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DISTRIBUTION OF Mn AND Zn IN RUBBER GROWING SOILS AND ITS STATUS IN RELATION TO SELECTED MANAGEMENT PRACTICES

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ABSTRACT

A study was undertaken to assess the distribution profile of manganese (Mn) and zinc (Zn) in rubber growing soils and its status in relation to some soil management practices. Among the micro nutrients, Mn and Zn are considered as important for rubber. The acid extractable Mn and Zn contents which are considered as indicators of Mn and Zn reserves in soil, indicated significant differences between soil types. Matale soil series recorded the highest concentration of acid-extracted Mn and Zn followed by Ratnapura and Parambe series soils. Other soil series studied had low contents of both Mn and Zn. The profile distribution of acid-extracted, total Mn content showed a decrease with increase in soil depth while Zn content showed an opposite trend. The Mn and Zn contents in A and B horizons also exhibited a similar tendency. There was a negative correlation between Zn content and soil organic carbon content.

Assessment of Mn and Zn status in relation to some soil management practices indicated that rice straw and poultry litter application enhanced the soil and leaf Mn contents significantly. Application of rubber factory effluent to rubber lands and different planting practices such as rubber and tea and rubber and cinnamon multi-cropping systems on Mn and Zn status of rubber growing soils were also investigated. Leaf contents of both Mn and Zn of different legume cover species and their effect on soil Mn and Zn status were also studied. RRIC 100 series clones showed higher leaf Mn and Zn contents compared to clone PB86 at the same Mn and Zn soil levels.

Key words: *Hevea*, cover crops, micro-nutrients, poultry litter, rubber growing soils, soil management

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INTRODUCTION

Since the introduction of rubber in Sri Lanka in the late nineteenth century, many plantations have undergone at least three planting cycles, approximately 30 years per cycle. Simultaneously, the commercial yields have also increased appreciably from about 250 kg per ha. to the present level of approximately 1500 kg per ha., a six fold increase.

Regular removal of nutrients via latex and timber in addition to leaching, erosion and other losses from a *Hevea* eco-system, demands replacement of these nutrients (Samarappuli & Yogaratnam, 1996). Rubber plants are known to require a number of elements, some in relatively large amounts, *viz* the macro-nutrients, while others only in tracers, *viz.* the micro-nutrients for normal, healthy growth and development. Among the micro nutrients, Mn and Zn are considered as important for rubber (Yogaratnam & Perera, 1985; Samarappuli, 1995). The agricultural cropping system adopted in rubber plantations over the last several decades using the same agro-management practices with continuous application of inorganic fertilizers, introduction of new clones, adoption of intercropping practices and different soil management practices are conducive for the occurrence of deficiencies or toxicities of Mn and Zn (Samarappuli *et al.*, 1996; Samarappuli *et al.*, 1997).

A study was therefore undertaken to assess the distribution of Mn and Zn in rubber growing soils and its status in relation to management practices.

MATERIALS AND METHODS

In experiment 1, Mn and Zn status of the soils under rubber were studied. Six soil series; *Parambe, Matale, Boralu, Ratnapura, Agalawatte* and *Homagama* were included and the effects of soil depth and horizon on the distribution of Mn and Zn were studied. A brief description of each soil series is given in Table 1 (Silva, 1964; Alwis & Panabokke, 1972; Mapa *et al.*, 1999). For each soil series three sites were identified and soil profiles were cut and two soil samples were collected from each layer for analysis. Site selection, cutting of soil profiles and collection of soil samples were done in collaboration with the Land Use Division of the Irrigation Department. The parameters that were analyzed included acid (HCl and HNO_3) and ammonium acetate extractable Mn and Zn. In addition, some physico-chemical characteristics of the soil such as exchangeable Ca, organic C and pH were also considered in order to study the relationship between Mn, Zn contents and these soil characteristics.

In experiment 2, Mn and Zn status under different soil management practices such as cover cropping, application of poultry litter, mulching with rice straw, land application of rubber factory effluent and different farming systems such as tea and rubber multicropping, intercropping with cinnamon were studied by collecting and analyzing soil and leaf samples from long term on going field experiments (RRIM, 1971a; RRIM, 1971b; RRISL, 1996).

Statistical analyses of all experimental data were done by Analysis of Variance (ANOVA) followed by a mean separation procedure, Duncan's Multiple Range Test (DMRT), at the probability level 0.05. Mean values of this analysis are presented in tabular form and the values with the same letter are not significantly different at the specified probability level.

Table 1. *A description of parent material and classification of different soil series*

Soil Series	Parent material	Classification	
		Local (Great soil group)	USDA Soil Taxonomy
Matale	Crystalline limestone	Reddish Brown Latosol	Typic Rhodusalfs
Parambe	Biotite gneiss	Reddish Brown Latosol	Typic Troporthents
Ratnapura	Garnetiferous rocks	Red Yellow Podzol	Typic Haplohumults
Homagama	Quartz schist rocks	Red Yellow Podzol	Typic Tropopsamments
Agalawatta	Granitic and Gneissic rocks	Red Yellow Podzol	Typic Hapludults
Boralu	Vijayan and Khondalite rocks	Red Yellow Podzol	Typic Paleudults

RESULTS

The acid extractable Mn and Zn contents in the 0-15cm soil layer indicated significant differences between soil types. *Matale* series soils showed the highest Mn and Zn contents of 1784.2 and 93.8mg/kg, followed by *Ratnapura* and *Parambe* series soils. Other soil series had low contents of both Mn and Zn. There was a significant difference for ammonium acetate extractable Mn content among different soil series. However, the ammonium acetate extractable Zn fractions between soil series were not significantly different (Table 2). The soils studied would therefore fall into three broad categories with *Matale* as the highest, *Parambe* and *Ratnapura* as moderate and *Homagama*, *Agalawatta* and *Boralu* soils as the lowest (Table 3), according to Yogaratnam & Perera (1985).

The total Mn and Zn contents in A and B soil horizons are presented in Fig 1 and 2, respectively. Although total Mn content in the B horizon is lower in comparison to A horizon, the total Zn content is higher in the subsurface B horizon compared to surface A horizon. Profile distribution of total Mn and Zn contents in different rubber growing soils indicated that, while total Mn content decreased with increase in soil depth, total Zn content exhibited an opposite trend (Fig. 3 and 4). Assessment of the relationship between Mn content and some soil characteristics indicated that exchangeable Ca and soil pH are negatively related ($p<0.05$) to acid extractable Mn fraction in the soil. Similar results were obtained for Zn fraction also. It was further observed that there was a negative correlation between Zn content and soil organic carbon content. This trend was however, noted for soil organic carbon content between zero and 2% (Table 4).

Table 2. *Variation in acid and ammonium acetate extracted Mn and Zn contents in rubber growing soils (0-15cm soil depth)*

Soil Series	Mn content (mg/kg) by extractants		Zn content (mg/kg) by extractants	
	Acid	Ammonium acetate	Acid	Ammonium acetate
Matale	1784.2[a]	93.8[a]	44.9[a]	2.9[a]
Parambe	263.1[b]	36.4[b]	20.6[b]	1.9[a]
Ratnapura	435.9[b]	22.7[b]	23.9[b]	0.9[a]
Homagama	39.4[c]	8.2[c]	9.5[c]	1.3[a]
Agalawatta	30.2[c]	5.3[c]	15.5[c]	0.9[a]
Boralu	21.4[c]	3.1[c]	10.8[c]	0.7[a]

(Means with the same letter are not significantly different at 0.05 probability level)

Table 3. *Categorization of rubber soils according to Mn and Zn status*

Mn and Zn status	Soil series
High	*Matale*
Moderate	*Parambe, Ratnapura*
Low	*Homagama, Agalawatta, Boralu*

Table 4. *Correlation between some selected soil characteristics and soil Mn and Zn contents*

Soil characteristics	Correlation coefficient	
	Mn	Zn
Exchangeable Ca	- 0.783	- 0.812
Organic C	+ 0.585	- 0.756
pH	- 0.827	-0.834

In experiment 2, there was no significant correlation between soil and leaf contents of Mn and Zn. However, leaf Mn content indicated significant differences ($P<0.05$) due to stage of maturity (Table 5).

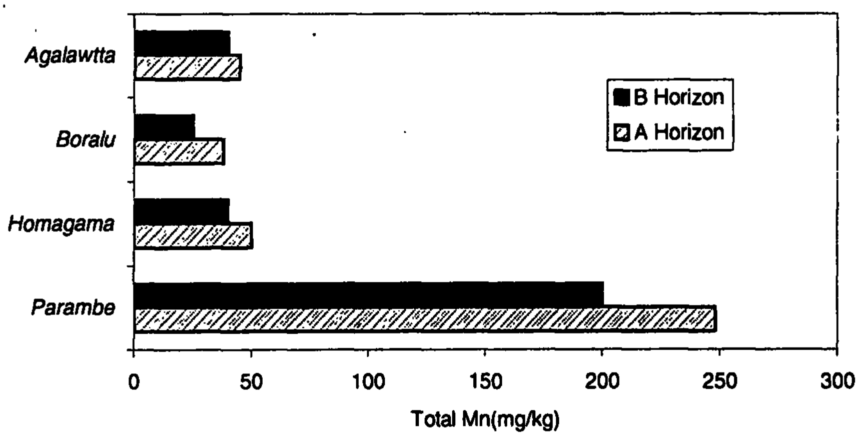

Fig. 1. Total Mn content of different soil series in A and B horizons

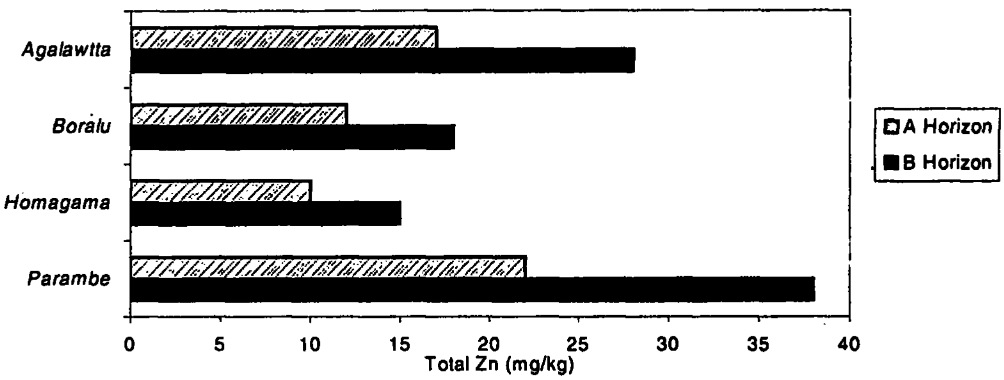

Fig.2. Total Zn content of different soil series in A and B

Table 5. *Variations in leaf Mn and Zn contents in relation to leaf age*

Stage of maturity	Leaf Mn content (mg/kg)	Leaf Zn content (mg/kg)
Tender	55.8	18.8
Intermediate	59.9	20.1
Mature	69.5	23.4
L.S.D.	7.3	4.5

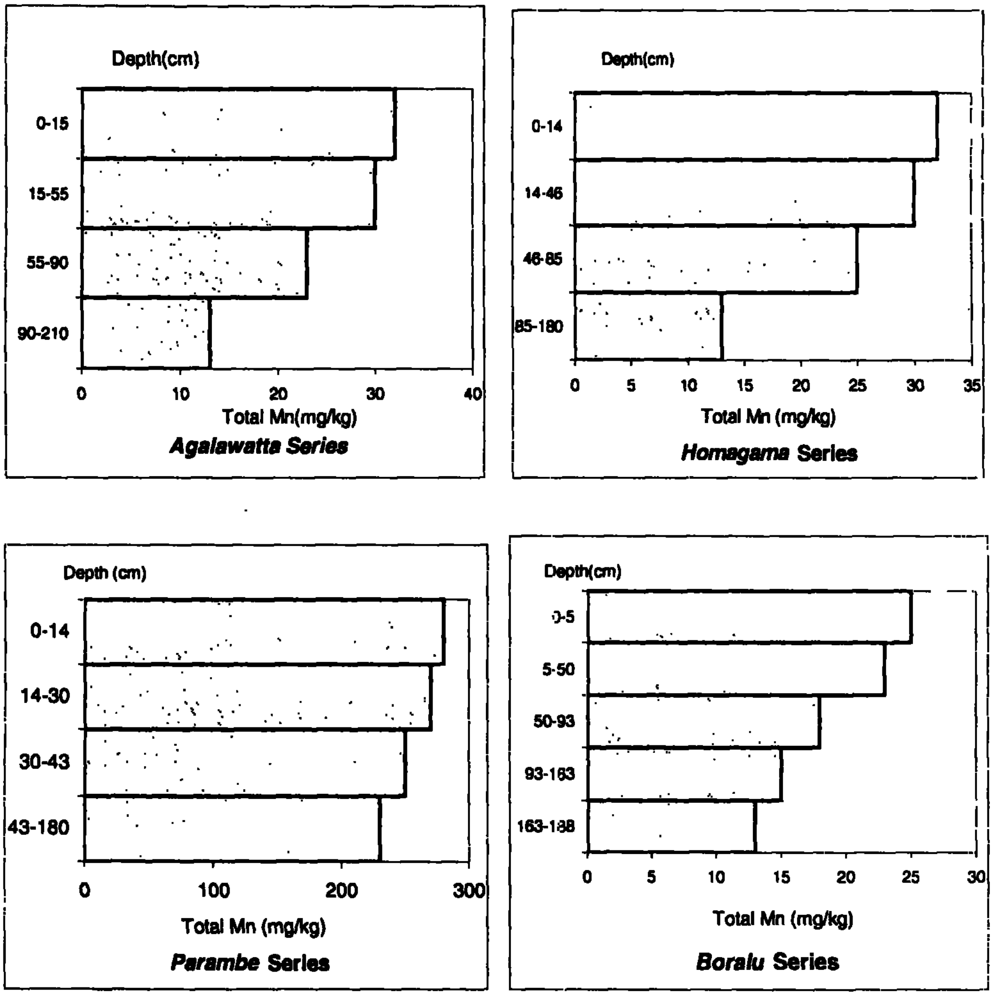

Fig. 3. Profile distribution of soil Mn in different rubber growing soils

Leaf Mn and Zn contents of different legume cover species are presented in Table 6. It is clear that *Pueraria phaseoloides* and *Centrocema pubescens* have higher Mn content compared to *Calopogonium mucunoides*, while Zn content indicated an opposite trend. The Mn and Zn contents of rice straw are presented in Table 7.

Table 6. *Leaf Mn and Zn contents of different cover species*

Cover species	Leaf Mn content (mg/kg)	Leaf Zn content (mg/kg)
Pueraria phaseoloides	72.4	28.0
Centrocema pubescens	75.1	22.1
Calopogonium mucunoides	58.3	35.2

Table 7. *Mn and Zn contents of rice straw*

Nutrient	Amount (mg/kg)
Mn	28.3
Zn	35.2

The effect of different soil management practices on soil and leaf Mn and Zn status are presented in Table 8. There were significant differences between different soil management practices for soil Mn content, highest value being recording with straw mulch. The changes in soil Mn and Zn contents with time after application of rice straw, are presented in Figure 5. In general, application of rice straw has increased the soil Mn content by 2.4mg/kg with time, suggesting the presence of readily available Mn in rice straw and the Zn content of the soil by 40%. These data also suggest that incorporation of straw into the soil releases more Mn and Zn than surface mulching (Table 9). The Mn and Zn contents of different tree legume species recommended for planting with rubber are presented in Table 10. Their effect on soil and leaf Mn and Zn contents are presented in Table 11.

Table 8. *Effect of different soil management practices on Mn and Zn contents of soil and leaf, six years after planting*

Treatment	Mn content (mg/kg)		Zn content (mg/kg)	
	Soil	Leaf	Soil	Leaf
Legumes	1.7^a	51.4^a	0.7^a	19.3^a
Naturals	1.1^a	48.8^a	0.6^a	18.8^a
Straw mulch	2.8^b	51.2^a	0.4^b	17.3^a

(Means with the same letter are not significantly different at 0.05 probability level)

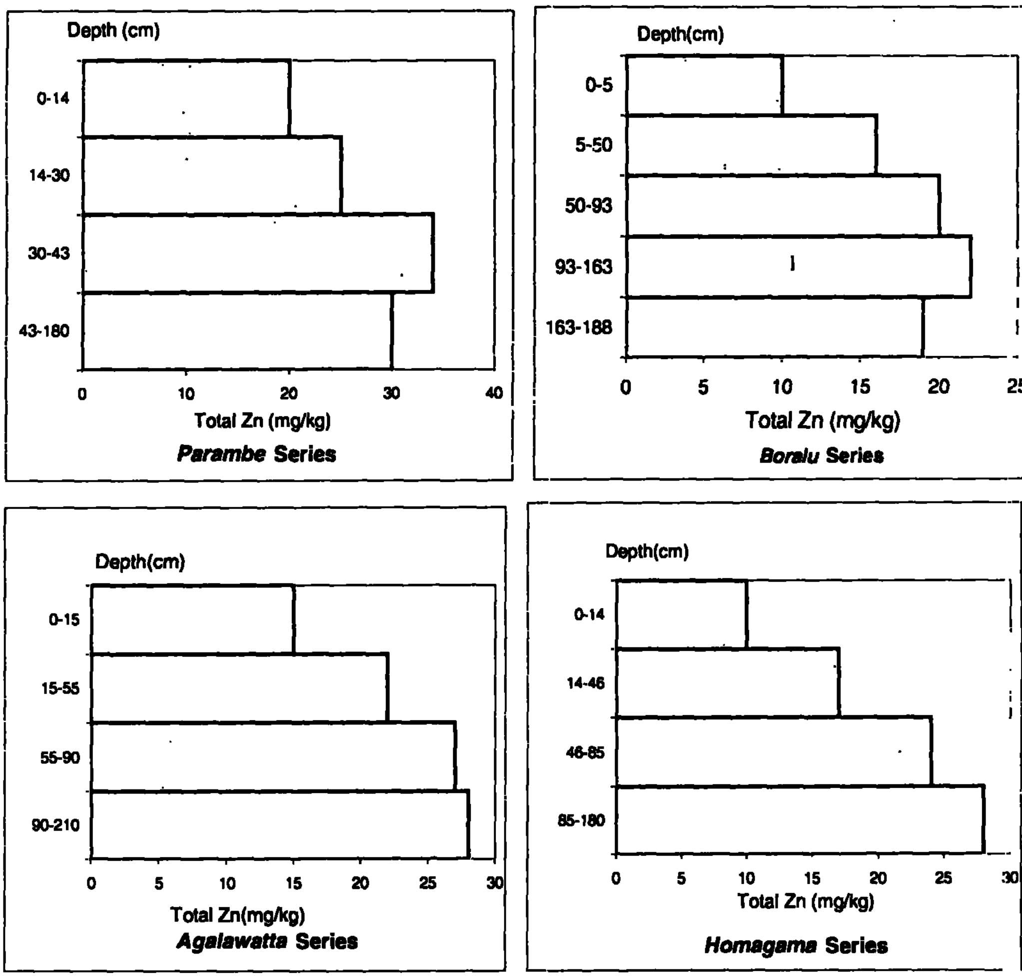

Fig. 4. Profile distribution of soil Zn in different rubber growing soils

Table 9. *Effect of mulching on Mn and Zn contents of soil, four months after application*

Treatment	Mn (mg/kg)	Zn (mg/kg)
Nil straw	1.4[a]	3.3[a]
Straw (incorporation)	3.9[b]	1.5[b]
Straw (surface mulching)	3.7[b]	1.2[b]

(Means with the same letter are not significantly different at 0.05 probability level)

Table 10. *Leaf Mn and Zn contents of different tree legume species*

Species	Leaf Mn content (mg/kg)	Leaf Zn content (mg/kg)
Flemingia congesta	92.5	47.5
Crotolaria anagyroides	88.5	49.2
Tephrosia vogelli	85.2	39.9

Table 11. *Effect of different tree legume species on Mn and Zn contents of soil and leaf, six years after planting*

Treatment	Mn content (mg/kg)		Zn content (mg/kg)	
	Soil	Leaf	Soil	Leaf
Flemingia macrophylla	2.8[a]	57.1[a]	1.1[a]	25.1[a]
Crotolaria micans	2.5[a]	58.7[a]	0.9[a]	27.1[a]
Tephrosia vogelli	2.4[a]	54.9[a]	1.1[a]	23.2[a]

(Means with the same letter are not significantly different at 0.05 probability level)

The Mn and Zn contents of different types of poultry litter are presented in Table 12. Poultry litter application to rubber lands enhanced the available soil Mn content by 26% and also the leaf Mn content from 25.8mg/kg to 59.6mg/kg. However, application of poultry litter has decreased the Zn content of the soil by 28% (Table 13). Application of rubber factory effluent to rubber lands did not show any significant changes in soil Mn and Zn contents (Table 14). There was a significant decrease in soil Zn status in rubber and tea multi-cropping system compared to rubber as a mono-crop system (Table 15). Rubber and cinnamon planting systems did not show any significant changes in soil Mn and Zn contents (Table 16). RRIC 100 series clones showed higher leaf Mn and Zn contents compared to clone PB 86 which had only 32.1mg/kg and 13.3mg/kg, respectively (Table 17).

Table 12. *Mn and Zn contents of different types of poultry litter*

Types	Mn content (mg/kg)	Zn content (mg/kg)
Chick litter	395.7	320.5
Broiler litter	317.4	219.2
Layer litter	369.1	256.0

Table 13. *Effect of poultry litter application on Mn and Zn contents of soil and leaf, five years after planting*

Treatment	Mn content (mg/kg)		Zn content (mg/kg)	
	Soil	Leaf	Soil	Leaf
Without poultry litter	2.0^{a}	25.8^{a}	0.7^{a}	28.7^{a}
With poultry litter	2.6^{b}	59.6^{b}	0.5^{b}	18.1^{b}

(Means with the same letter are not significantly different at 0.05 probability level)

Table 14. *Effect of rubber factory effluent application on Mn and Zn contents of soil and leaf, six years after planting*

Treatment	Mn content (mg/kg)		Zn content (mg/kg)	
	Soil	Leaf	Soil	Leaf
Normal fertilizer mixture (12:14:14)	1.5^{a}	42.2^{a}	1.9^{a}	21.9^{a}
½ normal fertilizer mixture + 1:1 diluted serum	1.6^{a}	43.0^{a}	1.5^{a}	19.5^{a}
1:1 diluted serum only	1.4^{a}	52.3^{a}	1.8^{a}	22.8^{a}
Undiluted serum only	1.5^{a}	53.8^{a}	1.6^{a}	22.6^{a}
Control (Water only)	1.8^{a}	47.7^{a}	1.4^{a}	24.5^{a}

(Means with the same letter are not significantly different at 0.05 probability level)

Table 15. *Effect of different planting practices of tea and rubber on Mn and Zn contents*

Treatment	Mn content (mg/kg)		Zn content (mg/kg)	
	Soil	Leaf	Soil	leaf
Rubber only	2.4^{a}	59.1^{a}	2.2^{a}	24.2^{a}
Tea and rubber (rehab.)(8'x27')	2.1^{a}	52.3^{a}	1.1^{b}	22.1^{a}
Tea and rubber (unrehab.)(8'x2w')	2.0^{a}	55.8^{a}	1.0^{b}	20.5^{a}
Tea and rubber (rehab.)(8'x40')	2.1^{a}	55.1^{a}	1.6^{b}	22.6^{a}
Tea and rubber (unrehab.)(8'x40')	2.2^{a}	52.6^{a}	1.4^{b}	23.6^{a}

(Means with the same letter are not significantly different at 0.05 probability level)

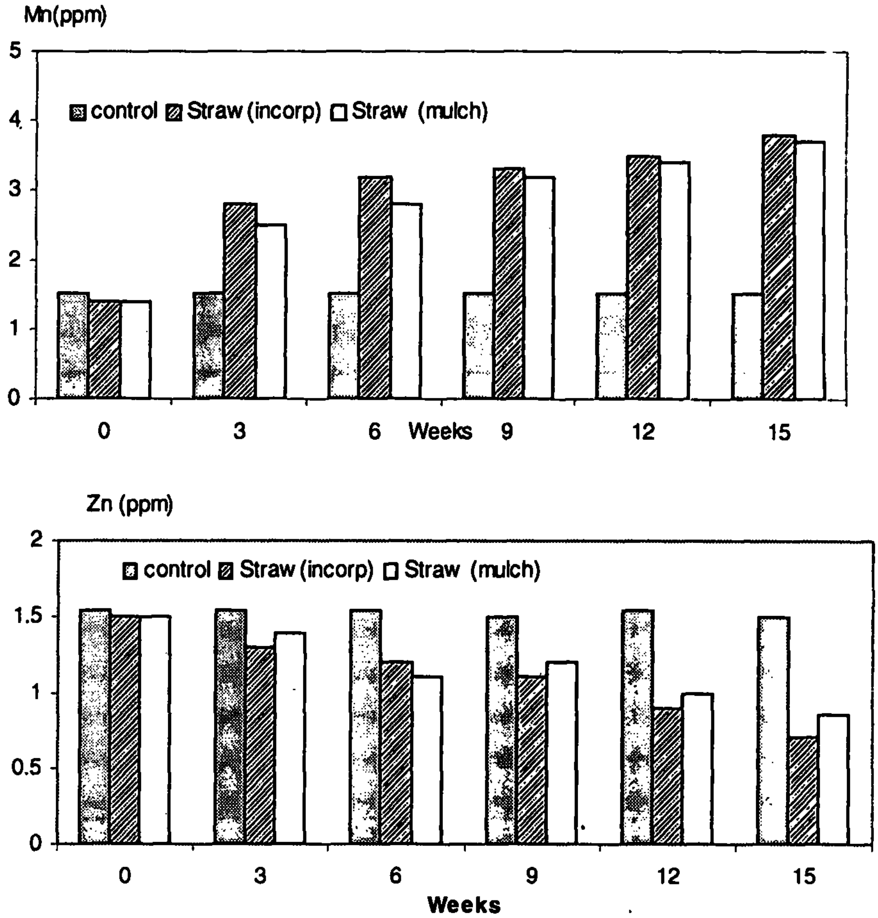

Fig. 5. Effect of rice straw on soil Mn and Zn contents

Table 16. *Effect of cinnamon as an inter-crop with rubber on leaf Mn and Zn content*

Treatment	Mn content (mg/kg)		Zn content (mg/kg)	
	Soil	Leaf	Soil	leaf
Rubber only	2.3[a]	67.1[a]	1.9[a]	23.4[a]
Rubber and cinnamon (5 ft. away)	2.4[a]	55.3[a]	1.2[a]	22.1[a]
Rubber and cinnamon (7 ft. away)	1.9[a]	54.1[a]	1.4[a]	26.9[a]
Rubber and cinnamon (9 ft. away)	2.2[a]	59.6[a]	1.6[a]	25.6[a]

(Means with the same letter are not significantly different at 0.05 probability level)

Table 17. *Variation of leaf Mn and Zn contents in different rubber clones*

Clone	Mn (mg/kg)	Zn (mg/kg)
RRIC 100	57.4	29.8
RRIC 101	45.8	27.4
PB 86	32.1	13.3

DISCUSSION

Mn and Zn are considered as important micro-nutrients in rubber cultivation. Due to the removal of these nutrients via timber and latex in addition to other losses from a *Hevea* eco-system, a need may arise to replace these nutrients in the system.

Effect of different soil series

The total Mn and Zn contents, which are considered as an indicator of the Mn and Zn reserves in the soil show significant differences between soil types. The soils studied would therefore, fall into three broad categories with *Matale* as high, *Parambe* and *Ratnapura* as moderate and *Homagama*, *Agalawatta* and *Boralu* soils as low. These categorization is in line with the findings of Yogaratnam & Perera (1985). Factors that contribute to the variations in the Mn and Zn contents appear to be mainly the parent material and soil pH. It was observed that the total Mn and Zn contents of rubber growing soils except *Matale* series soil were low. These low levels are probably due to leaching of acidic soils under conditions of high rainfall. Mn and Zn deficiencies may therefore, occur in these soils. Nevertheless, as low soil pH would make these micro-nutrients more available to plants (Ng & Bloomfield, 1962), which possibly explains as to why deficiencies have not been reported. Similarly, toxicity from excessive uptake of Mn and Zn from *Matale* series was unlikely to occur in view of the high pH and high exchangeable Ca and consequent lower availability of Mn and Zn. It has also been shown that a high concentration of Mn in manufactured rubber promotes oxidation and therefore, there is a legal tolerance limit of 10ppm in the amount of Mn that may be present (Anonymous, 1957). Further, significant increases in the Mn content of leaf, bark and latex were also observed, with increasing level of Mn in the soil and these increases were more clearly shown in leaves than latex (Shorrocks & Watson, 1961). The lower availability of Mn due to high soil pH and high exchangeable Ca, in Mn rich *Matale* series soils where Mn occurs in excessive quantities is very useful in maintaining the legal tolerance limit of 10ppm Mn in the latex.

Effect of soil pH, organic matter and clay content

Profile distribution of total Mn and Zn contents in different rubber growing soils indicated that, while total Mn content decrease with increase in soil depth, total Zn content exhibited an opposite trend. These differences are probably due to the variations in the organic matter content and clay content in the different soil depths. Therefore, changing the depth of planting may help in alleviating Mn and Zn deficiency or toxicity problems in some instances.

It is apparent from the data that both Mn and Zn contents decrease with increase in soil pH. Assessment of the relationship between Mn and Zn contents and exchangeable Ca indicated a similar trend. Such negative significant relationship between pH and exchangeable soil Mn was also reported by Baser & Saxena (1970) and a positive significant relationship for Mo by Yogaratnam & Perera (1985). It was further observed that there was a positive correlation between Mn content and soil organic carbon content and a negative correlation between Zn content and soil organic carbon content. Divalent Mn absorbed to organic matter and clay minerals is the most important Mn form in the soil solution. In soil solution Mn is largely present as organic complexes and therefore, organic matter content and microbial activity influence the Mn availability in soil. Similar results were also observed by Nagarajah *et al.* (1989), for rice soils.

Effect of legume covers and rice straw

Legume covers and rice straw contain about 20-100 mg/kg of Mn and 20-50 mg/kg of Zn. Incorporation of rice straw and continuous lopping and mulching of tree legumes during the six year immature period would contribute an appreciable quantities of Mn and Zn. There were significant differences between different ground cover management practices on both soil Mn and Zn contents. These data indicated that soil Mn content has increased with time after application of rice straw. The influence of cover plants on soil improvement is of considerable importance although they may compete for essential nutrients with rubber plants (except for nitrogen). On the other hand there is no such competition for nutrients with dead mulch (Samarappuli *et al.*, 1998). Additionally, the gradual release of soil nutrients by mulch would have been a contributory factor in increasing the nutrient contents of *Hevea* under mulched conditions. The importance of ground cover management *viz* growing legumes and mulching in enhancing the organic carbon status of the soil was reported earlier (Yogaratnam *et al.*, 1984; Samarappuli *et al.*, 1998). Although decomposition of organic matter is rapid under tropical condition, organic matter tends to accumulate in the form of mulch of decaying straw due to continuous mulching at six months intervals (Samarappuli *et al.*, 1998). A possible explanation for the higher amount of organic carbon found under mulch is that rice straw has a higher C/N ratio than legume litter (Samarappuli, 1992) and therefore could serve as a carbon source for a longer period of time. The nitrogen content of the leguminous cover leaves, green matter and litter is greater (Yogaratnam *et al.*, 1984) and the C/N ratio of the litter was lesser in the legume loppings. It is known that materials with low C/N ratio are expected to mineralize rapidly with its nutrients becoming quickly available again for uptake by *Hevea* (Watson, 1961). In addition, organic materials are good sources of energy to micro-organisms in the soil and therefore, microbial activity may influence the Mn availability in the soil to a great extent. Data presented also indicate that the Zn content of the soil has decreased with time after application of rice straw. Therefore. excess organic matter may be undesirable because it decreases the availability of Zn.

Mulching with rice straw and growing of bush legumes between the rows of rubber plants and use of loppings of these trees at suitable intervals for mulching the ground along the clean weeded strip or circles of the planting row of rubber can therefore, be considered as a useful agro-management practice towards Mn and Zn status of rubber plantations.

Effect of organic manure

It is a well known that balanced fertilization is a primary step towards improving fertilizer use efficiency. We are entering an era of multiple nutrient deficiencies where a single nutrient approach can lower fertilizer use efficiency. Balanced nutrition implies that there are no deficiencies, no antagonisms and no negative interactions. All nutrients need to be at an optimum by themselves and in relation to each other enabling positive interactions leading to enhanced tree performances. Apart from major nutrients. micronutrients like Mn and Zn are also gaining importance in recent years. While no serious problems are encountered in dealing with macro nutrients, correction of micro nutrient imbalance or deficiency is not a simple task since very small amounts are involved. A small excess of micro nutrients may prove to be fatal to the rubber plant. Moreover, the drawbacks associated with either mineral or organic sources of plant nutrients are often overcome when they are used in judicious combination. Interactions occur and the increase in tree performance is sometimes more than those obtainable from the use of equivalent quantities of nutrients from either source alone (synergistic effect). Moreover, environmental hazards attributed to micronutrient toxicity could easily be mitigated by optimizing fertilizer use efficiency through a judicious mixture of organic manures like poultry litter, which are easily accessible to the rubber grower. The data suggests that rubber plant can meet much of its Mn and Zn requirement from this source. if managed properly, mainly through mineralization of organic matter.

Effect of inter-cropping

Minor differences were detected for Mn and Zn contents under different inter-cropping systems. The nature of the crop and the use of inorganic fertilizers may be the main reasons for these observations. The data indicated that soil Zn content is significantly lower in plots with rubber and tea multi-cropping system. This can be attributed to the continuous demand for Zn by tea and it appears that the Zn supplying capacity of soils has decreased considerably. Therefore, special emphasis has to be given to maintain the Zn status of the rubber growing soils under rubber and tea multi-cropping system.

Effect of different clones

The data also suggest that RRIC 100 series clones have higher demand for both Mn and Zn compared to clone PB 86 and therefore, due consideration should be given to maintain the Mn and Zn status of the rubber growing soils in the near future.

It appears that rubber growing soils in Sri Lanka have adequate supply of both Mn and Zn for satisfactory performance of rubber trees. However, they may, in time to come be low in organic matter. Therefore, practically all rubber lands would benefit from liberal annual doses of organic manures such as animal manure, crop residues, green manure *etc.* The organic manure application helps to recycle the nutrients and correct deficiencies particularly of micronutrients. Further, it may be possible to alleviate Mn and Zn deficiency/toxicity problems by adopting suitable agronomic practices, *viz* management of leguminous cover crops, mulching, adopting correct planting systems, appropriate fertilizer programmes for different clones. Plant nutrition in future will therefore, require the judicious and integrated management of all sources of nutrients and management practices.

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