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Nitrogen transformations in acidic hilly soil under tea cultivation

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ABSTRACT

Nitrogen fertilization plays an important role in tea plantation crop where the ultimate aim is the stimulation of vegetative growth. A nitrogen transformation in soil influences nitrogen losses via NH_3 volatilization, denitrification, surface runoff and leachate that degrade the environment. To elucidate information on the nitrogen transformations, an incubation experiment was carried out with two acidic soils (clay loam and sandy clay loam) under tea cultivation collected from the farms of UPASI, Coonoor and Valparai. Five levels of nitrogen (0, 250, 375, 500 and 625 kg ha^{-1}) as urea were applied to each soil and different forms of nitrogen were monitored periodically during 90 days of incubation period. Urea hydrolysis followed the first order reaction and it was high in clay loam soil during early period of incubation. Increasing levels of nitrogen application increased the nitrogen fractions such as NH_4-N and NO_3-N in both the soils. The NH_4-N content of the soil increased upto 5th day, whereas NO_3-N content of the soil increased upto 30th day of incubation.

Key words : Hilly soil, nitrogen transformation, soil texture

INTRODUCTION

Success of food grain production and increase in the yield of plantation crops in developing countries hinge on the expansion of fertilizer use. Conventional tea plantations make heavy use of chemical fertilizers and pesticides. Among the chemical fertilizers, nitrogen fertilization plays an important role in tea crop where the ultimate aim is stimulation of vegetative growth. Primarily, on account of its importance, nitrogen has been the most extensively researched nutrient element and will continue to be so in the years to come. Secondly, owing to the complex and dynamic transformations that nitrogen and its compounds undergo in the soil and the considerable loss that occurs through various pathways, there is an imperative need to understand the nitrogen transformations, its losses and its impact on environment. Hence, incubation experiment was conducted to study the nitrogen transformation in the applied urea.

MATERIALS AND METHODS

The soils used for the present experiment were collected from the farm of United Planters Association of Southern India (UPASI), Coonoor (Attavalli series) and UPASI, Valparai (Attavalli series) to study the nitrogen mineralization rate with different levels of nitrogen such as 0, 250, 375, 500 and 625 kg ha^{-1} under field capacity moisture regime. These soils are classified under Typic Dystropepts. The basic characteristics of the soils used in the study are given in Table 1.

Details of the Experiment

Bulk soil samples collected from 0-7.5 cm layer of Coonoor and Valparai sites were shade dried, processed and sieved through 2 mm sieve. One hundred and fifty gram of processed soil samples were taken into 250 ml conical flask and mixed thoroughly with different nitrogen levels (0, 46.3, 69.4, 92.59 and 115.74 mg N calculated based on the weight of the surface 7.5 cm depth of soil equivalent to 0, 250, 375, 500 and 625 kg N ha^{-1}) in the form of urea.

This experiment was conducted at field capacity and the loss of moisture was compensated by periodic addition of water. Each flask was covered tightly with rubber cork and incubated at 27±1°C and each treatment was replicated twice.

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Table 1. Properties of the experimental soil

Particulars	Coonoor soil	Valparai soil
	0-22.5 cm	0-22.5 cm
I. Physical properties		
(a) Particle size distribution (g kg^{-1})		
Clay	398	300
Silt	160	200
Fine sand	220	165
Coarse sand	209	327
Texture	cl	Scl
(b) Bulk density (Mg m^{-3})	1.08	1.25
(c) Particle density (Mg m^{-3})	2.5	2.28
(d) Pore space (%)	56.6	45.1
(e) Pore space volume (ml)	10.0	7.21
(f) Field capacity (%)	22.4	20.0
(g) Wilting point (%)	19.0	17.0
II. Physico-chemical properties		
(a) Soil reaction	4.75	4.41
(b) Electrical conductivity (dSm^{-1})	0.51	0.31
III. Chemical properties		
(a) Organic carbon (g kg^{-1})	30.8	24.13
(b) Total nitrogen (g kg^{-1})	3.20	2.10
(c) Ammoniacal nitrogen (mg kg^{-1})	56.0	28.0
(d) Nitrate nitrogen (mg kg^{-1})	42.0	28.0
(e) Ammonium fixing capacity (Cmol kg^{-1})	2.5	2.0

There were eight batches of flasks to facilitate analysis at the interval of 1, 2, 3, 4, 5, 30, 60 and 90 days after incubation. Each batch consisted of 20 flasks for both the soils. At the end of each incubation period, the soil in each flask was mixed well and analysed for pH, EC, urea N, NH_4-N, NO_3-N, $KMnO_4$-N and total nitrogen content by standard methods (Table 2) in moist condition and the results were given on oven dry basis. The data were analyzed statistically by FCRD (Gomez and Gomez, 1984).

Table 2. Details of analytical methods employed in the soil analysis

Determination	Methodology	References
A. Physical properties		
1. Particle size analysis	International pipette method	Piper (1966)
2. Bulk density	Keen-Raczkowski brass cup method	Piper (1966)
3. Moisture retention at 1/3 bar and 15 bar pressure	Pressure plate apparatus method	Richards (1965)
B. Physico-chemical properties		
1. Soil reaction	pH meter with glass electrode (1 : 2.5 soil : water suspension)	Jackson (1973)
2. Electrical conductivity	'Elico' conductivity bridge (1 : 2.5 soil : water suspension)	Jackson (1973)
C. Chemical properties		
1. Total nitrogen	MacroKjeldahl method	Piper (1966)
2. Urea nitrogen	Colorimetric method	Douglas and Bremner (1970)
3. Ammoniacal and nitrate nitrogen	Steam distillation method	Bremner and Keeney (1966)

Measurement of Volatilization Loss of Nitrogen

In each flask, volatilized ammonia was trapped in vials containing 5 ml of 0.5 M H_2SO_4 with methyl red indicator. The acid used for absorbing the ammonia was changed every day and it was titrated against 1N KOH to quantify the ammonia losses through volatilization.

RESULTS AND DISCUSSION

This experiment was conducted in two soil textures viz., clay loam and sandy clay loam at 1/3 bar pressure, since the field capacity condition prevails most of the time in tea fields due to high slope (48%). Balwinder Singh and Lakhwinder Singh (1999) observed that urea hydrolysis and mineralization rate was rapid under field capacity condition than any other soil : water ratio.

Urea Hydrolysis

In clay loam soil, urea hydrolysis occurred upto five days, whereas in sandy clay loam soil it occurred upto four days. This variation was due to the soil pH which increased from 4.70 to 5.24 in clay loam soil, whereas it increased from 5.52 to 6.38 in sandy clay loam soil upto five days of incubation (Kumar and Wagnet, 1984). In clay loam soil, 4.30, 3.27, 2.07, 0.09 and 0.02% of added urea N was recovered on 1st, 2nd, 3rd, 4th and 5th day of incubation, respectively. But in sandy clay loam soil, 4.93, 2.91, 0.62 and 0.01% was detected on 1st, 2nd, 3rd and 4th day of incubation, respectively (Fig. 1). Thus, urea hydrolysis was high in clay loam soil during early period, which might be due to increase in urease activity. This enzyme activity was reported to be highly and positively correlated with organic carbon (Ramesh *et al.*, 2003) and total nitrogen (Sahrawat, 1980). In this experiment, organic carbon and total nitrogen of clay loam soil was 21.7 and 34.4% higher than sandy clay loam soil, respectively. This rapid hydrolysis rate agrees with the findings of Gupta *et al.* (1999).

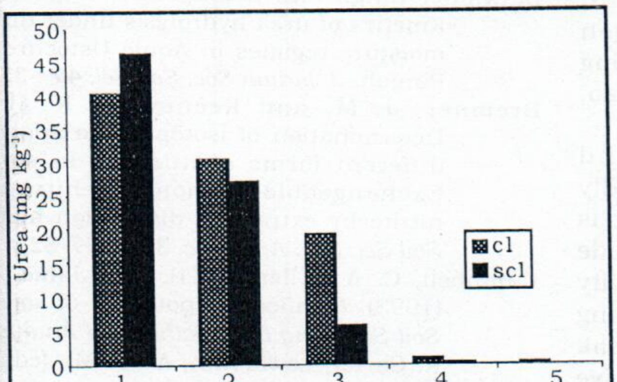

Fig. 1. Changes in urea concentration during incubation.

Volatilization Loss of Nitrogen

In the present experiment, no volatilization loss was observed after urea application. It might be due to insufficient increase in pH value by the treatments. The increase was 1.02 units (5.34-4.32) and 1.89 units (6.6-4.71) for clay loam and sandy clay loam soil, respectively (Fig. 2). According to Tisdale *et al.* (1995), the required pH value for volatilization loss was more than 7.5.

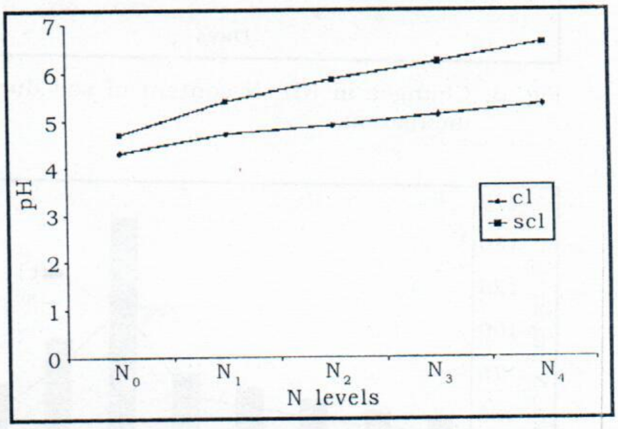

Fig. 2. Changes in pH values of soil during incubation period.

NH_4-N Content of Soil during Incubation

Increase in the levels of nitrogen application increased the NH_4-N content in the soil (Table 3) due to transformation of urea nitrogen into NH_4-N. As the period of incubation was prolonged, the content of NH_4-N decreased in the soil (Fig. 3) due to the following reasons : (i) being an intermediate product of mineralization process, NH_4-N might have been preferentially consumed by microorganisms (Patrick *et al.*, 1985) which resulted in its decline after 5th day of incubation, (ii) increase in fixed NH_4^+ and (iii) the decrease was due to the concomitant increase in the NO_3-N content at 30th day of incubation (Suraj Bhan *et al.*, 1990) (Fig. 4).

Table 3. Nitrogen content (mg kg^{-1}) at different nitrogen levels and soil textures during incubation

N levels	NH_4-N		NO_3-N	
	cl	scl	cl	scl
N_0	62.80	38.41	33.42	26.64
N_1	156.61	143.78	56.74	41.64
N_2	260.33	232.50	76.92	56.35
N_3	336.63	286.65	93.36	68.17
N_4	390.8	338.15	117.14	97.48
S. Ed	3.96	3.41	1.15	0.62
C. D. (P=0.05)	8.01	6.91	2.33	1.25

cl : clay loam soil; scl : sandy clay loam soil.

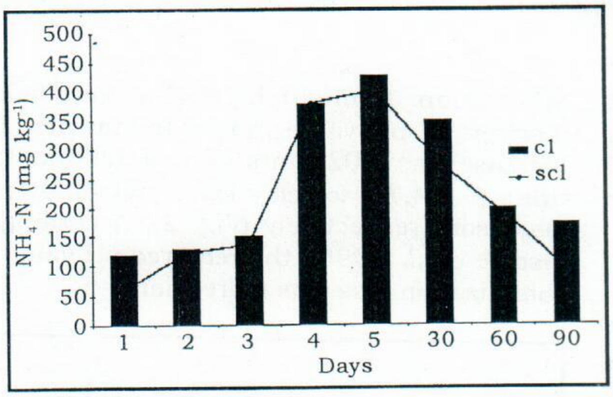

Fig. 3. Changes in NH_4-N content of soil during incubation.

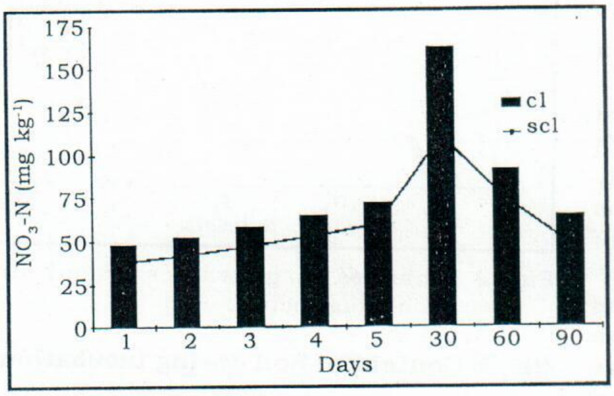

Fig. 4. Changes in NO_3-N content of soil during incubation.

NO_3-N Content of Soil during Incubation

Increase in the rate of nitrogen addition recorded increased amount of NO_3-N content in the soil during incubation periods (Table 3). This could be due to higher substrate (NH_4-N) content with increased rates of nitrogen application that resulted in more NO_3-N during nitrification (Siddaramappa and Seshagiri Rao, 1971).

Nitrogen mineralization and subsequent nitrification proceeded rapidly during the first five days of incubation. It is attributed to mineralization of organic amide form of nitrogen by enhanced bacterial activity at 27±1°C (Rao and Batra, 1983) and priming effect. However, nitrification attained the peak at 30th day of incubation because of active nitrification of NH_4-N (Dey and Jain, 1997) that was confirmed by the decrease in the content of NH_4-N on 30th day of incubation. As the period of incubation prolonged, this NO_3-N content decreased which might be due to immobilization (Nishio *et al.*, 2001) or retardation of microbial activity and denitrification (Yadvinder Singh *et al.*, 2001) (Fig. 4).

In clay loam soil, NO_3-N content increased remarkably at 30th day of incubation, when compared to sandy clay loam soil (Fig. 4). It could be attributed to higher organic carbon and total nitrogen content of initial clay loam soil than sandy clay loam soil.

Net nitrate accumulation was high in clay loam soil (160.8 mg kg^{-1}) when compared to sandy clay loam soil (109.4 mg kg^{-1}). It might have resulted from the high amount of initial NH_4-N content (Campbell *et al.*, 1993).

CONCLUSION

- Urea hydrolysis was high in clay loam soil during early period of incubation. This trend was reversed at the later stages of the incubation experiment.
- In both the clay loam and sandy clay loam soils, no volatilization loss was observed due to urea application.
- Increasing levels of nitrogen application increased the NH_4-N and NO_3-N content of the soil irrespective of the soil texture. The NH_4-N content increased upto 5th day of incubations, whereas NO_3-N content of the soil increased upto 30th day.

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