

## EFFECT OF NITROGEN, PHOSPHORUS, POTASSIUM AND MAGNESIUM FERTILIZERS ON THE LEAF NUTRIENT COMPOSITION OF LOW-GROWN TEA IN SRI LANKA

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The influence of N, P, K and Mg fertilizers on the N, P, K, Mg, Ca and Mn content of tea leaves was studied by analysis of leaf samples obtained from five long-term fertilizer experiments conducted on clonal tea in the lowlands of Sri Lanka. The application of N, P, K and Mg fertilizers increased the content of these elements in the leaf. A decrease in the content of leaf K was caused by N and Mg fertilizers; leaf Mg by N and K fertilizers, and leaf Ca by K and Mg fertilizers. N fertilizer increased leaf Mn, and P fertilizers on the leaf content of the other elements studied was either not consistent or not significant. Luxury consumption of N, P, K and Mg by the tea plant was evident.

### INTRODUCTION

Leaf analysis or foliar diagnosis is one of the techniques used to assess the nutritional requirements of a crop. In this method, the concentration of nutrients in the leaves is related to the level of productivity of the crop. This is done by establishing a critical level for each nutrient. Prevot and Ollagnier (1945) in their classical studies on oil palm defined the critical level as "the concentration of the element in the leaf (dry matter basis) above which a yield response from the element in the fertilizer is unlikely to occur". In other words, attainment of the critical level would maximise yield. Wettasinghe (1975) has shown that the nitrogen fertilizer level required to obtain maximum yields in tea in the lowlands of Sri Lanka was uneconomic at the prevailing fertilizer prices. For the purpose of advising growers, it would therefore be necessary to determine the leaf nutrient levels related to the optimal level of production which, of course, would vary according to the cost of fertilizer and other costs of production and the selling price of the product. This means, in situations where the trading conditions are not stable, it would be necessary to establish leaf nutrient concentrations at various levels of production, and the optimum leaf nutrient concentration at a given time would be related to the optimal level of production at that time.

Leaf analysis has been used for determining the nutrient status and, as a guide to fertilizer usage, in several crops — e.g. apple (Bould, 1966), peanuts and oil palm (Prevot and Ollagnier, 1954), sugar cane (Clements, 1961) and rubber (Watson, 1963). With tea, Lin (1969) working in Taiwan reported that the N, P and K concentrations in the leaf were correlated with yield and proposed critical levels of these nutrients. In the USSR, Zuhrbatikii and Shtrausberg (1963), Pritula (1967) and Burculadze (1970) showed that tea yields were correlated with leaf levels of N and K; N, P and K and N

respectively. Optimum levels of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O in the leaf were proposed by Ahmetov and Bairomov (1968). In East Africa, Willson (1969) reported critical levels for leaf N, P and K. These were later modified by Tolhurst (1970).

The nutrient concentration in leaves is influenced by several factors, such as, maturity of the leaf, cultivar, season of sampling, nutrient supply, location, etc. A study of the influence of these various factors on the leaf nutrient content is a prerequisite to the use of the leaf analysis technique to diagnose the nutritional status of tea plants. The influence of the age of the leaf and its position on the plucking table was studied by Hasselo (1965) and this led to the standardization of the tissues selected for analysis in Sri Lanka. The authors studied the influence of various fertilizer treatments on the leaf nutrient composition of clonal tea grown in the lowlands of Sri Lanka. The effect of N, P, K and Mg fertilizers is reported in this paper.

### MATERIALS AND METHODS

The samples for analysis were drawn from five fertilizer trials. The fertilizer treatments and other relevant details of these trials are shown in Table 1. Mature leaf, from the plucking table, with a pluckable shoot in the axil was the tissue taken for analysis (Hasselo, 1965). One or two leaves were taken from each bush to provide a composite sample of 50 - 100 leaves per plot.

TABLE 1 — *Design, Fertilizer Treatments and Location of the Trials from which Leaf Samples were drawn*

<i>Experiment</i>	<i>LA 28</i>	<i>LA 31</i>	<i>LA 24</i>	<i>LA 2</i>	<i>LA 4</i>
<i>Design</i>	<i>3<sup>5</sup> Factorial 1/3rd Replicate</i>	<i>3<sup>4</sup> Factorial Single Replicate</i>	<i>3<sup>4</sup> Factorial Single Replicate</i>	<i>3<sup>4</sup> Factorial Single Replicate</i>	<i>3<sup>5</sup> Factorial 1/3rd Replicate</i>
<i>Clone</i>	<i>TRI 2026</i>	<i>TRI 2026</i>	<i>TRI 2023</i>	<i>TRI 2023</i>	<i>TRI 2023</i>
<i>Location</i>	<i>Hapugastenne Estate, Ratnapura</i>	<i>Talangaha Estate, Galle</i>	<i>Deniyaya Estate, Deniyaya</i>	<i>Palmgarden Estate, Ratnapura</i>	<i>TRI Sub-station, Galle</i>
<i>N</i> (kg/ha/yr)	0 1 2	270 405 540	170 340 510	180 360 540	85 170 255
<i>P<sub>2</sub>O<sub>5</sub></i> (kg/ha/yr)	0 1 2	0 35 70	— — —	— — —	0 35 70
<i>K<sub>2</sub>O</i> (kg/ha/yr)	0 1 2	0 65 130	— — —	— — —	55 110 165
<i>MgO</i> (kg/ha/yr)	0 1 2	— — —	— — —	— — —	0 27 54
<i>Commence- ment of Treatments</i>	<i>December 1966</i>	<i>June 1969</i>	<i>December 1966</i>	<i>May 1961</i>	<i>December 1963</i>
<i>Leaf Sampling</i>	<i>July 1971</i>	<i>October 1972</i>	<i>November 1972</i>	<i>September 1967</i>	<i>July 1967</i>

**Laboratory Procedure** — The leaf samples were oven-dried for 18 hours at 100°C, crushed by hand and ground to a powder in a sample mill and redried overnight at 100°C. Nitrogen was determined on the dried sample by the microkjeldahl method. Phosphorus, K, Ca, Mg and Mn were estimated in the solution made up after dry ashing by the method described by Sivasubramaniam and Jayman (1975). Phosphorus was determined by the Vanadomolybdate method; K and Ca using a flame photometer and Mg by the Titan Yellow method (Chenery, 1964). Manganese was determined by the Formaldoxine method (Bradfield, 1957).

## RESULTS AND DISCUSSION

The nutrient content of leaf samples drawn from experiments LA 2, LA 4, LA 24, LA 28 and LA 31 are presented in Tables 2, 3, 4 and 5. The N, P, K and Mg fertilizers were all found to affect the leaf nutrient composition and the results are summarised in Table 6.

TABLE 2—*Effect of N Fertilizer on Leaf Nutrient Composition and Yield*

TREATMENT	EXPERIMENT					
	LA 28	LA 31	LA 24	LA 2	LA 4	
(a) % N	0	3.46	3.41a	3.24	3.12a	—
N	1	3.49	3.54b	3.24	3.20a	—
	2	3.54	3.67c	3.33	3.47b	—
LSD (P = 0.05)		NS	0.09	NS	0.16	—
(b) % P	0	0.100	0.144	0.165a	0.183a	0.127
N	1	0.097	0.143	0.159b	0.172b	0.128
	2	0.105	0.140	0.157b	0.167b	0.133
LSD (P = 0.05)		NS	NS	0.005	0.010	NS
(c) % K	0	0.84	1.04	0.83	0.94a	0.67a
N	1	0.81	1.00	0.80	0.81b	0.55b
	2	0.81	1.05	0.75	0.78b	0.51c
LSD (P = 0.05)		NS	NS	NS	0.12	0.04
(d) % Ca	0	2.13	1.61	1.45	1.34a	1.49ab
N	1	2.26	1.56	1.48	1.22b	1.56b
	2	2.15	1.51	1.49	1.15b	1.40a
LSD (P = 0.05)		NS	NS	NS	0.08	0.10
(e) % Mg	0	0.27	0.32a	0.44	0.27a	0.26
N	1	0.27	0.28b	0.42	0.25b	0.26
	2	0.25	0.27b	0.46	0.24b	0.25
LSD (P = 0.05)		NS	0.02	NS	0.02	NS
(f) ppm Mn	0	1236a	355a	247	—	367
N	1	1875b	461b	266	—	362
	2	1972b	454b	263	—	358
LSD (P = 0.05)		395	88	NS	—	NS
(g) Yield (kg/ha)	0	3545a	5010	5133	3912a	911a
N	1	3543a	5050	5172	4222b	1467b
	2	3718b	4966	5162	4245b	2078c
LSD (P = 0.05)		125	NS	NS	170	188

TABLE 3 — *Effect of P Fertilizer on Leaf Nutrient Composition and Yield*

TREATMENT			EXPERIMENT	
			LA 28	LA 4
(a) % N	P <sub>2</sub> O <sub>5</sub>	0	3.50	—
		30	3.47	—
		60	3.52	—
	LSD (P = 0.05)		NS	
(b) % P	P <sub>2</sub> O <sub>5</sub>	0	0.090a	0.111a
		30	0.099ab	0.134b
		60	0.108b	0.143c
	LSD (P = 0.05)		0.009	0.007
(c) % K	P <sub>2</sub> O <sub>5</sub>	0	0.82	0.68a
		30	0.84	0.53b
		60	0.82	0.52b
	LSD (P = 0.05)		NS	0.04
(d) % Ca	P <sub>2</sub> O <sub>5</sub>	0	2.15	1.26a
		30	2.19	1.45b
		60	2.20	1.65c
	LSD (P = 0.05)		NS	0.10
(e) % Mg	P <sub>2</sub> O <sub>5</sub>	0	0.26	0.26
		30	0.28	0.26
		60	0.26	0.26
	LSD (P = 0.05)		NS	NS
(f) ppm Mn	P <sub>2</sub> O <sub>5</sub>	0	1826	375
		30	1561	366
		60	1695	354
	LSD (P = 0.05)		NS	NS
(g) Yield (kg/ha)	P <sub>2</sub> O <sub>5</sub>	0	3588	1268a
		30	3590	1589b
		60	3627	1598b
	LSD (P = 0.05)		NS	188

TABLE 4—Effect of K Fertilizer on Leaf Nutrient Composition and Yield

TREATMENT			EXPERIMENT		
			LA	LA 2	LA 4
(a) % N	K <sub>2</sub> O	0	3.49	3.31	—
		1	3.50	3.27	—
		2	3.50	3.22	—
	LSD (P = 0.05)		NS	NS	
(b) % P	K <sub>2</sub> O	0	0.102	0.172	0.137a
		1	0.101	0.171	0.126b
		2	0.100	0.179	0.124b
	LSD (P = 0.05)		NS	NS	0.007
(c) % K	K <sub>2</sub> O	0	0.74a	0.74a	0.28a
		1	0.83b	0.89b	0.58b
		2	0.90b	0.90b	0.87c
	LSD (P = 0.05)		0.08	0.12	0.04
(d) % Ca	K <sub>2</sub> O	0	2.29	1.28	1.61a
		1	2.13	1.23	1.46b
		2	2.13	1.20	1.38b
	LSD (P = 0.05)		NS	NS	0.10
(e) % Mg	K <sub>2</sub> O	0	0.30a	0.28a	0.26
		1	0.26b	0.25b	0.26
		2	0.24b	0.23b	0.25
	LSD (P = 0.05)		0.02	0.02	NS
(f) ppm Mn		0	1808	—	320
		1	1698	—	401
		2	1577	—	366
	LSD (P = 0.05)		NS	—	NS
(g) Yield (kg/ha)	K <sub>2</sub> O	0	3563	4083	1419
		1	3614	4164	1476
		2	3628	4131	1557
	LSD (P = 0.05)		NS	NS	NS

TABLE 5—Effect of Mg Fertilizer on Leaf Nutrient Composition and Yield

TREATMENT			EXPERIMENT	
			LA 2	LA 4
(a) % N	Mg	0	3.18	—
		1	3.27	—
		2	3.34	—
		LSD (P = 0.05)	NS	—
(b) % P	Mg	0	0.712	0.131
		1	0.170	0.128
		2	0.180	0.129
		LSD (P = 0.05)	NS	NS
(c) % K	Mg	0	0.92a	0.62a
		1	0.82ab	0.56b
		2	0.79b	0.55b
		LSD (P = 0.05)	0.12	0.14
(d) % Ca	Mg	0	1.34a	1.61a
		1	1.19b	1.46b
		2	1.17b	1.38b
		LSD (P = 0.05)	0.08	0.10
(e) % Mg	Mg	0	0.22a	0.23a
		1	0.27b	0.26b
		2	0.27b	0.27b
		LSD (P = 0.05)	0.02	0.01
(f) ppm Mn	Mg	0	—	366
		1	—	317
		2	—	404
		LSD (P = 0.05)	—	NS
(g) Yield (kg/ha)	Mg	0	4005	1447a
		1	4156	1379a
		2	4161	1630b
		LSD (P = 0.05)	NS	188

TABLE 6—*Summary of effects of applied elements on the Leaf Nutrient Composition of Tea*

<i>Fertilizer Added</i>	<i>Element measured in the leaf</i>					
	<i>N</i>	<i>P</i>	<i>K</i>	<i>Mg</i>	<i>Ca</i>	<i>Mn</i>
<i>N</i>	+	?	—	—	?	+
<i>P</i>	0	+	?	0	+	0
<i>K</i>	0	?	+	—	—	0
<i>Mg</i>	0	0	—	+	—	0

Key: + = Increase  
 — = Decrease  
 0 = No Change  
 ? = Not consistent

TABLE 7—*Effect of N Fertilizer on Leaf Nutrient Composition*

<i>Experiment</i>	<i>Nitrogen kg/ha/yr</i>	<i>% N</i>
LA 2	84	3.12
LA 2	168	3.20
LA 31	168	3.41
LA 24	179	3.24
LA 2	252	3.47
LA 28	269	3.46
LA 31	336	3.54
LA 24	358	3.24
LA 28	403	3.49
LA 31	504	3.67
LA 28	538	3.54
LA 24	538	3.33

Increasing the rate of N fertilizer applied resulted in an increase in leaf N, and confirms the findings of Eden (1943); Zhurbitskii and Shtrausberg (1963); Ahmetov and Bairamov (1969); Lin (1969); Burculadze (1970) and Hilton (1972). In the experiments reported in the present study the N fertilizer levels tested ranged from 84 to 538 kg/ha/annum. Although the leaf N concentration increased with increasing levels of N fertilizer at each location, this relationship was not quite clear when data from all the experiments were pooled (Table 7). This indicates that factors such as climate, soil type and clone also exert a considerable influence on the leaf N content. In addition to increasing leaf N content, raising the level of N fertilizer caused a decrease in the leaf K and leaf Mg content, and increased leaf Mn content. Ahmetov and Bairamov (1969); Lin (1969) and Hilton (1972) have reported a similar decrease in leaf K content. The effect on leaf P and leaf Ca was not consistent. Lin (1964) reported an increase while Ahmetov and Bairamov (1969), and Hilton (1972) reported a decrease in the leaf P content.

Raising the level of fertilizer P caused an increase in the leaf P and Ca content. An increase in leaf P has been shown by Eden (1943), Burculadze (1969) and Hilton (1972). The phosphate fertilizer used in our experiments was rock phosphate containing large amounts of Ca and, this could account for the increase in leaf Ca. While the effects on leaf K was not consistent there was no effect on leaf N, Mg and Mn.

The application of K fertilizer increased the leaf K content and confirms the results of Eden (1943); Zhurbitskii and Shtrausberg (1963) and Hilton (1972). The increase in leaf K content was associated with a decrease in leaf Ca and Mg. It appears that K is antagonistic to both Ca and Mg and suppresses their uptake. Potash fertilizer had no effect on leaf N and Mn; and the effect on leaf P was not consistent.

The application of Mg fertilizer caused an increase in leaf Mg but was antagonistic to K and Ca causing a decrease in the concentration of these elements in the leaf. Magnesium fertilizer had no effect on the leaf N, P and Mn content.

These results clearly indicate the importance of supplying nutrients in the correct proportions. There appears to be a fine balance between N, K and Mg. High levels of N fertilizer were seen to depress the leaf K and Mg content. The commonly observed appearance of Mg deficiency symptoms in tea receiving high levels of N is most probably due to this antagonism, rather than to a true deficiency due to an inadequate supply of Mg. If applications of Mg fertilizer are made to correct the deficiency symptoms the antagonistic effect of both N and Mg fertilizer could cause K deficiency.

It is premature at this stage to attempt to define critical values for the various nutrients. However, it is interesting to note that increase in the leaf content of all four nutrients studied viz: N, P, K and Mg are not necessarily accompanied by an increase in yield (Tables 2, 3, 4 and 5). There is evidently a luxury consumption of N, P, K and Mg by the tea plant.

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