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Manganese Deficiency in Hevea: The Effect of Soil Application of Manganese Sulphate on the Manganese Status of the Tree

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The effect of soil application of manganese sulphate on the nutrient status of Hevea brasiliensis trees affected by a deficiency of manganese in the soil was investigated. Significant increases in the manganese content of leaf, latex, bark and bark scrap rubber were observed, with increases more clearly shown in leaves and bark than in the bark scrap rubber and latex. Different rates and frequencies of application of manganese sulphate were used, and it was concluded that two broadcast applications of four ounces per tree was the minimum treatment required to improve the manganese status of trees affected by moderate to severe manganese deficiency.

Many cases of manganese deficiency on immature and mature *Hevea* have been observed throughout Malaya (RUBBER RESEARCH INSTITUTE OF MALAYA, 1961a) since the description of the characteristic symptoms of deficiency by BOLLE-JONES (1956). The deficiencies are evidently the result of absolute deficiencies of manganese in the soil, since *Hevea* is grown on soils of low organic matter content with pH values in the range 4.5 – 5.5 — conditions under which soil manganese is freely available, if present. This is in contrast with the more usual cases of induced manganese deficiency where soil manganese is rendered unavailable for plant uptake because of high pH or organic matter levels (MULDER AND GERRETSON, 1952).

AKHURST (1933) found that the total manganese content of Malayan soils (except some derived from limestone) was low, averaging 279 p.p.m. This low level of manganese in many Malayan soils is probably the direct result of the severe leaching of the acid soils under conditions of high rainfall. The exchangeable manganese content of typical inland Malayan soils is normally less than 0.036 m-equiv./100 g while levels of less than 0.0071 m-equiv./100 g are frequently found. These figures can be compared with levels of 0.18 – 0.72 m-equiv./100 g reported by WATSON (1960) in some temperate climate soils where manganese uptake was excessive at pH levels of about 4.5. These can only be approximate comparisons of course, for other factors such as the exchangeable calcium, soil aeration and the proportion of total and 'reducible' manganese present will also affect the availability of manganese, but these figures represent the general order of differences that are found.

Since a deficiency of manganese can adversely affect tree growth (BOLLE-JONES, 1957) it is important to determine ways in which the condition can be remedied. This paper presents results obtained from two experiments laid down primarily to study manganese uptake by *Hevea*, and also results from three other experiments which involve treatments with manganese sulphate. In all these experiments soil applications of manganese sulphate fertiliser have been tested, rather than application by spray or injection, since the problem is one of simple soil deficiency and not of deficiency induced by unfavourable soil conditions.

The effects on the manganese status of the tree have been followed by periodical leaf, latex, bark and bark scrap rubber sampling. The study of bark scrap rubber was required because a high concentration of manganese

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in the rubber has the deleterious effect of promoting oxidation, and there is a legal tolerance limit of 10 p.p.m. on the amount of manganese that may be present in commercial rubber (RUBBER MANUFACTURERS ASSOCIATION N.Y., 1957).

The studies were carried out on areas showing leaf symptoms of manganese deficiency; otherwise the areas were not markedly deficient in any particular nutrient, but were situated on soils on which responses to normal NPK fertilisers could be expected.

SAMPLING METHODS

Details of the five fertiliser experiments are given in *Table 1*. Sampling details are given below, and a discussion of each experiment and its results follow.

Leaf Sampling

The same type of leaf was sampled in all experiments. Two mature whorls exposed to full sunlight and situated on the outside of the canopy were chosen on each tree sampled, and the four basal leaves on both whorls were collected.

In Experiments 1 and 2, six trees were selected at random in each plot at the start of the investigation and were sampled throughout.

In Experiment 3, sixteen trees per plot were selected at random, and in Experiments 4 and 5 six trees per plot were selected. All leaves collected within each plot were bulked for analysis.

Latex Sampling

In Experiment 1, latex sampling was carried out at approximately the same date as leaf sampling, and from the same trees. An aliquot of the total latex from the six trees, collected after latex had stopped flowing, was taken for analysis.

Bark Sampling

In Experiment 1, bark samples were taken from a height of 100–106 inches above the union from all recorded trees in each plot.

Bark Scrap Rubber Sampling

In Experiments 1 and 2, bark scrap rubber samples were collected from all recorded trees twenty-four hours after tapping, and the samples from all plots of the same treatment were bulked for analysis. The samples were not washed prior to analysis, although contaminating particles of bark were removed by hand.

The preparation and analysis of the leaf and bark samples were carried out by the methods described by BOLLE-JONES (1954)

TABLE 1. DETAILS OF EXPERIMENTS

Experiment No.	Clone	Year budded	Plot size (acres)	Rate of manganese sulphate application (oz/tree/annum)	Dates of application
1	Tjir 1, BR 2	1950	0.11	0, 4 and 8*	First, 8.5.57; second, 27.5.58
	PB 49, AVROS 157				
2	RRIM 509	1950	0.11	0 and 4	First, 11.6.58; second, 9.5.59; third, 23.4.60
3	Tjir 1 Clonal Seedlings	1955**	0.50	0 and 2	First, 23.9.59
4	PB 86	1950	0.54	0 and 4	First, 15.2.60
5	PB 86	1950	0.73	0 and 4	First, 19.2.60

* Only half the plots received the second application.

** Year of planting.

and by BOLLE-JONES, MALLIKARJUNESWARA AND RATNASINGAM (1957). The petioles and mid-ribs of leaves were discarded before analysis.

Soil Sampling

In Experiment 1 soil samples were collected once, approximately four years after the first experimental manuring. Eight core samples, 0–12 in., were taken from the intra-row areas in each plot. The total soil manganese content was estimated after acid extraction by the method described by PIPER (1950), and the exchangeable soil manganese after extraction with *N* ammonium acetate.

EXPERIMENT 1

This experiment was located in an avenue planting sited on a coarse sandy, granite-derived soil cleared from jungle in 1941, cultivated for food crops and then planted as a seed garden in 1949, with five *Hevea* clones Tjir 1, BR 2, PB 49, AVROS 157 and RRIM 509. The planting distance was 60 × 4½ ft. Along each of three adjacent rows, six single-row plots of twenty trees, each containing similar numbers of the different clones, were marked out, the two trees at each end of the plots being used as 'guard' trees. To minimise poaching across the rows, a plough furrow was driven up the inter-row areas in the first year, but this was not repeated after analytical results had revealed few, if any, poaching effects.

Pre-treatment sampling of leaves and bark was carried out, before application of manganese sulphate (30% manganese content) at rates of 0, 4 oz and 8 oz per tree. Treatments were in sextuplicate, and the fertiliser was sprinkled evenly over a 10 ft wide strip on both sides of the tree rows.

Analytical results in the first year of the experiment showed a marked effect of the treatments on the manganese content of the trees. In order to test the persistence of this effect only half of the plots initially manured received manganese sulphate in the second year.

Leaf, latex, bark and bark scrap rubber samples were taken at intervals as indicated in *Tables 3, 4* and *5*, and *Figures 1* and *2*.

RESULTS OF EXPERIMENT 1

Visual Observations

Visual assessment in the field of the incidence of manganese deficiency symptoms indicated an improvement of the foliage at five months after the first application of manganese sulphate. An assessment made after thirty months indicated that the order of effectiveness of the treatments in improving foliage condition was:

$$2 \times 8\text{ oz} > 2 \times 4\text{ oz} > 1 \times 8\text{ oz} > 1 \times 4\text{ oz}$$

Visual assessment of the severity of the symptoms shown by individual plot samples of 48 leaves each was carried out on twelve sampling occasions, and the comparison of the assessment with the leaf manganese contents is given in *Table 2*.

TABLE 2. EXPERIMENT 1. MANGANESE CONCENTRATION IN MANGANESE DEFICIENT LEAVES

Symptom expression	No. of cases	Mn p.p.m. mean	Standard deviation
None	134	88	44.9
Slight	48	51	22.6
Moderate	15	23	11.0
Severe	19	19	5.2

Results indicate that a sample that exhibits definite symptoms of manganese deficiency will have a content of less than 50 p.p.m. manganese, while severe symptoms will be associated with a content of approximately 20 p.p.m. manganese.

Leaf Analysis

One application. The first post-treatment sampling, at six months after application, showed that both the 4 oz and the 8 oz applications had significantly increased leaf manganese content (*Table 3*). This effect reached its maximum at twelve months after applica-

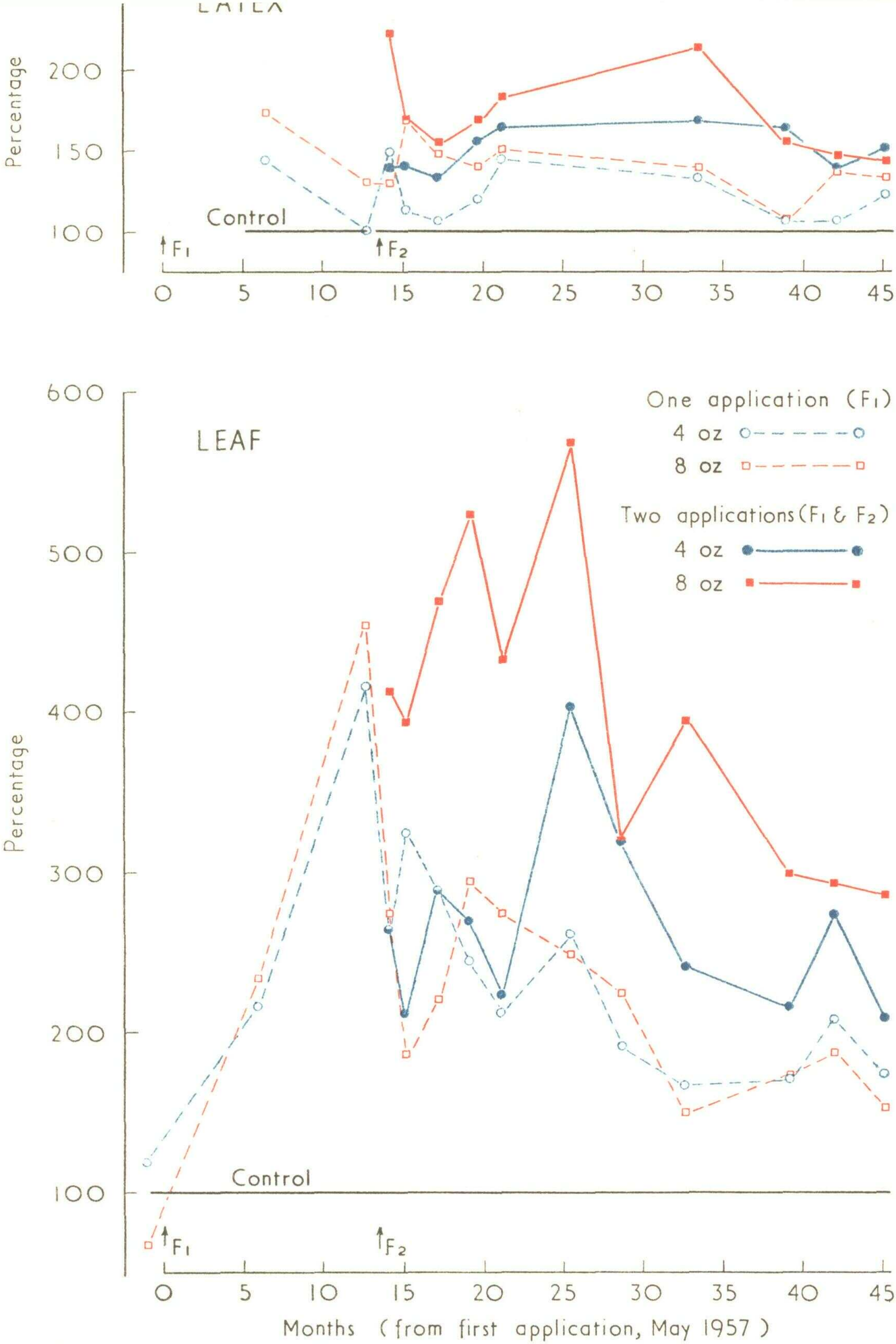

Figure 1. Experiment 1. The effect of manganese sulphate on the leaf and latex manganese content. (Manganese contents are expressed as a percentage of control for each sampling occasion).

tion when the leaf manganese content was increased to a level four and a half times greater than that of the control (*Figure 1*). The significant positive effect was observed for a period of thirty-six months after application, with no significant difference between the 4 oz and 8 oz applications becoming evident.

Two applications. The leaf manganese content was increased further by the second application of manganese sulphate, with a maximum mean of 159 p.p.m. observed after two applications of 8 oz (*Table 3*). The two applications of 8 oz caused marked significant increases in the leaf manganese content during the period studied, which covered thirty months after the second application. The increases reached a maximum at eleven months, when the manganese content was five and a half times greater than that of the control (*Figure 1*).

Whilst the two applications of 4 oz did not always result in a significant increase in the leaf manganese content, there were strong indications of a positive effect throughout. Likewise there were indications that the effect of the two 8 oz applications was greater than that of the two 4 oz applications. The decline in the leaf manganese content following the two applications was less evident than that following the one application, and the lowest manganese content recorded following the double 8 oz applications was 82 p.p.m.

The order of effectiveness of manganese sulphate in improving the leaf manganese status, judged from the data covering the third year after the first application, was as follows:

$2 \times 8\text{ oz} > 2 \times 4\text{ oz} > 1 \times 8\text{ oz} = 1 \times 4\text{ oz}$

No consistent significant effects of manganese sulphate on the magnesium, potassium, calcium, nitrogen and phosphorus contents of the leaves were observed (RUBBER RESEARCH INSTITUTE OF MALAYA, 1961b). There were however indications of a negative effect of manganese sulphate on the leaf magnesium and potassium contents, and a positive effect on the leaf calcium content.

Latex Analysis

One application. The latex manganese content was significantly increased by the 8 oz, but not by the 4 oz application (*Table 4*). A significant, positive, residual effect of the 8 oz application was observed on two sampling occasions in the second year after application, and there were indications of a similar residual effect on other occasions. The maximum mean concentration, observed at twelve, fourteen and thirty-one months after the single application of 8 oz, was 2.4 p.p.m. manganese.

Two applications. Both the two 4 oz and the two 8 oz applications caused significant increases in the latex manganese measured at two months after the second application (*Table 4*), and these effects were maintained for thirty months after the second application.

On three sampling occasions the positive effect of the two 8 oz applications was significantly greater than that of the two 4 oz applications: there were also strong indications of such a difference persisting for up to nineteen months after the second application. The maximum mean concentration, observed nineteen months after the second 8 oz application, was 3.7 p.p.m. manganese, approximately two and a quarter times greater than the manganese content of the control (*Figure 1*).

The order of effectiveness of manganese sulphate in increasing the latex manganese status, was as follows (*Figure 1*):

$2 \times 8\text{ oz} > 2 \times 4\text{ oz} > 1 \times 8\text{ oz} = 1 \times 4\text{ oz}$

No consistent significant effects of manganese sulphate on the nitrogen, phosphorus, potassium and copper content of the latex were observed (RUBBER RESEARCH INSTITUTE OF MALAYA, 1961b). There were however indications of a positive effect of manganese sulphate on the latex magnesium content.

Bark Analysis

A marked positive effect on the bark manganese content of both the 4 oz and the 8 oz dressings was recorded after six months (*Table 5*). Eight months after the second application it was observed that the bark

TABLE 3. EXPERIMENT 1. THE EFFECT OF MANGANESE SULPHATE ON THE MANGANESE CONCENTRATION IN THE LEAVES

Dates of Application: first (to all plots), 8.5.57 (F1); second (to half of the plots), 27.5.58 (F2)

	p.p.m. Mn in dry lamina													
Dates of sampling	17.4.57 (F1)	31.10.57	21.5.58 (F2)	16.6.58	16.7.58	8.9.58	3.11.58	29.12.58	27.4.59	5.8.59	23.11.59	6.5.60	8.8.60	4.11.60
Control	32	29	29	49	38	30	25	28	26	36	45	61	41	32
Mn_1 4 oz 1957 only	38	63	121	99	107	78	53	48	63	54	62	92	67	50
Mn_2 8 oz 1957 only	22	68	132	103	62	60	64	62	60	63	56	93	60	44
s.e.	± 11.1	± 8.2	± 21.0	± 11.1	± 9.0	± 10.3	± 8.7	± 4.3	± 4.7	± 2.7	± 9.7	± 7.6	± 8.0	± 4.7
Min. 5% sig. diff.	N.S.	25.9	66.3	43.5	35.5	40.5	34.1	17.0	18.3	10.5	N.S.	29.8	N.S.	N.S.
Control				26	28	24	18	17	22	20	29	45	23	25
Mn_1 4 oz 1957 and 1958				99	70	78	58	50	97	90	90	115	88	60
Mn_2 8 oz 1957 and 1958				156	130	127	113	98	137	90	147	159	95	82
s.e.				± 11.7	± 13.6	± 25.5	± 21.3	± 16.0	± 30.7	± 17.7	± 13.4	± 25.1	± 14.7	± 16.4
Min. 5% sig. diff.				46.1	53.4	100.1	83.4	62.8	120.5	69.6	52.6	98.7	57.8	53.6

TABLE 4. EXPERIMENT 1. THE EFFECT OF MANGANESE SULPHATE ON THE MANGANESE CONCENTRATION IN THE LATEX

Dates of Application: first (to all plots), 8.5.57 (F1); second (to half of the plots), 27.5.58 (F2)

	p.p.m. Mn in total solids										
Dates of sampling (F1)	31.10.57	23.5.58 (F2)	16.6.58	18.7.58	8.9.58	19.11.58	29.12.58	16.12.59	16.5.60	14.8.60	14.11.60
Control	1.3	1.8	1.3	1.6	1.4	1.5	1.5	1.8	1.3	1.3	1.5
Mn_1 4 oz 1957 only	1.9	1.8	1.8	1.6	1.5	1.5	2.2	2.3	1.3	1.3	1.5
Mn_2 8 oz 1957 only	2.3	2.4	1.6	2.4	2.1	2.0	2.3	2.4	1.3	1.7	1.6
s.e.	± 0.26	± 0.22	± 0.31	± 0.18	± 0.16	± 0.21	± 0.29	± 0.28	± 0.06	± 0.28	± 0.21
Min. 5% sig. diff.	0.83	N.S.	N.S.	0.71	0.64	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Control			1.0	1.2	1.3	1.3	1.5	1.6	1.1	1.1	0.8
Mn_1 4 oz 1957 and 1958			1.7	2.0	1.9	2.2	2.5	2.9	2.0	1.7	1.7
Mn_2 8 oz 1957 and 1958			2.7	2.4	2.2	2.4	2.8	3.7	1.9	1.8	1.6
s.e.			± 0.47	± 0.09	± 0.08	± 0.06	± 0.07	± 0.20	± 0.10	± 0.22	± 0.09
Min. 5% sig. diff.			N.S.	0.34	0.33	0.23	0.29	0.78	0.38	N.S.	0.35

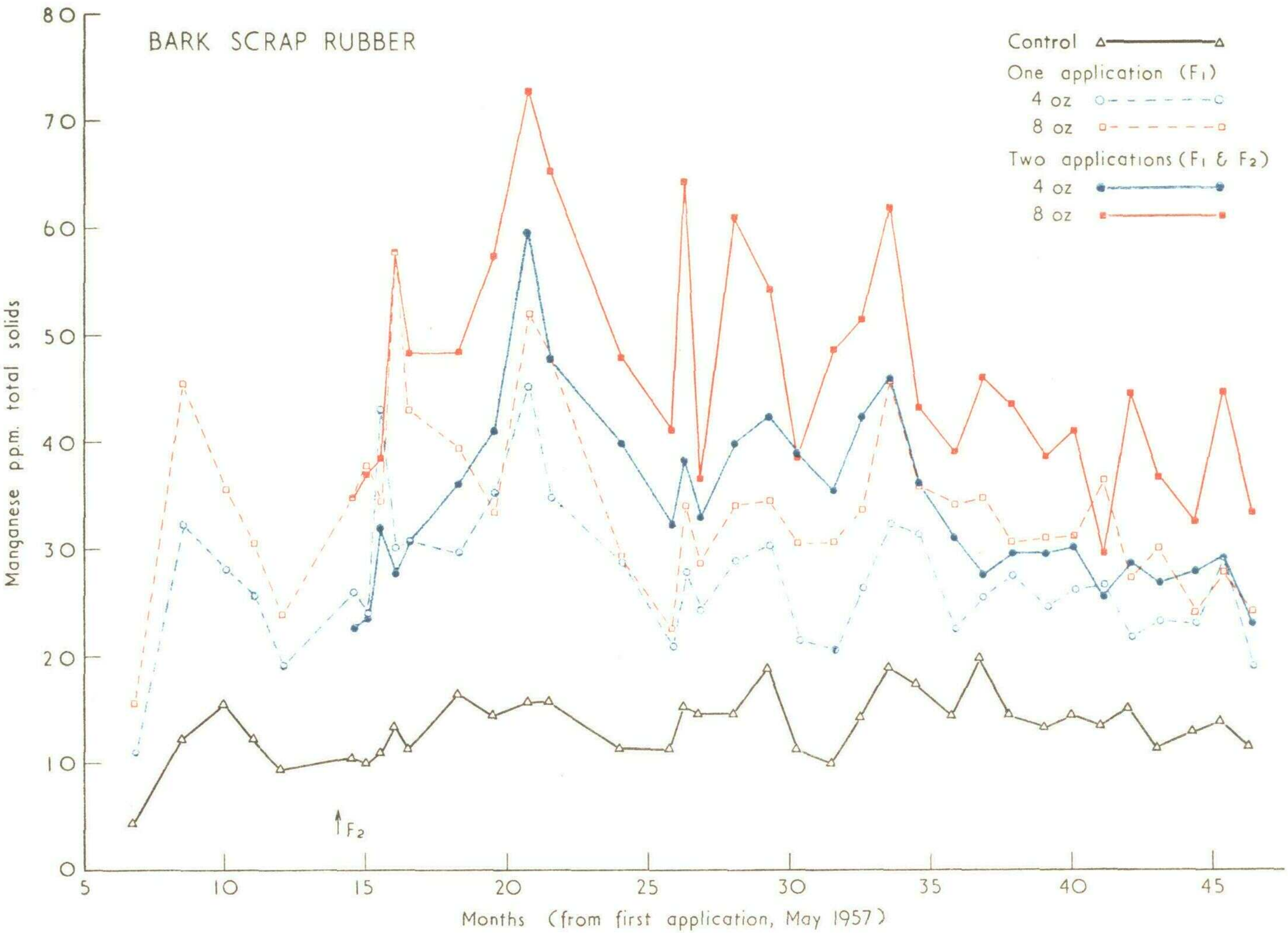

Figure 2. Experiment 1. The effect of manganese sulphate on the manganese content of bark scrap rubber.

TABLE 5. EXPERIMENT 1. THE EFFECT OF MANGANESE SULPHATE ON THE MANGANESE CONCENTRATION IN THE BARK

Dates of Application: first (to all plots), 8.5.57 (F1); second (to half of the plots), 27.5.58 (F2)

p.p.m. Mn in dry bark				
Dates of sampling	16.4.57 (F1)	31.10.57 (F2)	21.1.59	4.3.61
Control	43 (100)	44 (100)	69	54
Mn_1 4 oz 1957 only	39 (91)	97 (220)	122 (230)*	63 (134)*
Mn_2 8 oz 1957 only	34 (79)	117 (266)	110 (207)*	62 (132)*
s.e.	± 8.6	± 9.7	± 22.5	± 6.5
Min. 5% sig. diff.	N.S.	30.7	N.S.	N.S.
Control			37	40
Mn_1 4 oz 1957 and 1958			147 (277)*	77 (164)*
Mn_2 8 oz 1957 and 1958			224 (422.6)*	92 (196)*
s.e.			± 23.3	± 7.8
Min. 5% sig. diff.			91.3	30.8

The contents expressed as a percentage of the control are given in parenthesis.

* Values calculated using mean of all control plots.

manganese content had been further increased significantly by the two applications of 4 oz and 8 oz, whilst at the same time there were strong indications of a residual effect due to one application of 4 oz or 8 oz. Significant residual effects of the two applications only were observed after four years.

The increases in the bark manganese content were of the same order as the increases in the leaf manganese content for the individual sampling occasions. The order of effectiveness of the different applications of manganese sulphate in increasing the bark manganese content was the same as that observed for the leaf and latex manganese content.

No significant effects of manganese sulphate on the bark magnesium content were observed (RUBBER RESEARCH INSTITUTE OF MALAYA, 1961b).

Analysis of Bark Scrap Rubber

One application. Both the 4 oz and 8 oz applications caused marked increases in the manganese content of the bark scrap (*Figure 2*). The maximum manganese content of 58 p.p.m. (approximately four and a half times greater than the manganese content of the control) was observed sixteen months after the application of 8 oz. Thereafter a gradual decline, to approximately 20 – 30 p.p.m. was observed.

Two applications. The second application of both the 4 oz and the 8 oz manganese sulphate resulted in further increases in the manganese content.

The two 8 oz applications caused the greatest increase in bark scrap manganese, and a maximum content of 73 p.p.m. (approximately four and a half times greater than that of the control) was observed at seven months after the second application (*Figure 2*).

Soil Analysis

The total soil manganese content, as measured on the control plots was 19 p.p.m. Mn and the exchangeable manganese content was 0.0025 m-equiv./100 g. In *Table 6* the effects of the different rates of manganese sulphate application on both total and exchangeable manganese content are clearly shown. It is to be noted that the positive effect of manganese sulphate on the exchangeable soil

TABLE 6. EXPERIMENT 1. SOIL ANALYSIS

Date of sampling 4.3.61

	Total Mn p.p.m.	Exchange-able Mn m-equiv./ 100 g
Control	19	0.0022
Mn_1 4 oz 1957 only	23	0.0062
Mn_2 8 oz 1957 only	26	0.0073
s.e.	2.0	0.00055
Min. 5% sig. diff.	7.9	0.00222
Control	18	0.0029
Mn_1 4 oz 1957 and 1958	33	0.0116
Mn_2 8 oz 1957 and 1958	42	0.0135
s.e.	6.0	0.00193
Min. 5% sig. diff.	23.4	0.00765

manganese was evident three and four years after application.

EXPERIMENT 2

This experiment was adjacent to Experiment 1, on the same soil type and using the same planting material, with similar plot sizes, and was laid down to study the uptake of copper, molybdenum and manganese by the trees. For the purpose of this paper, only the manganese treatments, consisting of 0 and 4 oz/tree applications of manganese sulphate need to be considered. The application of manganese sulphate was carried out annually for three years.

RESULTS OF EXPERIMENT 2

Leaf Analysis

An increase in the leaf manganese content, significant at the 10% level, was observed at five months after the first application of 4 oz of manganese sulphate (*Table 7*). After the second application of manganese sulphate significant increases in leaf manganese content were recorded on all sampling occasions. Whilst a maximum leaf concentration of 165 p.p.m. manganese was recorded two weeks after the third 4 oz application, the effect of both the second and third application of manganese sulphate was to maintain the manganese content at a level of approximately four times greater than that of the control, an increase of the same order as the maximum observed in Experiment 1 (*Figure 1*) following two applications of 4 oz.

There were strong indications of a depressive effect of manganese sulphate on the leaf molybdenum content (*Table 7*), after the second application, and a significant interaction between manganese and molybdenum on uptake of molybdenum was observed, whereby the effect of sodium molybdate in increasing the leaf molybdenum content was considerably reduced in the presence of applied manganese.

Analysis of Bark Scrap Rubber

In this experiment the effect of one 4 oz application of manganese sulphate on the bark scrap manganese content appeared to be slightly greater than in Experiment 1 (*Table 7*). The effect became apparent after three months and a maximum mean concentration of 46 p.p.m. was recorded after five months.

EXPERIMENTS 3, 4 AND 5

These experiments are fertiliser experiments of factorial design, in which the application of 4 oz per tree of manganese sulphate is one treatment. Data on post-treatment leaf analysis are given in *Table 8* as confirmatory evidence of the effect of manganese sulphate on leaf manganese content.

TABLE 8. THE EFFECT OF MANGANESE SULPHATE ON THE MANGANESE CONCENTRATION IN THE LEAVES

Experiment No.	3	4	5
Time of sampling (months after application)	9	8	7
p.p.m. Mn in dry lamina			
Control	47	90	43
Mn*	57	117	80
s.e.	1.6	8.9	4.2
Min. 5% sig. diff.	4.8	26.1	12.7

* See Table 1 for rates of application in each experiment.

TABLE 7. EXPERIMENT 2. THE EFFECT OF MANGANESE SULPHATE ON THE MANGANESE AND MOLYBDENUM CONCENTRATIONS IN THE LEAVES, AND ON THE MANGANESE CONCENTRATION IN THE BARK SCRAP RUBBER

Dates of Application: first, 11.6.58 (F1); second, 9.5.59 (F2); third, 23.4.60 (F3)

Dates of sampling	22.5.58	(F1) 20.6.58	18.7.58	11.9.58	8.11.58	20.4.59	(F2) 13.7.59	5.10.59	(F3) 4.5.60	5.8.60	2.11.60
p.p.m. Mn in dry lamina											
Control	34	35	27	22	19	24	24	19	40	30	20
Mn 4 oz	27	26	21	24	28	84	73	76	165	111	80
s.e.	± 2.6	± 3.2	± 1.6	± 1.6	± 1.8	± 10.6	± 1.9	± 5.9	± 3.5	± 7.8	± 4.6
Min. 5% sig. diff.	N.S.	N.S.	N.S.	N.S.	N.S.*	N.S.*	11.7	35.8	21.2	48.0	27.8
p.p.m. Mo in dry lamina											
Control	0.08	0.21	0.12	0.14	0.12	0.26	0.37	0.37	1.18	0.36	0.27
Mn 4 oz	0.08	0.23	0.15	0.15	0.13	0.27	0.32	0.24	0.97	0.24	0.19
s.e.	± 0.007	± 0.015	± 0.009	± 0.022	± 0.009	± 0.036	± 0.022	± 0.027	± 0.063	± 0.018	± 0.037
Min. 5% sig. diff.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.*	N.S.	0.109	N.S.

Dates of sampling	(F1) 21.6.58	5.7.58	19.7.58	22.8.58	15.9.58	13.10.58	20.11.58	16.12.58	21.4.59	(F2) 24.7.59
p.p.m. Mn in bark scrap rubber										
Control	11	11	9	12	13	15	19	14	14	15
Mn 4 oz	9	10	11	18	24	34	46	38	38	44

* Significant $P < 0.10$

DISCUSSION

At the time of commencement of the above experiments, the wide occurrence of manganese deficiency conditions in rubber growing areas was not fully appreciated. Information on methods of increasing the manganese status of trees was obviously required however, and Experiments 1 and 2 were sited on available areas of known low manganese status, although it was appreciated that the clonal variation present and small plot size would render difficult the measurement of response in terms of growth and latex yield. Nevertheless it is worth recording that in Experiment 2 a significant positive effect on growth of the manganese sulphate application was recorded in the second year of the experiment. In all experiments improvements in foliage colour have been observed following application of manganese sulphate.

Results show that two dressings of 4 oz of manganese sulphate, applied with a twelve month interval, were more effective than one application of 8 oz. The residual effect of two applications of 4 oz or 8 oz was quite definite two and a half years after the second application, whereas at the same time the leaf manganese content of trees treated with one application had declined to a level where deficiency symptoms could be expected. It is therefore judged that two applications of 4 oz manganese sulphate is the minimum required to improve the manganese status of mature trees affected by moderate to severe manganese deficiency. In cases of severe deficiency, where the leaf interveinal areas are yellow rather than pale green (BOLLE-JONES, 1956), two applications of 6 oz per tree would be preferable.

The increase in the manganese status of the trees was more clearly shown by the leaf and bark than by the bark scrap rubber, which in turn showed the effect more than did latex. The marked differences between the low manganese content of the latex and the high content of the bark scrap rubber is probably due to the fact that the bark scrap rubber remained in close contact with the bark, which has a high manganese content, for twenty-four hours. If collection of bark scrap rubber had been delayed for the full period of two days between tappings, the difference would probably have been greater.

The manganese content of the latex did not rise sufficiently to cause concern, but that of the bark scrap rubber, which was not soaked before analysis, rose well above the tolerance limit of 10 p.p.m. Under normal estate practice such bark scrap would be soaked and washed during milling, and the manganese content would be effectively reduced.

The general leaf analysis in Experiment 2 showed evidence of an antagonism between manganese and molybdenum similar to that reported by MULDER (1954), whereby applied manganese sulphate depressed the molybdenum content of the leaves. Except for this, no consistent interactions between the manganese content and that of the other nutrients have been recorded.

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