

## EFFECT OF FORMS AND LEVELS OF NITROGEN ON THE GROWTH AND ACCUMULATION OF NITROGEN, PHOSPHORUS, POTASSIUM AND CALCIUM BY YOUNG TEA PLANTS (*CAMELLIA SINENSIS L.*) GROWN IN SAND CULTURE

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The effect of four forms of nitrogenous fertilizers applied at five rates on the growth and uptake of N, P, K and Ca by young tea plants was studied. An increase in N supply usually improved growth up to a point beyond which it was not utilized in growth. Ammonium sulphate was exceptional in reducing growth as the supply increased, and leaf symptoms presumed to be caused by ammonium toxicity were seen when this fertilizer was applied at the higher rates.

The contents of N, P, K and Ca in the leaves were generally increased with increased supply of N as ammonium nitrate or urea. However, when nitrate was the sole source of N, the uptake of P was markedly reduced as the concentration of N was increased. Increased supply of Ca ions in the medium also resulted in reduced uptake of K.

### INTRODUCTION

The tea crop is very responsive to nitrogen. The commonest form applied is ammonium sulphate, but in recent years urea has been increasingly used mainly for reasons of economy. Calcium ammonium nitrate was used for a short time. The field experiments of Eden (1942, 1943) and of Tolhurst (1968) have indicated that ammonium sulphate generally resulted in greater yields than either sodium or calcium nitrate. Recent trials have indicated that while urea and ammonium sulphate gave similar responses, calcium ammonium nitrate reduced yields (Wettasinghe, 1974).

The form of N has been shown to influence the uptake of other major nutrients such as P and K which are also very essential for the optimum growth of most crops. Plants utilizing ammonium and urea fertilizers contained more P than did the plants receiving nitrate fertilizers (Breon, Gillam and Tendam, 1944; Lorenz and Johnson, 1953). Olson and Dreier (1956) reported that plants treated with  $\text{NH}_4^+$  or  $\text{NH}_4^+$  producing materials (eg urea) contained much more P than those treated with  $\text{NO}_3^-$ .

Most of the above findings were based on the data obtained from field trials. Kularatna and Bhavanandan (1971), on the other hand, listed various factors which limited the usefulness of field trials alone in determining the merits of fertilizers containing ammonium and nitrate and their influence on the uptake of other major elements. These limitations are largely eliminated in sand culture studies. The present study was, therefore, undertaken to obtain information on the form and level of N supplied and the interactions between them on the growth of tea plants growing in sand and to estimate the effects of treatment on the total weight of N, P, K and Ca in the leaves.

## MATERIALS AND METHODS

Three-month-old vegetatively propagated plants of clone TRI 2023 growing in soil were transplanted into sand in tapered cement pots 30.0 cm in height and with an internal diameter of 22.5 cm at the top. For the first 12 weeks all the plants were supplied with quarter strength modified Hewitt's nutrient solution daily in the morning. Details of the composition of this solution have been reported earlier (Pethiyagoda, Krishnapillai and Nagarajah, 1969). The differential treatments were commenced at the end of 12 weeks when the plants were uniform and averaged about 30.0 cm in height. Each of the four nitrogenous salts employed (ammonium sulphate (AS), ammonium nitrate (AN), urea (U) and calcium nitrate (CN)), was tested at five different levels of supply of N, i.e. 1.25, 2.50, 3.75, 5.00 and 6.25 mM, equivalent to 35, 70, 105, 140 and 175 ppm N respectively.

Each plant received 250 ml of nutrient solution daily in the morning. The 20 treatments were replicated five times and the pots were arranged in the glasshouse in a randomized block design.

In the treatments where CN was used to supply more than 70 ppm N, the calcium supply exceeded the usual 100 ppm. In the other treatments calcium sulphate was used to provide the requisite quantity (100 ppm) of calcium. Sulphate was used as the balancing ion. Thus, with the exception of sulphate and calcium all the other major and minor elements were maintained at the following concentrations:  $K_2SO_4$  (0.500 mM),  $NaH_2PO_4$  (1.330 mM),  $MgSO_4$  (1.540 mM), ferric citrate (0.050 mM),  $MnSO_4$  (0.010 mM),  $CuSO_4$  (0.0011 mM),  $ZnSO_4$  (0.001 mM), boric acid (0.030 mM), ammonium molybdate (0.003 mM),  $CoSO_4$  (0.0001 mM) and NaCl (0.010 mM). The treatments were continued for a period of eight months at the end of which a single growth assessment was carried out. The leaf area and the dry weight of stems, roots and leaves were determined for each plant separately.

The entire dried leaf material from the 20 treatments was separately bulked and ground samples were used for the estimation of N, P, K and Ca.

### Analytical Procedure:

**Total N.**—Estimation of the total N content of leaves was carried out by the micro-Kjeldahl method.

**Phosphorus, Potassium and Calcium.**—Oven dried leaf samples (0.02 g) were ashed overnight (at 450°C) dissolved in 0.5 ml conc.  $HNO_3$  and HCl (1:1 diluted twice), evaporated to dryness and subsequently dissolved in 10 ml of 0.05 N HCl. Aliquots were used for the estimation of K and Ca by the flame photometry and P calorimetrically using the molybdovanadate method.

## RESULTS

At the early stages of growth AS, AN and U produced darker foliage than CN. Symptoms of ammonium toxicity were noted on the leaves after two months at higher rates of AS resulting progressively in chlorosis and necrotic lesions and leading eventually to crinkling and recurving of leaves along the axis. Where ammonium sulphate was used as the source of N, those plants receiving low levels of N (35 ppm and 70 ppm N) were superior to those supplied with higher levels (105, 140 and 170 ppm N) (Figs. 1 and 2). At the highest level, the growth was severely affected with the production of more chlorotic leaves.

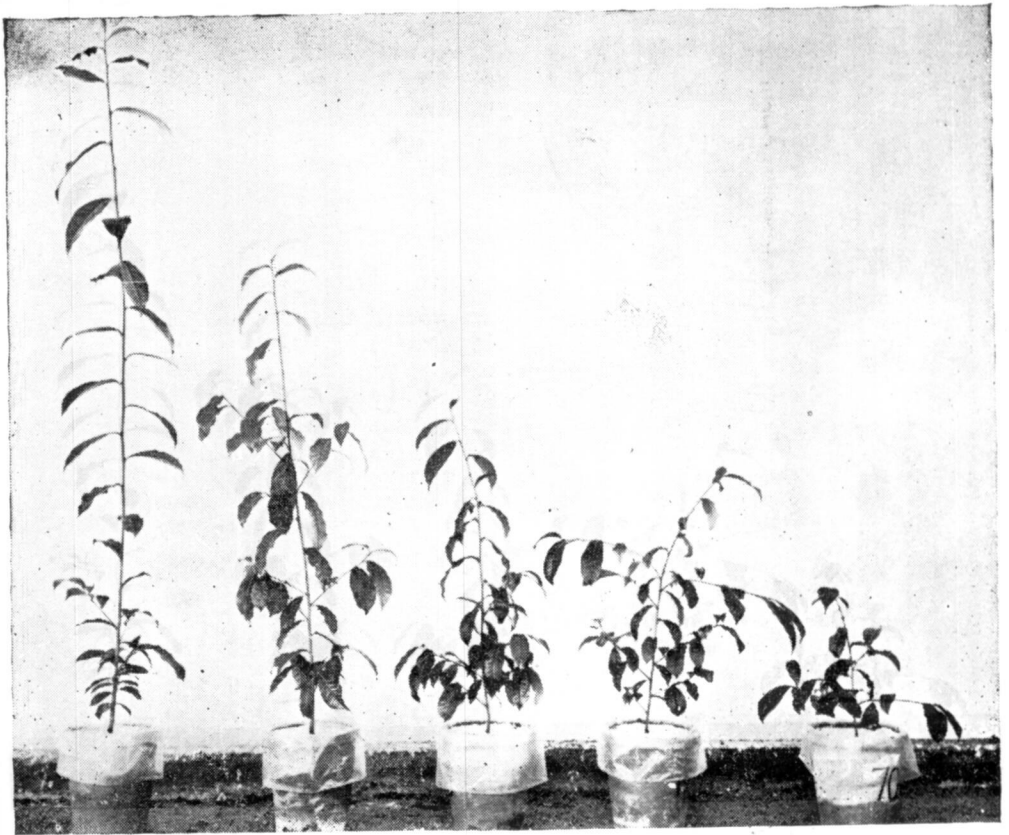
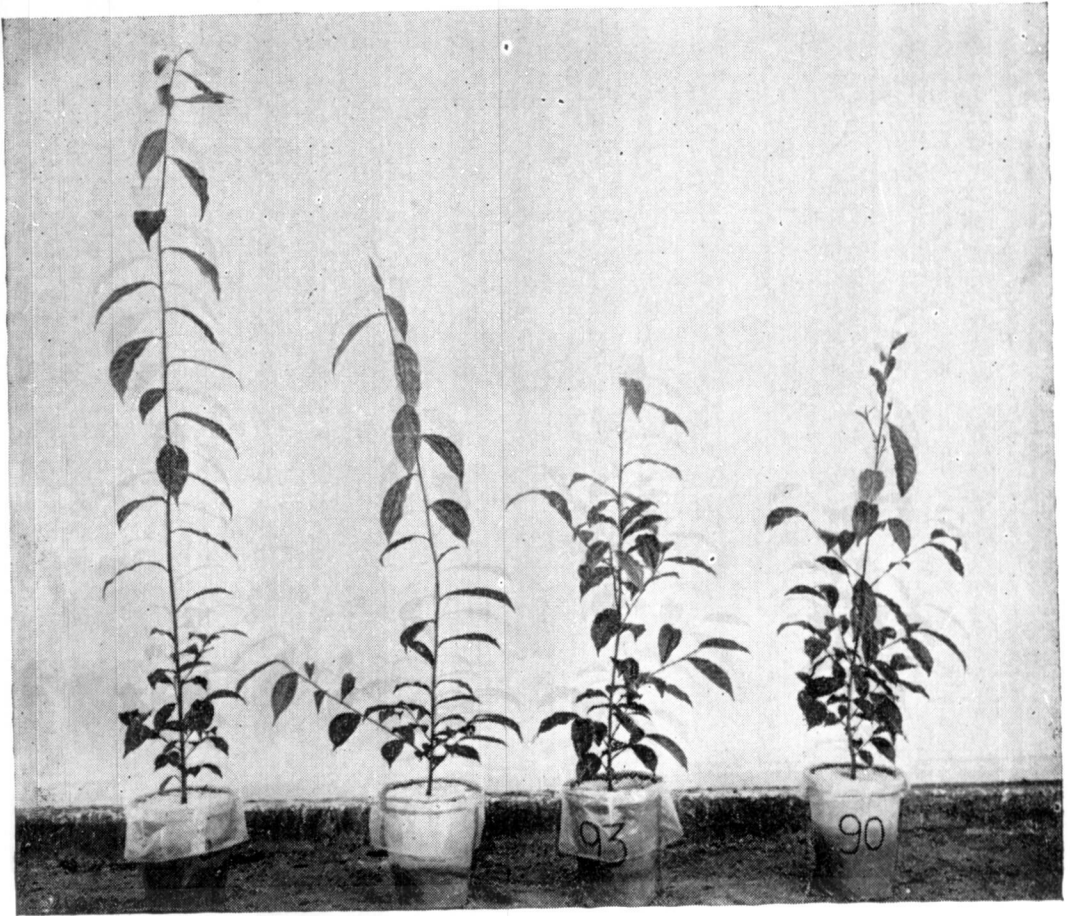


Fig. 1. — Appearance of plants receiving Ammonium Sulphate at different levels. Photographed at time of final assessment. (Pts L to R 35, 70, 105, 140 and 175 ppm N)



*Fig. 2.* — Plants at the lowest level of supply of nitrogen of the four forms (Pts L to R-AS, AN, U and CN)

Fig. 3 represents the manner in which total dry matter production was influenced. For all the forms with the exception of AS, an increase in the supply of N resulted in an increased dry matter of all plant components.

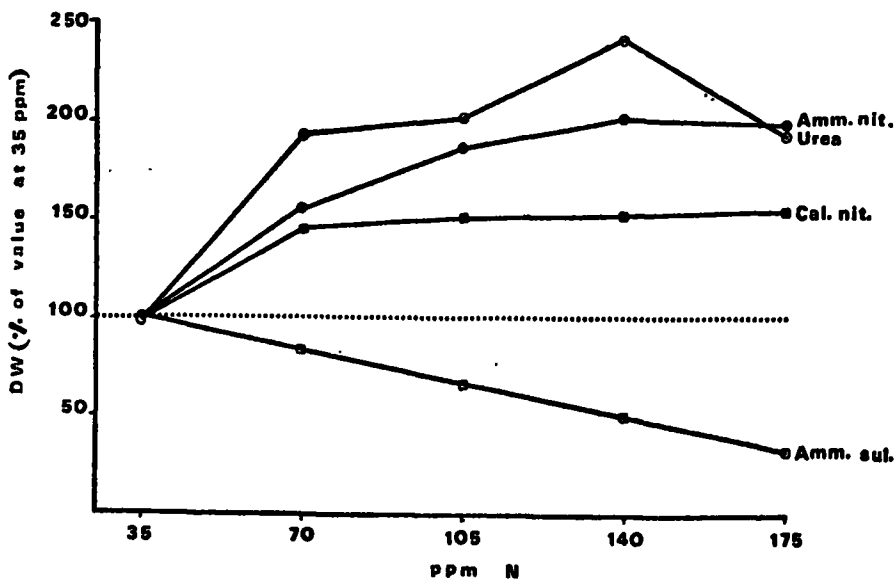


Fig. 3.—Effect of increasing supply of nitrogen in each of the four forms, on total dry matter production.

With AS as the sole source of N, the growth of plants was linearly retarded by increasing levels of N in this form. At the highest level of ammonium supply root development was severely affected. These roots were brownish in colour in contrast to the abundance of fleshy, white feeder roots in the other three treatments (Fig. 4).

The growth response obtained for plants receiving CN was smaller than that obtained either with AN or U. There was also a tendency for the effects to level off when the  $\text{NO}_3^-$  supply increased above 70 ppm. With AN and U, the increase continued beyond this point but lessened progressively with increasing N.

The cation and anion contents of the leaves are expressed both on (a) concentration (percentage) basis and (b) as total amount in the leaves per plant (Figs. 5 a, b, c, and d).

Generally, the inorganic ion contents of P and K of the leaves when expressed on a percentage basis (concentration) are higher in plants receiving lower levels of N. This was evident in all the forms of N used except AS. On the other hand, when the results are expressed on an 'amount per plant' basis, the relationship is reversed. The exceptions are N and Ca. The former with the exception of AS treatment and the latter in the nitrate treatment, increase with increased level of supply.

With CN treatments, with an increase in the supply of nitrate ions there was a marked decrease in the uptake of P when expressed both on a percentage and total per plant basis (Fig. 5 b). Similarly, with an increase in the supply of Ca in

the  $\text{NO}_3^-$  treatments, there was a sudden drop in K content (concentration) and the total uptake of K was low when compared with AN and U treatments.

The absorption of K by the plants was much higher than either of Ca or P. A vigorous growing plant absorbed about 2 to 3 times more K than Ca, although of both were supplied at the same concentration (3.75 mM). Even in treatments where the Ca supply was 250 ppm, the total quantity of Ca absorbed was still less than the total quantity of K absorbed by a healthy vigorous growing plant (Fig. 5 c and 5 d).

## DISCUSSION

This study permitted an evaluation of the preference that tea plants, grown in sand culture, show for different forms and levels of N.

While the plants generally grew better with higher levels of N, the forms of N used also greatly influenced growth. The most striking feature is that AN, U and CN caused positive responses to increasing levels of N whereas AS showed a linear negative response. Of the four nitrogenous compounds used AN and U appeared to be the most satisfactory forms of supply.

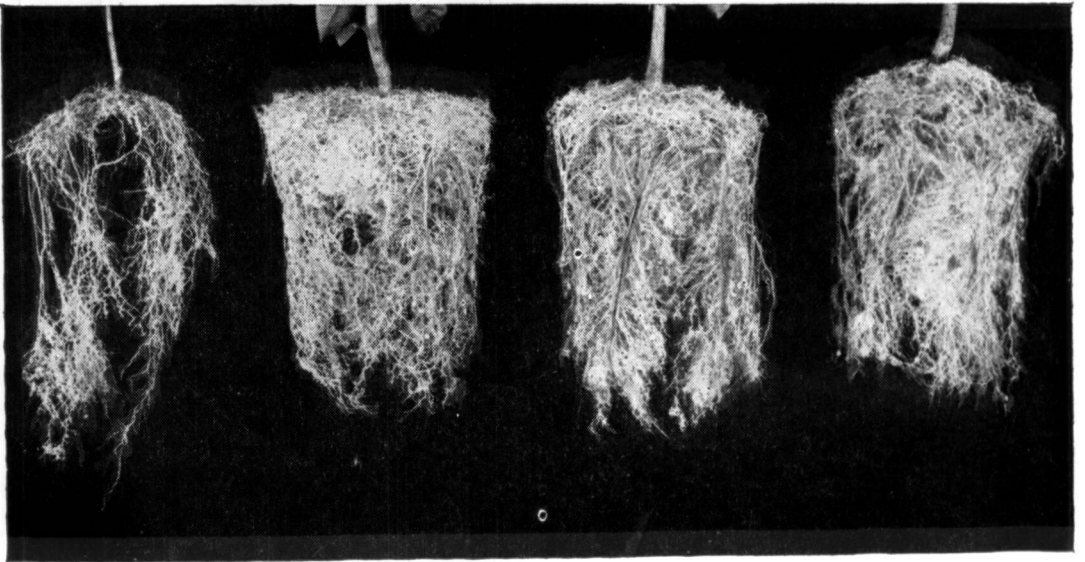
The restriction of growth at the lowest rates of N supply was due to a deficiency of this element. Plants which received higher levels of N in the form of AN and U showed vigorous and prolonged growth. The observations are indicative of some factor related to N nutrition being responsible for maintaining buds in an active state (Kulasegaram and Kathiravetpillai, 1971).

The response to AS as a source of N in this sand culture experiment was noteworthy. While at the lowest concentration of ammonium supply the plants were comparable with those receiving the other three forms (Fig. 2) growth was retarded and the severity of toxicity symptoms increased with the ammonium concentration in the nutrient solution (Fig. 1). Ammonium toxicity symptoms have also been reported for many other crops (Barker, Volk and Jackson, 1966).

In field experiments ammonium fertilizers have generally proved to be superior sources of N for tea plants. Studies on tea soils have shown the presence of substantial quantities of nitrates in fields fertilized with AS. In addition, studies on nitrification capacities of tea soil have revealed that more than 50% of the added ammonium is nitrified within a period of 30 days in spite of the pH of the soil being 4.5 (Sandanam, Krishnapillai and Sabaratnam, 1978). It would therefore seem that the normal rates of nitrification occurring in tea soils would be adequate to ensure that the plant roots have access to both ammonium and nitrate ions, and prevent excess uptake of  $\text{NH}_4^+$  avoiding its toxicity.

The effect of form and level of N on the uptake of P, K and Ca was also evident in this study. With improved growth at higher levels of N, there was always more uptake of N by the plants. The values of N in the leaves increase both on concentration basis and per plant basis, with increased supply of N. This was true for both AN and U (Fig. 5 a).

However, when the uptake of other mineral elements was considered there was a marked difference between the percentage values and the 'total leaf ion content per plant'. When the results are expressed on a percentage basis it is seen that with increased supply of N the contents of K and P decreased, with the contents of the ions being lowest in the plants that received the highest N supply. On the other hand, when the data on the total weight of nutrients in the plants



*Fig. 4. — Root systems of typical plants receiving N at 175 ppm in each of the four forms (Pts L to R - AS, AN, U and CN)*

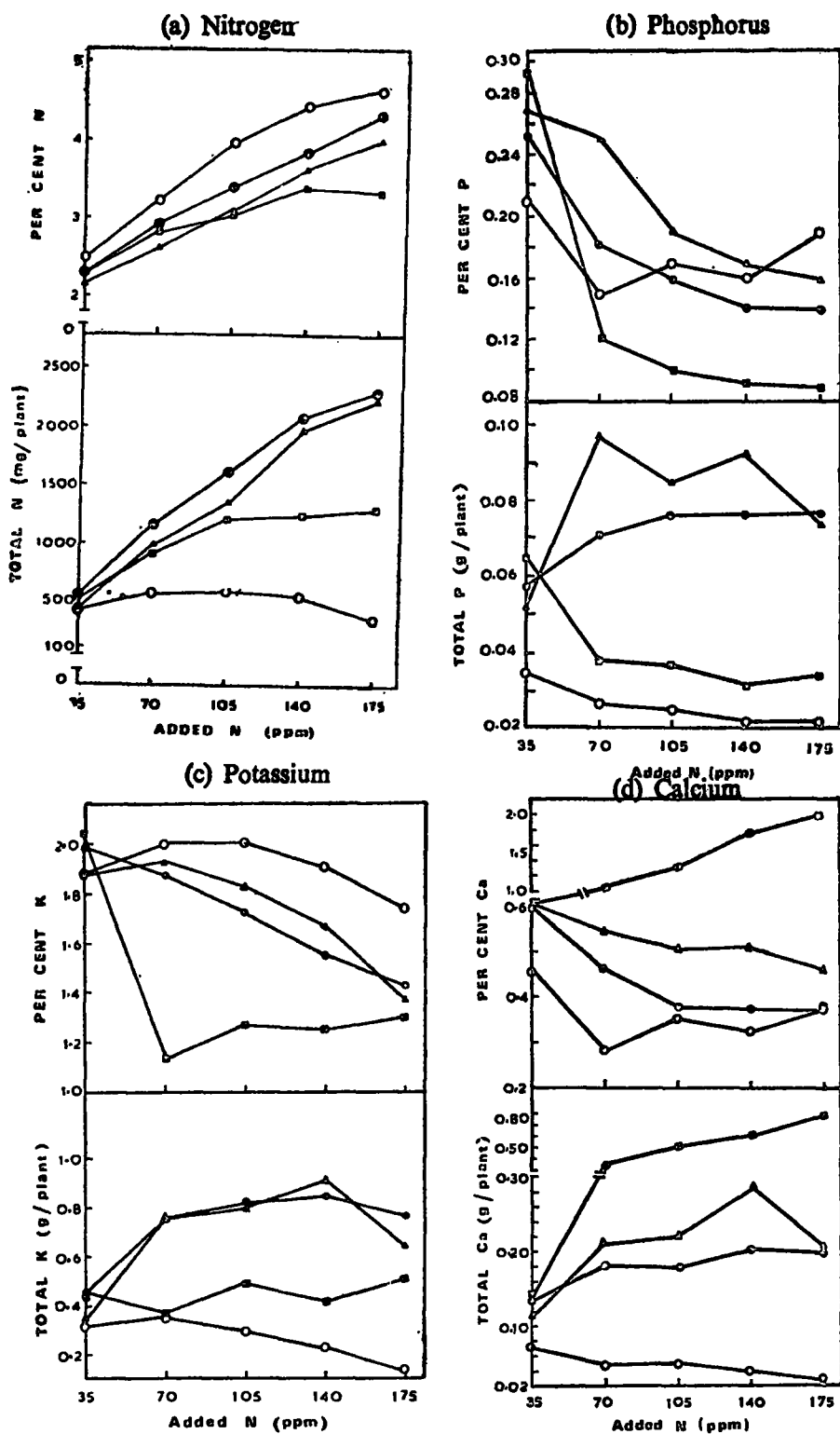


Fig. 5 (a, b, c and d).—Nitrogen, phosphorus, potassium and calcium contents of dried leaf samples as influenced by form and level of nitrogen. (The upper section presents percentage on a dry weight basis, and the lower section the total content).

■—■ CN, ▲—▲ U, ⊙—⊙ AN and ○—○ AS

(on a plant basis) is considered, it is clear that there are always higher amounts of P and K in the foliage of plants receiving higher nitrogen supply. When the nitrogenous nutrients promote growth, there is an apparent dilution effect developed within the plants (Taylor, 1967). Particularly with nitrogen studies the growth differences between treatments are so large that the trends for inorganic ion contents as percentages are virtually reversed when such values are expressed on a 'plant basis'. This confirms that in terms of total growth and nutrient content, the best response to N is obtained when other major elements such as P and K are also available in adequate quantities.

The competition between the entry into plant of ions of similar charges was also evident in this study. When  $\text{NO}_3^-$  was supplied in lieu of ammonium nitrate or urea less phosphate was taken up from the medium probably due to anion competition (Fig. 5b). Since  $\text{NO}_3^-$  is more readily absorbed, the decreased uptake of P is generally attributable to the increased uptake of  $\text{NO}_3^-$ . The per cent P values found for the leaves of plants receiving  $\text{NO}_3^-$  N above 35 ppm are closer or even less than the values reported for tea leaves deficient in P. Similarly, in the same treatment, with the uptake of more Ca, reduced quantities of K have been absorbed. This clearly indicates the true antagonism between ions of similar charges. It is probably for this reason, that the  $\text{NO}_3^-$  plants produced poor growth at higher N supplies. Under favourable conditions and at soil pH values above 5.0, the applied ammonium and urea fertilizers in the field could get nitrified rapidly resulting in the accumulation of more of the  $\text{NO}_3^-$  form of N in the soil. Under such circumstances the uptake of P may be greatly reduced as a result of increased uptake of nitrate ions, and the response to applied P may be low.

With plants receiving ammonium nitrate as the source of N the uptake of almost matching quantities of ammonium and nitrate (Krishnapillai, 1975) could not have affected the uptake of other cations and anions from the medium. With urea, since its hydrolysis to ammonium carbonate and subsequent partial nitrification of the ammonium so formed had been found to occur in the medium within 1 to 3 days, the urea nutrition could be regarded as one of ammonium nitrate (Krishnapillai and Pethiyagoda, 1980). It is for this reason that, here too, the uptake of other cations and anions was not affected and the plants accumulated adequate quantities of P and K in the same way found for plants receiving ammonium nitrate.

The fertilizer, calcium ammonium nitrate (CAN) was also introduced as a nitrogenous fertilizer for mature tea in Sri Lanka in the mid 60s but its use is now abandoned for lack of response on growth. When CAN was used as the source of N, the increased uptake of both  $\text{NO}_3^-$  and calcium from the applied fertilizer could have affected the uptake of P and K respectively, resulting in undesirable effects. This may be a reason why CAN and other nitrate fertilizers have proved to be inferior fertilizers to ammonium sulphate and urea in most fertilizer trials (Wilson, 1975).

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## REFERENCES

- BARKER, A. V., VOLK, R. J. & JACKSON, W. A. (1966). Growth and nitrogen distribution patterns in bean plants (*Phaseolus vulgaris* L.) subjected to ammonium nutrition. 1 - Effects of carbonates and acidity control. *Soil Sci. Soc. Am. Proc.*, 30, 228-232.
- BREON, W. S., GILLAM, W. S. & TENDAM, D. J. (1944). Influence of phosphorus supply and the form of available nitrogen on the absorption and the distribution of phosphorus by the tomato plant. *Plant Physiol.* 19, 495-506.
- EDEN, T. (1942). Report of the Agricultural Chemist for 1941. *Bull. Tea Res. Inst. Ceylon*, 23, 52-57.
- EDEN, T. (1943). Report of the Agricultural Chemist for 1942. *Bull. Tea Res. Inst. Ceylon*, 24, 37-41.
- KRISHNAPILLAI, S. (1975). Some factors affecting the uptake and utilization of nitrogen by young tea plants (*Camellia sinensis* L.) in sand culture. Ph.D. thesis, University of Sri Lanka, 329 pp.
- KRISHNAPILLAI, S. & PETHIYAGODA, U. (1980). Effect of calcium carbonate on ammonium and urea nutrition of young tea plants (*Camellia sinensis* L.) grown in sand culture. *Plant and Soil*, 55, 455-463.
- KULARATNA, T. & BHAVANANDAN, V. P. (1971). Uptake and utilization of ammonium and nitrate ions by tea plants as determined by the use of <sup>15</sup>N-labelled compounds. *Tea Q.*, 42, 101-108.
- KULASEGARAM, S. & KATHIRAVETPILLAI, A. (1971). Studies on the dormancy of tea shoots. 3. The effects of fertilizer levels and hormones. *Tea Q.*, 42, 57-74.
- LORENZ, O. A. & JOHNSON, L. M. (1953). Nitrogen fertilization as related to the availability of phosphorus in certain California soils. *Soil Sci.*, 75, 119-129.
- OLSON, R. A. & DREIER, A. F. (1956). Nitrogen, A key factor in fertilizer phosphorus efficiency. *Soil. Sci. Soc. Am. Proc.* 20, 509-514.
- PETHIYAGODA, U., KRISHNAPILLAI, S. & NAGARAJAH, S. (1969). Studies on the mineral nutrition of tea. 1. Techniques for growing tea plants in sand culture. *Tea Q.*, 40, 145-152.
- SANDANAM, S., KRISHNAPILLAI, S. & SABARATNAM, J. (1978). Nitrification of ammonium sulphate and urea in an acid red yellow podzolic tea soil in Sri Lanka in relation to soil fertility. *Plant and Soil.*, 49, 9-22.
- TAYLOR B. K. (1967). The nitrogen nutrition of the peach tree. 1. Seasonable changes in nitrogenous constituents in mature trees. *Aust. J. Biol. Sci.* 20, 379-387.
- TOLHURST J. A. H. (1968). Report of the Agricultural Chemistry Division. *Rep. Tea Res. Inst. Ceylon* 1967, 2, 25-41.
- WETTASINGHE, D. T. (1974). Report on the Low Country Station. *Rep. Tea Res. Inst. Ceylon* (1973), 2.
- WILSON, K. C. (1975). Studies on the mineral nutrition of tea. V Calcium. *Plant and Soil*, 43, 295-307.