Tropical Ecology 31 (1): 12-15, 1990 ISSN 0564–3295

LOW SOIL NITROGEN MINERALIZATION RATES IN A HUMID TROPICAL PASTURE

MARY C. SCHOLES AND P. A. SANCHEZ

Botany Department, University of the Witwatersrand, PO WITS 2050, Republic of South Africa; and Soil Science Department, North Carolina State University, Raleigh, NC 27695-7619, USA.

Abstract: Extremely low in-situ N mineralization and nitrification rates were observed in a grazed pasture in which the topsoils remained constantly near field capacity. Laboratory incubations showed that a single five day drying period followed by rewetting increased N mineralization and nitrification rates seven-fold and that three successive wetting and drying cycles increased the rate fourteen-fold.

Résumé : Des taux extremement faibles de mineralisation et de nitrification de l'azote ont été observes in situ dans un paturage dont les horizone superieurs du sol restent constamment pres de la capacite au champ. Les incubations au laboratoire montrent qu'une seule period seche de 5 jours suivie d'une rehumidification multiplie par 7 les taux de mineralisation et de nitrification de l'azote, et que trois cycles successifs d' humidification et de secheresse multiplient les taux par 14.

Resumo: Taxas extremamente baixas de mineralização e nitrificação foram observadas numa pastagem pastada e na qual a camada superficial do solo permaneceu constantemente próxima da capacidade de campo. As incubações laboratoriais mostraram que bastavam cinco dias de secagem, seguidos por uma rehumidificação para aumentar sete vezes as taxas de mineralização e nitrificação do N e que três ciclos sucessivos de humidificação e secagem aumentaram aquela taxa de um valor igual a quatorze vezes.

Key Words: Amazon basin, Birch effect, Nitrification rates.

INTRODUCTION

Pastures are a major form of land use in the humid tropics of South America. Poorly adapted grasses, infertile soils and overgrazing are in many cases leading to pasture degradation and soil erosion. Research is being focussed on developing stable persistent grass-legume mixtures that are tolerant to acid soil conditions (Sanchez *et al.* 1985). It has been suggested that mixed grass-legume pastures may play an important part in the nitrogen dynamics of nutrient poor systems. Estimates have been made of nitrogen fixation and transfer in mixed pastures (Ledgard *et al.*1985; Johansen & Kerridge 1979), but little information exists on mineralization and nitrification rates.

Soil moisture and temperature regimes are of paramount importance in determining soil organic-N mineralization rates. Major pulses of N mineralization occur as a result of increases in microbial activity caused by alternate wetting and drying (Birch 1958; Cabrera & Kissel 1988a & b). Given a lack of a pronounced dry season and high constant temperatures of udic isohyperthermic regimes encountered in the humid tropics, N mineralization rates are expected to be high (Greenland & Nye 1959).

Nitrogen mineralization and nitrification rates were measured in Ultisols of the Yurimaguas Experiment Station in the Amazon of Peru. The climate is lowland humid tropical with mean annual temperature of 26°C and mean annual rainfall of 210 mm without a pronounced dry season.

The soil is classified as fine loamy, siliceous isohyperthermic Typic Paleudult. Nitrogen mineralization rates were found to be lower in the pastures compared with other management options eg. low-input cropping, even though the temperatures and substrate availability were high. The purpose of this investigation was to determine whether these low rates were associated with the lack of altennate wetting and drying in the pasture.

METHODS

In-situ nitrogen mineralization and nitrification rates were measured in a *Brachiaria humidicola* (Rendle) Schweick.-*Desmodium ovalifolium* Wall. pasture, which had been established in 1980. Samples were taken at two-weekly intervals for a seventy day period from June to September 1986 using undisturbed soil cores as described by Raison, Connell & Khanna (1987). This method involves in-situ incubation of undisturbed soil cores isolated within 150 mm long PVC tubes. Tubes were knocked into the ground in pairs. One tube from each pair was immediately removed, the soil expelled and the mineral nitrogen content determined as described below. The remaining tube which was covered by a loose fitting cap, to exclude rainfall was left in the field for a 14 day period, after which the mineral nitrogen content was determined. Soil moisture contents were determined at the same time.

Soil samples from the 0-150 mm depth interval were collected in triplicate from the pasture and subjected to the following treatments in the laboratory : (1) Incubation in plastic bags at the field moisture content of 0.24 kg kg^{-1}; (2) Air-dried for five days to reduce the moisture content to 0.19 kg kg^{-1} and rewetted to 0.24 kg kg^{-1} before incubation, and (3) Air-dried for five days and rewetted to 0.24 kg kg^{-1} three times in succession before incubation.

All samples were incubated in the dark at room temperature for 14 days. A 10 g sub-sample was taken immediately before and after the incubation for mineral N determination. Samples were shaken with 20 ml of 0.5M K_2SO_4 for 30 minutes. Filtrates were analyzed for nitrate and ammonium using colorimetric techniques described by Cataldo *et al.* (1975) and Dorich & Nelson (1983) respectively. Net mineralization was determined as the difference between final and initial ammonium+nitrate levels. Net nitrification was determined as the difference between final and initial nitrate levels.

RESULTS

The pattern of mineralization over the period June-September is shown in Table 1. The values obtained vary widely with time and show that these processes are not constant despite the alleged constancy of tropical climates. The field capacity of the pasture site was 0.26 kg kg^{-1}. It can be seen that the soil remained close to this value throughout the season.

The values for the tube incubations shown in Table 2 are mean values for the entire sampling period. It can be seen that the net mineralization rates are much higher than net nitrification rates. This can be accounted for by the accumulation of ammonium in the tubes during the incubation. A single drying cycle in the laboratory incubations increased net mineralization and nitrification rates approximately seven-fold. Subjecting the soil to three wetting and drying cycles doubled these rates again (Table 2). All the differences were highly significant. In-situ nitrification rates, were significantly lower than those measured in the laboratory.

TABLE 1. Net mineralization rates and percentage moisture of the topsoils (0-150 mm) in the pasture.

Time of Sampling	Net Mineralization Rate (μg N kg^{-1} dry mass day^{-1})		Moisture (kg · kg^{-1})	
	mean	se	mean	se
18 June	97.8	119.2	0.22	0.007
8 July	182.1	112.9	0.22	0.01
26 July	248.6	144.2	0.26	0.005
14 August	– 232.9	149.2	0.25	0.004
2 September	-5.0	61.4	0.24	0.001

TABLE 2. Net N mineralization and nitrification rates (μg N kg^{-1} dry mass day^{-1}) measured by various procedures in topsoil (0-150 mm) soil samples from a tropical pasture.

Process	Field		Laboratory	
	Tube incubation	Continously wet	One drying cycle	Three drying cycles
Net mineralization	58.12[a]	63.6[b]	474.3[c]	909.3[d]
Net nitrification	25.49[a]	57.1[b]	435.7[c]	715.7[d]

* Within-row values followed by different letters are significantly different at the 95 per cent confidence level.

DISCUSSION

Alternate wetting and drying in soils with ustic, isohyperthermic soil moisture and temperature regimes has shown to be responsible for the pulsing of nitrogen availability (Greenland 1958; Birch 1964; Agarwal, Singh & Kanehiro 1971; Cabrera & Kissel 1988a & b). In continuously wet topsoils two possible situations may result in low apparent mineralization: (1) mineralization is taking place extremely slowly, and only upon drying of the soils does the mineralization rate increase, or (2) mineralization is proceeding at normal rates but denitrification in localized anaerobic conditions prevent the measurement of nitrification by the accumulation of nitrate.

The rate of nitrogen loss from soil due to denitrification is increased by factors that increase the extent of anaerobic sites in soil (Firestone 1982). Increasing soil moisture acts as one such factor by decreasing the rate of oxygen diffusion through the soil matrix, allowing the development of anaerobic microsites as oxygen consumption exceeds the rate of diffusive supply. Continuously high soil moisture contents near field capacity (Table 1) and soil compaction due to animal trampling for five years suggests that denitrification may be considerable. Smith & Tiedje (1979) suggested that it was important to understand the short term denitrification response to increasing soil moisture, in order to better characterize denitrification losses from field soils following rainfall or irrigation. The measurement of net nitrification does not permit the separation of nitrification from denitrification. Direct denitrification measurements are needed.

It is difficult to know whether or not the low rates observed in the in-situ measurements are under-estimates of what is occuring in the pastures. On the other hand the disturbance by removing samples from the field and placing them in plastic bags results in rapid oxidation of organic nitrogen compounds. Thus, the laboratory incubations are expected to over-estimate mineralization, especially if drying is allowed to occur.

ACKNOWLEGEMENTS

The authors extend thanks to the staff of the Yurimaguas Research Station especially Rafael Roman and Pedro Ruiz for their assistance in laboratory analyses. Thanks also to Cheryl Palm, Miguel Ayarza and Bob Scholes for helpful discussions.

REFERENCES

Agarwal, A.S., B.R. Singh & Y. Kanehiro. 1971. Soil nitrogen and carbon mineralization as affected by dry-rewetting cycles. *Soil Sci. Soc. Am. Proc.* 35 : 96-100.

Birch, H.F. 1958. The effect of soil drying on humus decomposition and nitrogen availability. *Plant and Soil* 10 : 9-31.

Birch, H.F. 1964. Mineralization of plant nitrogen following alternate wet and dry conditions. *Plant and Soil* 20 : 43-50.

Cabrera, M.L. & D.E. Kissel. 1988a. Potentially mineralizable nitrogen in disturbed and undisturbed soil samples. *Soil Sci. Soc. Am. J.* 52 : 1010-1015.

Cabrera, M.L. & D.E. Kissel. 1988b. Evaluation of a method to predict nitrogen mineralized from soil organic matter under field conditions. *Soil Sci. Soc. Am. J.* 52 : 1027-1031.

Cataldo, D.A., M. Haroon, L.E. Schrader & V.L. Youngs. 1975. Rapid colorimetric determination of nitrate in plant tissue by nitration of salicyclic acid. *Comm. Soil Sci. Plant Anal.* 6 : 71-80.

Dorich, R.A. & D.W. Nelson. 1983. Direct colorimetric measurement of ammonium in potassium chloride extracts in soil. *Soil Sci. Soc. Am. J.* 47 : 833-836.

Firestone, M.K. 1982. Denitrification. pp. 289-326. *In* : F.J. Stevenson *et al.* (eds.) *Nitrogen in Agricultural Soils.* Agronomy 22. Am. Soc. of Agronomy Inc. Madison, Wisconsin.

Greenland, D.J. 1958. Nitrate fluctuations in tropical soils. *J. Agr. Sci.* (Camb.)50 : 82-91.

Greenland, D.J. & P.H. Nye. 1959. Increases in the carbon and nitrogen contents of tropical soils under natural fallows. *Soil Sci.* 9 : 284-299.

Johansen, C. & P.C. Kerridge. 1979. Nitrogen fixation in tropical legume-grass swards in south-eastern Queensland. *Tropical Grasslands* 13 (3) : 165-170.

Legard, B.K., J.R. Simpson, J.R. Freney & F.J. Bergersen. 1985. Field evaluation of ^{15}N techniques for estimating nitrogen fixation in legume-grass associations. *Aust. J. Agric. Res.* 36 : 247-258.

Raison, R.J., M.H. Connell & P.K. Khanna. 1987. Methodology for studying fluxes of mineral-N in-situ. *Soil Biol. Biochem.* 19 : 521-530.

Sanchéz, P.A., M.A. Ara & M.A. Ayarza. 1985. Nitrogen contribution of legumes in mixed pastures in the humid tropics. *In:* C.B. McCants (ed.) *Tropsoils Triennial Technical Report* 1981-1984. NCSU Raleigh, North Carolina.

Smith, M.S. & J.M. Tiedje. 1979. Phases of denitrification following oxygen depletion in soil. *Soil Biol. Biochem.* 11 : 261-267.

(Accepted for publication on 16 August 1989)