

UREA HYDROLYSIS IN SOME TEA SOILS

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Key words

Polyphenols Tea soils Urea

Summary

The rate of conversion of urea to ammonium was studied in some acid tea soils of Sri Lanka. The stable levels of urease present in these soils are adequate to hydrolyse the applied urea. There was rapid and almost complete conversion of urea to ammonium and the rate of hydrolysis was independent of soil moisture at 25 per cent and above. The rate of conversion of urea to ammonium depended on the soil polyphenol concentration and had no relationship with either the organic carbon content or the texture.

Introduction

Sulphate of ammonia has been widely used as the main source of nitrogenous fertilizer for tea cultivation in Sri Lanka up to 1965. The continuous use of high rates of ammonium sulphate (200–300 kg N ha⁻¹ annum⁻¹) has resulted in tea soils becoming very acidic (pH 3.5–4.5). Urea is now being increasingly used as an alternative source of nitrogen because of its high nitrogen content coupled with the low cost per unit of N and less soil acidifying properties when compared with sulphate of ammonia.

It is well established that the conversion of urea to ammonium in soil is brought about by the enzyme urease. Although considerable information is available on urea reaction in tropical and temperate soils little is known of the rates of urea hydrolysis in tea soils¹. The investigations of these authors¹ were based on a buffer method⁷. However the buffer method does not represent the true ability of soils to hydrolyze fertilizer urea^{1,2}. Since there is a paucity of information on the fate of applied urea in tea soils an attempt has been made to investigate urea transformations in tea soils by direct estimation of urea in the absence of any buffers⁴.

Materials and methods

Surface soil (0–15 cm) used in these experiments were sampled from four different tea growing districts. Some physical and chemical properties of these soils are given in Table 1. Before use, each sample was air dried and screened through a 2 mm sieve and the analysis reported in Table 1.

Table 1. Description of the tea soils

Sampling depth and location	Soil texture*			Total N (%)	Org. C (%)	pH in 2 N KCl
	Clay	Silt	Sand			
A. 0-15 cm St Coombs (1500 m amsl.)	39.6	23.2	37.2	0.18	2.64	4.1
B. 0-15 cm Passara (800 m amsl.)	26.8	14.2	59.0	0.17	2.30	4.0
C. 0-15 cm Hantane (1000 m amsl.)	37.6	10.6	51.8	0.12	1.42	4.1
D. 0-15 cm Ratnapura (500 m amsl.)	28.9	6.4	64.7	0.11	1.35	4.5

* Per cent of oven dry soil (105°C).

Urea hydrolysis to ammonia was measured at five moisture regimes (15, 20, 25, 30 and 40 per cent) ranging from permanent wilting point to field capacity.

The rates of urea hydrolysis in the above soils were determined by the following procedure. Air dry soil equivalent to ten g oven-dry soil was treated in 125 ml wide-mouth bottles with one ml of urea solution containing 1000 µg urea N and their water contents adjusted from 15-40 per cent by the addition of distilled water. Each bottle was stoppered with a cork fitted with a glass tube in which a rolled filter paper saturated with 0.5 N H₂SO₄ was placed to absorb any gaseous ammonia formed during the incubation period. All incubations were carried out in duplicate at 22°C under aerobic conditions for seven days and the extent of urea hydrolysis determined by analysing for unreacted urea and ammonia produced. To estimate the rate of conversion of urea to ammonium the incubated samples were shaken with 100 ml of 2 M KCl containing 5 µg ml⁻¹ phenyl mercuric acetate for 30 minutes at 3 to 6 hour intervals depending on the rate of hydrolysis. The resulting soil suspension was filtered and analysed for urea-N⁴, NH₄⁺-N¹¹ and pH. Gaseous ammonia losses were estimated by shaking the filter paper with 50 ml 2 N KCl for 30 minutes and analysing the NH₄⁺-N¹¹. Duplicate samples of soil which received no urea were also included in order to distinguish the ammonia derived from other sources.

Results and discussion

The conversion of urea to ammonium N in the four soils (A, B, C and D) during a seven day incubation period at 30 per cent soil moisture is shown in Fig. 1. In soils (C) and (D) 1000 µg urea-N was converted to NH₄⁺-N within 20 hours at all soil moisture contents above 20 per cent and at 22°C indicating very high urease activity in these two soils. Soils (A) and (B) took a relatively longer time to hydrolyse the urea but again the rate of hydrolysis was independent of the soil moisture above 20 per cent. The conversion was

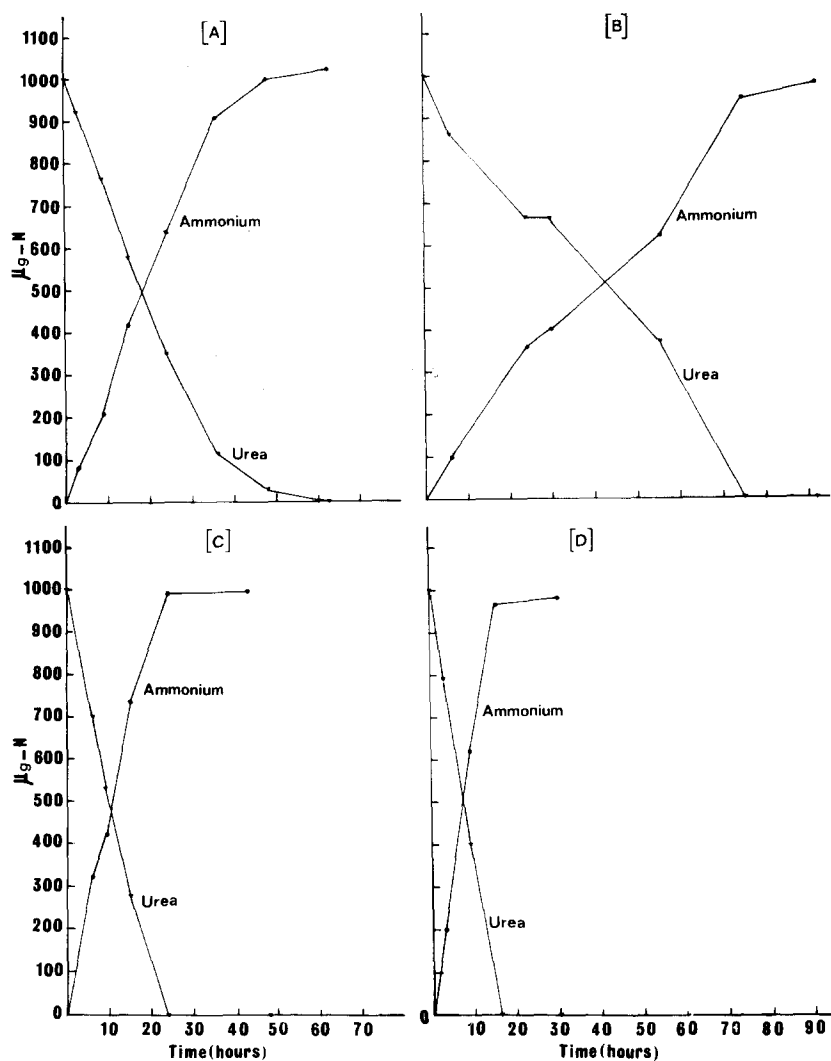


Fig. 1. Conversion of urea to ammonium in tea soils A, B, C and D at 30 per cent soil moisture.

essentially complete in 56 and 75 hours for soils (A) and (B) respectively (Fig. 1A and B). The rate of production of ammonia was directly related to the rate of disappearance of urea in all the soils.

The added urea could be quantitatively accounted for either as unreacted urea or as ammonium indicating no measurable loss of gaseous NH_3 from urea. Fernando and Roberts⁵, using an aerated system reported, that the gaseous loss of ammonia from urea

was not higher than five per cent of the total urea nitrogen applied. In the present study the NH_4^+ -N formed by the hydrolysed urea was accountable in the soil even at the end of seven days again indicating that loss of gaseous NH_3 was negligible in these soils.

It is generally accepted that urease activity tends to increase with organic matter content and that sandy soils tend to have a lower urease activity. Pancholy and Rice⁹ found that urease activity in nine Oklahoma surface soils was not significantly correlated with organic carbon and concluded that the level of urease activity in these soils were determined by the type of vegetation. In our work with tea soils we did not observe a relationship between urease activity and organic carbon. On the contrary the soils (C) and (D) where the organic carbon was 1.42 and 1.35 respectively had a very much higher urease activity than the soils A and B which had organic carbon values of 2.6 and 2.3 respectively (Table 1). This could be due to the relatively high polyphenolic residues in the organic matter (which is mostly derived from the tea leaf litter containing as much as 15–20 per cent polyphenol) which inhibits urease activity^{2,6}. In order to clarify whether the soil polyphenols determined the rates of urea hydrolysis in these soils the total soil polyphenols were extracted with seventy per cent acetone water³ and estimated colorimetrically using Folin reagent¹⁰. The total polyphenol content and the respective rates of urea hydrolysis for these soils are given in Table 2. It is evident that there is a direct relationship between the soil polyphenol level and the rates of urea hydrolysis. For example, the soils C and D which had very high rates of urea hydrolysis had relatively low polyphenol contents 24 and 17 $\mu\text{g gram}^{-1}$ soil respectively compared to soils A and B where the rates of hydrolysis were very much slower. This observation supports the previous findings^{2,6} that polyphenols inhibit urease activity in soils. In addition it offers a clear explanation for the different rates of urea hydrolysis in these tea soils, which confirms the observations of Pancholy and Rice⁹ that the urease activity of a soil is determined predominantly more by the nature of the vegetation (especially if the plants have a high polyphenol content as in tea) rather than the organic carbon content and the texture.

It is well-known that urea hydrolysis occurs over a wide pH range and the optimal rates being observed at neutral to near neutral pHs. However, in the present study we have found very high levels of urease activity in tea soils even at very acid soil pHs (4.0–4.5). In fact the rates of urea hydrolysis in these soils were so high that as much as 1.6–6.7 $\mu\text{g urea N g}^{-1}$ soil hour⁻¹ (Fig. 1A–D) was hydrolysed. In all experiments in spite of this urea

Table 2. Relationship between level of soil polyphenol and rate of urea hydrolysis in tea soils

Soil	Total soil polyphenols	Rate of urea hydrolysis
	$\mu\text{g g}^{-1}$ soil	$\mu\text{g N g}^{-1}$ soil h ⁻¹
(St Coombs) A	30	2.5
(Passara) B	68	1.6
(Hantane) C	24	4.5
(Ratnapura) D	17	6.7

hydrolysis, the soil pH increased temporarily only by 0.1 to 0.2 for a pH unit because of the very high buffering capacities of these soils.

It is hence conceivable that in tea soils in general, the stable levels of urease activity present in the soils are more than adequate to hydrolyse the applied urea. There was rapid and almost Stoichiometric conversion of urea to ammonium ions and the rate of hydrolysis was independent of soil moisture at 25 per cent and above. Thus it is apparent that the nitrogen added in the form of urea would be effectively released to the soil as ammonium ions. It is also known that the tea plant preferentially absorbs NH_4^+ -N compared to Nitrate-N⁸. Thus, as far as the uptake of ammonium nitrogen by the tea plant is concerned there will not be any discrimination between the NH_4^+ -N regardless of the source, whether it is from hydrolysed urea or sulphate of ammonia. This is in agreement with the general field observations that urea is an equally effective source of nitrogenous fertilizer compared to sulphate of ammonia in supplying the nitrogenous, fertilizer requirements of tea plants.

Received 25 March 1981. Revised June 1981

References

- 1 Bhavanandan, V. P. and Fernando, V. 1970 *Tea Quart.* **41**, 94–106.
- 2 Bremner, J. M. and Douglas, L. A. 1971 *Soil Biol. Biochem.* **3**, 297–307.
- 3 Coulson, C. B. *et al.* 1960 *Soil Sci.* **11**, 20–29.
- 4 Douglas, L. A. and Bremner, J. M. 1970 *Soil Sci. Soc. Am. Proc.* **34**, 859–862.
- 5 Fernando, V. and Roberts, G. R. 1975 *Plant and Soil* **42**, 287–291.
- 6 Fernando, V. and Roberts, G. R. 1976 *Plant and Soil* **44**, 81–86.
- 7 Hoffman, E. 1963 Urease. *In Methods of Enzymatic Analysis*. Ed. H. U. Bergmeyer. Academic Press, New York pp 913–916.
- 8 Kularatne, T. and Bhavanandan, V. P. 1971 *Tea Quart.* **42**, 101–108.
- 9 Pancholy, S. K. and Rice, E. L. 1973 *Soil Sci. Soc. Am. Proc.* **37**, 47–50.
- 10 Swain, T. and Hills, W. E. 1959 *J. Sci. Food Agric.* **10**, 63–68.
- 11 Tetlow, J. A. and Wilson, A. L. 1964 *Analyst* **89**, 453–465.
- 12 Zantua, M. I. and Bremner, J. M. 1975 *Soil Biol. Biochem.* **7**, 291–295.