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THE USE OF FERTILIZER FOR TEA IN SRI LANKA

2—FOLIAR AND SOIL ANALYSIS WITH PARTICULAR REFERENCE TO POTASSIUM

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With increasing levels of K application to soil, the K content in the foliage of tea plants increased. The increase was marked from level zero potassium (K_0) to K_1 (84 Kg/ha/annum) but was not so sharp up to level K_2 (168 Kg/ha/annum). Yields showed a similar trend. The difference in the K content was greatest in the mature leaf indicating that it was more sensitive to K supply than either the bud or the third leaf. Water-soluble soil K was better correlated with K requirements of the plant than either exchangeable or total K. With increasing levels of K applied to soil, the Mg content increased in the bud, but decreased in the mature leaf. An increase in the soil water-soluble magnesium enhanced K uptake by the foliage. Chemical analysis of the mature leaf, rather than the third leaf or bud would be preferable as it would be a more reliable index of the needs of the tea plant for Mg. Mg deficiency symptoms can occur due to a lack of soil Mg, or due to an excess of K, despite the presence of adequate Mg, in the soil.

INTRODUCTION

In the first article in this series (Sivasubramaniam 1972) the use of NPK fertilizer for tea in Sri Lanka, based on results from field experiments over the last four decades was reviewed. In addition to field experiments, both foliar and soil analytical data from field experiments have also been used in understanding the complexity of tea nutrition and in formulating fertilizer practices for tea. This involved a thorough examination of several parameters such as the effect of climate, soil type, age of leaf analysed, time of application, genetic constitution of cultivars, vigour of growth, time of sampling and type of organ to be sampled. In order to use foliar analysis to predict fertilizer requirements or to investigate the nutritional status of any crop the most important factor is the type of tissue or organ selected for chemical analysis. From a practical point of view, the choice may be determined primarily, by the nature of the plant, the cultural practices and the methods of harvesting. Thus the organ selected, in addition to being sensitive to nutritional changes, should also be large enough to provide a sample of the required quantity and should contain the nutrient under investigation in quantities sufficient for analysis.

From data obtained by chemical analysis of tea leaves of different physiological age over several years (Tolhurst, unpublished) found that the mineral content of the first mature leaf, *i.e.*, the leaf from the axil of which the present pluckable shoot has emerged, varied the least under the influence of changing environmental conditions. Hasselo (1965) analysed tea leaves of increasing age and concluded that the mature leaf provided a better index of the nutritional status of tea plants grown under a wide range of environmental conditions than leaves above the plucking table. Wilson (1969) however, claims that chemical analysis of the bud and third leaf provides a better index of the fertilizer requirements of the tea plant. In order to test the validity of this claim, the bud, the third and the mature leaves were sampled, together with soils, from a long-term experiment at the Tea Research Institute of Sri Lanka, Talawakele (1200 m amsl). The data obtained from the analyses are presented and discussed with special reference to sensitivity of the type of organ to K and Mg absorption as influenced by NPK manuring.

METHODS AND MATERIALS

Field Experiment

The experimental design was a 3^3 factorial replicated twice, laid out in 1931 (Eden, 1931) on low jat seedling tea with plot sizes of 335 m^2. The soil was mainly kaolinitic and ranged from loam to clay loam.

1—Leaf sampling

A bud, a third leaf, and a mature leaf were sampled from each plant in the plot. Samples were quickly wiped with cotton wool dipped in distilled water and samples dried overnight in an oven at 100° C. These were crushed and ground to pass through a sieve whose aperture was 0.425 mm and stored in glass vials.

2—Soil Sampling

About ten sites were sampled from each plot using a posthole auger to a depth of 15 cm from the surface. Care was taken to avoid samples near drains or ravines. After thoroughly mixing all the samples, a subsample was taken for chemical analysis. Prior to chemical analysis, the subsamples were air-dried in the laboratory, crushed lightly with a rubber-tipped pestle and sieved through a 2 mm mesh.

Methods of chemical analysis

1—Leaf samples

Portions of the oven dried samples of 0.4 g each were ashed overnight at 450° C, dissolved in the minimum quantity of a digestion mixture (50 ml distilled water, 25 ml conc. HCl and 25 ml conc. HNO_3) evaporated to dryness and subsequently dissolved in exactly 25 ml of 0.05 N HCl. K was estimated by flame photometry and Mg by atomic absorption spectrophotometry.

2—Soil samples

Water - soluble cations

Portions of the air-dried samples of 100 g each were weighed into shaking bottles and 100 ml of distilled water were added to each. These were shaken for 24 h in a reciprocating machine, filtered into dry receivers and analyses carried out as outlined for leaf samples. Moisture was determined on separate samples and all values expressed on an oven-dried basis. K and Mg values so obtained represent the water-soluble fractions.

Exchangeable cations

Portions of the air-dried soils of 10 g each were weighed into shaking bottles and the soluble salts removed with 40% v/v ethanol. Thereafter 100 ml N NH_4Cl were added to each and the contents were shaken overnight. After filtration chemical analysis was carried out on the filtrate as outlined earlier.

RESULTS AND DISCUSSION

Leaf and soil potassium

Table 1 gives the K content in the three types of organs sampled for the three levels of potash applied to the soil.

TABLE 1 — *Mean K content of organs from plants given three levels of K*

Level of K applied (Kg K_2O/ha/annum)	K content % Type of organ		
	Bud	3rd leaf	mature leaf
K_0 (O)	1.73	1.38	0.98
K_1 (84)	2.02	1.79	1.71
K_2 (168)	2.11	1.91	1.94
LSD ($P = 0.05$)	0.12	0.08	0.10
($P = 0.01$)	0.16	0.10	0.14
($P = 0.0001$)	0.22	0.13	0.18

Table 1 shows that the K content of each type of organ increased with increasing levels of K applied to soil. This increase was marked between levels K_0 and K_1 but not so pronounced between levels K_1 and K_2. The effect of application of the three levels of K_2O on the yield of made tea at the end of the 12th cycle is given in Table 2.

TABLE 2 — *Yield response to K for the 12th cycle*

Level of K (Kg K_2O /ha/annum)	Yield (Kg/ha/annum)
K_0 (O)	715
K_1 (84)	1564
K_2 (168)	1543
LSD ($P = 0.05$)	122
($P = 0.01$)	163
($P = 0.001$)	213

As shown in Table 2, a response was obtained between level K_0 and K_1 but there was a depression in yield between level K_1 and K_2. A similar trend in the response to higher levels of potash has been observed not only in Eden's experiment at St Coombs but also in many others both on clonal and seedling tea (Manipura 1971; Wettasinghe 1971).

Thus crop yield did not respond to K treatment beyond level K_1 and any further increase in K application to soil resulted in the plant absorbing K without any increase in yield, indicating luxury consumption. It is further observed that the difference between the K content in each type of organ at the various levels of K applied was greatest in the mature leaf, indicating that the mature leaf was more sensitive to changes in soil K than either the bud or the third leaf.

Table 3 gives the various forms of soil potassium for the three levels of potash applied.

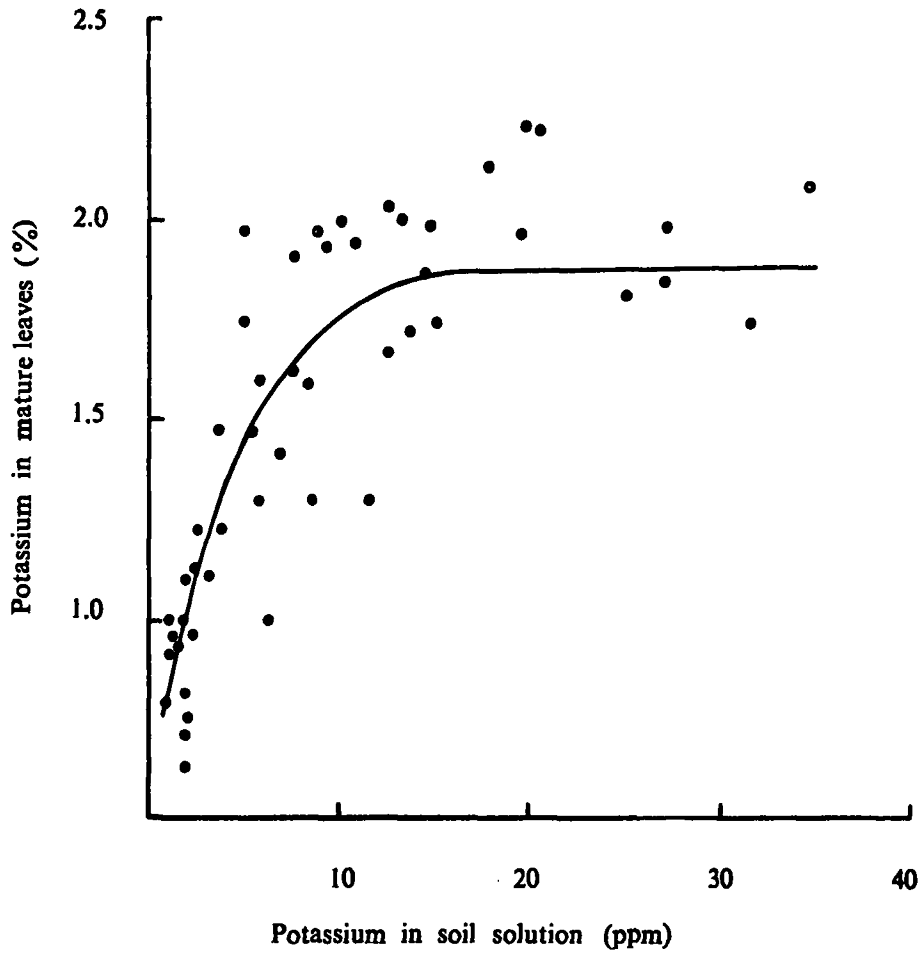

FIG. 1 — *Relationship between potassium in soil solution and that in mature leaves*

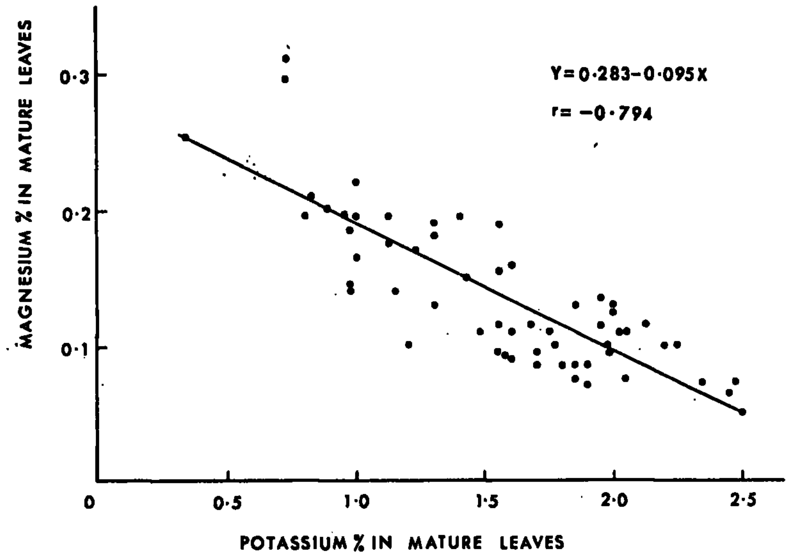

FIG. 2 — *Relationship between potassium in mature leaves and magnesium in mature leaves*

TABLE 3 — *K content in soil at 3 levels of K application*

Level of K applied (Kg K_2O /ha/annum)	K content in soil (ppm) Water-soluble K	Exchangeable K	Total K	Inert K
K_0 (0)	2.4	49.4	4730	4680
K_1 (84)	11.8	107.4	4880	4973
K_2 (168)	17.6	141.1	5170	5030

Water-soluble, exchangeable and total K in soil increased with increasing levels of K applied to soil, and the increase was more marked from level K_0 to K_1, especially in the water-soluble fraction. The soil in this experiment consisted largely of the 1:1 lattice type clay mineral and K feldspar together with other weatherable minerals such as micas, and ferro-magnesian minerals such as hornblende and biotite. These latter minerals are of the 2:1 lattice type and are capable of K fixation to an appreciable extent. This is seen from the total K content, where the application of K has appreciably altered the reserve inert K (Table 3). It will also be seen that the plots that did not receive any K over the same period, had a fair quantity of total and reserve inert K. Cushman (1907) showed that K feldspars containing 10 % K_2O yielded only 0.25% K_2O to water and 0.036% K_2O to dilute acids. It is therefore possible that the water-soluble K (2.4 ppm) in the plots that did not receive K, for about 40 years, was derived from the reserve inert K. In these plots the plants began to show K deficiency symptoms and drop in yield 12 years after the experiment was begun (Eden 1949). A possible explanation could be that in a soil where K release is slow, continuous cropping could result in the exhaustion of K in solution. It can be concluded therefore, that in these plots where water-soluble K was only 2.4 ppm, the requirements of the plant for K were not fully satisfied, although the exchangeable K was 49 ppm. Although an equilibrium exists between water-soluble and exchangeable K, the latter may not be the best indicator of K availability for plant uptake.

Fig. 1 shows the relationship between water-soluble K and the K content in the mature leaf. It is seen that the leaf K reached a maximim value when the water-soluble K content was about 12 ppm and this figure closely corresponds with 84 Kg K_2O /ha/annum, *i.e.* level K_1. It was mentioned earlier that beyond level K_1 there was no yield increase, although the K in solution increased with increase in the level of K applied. This would mean that beyond level K_1, K application was unwarranted and supraoptimal.

Leaf and soil magnesium

The magnesium content in the various organs for the three levels of K applied are presented in Table 4.

TABLE 4 — *Magnesium content in various organs at 3 levels of application of K*

Level of K applied (Kg K_2O/ha/annum)	Mg content in various organs (%) Bud	Third leaf	Mature leaf
K_0	0.172	0.188	0.189
K_1	0.187	0.173	0.117
K_2	0.199	0.182	0.113
LSD (P=0.05)	0.018	0.011	0.033

In the bud, with increasing K application, the Mg content increased. In the third leaf the Mg content decreased significantly with increasing K from K_0 to K_1 and the Mg content increased from level K_1 to K_2. The Mg content in the mature leaf decreased significantly with increasing levels of K applied.

Fig. 2 shows the K content in the mature leaf in relation to the Mg content in the same organ. The relationship was negative and was significant. For the bud samples the relationship was found to be positive but was not significant. From Table 3, it is seen that with increasing levels of K applied, the K content in the water-soluble and exchangeable fractions also increased and it is possible that this K exerted an antagonistic effect on Mg uptake by the plant. When a stress upon the Mg uptake is imposed by increasing the soluble K concentration in the soil, the Mg required by the growing bud must be supplied from the reserve in the older leaves. In such a case, Mg deficiency will be shown not by the bud, but by the mature leaves.

When K was not applied (K_0) the Mg content increased slightly with increasing maturity of the foliage but with K application the trend was reversed (Table 4). Hasselo (1965) observed that the older leaves tended to give higher Mg values than the younger leaves and pointed out that this was contrary to what was found in other crops, *e.g.*, oil palm. He concluded that this might be an indication that the plant was absorbing Mg in excess of its requirements resulting in the accumulation of Mg in the older leaves. Our data supported Hasselo's observation only when there was no K applied to the soil, *i.e.*, when plants were able to absorb Mg without any antagonistic effect from soil K.

In Sri Lanka dolomite is broadcast after tea plants are pruned and this helps replenish the supply of Ca and Mg. A plot of the K content in the mature leaf against the water-soluble soil Mg was found to be positive ($Y = 0.341 \times 1.164$, $r = +0.22$) but not significant. This positive relationship was surprising because of the accepted belief of the K $\times$ Mg antagonism. However, because of the positive correlation obtained it may be concluded that soluble Mg in soil stimulated the uptake of K. Omar and El Khobia (1966) working with lucerne in sand culture also observed that the K content in the foliage increased with increasing Mg concentration in soil and proportionately decreased the Mg content in the foliage. They concluded that this effect was the result of competition for metabolically-produced binding compounds, and the fact that Mg had no effect on the K content in the foliage was attributed to the stimulating effect of Mg on K absorption by the plant.

For the purpose of predicting the Mg requirements of the plant, the first mature leaf is, therefore, the best organ to be sampled for chemical analysis. However, the interpretation of the leaf Mg content thus obtained could be best made if the water extract of the soil is also analysed simultaneously. It must be stressed that Mg deficiency sym ptoms could result either from a lack of soil Mg or due to an excess K, despite the presence of adequate Mg, in the soil.

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