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EFFECT OF UREA AND AMMONIUM SULPHATE ON THE NITRIFICATION AND THE RELEASE OF POTASSIUM, MAGNESIUM AND CALCIUM IN ACID TEA SOILS

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Hydrolysis, leaching and nitrification of urea and ammonium sulphate fertilizers in tea soils and the consequent dissolution of soil K, Ca and Mg were examined under simulated field conditions.

Unhydrolysed urea was not detected in the first 10 cm or any other soil depth confirming that leaching of unhydrolysed urea into the deeper soil layers, beyond the root zone, does not occur in tea soils because of the rapid hydrolysis of urea to ammonium ions.

Despite the high soil acidity, urea as well as ammonium sulphate were nitrified equally rapidly and the nitrate N in the soil solution reached a peak concentration between 25-30 days after the addition of fertilizer N.

Ammonium sulphate releases more acidity to the soil compared with urea and released more K, Ca, Mg into the soil solution from the cation exchange sites in the clay minerals.

INTRODUCTION

The tea plant (*Camellia sinensis* L.) responds to very high levels of fertilizer nitrogen (200-300 kg N ha^{-1} $year^{-1}$). The two leaves and the bud harvested for tea manufacture contain as much as 3 to 4 per cent N and thus remove much of this nutrient with every harvest which is carried out at 7 to 10 day intervals. Nitrogen is applied to the crop in the form of urea and/or ammonium sulphate. Field experiments comparing the effect of different nitrogenous fertilizer treatments on the yield of tea have shown that urea and ammonium sulphate treatments individually give very similar yields but that calcium ammonium nitrate gives lower yields (Bhavanandan and Manipura, 1969; Tillekeratne 1970; Watson and Wettasinghe, 1972; Sandanam *et al.*, 1980).

Urea is being increasingly used as an alternative source of N because it is cheaper per unit of N and acidifies the soil less than ammonium sulphate. Although financial gains from the use of urea are very promising, it is necessary to evaluate the utilization efficiencies of both fertilizers by the tea plant by measuring leaf N content and their transformations in the soil i.e. immobilization, mineralization, nitrification and the dissolution of soil K, Ca and Mg. Wickremasinghe *et al.* (1983) using ^{15}N labelled fertilizers reported that urea and ammonium sulphate were equally efficient sources of N for mature tea. It has also been shown that these two fertilizers were immobilized and mineralized to very similar extents under Sri Lankan acid tea soil conditions (Wickremasinghe *et al.*, 1984). In this study, we further examine the effects of these two fertilizers on the nitrification and release of potassium, magnesium and calcium in acid tea soils.

MATERIALS AND METHODS

Hydrolysis, leaching, nitrification and plant uptake of urea and ammonium sulphate by mature tea plants and the consequent dissolution of soil K, Ca and Mg were examined under simulated field conditions. Seven-year-old tea plants in

1.2 x 0.6 x 1.2 metre (l x w x h) cement pots were used together with a "control" pot. Before adding the fertilizer the soil was brought to field capacity. Labelled urea or ammonium sulphate (7g N per pot of 9 atom percent N^{15} excess ≡100 kg N ha^{-1} per application) were added to the soil in duplicate. The "control" pot was given 7g urea-N. The pots were watered daily equivalent to 2 cm rain day^{-1} for a week initially, which was reduced to 1 cm day^{-1} thereafter for 98 days. The excess water leached out of the bottom of the pots, preventing water logging.

The soil solution at depths ranging from 10 to 60 cm was sampled after 3 to 70 days from addition of fertilizer N (Golden *et al.*, 1981).

The hydrolysis, nitrification and other related transformations of urea and ammonium sulphate were studied by analysing the soil solution for unhydrolysed urea (Douglas and Bremner, 1970), NH_4-N (Tetlow and Wilson, 1964), NO_3-N (Middleton, 1959) and K, Ca and Mg (Atomic Absorption Spectrometry).

RESULTS AND DISCUSSION

Urea does not ionise and, until hydrolysed in the soil to ammonium ions by the enzyme urease it cannot be held by cation exchange sites in the soil unlike ammonium sulphate. This would allow unhydrolysed urea to be leached into the lower soil layers. Broadbent *et al.* (1958) and Bhavanandan (1969) have shown that urea is not so easily leached due to its rapid conversion to ammonium carbonate. More recently, Wickremasinghe *et al.* (1981) have clearly demonstrated that the ambient levels of urease in acid tea soils can hydrolyse the equivalent of 100 kg urea-N ha^{-1} in less than 4 days.

In the present experiments, unhydrolysed urea was not detected in the first 10 cm or any other soil layer at any time after fertilizer application, thus confirming that leaching of unhydrolysed urea into the deeper soil layers beyond the root zone does not occur in tea soils because of its rapid hydrolysis to ammonium ions. These are then retained in the upper soil layers, or root zone, as completely as those from ammonium sulphate.

Nitrification

Despite the high soil acidity (pH 4.0), urea-N and ammonium sulphate-N were nitrified rapidly and the nitrate-N in the soil solution reached a peak concentration (80—100/μg nitrate-N ml^{-1}) between 25 and 30 days after the addition of fertilizer N (Fig. 1). However, the nitrate-N decreased thereafter as a result of continuous plant uptake and leaching in the treatments with the plant. while the "control" pot continued to accumulate nitrate-N over the entire 80 days of the experiment because of its slower percolation rate, probably because the soil was more compacted due to the absence of root growth.

Release of potassium (K^+), calcium (Ca^{++}) and magnesium (Mg^{++})

The release of K, Ca and Mg into the soil solution in these acid soils can be caused by the release of H^+ (acidity) to the soil solution (1) by the hydrolysis of Al, Fe and Si during the weathering of clay minerals

e.g. $Al^{3+} + H_2O \quad Al(OH)^{2+} + H^+$

$Al(OH)^{2+} + H_2O \quad Al(OH)_2^+ + H^+$

$Al(OH)_2^+ + H_2O \quad Al(OH)_3 + H^+$

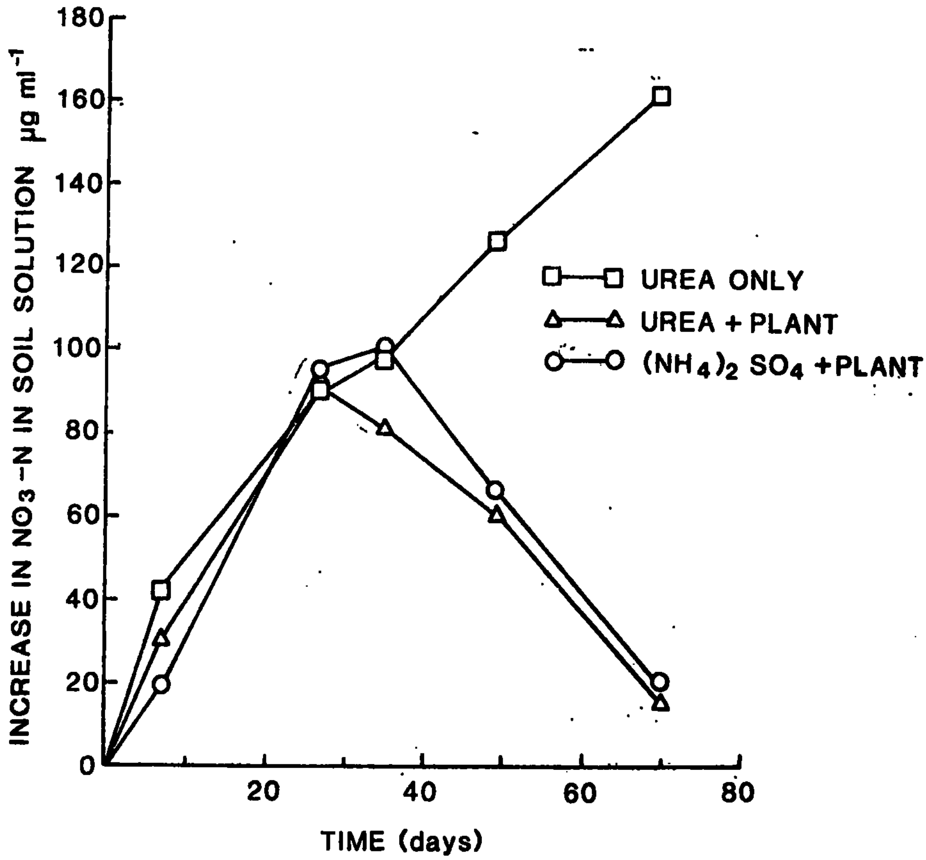

Fig. 1.—Increase in nitrate concentration in soil solution (0-60 cm) depth with time.

and (2) during the nitrification of urea-N and ammonium sulphate-N according to the following reactions :—

Urea

(i) $CO(NH_2)_2 + H_2O \xrightarrow[\text{(hydrolysis)}]{\text{(urease)}} NH_4COONH_2$

(ii) $NH_4COONH_2 + H_2O \longrightarrow (NH_4)_2CO_3$

(iii) $(NH_4)_2CO_3 \longrightarrow 2NH_4^+ + CO_3^{--}$

(iv) $CO_3^{--} + 2H_2O \longrightarrow H_2CO_3 + 2OH^-$

(v) $NH_4^+ + 3(O) \xrightarrow[\text{oxidizing bacteria}]{\text{ammonium}} NO_2^- + H_2O + 2H^+$

(vi) $NO_2^- + (O) \xrightarrow[\text{oxidizing bacteria}]{\text{nitrite}} NO_3^-$

Net acidity $2H^+$ per urea molecule, i.e. 1 H^+ per N atom.

Ammonium sulphate

(i) $(NH_4)_2SO_4 \longrightarrow 2NH_4^+ + SO_4^{--}$

(v) and (vi) as with urea

Net acidity $4H^+$ per $(NH_4)_2SO_4$ molecule, i.e. $2H^+$ per N atom.

Hence, the use of ammonium sulphate releases fifty per cent more acidity compared with urea per N atom, thus releasing more K, Ca and Mg into the soil solution from the cation exchange sites in the clay and even causing the breakdown of the less stable clay minerals.

The soil treated with ammonium sulphate released more K and Mg into the soil solution than that with urea (Figs 2 and 3). However in both treatments, maximum K and Mg concentrations in the soil solution appeared 35 days after fertilizer application and decreased thereafter due to plant uptake and leaching. The fact that K and Mg maximum concentrations (10 μg K ml^{-1} and 20 μg-Mg ml^{-1} with ammonium sulphate and 4 μg K ml^{-1} and 9 μg-Mg ml^{-1} with urea) over-lapped with the maximum nitrate concentration with both fertilizer treatments (Fig. 1) confirms that the H^+ produced during nitrification was responsible for the release of K and Mg. Figure 4 shows the release of calcium into the soil solution and this was independent of the release of K and Mg and reached a maximum about 50 days after fertilizer application in both treatments. This fact and the close relationship between the release of K and Mg and the different concentrations observed with the two fertilizers (Figs 2 and 3) suggest that with the ammonium sulphate treatments, additional K and Mg were also released from structural sites during the breakdown of clay minerals, which would also release structural Al into

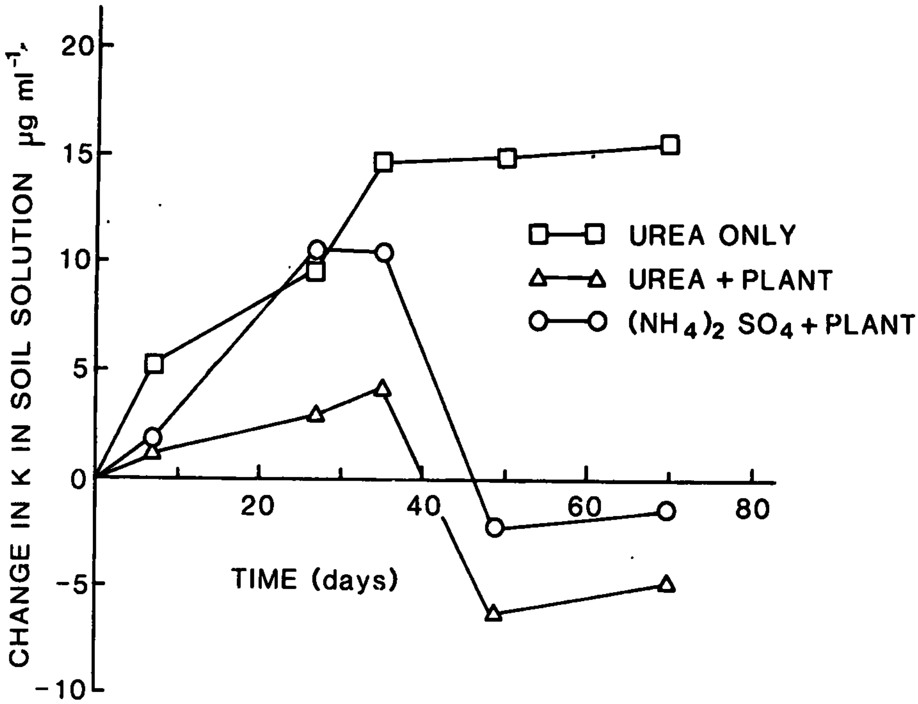

Fig. 2. — Change in K concentration in soil solution (0-60 cm) depth with time.

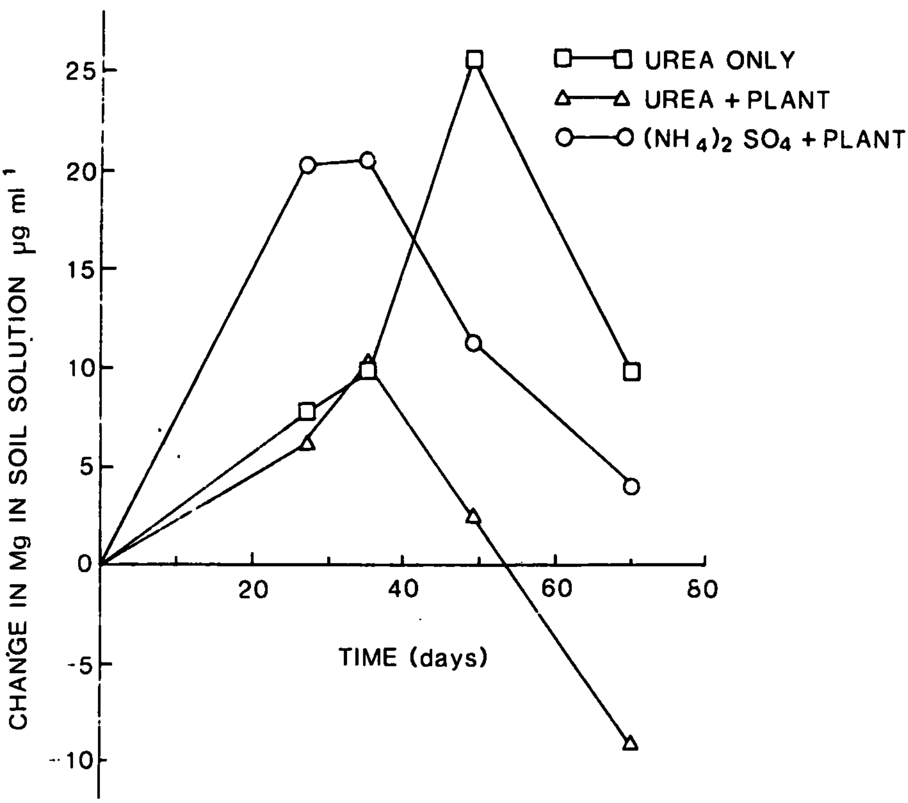

Fig. 3. — Change in Mg concentration in soil solution (0-60 cm) depth with time.

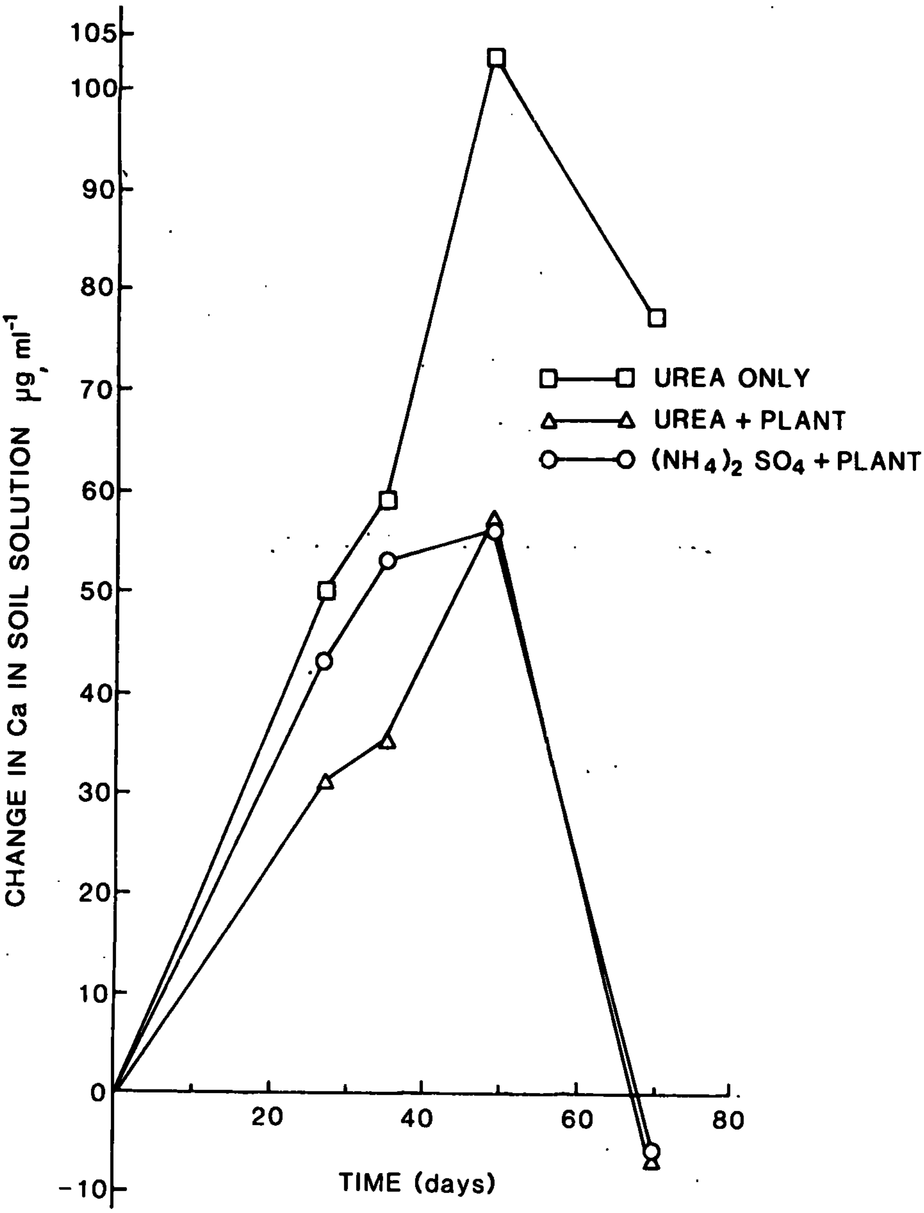

Fig. 4. — Change in Ca concentration in soil solution (0-60 cm) depth with time.

the soil solution. During acidification, Mg and Ca concentrations in the soil solution also increase from the dissolution of dolomite ($CaCO_3 + MgCO_3$) applied to the soil as a source of Mg for the plants which also helps to counteract soil acidity.

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