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Total and Available Molybdenum in Some Soils under Rubber and Their Effect on Hevea

C.H. LAU* AND T.S. LIM*

Total and available molybdenum in nine major soil series in Peninsular Malaysia were determined. Total Mo in the soils varied from 1.13 mg/kg to 10.53 mg/kg while available Mo ranged from 155 µg/kg to 721 µg/kg soil. Among the soils, the marine clays of the Selangor series soil and the basaltic Kuantan series soil have the highest total Mo content. Within the soil profiles, the A_p horizons appeared to have higher total and available Mo. Application of different levels of sodium molybdate to rubber seedlings grown in the glasshouse failed to induce any visual Mo toxicity symptom in the plants although dry matter yield declined at levels beyond 0.120 kg sodium molybdate/ha. Liming at rates of 2000 kg and 2800 kg ground magnesium limestone/ha enhanced the availability of Mo in the sandy Holyrood series soil. However, this effect could be marred by the rapid leaching loss of the nutrient.

In soils, molybdenum occurs in four possible main forms: i) water-soluble; ii) in association with organic matter; iii) exchangeable anion MoO_4^{2-}, adsorbed on colloidal complex; and iv) insoluble, held in the crystal lattices of minerals[1]. The status of Mo as a plant nutrient has been well established and documented by many workers[2,3,4]. In soils with low pH, the Mo is immobilised and becomes less available to plants. Barshad[1] showed that soils with higher pH values released more adsorbed Mo into solution during plant growth than soils with lower pH values. Field experiments on Ultisols carried out by Burmester *et al.*[5] suggested that Mo deficiency in soybean was a more common factor of acid soil infertility than aluminium toxicity and liming appeared to alleviate these adverse influence on crop yield.

In Malaysia, the occurrence of Mo deficiency has not been conclusively established although growth responses by leguminous plants to added Mo were first reported by Sandison and Hanly[6]. In sand culture studies in which rubber seedlings were deprived of Mo or given a very low level of Mo supply, Bolle-Jones[7] observed that the seedlings were shorter, of smaller girth and dry weight, and developed a marginal or tip scorch in the mid-stem and upper laminae. Increased Mo supply reduced the concentration of No_3-N within the laminae as well as the concentrations of S, Mg, and K but increased that of Mn. Under Malaysian field conditions, Bolle-Jones[7] noted that Mo deficiency in rubber may occur but this does not appear to be accompanied by well defined foliar symptoms.

While there was evidence that the concentration of Mo in rubber is related to the Mo content in the soils, the Mo status of the soils was not extensively studied. Abdul Aziz[8] found that soils developed on recent alluvium in Peninsular Malaysia were adequate in total trace element content with Mo content ranging from 2 µg to 30 µg/g soil. However, the mobile or extractable components were low. Additionally, the trace elements were closely associated with the finer fractions of the soils.

*Rubber Research Institute of Malaysia, P O Box 10150, Kuala Lumpur 50908, Malaysia

This paper attempts to determine the Mo status of some major soils where rubber is grown. The performance of rubber seedlings grown in one of the soils and receiving Mo or nil Mo in the glasshouse was assessed and discussed. In association with this study, the effect of liming on the availability and uptake of Mo by soyabean is also reported.

EXPERIMENTAL

For each soil type, samples were collected from a soil profile pit dug in the inter-row area of rubber as this is expected to be least disturbed by fertiliser inputs. The soil samples taken at 0–45 cm depth where maximum root concentration occurs[9] and at different horizons in the soil profile were air-dried at 305°K, ground to pass through a sieve (<2 mm size) and sub-sampled for analysis[10]. In this study, nine different soils were sampled and their relevant properties are given in *Table 1*.

Determination of Total and Available Molybdenum

Total Mo was determined by the procedure reported by Grigg[11]. 5 g of ground soil (<60 mesh) in a platinium crucible was ashed at 723°K and the ashed sample treated with hydrofluoric acid to remove silica. The residue obtained was dissolved in concentrated HCl and the solution filtered and evaporated to dryness. A further 5 ml of HCl and 1 ml of 72% $HClO_4$ was added and the mixture evaporated to dryness. This process was repeated twice before the final residue was re-dissolved in about 5 ml hot concentrated HCl and transferred to a graduated glass-stoppered test tube to which 5 ml of 5% NaF solution, 1.5 ml of 20% KCNS and 3 ml of 40% $SnCl_2$ were added. The content in the tube made up to the 32 ml mark with water followed by the addition of 10 ml isoamyl alcohol was shaken and then immersed in a hot water-bath at 353°K for 20 min. The aqueous phase was removed with a suction pipette while the amyl alcohol layer in the tube was mixed with a 25 ml portion of $SnCl_2$ solution and placed in the water-bath until all the iron colour had faded. The aqueous phase was again removed and the isoamyl alcohol layer shaken with a second portion of the $SnCl_2$ solution. After completing the washing, the aqueous layer was completely removed and the amyl alcohol solution filtered through a dry Whatman No. 1 filter paper into a dry tube. Total Mo in the soil was determined from the absorption of the alcohol solution in a 50 mm micro-cuvette with a previously calibrated spectrophotometer at a wavelength of 465 mμ.

For available Mo, 25 g of the air-dried soil was shaken with 250 ml of acid ammonium oxalate buffer containing 498 g of $(NH_4)_2C_2O_4$ and 252.1 g of $H_2C_2O_4$ per 20 litres at room temperature overnight. An aliquot of the extract which was separated by centrifugation was evaporated to dryness, ignited for 3 – 4 h at 723°K to remove oxalate and organic matter and then treated with concentrated HCl as described in the procedure for total Mo. The available Mo in the amyl alcohol solution was determined as before.

Effect of Molybdenum on Performance of Rubber Seedlings

In each 45 kg pot filled with Rengam series soil (Typic Kandiudults) that had previously been passed through a 2 mm sieve, five *Hevea* plants were grown. Molybdenum as sodium molybdate ($Na_2MoO_4.2H_2O$) was applied to the soil in a single dressing when the seedlings were two months old starting from germination and at rates of 0, 0.012, 0.12, 1.2 and 12 kg/ha. The amount of Mo was calculated on the basis of 2×10^6 kg soil/ha. To each pot, basal applications of 10 g $(NH_4)_2SO_4$, 57 g Christmas Island rock phosphate, 6 g KCl and 7 g $MgSO_4$ were made at monthly intervals. Each treatment was done in triplicate.

When the plants were four months old, micro-tapping of the seedlings commenced. To each plant, fifteen pin punctures were made on the bark at a standard height of

TABLE 1 SOME PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL (0 – 45 cm)

Soil series	Sampling area	Sub-group[a] (parent material)	Texture[b]	pH	Organic carbon (g/kg soil)	Cation-exchange capacity (cmol/kg soil)
Durian	Ayer Hitam	Plinthaquic Paleudults (siliceous shale)	sicl-cl	4.5	14.5	5.22
Holyrood	RRIM Experiment Station, Sg Buloh	Typic Quartzisamments (sub-recent alluvium)	sl	4.6	11.8	3.42
Kuantan	Kuantan	Typic Hapludux *(basalt)*	sil-cl	4.6	25.3	3.28
Munchong	RRIM Experiment Station, Sg Buloh	Typic Hapludux (schist)	cl	4.4	18.3	5.64
Prang	Seremban	Typic Hapludux (schist)	cl	4.4	13.6	4.87
Rasau	Segamat	Typic Kandiudults (sub-recent alluvium)	sl-scl	4.7	12.4	2.90
Rengam	RRIM Experiment Station, Sg Buloh	Typic Kandiudults (granite)	coscl	4.4	15.8	4.53
Selangor	Kapar	Typic Tropaquepts (marine clay)	cl-sicl	3.9	32.7	18.32
Serdang	RRIM Experiment Station, Sg Buloh	Typic Kandiudults (sandstone)	scl-sl	4.3	12.5	3.96

[a]According to *Keys to Soil Taxonomy* by Soil Survey Staff — USDA (1989)
[b]c = clay, si = silty, s = sandy, l = loam, co = coarse

10 cm above soil level and the latex flowing out was absorbed by a filter paper strip (1.5×6.0 cm) attached to the stem. After allowing 3 h of latex flow, the wet filter paper strips were oven-dried and weighed. The increase in weight of the filter paper was taken as the yield expressed as milligramme latex per tapping per plant. A total of seven tappings spread over a period of three weeks was completed. When the seedlings were twelve months old, the girth and height of each plant were measured. The whole plant was then harvested for dry matter determination. The leaf and stem samples were separated and analysed for Mo content.

Effect of Liming on Molybdenum in the Soil

Soyabean *(Glycine max)* of the Palmetto variety and inoculated with *Bradyrhizobium japonicum* were planted on Holyrood series soil (Orthoxic Quartzipsamments) in Pilmoor Estate, Selangor. Molybdenum at rates of 0, 35 and 70 g Mo/ha and ground magnesium limestone (GML) at levels of 0, 1000, 2000 and 2800 kg/ha were applied to 2.0×2.0 m plots separated by a distance of 0.4 m. A randomised block design with three replications was used. Upon planting, a basal dressing of NPK fertiliser containing N, P_2O_5 and K_2O at 40, 60 and 30 kg/ha, respectively, was uniformly applied to all the plots. About two months after planting, a further top dressing of N (20 kg/ha) was made. At ninety days, the plants were uprooted, seeds separated, dried and analysed for Mo. In addition, soil samples taken at different depths were analysed for available and total Mo.

Analysis of Soil and Plant Samples

Soil samples for routine determination of pH, organic carbon and cation-exchange capacity were dried at 328°K, ground and sieved (< 2 mm size). Soil pH was measured with a pH meter on a suspension of soil in distilled water, soil : water ratio being 2:5. Soil organic carbon was determined by Walkley and Black's titration method. The cation-exchange capacity of the soil was obtained from the amount of NH_4^+ ions adsorbed when the soil was leached with neutral normal ammonium acetate solution[10]. Molybdenum in plant samples were determined according to the procedure of Piper and Beckwith[12]. About 2 g of oven-dried ground sample was wet digested with HNO_3, H_2SO_4 and $HClO_4$ acids. The Mo in the digest extracted as molybdenum-dithiol complex in amyl-acetate was determined colorimetrically with a calibrated Spekker (Hilger) colorimeter using Filter No. 8 and a 4 cm cell.

RESULTS

The nine soils selected for this study originated from different parent materials and have pH values ranging from 4.7 to 3.9 *(Table 1)*. Among the soils, the Selangor series soil has the highest cation-exchange capacity attributed to the presence of significant amounts of organic matter and 2:1 expanding lattice minerals[13,14]. Elsewhere, the Holyrood, Kuantan, Munchong, Prang, Rasau, Rengam and Serdang series soils are dominated by kaolinite (> 50%) with small amounts of goethite and gibbsite. Apart from these properties, the soils also differed considerably in the proportion of sand, silt and clay. In one extreme, the Selangor, Durian and Kuantan series soils consist mainly of silt and clay while in the other, the Holyrood, Rasau and Serdang series soils were predominantly sand.

Available and Total Molybdenum in the Soils

Total Mo content of the nine soils varied from 1.13 mg to 10.53 mg/kg soil *(Table 2)*. The Mo content in the Selangor series soil was the highest and this was followed by Kuantan, Prang, Rengam, Rasau, Munchong, Serdang, Durian and Holyrood series soil. The range of total Mo content found in these soils was comparable with the values of soils from Hawaii (8.9 – 73.8 mg/kg), France (4.3 – 6.9 mg/kg), United States (0.8 – 3.3 mg/kg) and Australia (0.6 – 3.5 mg/kg) reviewed by Sauchelli[3]. The

TABLE 2 TOTAL AND AVAILABLE MOLYBDENUM IN SURFACE SOILS (0 45 cm)

Soil series	Total Mo (mg kg soil)	Available Mo (μg/kg soil)	Available/ Total Mo (%)
Selangor	10 53A	721a	6 8
Kuantan	4 38B	183ed	4 2
Prang	3 84C	194ced	5 1
Rengam	3 67C	235cb	6 4
Rasau	3 07D	155e	5 0
Munchong	2 95D	228cbd	7 7
Serdang	2 69D	247b	9 2
Durian	1 72E	207cbd	12 0
Holyrood	1 13F	190ced	15 5
Mean	3 78	262	8 1
CV(%)	7 7	10 4	

Values in the same column followed by the same letter(s) are not significant at LSD (0 5)

high Mo content of the Selangor series soil is attributed to the marine deposits which are composed of kaolinite, smectite, mica, quartz and gibbsite Examination of the soil under a scanning electron microscope showed that the clays of the Selangor series, besides the clay minerals, also consist of fragmented micro-structures which had been found to associate with biorelicts from shells of molluscs and echinoderms and plant remains[15] The Kuantan series soil has moderately high Mo content as it is derived from basalt which was reported by Mitchell[16] to contain high levels of Mo As for the sandy Holyrood series soil, prolonged leaching probably results in the depletion of its native Mo

Unlike total Mo, available Mo in the soils varied within narrow limits, *viz* 155 – 721 µg/kg soil It is of interest to note that the level of available Mo is not closely related to the total Mo content in the soil For all the soils, available Mo constitutes about 8 1% of the total Mo content These results suggested that a major portion of the Mo in soil is either associated with the parent materials or occurs in forms which are not readily available In the acid soils[17] with mean pH 4 5 and dominated by Fe and Al sesquioxides, fixation of Mo as MoO_4^{2} through adsorption on the sesquioxides or clay minerals probably contributes to the low available Mo This observation applies to soils like the Selangor and Kuantan series which have relatively high total Mo content but a low degree of availability

Molybdenum Status of Some Profiles

The distribution of available and total Mo in four soil profiles are shown in *Table 3* Values for total and available Mo in surface horizons *(A_p)* ranged from 3 90 mg/kg to 1 45 mg/kg and 267 μg/kg to 219 μg/kg soil, respectively, while the mean pH value was 4 5 Both total and available Mo did not appear to show any regular pattern with depth of the profiles although the surface horizons consistently had higher values These data suggest that organic matter accumulated in the surface soils has a strong influence on the Mo status of the soils The Mo could be associated with the soil organic matter Additionally, the

TABLE 3 TOTAL AND AVAILABLE MOLYBDENUM IN FOUR PROFILE SOIL SAMPLES

Soil series	Horizon	Depth (cm)	pH	Mo Total (mg kg)	Mo Available (μg kg)
Durian	A_p	0–7	4.5	2.03	219
	B_{1t}	7–22	4.4	1.89	207
	B_{21t}	22–48	4.2	1.75	182
	B_{22cn}	48–51	4.3	1.67	175
	B_3	51–104	4.1	1.82	190
	C	104–137	4.4	1.58	184
Holyrood	A_p	0–18	4.6	1.45	245
	A_c	18–46	4.9	1.32	198
	C_1	46–89	4.9	1.27	180
	C_2	89–130	5.0	1.19	211
Munchong	A_p	0–5	4.5	3.20	267
	B_{21ox}	5–50	4.3	3.31	225
	B_{22ox}	50–137	4.4	2.98	203
Rengam	A_p	0–10	4.4	3.90	251
	B_{21t}	10–74	4.5	3.52	238
	B_{22t}	74–135	4.3	3.78	210

organic matter could interact with the Fe and Al hydrous oxides resulting in less adsorption of Mo[17]. Despite higher total Mo in the Munchong and Rengam series soils, available Mo in these two soils was moderately above those in the Durian and Holyrood series soils. With the exception of the Holyrood series soil, available Mo forms less than 10% of total Mo.

Effect of Molybdenum on Performance of Rubber Seedlings

The data for uptake, growth, yield and dry matter content of rubber seedlings treated with different levels of sodium molybdate in the glasshouse are presented in *Table 4*. At rates of 0.012 kg/ha and 0.120 kg/ha, there was a significant increase in girth over that of the control plants. However, beyond 0.120 kg/ha, there was a significant drop in girth. The decrease in girth at 1.20 kg/ha and 12.0 kg/ha implies that the plants suffered toxicity at these high rates of sodium molybdate application. Besides girth, mean height and total dry matter content also declined. In terms of percentage increase in girth and height determined from values at the beginning before molybdate was applied and at the end of the experiment, the control pots appeared to show better performance than the treated pots. This discrepancy shows that the effect of Mo based on growth of rubber seedlings alone could not be convincingly established. Generally, there is an increase in yield of latex in the molybdate treated pots although the yield values as shown in *Table 4* were not significantly related to the levels of molybdate applied *(Table 4)*.

The effects of molybdate application on Mo content in the rubber seedlings were examined *(Table 5)*. Evidently increasing

TABLE 4 EFFECT OF APPLICATION OF MOLYBDENUM ON GIRTH, HEIGHT, DRY MATTER CONTENT AND LATEX YIELD OF RUBBER SEEDLINGS GROWN IN THE GLASSHOUSE

Treatment[a] with sodium molybdate (kg/ha)	Mean girth[b] (cm)	Girth increment[c] (%)	Mean[d] height (cm)	Height increment[c] (%)	Total dry matter content[d] (g/plant)	Yield[b] (mg)
0	1 31	299 2	131 7	127 7	119 2	15 0
0 012	1 44	286 8	141 7	107 5	144 2	19 6
0 120	1 48	263 5	137 1	112 6	153 3	18 2
1 200	1 34	288 8	123 6	113 1	128 4	26 3
12 000	1 23	282 3	128 6	122 9	110 4	19 7
S E of difference between mean	±0 053	–	–	–	±7 87	±3 27
L S D (P<0 05)	0 113	–	–	–	21 8	6 4

[a]Source of Mo is sodium molybdate

[b]Measurement taken when the seedlings were four months old Yield is expressed as milligramme per plant per tapping

[c]Girth and height increments were recorded when the plants were twelve months old, increments expressed as percentages of the initial values before Mo was applied

[d]Mean height and dry weight of whole plants at twelve months inclusive of senescent leaves

TABLE 5. MOLYBDENUM CONTENT IN LEAVES AND STEMS OF RUBBER SEEDLINGS

Treatment with sodium molybdate (kg/ha)	Molybdenum content (mg/kg material)				Total Mo per plant[b] (μg)
	Leaves				
	Top whorl	Bottom whorl	Total	Stems[a]	
0	0.19	0.17	0.36	0.06	8.21 –
0.012	0.17	0.16	0.32	0.12	17.93 (8.70)
0.120	0.42	0.53	0.95	0.12	24.31 (1.45)
1.200	0.89	1.39	2.28	0.77	103.36 (0.85)
12.000	6.30	20.40	26.70	15.50	1 706.89 (1.51)

[a]Include petioles and senescent leaves
[b]Figures within brackets are Mo uptake expressed as percentages of applied Mo.

the amount of sodium molybdate applied gave rise to a higher Mo content in the leaves (top and bottom whorls) and stems which include the senescent leaves and petioles. The combined amount of Mo in the leaves which varied from 0.32 mg/kg to 26.70 mg/kg was generally greater than that in the stem which ranged from 0.06 mg/kg to 25.50 mg/kg. At Mo concentration of 26.70 mg/kg in the leaves, no visual foliar toxicity symptoms were recorded although total dry matter content indicated the toxicity effect of Mo. Additionally, the uptake of Mo does not increase proportionally with the level of molybdate applied. The increase was gradual at lower molybdate levels, and steep at rates of 1.20 kg/ha and 12.0 kg/ha, respectively. At higher levels, there is a possibility that the Mo applied is in excess of what the soil can retain either through adsorption or reaction with the iron and aluminium hydrous oxides and is also more than sufficient for the plants requirement. After all, the amount of applied Mo taken up by the seedlings came to about 8.70%–1.45% and 0.85%–1.51% of applied Mo for levels 0.012–0.120 kg/ha and 1.20–12.0 kg/ha, respectively.

Effect of Liming on Molybdenum Status of the Soil and Soyabean

The effects of liming on Mo status of the soil and soyabean are summarised in *Table 6*. An increase in the level of Mo applied to the soils results in the corresponding higher content of total and available Mo in both top and sub-soils ($P < 0.001$ and $P < 0.01$, respectively). The high total and available Mo content in the treated soils at 15–60 cm and 60–90 cm depths indicate that there is considerable downward movement of the applied Mo. Liming at rates of 2000 kg/ha and 2800 kg/ha raised the pH of the top soils by 1.0 to 1.7 units and also appeared to enhance the availability of Mo in the soil ($P < 0.05$). At 2800 kg GML/ha, there was a slight increase in available Mo in the top soil (about 8%) over that of the control plot. The influence of lime on the movement of Mo to lower depths was not observed as available Mo at lower soil depths was not markedly increased. In fact, for soils at 60–90 cm depth, available Mo was marginally lower than in the control plots.

Besides raising the available and total Mo content in the soil, application of Mo also increases the amount of Mo in soyabean ($P < 0.001$). At 70 g Mo/ha, there was a four-fold increase in plant Mo. As for rubber seedlings, the amount of Mo in soyabean less that of the control forms about 7.0% of the applied Mo. Application of lime generally improve growth and yield of soyabean and hence leads to more Mo being absorbed by the plants ($P < 0.05$).

TABLE 6. EFFECT OF MOLYBDENUM AND APPLICATION OF LIME ON MOLYDENUM STATUS IN THE SOIL AND SOYABEAN

Treatment	Soil depth (cm)	pH (H_2O)	Soil Mo		Total Mo in plants/treatment[a] (mg)	Percentage uptake[b]
			Available (µg/kg)	Total (mg/kg)		
Molybdenum (g/ha)						
Nil	0–15	4.6	190	1.10		
	15–60	4.5	172	0.75	0.58	
	60–90	4.4	114	0.45		
35	0–15	5.2	225	3.03		
	15–60	4.9	198	2.87	1.63	7.5
	60–90	5.1	208	2.33		
70	0–15	5.3	291	4.86		
	15–60	5.1	234	4.36	2.31	6.2
	60–90	4.8	256	4.22		
GML (kg/ha)						
0	0–15	4.4	235	2.93		
	15–60	4.4	196	2.57	0.72	
	60–90	4.3	190	2.33		
2000	0–15	5.4	210	2.69		
	15–60	5.0	208	2.82	1.92	
	60–90	4.9	182	2.59		
2800	0–15	6.1	253	2.87		
	15–60	5.5	201	2.66	1.84	
	60–90	5.2	177	2.71		
F-Test						
Mo		NS	**	***	***	
Lime		**	*	NS	**	
Mo × Lime		NS	NS	NS	NS	
C.V. (%)		7	25	18	28	

[a]Total Mo in plants per plot per treatment (each value is a mean of three plots with about forty plants each).
[b]Total Mo in plants expressed as percentage of Mo applied.
Significant at *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$ levels. NS = Not significant.
GML = Ground magnesium limestone

Linear regression analysis of the data showed that plant dry mass (gramme per plot per treatment) of soyabean was related to available Mo in the soil at $P < 0.05$ level but not total Mo. No linear relationship between seed yield of soyabean and Mo status (both available and total) of the soil was obtained.

DISCUSSION

The methods developed by Grigg[11] were found to be suitable for determining the total and available Mo content in Malaysian soils. Despite the complexities of the methods which require the isolation of Mo from the soil extracts by amyl alcohol for colorimetric determination and the presence of Mo in minute quantities, good agreement between replicate determinations was obtained. Mean coefficients of variation of total and available Mo computed from replicate determinations over the nine soils were 10.4% and 7.7%, respectively. The chemical determination of Mo in plant samples is precisely that described by Piper and Beckwith[12] and adopted by Bolle-Jones[7] for the determination of Mo in the laminae of *Hevea* seedlings. For values of 0.87 μg/kg to 3.38 μg/kg in the laminae, the coefficient of variation was in the range 3.3% to 12.8%.

Although the nine soils have different levels of total Mo and mean pH values less than 4.5, available Mo in all the soils are above the critical value of 150 μg/kg soil determined by Grigg[18]. It is probably for this reason that Mo deficiency symptoms in *Hevea* plants could not be established. Bolle-Jones[7] found that severe visual symptoms of Mo deficiency would not be consistently obtained until the concentration of Mo in the dried laminae was well below 0.07 mg/kg, probably at a level of about 0.010 mg/kg. In this study, the Mo concentration in the leaves was in the range 0.16 mg/kg to 20.40 mg/kg and therefore Mo deficiency symptoms would least be expected. Furthermore, the *Hevea* plants could tolerate high levels of Mo application without exhibiting any toxicity effect. The fact that Mo concentration in leaves at 12.0 kg/ha is about eighty-four times that at 0.012 kg/ha lends support to this observation. Although the adverse effect of high Mo application was not manifested visually by the leaves, the decline in dry matter content beyond the level of Mo application at 0.120 kg/ha did indicate its toxicity effect. The employment of pin puncture tapping in this study was the closest to the conventional method of tapping by bark removal currently in practice. The lack of relationship between latex yield by pin-puncturing and Mo input or Mo concentration in the leaves was contrary to that reported by Bolle-Jones[7] who took latex concentration in the petioles as yield. In his sand culture experiments, it was reported that the concentration of rubber in the petioles diminished significantly as the Mo status in the plant improved. The reduced rubber concentration in the petioles was caused by the decrease in concentration of N, S, P, Mg and K in the laminae and an increase in Mn content.

Unlike the other micro-nutrients, the availability of Mo has been known to increase as the soil pH approaches neutrality or increases above it. Kariman and Cox[17] found that adsorbed Mo was negatively correlated with pH and P levels. An increase in pH through liming would reduce the activity of the hydrous iron oxides and hence increase the mobility of Mo which is present mainly as the MoO_4^{2-} or $HMoO_4^{-1}$ ions. In the liming experiment, results indicate that liming has no appreciable effect on the availability of Mo in the soil although it enhances crop yield and consequencely Mo content in the plants. This is partly attributed to the sandy nature of the soil that leads to the leaching loss of Mo which is made available by liming.

CONCLUSION

The available and total Mo content of Malaysian soils depend on the parent materials from which they orginate. Soils derived from marine alluvial clays and basalts have higher Mo status. The lack of visual Mo deficiency or toxicity symptoms in rubber seedlings and soyabean is attributed to the high tolerance of Mo in the plants and the adequate amount of the nutrient which is inherent in Malaysian soils. The toxicity or deficiency symptoms, if at all present, can only be detected through proper determination of the biomass production and nutrients that are immobilised in the plant. Although liming has been known to improve the Mo status of the soils, its effect could not be observed in the sandy Holyrood series soil as leaching loss could possibly be the over-riding factor Finally, there is a need to improve on the existing methods of determining Mo content in soil and plant samples Methods for direct determination of Mo in soil and plant extracts by graphite furnace atomic-absorption spectrometry and inductively coupled plasma spectrometry would form the core of future studies Without this development, it is difficult to monitor the effect of Mo in *Hevea* cultivation on a regular basis

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