

# STUDIES ON THE MINERAL NUTRITION OF TEA

## 2—EXPERIMENTALLY—INDUCED MAJOR NUTRIENT DEFICIENCY SYMPTOMS

U. Pethiyagoda & S. Krishnapillai

This paper, which is the second in the present series, describes the symptoms displayed by tea plants grown in sand culture and supplied with nutrient solutions from which each of the major nutrient elements have been singly excluded.

An illustrated account is given of the symptoms produced in the leaves of such deficient plants, supported by analytical data on the contents of some of these elements. Some information on the recovery by such deficient plants when supplied with the missing element is also included.

The results are discussed in relation to current fertilizer practices.

### INTRODUCTION

Plants require certain chemical elements in suitable quantities and forms in order to grow and function normally. Imbalance or inadequacy of any of these elements leads to functional disorders or abnormal appearances of the plant organs. Such abnormalities are referred to as "deficiency symptoms" (or sometimes, "deficiency diseases").

Depending upon the quantities in which the various essential elements are required, they are generally classified into two groups—the "major" elements (or "macronutrients") and the "minor elements" (or "trace elements or "micronutrients"). It is to be stressed that the use of the terms "major" and "minor" is no reflection on the relative functional importance of these elements. The lack of a minor element can cause symptoms quite as dramatic or often even more so than the lack of a major element.

The major elements required by a plant for healthy normal growth are generally considered to be ten in number. They are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and iron. With the exception of the first three elements which enter into the composition of the plant in the form of water and carbon dioxide, the others have to be absorbed in the form of mineral salts in solution by the roots. This paper presents an illustrated account of the symptoms which are manifested when each one of these last seven elements is intentionally withheld singly from the nutrient supply.

The symptoms caused in tea plants by the omission of the minor elements are to form the subject of a subsequent publication.

As would be expected, the most apparent and easily recognized deficiency symptoms are manifested in the overall growth of the plants and in their leaves. The use of such symptoms for the diagnosis of nutrient needs and gross shortages is a long established agricultural practice. A great deal of information is available on the deficiency symptoms exhibited by many of the more important crop plants. Among the more comprehensive accounts of such symptoms may be cited the books by Wallace (1951) and by the American Society of Agronomy and the National Fertilizer Corporation (Anon. 1949).

It is to be appreciated that deficiency symptoms are often apparent only when an element has become badly deficient, and that quite large deviations from the optimum can be tolerated by plants before they display visual symptoms. Stages of incipient deficit are better detected by chemical analysis of plant parts or the soil.

In the case of tea, conditions of deficiency of several elements have been observed, identified and corrected in the field. The earliest record of a deficiency disease of tea was that of Storey and Leach (1933) who diagnosed an obscure disease described as "Tea Yellows" in Nayasaland, to be caused by a deficiency of sulphur. Illustrated accounts of individual nutrient deficiency symptoms on Ceylon tea have appeared from time to time, *viz* potassium by Portsmouth (1953), magnesium by Mulder and de Silva (1959), nitrogen by Mulder and Visser (1960), zinc by Tolhurst (1962) and manganese by Tolhurst (1963). The Tea Research Institute of East Africa illustrates deficiencies of several elements in the "Tea Growers Handbook 1969".

Attempts to induce and describe deficiency symptoms in tea grown under controlled conditions of nutrient supply, appear to be relatively few and it is this gap that the present publication seeks to fill. De Haan and Schoorel (1940) obtained symptoms of potassium deficiency in tea plants grown in sand. Symptoms of nitrogen, phosphorus, magnesium, calcium and sulphur deficiencies in similar experimental plants were described by de Haan (1941).

## EXPERIMENTAL

The current series of experiments on the nutrition of tea in sand culture was commenced at the beginning of 1966. Successful techniques for obtaining good growth of experimental plants were detailed in an earlier paper (Pethiyagoda, Krishnapillai and Nagarajah 1969) and were substantially the same in the present investigation.

The observations detailed here were from two main experiments but where necessary, information from other experiments is also drawn in to complete the picture.

In Experiment I, the clone under study was CY 9 (selected because of its known vigour of growth). Seven-month-old plants were transplanted from soil to nine-inch cement pots containing sand. Two plants were established in each pot. The procedures detailed by Pethiyagoda *et al.* (1969) were followed. The plants were initially maintained with a complete nutrient supply until normal vigorous growth was evident. When the plants were judged to be ready, matched groups of three pots were supplied with appropriate nutrient solutions deficient in each of the elements under study. The preparatory stage took seven months.

In Experiment II, the four clones Drayton 1, Tillicoultry 9, TRI 2024 and TRI 2027 were employed. The ages of cuttings ranged from seven to nine months. Single plants were established in sand in pots of six-inch diameter. Four pots comprised a treatment plot and there were two replicates. The deficiency treatments were imposed after three months of complete nutrient supply. The main aim of this study was to determine whether clones differ in the deficiency symptoms they manifest.

Table 1 indicates the manner in which the respective treatment solutions are made up. Details of actual amounts of the component salts employed in making up of stock solutions is excluded as they have already been presented in the first paper of this series (Pethiyagoda, Krishnapillai and Nagarajah 1969).

Table 1 (a) lists the component salts in each of the treatment solutions. Table 1 (b) presents the actual content (in parts per million) of the elements under study in each of the solutions. Table 1 (c) gives the contents of micronutrients in a combined solution, that was supplied to all pots in the experiments considered here.

TABLE 1 — (a) *Components of nutrient solutions*

Salts	Control	—N	—P	—K	—Ca	—Mg	—S	—Fe
Ammonium sulphate	+	0	+	+	+	+	0	+
Sodium dihydrogen orthophosphate (2H <sub>2</sub> O)	+	+	0	+	+	+	+	+
Potassium sulphate	+	+	+	0	+	+	0	+
Calcium nitrate (4H <sub>2</sub> O)	+	0	+	+	0	+	+	+
Magnesium sulphate (7H <sub>2</sub> O)	+	+	+	+	0	0	0	+
Ferric citrate (5H <sub>2</sub> O)	+	+	+	+	+	+	+	0
Aluminium sulphate	+	+	+	+	+	+	0	+
Micronutrients (see below)	+	+	+	+	+	+	+	+
Calcium sulphate	—	+	—	—	—	—	—	—
Sodium sulphate	—	—	+	—	—	—	—	—
Magnesium nitrate (6H <sub>2</sub> O)	—	—	—	—	+	—	+	—
Aluminium chloride (6H <sub>2</sub> O)	—	—	—	—	—	—	+	—
Potassium nitrate	—	—	—	—	—	—	+	—

(b) *Composition of nutrient solutions (in parts per million)*

Element	Treatment							
	Control	—N	—P	—K	—Ca	—Mg	—S	—Fe
Nitrogen	105	—	105	105	105	105	105	105
Phosphorus	21	21	—	21	21	21	21	21
Potassium	99	98	98	—	98	98	98	98
Calcium	100	100	100	100	—	100	100	100
Magnesium	18	18	18	18	18	—	18	18
Sulphur	99	145	109	59	99	75	—	99
Iron	2.8	2.8	2.8	2.8	2.8	2.8	2.8	—

(c) *Micronutrients in parts per million (supplied to all treatments)*

Manganese sulphate	—	(0.275Mn)
Copper sulphate, 5H <sub>2</sub> O	—	(0.032 Cu)
Zinc sulphate, 7H <sub>2</sub> O	—	(0.0325 Zn)
Boric acid	—	(0.185 B)
Ammonium molybdate, 4H <sub>2</sub> O	—	(0.0095 Mo)
Cobalt sulphate, 7H <sub>2</sub> O	—	(0.003 Co)
Sodium chloride	—	(1.775 Cl)

In composing nutrient solutions deficient in single elements, various complications are encountered and two main precautions need to be observed. These are :

- (a) to replace the accompanying ion in appropriate form and amount, and
- (b) in doing so, to avoid the inclusion of any ion in the replacing salt that could itself affect the performance of the plant.

It is inherently impossible to exclude a single element without any alteration of the content of other elements. A complete identity of all other elements is not possible and some compromise has to be accepted.

The common forms in which soluble salts are available are as chlorides, nitrates and sulphates. The chloride ion, if present in excess causes toxicity problems. The nitrate ion, through its supply of nitrogen, itself affects growth. The sulphate ion is considered relatively "safe" and inert. It is generally the preferred "accompanying ion" in plant nutrition studies. Where possible, therefore, sulphates are used as replacement salts. It will accordingly be seen in Table 1 (b) that the sulphur content is selected as the inevitable variable component in the test solutions.

Bearing these points in mind, a few selected examples will illustrate the manner in which the nutrient elements are balanced.

(i) Where nitrogen is to be excluded, the two supplying salts ammonium sulphate and calcium nitrate are omitted. In addition to nitrogen, this also removes a quantity of the sulphate ion and calcium. As sulphate is probably already available in ample amount through its supply from other salts in the mixture, no effort is made to replace the exact amount removed. The calcium removed is supplied in the form of calcium sulphate.

(ii) Where phosphorus is to be deficient, the sodium dihydrogen phosphate is excluded but the sodium thereby removed is replaced by the supply of an appropriate amount of sodium sulphate.

(iii) Where potassium or magnesium is to be excluded, the respective sulphates are omitted and no special effort is required to replace the sulphur so excluded.

(iv) Where calcium is to be excluded, the nitrate removed cannot be made good without bringing in excessive amounts of some other metallic ion. It is convenient in this case, to exclude both calcium nitrate and magnesium sulphate and to supply an appropriate amount of magnesium nitrate instead, when both the nitrate and magnesium are supplied at the levels required.

(v) Where sulphur is to be excluded, sulphates of ammonium, potassium, magnesium and aluminium have all to be omitted. Appropriate amounts of the accompanying elements are supplied by employing the required amounts of magnesium nitrate, potassium nitrate, and aluminium chloride. In this treatment we were obliged to supply all the nitrogen required in the form of nitrate. Further, chlorides of the micronutrient elements were used in place of the corresponding sulphates.

As indicated in Table 1 (b) careful regulation of the amounts of the replacement salts employed ensures that all but the excluded element in each case is held in exact balance. As explained earlier, the amount of sulphur supplied is the exception.

## RESULTS

### (a) *Description of deficiency symptoms*

The descriptions of symptoms caused by extreme deficiencies of each of the nutrient elements tested, are based primarily on the results of Experiment I with clone CY9. The observations on the four other clones tested in Experiment II were generally the same. Any deviations from this symptom pattern, that is exhibited by particular clones are specifically mentioned.

It has proved extremely difficult to depict with complete accuracy in the colour plates, the symptoms shown by the plants. A certain amount of accuracy in colour, tone and detail is lost in the original photograph and a further loss occurs in the reproduction as colour plates. Despite these limitations, it is hoped that the plates have brought out the salient features and that in conjunction with the descriptions, an accurate picture of the deficiency symptoms will emerge.

## Nitrogen

Nitrogen was the element whose deficiency produced the earliest symptoms. Within four weeks of commencement of the treatment, plants showed a generalised paler colour of leaves. Over-all growth was markedly slowed down and by a further four weeks all these plants were banji. There followed a considerable production of flower buds at the nodes. The plants remained stunted, the apical banji being nearly permanent and little or no branching occurred. There followed a rapid loss of mature leaves and a decline and debilitation of the plants.

Along with the yellowing of leaves, there is a pronounced lack of lustre. In texture, the leaves become rough and hard. Leaf size is reduced.

In Figure 1, the leaf at the right shows the early stage of generalised yellowing while on the left is an older leaf showing more advanced symptoms. The brown areas of dead tissue commence as a large number of small dying patches which expand into larger areas. The leaf generally drops at this stage.

The symptom of pinkish-yellow flush described earlier as an effect of nitrogen deficiency (Mulder and Visser 1960) for clone TRI 2024, was shown only by this clone among the five clones tested. Field observations suggest that this particular symptom is confined to clones TRI 2024 and TRI 2023 and perhaps a few others. TRI 2025, 2027, DTI, TC9 and CY9 were clones tested and shown not to display this symptom.

The powers of recovery of tea plants with even acute nitrogen deficiency symptoms are striking. Within two weeks of return to a solution containing nitrogen, the green colour of leaves is restored and vigorous growth commences.

## Phosphorus

Omission of this element has failed to produce any characteristic symptoms. It has been reported (Tea Research Institute of East Africa 1969) that a loss of glossiness of the older leaves and death of branches are characteristic symptoms.

In the present experiments, plants grown without phosphorus showed no adverse effects and overall growth was as good as in the controls. There was a slight suggestion that the more mature leaves appeared a darker bluish-green but this could not be confirmed.

## Potassium

In our experiments, potassium deficiency symptoms become evident within about 4 to 4½ months from commencement of treatment.

There are interesting clonal differences in the manifestation of deficiency symptoms. In the majority of the clones tested (CY9, DTI, TC9 and TRI 2027), the sequence is as follows :— Fully expanded leaves of medium age show a scorching of the tips. This is followed by the typical marginal scorch characteristic of potassium deficiency (Portsmouth 1953). Some of the leaves show a pronounced purple colour (bronzing) over the entire leaf blade. This is most evident on the underside of the leaf (see the centre leaf in Figure 2). The marginal necrosis is followed by drying of the margins to a papery consistency. Saprophytic fungi are often seen to have colonized these dead patches. It was suspected that in the complete absence of potassium, even relatively small amounts of sodium (supplied as sodium dihydrogen phosphate) aggravates these leaf symptoms. Confirmatory evidence of this



FIG. 1 — Nitrogen deficiency—Control leaf (centre) flanked by leaves showing extreme deficiency (left) and milder deficiency (right)



FIG. 2 — Potassium deficiency—Early stage of deficiency (centre) flanked by advanced stages (left and right) of symptom development



FIG. 3—*Potassium deficiency*—Leaf of Clone TRI 2024 showing marginal yellowing, an early symptom



FIG. 4—*Calcium deficiency*—progressive increase in severity of symptoms (from right to left)



FIG. 5—*Magnesium deficiency—Faint interveinal chlorosis in mature leaves of clone TRI 2024*



FIG. 6—*Sulphur deficiency—Younger leaves showing pronounced interveinal chlorosis*

has been obtained in a subsequent experiment. Although the overall size of the plant is not evidently affected by potassium deficiency, it is very apparent that development of wood is markedly reduced and the stems remain sparse and slender.

In the case of clones TRI 2024 and TRI 2025, in addition to the symptoms described above, the young leaves are also simultaneously affected. The margins of these leaves are paler in colour and show a very marked smoothening of the surface and appear to be abnormally stretched while the central portions of the leaf blade are puckered and thrown into marked folds. At a slightly later stage, the margins are very obviously chlorotic (Figure 3). The yellow margins subsequently show the typical scorch.

The size of leaves is greatly reduced in potassium deficient plants and leaf deformation is also common.

Return of deficient plants with advanced symptoms to a nutrient supply including potassium, readily restored normal growth, although the already affected mature leaves naturally showed no signs of improvement. New leaves produced were normal.

### Calcium

Symptoms of calcium deficiency are strikingly manifested in two regions of the plant—the leaves and the stem apex.

Deficient plants are stunted and within 3 to 3½ months, symptoms begin to appear on the leaves. One of the earliest signs was a strong recurving of the leaves, downwards along the stem axis. At the same time, the leaf blade became boat-shaped with the upper surface on the convex side. The leaves thickened and became brittle in texture. The most characteristic symptom which followed was a development of large numbers of small translucent spots on the undersides of the newly formed leaves. These resembled "oil-spots" and gradually enlarged and coalesced into water-soaked areas which subsequently became necrotic and still later dried up.

Following the leaf symptoms, there were signs of considerable interference with apical activity. The growing points either died or produced very small deformed leaves which themselves showed the symptoms described. Figure 4 illustrates the progressive pattern of symptom development. For ease and clarity of depiction, leaves with minimum deformity have been selected.

Restoration of a calcium containing nutrient solution quickly caused a commencement of normal growth. The new organs formed were of normal appearance although the symptoms already produced in the maturing leaves were not cured.

### Magnesium

Mulder and De Silva (1959) described an interveinal or generalized chlorosis of the older leaves as the characteristic symptoms of magnesium deficiency. Their observations were confirmed in the case of clones TRI 2024 and TRI 2027 tested in the present experiments.

However, the other clones (CY9, TC9 and DT1) which could be considered of lower jat, did not show these symptoms. Instead, there was a very obvious premature shedding of the lower leaves and within a relatively short time the plants were completely defoliated with the exception of small tufts of young leaves at the branch

ends. Growth is very markedly reduced. Analyses of some of these shed leaves revealed magnesium contents as low as 0.02 to 0.09% (normal levels are 0.3 to 0.5%). The leaves of deficient plants are noticeably pale in colour. Affected plants die relatively rapidly if not supplied with a nutrient solution including magnesium.

Figure 5 illustrates the symptoms of interveinal chlorosis in clone TRI 2024 with the veins standing out clearly in a darker green colour. The leaves were hard and brittle.

### **Sulphur**

Symptoms of sulphur deficiency appeared within 3 to 4 months of commencement of treatment.

Plants deprived of sulphur show leaf symptoms which resemble to some extent, those caused by nitrogen deficiency. They include a general yellowing of the leaves and a decrease of leaf size. However, in the case of this deficiency, the younger leaves are usually affected before older ones, contrasting with the generalised yellowing of all leaves on the plant in the case of nitrogen deficiency. A very characteristic symptom of sulphur deficiency is a "net veining", particularly of the younger leaves. While the leaf blade takes on a strikingly yellow colour, the veins down to the finest branchings, stand out prominently in a dark green colour (Figure 6). The young shoots assume a prominent yellow colour and constitute an easily recognizable feature of sulphur deficiency. If the deficiency remains uncorrected for a long time, the yellowed leaves finally show necrosis of tips and margins with subsequent defoliation.

All the clones tested showed the same general symptoms. Sulphur deficiency is easily corrected by supply of the element lacking.

### **Iron**

We were unable to obtain any symptoms in the experimental plants deprived of this element.

#### **(b) *Chemical analyses of leaf samples***

With the kind collaboration of the Agricultural Chemistry Division, analyses of leaf samples were carried out for relevant elements for which analytical facilities are available. Sulphur analyses could not be done.

Samples of appropriate leaves were collected from plants showing acute symptoms of individual nutrient deficiencies. Complete nutrient solutions were restored to a replicate batch and further samples were obtained when the plants showed evidence of complete recovery from the deficiency. Dried and stored samples were used for the analyses.

Table 2 (a) gives the contents of each element on leaf samples from deficient plants and controls. In Table 2 (b) are presented the values from plants that have recovered from some of the respective deficiencies.

TABLE 2 — Analyses of leaf samples—All figures are expressed as percentage of the element under consideration, based on dry weight of the sample

(a) Nutrient contents in samples from deficient plants

Treatment	Leaves Sampled	% N	% P	% K	% Ca	% Mg
Control	Mature	3.83	0.28	1.88	0.68	0.26
Nitrogen deficient	Young	2.59*	0.51	6.00	0.48	0.44
Phosphorus "	Mature	3.82	0.08*	1.22	0.48	0.27
Potassium "	Mature	4.34	0.54	0.19*	0.56	0.48
Calcium "	Mature	4.96	0.21	2.00	0.09*	0.45
Magnesium "	Dropped	4.58	0.76	1.56	0.68	0.02*
Sulphur "	Young	4.98	0.18	2.76	0.56	0.35
—do—	Mature	3.95	0.34	1.38	1.13	0.50

\* denotes the deficient element

(b) Nutrient contents in samples from plants that have recovered from deficiencies

Treatment	Leaves sampled	% N	% P	% K	% Ca	% Mg
Phosphorus deficient	New	3.92	0.26*	1.94	0.48	0.24
Potassium "	New	4.44	0.33	2.09*	0.48	0.40
Calcium "	New	4.35	0.28	2.31	0.31*	0.30
Sulphur "	New, young	4.68	0.26	3.00	0.44	0.24
—do—	New, mature	4.47	0.75	1.44	0.81	0.50

\* denotes element previously deficient

It will be seen that these data confirm the low levels of the respective elements in deficient plants. It is evident that the level of one element may strongly influence the uptake of another. For example, there are apparently high levels of potassium in nitrogen deficient plants. However, as only a few samples were analysed and as such considerations have little bearing on the subject of this paper, detailed reference is excluded. *high levels of Ca with S def. ?*

It is apparent that the plants displaying visible signs of recovery from deficiency, have also built up leaf contents of the element concerned to levels of adequacy.

## DISCUSSION

Of the elements for which deficiency symptoms have been described in this paper, the only ones that have been observed in the field are those of nitrogen, potassium and magnesium.

Sulphur is apparently normally supplied in adequate amount as an accompanying element where sulphate of ammonia is the normal form of nitrogen supply. With the generally increasing use of urea, the possible appearance of this deficiency needs to be anticipated. Calcium which is generally of great importance for sustaining apical activity (which is of paramount importance to a crop like tea), perhaps is amply supplied by the use of saphosphosphate and dolomite as traditional fertilizer components. Prolonged omission of the use of calcium containing phosphatic fertilizers may result in the appearance of calcium deficiency symptoms.

The failure to obtain specific symptoms of phosphorus and iron deficiencies is interesting, although unlikely to be of practical significance as these two elements are generally detectable in ample amounts in tea soils. Although phosphate levels in the leaf samples from the deficiency treatment are demonstrably low, it is not unlikely that it enters as a contaminant from slowly released forms in the sand used in the experiments, and as a dust originating from a fertilizer store in the vicinity of the glasshouse. A further trial with appropriate precautions seems warranted.

The specific deficiency symptoms obtained with tea are compatible with the known physiological functions of each element.

Thus nitrogen is necessary for the production of vital proteins, chlorophyll and other biologically important compounds. Its absence results in stunted growth and yellow, chlorophyll deficient leaves. The premature senescence of leaves arises out of the disorganisation of protein metabolism and perhaps of the formation of other important compounds.

The earlier reported symptom of pinkish flush as a symptom of nitrogen deficiency (Mulder & Visser 1960) for clone TRI 2024, has been confirmed in these experiments. However, this does not appear to be a general symptom. Certain clones (TRI 2024, 2023 and a few others) display this symptom. The immediate cause is the formation of a purple coloured pigment called anthocyanin. The predisposition of clones of the TRI "2020 series" to form this pigment probably arises genetically through the fact that one of the parents was a pigmented clone. It is believed that localised accumulation of sugars is related to the production of anthocyanin (eg see Nagarajah and Pethiyagoda 1965, p.96). Thus, apart from nitrogen deficiency, pinkish colourations have been noted to occur during periods of cold, drought or from such causes as ring-barking. In these cases, sugars presumably accumulate in the leaves due to a failure of translocation or utilization for the synthesis of other compounds like proteins. Absence of nitrogen would clearly affect the latter. Evidence indicates that most clones and seedling plants will not produce pink flush as a result of nitrogen deficiency.

Potassium performs a hitherto unspecified but nevertheless vital role in living tissues. Interference with normal functioning of leaf cells must account for death of the tissues as reflected by the marginal scorch on leaves.

Calcium enters into the formation of plant cell walls, in the form of calcium pectate. It is considered a relatively immobile element within the plant and symptoms normally appear in the later formed organs, once limited supplies available are used up by the earlier formed ones. However, the appearance of translucent patches, even in relatively mature leaves, is suggestive of a breakdown of cell wall structures. Results of examinations of thin sections under the microscope, although insufficient to establish this, were very suggestive. If this were so, it would seem that the calcium in already formed cell walls is being remobilised for use in the newly forming leaves. More elegant techniques to check this possibility are clearly desirable.

Magnesium is required for the synthesis of the green leaf pigment chlorophyll. In its absence, leaves become paler and in the case of some clones, the chlorophyll deficient tissues show a particular distribution as interveinal areas (Mulder & De Silva 1959). In the majority of tea clones and seedling plants, however, there is no recognizable pattern of chlorosis and the leaves are prematurely shed. This is consistent with the normal response of woody perennials to magnesium deficiency, although perhaps the first record for tea. Frequently reported instances from estates, of prominent defoliation, although it may arise from other causes too, may be related to the availability of this element.

Sulphur deficiency also interferes with chlorophyll production in the young leaves and thus results in the characteristic striking chlorosis with "net-veining".

### SUMMARY

This paper deals with the specific leaf and other symptoms arising when each of the major nutrient elements normally absorbed by the roots, are excluded singly from a nutrient solution.

Analyses of leaves confirm the low levels of the particular elements associated with the appearance of diagnostic symptoms.

An attempt is made to summarise the symptoms caused by the deficiencies of each of the elements studied, in the key below :-

#### *Key to the identification of major element deficiencies in tea*

<i>Overall growth</i>	<i>Chlorosis (yellowing)</i>	<i>Other symptoms</i>	<i>Deficient element</i>
Stunted	Generalised	Banji; flowering; older leaves show necrotic patches and drop prematurely.	Nitrogen
	Not evident	Leaves droop backwards; deformed, boat shaped; "oil spots" leading to necrotic patches. Apical death or production of small leaves.	Calcium
Apparently little affected	Generalised	Premature shedding of old leaves. Thin wood. Chlorosis may be in a distinct interveinal pattern in the lower leaves.	Magnesium
		Yellow flush. Leaves clearly net-veined. Symptoms most prominent on young leaves.	Sulphur
	Not evident	Tip and marginal scorch of older leaves; occasional deformities. Thin wood. Sometimes "bronzing" of leaves. Some clones show a marginal smoothening and chlorosis of young leaves.	Potassium
		No decisive symptoms. A lack of lustre and dark bluish-green colour of lower leaves ?	Phosphorus

No symptoms were obtained for iron deficiency.

## ACKNOWLEDGEMENTS

Our thanks are expressed to Mr S. Nagarajah for collaboration in the early stages of this work. To the Superintendent of Aislaby Estate, Bandarawela for the supply of the sand. To Mr D. J. M. Hettiarachchi for preparing the photographs and to Dr E. M. Chenery for his close interest and advice in the course of this work. We are also indebted to the Agricultural Chemistry Division for the analysis of leaf samples.

## REFERENCES

- ANON. (1949). *Hunger signs in crops*. The American Society of Agronomy and The National Fertilizer Association, Washington, DC, 390 pp.
- DE HAAN, I. & SCHOOREL, A. F. (1940). Potash deficiency in the tea culture. *Arch. Theecult. Ned. - Ind.* 14, 43-81. (Dutch with English summary).
- DE HAAN, I. (1941). Deficiency-symptoms on tea, caused by an insufficient supply with the most important nutrient elements except potassium. *Arch. Theecult. Ned. - Ind.* 15, 1-32. (Dutch with English summary).
- MULDER, D. & DE SILVA, R. L. (1959). Deficiency diseases and the symptoms of magnesium deficiency. *Tea Q.* 30, 1-9.
- MULDER, D. & VISSER, T. (1960). Nitrogen deficiency in clonal plants. *Tea Q.* 31, 153-155.
- NAGARAJAH, S. & PETHIYAGODA, U. (1965). The influence of 'lungs' on carbohydrate reserves and growth of shoots. *Tea Q.* 36, 88-102.
- PETHIYAGODA, U., KRISHNAPILLAI, S. & NAGARAJAH, S. (1969). Studies in the mineral nutrition of tea. 1—Techniques for growing tea plants in sand culture. *Tea Q.* 40, 145-152.
- PORTSMOUTH, G. B. (1953). Potash deficiency in tea. *Tea Q.* 24, 79-81.
- STOREY, H. H. & LEACH, R. (1933). A sulphur deficiency disease of the tea bush. *Ann. appl. Biol.* 20, 23-55.
- TEA RESEARCH INSTITUTE OF EAST AFRICA. (1969). *Tea Growers Hand-book 1969*, 152 pp.
- TOLHURST, J. A. H. (1962). Zinc deficiency of tea in Ceylon. *Tea Q.* 33, 134-137.
- TOLHURST, J. A. H. (1963). Manganese deficiency symptoms of tea. *Tea Q.* 34, 148-149.
- WALLACE, T. (1951). *The diagnosis of mineral deficiencies in plants by visual symptoms*. H.M. Stationery Office, London, 107 pp. + 312 col. plates.