA 6150 Australia

Abstract
Sandy soils of Central Vietnam represent an important soil order that increasingly contributes to regional economic growth. However these soils have generally low productivity because of chemical and physical constraints associated with low pH values and sand contents exceeding 70%, are common for those soils. Obviously, organic matter management represents a key factor for crop productivity improvement on these soils. However, before considering the possible contributions of various organic amendments, it is important to evaluate the actual contribution of the initial soil organic matter through its N-mineralization, considered as a prime source of N for plants. Therefore, soil samples (0-20 cm) representing peanut growing sandy soils were collected before the spring season to incubate with 4 types of organic materials which added to the same sandy soil amount under anaerobic conditions for 0, 5, 10, 20, 30 and 40 days to determine their N-mineralization capacity. The release of NH_4^+, NO_3^- was on average higher in treatments with added organic fertilizers. Significant amounts of NH_4^+ and NO_3^- were found with different types of organic materials added to the soil and increased with the time of incubation from 5 to 40 days after incubation. Fitting the results with a first order kinetic equation led to the calculation of potentially mineralizable nitrogen. The N-pool identified in this study can be considered as very labile N which might be available to crops within few weeks. Therefore, the total N-content of soils cannot be considered as a reliable indicator of short term N-availability.

Key Words
N mineralization, organic fertilizer, sandy soil, Central Vietnam

Introduction
In a variety of ecosystems, rates of N-mineralization and the total soil-N are indicators of soil fertility (Vitousek and Matson 1985). However, a large nitrification rate can increase potential N losses, either through leaching, leading to groundwater pollution, or through gaseous emission, contributing to green-house effect (Vitousek and Matson 1985). One strategy to meet crop N demand is to maximize the stabilization of organic-N in soils, and thereby, build up a soil organic matter pool, rich in organic-N (Jansson and Persson 1982). In such systems, N-mineralization from this organic pool determines the amount of available N for crops.

On sandy soils (<5 % clay), mineral-N is generally low (<10 kg N ha^{-1}) with very small variations between sites (Østergaard et al 1985). Correlation between mineral-N in spring and nitrogen uptake in aerial plant parts is low, indicating that mineral-N provides little information about the mineralization potential of sandy soils. A method to determine the nitrogen mineralization potential of a sandy soil is therefore needed, for better estimation of the optimum nitrogen fertilizer demand by crops (Appel and Mengen 1992). Therefore, the present study was carried out to assess the effect of added organic manures on the short-term gross N mineralization in coastal sands of Central Vietnam.

Methods
Soils sampling and characterization
Soil used in this study is typical of those used for growing peanut and classified as Haplic Arenosols following FAO – UNESCO (Le Thai Bat and Pham Quang Khanh, 2015). A composite soil was collected from the plough layer (0-20 cm) of an arable field at the Cat Trinh commune (14^0 01' 210''N and 109^0 03' 867''E), Phu Cat district, Binh Dinh province in January, 2014 (Table 1). All the soil samples were air dried and ground to pass through a 2 mm sieve. They were analysed for pH in water and in 1 M KCl (1:5 soil-solution ratio), electrical conductivity (EC, 1:5 soil-water ratio), organic carbon content (OC, Walkley and Black method), total nitrogen content (Kjeldahl method), cation exchange capacity (CEC, leaching with 1 M NH_4-acetate pH 7, desorption with 1 M KCl, and measurement of NH_4^+ by distillation) (Page et al 1996).

Table 1. Characteristics of the soil used in this study

pH_{H2O}	pH_{KCl}	EC $\mu S\ cm^{-1}$	OC %	N %	P_2O_5 %	K_2O %	CEC cmolc kg^{-1}
6.00	4.76	13.1	0.84	0.019	0.019	0.14	0.80

Properties of organic matter

Four types of organic matter were used amendments in the incubation experiment (Table 2). After collection, organic fertilizer samples were oven dried at 65°C and ground to pass through a 1mm sieve. They were analysed following standard methods: C was analysed by wet oxidation (Walkley Black), total N by Kjeldahl. Total phosphorus and total potassium (HNO_3: $HClO_4$ digestion). Mineral N was determined in 1 M potassium chloride extracts through a Kjeldahl method. The pH was determined on 0.01M KCl extracts (1:5 manure/solution).

Table 2. Properties of organic matters used in the incubation experiment

Properties	DM (%)	pH_{KCl}	C (%)	N (%)	NH_4^+ (mg/kg)	NO_3^- (mg/kg)
Cattle dung in open compost heap on soil (CFH)	36.3	7.95	38.4	0.81	62.0	235.6
Cattle dung + rice straw from farmer household (1:1 ratio) in compost pit in brick enclosure covered with plastic (CFP)	35.9	7.84	39.9	1.16	72.0	233.5
Cattle dung + rice straw (1:0.5) in compost heap on compacted earth covered with plastic (CTH)	30.3	8.19	33.9	0.85	43.2	314.1
Cattle dung + rice straw (1:0.5) in compost pit in brick enclosure covered with plastic (CTP)	36.2	8.02	36.8	1.15	61.2	696.0

Treatments

There were five treatments including sandy soil and sandy soil added with different types of organic matters as follows:

1. Sandy soil (control) (T1)
2. Sandy soil + 0.15 g CFH (T2)
3. Sandy soil + 0.15 g CFP (T3)
4. Sandy soil + 0.15 g CTH (T4)
5. Sandy soil + 0.15 g CTP (T5)

Procedure of incubation

The air-dried soils (5 g) were incubated in three replications in waterlogged conditions at optimum temperature for biological activity following a technique recommended for characterizing the mineralization capacity of soil organic matter (Drinkwater et al 1996). Another sub-sample of each soil (5 g) was used for extraction of the initial NH_4^+-N; NO_3^- -N content by 2 M KCl, based on a method described by Bundy and Meisinger (1994). The NH_4^+-N, NO_3^- -N concentration was determined using a Kjeldahl distillation method. This experiment was conducted in the laboratory of Hue College of Agriculture and Forestry, Hue University from February to April, 2014.

Statistical Analysis of Data

The SPSS 16.0 analytical software package was used for all statistical analyses. Statistical analysis was performed to fit a first order kinetic equation for N-mineralization, using the SPSS general non linear model procedure.

Results

The N-mineralization data, expressed as NH_4^+-N and NO_3^--N extracted from soils after each period of incubation, are shown in Figure 1.

The shape of NH_4^+ release *vs* time curves has a typical curvilinear shape, which indicates a decreasing mineralization rate with time. It can be attempted to fit such type of curves with a first order kinetic equation for N-mineralization. If we consider that the amount of NH_4^+ and NO_3^- released from time 0 to t is equal to the decrease of N_{soil}, then the balance equation is:

$$[NH_4^+]_t - [NH_4^+]_0 = N_{soil,t} - N_{soil,0}$$

$[NH_4^+]_t - [NH_4^+]_0 = N_{soil,0} (1 - e^{-k\,t})$
$[NO_3^-]_t - [NO_3^-]_0 = N_{soil,t} - N_{soil,0}$
$[NO_3^-]_t - [NO_3^-]_0 = N_{soil,0} (1 - e^{-k\,t})$

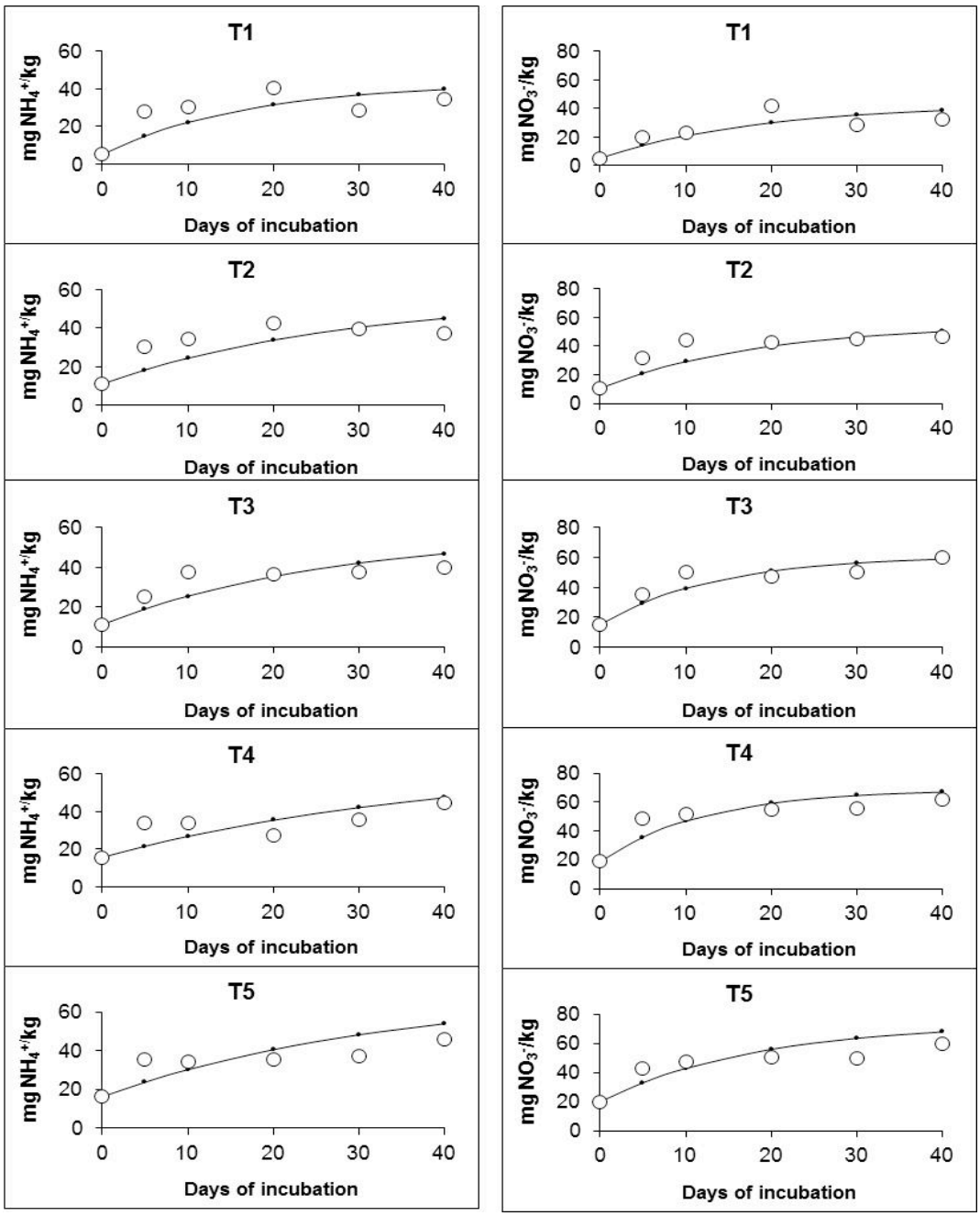

Figure 1. NH_4^+-N and NO_3^- - N extracted from soils as a function of incubation time
These numbers are average of three lines from each replication. Open circles: experimental values; lines: non linear regression according to first order kinetic equation for N-mineralization.

$N_{soil,0}$ and k can be calculated by non linear regression of experimental values of extracted NH_4^+ and NO_3^- *vs* time. NH_4^+- N and NO_3^- - N mineralization were clearly affected by the addition of organic fertilizers. For all treatments and at all times of incubation, the addition of organic fertilizers resulted in an increase of the N mineralization (Figure 1). The increase of N mineralization rate is more significantly marked with compost made in a pit compared to soil before experiment and composting in heap, and generally most marked at the initial period of incubation. This observation may be attributed to the existence of different organic-N pools depending on their kinetics of mineralization. The first pool revealed after some weeks of incubation can be qualified as labile organic-N. As generally observed in other studies (e.g. Wander et al 1994), at least two other N-pools may be distinguished in soils, one pool of less stable but still labile organic-N, and one pool of

more stable organic-N which is involved in humification processes and only released at long term scale. All treatments during incubation experiment, demonstrate higher values of NH_4^+- N and NO_3^- - N in the first half of incubation (0 to 20 days), followed by lower values in the last half of the incubations (20 - 40 days) in treatment with only sandy soil. Throughout the total incubation period, the N mineralization was higher for all organic fertilizer treatments compared to the control treatment.

Conclusion

Mineralizable-N was usually higher for manure-treated soils than the control, due to increasing the total N and organic carbon contents in soil and enhanced decomposition. According to a first order kinetic equation, the soil N-pool participating in short term N-mineralization was much smaller than the total N content, which supports the general view of different soil N-pools with different potential availability to plants. Consequently, even if some correlation was observed between NH_4^+ and NO_3- release and total N content, this routine characteristic of soils cannot be considered as a reliable indicator of N-availability for crops cultivated in the coastal sandy area of Central Vietnam. This justifies further study to better assessment of native fertility of these soils and proper techniques for optimum management of organic matter in local farming systems. To that purpose, long term mineralization experiments, according for example to the leaching-incubation method proposed by Stanford and Smith (1972), are also necessary.

Acknowledgements

The study has been funded by the Australian Centre for Agriculture Research (ACIAR) in the frame of project of SMCN/2007/109/2.

References

Appel T and Mengel K (1992). Nitrogen uptake of cereals grown on sandy soils as related to nitrogen fertilizer application and soil nitrogen fractions obtained by electroultrafiltration (EUF) and $CaCl_2$ extraction. European Journal of Agronomy. Vol. 1, no. 1: 1-9.

Bundy LG, Meisinger JJ (1994). Nitrogen availability indices. In: Mickelson SH. ed. Methods of soil analysis, Part 2. Microbiological and Biochemical Properties. Chapter 41. Soil Science Society of America, Madison, Wisconsin. 951-984.

Drinkwater LE, Cambardella CA, Reeder JD, Rice CW (1996). Potentially mineralizable nitrogen as an indicator of biologically active soil nitrogen. In: Doran JW and Jones AJ. eds. Methods for assessing soil quality. Special edition Nr 49. Madison, Soil Science Society of America, 217-229.

Jansson SL and Persson J (1982). Mineralization and immobilization of soil nitrogen. In Nitrogen in Agricultural Soils. pp. 229-252. Ed. Stevenson FJ. American Society of Agronomy, Madison.

Le Thai Bat and Pham Quang Khanh. 2015. Soil resources of Vietnam, major soil types and their use in agriculture. In Proceedings of National Workshop on Vietnam soils: present use and opportunities. Hanoi Agricultural Publishing House. p 16 – 46.

Østergaard HS, Hvelplund EK, Rasmussen D (1985). Assessment of optimum nitrogen fertilizer requirement on the basis of soil analysis and weather conditions prior to the growing season. In: Neeteson JJ and Dilz K. ed. Assessment of nitrogen fertilizer requirement. Institute for Soil Fertility, Haren, 25-36.

Page AL, Miller RH and Keeney DR (1996). Methods of soil analysis, chemical and microbiological properties - Part 2. ASA Monograph No. 9. 2nd ed. ASA, Madison, WI.

Stanford G, Smith SJ (1972). Nitrogen mineralization potential of soils. Soil Science Society of America Proceedings, 36, 3: 465-472.

Vitousek PM, Matson PA (1985). Disturbance, nitrogen availability and nitrogen losses in an intensively managed loblolly pine plantation. Ecology, 66: 1360-1376.

Wander MM, Traina SJ, Stinner BR, Peters SE (1994). Organic and conventional management effects on biologically active soil organic matter pools. Soil Science Society of America Journal. 58, 4: 1130-1139.