A Magnesium-Manganese Interrelationship in the Mineral Nutrition of Hevea Brasiliensis

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Increased supplies of magnesium to rubber plants fed with low or normal levels of manganese produced symptoms of manganese deficiency and reduced the concentration of manganese found in the laminae. At the lower levels of magnesium supply an increased concentration of magnesium in the laminae was accompanied by a decrease in that of manganese. At a luxury level of magnesium supply an increase in the magnesium concentration was accompanied by a similar increase in that of manganese.

DEFICIENCY SYMPTOMS OF BOTH MAGNESIUM AND MANGANESE, in *Hevea brasiliensis*, occur in Malaya. Magnesium deficiency is widespread and can cause a marked retardation in growth; the occurrence and severity of manganese deficiency in the field is not yet fully known as a description of the leaf symptoms was not published until recently (BOLLE-JONES 1954b). The highly acid nature of Malayan soils makes probable a high available manganese content; the possibility that this was involved in the production of the magnesium deficiency warranted investigation. It was already known that manganese may accumulate to some extent in the laminae of magnesium deficient plants (BOLLE-JONES 1954b) and that increasing levels of magnesium consistently decreased the manganese concentration of the laminae (BOLLE-JONES 1954c). Further confirmation of this effect was necessary. To this end, the influence of magnesium status on the concentration of manganese in the laminae of plants grown at varying levels of manganese supply was investigated.

BEAUFILS (1955) has stated that a highly significant, positive, direct correlation existed between the magnesium and manganese concentrations found in leaves of *Hevea brasiliensis*. However, apart from this reference and those given above there is no information regarding the interrelationship of magnesium and manganese in the nutrition of *Hevea brasiliensis* and, apart from their effect on enzyme activity, little is reported in the general literature.

SWANBACK (1939) concluded that manganese (as well as potassium and calcium) antagonised the absorption of magnesium by tobacco plants and it can be tentatively inferred from his data that an increase in manganese level decreased the uptake of magnesium. LOUSTALOT, WINTERS and CHILDERS (1947) grew cinchona seedlings under high soil moisture conditions; the seedlings developed symptoms which resembled magnesium deficiency or manganese toxicity in other plants. This lack of definite characterisation may have implied the presence of both types of symptom and a possible interrelationship between the elements. PLANT (1953) showed, by the use of indicator crops, that plants grown on acid soils developed magnesium deficiency symptoms and that these were usually accompanied by either manganese or aluminium toxicity effects or both. He concluded that a reduction of manganese content, as effected by liming, was associated with an increased magnesium content although this increase was not convincingly illustrated in his analytical results. MULDER and

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GERRETSEN (1952) have also pointed out that magnesium deficiency develops in plants grown on acid soils which contain large amounts of available manganese.

There is therefore some evidence which indicates that magnesium deficiency may be sometimes associated with manganese toxicity effects but no indication that magnesium level may affect the manganese status of the plant. The present experiment carried out in sand culture revealed that both elements were closely interrelated in the nutrition of *Hevea*. Increasing supplies of magnesium consistently decreased the manganese concentration of the laminae from any stem position while the effect of increasing manganese level was to decrease the magnesium concentration of laminae taken from the top storeys.

EXPERIMENTAL

Hevea brasiliensis seedlings, clone Tjir 1, were grown in a pot sand culture experiment in which magnesium and manganese were each applied at three levels, to give a total of nine treatments. The levels used represented low or deficiency (Mg_1 and Mn_1), normal (Mg_2 and Mn_2) and high (Mg_3 and Mn_3) rates of application:

Milligram equivalents per litre

Mg_1	... 0.4	Mn_1	... 0.0005 (approx)
Mg_2	... 1.6	Mn_2	... 0.05
Mg_3	... 6.4	Mn_3	... 1.00

For the first part of the experiment, until September 1954, nitrate, phosphate, potassium and calcium ions were supplied at 7, 3, 4 and 1 milligram equivalents per litre, respectively. Later it was found necessary, owing to the appearance of iron deficiency effects to alter the nutrient composition to the following levels (in m.eq./l): NO_3^- 5.0; NH_4^+ 3.0; PO_4^{---} 3.0; K^+ 3.0; Ca^{++} 4.0. In addition, sodium was supplied at 1.0 m.eq./l and sulphate varied between 5 and 12 m.eq./l, the concentration increasing with magnesium level. Throughout the experiment iron, boron, copper, zinc and molybdenum were supplied at the rate of 17, 0.07, 0.06, 0.06 and 0.02 parts per million, respectively. The sand used in this experiment had been washed with hydrochloric acid and was contained either in pyrex glass pots (Mn_1) or in bitumen painted, five gallon clay pots (Mn_2 and Mn_3). Each treatment was duplicated and each replicate contained three pots.

Thirteen 'selfed' seeds of clone Tjirandi 1 were sown in each pot in March 1954: subsequently, in the following April, June, August and November the seedlings were progressively removed for analysis until in April 1955 — the time of the final harvesting — one plant only remained.

At each sampling the total dry weight per plant per treatment was recorded and the following values determined: percentage rubber in the green portion of the stems, concentrations of magnesium, potassium, calcium, phosphorus and manganese in the laminae. The analytical procedures employed have been described (BOLLE-JONES 1954a). The leaves for analysis, were removed from definite storey positions; the midrib was excised and discarded and the remainder of the lamina used for analysis. Not all the results of analyses are reported below but only a representative few of those collected.

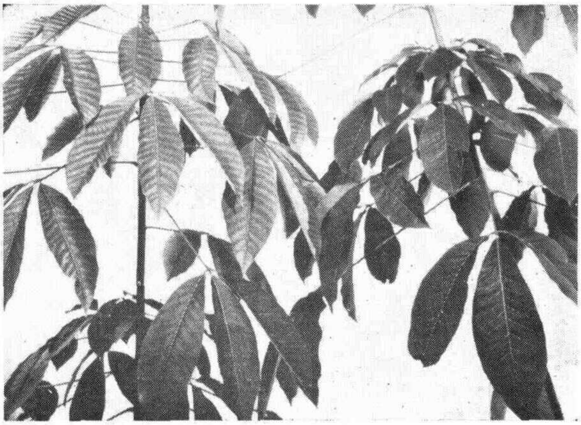

Figure 1. Mg_2 Mn_1 (left); Mg_1 Mn_1 (right). *Note clear symptoms of manganese deficiency in left hand plant as a result of increased magnesium level. Plants twelve months old.*

RESULTS

Visual Observations

Deficiency symptoms of manganese were observed in April before those of magnesium, which did not appear until May. The manganese deficiency symptoms first occurred in the Mn_1 plants, but were observed later in October and November, in the Mn_2 plants, particularly at the higher Mg levels. It did in fact appear that increased magnesium level could induce a deficiency of manganese (*Figure 1*).

Magnesium deficiency symptoms were mainly confined to the Mg_1 plants but some slight symptoms were observed in the Mg_2 plants at the higher manganese levels. The magnesium deficiency symptoms occurred more frequently in plants of the higher (than of the low) manganese treatments.

Some symptoms, suspected to be those of iron deficiency, appeared, in August, in the Mg_3 Mn_3 plants. To avoid rapid deterioration of all plants in the Mg_2 and Mg_3 treatments and to give a better and more vigorous growth the composition of the nutrient was changed (as indicated above); as a result, much healthier growth was obtained.

TABLE 1. TOTAL DRY WEIGHT PER PLANT
(*grams*)

Level	*April 1954*			*August 1954*			*April 1955*		
	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3
		(± 0.10)			(± 1.4)			(± 54)	
Mg_1	1.0	1.4	1.2	7.6	7.6	10.3	484	396	416
Mg_2	0.9	1.3	1.3	18.2	15.4	18.0	472	494	523
Mg_3	1.0	1.2	1.3	20.5	18.2	20.7	476	528	358

Dry Weight Per Complete Plant (Table 1)

The dry weight of month old seedlings significantly increased with manganese supply but little effect of magnesium was observed. However, by the June sampling, magnesium seemed to limit growth more than manganese and the results given for August (Table 1) show a very significant positive effect of magnesium, but none of manganese, on dry weight production. The final sampling, made a year after sowing, showed no significant effect attributable either to magnesium or manganese.

Thus for the first two or three months of the seedlings development manganese seemed to be required more than magnesium but later, up to the eight months stage, the predominant requirement was for magnesium.

TABLE 2. CHEMICAL COMPOSITION OF LAMINAE

	April 1954 *Top Storey*			*August 1954* *2nd Storey*			*November 1954* *Top & 2nd Storey*			*April 1955* *Top & 2nd Storey*		
				MAGNESIUM IN DRY LAMINA %								
Level	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3
		(± 0.019)			(± 0.022)			(± 0.015)			(± 0.015)	
Mg_1	0.24	0.16	0.18	0.09	0.10	0.12	0.12	0.10	0.10	0.14	0.10	0.08
Mg_2	0.26	0.20	0.20	0.19	0.20	0.16	0.28	0.20	0.22	0.23	0.20	0.18
Mg_3	0.30	0.28	0.26	0.36	0.39	0.42	0.32	0.34	0.32	0.28	0.31	0.26
				MANGANESE IN DRY LAMINA, P.P.M.								
Level	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3
		(± 2.5)			(± 3.8)			(± 48)			(± 66)	
Mg_1	14	13	32	36	24	74	122	325	1037	25	324	2306
Mg_2	16	16	27	14	18	56	49	138	592	24	196	1190
Mg_3	10	12	30	8	12	44	37	118	324	13	172	673
				PHOSPHORUS IN DRY LAMINA, %								
Level	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3
		(± 0.022)			(± 0.028)			(± 0.037)			(± 0.029)	
Mg_1	0.37	0.28	0.27	0.34	0.25	0.20	0.40	0.36	0.26	0.38	0.37	0.43
Mg_2	0.40	0.28	0.27	0.27	0.25	0.20	0.42	0.32	0.30	0.34	0.32	0.31
Mg_3	0.39	0.28	0.30	0.25	0.22	0.24	0.41	0.29	0.38	0.43	0.34	0.34
				POTASSIUM IN DRY LAMINA, %								
Level	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3
		(± 0.11)			(± 0.14)			(± 0.10)			(± 0.08)	
Mg_1	1.4	1.3	1.2	3.2	3.1	3.1	1.7	1.4	1.4	1.4	1.6	1.3
Mg_2	1.4	1.2	1.1	2.6	3.0	2.6	1.1	1.2	1.2	1.2	1.0	1.1
Mg_3	1.4	1.3	1.2	2.0	1.5	1.5	1.0	1.1	1.0	1.0	0.8	1.0
				CALCIUM IN DRY LAMINA, %								
Level	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3	Mn_1	Mn_2	Mn_3
		(± 0.014)			(± 0.052)			(± 0.068)			(± 0.061)	
Mg_1	0.07	0.04	0.06	0.56	0.48	0.50	1.14	0.94	0.90	0.70	0.95	1.04
Mg_2	0.14	0.09	0.06	0.49	0.44	0.50	0.94	0.64	0.57	0.58	0.66	0.60
Mg_3	0.14	0.10	0.10	0.43	0.47	0.52	0.57	0.53	0.51	0.53	0.53	0.41
				IRON IN DRY LAMINA, P.P.M.								
									Level	Mn_1	Mn_2	Mn_3
											(± 4.7)	
									Mg_1	97	84	74
									Mg_2	90	80	62
									Mg_3	89	76	66

Analytical Data (Table 2)

Rubber was determined in stems, petioles and laminae but no consistent effect of mineral status on the concentration of rubber in the tissues was found. Neither was any significant effect of mineral supply on the chlorophyll content of the laminae observed, although, in general, an increased supply of magnesium tended to increase and of manganese, decrease, the values obtained.

Increased magnesium supply always and markedly increased the concentration of magnesium found in the leaves, this effect became more marked with time, as the Mg_1 plants became progressively more magnesium deficient. Samples, which contained laminae taken from the top storey, showed, one month and thirteen months after planting, a significant reduction in magnesium concentration due to increased levels of supply of manganese. This effect was always most marked at the lower Mg levels; it was also detectable for the November sampling but was not observed for the June and August samplings. The leaves sampled in June and August were taken predominantly from the second storey, whereas the remainder of the samplings included top storey leaves; thus the suppressing effect of manganese on the accumulation of magnesium was only detectable in samples which included top storey leaves.

Increased supplies of manganese consistently increased the concentration of manganese found in the laminae. For the earlier samplings, the Mn_3 laminae contained roughly twice or thrice the concentration found in Mn_1 laminae but later, after the change to the ammonium type nutrient, this differential increased to fifty or more times. For all samplings, except the first, it was found that increased levels of magnesium significantly reduced the concentration of manganese in the laminae. This effect was highly consistent and became more marked with time. There was ample evidence to suggest that at low levels of supply of manganese the addition of an excess of magnesium can cause a severe deficiency of manganese to arise.

Laminae sampled up to and including November showed a significant reduction in their concentration of phosphorus as a result of manganese addition; this effect of manganese was usually most marked at the lower magnesium levels. Generally, magnesium addition was not observed to produce a consistent effect on the laminar phosphorus concentration. An increased supply of magnesium usually decreased the concentration of potassium and calcium in the laminae. For the earlier samplings increased manganese supply also reduced the calcium concentration within the laminae. The iron concentration of the laminae was determined for the material harvested in April 1955; it was found that increased manganese level significantly reduced the concentration of iron in the laminae.

DISCUSSION

Both the visual observations and the analytical data support the idea that magnesium and manganese are directly related in the nutrition of the rubber plant. Thus, increased supplies of magnesium markedly diminished the concentration of manganese in the laminae and induced the appearance of manganese deficiency symptoms. Some of the data also showed that increased manganese supply could reduce the magnesium concentration of the upper laminae; this effect was sometimes, but not always, accompanied by the appearance of magnesium deficiency symptoms. These findings are not in apparent accord with the direct magnesium-manganese correlationship reported by Beaufils (1955) for field grown plants.

When the manganese and magnesium concentrations, found in the laminae were plotted against one another certain trends were noted. Thus, for the samplings taken at the time of nitrate nutrient supply (*Figure 2*), an increased concentration of magnesium in the laminae of the Mg_1 and Mg_2 plants was accompanied by a decrease in that of manganese. However, for the Mg_3 plants evidence of the opposite effect was obtained; that is, an increase in the manganese occurred as the magnesium concentration increased. Similar trends were noted for the samplings taken from plants supplied with the ammonium type nutrient (*Figure* 3). A marked, almost linear decline in manganese concentration was observed for the Mg_1 plants with increasing magnesium, and of a tendency for a limited increase in manganese concentration with increased magnesium at the Mg_3 level. The relationship obtained for the Mg_2 plants seemed intermediate between the effects observed for the Mg_1 and Mg_3 plants. Thus the nature of these main effects was not altered as a result of the change in nutrient composition.

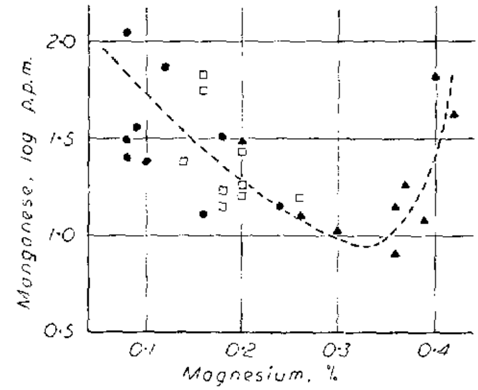

Figure 2. Relationships between the concentrations of manganese and magnesium found in the dry laminae of plants sampled in April, June and August 1954

Mg_1 • Mg_2 ▫ Mg_3 ▴

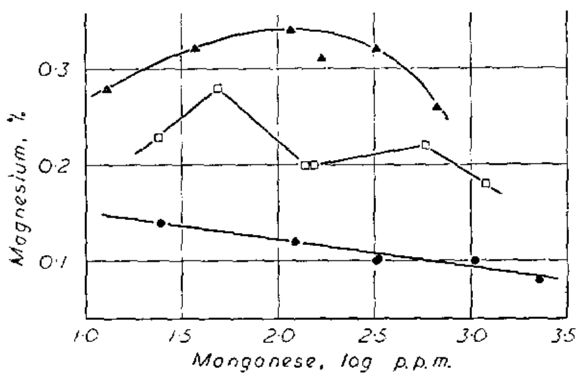

Figure 3. Relationships between the concentrations of manganese and magnesium found in the dry laminae of plants sampled in November 1954 and April 1955. Note linear negative relationship obtained at the Mg_1 level.

Mg_1 • Mg_2 ▫ Mg_3 ▴

The ease of identification of magnesium deficiency symptoms permits the rough assessment of the occurrence of the deficiency, and of the conclusion that it occurs extensively in Malaya, especially on replanted areas. Commonly, the remedial measure for the deficiency is the application of magnesium limestone. Both the calcium and magnesium constitutents of this limestone may depress the manganses uptake of the laminae. As there are indications that manganese deficiency, in a mild or incipient form, is quite common in Malayan rubber plantations, it may ultimately prove necessary, to supply a manganese supplement at the same time as the magnesium limestone is applied. Whether such action might prove necessary will depend on a full evaluation of the occurrence and severity of manganese deficiency symptoms and on the finding of whether, under normal estate conditions, these symptoms cause a marked diminution in growth and yield of rubber per tree.

An enhanced supply of manganese not only influenced magnesium status but also reduced the concentration of iron and phosphorus found in the laminae. The effect of manganese level on iron concentration is in agreement with observations, reported by other workers (WALLACE & HEWITT 1946) who have shown that nutrients possessing a high Mn/Fe ratio, may produce iron deficiency effects. However, the effect of manganese, a micronutrient, on the accumulation of phosphorus, a macronutrient, in the laminae, is not generally known. The results reported here show a definite decrease in phosphorus concentration as the manganese supply to the plant increased. Increased phosphorus supply may decrease the laminar concentration of manganese found for potato (BOLLE-JONES 1955) but increase that found for rubber (BOLLE-JONES 1954c); why such a difference of behaviour between the two plants should exist is difficult to explain and confirmation of these trends is required. However, there seems little doubt on the basis of these reports that both manganese and phosphorus are closely interrelated in the mineral nutrition of plants.

Earlier work (BOLLE-JONES 1954c) showed that increased magnesium supply influenced, usually increased, the phosphorus concentration of the lamina and that, for the earlier stages of the seedlings development, growth seemed to be governed more by the supply of magnesium than by phosphate. The present study shows that the concentration of manganese in the laminae is closely related to the magnesium status of the plant, that the level of manganese supply may influence the amount of phosphorus found in the lamina, and that growth is limited more by manganese than by magnesium in the early stages of development. Therefore it would seem that not only are the three elements closely connected but the requirement for an adequate external supply of manganese takes priority over that of magnesium which, in turn, is required more than phosphorus during the earlier stages of seedling development. This situation could be caused by relatively low reserves of manganese stored in the seed as compared with those of magnesium and phosphorus.

SUMMARY

Seedlings of *Hevea brasiliensis* were grown in sand culture at low, normal and high levels of magnesium and manganese. Increased levels of supply of magnesium induced the appearance of manganese deficiency symptoms in plants supplied with the lower levels of manganese and significantly reduced the concentration of manganese found in the laminae of those plants. The concentration of magnesium found in the upper laminae decreased as the nutrient supply of manganese increased and, in consequence, symptoms of magnesium deficiency were sometimes produced. At the lower levels of magnesium supply, it was shown that with an increased concentration of magnesium in the laminae the concentration of manganese decreased. At the high or 'luxury' level of magnesium supply an increase in the concentration of magnesium in the laminae was accompanied by an increase in the manganese concentration. The suggestion was made that in the early stages of the rubber seedling's development the requirement for an external supply of manganese was more important than that of magnesium which, in turn, was required more than phosphorus; these relative requirements may be related to the amount of mineral reserves present in the seed.

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