In situ incubation to evaluate inorganic nitrogen dynamics in a cropped tropical sandy soil

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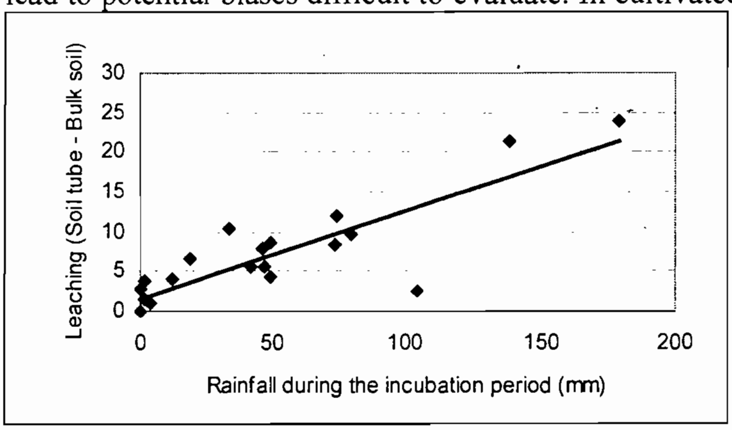
Abstract

Most inorganic nitrogen in soils originates from the mineralisation of organic matter and plant residues. Inorganic nitrogen dynamics in involved in many major issues like plant nutrition, global changes and environmental pollution. However, the understanding of inorganic nitrogen dynamics was long restricted by a lack of suitable methods under field conditions. The objective of the paper is to evaluate the in situ incubation method first introduced by Raison *et al.* (1987) to study temperate forest soils under tropical conditions, and to present some results obtained with this method.

This study was conducted in Thailand near Nakhon Ratchasima (15°N, 102°E). The soil is an Arenic Acrisol in the FAO classification (Nam Phong series in the Thai soil reference system). Twenty plots (6x8 m) from a factorial block design experiment with two factors (control/lime and bare/cropped) and 5 blocks were studied for 16 months. The change in total nitrogen with time was determined by taking soil samples three times before the start of the experiment and once at the end. For each plot twelve samples were taken in the 0-20 cm layer using a small-diameter auger. Total nitrogen was determined by the Kjeldahl method on the bulk sample. The pattern of inorganic nitrogen dynamics was studied using in situ incubation. Every fortnight five capped PVC tubes, 5 cm in diameter and 20 cm in length, were inserted in each plot to 10 cm, and five soil samples were collected from the bulk soil and kept refrigerated. The PVC tubes were collected 2 weeks later, then the samples of each plot were bulked together and kept refrigerated. Soil water content was determined in the oven at 105°C, and inorganic nitrogen was extracted using 1M KCl and analysed by colorimetry. The difference between inorganic nitrogen at the beginning and at the end of the two-week periods gave the rate of mineralisation over the period.

One potential problem of the in situ incubation method is the possibility of a difference in soil water content between the soil inside the incubation tube and the bulk soil. The results showed that the soil water content in the tube equilibrated with the bulk soil within a few days after each rain. In case of drought the soil inside the tube was on average 0.01 $m^3\ m^{-3}$ wetter than the bulk soil. These soil water differences may lead to potential biases difficult to evaluate. In cultivated plots the soil inside the tubes was not drier than the bulk soil, indicating that not roots developed within the tubes.



For both the bare and the cropped plots the rates of mineralisation as nitrate and as ammonium as well were not different in the control (pH_w 5.3) and in the lime treatment (pH_w 5.9) over the 16-month period. No difference were measured in the inorganic content of the bulk soil either. As a consequence the calculations were carried out after merging the data from the control and limed plots.

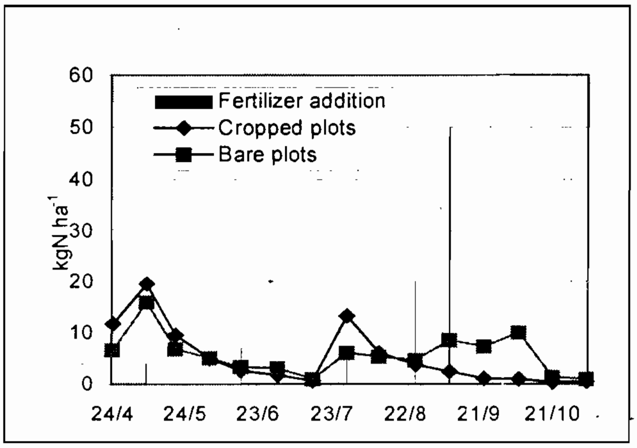
	Bare	Cropped	P
NH_4	-1.4 ± 7.3	2.0 ± 6.4	ns
NO_3	89.0 ± 11.4	59.4 ± 14.5	0.002

Table 1. Annual rate of mineralisation in the 0-10 cm layer (kgN ha^{-1} ±95% confidence interval)

The annual rate of mineralisation as ammonium was not different from zero for the bare and the cropped plots (Table 1). The rate of mineralisation as nitrate was higher for the bare plots than for the cropped ones. The annual rate of mineralisation was 19% of the total N in the 0-20 cm layer for the bare plots (463 kgN ha^{-1}) and 14 % in the cropped plots (426 kgN ha^{-1}). The decrease in total N over three years was 120±95 kgN ha^{-1} for the bare plots and 101±70 kgN ha^{-1} for the cropped ones. As one of the three years was particularly dry the results from the incubation and from the decrease in total N are coherent. This extremely high rate is probably a consequence of intensive soil tillage, optimum temperature (between 25 and 35°C at 10 cm) and soil fertilisation. The higher mineralisation rate in the bare treatment seems mainly due to the mineralisation of reorganised N fertiliser.

Leaching over each incubation period can be estimated for the bare plots by difference between the inorganic nitrogen content inside the tube at the end of the incubation period and the inorganic content of the bulk soil (Figure 1). Leaching was higher than 50% of the mineralisation rate when rainfall was higher than 20 mm. Leaching was trivial for ammonium whatever the rainfall. Nitrate leaching is thus a serious problem in this soil.

Nitrogen fertilizer applied as ammonium or urea lead to an increase in ammonium content in the bulk soil less than two weeks after application, but the increase was much lower than the amount applied, with little difference between the bare and the cropped plots. The nitrate content did not change in the weeks following fertilisation. This result proves that some fertiliser N was reorganised before it could be converted to nitrate.



Cowpea was grown in May and June, maize from August to October. April and July were the onsets of the two rainy seasons. The peak of mineralisation of each rainy season led to a production of less than 20 kgN ha^{-1}, with no significant difference between the cropped and the bare plots (Figure 2). The amount of nitrate was less than 5 kgN ha^{-1} under the crop. In one hand this low amount decreased the hazard of leaching, but in the other hand the plant had to rely mostly to the rate of mineralisation (only 0.3 $kgNO_3$-N ha^{-1} on average) to cover its needs.

Even though the in situ incubation technique may lead to overestimated rates of mineralisation because of a higher soil water content in the incubation tubes, it seems to be an easy-to-use and robust method to assess many aspects of the dynamics of inorganic nitrogen in tropical soils.

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