

AVAILABLE ZINC, COPPER, MANGANESE AND IRON STATUS OF LOW COUNTRY WET ZONE RICE SOILS OF SRI LANKA

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ABSTRACT

The low country wet zone rice soils (132 surface samples) of Sri Lanka representing the districts of Colombo, Kalutara, Galle and Gampaha showed considerable variation in available Zn, Cu, Mn and Fe content as determined by 0.05 N HCl, 0.05 M EDTA-NH₄OAc (pH 7.0) and 1N NH₄OAc (pH 4.6) extractants. The 0.05 N HCl extractable Zn content varied from 0.01 to 9.56 ppm (av. 1.11 ± 1.12 ppm); the NH₄OAc extractable Zn varied from traces to 1.73 ppm (av. 0.25 ± 0.35 ppm) and the EDTA-NH₄OAc extractable Zn varied from 0.53 to 9.40 ppm (av. 2.29 ± 1.67 ppm). The NH₄OAc extractable Cu, Fe and Mn content of soils varied from traces to 0.39 ppm (av. 0.10 ± 0.07 ppm), 1.40 to 21.90 ppm (av. 12.80 ± 4.97 ppm) and 0.05 to 19.12 ppm (av. 4.48 ± 3.78 ppm), respectively. The EDTA-NH₄OAc extractable Cu content of soils varied from 0.35 to 7.23 ppm (av. 2.49 ± 1.50 ppm). Sixty-eight percent of the soils analysed showed deficiency with respect to 0.05 N HCl extractable Zn, 80% with respect to NH₄OAc extractable Zn, and 65% with respect to EDTA-NH₄OAc extractable Zn. Most of the soils analysed were found to be deficient in NH₄OAc extractable Cu but these soils were found to contain adequate level of EDTA-NH₄OAc extractable Cu. Available Fe and Mn in NH₄OAc extract was adequate in most of the soils except for a few exceptions. Field studies are needed to assess the extent to which Cu and Zn deficiency occurs in the rice soils of the low country wet zone.

KEY WORDS: Copper, Iron, Manganese, Micronutrients, Rice soils, Zinc

INTRODUCTION

The low country wet zone soils of Sri Lanka are located on the west coast comprising mainly the Colombo, Kalutara, Galle and Gampaha districts. The annual rainfall in this region is very high (2500 - 5000 mm) and rice is the main crop in maha and yala seasons. Since low country wet zone receives very high rainfall and remains always wet, the soils are highly acidic in reaction. The soils are mainly mineral soils but in many areas bog and half-bog soils also exist side by side with mineral soils. As a result of this wide variation in soil types, the fertility status of soils vary widely with respect to both macro and micronutrients. Rice is the main crop in the region and rice yields are

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very low compared to the other rice growing areas of the island. Soils of this region have been reported to have very high Fe content and 'bronzing' in rice associated with iron toxicity is known to limit rice yields. Pavanasasivam and Kalpage (1973) while reviewing the micronutrient work done in Sri Lanka indicated that unlike major nutrients, micronutrients have not received sufficient emphasis in Sri Lanka and the information available is scarce, sporadic and uncoordinated. Even today this observation is valid as no systematic study has been initiated to evaluate micronutrient status of soils belonging to different agroecological zones.

The present investigation was undertaken with a view to evaluate the micronutrient, fertility status of low country wet zone rice soils with special reference to zinc, iron, copper and manganese using appropriate chemical extractants.

MATERIALS AND METHODS

One hundred and thirty-two surface (0-20 cm depth) soil samples were collected from rice fields of low country wet zone (Fig. 1), representing the districts of Colombo (36 samples), Kalutara (51 samples), Galle (34 samples) and Gampaha (11 samples). The soils samples were ground using a porcelain mortar and pestle and passed through a nylon screen (60 mesh). The variations in the soil properties in different districts from which the soil samples were collected are given in Table 1. All the soils samples were analysed for

Table 1. Important characteristics of low country wet zone soils obtained from the districts of Colombo, Kalutara, Galle and Gampaha

Soil characteristics	Colombo	Kalutara	Galle	Gampaha	Low country wet zone
pH (H ₂ O)	4.1-5.1 (4.7)	3.5-5.1 (4.5)	3.9-5.5 (4.5)	4.4-5.3 (4.8)	3.5-5.5 (4.6)
Clay (%)	11.0-39.3 (21.7)*	0.5-64.1 (25.5)**	0.5-46.3 (17.3)#	4.7-19.3 (11.4)##	0.5-64.1 (20.4)
CEC(c mol (p+) kg ⁻¹)	3.2-31.7 (17.2)	4.4-62.2 (19.2)	13.3-46.8 (27.4)	2.5-11.9 (6.2)	2.5-62.2 (19.8)
Organic matter (%)	3.7-24.5 (11.0)	3.2-37.9 (11.3)	4.9-24.0 (13.5)	2.4-6.0 (4.1)	2.4-37.9 (11.2)
Available K (c mol (p+) kg ⁻¹)	0.02-0.32 (0.16)	0.02-0.82 (0.20)	0.11-0.49 (0.25)	0.02-0.44 (0.11)	0.02-0.82 (0.19)
Olsen P (ppm)	5.0-27.0 (13.4)	1.0-46.0 (11.3)	1.0-18.0 (7.8)	3.0-17.0 (7.0)	1.0-46.0 (10.6)

* Based on 13 samples; ** Based on 33 samples; # Based on 29 samples; ## Based on 11 samples; Figures in parenthesis indicate the mean value

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available Zn by three extractants, 0.05 N HCl (Katyál and Ponnámpéruma, 1974), 1 N NH_4OAc of pH 4.6 (Lyman and Dean, 1942) and 0.01 M EDTA - 1 N NH_4OAc of pH 7.0 (Tiller *et al.*, 1972). Available Cu, Mn and Fe in soils were determined in 1 N NH_4OAc (pH 4.6) extract (Lyman and Dean, 1942) while potentially available Cu was determined in EDTA - 1 N NH_4OAc (pH 7.0) extract (Tiller *et al.*, 1972). The micronutrients in the different extracts were determined by atomic absorption spectrophotometry.

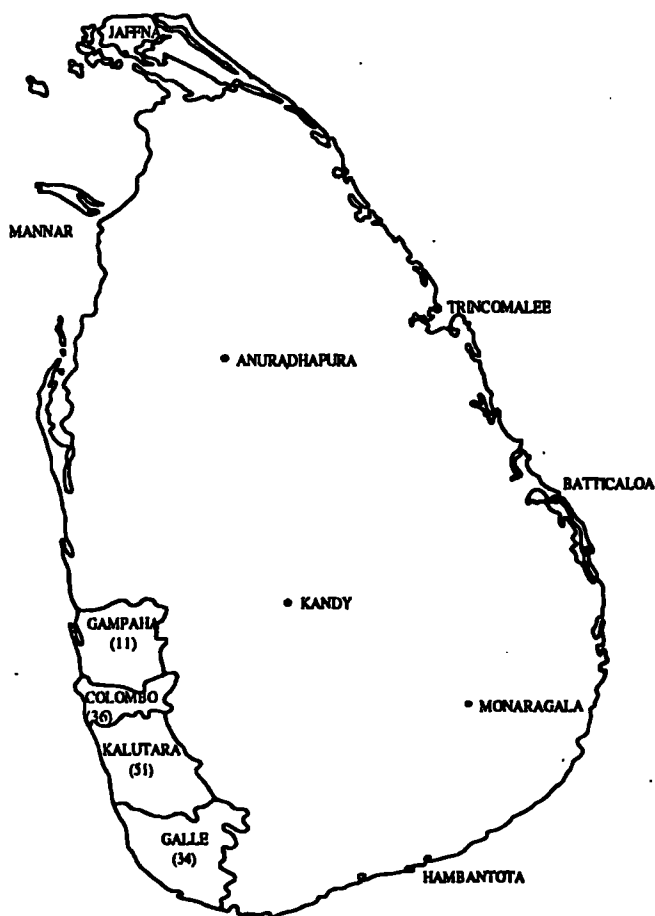


Fig. 1. Map of Sri Lanka showing the districts where soil samples were collected. Figure within bracket refers to the number of samples taken

RESULTS AND DISCUSSION

The range, mean values and median values for each micronutrient as determined by the different methods are presented in Table 2. The critical values at which the soils were considered deficient, marginal and adequate with respect to different extractants are given in Table 3. The critical limits were same as those described by Raman and Deb (1979) and Deb *et al.* (1984).

Available Zn status of soils

Data presented in Table 2 indicate that there is a wide variation in the available Zn content of the soils collected from different fields even in the same district. The 0.05 N HCl extractable Zn content of low country wet zone soils varied between 0.01 to 9.56 ppm (av. 1.11 ± 1.12 ppm), the NH_4OAc extractable Zn varied from trace to 1.73 ppm (av. 0.25 ± 0.35 ppm) and the $\text{EDTA-NH}_4\text{OAc}$ extractable Zn varied from 0.53 to 9.40 ppm (av. 2.29 ± 1.67 ppm). Higher standard deviation is indicative of the skewed nature of the distribution of 0.05 N HCl extractable Zn content in soil samples. This is true for all micronutrients estimated by the different extractants and is corroborated by the median values included in Table 2. Rice soils having 0.05 N HCl extractable Zn content less than 1 ppm have been classified as deficient in zinc (Katyal and Ponnamperna, 1974). Data on the distribution of percent soil samples in deficient category with 0.05 N HCl indicate that with the exception of Galle district, more than half of the soils suffer from zinc deficiency (Table 3).

It is evident from the individual data on 0.05 N HCl extractable Zn, NH_4OAc extractable Zn and $\text{EDTA-NH}_4\text{OAc}$ extractable Zn, that the available Zn content of the majority of soils collected from the Colombo district are in the deficient range. In order to ascertain exactly to what extent zinc deficiency is prevalent in Colombo district, the percent of soil samples falling in the deficient (up to critical level) for a particular extractant, marginal (critical limit + up to 10% above it except 0.05 N HCl) and adequate (above marginal limit) categories were calculated. The data presented in Table 3 indicate that in Colombo district, 72% of samples analysed were deficient in 0.05 N HCl extractable Zn while 11 and 17% of the samples were in the marginal and adequate categories.

Almost similar situation exists in the districts of Gampaha and Kalutara (Table 3). More than 60% of the soil samples analysed from the district of Galle were found to be deficient in readily available Zn (NH_4OAc) and 50% of the samples analysed measured adequate with respect to readily + potentially available Zn ($\text{EDTA-NH}_4\text{OAc}$).

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Table 2. Range, mean and median values of available Zn, Cu, Fe and Mn content in soils of different districts of low country wet zone

<i>Method</i>	<i>Range (ppm)</i>	<i>Mean $\pm$ SD (ppm)</i>	<i>Median (ppm)</i>
LOW COUNTRY WET ZONE (132)*			
HCl-Zn	0.01 - 9.56	1.11 $\pm$ 1.12	0.78
NH ₄ OAc-Zn	Tr - 1.73	0.25 $\pm$ 0.35	0.10
EDTA-NH ₄ OAc-Zn	0.53 - 9.40	2.29 $\pm$ 1.67	1.63
NH ₄ OAc-Cu	Tr - 0.39	0.10 $\pm$ 0.07	0.08
EDTA-NH ₄ OAc-Cu	0.35 - 7.23	2.49 $\pm$ 1.50	2.03
NH ₄ OAc-Fe	1.40 - 21.90	12.80 $\pm$ 4.97	12.92
NH ₄ OAc-Mn	0.05 - 19.12	4.48 $\pm$ 3.78	3.20
COLOMBO (36)*			
HCl-Zn	0.01 - 9.56	1.22 $\pm$ 1.77	0.74
NH ₄ OAc-Zn	Tr - 1.41	0.15 $\pm$ 0.29	0.01
EDTA-NH ₄ OAc-Zn	0.75 - 4.15	1.64 $\pm$ 0.90	1.23
NH ₄ OAc-Cu	0.04 - 0.18	0.09 $\pm$ 0.03	0.08
EDTA-NH ₄ OAc-Cu	0.75 - 5.35	2.36 $\pm$ 1.04	2.05
NH ₄ OAc-Fe	5.74 - 21.86	13.39 $\pm$ 3.69	13.20
NH ₄ OAc-Mn	0.85 - 16.73	3.50 $\pm$ 3.15	2.57
KALUTARA (51)*			
HCl-Zn	0.08 - 3.19	0.92 $\pm$ 0.64	0.72
NH ₄ OAc-Zn	Tr - 1.73	0.25 $\pm$ 0.37	0.10
EDTA-NH ₄ OAc-Zn	0.68 - 9.40	2.42 $\pm$ 1.88	1.63
NH ₄ OAc-Cu	0.02 - 0.29	0.08 $\pm$ 0.06	0.06
EDTA-NH ₄ OAc-Cu	0.43 - 6.53	2.15 $\pm$ 1.31	1.83
NH ₄ OAc-Fe	4.64 - 21.78	13.32 $\pm$ 4.83	13.00
NH ₄ OAc-Mn	0.50 - 16.01	3.36 $\pm$ 2.63	2.90
GALLE (34)*			
HCl-Zn	0.14 - 3.80	1.39 $\pm$ 0.92	1.37
NH ₄ OAc-Zn	Tr - 0.94	0.37 $\pm$ 0.32	0.33
EDTA-NH ₄ OAc-Zn	0.55 - 8.10	3.15 $\pm$ 1.75	2.55
NH ₄ OAc-Cu	0.01 - 0.39	0.16 $\pm$ 0.08	0.15
EDTA-NH ₄ OAc-Cu	0.43 - 7.23	3.39 $\pm$ 1.87	3.25
NH ₄ OAc-Fe	1.40 - 21.90	12.80 $\pm$ 5.70	12.80
NH ₄ OAc-Mn	1.50 - 19.10	7.1 $\pm$ 4.70	6.65
GAMPAHA (11)*			
HCl-Zn	0.39 - 1.50	0.79 $\pm$ 0.34	0.76
NH ₄ OAc-Zn	Tr - 1.54	0.30 $\pm$ 0.44	0.14
EDTA-NH ₄ OAc-Zn	0.53 - 1.88	1.10 $\pm$ 0.44	1.08
NH ₄ OAc-Cu	Tr - 0.11	0.05 $\pm$ 0.03	0.06
EDTA-NH ₄ OAc-Cu	0.35 - 5.31	1.73 $\pm$ 1.32	1.65
NH ₄ OAc-Fe	1.62 - 16.96	8.28 $\pm$ 5.10	8.52
NH ₄ OAc-Mn	0.05 - 10.79	4.65 $\pm$ 3.34	4.80

*Figures in parenthesis indicate the number of soil samples

Table 3. Available Zn, Cu, Fe and Mn status of soils in different districts of low country wet zone (expressed as % soils analysed in each district)

District (*)	Deficient	Marginal	Adequate
ZINC			
<i>HCl</i>	< 1.0 ppm	1.0-1.4 ppm	>1.4 ppm
Colombo (36*)	72.2	11.1	16.7
Kalutara (51)	66.7	17.0	16.3
Galle (34)	41.2	20.6	38.2
Gampaha (11)	90.9	-	9.1
<i>NH₄OAc</i>	< 0.5 ppm	0.5-0.6 ppm	>0.6 ppm
Colombo (36)	91.7	2.8	5.5
Kalutara (51)	82.4	5.9	11.8
Galle (34)	64.7	8.8	26.5
Gampaha (11)	81.8	9.1	9.1
<i>EDTA-NH₄OAc</i>	<2 ppm	2-2.5 ppm	> 2.5 ppm
Colombo (36)	75.0	8.8	16.2
Kalutara (51)	54.9	17.6	27.5
Galle (34)	29.4	20.6	50.0
Gampaha (11)	100.0	-	-
COPPER			
<i>EDTA-NH₄OAc</i>	<1 ppm	1-1.2 ppm	>1.2 ppm
Colombo (36)	2.8	2.8	94.4
Kalutara (51)	15.7	9.8	74.5
Galle (34)	14.7	-	85.3
Gampaha (11)	18.2	18.2	63.6
<i>NH₄OAc</i>	< 0.2 ppm	0.2-0.3 ppm	>0.3 ppm
Colombo (36)	100.0	-	-
Kalutara (51)	92.0	6.0	2.0
Galle (34)	73.5	20.6	5.9
Gampaha (11)	100.0	-	-
IRON			
<i>NH₄OAc</i>	< 2 ppm	2-2.5 ppm	>2.5 ppm
Colombo (36)	-	-	100.0
Kalutara (51)	-	-	100.0
Galle (34)	6.0	-	94.0
Gampaha (11)	9.0	9.0	82.0
MANGANESE			
<i>NH₄OAc</i>	< 3 ppm	3-3.5 ppm	>3.5 ppm
Colombo (36)	67.7	8.0	25.0
Kalutara (51)	51.0	12.0	37.0
Galle (34)	18.0	-	73.0
Gampaha (11)	36.0	-	64.0

* Figures in parenthesis indicate the number of soil samples

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Critical examination of the data revealed that 5 to 26% of the soil samples analysed were adequate with respect to readily available Zn in 4 districts of low country wet zone whereas the readily + potentially available Zn was found to be adequate in 16 to 50% of the samples analysed leaving aside the soils from Gampaha where all the soils tested deficient in readily + potentially available Zn.

Considering the overall available Zn status of low country wet zone soils, 68% of the soils analysed showed deficiency in 0.05 N HCl extractable Zn, 80% in NH_4OAc extractable Zn, and 65% in EDTA- NH_4OAc extractable Zn.

From the data reported above, it is evident that zinc deficiency is very much widespread in the low country wet zone soils; the exact magnitude of the extent of zinc deficiency cannot however, be ascertained without performing soil test-crop response correlation studies. From such studies only one can ascertain as to which extractant is ideal for low country wet zone soils.

Of the micronutrients, only zinc has been found to be limiting to rice growth. Zinc deficiency in rice has been reported in India, Bangladesh, Pakistan and the Philippines. Addition of zinc sulphate is recommended to correct zinc deficiency (Castro, 1977). In Sri Lanka, in an alkaline, poorly drained soil having a very low 0.05 N HCl extractable Zn (0.24 ppm), rice gave significant response to zinc addition in 3 out of the 4 seasons tested (Nagarajah *et al.*, 1983). On the hand, rice grown in an acidic soil with a 0.05 N HCl extractable Zn of 3.24 ppm failed to show any response to zinc addition. Studies should therefore, be undertaken in farmers' fields to assess the response of rice to zinc application in the low country wet zone before making recommendations.

Available Cu status of soils

The available Cu of soils in different districts is presented in Table 2. For the entire low country wet zone soils, the NH_4OAc extractable Cu varied from traces to 0.39 ppm with an average of 0.10 ppm. The standard deviation for the mean available Cu content was 0.07 ppm which indicates that the variation in the available Cu content of soils was very great. The average content of available Cu in NH_4OAc extract is much lower than the critical limit of 0.20 ppm as compiled by Katyal and Rattan (1990) for 1 N NH_4OAc (pH 4.8). In spite of the skewed distribution of the data, most of the soils were found to be deficient in readily available Cu. The readily + potentially available Cu content of soils in EDTA - NH_4OAc extract varied from 0.35 to 7.23 ppm with an average value of 2.49 ppm.

Although most of the soils analysed were deficient with respect to readily available Cu (NH_4OAc), the potentially available sources of Cu (EDTA - NH_4OAc) was

found to be adequate (Table 3). The soils analysed from Colombo, Kalutara, Galle and Gampaha districts showed 3, 16, 15 and 18% of soils, respectively as deficient in potentially available sources of Cu.

Cu deficiency in rice has not been widely reported. However, positive responses to the application of copper sulphate have been found in high pH soils (Kanwar and Randhawa, 1974) and organic soils (Green, 1957). Field studies are needed to determine the extent to which Cu deficiency occurs in the low country wet zone rice soils.

Available Fe status of soils

The available Fe content of the low country wet zone soils varied between 1.40 to 21.90 ppm with an average of 12.80 ± 4.97 ppm. There is a wide variation in the available Fe content in the soils (Table 2). Most of the soils are adequately supplied with available Fe (Table 3). From the average available Fe content of the air-dried soils, it is evident that the available Fe content of many soils will shift to the toxic range after few weeks of submergence.

In Galle and Gampaha districts, 6.0 and 9.0 % of the soils analysed were found to be deficient in available Fe whereas in rest of the soils the available Fe content of soils were in the adequate/high range.

Excess of available Fe in soil will pose not only problem of Fe toxicity to rice but will also be responsible for physiological deficiency of Zn, Mn, Cu and P at the rice root surface. The low yields of rice in low country wet zone even in the presence of adequate levels of NPK fertilizer may be the result of excess Fe and low availability of Zn, Cu and P. In fact, 'bronzing' in rice due to excess Fe has been widely reported in these soils. Several measures such as liming, use of interceptor drains, use of tolerant rice varieties etc to minimize the effect of iron toxicity are practised in this region. Application of adequate level of P, Zn, Cu and well-decomposed organic matter may mitigate the adverse effects of Fe and improve the grain yield.

Available Mn status of soils

The available Mn content of soils of low country wet zone varied from 0.05 to 19.12 ppm with an average of 4.48 ± 3.78 ppm (Table 2). As suggested by median values, there are many areas where Mn is deficient in the soils. This is further substantiated from the data presented in Table 3 which shows that 67% of the soils analysed in Colombo district were deficient in available Mn, followed by 51, 18 and 36% in Kalutara, Galle and Gampaha districts, respectively.

The available Mn content of the soils from Colombo and Kalutara districts showed widespread Mn deficiency. In some soils, however, the available Mn content

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was found to be very high. It is expected that the extent of the deficiency may disappear to a certain extent after the soils are submerged. But presence of very high levels of divalent Fe may antagonize the availability of divalent Mn to rice root. The high level of available Mn already present in some soils may increase further after submergence but high Fe content is likely to regulate the availability of Mn to plant roots.

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