Plant and Soil 65, 281–286 (1982). 0032-079X/82/0652-0281$00.90. Ms. 4911

Nitrification in some tropical soils

K. L. SAHRAWAT*
The International Rice Research Institute, Los Baños, Philippines

Key words Acid pH Acid sulfate Aerobic incubation Alkaline soils Histosols Nitrate formation Rice soils Soil pH and nitrification

Summary Nitrification of soil N in 8 mineral and 2 histosols having a wide range in pH (3.4 to 8.6), organic C (1.22 to 22.70%) and total N (0.09 to 1.20%) was studied by measuring nitrate formation under aerobic incubation of the soil samples at 30°C for 4 weeks. The amounts of NO_3–N produced in the soils varied from 0 to 123 µg/g of soil. Soil N in the two acid sulfate soils and one other acid soil did not nitrify under conditions that stimulate nitrification. Soils having pH more than 6.0 nitrified at a rapid rate and released NO_3–N ranging from 98 to 123 µg/g. The two organic soils differed considerably in their capacity to nitrify though the total amounts of mineral N released were similar in these soils. The amounts of NO_3–N formed in the soils was highly positively correlated with the soil pH but was not significantly correlated with the organic C of total N content of the soils. Statistical analysis also showed that nitrate formation was not significantly correlated with soil pH in soils having pH higher than 6.0.

Introduction

Nitrification, the biological oxidation of ammonium nitrogen to nitrate via nitrite is very important for fertilizer use efficiency and N nutrition of crops. Nitrification results in conversion of a relatively immobile cationic form, NH_4^+–N into a more mobile anionic form, NO_3^-–N. Nitrate formed is liable to losses by leaching and denitrification[7]. Focht and Verstraete[4] have discussed in detail the factors affecting nitrification in soils and reported that pH, moisture regime, oxygen supply and temperature are the most important factors controlling nitrification. Loss of nitrogen by denitrification is thought to be an important mechanism of nitrogen loss in tropical rice soils[7].

The nitrifying capacity of tropical rice soils has not been extensively investigated though nitrification is directly involved in nitrogen loss through denitrification and leaching. The purpose of this study was to investigate nitrification of soil N in 10 soils having a wide range in pH, organic matter and total N by measuring nitrate produced during a 4-week aerobic incubation of the soils under conditions that stimulate nitrification. Relationship between amounts of nitrate formed and soil properties such as pH, organic C and total N contents were worked out.

* Present address: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), ICRISAT Patancheru P.O., Andhra Pradesh 502324, India.

Table 1. Analyses of soils used

Soil	pH (1:1 H_2O)	Organic C (%)	Total (%)
Calalahan sandy loam	3.4	1.57	0.110
Malinao loamy sand	3.7	1.22	0.090
Luisiana clay	4.4	1.52	0.175
Morong peat	5.6*	12.80	0.560
Lam Aw peat	6.1*	22.70	1.200
Maahas clay	6.5	1.50	0.120
Quingua Silty loam	6.5	1.28	0.115
Pila clay	7.5	2.27	0.185
Lipa Loam	7.5	2.50	0.190
Maahas clay, alkalized**	8.6	1.50	0.120

* pH measurement made on soil suspension using a soil to water ratio of 1:2.
** Maahas clay + 1.3% Na_2CO_3.

Materials and methods

Soils

The soils used (Table 1) in the study consisted of 8 mineral and 2 organic soils and provided a wide range in pH (3.4 to 8.6), organic C (1.22 to 22.70%) and total N (0.09 to 1.20%) contents. Soil samples were air-dried, ground and sieved through a 2-mm screen before use. Soil analysis reported in Table 1 was done as described earlier[8].

Incubation method

Ten g soil samples in duplicate were transferred to 125-ml conical flasks. Distilled water was then added to bring the moisture content of the soil samples to 50% of water holding capacity (WHC). The mouths of the flasks were covered with aluminum foil and the flasks were incubated at 30°C for 4 weeks. The samples were aerated daily by removing the covers. Also the moisture content of the incubated soil samples was maintained by addition of water to make up the loss of water through evaporation.

After 4 weeks' incubation, the soil samples were extracted with 100 ml of 2 *M* KCl solution by shaking for one hour. NH_4^+ and NO_3^--N contents were determined by distillation of 20 ml aliquots of the filtered extract with MgO and Devarda's alloy[2]. Nitrite was not detected in any significant amounts in any of the incubated soil samples.

Results and discussion

The amounts of NO_3^- formed during the four weeks ranged from 0 to 123 μg/g of soil (Table 2). No nitrate could be detected in the acid soils having pH of 3.4, 3.7 and 4.4 following their aerobic incubation for 4 weeks though these soils produced NH_4^+-N ranging from 89 to 102 μg/g of soil (Table 3). The highest amount of NO_3^--N (123 μg/g) accumulated in Pila clay having a pH of 7.5.

In general, soils having pH higher than 6 nitrified at a rapid rate and released NO_3^- ranging from 98 to 123 μg/g (Table 2). Alkalization of Maahas clay by

Table 2. Nitrification of soil nitrogen as indicated by accumulation of NO_3^- in 10 soils incubated aerobically at 30°C for 4 weeks

Soil	Nitrate formed* (μg/g soil)
Calalahan sandy loam	0
Malinao loamy sand	0
Luisiana clay	0
Morong peat	5
Lam Aw peat	116
Maahas clay	106
Quingua silty loam	115
Pila clay	123
Lipa loam	98
Maahas clay, alkalized	118

* The values reported are means of duplicate independent analysis and the two values did not differ by more than 4% from each other.

addition of 1.3% Na_2CO_3 raised the soil pH from 6.5 to 8.6 and increased the amount of NO_3^- formed from 106 to 118 μg/g. However, the total mineral N released in these soils were similar (Table 3).

The two histosols had divergent nitrification pattern which probably can be explained on the basis of soil pH. While Morong peat (pH 5.6) produced only 5 ppm of NO_3^-–N, Lam Aw peat (pH 6.1) released 116 μg/g of NO_3^- during 4 weeks. Though they had divergent pattern in NO_3^- formation, the total

Table 3. Mineralization of soil nitrogen in 10 soils incubated aerobically at 30°C for 4 weeks*

Soil	NH_4^+ (μg/g)	NO_3^- (μg/g)	Total	Total N mineralized (per cent)
Calalahan sandy loam	89	0	89	8.1
Malinao loamy sand	93	0	93	10.3
Luisiana clay	102	0	102	5.8
Morong peat	243	5	248	4.4
Lam Aw peat	404	116	520	4.3
Maahas clay	31	106	137	11.4
Quingua silty loam	18	115	133	11.6
Pila clay	21	123	144	7.8
Lipa loam	17	98	115	6.0
Maahas clay, alkalized	21	118	139	11.6

* The values of mineral N reported are means of two independent analysis and the two values did not differ by more than 4% from each other.

mineralizable N ($NH_4^+ + NO_3^-$–N) produced in the two organic soils formed similar fraction of total N and the mineralizable N released constituted 4.4 and 4.3% of total N respectively in Morong and Lam Aw peat soils (Table 3). The results of this study provide further support to earlier conclusion that acid sulfate soils do not nitrify when incubated under conditions that stimulate nitrification[9]. Studies on mineralization of N in peat soils by several researchers have indicated accumulation of high amounts of nitrate and mineral N in organic soils[1,5,6]. In the present study, the mineralization of organic N resulted in accumulation of 248 and 520 µg/g of mineral N in the two organic soils during four weeks. However, nitrate formed in these soils were respectively 5 and 116 ppm. In a recent study, Terry[11] reported that the N mineralization rate for a 75-cm profile of peat from Florida was 686 kg N/ha for each cm of the soil lost due to microbial oxidation. Accumulation of NO_3^- in another Floridan peat ranged from approximately 57 to 311 µg/g of dry muck[12].

In an earlier communication, I reported that air-drying of 4 Histosols from the Philippines greatly enhanced ammonification of organic N under anaerobic incubation though there was virtually no mineralization in the permanently waterlogged Histosols[10]. This study reports the mineralization of soil N under aerobic conditions in two organic soils and supports the earlier results in that organic soils release high amounts of mineral N under aerobic conditions[5,6,11].

Another important finding from the present study is that the amounts of nitrate formed in the 10 soils was highly positively correlated with the soil pH (r = 0.86**). This is in accord with the results reported from several studies, where nitrification has been found to increase with the increase in pH from 5 to 9, nitrate formation being at very low ebb at pH 5 or lower[3,4]. Organic C and total N contents of soils were not correlated with nitrate formation (Table 4). Further, statistical analysis with 6 soils, having pH > 6.0 showed that nitrate formation was not related to soil pH. This suggests that nitrate formation in soils with pH higher than 6.0 was not further influenced by increase in soil pH. Again, the nitrate formation in the 6 soil samples (pH > 6.0) was not significantly correlated to organic C and total N (Table 5).

Table 4. Correlations between the amounts of NO_3^- formed during a 4-week aerobic incubation and other soil properties (n = 10)

Soil property	Correlation coefficient (r)
pH	0.86**
Organic C	0.10 ns
Total N	0.14 ns

** = significant at the 1% level.
ns = not significant.

Table 5. Correlations between the amounts of nitrate formed during a 4-week aerobic incubation of six soils having pH higher than 6.0 and other soil properties (n = 6)

Soil property	Correlation coefficient (r)
pH	0.13 ns
Organic C	0.16 ns
Total N	0.16 ns

ns = not significant.

Though the three acid soils with pH ranging from 3.4 to 4.4 did not show any nitrification during 4 weeks in the present study, it is relevant here to mention that some researchers have claimed occurrence of heterotrophic nitrification in acid soils. From an extensive review of literature, Focht and Verstraete[4] reported that heterotrophic nitrification may be important in acid soils having pH ranging from 3.0 to 5.4. This study however, did not give any evidence of heterotrophic nitrification being operative in the two acid sulfate and one acid soils. Perhaps longer incubation period than 4 weeks used in the present study as well as amendment of the soils with organic N source may be essential for the stimulation of heterotrophic nitrification dicounted in these soils.

The results of this study suggest that nitrogen loss due to denitrification may not be serious problem in acid soils, which do not have a capacity to nitrify because formation of nitrate which is substrate for denitrification is limiting. In mineral and organic soils with near neutral and alkaline pH, nitrification is rapid under aerobic conditions and nitrate formed is likely to be lost through denitrification during subsequent flooding or under fluctuating moisture regime not uncommon in tropical rice paddies due to improper water control.

Acknowledgement I gratefully thank the International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines for financial support of this work and Dr. F. N. Ponnamperuma, Principal Soil Chemist, IRRI for valuable suggestions during planning of the work and preparation of the manuscript.

Received 29 October 1981

References

1 Avnemelech Y 1971 Nitrate transformation in peat. Soil Sci. 111, 113–118.
2 Bremner J M 1965 Inorganic forms of nitrogen. *In* Methods of Soil Analysis Part 2, Agron. 9. Ed. C. A. Black. pp 1149–1178. Am. Soc. Agron., Madison, Wisconsin.
3 Focht D D 1979 Microbial kinetics of nitrogen losses in flooded soils. *In* Nitrogen and Rice, pp 119–134. IRRI, Los Baños, Philippines.

4 Focht D D and Verstraete W 1977 Biochemical ecology of nitrification and denitrification. *In* Advances in Microbial Ecology, Vol. 1, Ed. M. Alexander. pp 135–214. Plenum Press, New York.
5 Guthrie T F and Duxbury J M 1978 Nitrogen mineralization and denitrification in organic soils. Soil Sci. Soc. Am. J. 42, 908–912.
6 Isirimah N O and Keeney D R 1973 Nitrogen transformations in aerobic and waterlogged Histosols. Soil Sci. 115, 123–129.
7 Sahrawat K L 1979 Nitrogen losses in rice soils. Fert. News 24, 38–48.
8 Sahrawat K L 1980 Soil and fertilizer nitrogen transformations under alternate flooding and drying moisture regimes. Plant and Soil 55, 225–233.
9 Sahrawat K L 1980 Nitrogen mineralization in acid sulfate soils. Plant and Soil 57, 143–146.
10 Sahrawat K L 1981 Ammonification in air-dried tropical lowland Histosols. Soil Biol. Biochem. 13, 323–324.
11 Terry R E 1980 Nitrogen mineralization in Florida Histosols. Soil Sci. Soc. Am. J. 44, 747–750.
12 Terry R E and Tate R L III 1980 Denitrification as a pathway for nitrate removal from organic soils. Soil Sci. 129, 162–166.