DISTRIBUTION OF EXTRACTABLE MICRONUTRIENTS IN SOILS OF SELECTED MAJOR LAND RESOURCE AREAS OF KERALA

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled " Distribution of extractable micronutrients in soils of selected major land resource areas of Kerala " is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship fellowship or other similar title of any other university or society.

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Certified that this thesis entitled " Distribution of extractable micronutrients in soils of selected major land resource areas of Kerala" is a record of research work done independently by Mr.Sathyanarayanan .R under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship

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Introduction

INTRODUCTION

Kerala is unique in its variety of agro-climatic conditions, landforms and vegetation. The difference in pedogenic factors have been responsible for the wide heterogenity in the physical and chemical properties of soils in the State. Pressure of population and intensive cultivation have brought large scale depletion of nutrients from the soil and imbalance of nutrients in fields. This is especially so because of the widespread use of high yielding varieties and high analysis fertilisers. Despite concerted efforts the yield of many crops are on the decline.

The capacity of any crop to produce yield is not only dependent on major-nutrients but also on micronutrients. Eventhough they are required only on micro levels, their importance in sustaining yield cannot be overlooked. It may be true that severe micronutrient deficiencies are not widely reported as evidenced by visual symptoms. However there is every possibility that deficiency of micronutrients may be responsible for limited crop yeilds in many areas of the State. The reason attributed to their deficiency may be due to use of high yielding varieties, increase in the use of micronutrient free-high analysis fertilisers, negative interactions between nutrients, and the influence of soil physico-chemical properties on the micronutrient availability to the crops.

The soils of Kerala are acidic in reaction and acid soils are supposed to be well supplied with iron, manganese, zinc, copper and boron. Inspite of all these, field workers have reported on the sporadic occurrence of zinc deficiency in some areas of the State.

Micronutrient problems which are at present considered minor and localised may well become more critical in future and prevalent over extensive areas creating widespread reduction in crop yields, if not studied properly and remedial measures taken in time. Although no serious attempts to study the micronutrient deficiencies have been made in our State, it is possible that a condition of hidden hunger or an imbalance between micronutrients may be prevalent resulting in restricted crop production.

Eventhough protracted studies on various micronutrients were carried out in the past, especially on the rice soils of Kerala, detailed and specific studies on the distribution of total and available micronutrients and the factors affecting their availability in different types of soils and also their vertical distribution in the profile have not seen to be taken up systematically in the State. At present the soils of Kerala are divided into sixteen major land resource areas (MLRAs) which exhibit identical physico-chemical properties and crop production potentialities. Wide variation in the total and available macro as well as micronutrients can be expected between the different MLRAs. Minor variations can be expected within the soils of the same MLRAs. Therefore it is worth while to investigate and assess the micronutrient status among the major MLRAs in terms of total and available forms, so that corrective measures can be taken up in cases of deficiencies or suitable measures devised to counteract deleterious effects due to excess if any.

The present study has been taken up with a view to investigating the spatial and vertical distribution of micronutrients in eight out of the sixteen MLRAs of the State. The investigation was intended to yield information which may prove to be useful in formulating improved managerial practices in terms of micronutrient supply or adopting corrective measures to counteract toxic effects if any.

With the above background, the present investigation was undertaken with the following objectives:-

a) To assess the status of total and available micronutrients namely iron, manganese, zinc, copper and boron in surface samples and also their vertical distribution in the selected major land resource areas (MLRAs) of the State.

b) To correlate the status of the above nutrients with the physico-chemical properties of the soils.

Review of Literature

REVIEW OF LITERATURE

The importance of micronutrients in increasing the agricultural production is a widely accepted fact. Though considerable work has been done on the distribution of the micronutrients in the Indian soils, especially in Kerala soils, the information relating to their occurrence in relation to various soil factors is still inadequate. The present chapter reviews the distribution of micronutrients like iron, manganese, zinc, copper and boron in relation to soil properties.

2.1 Distribution of iron in soils

2.1.1 Total iron

Pisharody (1965) while investigating the iron status of Kerala soils found that the total iron varied between 16,000 to 1,32,000 ppm. Kanwar and Randhawa (1967) reported that the total iron content in Indian soils ranged between 0.46 to 23.46 percent. Joshi *et al* (1981) found that the total iron content varied from 1.16 to 3.37 percent in some soils of the arid regions of Rajasthan. Harikumar (1989) on studying the dynamics and forms of soil iron in the acid soils of Kerala found that the total iron was highest in the *Kole* soils and lowest in the *Karappadom* soils.

Singh and Mongia (1994) reported that total iron content ranged between 1.7 to 11.5 ppm in selected watershed hilly regions of Tamilnadu and it followed a decreasing trend with depth. Paramasivam and Gopalswamy (1994) found that the total iron content decreased with depth in the profiles of selected watersheds of Tamilnadu and the content varied between 890 to 2980 ppm.

Gowrisanker and Murugappan (1995) revealed that the total iron content varied from 774 to 824 ppm in the soils of Amaravathy command area of Tamilnadu. Diwakar and Singh (1995) estimated that the total iron content varied from 15600 to 26500 ppm in vertisols and associated soils of Bihar. They have also noticed that the iron content decreased with depth.

Sheeja *et al* (1996) found that the total iron content varied between 8940 to 48960 ppm and 8120 to 47800 ppm respectively in the sweet potato growing sandy and lateritic soils of Kerala.

2.1.2 Available iron

Pisharody (1965) observed that the surface and subsurface soils are rich in available iron both under dry and submerged conditions in the rice soils of Kerala. Lodha and Baser (1971) on investigating micronutrient status of Rajastan soils found that the available iron ranged from 0.3 to 15.7 ppm. Balaguru and Dhanapalan (1972) reported that the depthwise distribution of available iron was uniform in black soils, while in red soils the trend was opposite, and in alluvial soils a decreasing trend was observed.

Rajagopal *et al* (1977) found that iron was ve

Kerala soils and the values ranged from 1.6 to 5066 ppm

observed that the available iron in the alluvial soils of Uttarpradesh varied from 0.35 to 18.35 ppm.

Suthar and Ramakrishnayya (1983) observed that the availabe iron varied from 0.58 to 5.21 ppm in the Goradu soils of Gujarat. In the studies carried out by Kuhad *et al* (1986) to assess the micronutrient status of Hissar in Haryana, the DTPA extractable iron was found to vary from 2.68 to 13.40 ppm. Jose *et al* (1985) revealed that the available iron ranged between 90.40 to 196.06 ppm in the coconut palm soils of the reclaimed marshy lands of Kerala.

Mariam (1989) on studying the micronutrient status of the rice soils of Kerala observed that the DTPA extractable iron varied from 97.92 to 387.44 ppm in lateritic alluvium, 70.68 to 771.21 ppm in *Kari*, 299.12 to 495 ppm in *Karappadom* and 168.24 to 466.08 ppm in *Kayal* soils of Kerala. Gajbhiye *et al* (1993) found that the available iron content varied from 3.26 to 11.04 ppm in the Saongi watersheds of Maharashtra.

Saini *et al* (1995) on investigating the available iron status, observed that the highest content was seen on the surface layers and it decreased with depth in the arid zone soils of Punjab. Usha (1996) found that the DTPA extractable iron content varied from 88 to 337 ppm, 201.6 to 422.6 ppm and 98 to 380.4 ppm respectively in Vellayani, *Kari* and *Karappadom* soil profiles of Kerala.

2.1.3 Factors affecting availability of iron

2.1.3.1 Organic carbon

Rajagopal *et al* (1977) from their studies on the status of available iron in Kerala reported a positive and significant correlation between organic carbon and available iron content in Trivandrum and Trichur districts. Pathak *et-al* (1979) found a significant positive correlation between available iron and organic carbon in the alluvial soils of Uttarpradesh. Similar results were obtained by Suthar and Ramakrishnayya (1983), and Chibba and Sekhon(1985).

Mariam (1989) observed that available iron was positively and significantly correlated with organic carbon in the lateritic and coastal sandy alluvial soils of Kerala. Tripathi *et al* (1994) found a significant positive correlation between DTPA extractable iron and organic carbon in the soils of Himachal Pradesh. Saini *et al* (1995) also found a significant positive correlation between DTPA extractable iron and orgnic carbon in the arid zone soils of Punjab.

2.1.3.2. pH

Balaguru and Dhanapalan (1972) observed significant negative correlation between available iron and pH in the soil profiles of Tamilnadu. Rajagopal *et al* (1977) found a significant negative correlation between available iron and pH in Alleppey and Palghat districts of Kerala. Gupta and Srivastava (1990) obtained a negative correlation between ammonium acetate extractable iron and pH in some cultivated soils of Sikkim.

Mariam (1989) found a significant negative correlation between DTPA extractable iron and pH in the *Kari* soils of Kerala. Similar results were got by

Mondal and Mete (1991) in West Bengal, and Sheeja *et al* (1993) in cassava growing soils of Tamil Nadu.

2.1.3.3. Clay content

Prasad and Sakal (1991) on estimating the available iron using extractants like EDTA and DTPA found a significant positive correlation of available iron and clay content in calcareous soils of Bihar. Adhikari (1991) observed a positive correlation between the different forms of iron and clay content in some acid soils of Bangladesh.

Maji *et al* (1993) noticed a positive and significant correlation between available iron in some coastal rice soils of West Bengal. Paramasivam and Gopalswamy (1994) obtained a highly significant positive corelation between DTPA extractable iron in Lower Bhavani project command area soil profiles of Tamil Nadu. Dhane and Shukla (1995) found a significant positive correlation between DTPA extractable iron and clay content in some bench mark soil series of Maharashtra.

2.1.3.4. Cation exchange capacity

Kuldeep Singh *et al* (1990) found that available iron was significantly and positively correlated with CEC in the semiarid alluvial soils of Haryana. Ghosh and Sarkar (1994) observed a significant positive correlation between DTPA extractable iron and CEC in the acid soils of Bihar. Dhane and Shukla (1995) also observed significant positive correlation between DTPA extractable iron and CEC in some soil series of Maharashtra.

2.2 Distribution of manganese in soils

2.2.1 Total manganese

Biswas(1953) reported that the total content of manganese in Indian soils ranged between 92 and 11500 ppm. Pisharody(1965) reported that the total content of manganese in fourteen typical rice soils of Kerala ranged from 355 to 625 ppm. Rajendran (1981) in an investigation on the total manganese content in various rice soils of Kerala found that it varied from 92 to 600 ppm,130 to 375 ppm,73 to 145 ppm,64 to 91 ppm and 88 to 330 ppm respectively in *Poonthalpadam, Kole, Pokkali, Kari* and *Karappadam* soils of Kerala.

Dangarwala *et al* (1986) found that the total content of manganese in Kheda district of Gujarat varied from 294 to 796 ppm. According to Jalali *et al* (1989) the total content of manganese varied between 760 to 950 ppm in some bench mark soils of Kashmir at different altitudes. Appavu and Sree Ramulu (1990) obtained a total manganese content between 206 to 792 ppm in seven soil series of Tamil Nadu which was found to decrease with depth in all the profiles.

Nath *et al* (1991)found that the total manganese content varied from 250 to 1563 ppm in lateritic soils under acacia plantations in West Bengal. Kannan and Mathan (1994) reported that the total manganese content varied from 39.6 to 265.5 ppm in selected watershed hilly regions of Tamil Nadu. Diwakar and Singh (1995) found that the total manganese content varied from 250 to 690 ppm in the vertisols and associated soils of Bihar.

2.2.2 Available manganese

According to Pisharody (1965) the total and water soluble manganese content of fourteen typical profiles of Kerala ranged from 1.8 to 14.8 ppm. Rajagopalan (1969) observed that the levels of water soluble and exchangable manganese was maximum in the *Kari* soils (82.5 ppm) and minimum (1.5 ppm) in the laterite soils of Kerala. Singh *et al* (1971) revealed that the hill soils of Pithoragarh contained about 3 to 90.33 ppm available manganese. Rajagopal *et al* (1977) while investigating the available manganese status of Kerala soils found that it ranged between 0.2 and 220 ppm.

Rajendran (1981) estimated that DTPA extractable manganese varied between 8 to 45 ppm, 10 to 50 ppm and 2 to 7.9 ppm in the *Karappadom, Kayal* and *Kari* soils of Kerala. Jose *et al* (1985) found that the available manganese content varies from 1.18 to 12.40 ppm with a mean value of 5.02 ppm in coconut growing soils of the reclaimed marshy lands of Kerala.

Nath *et al* (1991) observed that the ammonium acetate and DTPA extractable manganese varied between 11.7 to 95 ppm and 14.8 to 111.3 ppm respectively in the lateritic soils of West Bengal under *Acacia nilotica.* Gupta and Srivastava (1990) found that the ammonium acetate extractable manganese decreased with depth in all the three representative soil profiles of Sikkim.

Usha (1996) while investigating the acidity parameters of submerged soils of Kerala, noticed that the DTPA extractable manganese varied between 10 to

37.8 ppm, 17.2 to 80.6 ppm and 25.8 to 299 ppm in Vellayani, *Kari* and *Karappadom* soil profiles of Kerala.

2.2.3 Factors affecting availability of manganese

2.2.3.1 Organic carbon

Gopalswamy and Soundararajan (1962) reported that various forms of manganese were significantly correlated with organic carbon. A close relation between available manganese and organic carbon was observed by Pisharody (1965) also. Rajagopal *et al* (1977) noticed a significant positive correlation between organic carbon and manganese in Alleppey district of Kerala.

Mariam (1989) observed a significant positive correlation between available manganese and organic carbon in the *Kari* soils of Kerala. Similar observations were also made by Kannan and Mathan (1994) and Srivastava and Srivastava (1994).

2.2.3.2. pH

Rajagopal *et al* (1977) reported that the divalent manganese ions in the soil solution became predominant with increased acidity of the soil and that there was very significant negative correlation between exchangable manganese and pH in Alleppey soils. Sakal *et al* (1988) noticed a significant negative correlation between available manganese and pH in the alluvial soils of Bihar.

Arora and Sekhon (1981) in an investigation found a significant negative correlation between DTPA extractable manganese and pH in some soil series of Punjab. Similar observations were also made by Vinay Singh and Tripathi (1983).

2.2.3.3. Clay content

Gopalswamy and Soundararajan (1962) while studying certain soil profiles of Tamil Nadu found a non-significant negative relation between clay and the various forms of manganese. Pisharody (1965) reported a highly significant positive correlation between exchangable manganese and clay fractions in Kerala soils. Appavu and Sree Ramalu (1990) on studying the manganese status observed a positive correlation between available manganese and clay content in seven soil series of Tamil Nadu. Tiwari and Mishra (1990) noticed a positive correlation between available manganese and clay content in Tal land soils of Bihar.

Sheeja *et al* (1996) reported a highly significant positive correlation between DTPA extractable manganese and clay content in the sweet potato growing alluvial soils of India.

Cation exchange capacity

Muji and Bandhopadhyay (1992) got a significant positive correlation between available manganese and CEC in the coastal rice soils of West Bengal. Sharma *et al* (1992) found a positive correlation between DTPA extractable manganese and CEC in arid zone soils of Punjab. Sanghwan and Kuldeep Singh (1993) observed a positive correlation between available manganese and CEC in the semi arid soils of Haryana.

Sheeja *et al* (1993) also found a significant positive correlation between available manganese and CEC in the cassava growing soils of Tamil Nadu.

2.3. Distribution of zinc in soils

2.3.1 Total zinc

Lal *et al* (1960) reported that the total content of zinc in the alluvial, black and lateritic soils of India was in the range of 34 to 38 ppm, 69 to 76 ppm and 24 to 30 ppm respectively. Kanwar and Randhawa (1967) found that in most of the Indian soils the total content of zinc ranged from 2 to 1600 ppm. Nair (1970) reported that the total zinc content varied from 31 to158 ppm in onattukara soils and from 59 to 93 ppm in *kuttanadu* soils.

According to Praseedom (1970) the total zinc content of typical soils of Kerala varied from 3.5 to 100 ppm. Varughese (1971) found that the total zinc content varied from 15 to 92.5 ppm with an average of 45.43 ppm in the alluvial soils of Kerala. He also found that the total zinc decreased with depth in all the profiles. Valsaji (1972) reported that the total zinc content varied from 12.6 to 100 ppm in Amaravila series and 28.4 to 119.2 ppm in the Marukil series of Trivandrum district.

Gopinath (1973) obtained a zinc content of 12.5 to 41. 6 ppm in the surface layers and from 10.8 to 42.5 ppm in the subsurface layers of the acid peat soils of Kerala and noticed a decreasing trend with depth. Mandal *et al* (1992) while studying the availability of zinc in submerged soils of West Bengal found that the total zinc content varied between 43 ppm to 238 ppm. Paramasivam and Gopalswamy (1994) revealed that the total zinc varied between 220 ppm to 890 ppm in the soil profiles which decreased with depth in Lower Bhavani Project command area.

Diwakar and Singh (1995) did not find any regular pattern in the vertical distribution of total zinc in the soil profiles of vertisols of Bihar and the content of total zinc was seen to vary from 40 ppm to 330 ppm. Sheeja *et al* (1996) found that the total zinc content ranged between 108 and 180 ppm and 46 and 96 ppm in the sweet potato growing sandy and laterite soils of Kerala.

2.3.2 Available zinc

Bhumbla and Dhingra (1964) found that the amount of available zinc extracted with ammonium acetate averaged at 0.71 ppm and the content generally decreased with depth in the saline and alkaline soils of Punjab. Sharma and Motiramani (1969) observed that the available zinc ranged from 0.9 to 8.8 ppm in the soils of Uttar Pradesh and the content in the surface layers was found to be more than that in the deeper layers.

According to Tripathi *et al* (1969) the available zinc varied from 0.92 to 8.8 ppm in the soils of Uttarpradesh. Nair (1970) observed that the available zinc ranged between 0.51 to 5.01 ppm in *Onattukara* soils and from 0.5 to 2.47 ppm in *Kuttanad* soils of Kerala state.

According to Praseedom (1970) the available zinc ranged from 0.25 to 8 ppm in the soils of Kerala and in alluvial soils it ranged between 1.75 ppm to 3.85 ppm and the availability was found to decrease with depth. Aiyer *et al* (1975) observed that the available zinc content of the acid rice soils of *Kuttanadu* ranged between traces and 2.2 ppm.

Studies conducted by Rajagopal *et al* (1977) showed that the available zinc content of Kerala soils varied from 0.32 to 10.5 ppm, 0.3 to 1.2 ppm, 0.6 to 1.6 ppm, 0.5 to 4.8 ppm, 0.3 to 2.4 ppm, 0.1 to 4 ppm, trace to 2.9 ppm and 0.6 to 1.8 ppm in Allapuzha, Kottayam, Kollam, Trichur, Palghat, Kozhikode and Kannur districts respectively.

Rajendran (1981) found that the DTPA extractable zinc varied between 0.4 to 5.6 ppm in kari, 1 to 7.8 ppm in karappadom and 0.2 to 10.1 ppm in the kayal soils of Kerala. According to Singh and Abrol (1986), available zinc decreased with depth in the alkali soils of the Indo-Gangetic alluvial plains. Malik *et al* (1990) found that the available zinc decreased with depth in all the five typical semi arid soils of Haryana.

Singh and Sekhon (1991) observed that the DTPA extractable mean zinc content varied between 0.4 to 2.1 ppm in twenty soil series of India. Mandal *et al* (1992) estimated that the available zinc content using differant extractants like ammonium acetate, DTPA and EDTA varied between 0.33 to 1.78 ppm, 1.3 to 6.97 ppm and 0.68 to 7.50 ppm respectively in the submerged soils of West Bengal.

Gajbhiye *et al* (1993) reported that the available zinc content varied between 0.20 to 1.12 ppm in the vertisols and intergrades in Saongi watershed at Nagpur. Sheeja *et al* (1996) found that the available zinc content ranged between 0.04 to 2.90 ppm and 0.20 to 7.08 ppm in the sweet potato growing sandy and lateritic soils of Kerala and in both cases the content was found to decrease with depth.

2.3.3 Factors affecting availability of zinc

2.3.3.1 Organic carbon

Praseedom (1970) noticed a non significant negative correlation between available zinc and organic matter in Kerala soils. In kuttanadu and onattukara soils. Nair (1970) reported a positive but non significant correlation between organic carbon and zinc content.

Varughese (1971) obtained a significant correlation between available zinc and organic matter in the alluvial soils of Kerala. Gupta and Singh (1972) reported a positive correlation between organic carbon and available zinc in some soils of Indore, though the correlation was not significant.

Mariam (1989) obtained a significant positive correlation between DTPA extractable zinc and organic carbon in the *Kayal* soils of Kerala. Similar observations were made by Tripathi *et al* (1994) in Himachal Pradesh, Gowrisankar and Murugappan (1995) in Tamilnadu and Dhane and Shukla (1995) in Maharashtra.

2.3.3.2 pH

Varughese (1971) reported a negative correlation between available zinc and pH in the alluvial soils of Kerala. Lindsay (1972) found that the Zn^{++} activity decreased a hundred fold for each unit increase in pH. Valsaji (1972) observed a significant negative correlation between available zinc and pH in surface and subsurface soils in Amaravila series of Trivandrum district.

Vinay Singh and Tripathi (1983) established a significant negative correlation between DTPA extractable zinc and pH in the citrus growing soils of Agra region. Ghosh *et al* (1992) found that the deficiency of zinc increased with increase in pH and established a negatige correlation with soil pH in the soils of Orissa. Sheeja *et al* (1993) observed a significant negative correlation between available zinc and pH in the cassava growing soils of Tamilnadu.

2.3.3.3. Clay content

Nair (1970) noticed a significant negative correlation between available zinc and clay content in onattukara soils and a non significant positive correlation in kuttanad soils. Rajagopal *et al* (1977) reported that the availability of zinc decreased with decrease in clay content in Kerala soils. Tiwari and Mishra (1990) observed a significant positive correlation between available zinc and clay in the Tal Land soils of Bihar.

Dhane and Shukla (1995) obtained a significant positive correletion between available zinc and clay content in the benchmark soil series of Maharashtra. Sheeja *et al* (1996) got a significant positive correlation between available zinc and clay content in the sweet potato growing alluvial soils of Bihar.

2.3.3.4. Cation exchange capacity

Nair (1970) could find a positive relation between available zinc and CEC in onattukara soils of Kerala. Muji and Bandhopadhyay (1992) on an investigation found a significant positive correlation between available zinc and CEC in some coastal rice soils of West Bengal. Sanghwan and Kuldeep Singh (1993) noticed a positive correlation between available zinc and CEC in the semi arid soils of Haryana.

Gowrisankar and Murugappan (1995) observed a significant positive correlation between DTPA extractable zinc and CEC in the soils of Amaravathy command area of Tamil Nadu.

2.4 Distribution of copper in soils

2.4.1 Total copper

Kanwar and Randhawa (1967) noticed that the total copper content in seven soil profiles of Punjab, representing all climatic regions from humid to arid, varied from 6.6 to 36.4 ppm. Rajani (1965) investigated that the total copper content in the lateritic soils of Gujarat and found that it ranged between 90 to 130 ppm. Rai and Mishra (1967) observed that the total copper content in Madhya Pradesh soils varied between 10 to 140 ppm.

Nair (1970) revealed that the total copper content ranged from 27 to 136 ppm in the onattukara soils and from 53 to 97 ppm in kuttanadu soils of Kerala. According to Praseedom (1970) that the total copper content in some soils of Kerala varied from 5 to 325 ppm.

Varughese (1971) has reported that the total copper content of the alluvial soils of Kerala ranged from 25 to 168.75 ppm, the average being 68.4 ppm. According to Valsaji (1972) the total copper content varied from 13.4 to 31.8 ppm in the soil series of Trivandrum district.

Raghupathi and Vasuki (1993) determined the total copper content in vertisols of Karnataka and it ranged between 30.5 to 52 ppm. Paramasivam and Gopalswamy (1994) found that the total copper content varied between 50 ppm and 156 ppm in the profiles of the Lower Bhavani Project command area of Tamil Nadu.

Gowrisankar and Murugappan (1995) estimated that the total copper content to be in the range of 11ppm to 36.5 ppm in the soils of Amaravathy river command area of Tamil Nadu and the content was found to be decrease with depth in the soil profiles. Randhawa and Singh (1996) found that the total copper varied between 3 to 26 ppm in the alluvial soils of Punjab.

2.4.2 Available copper

Lal *et al* (1960) have reported that the peat soils of kuttanad contained an average of 9 ppm of available copper. Bandhopadhyay and Adhikari (1968) found that exchangable copper varied from 0.25 to 0.53 ppm in the rice soils of West Bangal and noticed a decreasing trend with depth in these soils.

Nair (1970) observed that the available copper content varied from 1.08 to 6.30 ppm in onnattukara soils and 0.8 to 3.31 ppm in kuttanad soils. Varughese (1970) noticed that the available copper content ranged between 0.65 and 4.35 ppm in some soil types of Kerala and found that the available copper decreased with depth in alluvial soils of Kerala.

Valsaji (1972) reported that the available copper in the Amaravila and Marukil series was in the range of 1.8 to 7.36 ppm and 1.41 to 6.64 ppm respectively in Trivandrum district. Gopinath (1973) found that the available copper varied from 0.40 to 1.80 ppm in the surface layers and 0.30 to 1.60 ppm in the subsurface layers in the acid peat *(Kari)* soils of Kerala.

Jose *et al* (1985) reported that the DTPA extractable copper ranged between 3.84 to 19.08ppm in the coconut palm growing soils of the reclaimed marshy lands of Kerala. Mariam (1989) determined the available copper content in the different rice soils of Kerala and found a significant variation in their status in the rice soils of Kerala.

Gajbhiye *et al* (1993) observed that the DTPA extractable copper ranged between 0.88 and 4.34 ppm in the vertisols and intergrades in the Saongi watersheds of Nagpur. Gowrisankar and Murugappan (1995) reported that the DTPA extractable copper ranged between 0.62 and 5.84 ppm in the soils of Amaravathy command area of Tamil Nadu. Sheeja *et al* (1996) noticed that the available copper content ranged between 0.12 and 6.48 ppm and 0.74 and 4.06 ppm in the sweet potato growing soils of Kerala and it was found to decrease with depth.

2.4.3 Factors affecting availability of copper

2.4.3.1. Organic carbon

Nair (1970) noticed a positive non significant correlation between organic matter and available copper. Praseedom (1970) and Varughese (1971) also obtained similar results in the *Kari* and alluvial soils of Kerala. Valsaji (1972) observed a significant positive correlation between available copper and organic carbon in the subsurface soils of Amaravila series in Trivandrum district.

In an investigation of acid sedentary soils of Gujarat, Ghosh and Sarkar

(1994) obtained a significant positive correlation between available copper and organic carbon. While studying the soils of Amaravathy river command area of Tamil Nadu Gowrisankar and Murugappan (1995) found a positive correlation between organic carbon and available copper.

Dhane and Shukla (1995) observed a significant positive correlation between DTPA extractable copper and organic carbon content in the benchmark and other established soil series of Maharashtra.

2.4.3.2. pH

Nair (1970) observed a significant negative correlation between pH and available copper in *Kuttanad* and *Onnattukara* soils. Varughese (1971) noticed a non significant negative correlation between pH and available copper in the alluvial soils of Kerala. Kanthaliya and Saxena (1992) found a significant negative correlation between available copper and pH in some semi arid soils of Rajasthan. Diwakar and Singh (1995) found a highly significant negative correlation between DTPA extractable copper and pH in the vertisols and associated soils of Bihar.

2.4.3.3. Clay content

Arora and Sekhon (1981) noticed a positive correlation between DTPA extractable copper and clay in some of the soil series of Punjab. Sahu *et al* (1990) found that the clay content significantly and positively correlated with available copper contents in eight group of rice soils. Hassan (1991) also observed a highly significant positive correlation between available copper and clay in some soil series of Bangladesh.

Gowrisankar and Murugappan (1995) found a significant positive correlation between DTPA extractable copper and clay content in the soils of Amaravathy command area of Tamilnadu. Sheeja *et al* (1996) got a highly significant correlation between available copper and clay in the sweet potato growing soils of Kerala.

2.4.3.4. Cation exchange capacity

Nair (1970) found a significant correlation between available copper and CEC in *Onattukara* soils of Kerala. Valsaji (1972) observed a significant positive correlation between available copper and CEC in the surface soils of Marukil series of Trivandrum district.

Ghosh and Sarkar (1994) while investigating the micronutrients in acid sedentary soils of Chotanagar region of Bihar noticed a significant positive correlation between available copper and CEC. Gowrisankar and Murugappan (1995) also got a significant positive correlation between DTPA extractable copper and CEC in the soils of Amaravathy river command areas of Tamilnadu.

2.5 Distribution of boron in soils

Boron status in soils

Mathur *et al* (1964) noticed that total and available boron levels were much greater in irrigated than in unirrigated soils.

Kushawaha and Singh (1981) reported that the hot water soluble boron varied from trace to 0.80 ppm (mean 0.27 ppm) and from 0.11 to 0.88 ppm (mean 0.34 ppm) in the surface and subsurface soils of sweet orange orchards of the Agra region in Uttarpradesh. Panda and Koshy (1982) observed that the water soluble boron was 0.33 ppm in alluvial acid soils, and found that it was nearly twice as much as in ferrugeneous red soils.

Suresh (1985) on assessing the boron status of the major upland soils of Trivandrm district found that the content was much higher in the forest soils (0.86 ppm). In all other soils it was less compared to forest soils. Jose *et al* (1985) found that hot water extractable boron ranged from 0.11 and 0.79 ppm in the coconut palms growing soils of the reclaimed marshy lands of Kerala.

Studies conducted by Tiwari *et al* (1988) in the soils of Rajkot command area showed that in profiles samples, available boron content ranged from 0.16 to 0.67 ppm. Hadwari *et al* (1992) on assessing the boron status observed that the hot water extractable boron ranged from 0.06 to 1.49 and 0.08 to 1.71 ppm in the Junagadh and Rajkot districts of Gujarat. Pakrashi and Haldar (1992) noticed that the hot water extractable boron content ranged from 0.17 and 0.43ppm in the soils of North Bengal.

Sarengi *et al* (1992) found that the available boron ranged between 0.10 and 2.20 ppm in the northern plateau region of Orissa. In an investigation of the alluvial soils of Assam Gogoi *et al* (1993) found that the available mean boron content was 1.7 ppm in these soils. Sheeja *et al* (1996) while investigating the micronutrient status found that the available boron ranged between 0.04 and 0.38 ppm in the sweet potato growing sandy soils of Kerala.

2.5.1 Factors affecting availability of boron

2.5.1.1 Organic carbon

Sharma and Shukla (1972) found that the available boron significantly increased with increasing organic matter content of the acid soils of Western Rajasthan. Suresh (1985) observed a positive correlation between available boron and organic matter in the sandy soils of Kerala.

Hadwari *et al* (1992) observed a positive correlation between available boron and organic carbon in the calcareous soils of Gujarat. Sheeja *et al* (1993) noticed a positive correlation between available boron and organic carbon in the cassava growing soils of Tamil Nadu.

2.5.1.2. pH

Mathur *et al* (1964) while investigating the soils of western Rajastan observed significant negative correlation between pH and available boron.Suresh (1985) obtained a significant correlation between available boron and pH in forest soils of Kerala.

Hadwari *et al* (1992) observed a positive correlation between pH and available boron content in the calcareous soils of Gujarath. Pakrashi and Haldar (1992) also noticed a positive correlation between boron content and pH in some soils of north Bengal.

2.5.1.3. Clay content

Talati and Agarwal (1974) observed that the available boron increased with increase in clay content of Rajasthan soils. Significant positive correlation between water soluble boron and silt and clay was reported by Gajbhiye and Kolarker (1979) in the soils of Western Rajasthan. Chauhan and Chauhan (1984) found a negative correlation between available boron and clay in the salt affected soils of semi-arid tracts.

Materials and Methods

MATERIALS AND METHODS

The present investigation was undertaken with the main objective of determining the total and available micronutrients in the soils of eight selected major land resource areas (MLRAs) of Kerala using different extractants. The study was confined to the estimation of micronutrients viz iron, manganese, copper, zinc and boron both in profiles and surface samples. The study also envisages working out correlation if any between micronutrients and also between the micronutrients and various physico-chemical properties of the soil. The details of soil samples investigated and the experimental procedures adopted are presented in this chapter.

3.1 Collection of soil samples:

The soils were collected from typical profiles representing the selected major land resource areas (MLRAs)of Kerala . The soils were sampled from these profiles as per the guidelines of the Soil Survey Staff, USDA (1951). The soil samples were collected from the profiles of eight soil series of Kerala, as listed below:-

DETAILS OF SOIL SAMPLE COLLECTED

Sl.No:	Name of the series	Soil Type
1.	**Palode**	Southern forest soil
2.	**Vellayani**	Red loam
3.	**Trivandrum**	Low level laterite
4.	**Kottarakkara**	Midland laterite
5.	**Mannar**	*Onattukara* loamy sand
6.	**Thakazhy**	*Kari* soil (Acid peat)
7.	**Ramankary**	*Karappadam* (Riverine alluvium)
8.	**D-Block (*Kayal* Lands)**	*Kayal* soil (Lake bottom sediments)

In addition to the profile samples collected from these areas, ten surface samples were also collected at a radial distance of 5 km around each profile site for detailed laboratory investigations.

3.2 Preparation of soil samples for analysis.

The samples collected from the profiles were serially numbered, were brought to the laboratory, air dried, powdered and sieved through a 2mm sieve and stored in plastic bottles for analysis.

3.3 Determination of physical properties:

3.3.1 Mechanical analysis

The mechanical analysis was carried out by the International Pipette Method (Piper, 1942).

3.3.2. Single value constants:

The single value constants were determined by Troells method using Keen Raczkowski boxes (Wright,1939)

3.4. Determination of Chemical properties :

3.4.1 pH:

The soil pH was determined with Elico model L1-120 pH meter (Jackson, 1973)

3.4.2. Electrical conductivity

The electrical conductivity was measured using Elico model CM-84 conductivity bridge (Jackson, 1973)

3.4.2 Cation exchange capacity:

Cation exchange capacity of soils were determined by neutral norma ammonium acetate method (Jackson, 1973).

3.4.3. Organic carbon:

Organic carbon was determined by the Walkley and Black rapid titration method (Jackson, 1973)

3.4.4. Total nitrogen:

Total nitrogen content in the soils were determined by microkjeldahl method (Jackson, 1973)

3.4.5 Exchangeable cations:

(a) Exchangeable sodium and potassium:- Exchangeable sodium and potassium were determined in the neutral normal ammonium acctate extract using systronics flame photometer (Jackson, 1973).

(b) Exchangeable calcium and magnisium:- Exchangeable calcium and magnesium were determined in the neutral normal ammonium acetate extract using Perkin Elmer 3110 Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978)

3.4.6 Determination of micronutrients:

(a) Total micronutrients: The soils were extracted by digestion with nitric-perchloric acid mixture (1:1 ratio). The extract was then read in a 3110 Perkin Elmer Atomic Absorption Spectropholometer (Jackson, 1973).

(b) Available micronutrients:

1) By DTPA extractant: The extract was prepared by shaking 10 g soil with 20 ml of 0.005 M DTPA for 2 hours. The extract was filtered through Whatman No: 42 filter paper and Fe, Mn, Zn, and Cu, in the extract were determined in a Perkin Elmer Atomic Absorption Spectrophotometer Model 3110 (Lindsay and Norwell, 1978)

2) By Ammonium accetate extractant:

10 g of soil were shaken with 100 ml of neutral normal ammonium acetate (1:10 soil to extractant ratio) and was filtered through no:42 Whatman filter paper. The micronutrients in the extract were read in a Perkin Elmer Model 3110 Atomic Absorption Spectrophotometer. (Stewart and Tahir, 1971)

3) By EDTA extractant:

Available iron, manganese, zinc and copper were extracted using EDTA extractant. 5 g soil and 50 ml of 0.02 M EDTA (1:10 soil water ratio) were shaken for one hour and filtered through Whatman No: 42 filter paper and the micronutrient concentration was read in Perkin Elmer 3110 Atomic Absorption Spectro photometer (Treiweiler and Lindsay, 1969)

3.4.7 Available boron:

Available boron content in soils was extracted by refluxing a 1:2 soil water mixture for five minutes and then filtering the extract. The boron was determined colorimetrically in the Klett Summerson photo electric calorimeter, after developing colour by treating the extract with curcumin followed by baking and dissolving the residue in alcohol (Jackson, 1973).

3.4.8 Determination of available micronutrients by Neubauer seedling technique:

The experiment was conducted in completely randomised design (CRD) with three replications. 100 g of soil were mixed with 50 g of acid washed quartz, repeatedly washed with triple distilled water and placed in plastic bottles of 12 cm diameter and 8 cm in height. 100 good quality germinated rice seeds of variety Bharathi were sown and irrigated periodically with triple distilled water. The bottles were placed in the sun for 5 hours daily. 17 days after sowing, the plant were uprooted and washed throughly. The plant materials were then dried, powdered in a Retsch ultracentrifugal mill and homogenised.Then 0.5 g of plant material were digested with 5 ml of perchloric-nitric acid mixture. (1:1 ratio) and the micronutrients estimated using 3110 Perkin Elmer AAS.

3.5 Statistical analysis.

The data obtained from the experiment were subjected to statistical analysis. Correlations were worked out between micronutrients and soil physico-chemical properties (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSION

The present study was conducted to assess the micronutrient distribution, vertically and spatially in the eight major land resource areas of Kerala.The total and available micronutrients were analysed and correlations were worked out. The details of the soil series collected and profile descriptions done are given in the Appendix. The results obtained from the laboratory studies and their relevant discussions are presented in this chapter:

3.1 Mechanical analysis of soils

The coarse sand, find sand, silt and clay content showed greater variation in the various horizons of the profiles studied and all these fractions followed an erratic trend with depth.

In the Palode series,the coarse sand fraction was highest in the surface layer with 32.3 percent and lowest in the third layer with 22.3 percent. A maximum content of fine sand fraction was noticed in the bottom layer with 28.3 percent and lowest in the surface with 22.5 percent and the content was found to increase with depth. The silt fraction was maximum in the third layer with 8.7 percent and least in the surface with 5.1 percent. The clay content was obeserved to be maximum in the third layer with 36.3 percent and least in the fourth layer having 31.5 percent. (Table No:1).

In the Vellayani series, the coarse sand fraction was highest in the surface with 29.9 percent and lowest in the third layer having 27.5 percent. The fine sand fraction was present in the maximum quantity in the bottom layer(30.3 percent) and least in the third layer (27.4 percent). The silt fraction showed a maximum content in the surface layer (3.3 percent) whereas it was minimum (3.0 percent) in the lowest layer. The clay content was also observed to be highest in the third layer (37.6 percent) and lowest in the surface having 32.3 percent. (Table No:1).

In the Trivandrum series, the coarse sand fraction varied from 37.5 percent in the surface to a minimum of 31.9 percent in the fourth layer. The fine sand fraction showed a maximum content in the fifth layer having 13.3 percent and least in the third layer with 9.2 percent. The silt fraction was observed to be highest in the second layer (16.7 percent) and lowest in the bottom layer (5.5 percent). A maximum quantity of clay fraction was noticed in the fourth depth with 45.5 percent and lowest in the surface having 30.9 percent. (Table No:1).

In Kottarakkara series, the coarse sand fraction was highest in the surface layer (42.1 percent) and least in the bottom layer (18.9 percent). The silt fraction was maximum in the bottom layer (22.7 percent) and lowest in the fourth layer (7.3 percent). The silt fraction was observed to be highest in the third layer (13.7 percent) and minimum in the bottom layer having 10.1 percent. The clay content was maximum in the fifth layer with 48.4 percent and least in the surface having 23.4 percent. (Table No:1).

Table No : 1 **Mechanical analysis of soils**

Sl.No:	Name of Series	Depth in Cm	Percentage (%)			
			Coarse sand	Fine sand	Silt	Clay
1.	Palode	0-10	32.3	22.5	5.1	32.1
		10-28	27.7	22.7	8.5	34.1
		28-47	22.3	24.7	8.7	36.3
		47-93	24.5	26.5	7.5	31.5
		93-170	25.4	28.3	6.2	32.1
2.	Vellayani	0-21	29.9	28.5	3.3	32.3
		21-52	28.3	27.6	3.2	34.9
		52-125	26.8	27.4	3.1	37.6
		125-180	27.5	30.3	3.0	34.2
3.	Trivandrum	0-15	37.5	10.1	16.5	30.9
		15-24	35.8	9.6	16.7	31.9
		24-57	33.1	9.2	10.2	45.2
		57-86	31.9	11.1	6.5	45.5
		86-114	36.8	13.3	6.3	38.5
		114-165	36.9	12.1	5.5	34.1
4.	Kottarakkara	0-5	42.1	19.1	12.2	23.6
		5-30	38.2	21.8	11.9	25.1
		30-57	30.4	10.7	13.7	42.2
		57-90	31.3	7.3	13.1	45.3
		90-130	20.1	18.3	10.2	48.4
		130-165	18.9	22.7	10.1	43.3

Table No : 1 Contd.......

Sl.No:	Name of Series	Depth in Cm	Percentage (%)			
			Coarse sand	Fine sand	Silt	Clay
5.	Mannar	0-25	50.6	31.1	9.2	6.9
		25-74	42.6	38.6	8.5	7.2
		74-125	41.3	41.7	5.3	9.3
		125-155	41.4	40.6	9.3	8.4
		155-180	40.4	40.6	9.1	8.2
6.	Thakazhy	0-12	6.1	4.0	30.8	55.1
		12-18	5.0	7.1	27.5	56.4
		18-30	6.2	3.9	27.7	58.2
		30-54	6.3	3.7	31.8	53.2
		54-140	5.2	6.9	32.0	51.9
7.	Ramankary	0-15	14.2	15.4	26.2	39.2
		15-41	8.7	9.2	34.3	43.8
		41-130	3.2	8.1	38.1	45.6
8.	D-Block	0-15	8.1	10.1	37.5	40.3
		15-31	7.0	9.1	36.3	42.4
		31-47	7.5	9.6	34.4	43.5
		47-60	7.8	9.3	32.1	46.8
		60-86	9.0	9.1	34.2	43.5
		86-136	9.2	9.3	35.4	42.1

In the Mannar series, the coarse sand fraction was highest in the surface layer (50.6 percent) and lowest in the bottom layer (40.4 percent). The fine sand fraction was observed to be highest in the third layer with 41.7 percent while it was minimum in the surface layer (31.1 percent). The silt fraction was highest in the fourth layer (9.3 percent), and minimum in the bottom layer (9.1 percent). A maximum quantity of clay fraction was observed in the third layer (9.3 percent) and least in the surface layer (6.9 percent).

In the Thakazhy series, ths coarse sand fraction varied from 6.1 percent in the surface to a minimum of 5 percent in the second layer. The fine sand fraction was highest in the bottom layer (6.9 percent) and lowest in the surface layer (4 percent). The silt fraction varied from 32 percent in the lowest layer to a minimum content in the second layer (27.5 percent). A maximum quantity of clay fraction was noticed in the third layer (58.2 percent) and minimum in the bottom layer with 51.9 percent. (Table No:1).

In the Ramankary series the coarse sand fraction varied from 14.2 percent in the surface to a minimum of 3.2 percent in the bottom layer. The find sand fraction varied from 15.4 percent in the surface layer to a minimum of 8.10 percent in the bottom layer. The maximum silt fraction was observed in the bottom layer having 38.10 percent and least in the surface layer with 26.20 percent. The clay content varied from 45.60 percent in the bottom layer to a minimum value of 39.20 percent in the surface layer.

In the D-Block series, the coarse sand fraction varied from 9.2 percent in the bottom layer to a minimum of 7 percent in second layer. The fine sand fraction was observed to be highest in the surface layer (10.1 percent) and least in the fifth layer (9.1 percent). A maximum silt fraction was noticed in the surface layer (37.50 percent) and minimum in the fourth layer (32.1 percent). The clay fraction was highest in the fourth layer with 46.8 percent and lowest in the surface layer with 40.3 percent (Table No: 1)

Among the profiles studied, the maximum coarse sand fraction (50.6 percent) and fine sand fraction (41.7 percent) were observed in the Mannar series. The highest silt fraction was noticed in the bottom layer of Ramankary series (38.1 percent) and the maximum clay content was obtained in the third layer of Thakazhy series (58.2 percent).

4.1.2 Single Value Constants.

The bulk density, particle density, percentage pore space and maximum water holding capacity showed great variation in the profiles studied. In the Palode series the bulk density varied from 1.01 Mg m^{-3} in the surface layer to a maximum of 1.30 Mg m^{-3} in the lowest layer. In this series the particle density was maximum in the fourth layer with 2.32 Mg m^{-3} and lowest in the surface layer with 2 Mg m^{-3}. The particle density was found to decrease with depth. The percentage pore space was highest in the second layer with 51.20 percent and lowest in the bottom layer (42.98 percent) and there was variation in the pore space noticed with depth, which followed no definite pattern. The maximum water holding capacity was noticed in the second layer with 48.22 percent and lowest in the bottom layer with 40.38 percent (Table No:2).

In Vellayani Series the bulk density was highest in the bottom layer with 1.31 Mg m^{-3} and lowest in the surface layer with 1.22 Mg m^{-3}. The particle density varied from 2.36 Mg m^{-3} in the lowest layer to a maximum of 2.39 Mg m^{-3} in the second layer. The percentage pore space was maximum in the surface layer with 48.73 percent and minimum in the lowest layer with 44.72 percent. The maximum water holding capacity was highest in the third layer with 50.91 percent and least in the surface layer with 47.5 percent.

In Trivandrum Series the bulk density was maximum in the lowest layer with 1.42 Mg m^{-3} and lowest in the bottom layer with 1.16 Mg m^{-3}, and the bulk density was found to increase with depth. The particle density was highest in the fifth layer with 2.51 Mg m^{-3} and lowest in the surface layer with 2.20 Mg m^{-3}, the percentage pore space varied between 47.34 percent in the fourth layer and 39.05 percent in the bottom layer. The maximum water holding capacity was highest in the fourth layer with 47.34 percent and lowest in the bottom layer with 38.78 percent.

In Kottarakkara Series, the bulk density showed a wide variation in the profile. The maximum was noticed in the fifth layer with 1.22 Mg m^{-3} and lowest in the third layer (1.13 Mg m^{-3}). The particle density also showed variation within the profile. It varied from 2.11 to a maximum of 2.16 Mg m^{-3}in the surface layer. The maximum value of percentage pore space was in the third layer with 47.44 percent and minimum in the fourth layer with 42.18 percent. The maximum water holding capacity was highest in the second layer (42.16 percent) and mimnimum in the surface layer (39.85 percent) and showed a wide variation in the profile. (Table No: 2)

In Mannar Series, the bulk density showed some variation in the profile, the highest value was noticed in the lowest layer with 1.60 Mg m^{-3} and lowest in the surface layer with 1.53 Mg m^{-3}. The particle density showed an irregular trend throughout the profile. The highest being 2.46 Mg m^{-3} in third layer and lowest in bottom layer with 2.35 Mg m^{-3}. The percentage pore space also showed variation in the profile, the highest being 39.40 percent in the fourth layer and least in the lowest layer with 35.31 percent. The maximum water holding capacity was observed to be highest in the fourth layer with 28.09 percent and lowest in the second layer with 23.83 percent (Table No:2).

In Thakazhy series, the bulk density varied from 1.29 Mg m^{-3} in surface layer to a maximum of 1.61 Mg m^{-3} in the third level. The particle density ranged from 2.42 Mg m^{-3} in fouth layer to highest value of 2.55 Mg m^{-3} in the surface layer. The percentage pore space ranged between 33.60 percent in the third layer and 49.41 percent in the surface layer. The maximum water holding

Table No : 2

SINGLE VALUE CONSTANTS

Sl. No:	Name of Series	Depth in cm.	Bulk Density Mg m^{-3}	Particle Density Mg m^{-3}	Pore Space %	Maximum Water Holding Capacity %
1.	Palode	0-10	1.01	2.00	49.50	46.32
		10-28	1.02	2.07	51.20	48.22
		28-47	1.16	2.21	47.51	45.70
		47-93	1.17	2.32	49.56	46.22
		93-170	1.30	2.28	42.98	40.38
2.	Vellayani	0-21	1.22	2.38	48.73	47.50
		21-52	1.24	2.39	48.11	48.21
		52-125	1.32	2.37	44.76	50.91
		125-180	1.31	2.36	44.72	49.42
3.	Trivandrum	0-15	1.16	2.20	47.27	45.68
		15-24	1.17	2.21	47.05	45.64
		24-57	1.16	2.18	46.78	43.56
		57-86	1.19	2.26	47.34	47.34
		86-140	1.35	.51	46.21	42.71
		114-165	1.42	2.33	39.05	38.78
4.	Kottarakkara	0-5	1.19	2.15	44.65	39.85
		5-30	1.16	2.16	46.29	42.16
		30-57	1.13	2.15	47.44	41.63
		57-90	1.21	2.20	45.00	40.49
		90-130	1.22	2.11	42.18	40.24
		130-165	1.21	2.12	42.92	40.23

Sl. No:	Name of Series	Depth in cm.	Bulk Density Mg m^{-3}	Particle Density Mg m^{-3}	Pore Space %	Mamium Water Holding Capacity %
5.	Mannar	0-25	1.53	2.42	36.77	24.06
		25-74	1.54	2.38	35.71	23.83
		74-125	1.55	2.46	36.99	27.36
		125-155	1.56	2.36	39.40	28.09
		155-180	1.60	2.35	35.31	23.84
6.	Thakazhy	0-12	1.29	2.55	49.41	22.33
		12-18	1.60	2.51	36.25	24.42
		18-30	1.61	2.47	33.60	26.13
		30-54	1.35	2.42	46.42	23.23
		54-140	1.38	2.53	45.45	23.41
7.	Ramankary	0-15	1.08	2..32	53.44	43.11
		15-41	1.13	2.12	46.69	42.33
		41-130	1.09	1.97	44.64	38.01
8.	D-Block	0-15	1.03	2.32	51.29	38.93
		15-31	1.09	2.20	50.45	38.13
		31-47	1.08	2.15	49.76	38.11
		47-60	1.06	2.10	49.52	37.32
		60-86	1.03	2.08	50.48	38.14
		86-136	1.01	2.05	50.73	38.24

capacity was least in the surface layer with 22.33 percent to a maximum of 26.13 percent in the third layer. The bulk density, particle density, percentage pore space and maximum water holding capacity showed an irregular pattern among the various layers. (Table No:2).

In Ramankary series, the second layer showed the maxiumum bulk density with 1.13 Mg m^{-3} and least in the surface layer having 1.08 Mg m^{-3}. The particle density varied from 1.97 Mg m^{-3} in the bottom layer to a maximum of 2.32 Mg m^{-3} in the surface layer. The percentage pore space was observed to be highest in surface layer having 53.44 percent and lowest in the bottom layer with 44.64 percent. The maximum water holding.capasity was highest in the surface layer with 43.11 percent and least in the bottom layer with 38.01 percent.

In D-Block, the bulk density was highest in the surface with 1.13 Mg m^{-3} and least in the bottom layer with 1.01 Mg m^{-3}, and it was found to decrease with depth. The particle density was highest (2.32 Mg m^{-3}) in the surface layer and lowest in the bottom layer (2.05 Mg m^{-3}) and it was found to decrease with depth. The percentage pore space was highest in the surface layer with 51.29 percent and least in the fourth layer (49.52 percent). The maximum water holding capasity was highest in the surface layer (38.93 percent) and lowest in the fourth layer(37.32 percent) and it was found to decrease upto fourth layer and then increased in the fifth and bottom layer.

Among the series studied the bulk density was highest in the third layer of Thakazhy series with 1.61 Mg m^{-3} and least in surface layer and bottom layer of Palode and D-Block respectively with 1.01 Mg m^{-3}. The particle density was highest in the surface layer of Thakazhy series with 2.55 Mg m^{-3} and lowest in the bottom layer of Ramankary series with 1.97 Mg m^{-3}. The percentage pore space was highest in surface layer of Ramankari series with 53.44 percent and least in the third layer of Thakazhy series with 33.60 percent. The maximum water holding capacity was found to be highest in the third layer of Vellayani series with 50.91 percent and lowest in the surface layer of Thakazhy series with 22.33 percent (Table No:2).

4.2 Chemical Properties of Soils.

4.2.1 pH.

The pH of the soil showed wide variation in all the profiles studied. The pH of most of the soils showed an increasing trend with depth. In Palode series it ranged from 4.85 in the surface layer to 5.09 in the bottom layer. In Vellayani series it was 5.01 in the surface layer which increased to a maximum of 5.81 in the lowest layer and it showed an increasing trend with depth. In Trivandrum series the lowest pH was noticed in the surface layer with 4.04 and highest in the fourth layer with 4.64. In Kottarakkara series the lowest pH value of 5.03 was observed in surface layer and it was highest in the fourth layer with 5.85. The variation in pH in different layers did not show any particular trend. In the Mannar series the surface layer showed the least pH value of 4.95 and it was highest in the third layer with a value of 6.4 in the Thakazhy series the least value of pH was in the surface layer (3.95) and highest in the bottom layer (4.08). In Ramankary series the pH was highest in the surface layer (4.50) and lowest in the bottom level (4.30). In D-Block the least pH value of 4.30 was observed in the surface layer and highest in the bottom layer with a value of 5.08 (Table No : 3)

Among the profiles studied the lowest pH was noticed in the fourth layer of Thakazhi Series (3.80) and the highest pH value (6.40) was obtained in the third layer of Mannar Series.

4.2.2 Electrical conductivity.

The electrical conductivity did not show much variation in the profiles except Ramankary, Thakazhy and D-Block series studied. Among the profiles studied the highest value was observed in the bottom layer of Thakazhi series with 5.60 dS m^{-1} and lowest in Kottarakkara series with 0.02 dS m^{-1} (Table No:3).

4.2.3 Cation exchange capacity

In Palode series the cation exchange capacity was highest in the surface layer with 5.90 cmol kg^{-1} and lowest in the bottom layer with 3.19 cmol kg^{-1} and it showed a decreasing trend with depth. In Vellayani series the CEC was observed to be maximum in the surface layer (2.5 cmol kg^{-1}) and least in the third layer (1.62 cmol kg^{-1}) the surface layer showed a maximum CEC (2.62 cmol kg^{-1}) and lowest in the fourth layer (2.08 cmol kg^{-1}) in Trivandrum series and it decreased upto the

Table No. 3. Chemical properties of soils

Sl. No.	Name of Series	Depth cm	pH	E.C dS m^{-1}	% Organic carbon	% Total nitrogen	C.E.C cmol kg-1	Exchangaeble cations (cmol kg^{-1}) Na	K	Ca	Mg
1.	Palode	0-10	4.85	0.20	4.23	0.12	5.90	0.13	0.28	0.83	0.28
		10-28	4.87	0.20	3.24	0.08	3.60	0.41	0.24	1.05	0.30
		28-47	4.94	0.22	1.74	0.05	3.00	0.16	0.22	1.27	0.29
		47-93	5.35	0.21	1.02	0.04	3.25	0.21	0.19	1.32	0.36
		93-170	5.09	0.22	0.63	0.03	3.19	0.22	0.16	1.45	0.31
2.	Vellayani	0-21	5.01	0.22	0.82	0.08	2.50	0.25	0.22	1.49	0.46
		21.52	5.32	0.21	0.72	0.07	1.84	0.16	0.20	0.66	0.38
		52-125	5.61	0.20	0.63	0.05	1.62	0.18	0.18	0.99	0.44
		125-150	5.81	0.20	0.64	0.03	1.68	0.13	0.14	0.89	0.33
3.	Trivandrum	0-15	4.04	0.21	0.84	0.09	2.62	0.18	0.22	1.32	0.44
		15-24	4.20	0.20	0.69	0.08	2.54	0.16	0.18	0.94	0.39
		24-57	4.54	0.22	0.69	0.07	2.40	0.09	0.17	0.63	0.33
		57-86	4.52	0.21	0.43	0.04	2.08	0.13	0.15	0.87	0.32
		86-114	4.64	0.20	0.23	0.03	2.12	0.11	0.13	0.81	0.28
		114-165	4.51	0.22	0.26	0.02	2.14	0.12	0.12	1.02	0.26

Table No .3 contd....

Sl. No.	Name of Series	Depth cm	pH	E.C dS m⁻¹	% Organic carbon	% Total nitrogen	C.E.C cmol kg-1	Exchangaeble cations (cmol kg^{-1}) Na	K	Ca	Mg
4.	Kottarakkara	0-5	5.03	0.04	1.29	0.09	3.90	1.12	1.18	1.10	1.13
		5-30	5.04	0.03	1.36	0.08	4.30	1.14	0.17	1.13	1.14
		30-57	5.82	0.04	1.05	0.06	4.40	1.08	0.15	1.21	1.16
		57-90	5.85	0.03	0.76	0.05	4.10	1.09	0.14	1.40	1.32
		90-130	5.80	0.02	0.39	0.03	4.20	1.01	0.12	1.16	1.41
		130-165	5.70	0.02	0.15	0.02	4.30	1.31	0.11	1.19	1.28
5.	Mannar	0.25	4.95	0.02	0.31	0.13	2.32	0.16	0.15	0.77	0.93
		25-74	8.20	0.05	0.20	0.11	2.24	0.17	0.12	0.86	0.66
		74-125	6.40	0.02	0.11	0.10	1.95	0.09	0.13	1.43	0.50
		125-155	6.38	0.03	0.08	0.10	1.98	0.11	0.11	0.77	0.33
		155-180	6.25	0.04	0.05	0.09	1.90	0.13	0.10	1.20	0.81
6.	Thakazhy	0-12	3.95	1.90	7.75	0.24	19.60	2.22	0.90	4.50	2.03
		12-18	4.01	3.50	8.52	0.17	18.10	2.09	0.89	5.05	1.59
		18-30	3.90	4.80	6.11	0.11	20.80	2.03	0.75	3.27	1.30
		30-54	3.80	5.50	8.64	0.10	19.40	2.41	0.65	3.28	1.64
		54-140	4.08	5.60	6.68	0.09	18.50	2.31	0.60	4.27	1.39

Table No .3 contd....

Sl. No.	Name of Series	Depth cm	pH	E.C dS m^{-1}	% Organic carbon	% Total nitrogen	C.E.C cmol kg-1	Exchangaeble cations (cmol kg^{-1}) Na	K	Ca	Mg
7.	Ramankary	0-15	4.50	1.35	3.05	0.34	11.10	1.81	0.42	4.79	2.03
		15-41	4.40	0.82	4.02	0.24	11.80	1.32	0.38	4.73	2.11
		41-130	4.30	0.71	4.21	0.18	12.10	1.61	0.35	4.19	2.69
8.	D-Block	0-15	4.30	1.21	3.83	0.30	11.94	1.10	0.53	2.63	1.21
		15-31	4.50	0.90	3.22	0.28	12.10	1.12	0.47	2.81	0.90
		31-47	4.50	1.01	4.97	0.21	14.11	1.32	0.45	2.35	1.01
		47-60	4.39	0.40	4.44	0.24	13.86	1.51	0.43	2.59	0.40
		60-86	5.00	0.05	3.12	0.22	12.21	1.62	0.41	2.31	0.50
		86-136	5.08	0.60	2.97	0.20	11.47	1.31	0.40	2.37	0.60

fourth layer and then slightly increased with depth. In Kottarakkara series the highest CEC was noticed in the third layer (4.4 c mol kg $^{-1}$) and least in the surface (3.9 cmol kg $^{-1}$) and it did not follow a regular trend with depth. A maximum CEC (2.32 cmol kg $^{-1}$) and was observed in the top most layer while it was least (1.90 cmol kg $^{-1}$) in the lowest layer analysed in Mannar series. In Thakazhy series the highest CEC of 20.08 cmol kg $^{-1}$ was found in the third layer and lowest in the second layer with 18.1 cmol kg $^{-1}$. In Ramankary series the CEC was maximum in the bottom layer (12.1 cmol kg $^{-1}$) and lowest in the surface layer (11.1 cmol kg $^{-1}$) and it found to increase with depth. In D-Block the CEC was highest in the third layer with 14.11 cmol kg $^{-1}$ and least in the lower most layer with a value of 11.47 cmol kg $^{-1}$. In the Thakazhy series and D-Block series the vertical trend in CEC did not follow any regular pattern. (Table No: 3).

Among the profiles studied the highest CEC was noticed in the third layer of Thakazhy Series (20.8 cmol kg $^{-1}$) and least in the third layer of Vellayani series (1.68 cmol kg $^{-1}$).

4.2.4 Organic carbon

Organic carbon was observed to be highest in the surface layer in majority of the profiles studied. In the Palode series the organic carbon was highest in the surface layer with 4.23 percent and lowest in the bottom layer with 0.63 percent. In Vellayani series it varied from 0.82 percent in the surface layer to a lowest value of 0.63 percent in the third layer. In Trivandrum series the highest organic carbon content was noticed in the surface layer having 0.84 percent and a minimum content of 0.23 percent was obtained in the fifth layer. In Kottarakkara series a maxiumum value was observed in the second layer (1.36 percent) and lowest in the bottom most layer (0.15 percent). In Mannar series the surface layer showed the highest organic carbon content (0.31 percent) and it was least in the bottom layer (0.05 percent). In Thakazhy series the highest organic carbon content was observed in the fourth layer with 8.64 percent and lowest in the third layer (6.11 percent) and it showed no consistent trend with depth. In Ramankary series the third layer showed the maximum organic carbon content (4.21 percent) and least in the surface layer (3.05 percent). A maximum organic carbon content (4.97 percent) was observed in the fifth layer whereas it was least in the surface layer (2.97 percent) in D-Block series. Here the vertical distribution of organic carbon in the profile did not follow any regular pattern (Table No : 3)

4.2.5 Total nitrogen

The total nitrogen was found to decrease with depth in all the profiles studied. In the Palode series the total nitrogen content was highest in the surface layer (0.12 percent) and least in the lower most layer (0.03 percent) and it showed a decreasing trend with depth. In the Vellayani series the maximum content was in the surface layer (0.08 percent) and lowest in the bottom layer (0.03 percent). In the Trivandrum series it varied from 0.09 percent in the surface layer to a minimum content in the bottom layer having 0.02 percent. In the Kottarakkara series it was highest in the surface layer (0.09 percent) while a minimum of (0.02 percent) was observed in the bottom layer. In the Mannar series the maximum content was observed in the surface layer (0.13 percent) and least in the lower most layer (0.09 percent). In the Thakazhy series it varied from a maximum content (0.24 percent) in the top layer to a minimum content (0.09 percent) in the lowest layer. In the Ramankary the highest content was noticed in the surface layer (0.34 percent) and least in the lowest layer (0.18 percent). In the D-Block series the highest content was in the surface layer (0.30 percent) and least in the bottom layer having 0.20 percent (Table No:3).

Among the profiles studied highest total nitrogen was observed in the surface layer of Ramankary series (0.34 percent) and least in the bottom layer of Trivandrum and Kottarakkara series (0.02 percent).

4.2.6 Exchangable cations

Exchangable cations like sodium, potasium, calcium and magnesium showed variation among the profile samples studied. The maximum exchangable Na content was observed in the surface layer of Thakazhy series with 2.22 cmol kg^{-1}. The lowest value was observed in the third layers of Mannar and Trivandrum series with 0.09 cmol kg^{-1}. The exchangable K content was highest in the surface layer of Kottarakkara series (1.18 cmol kg^{-1}) and it was least in the bottom layer of Mannar series (0.10 cmol kg^{-1}). The exchangable Ca content also showed variation among the profiles studied. The maximum exchangable Ca content was noticed in the second layer of Thakazhy series with 5.05 cmol kg^{-1} and it was least in the third layer of Trivandrum series (0.63 cmol kg^{-1}). The highest exchangable Mg content was observed in the surface layer of Thakazhy series having 2.03 cmol kg^{-1} and it was least in the bottom layer of Trivandrum series with 0.26 cmol kg^{-1} (Table No: 3).

4.0. DTPA extractable micronutrient status in soils.

In Palode series the DTPA-Fe content was highest in the surface layer (38.5 ppm) and lowest in the bottom layer (29.8 ppm) and the content was found to decrease with depth. A maximum DTPA-Mn content of 4.56 ppm was observed in the top most layer, while it was least in the lowest level (0.39 ppm) and it decreased with depth. The DTPA-Zn was maximum in the surface layer (0.30 ppm) whereas it was least in the bottom layer (0.08 ppm). The DTPA-Cu content showed a maximum content in the suface layer (4.82 ppm), whereas it was least in the bottom layer (0.49 ppm) analysed. (Table No: 4).

In Vellayani series the DTPA-Fe content was present in maximum quantity (9.56 ppm) in the surface layer, while it was minimum in the bottom layer (3.03 ppm). The DTPA-Mn content was highest in the surface layer with 22.76 ppm and lowest in the bottom layer with 17.32 ppm. The DTPA-Zn showed a maximum content (6.26 ppm) in the surface layer, whereas it was least (4.12 ppm) in the lowest layer. The DTPA-Cu content was also observed to be highest in

Table - 4. DTPA extractable micronutrient status

Sl. No	Name of Series	Depth in cm	ppm			
			Fe	Mn	Zn	Cu
1.	Palode	0-10	38.50	4.56	0.30	4.82
		10-28	32.50	3.52	0.24	2.41
		28-47	31.50	0.80	0.16	1.21
		47-90	30.80	0.50	0.10	0.53
		90-170	29.80	0.39	0.08	0.49
2.	Vellayani	0-21	9.56	22.76	6.26	4.00
		21.52	8.52	19.80	5.08	3.18
		52.125	5.51	18.22	4.35	0.72
		125-180	3.03	17.32	4.12	0.52
3.	Trivandrum	0-15	16.0	19.74	0.54	0.90
		15-24	14.0	18.52	0.41	0.80
		24-57	4.50	17.35	0.09	0.76
		57-86	3.50	4.00	0.08	0.69
		86-114	3.00	2.12	0.04	0.53
		114-165	2.80	2.08	0.04	0.49
4.	Kottarakkara	0-5	29.50	7.28	0.80	0.62
		5-30	28.90	5.36	0.60	0.58
		30-57	27.30	4.60	0.40	0.90
		57-90	25.20	3.50	0.30	0.08
		90-130	19.50	3.31	0.20	0.04
		130-165	18.80	3.28	0.09	0.06

Sl. No	Name of Series	Depth in cm	ppm			
			Fe	Mn	Zn	Cu
5.	Mannar	0-25	13.30	3.28	0.54	1.44
		25-74	12.52	2.89	0.51	1.41
		74-125	12.50	1.51	0.46	1.35
		125-155	10.5	1.32	0.44	0.82
		155-180	9.8	0.89	0.42	0.48
6.	Thakazhy	0-12	296.31	31.20	5.92	1.20
		12-18	422.32	30.51	5.81	0.90
		18-30	428.63	34.52	6.26	0.34
		30-54	105.63	33.32	8.31	0.28
		54-140	98.75	28.81	4.25	0.21
7.	Ramankary	0-15	267.5	48.50	12.68	5.79
		15-41	380.4	54.66	10.15	4.62
		41.130	513.5	112.6	6.28	4.58
8.	D-Block	0-15	147.5	46.52	2.80	1.00
		15-31	197.5	39.62	2.62	1.36
		31-47	411.5	178.96	3.10	1.38
		47-60	131.5	160.4	3.51	1.39
		60-86	108.2	38.50	3.32	0.90
		86-136	98.5	29.50	2.12	0.80

Fig 4.1 DTPA extractable micronutrient status in Palode Series

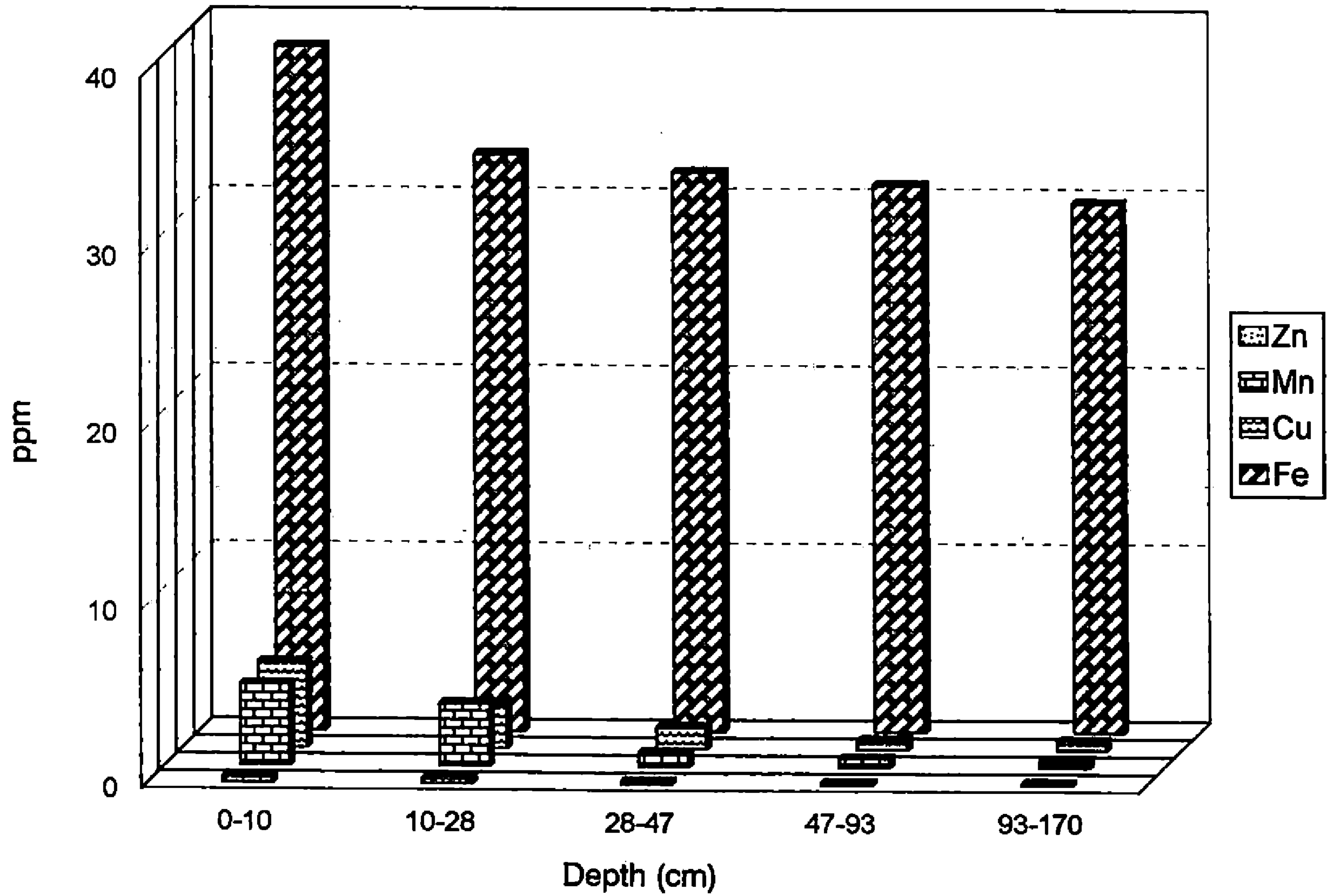


Fig 4.2 DTPA extractable micronutrient status in Vellayani Series

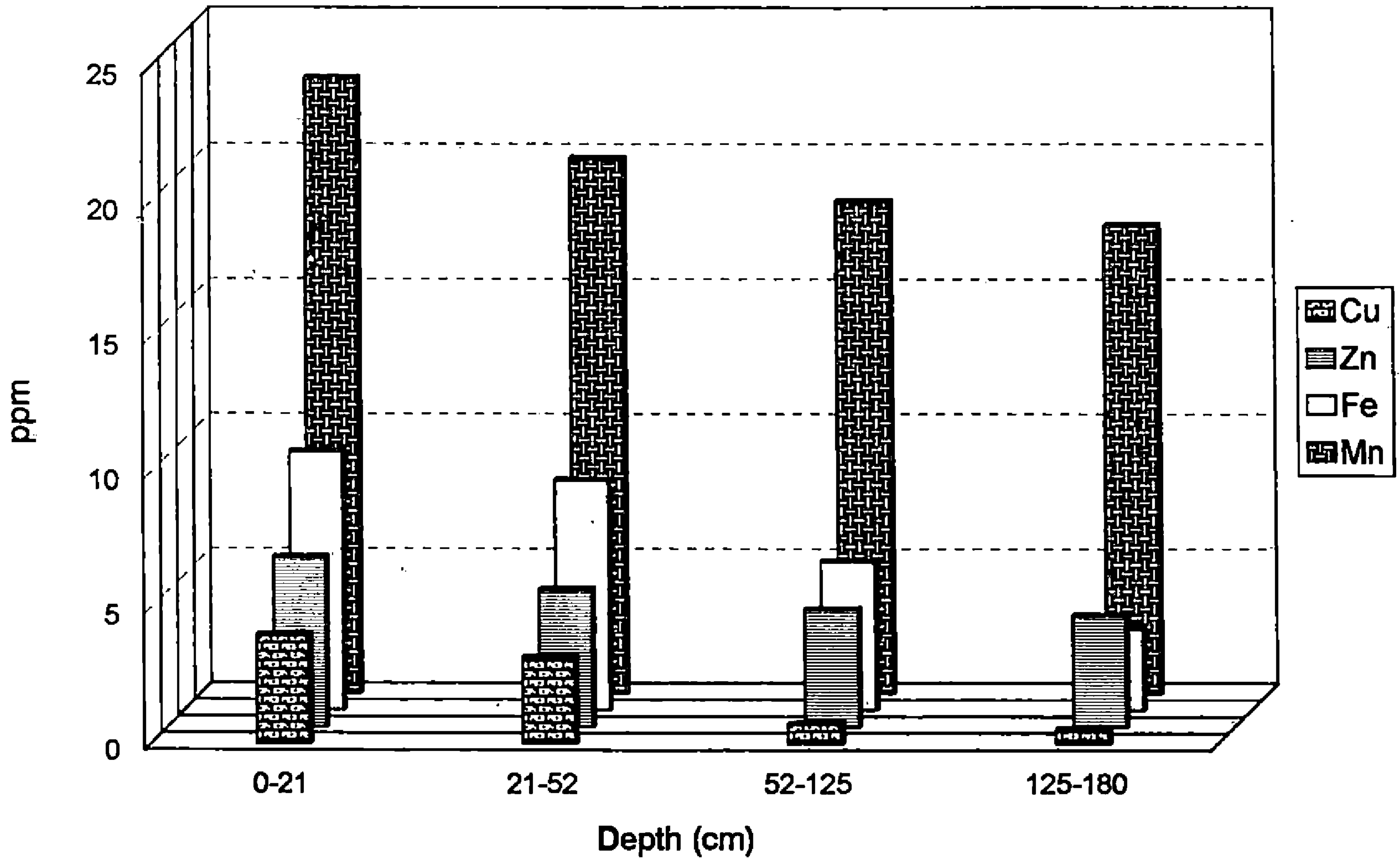


Fig 4.3 DTPA extractable micronutrient status in Trivandrum Series

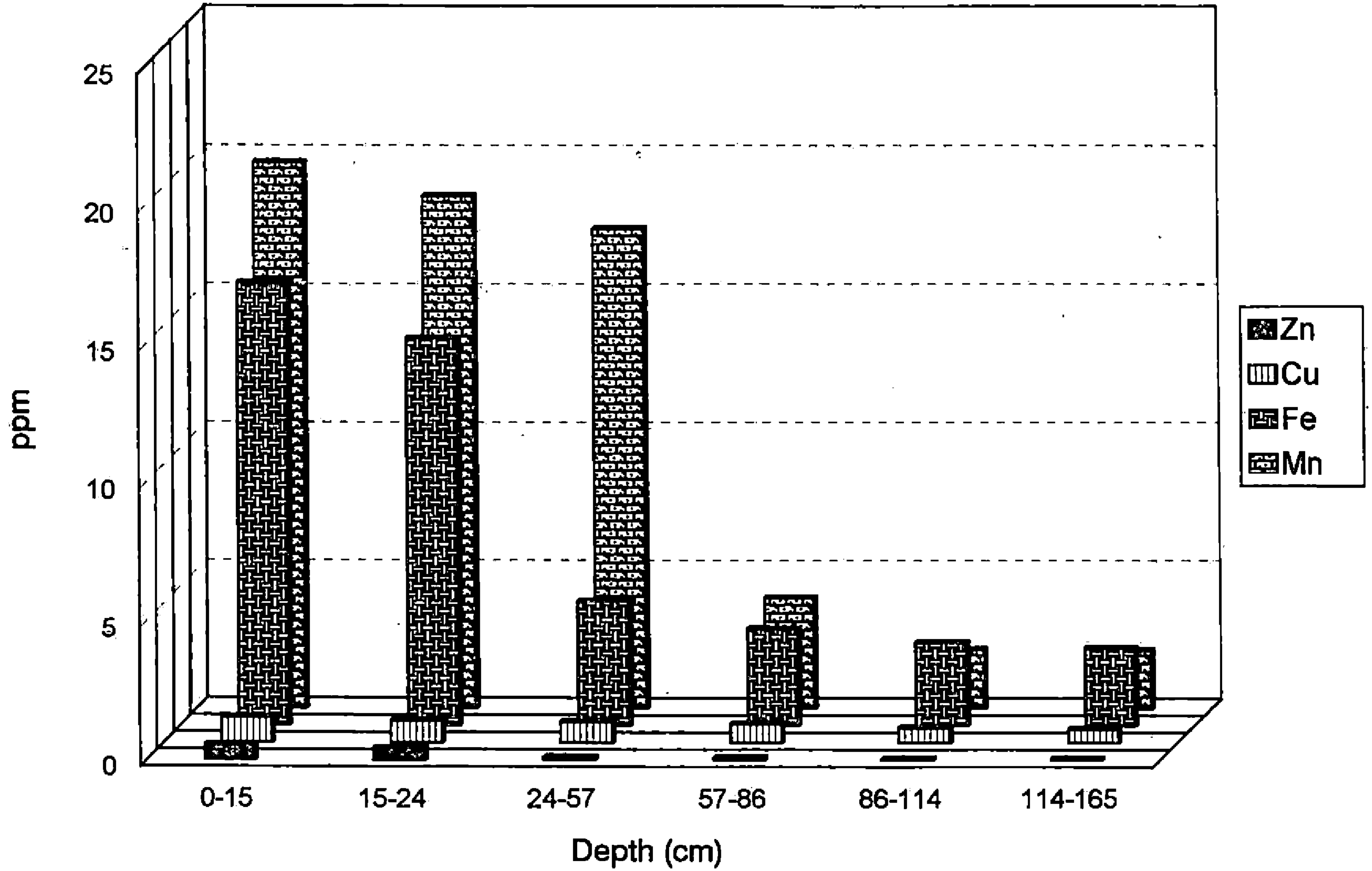


Fig 4.4 DTPA extractable micronutrient status in Kottarakkara Series

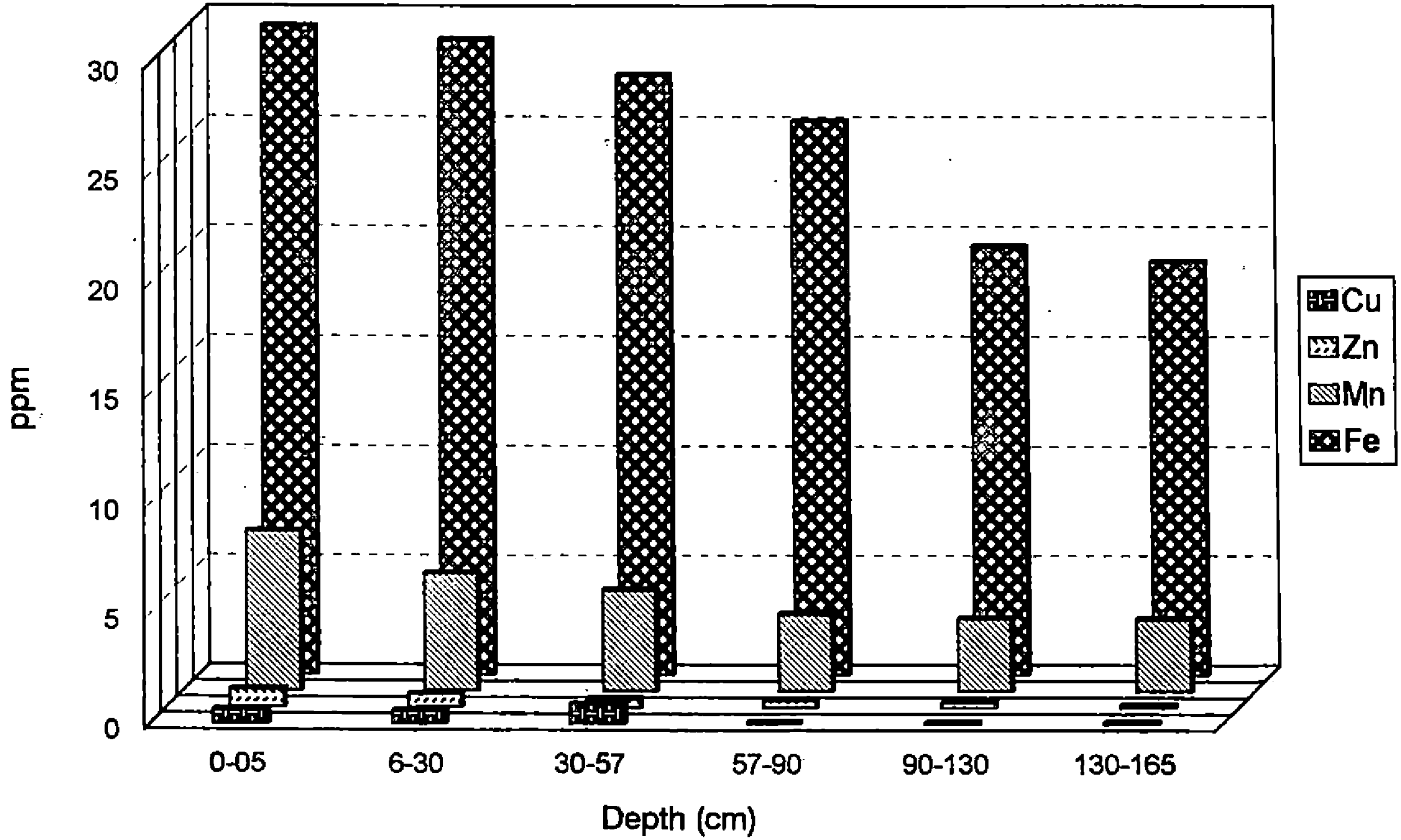


Fig 4.5 DTPA extractable micronutrient status in Mannar Series

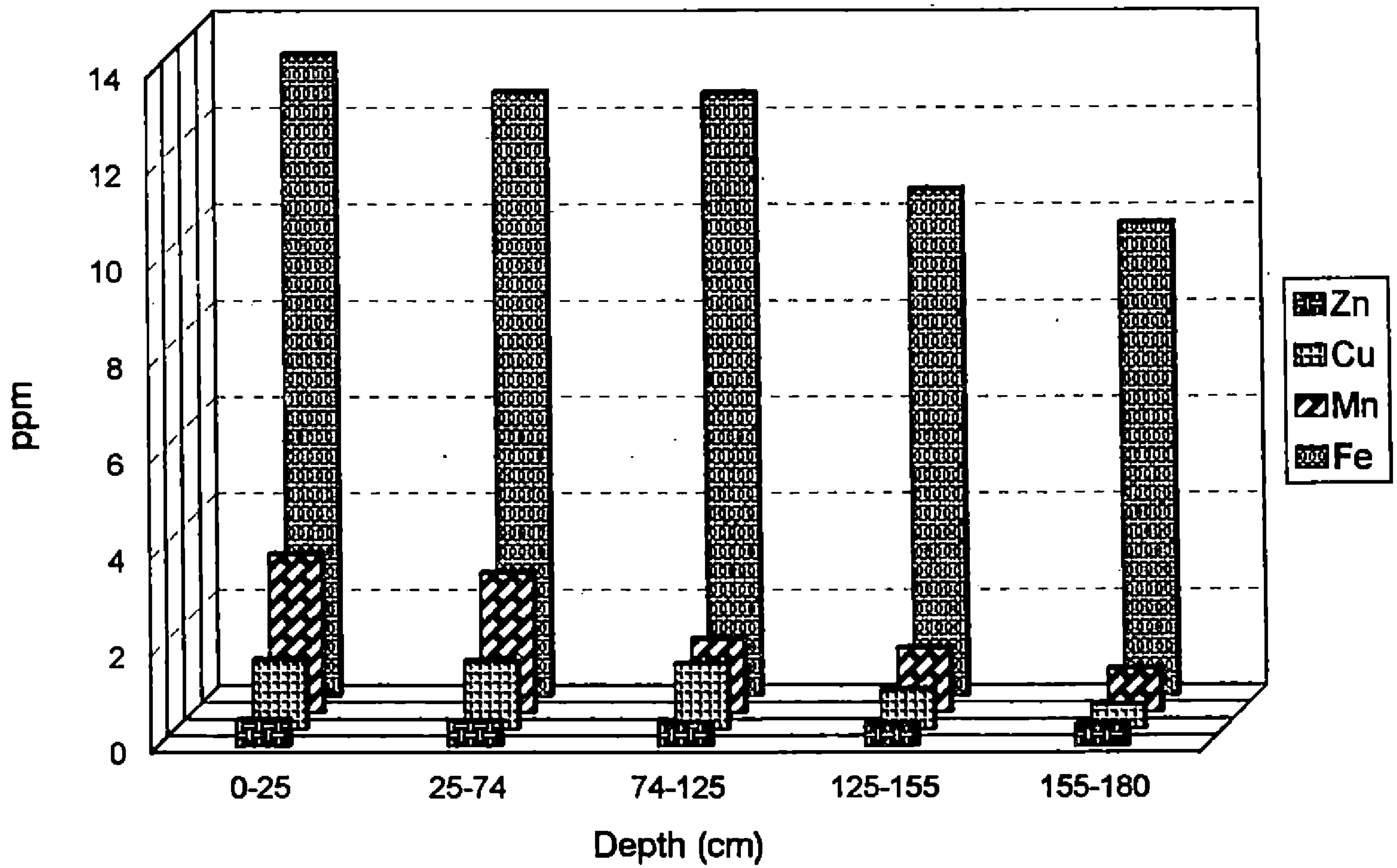


Fig 4.6 DTPA extractable micronutrient status in Thakazhy Series

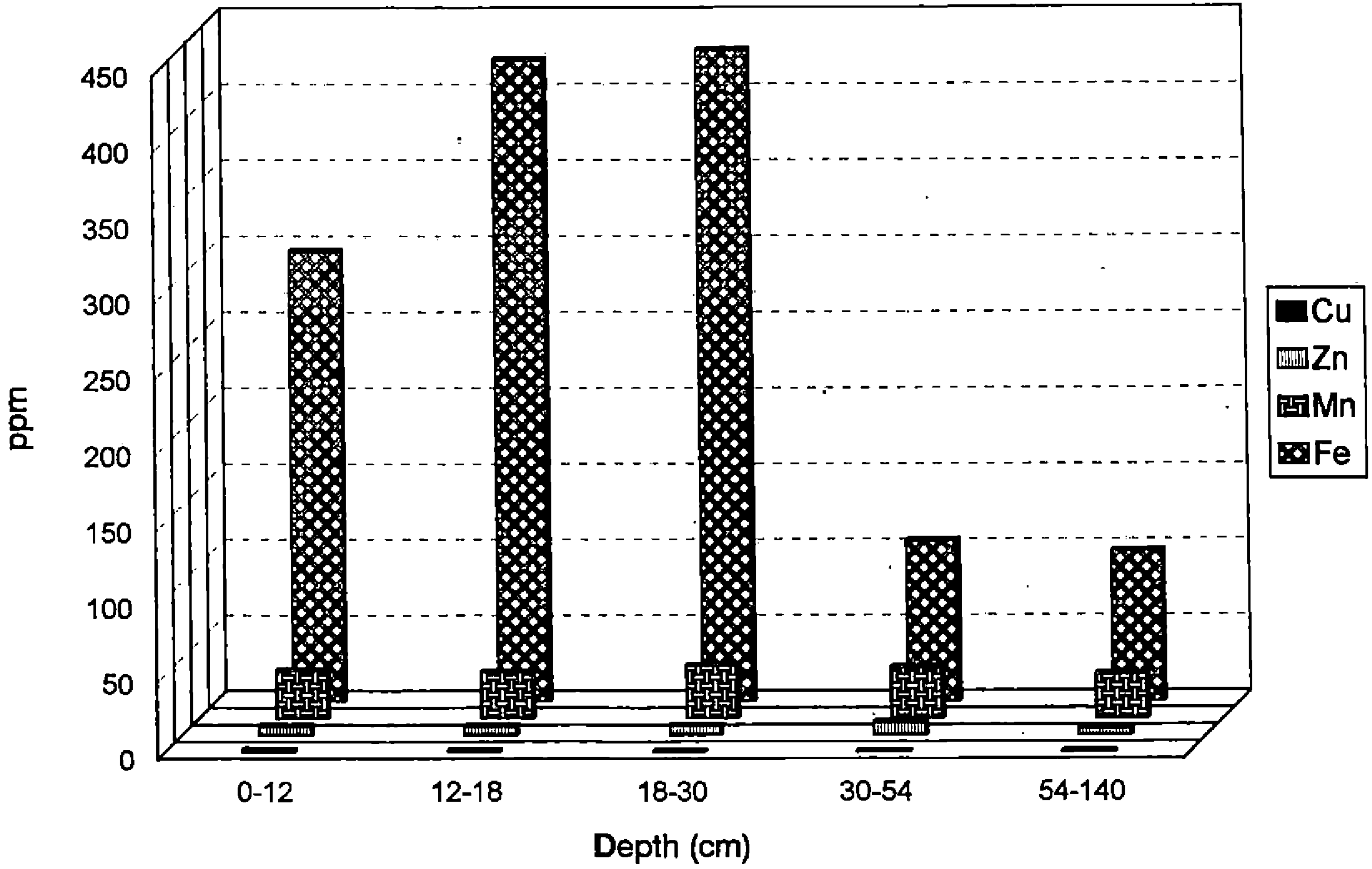


Fig 4.7 DTPA extractable micronutrient status in Ramankary Series

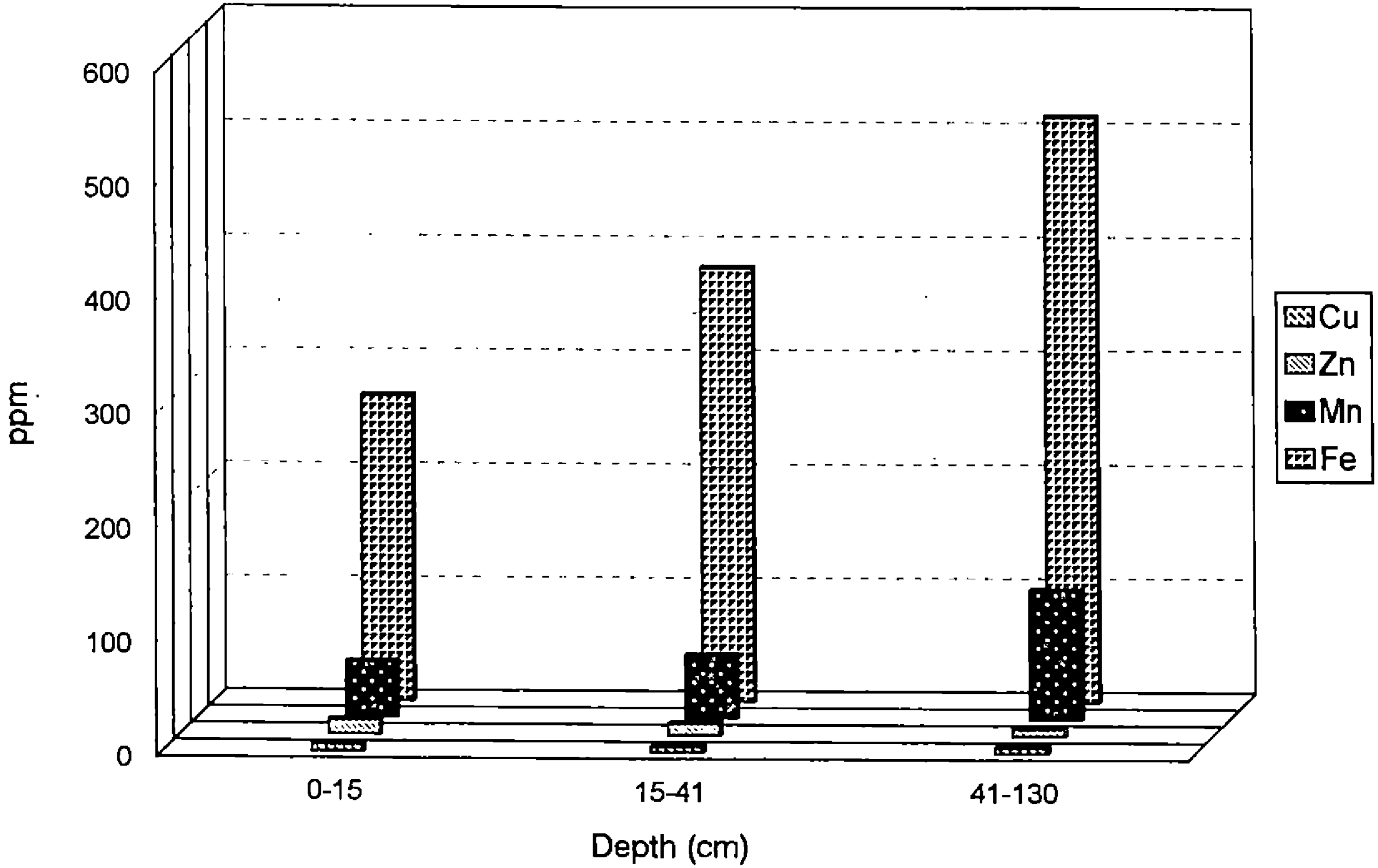
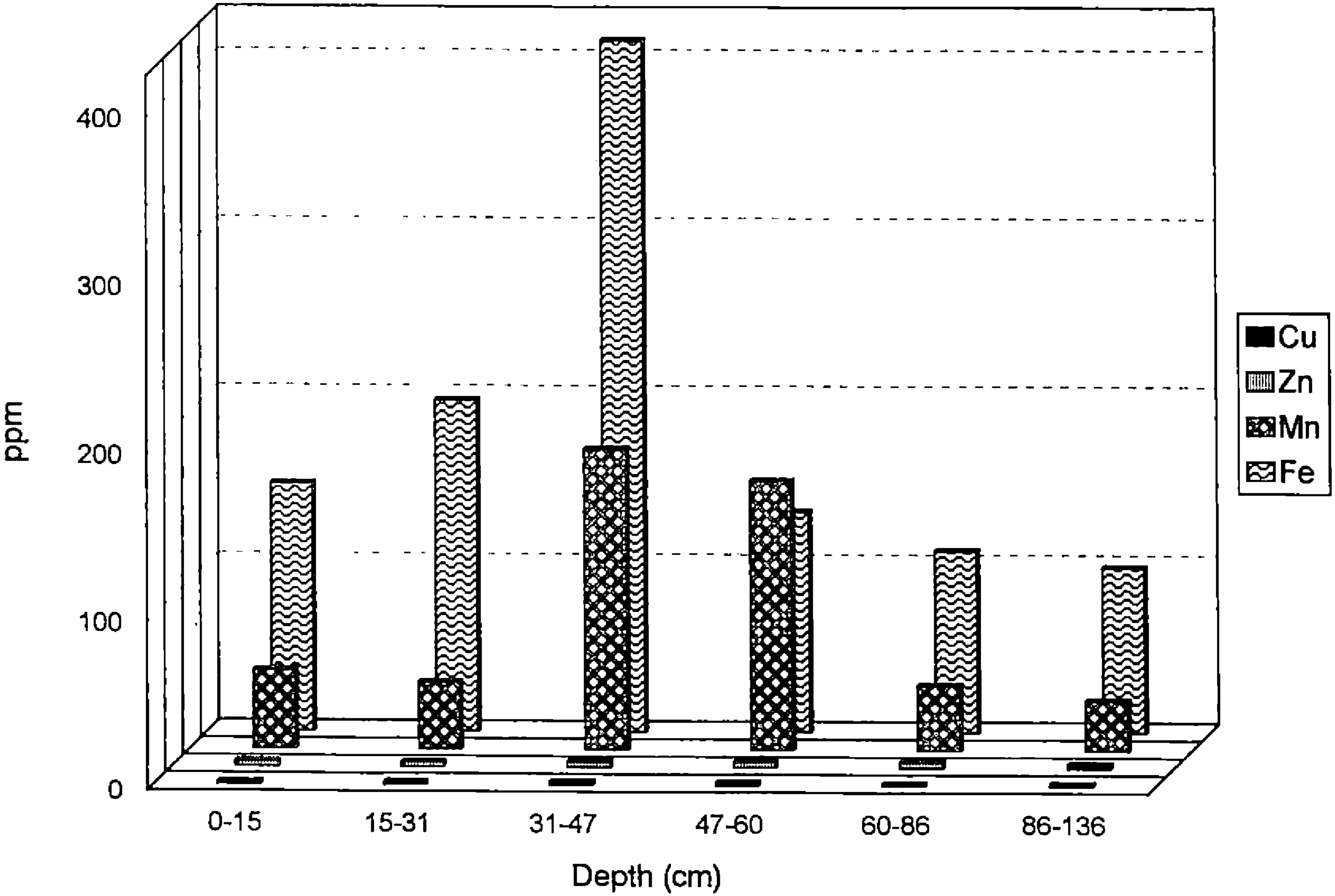


Fig 4.8 DTPA extractable micronutrient status in D-Block Series



the surface layer with 4 ppm and least in the bottom layer with 0.52 ppm. (Table No: 4).

In the Trivandrum series, the DTPA-Fe content was highest in the surface layer with 16 ppm and least in the bottom layer with 2.80 ppm. The presence of DTPA-Mn was highest in the surface layer having 19.74 ppm and lowest in the bottom layer with 2.08 ppm. A maximum content of DTPA-Zn was observed in the top most layer (0.54 ppm) and it was least in the bottom layer (0.04 ppm). The DTPA-Cu content was observed to be highest in the surface layer (0.90 ppm) and lowest in the bottom layer (0.49 ppm).

In the Kottarakkara series, the DTPA-Fe content was highest in the surface layer with 29.5 ppm and least in the bottom layer with 18.8 ppm. The DTPA-Mn content was present in the maximum quantity (7.28 ppm) in the surface layer, while it was minimum having a value of 3.28 ppm in the lowest level. In the case of DTPA-Zn the surface layer showed a maximum content of 0.80 ppm, whereas it was least (0.09 ppm) in the bottom layer. The DTPA-Cu content was highest in the surface layer with 0.62 ppm, while it was least in the lowest layer with 0.06 ppm.(Table No: 4).

In Mannar series, the DTPA -Fe content was maximum in the top most layer (13.3 ppm) and it was least in the lowest layer (9.8 ppm). The surface layer showed the highest DTPA-Mn content with 3.28 ppm, whereas it was minimum with 0.89 ppm in the bottom layer analysed. The DTPA-Zn content was maximum

(0.54 ppm) in the surface layer, while it was least in the lowest layer (0.42 ppm). The DTPA-Cu content was highest in the surface layer having 1.44 ppm and lowest in the bottom layer with 0.48 ppm.(Table No:4).

In the Thakazhy series the DTPA-Fe content was highest in the third layer (428.63 ppm) while it was lowest in the bottom layer (98.75 ppm). A maximum DTPA-Mn content was observed in the third layer having 34.52 ppm and it was least in the lowest layer with 28.81 ppm. The fourth layer showed a highest content of DTPA-Zn content (8.31 ppm), whereas it was least in the bottom layer (4.25 ppm). The DTPA-Cu content was maximum in the the surface layer (1.20 ppm) and it was minimum (0.21 ppm) in the lowest layer. (Table No:4)

In the Ramankary series the DTPA-Fe content was observed to be highest in the bottom layer (513.5 ppm) and it was minimum (267.5 ppm) in the surface layer. A maximum DTPA-Mn content was noticed in the lowest layer (112.6 ppm) and a minimum content (48.50 ppm) in the surface layer. The surface layer showed a maximum content of DTPA-Zn with 12.68 ppm, whereas it was least in the bottom layer having 6.28 ppm. The DTPA-Cu content was present in the maximum quantity (5.79 ppm) in the surface layer, while it was minimum (4.58 ppm) in the bottom layer. (Table No: 4).

In the D-Block series the highest DTPA-Fe content was observed in the third layer (411.5 ppm) and least in the bottom layer (98.5 ppm). The DTPA-Mn content was highest in the third layer with 178.96 ppm and minimum in the lowest layer with 29.50 ppm. The fourth layer showed a maximum content of DTPA-Zn (3.51 ppm), whereas it was least in the bottom layer (2.12 ppm). A maximum DTPA-Cu content was observed in the fourth layer with 1.39 ppm and lowest in the bottom layer with 0.80 ppm. (Table.No: 4).

Out of the eight soil series investigated in five series namely Palode, Vellayani, Trivandrum, Kottarakkara, and Mannar series all the micronutrients extracted by DTPA showed a decreasing trend with depth. The highest value for this fraction was noticed in the surface layer in all the above five series. An exeption to this trend was noticed only in the case of copper in the Kottarakkara series, where the maximum DTPA-Cu was noticed in the third depth (31-57cm). But its distribution have a non significant correlation with depth. Paramasivam and Gopalswamy (1994) on studying the micronutrient status in Bhavani project command area found that the DTPA extractable Zn, Fe and Cu decreased with depth. Tripathi *et al* (1994) also reported similar trend in the distribution and found a decreasing trend of micronutrients in soil profiles of Himachal Pradesh.

In the Thakazhy, Ramankary and D-Block series the occurence of DTPA-Fe and Mn was found to be highest in the third depth investigated, whereas the maximum content was noticed in the fourth depth in Thakazhy series and D-Block (*Kayal*) series. DTPA-Cu was found to be maximum in the surface layer of Thakazhy series and Ramankary series (*Karappadam*) whereas it was found in the highest quantity in the fourth layer of D-Block (*Kayal*) series.

The highest DTPA micronutrient content found in the first five series namely Palode, Vellayani, Trivandrum, Kottarakkara, and Mannar series was in the surface layer which had the highest organic carbon content. Therefore it can be said that the micronutrient distribution in these series can be associated with organic matter content. Mariam (1989) on studying the occurence and distribution of micronutrients in rice soils of South Kerala also noticed that the availability was greatly influenced by organic matter content in soils. Similar results were also obtained by Sharma *et al* (1992) and Ragupathi and Vasuki (1993).

The erratic profile distribution of DTPA extractable micronutrients in the Thakazhy, Ramankary and D-Block series can only be explained on the basis of hydrologic condition existing in these areas which are water logged for most of the year, and drainage induced during cultivation season, the alternate wetting and drying, oxidation-reduction conditions, change in pH, vertical movement of soil water through percolation, drainage and capillary rise causes constant change in the concentration of ions found at various depths in the profile. Usha (1996), while studying the acidity parameters on wet land soils of Kerala also found a varying micronutrient status in these water logged areas like Thakazhy series (*Kari*), D-Block (*Kayal*) series and *Karappadam* soils.

The maximum amount of DTPA-Fe was encountered in the third layer of Ramankary series (513.5 ppm). The highest value for DTPA-Mn in the third layer of D-Block series (178.96 ppm) and the greatest quantity of Zn and Cu (12.68 and 5.79 respectively) in the surface layer of Ramankary series. The highest values obtained in these series coincided with high acidity (pH 5.0 or less). Mariam (1989) found a significant negative correlation between DTPA extractable iron and pH in the *Kari* soils of Kerala. Sheeja *et al* (1993) observed a significant negative correlation between available zinc and pH in the cassava growing soils of Tamil Nadu. Similar results were obtained by Diwakar and Singh (1995) also.

5.0 Ammonium acetate extractable micronutrient status in soils.

In the Palode series the ammonium acetate extractable iron content was highest in the surface layer with 12.5 ppm and lowest in the bottom layer with 9.3 ppm and it was found to decrease with depth. A maximum content of ammonium acetate extractable manganese content was observed in the top most layer with 2.82 ppm, while it was least in the lowest layer with 1.15 ppm. This fraction also showed a decreasing trend with depth. The ammonium acetate extractable zinc content was maximum in the surface layer (4.91 ppm), whereas it was lowest in the bottom layer (1.62 ppm). The ammonium acetate extractable copper showed a maximum content in the surface layer (0.90 ppm) whereas it was least in the bottom layer (0.59 ppm) and it followed a decreasing trend with depth. (Table No: 5).

In the Vellayani series the ammonium acetate extractable iron content was present in the maximum quantity of 7.5 ppm in the surface layer, while it was minimum in the lowest layer (3.9 ppm). The ammonium acetate extractable manganese was highest in the surface layer with 18.42 ppm and lowest in the bottom layer with 14.13 ppm. The ammonium acetate extractable zinc content showed a maximum value of 3.32 ppm in the surface layer and it was least with 1.75 ppm in the lowest layer. The ammonium acetate extractable copper content was also observed to be highest in the surface layer with 1.41 ppm and least in the bottom layer with 0.62 ppm (Table No.5).

In the Trivandrum series the ammonium aceta

was highest in the surface layer (10.5 ppm) and least in the bottom layer (6.9 ppm). The presence of ammonium acetate extractable manganese content was highest in the surface layer (2.51 ppm) and lowest in the bottom layer (0.69 ppm). A maximum content of ammonium acetate extractable zinc was observed in the second layer with 2.72 ppm and it was least in the bottom layer having 1.69 ppm. The ammonium acetate extractable copper content was observed to be highest in the surface layer (0.62 ppm) and lowest in the bottom layer (0.38 ppm).

In the Kottarakkara series the ammonium acetate extractable iron content was highest in the surface layer with 14.5 ppm and least in the bottom layer with 9.8 ppm. The ammonium acetate extractable manganese was present in the maximum quantity (6.10 ppm) in the surface layer, while it was minimum having

Table No:5. Ammonium acetate extractable micronutrient status

Sl. No.	Name of Series	Depth in cm	ppm Fe	Mn	Zn	Cu
1.	Palode	0-10	12.5	2.82	4.91	0.90
		10-28	11.8	1.01	2.89	0.83
		28-47	10.9	1.32	2.41	0.78
		47-93	10.6	1.21	1.82	0.66
		93-170	9.3	1.15	1.62	0.59
2.	Vellayani	0-21	7.5	18.42	3.32	1.41
		21.52	6.8	18.18	2.93	1.38
		52.125	4.5	17.32	1.84	0.83
		125.150	3.9	14.13	1.75	0.62
3.	Trivandrum	0-15	10.5	2.51	2.51	0.62
		15.24	10.2	1.72	2.72	0.60
		24.57	9.8	0.86	1.86	0.58
		57.86	8.2	0.81	1.81	0.53
		86-114	7.8	0.72	1.72	0.42
		114-165	6.9	0.69	1.69	0.38
4.	Kottarakkara	0-5	14.5	6.10	2.61	0.20
		5-30	13.8	6.02	2.52	0.32
		30-57	12.9	5.13	2.32	0.36
		57-90	11.8	4.98	1.89	0.21
		90-130	10.1	4.41	1.85	0.42
		130-165	9.8	3.21	1.82	0.52
5.	Mannar	0-25	8.8	1.21	1.21	0.40
		25-74	7.5	1.10	1.11	0.38
		74-125	6.8	1.09	0.89	0.33
		125-155	5.2	0.80	0.78	0.30
		155-180	4.8	0.30	0.75	0.28

Table No. 5 Contd....

Sl. No.	Name of Series	Depth in cm	ppm			
			Fe	Mn	Zn	Cu
6.	Thakazhy	0-12	381.5	20.10	4.12	0.58
		12-18	362.5	18.19	4.09	0.43
		18-30	398.1	22.34	3.83	0.82
		30-54	250.1	21.12	3.41	0.63
		54-140	220.5	15.92	3.26	0.29
7.	Ramankary	0-15	485.1	13.19	12.28	1.82
		15-41	387.2	15.21	10.51	1.62
		41-130	398.1	16.51	7.16	1.31
8.	D-Block	0-15	228.5	30.72	2.40	0.52
		15-31	221.3	33.41	2.23	0.48
		31-47	303.2	48.20	2.41	0.87
		47-60	313.1	43.81	2.89	0.83
		60-86	208.1	32.19	2.12	0.29
		86-136	204.8	29.14	2.08	0.22

Fig 5.1 Ammonium acetate extractable micronutrient status in Palode Series

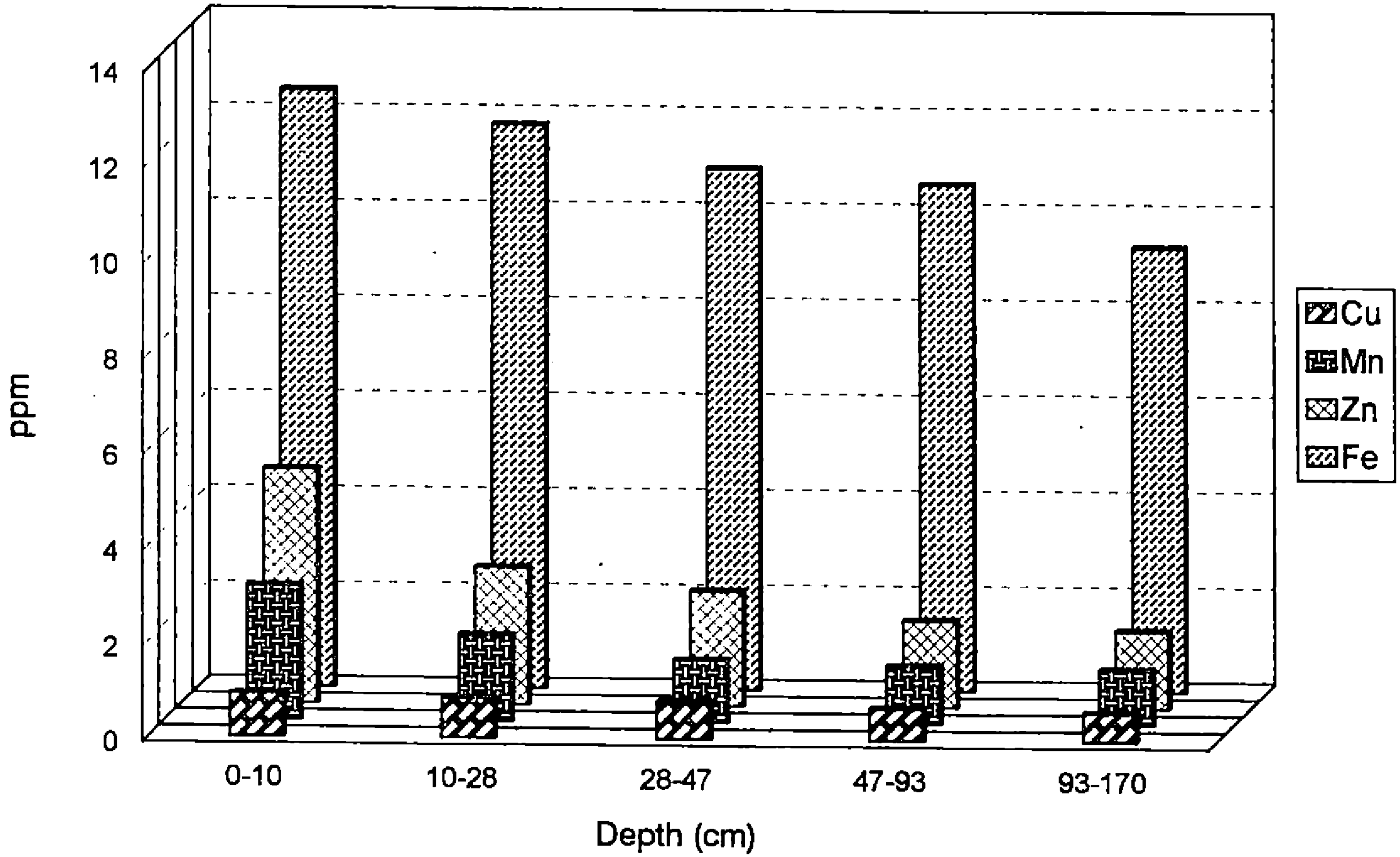


Fig 5.2 Ammonium acetate extractable micronutrient status in Vellayani Series

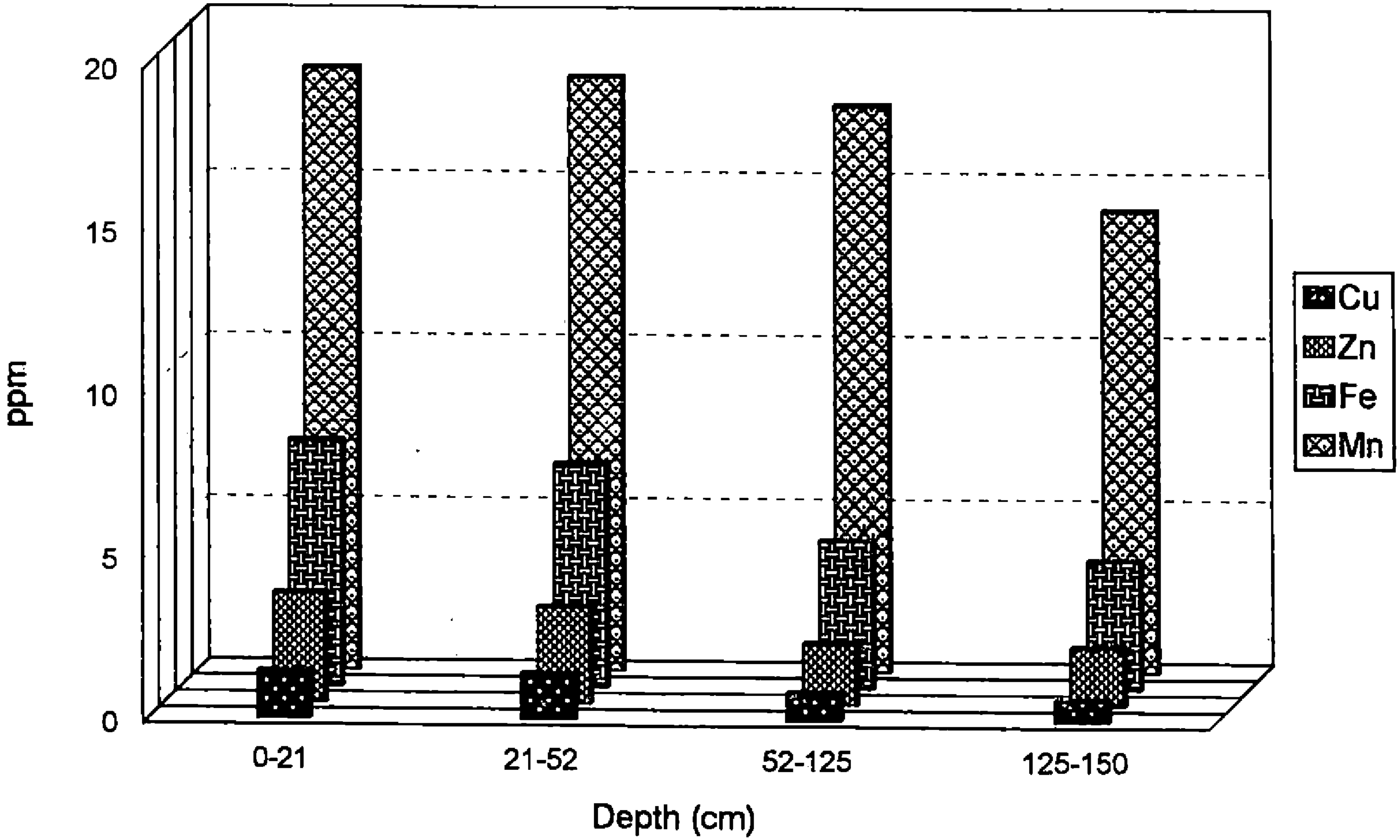


Fig 5.3 Ammonium acetate extractable micronutrient status in Trivandrum Series

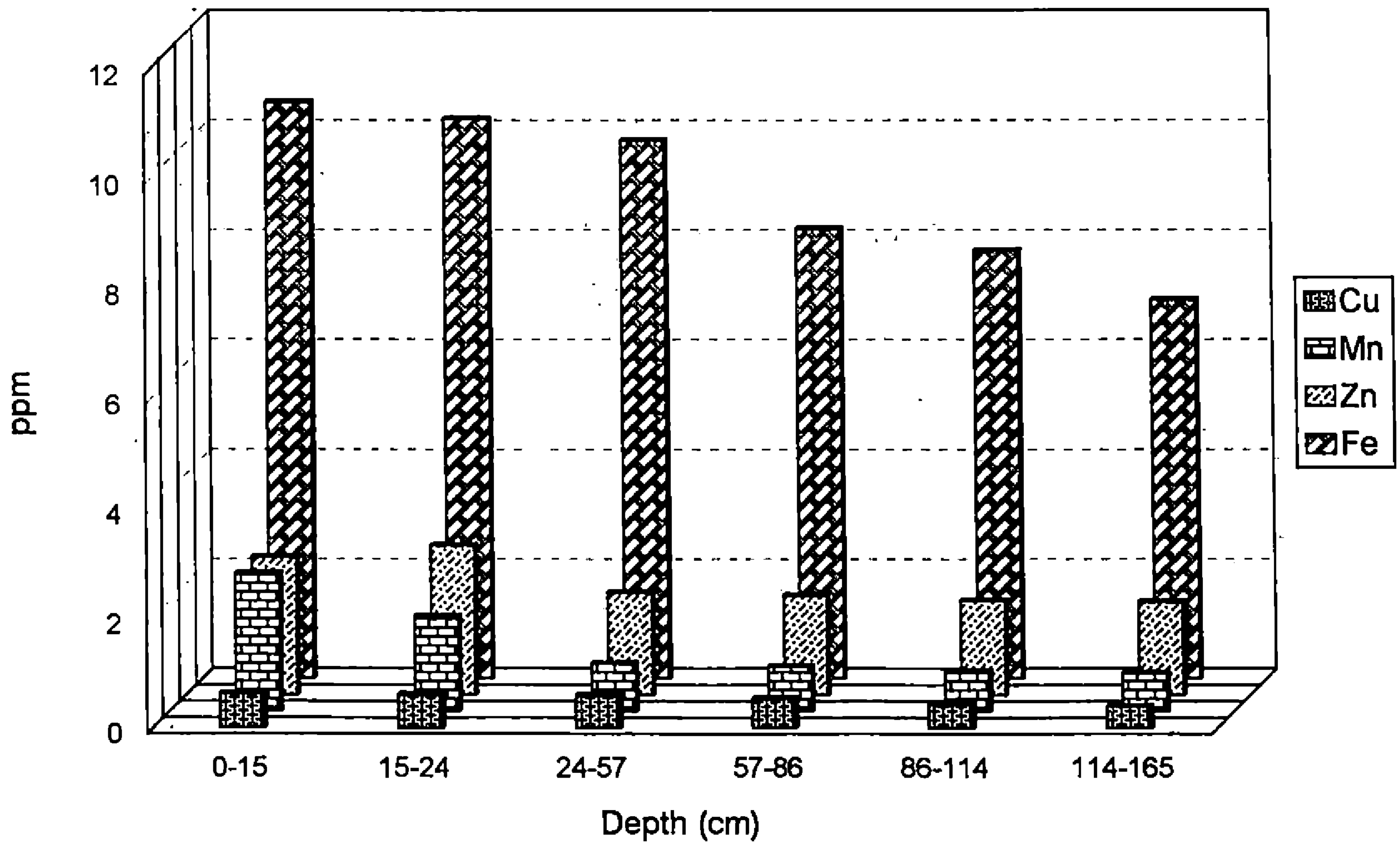


Fig 5.4 Ammonium acetate extractable micronutrient status in Kottarakkara Series

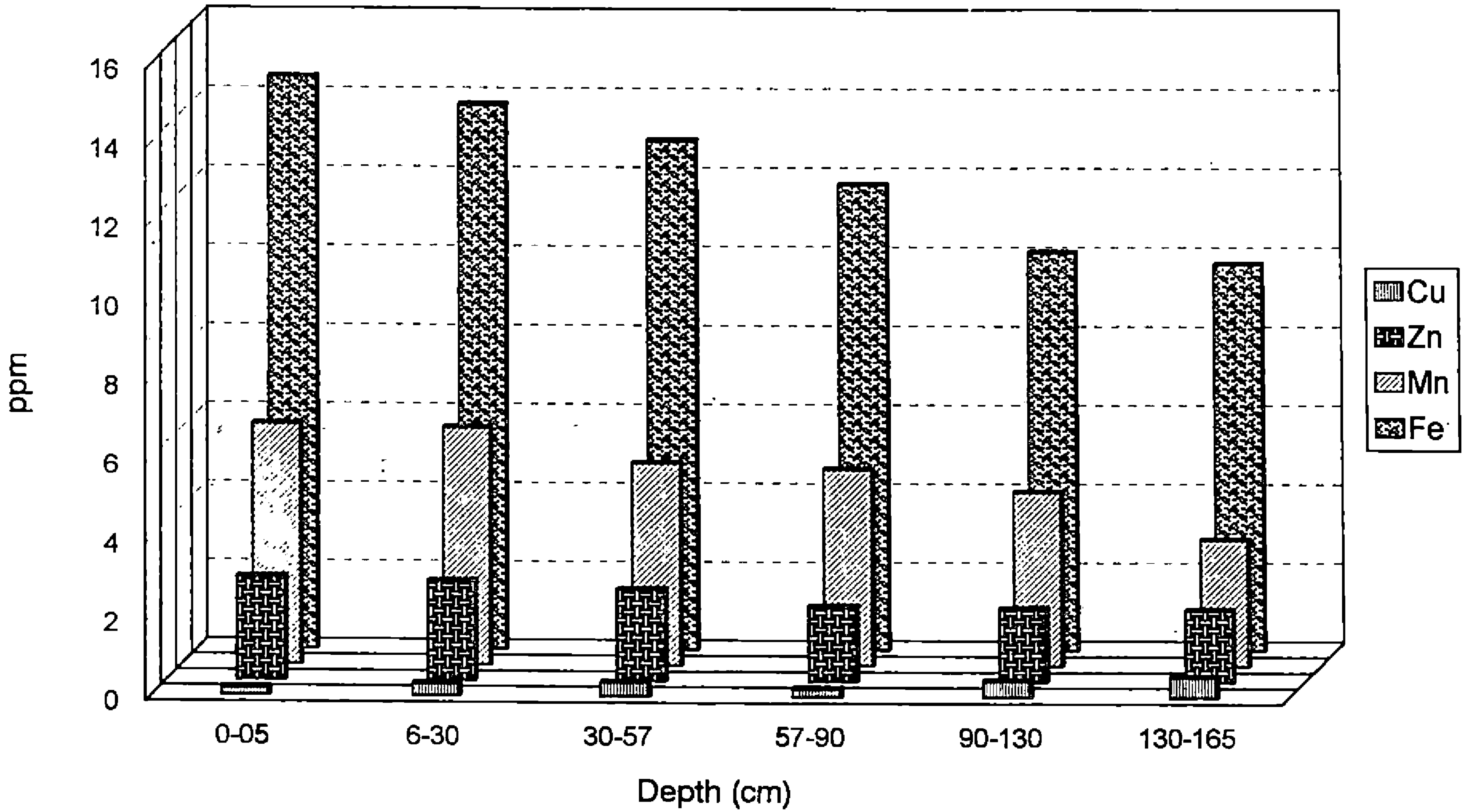


Fig 5.5 Ammonium acetate extractable micronutrient status in Mannar Series

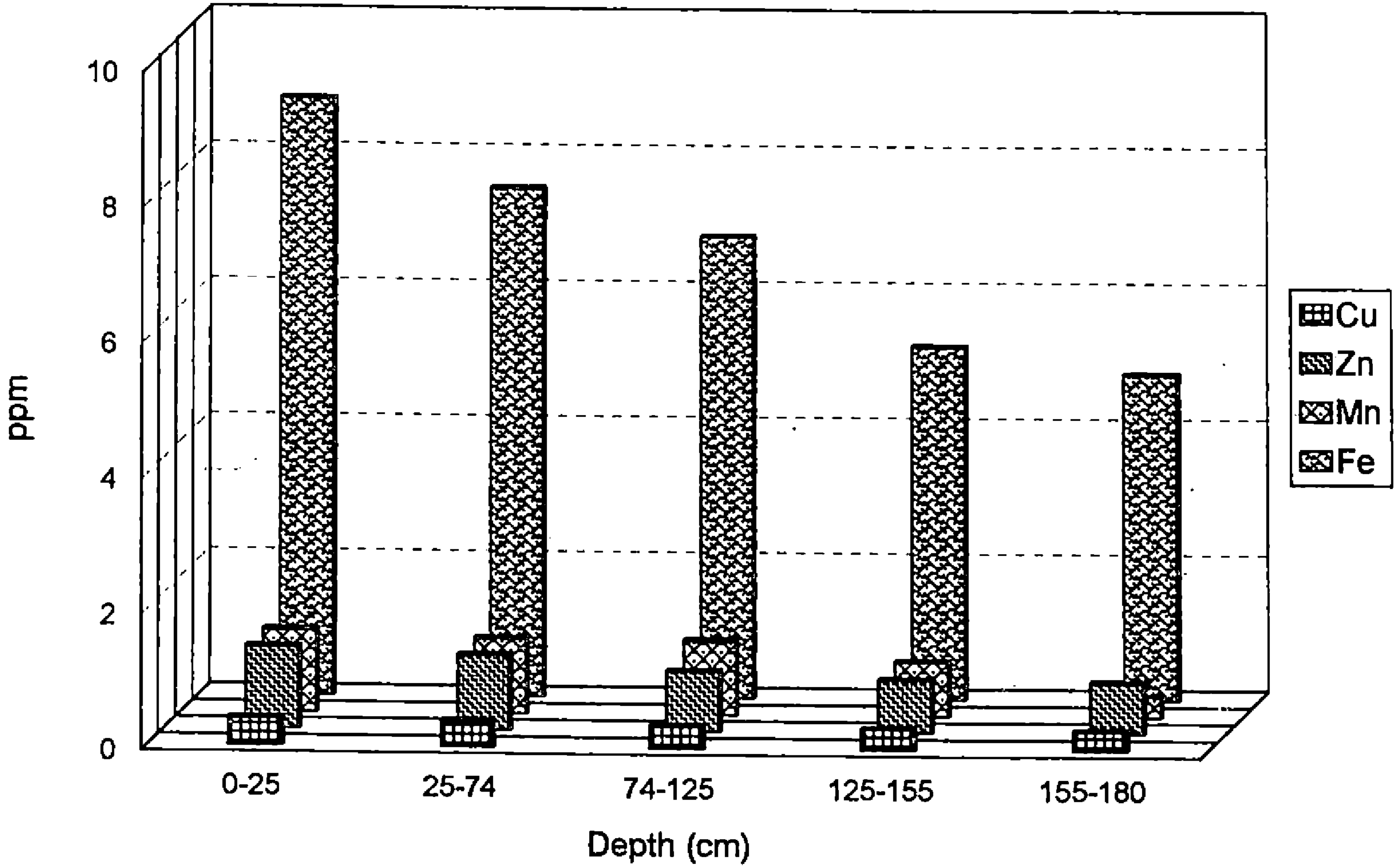


Fig 5.6 Ammonium acetate extractable micronutrient status in Thakazhy Series

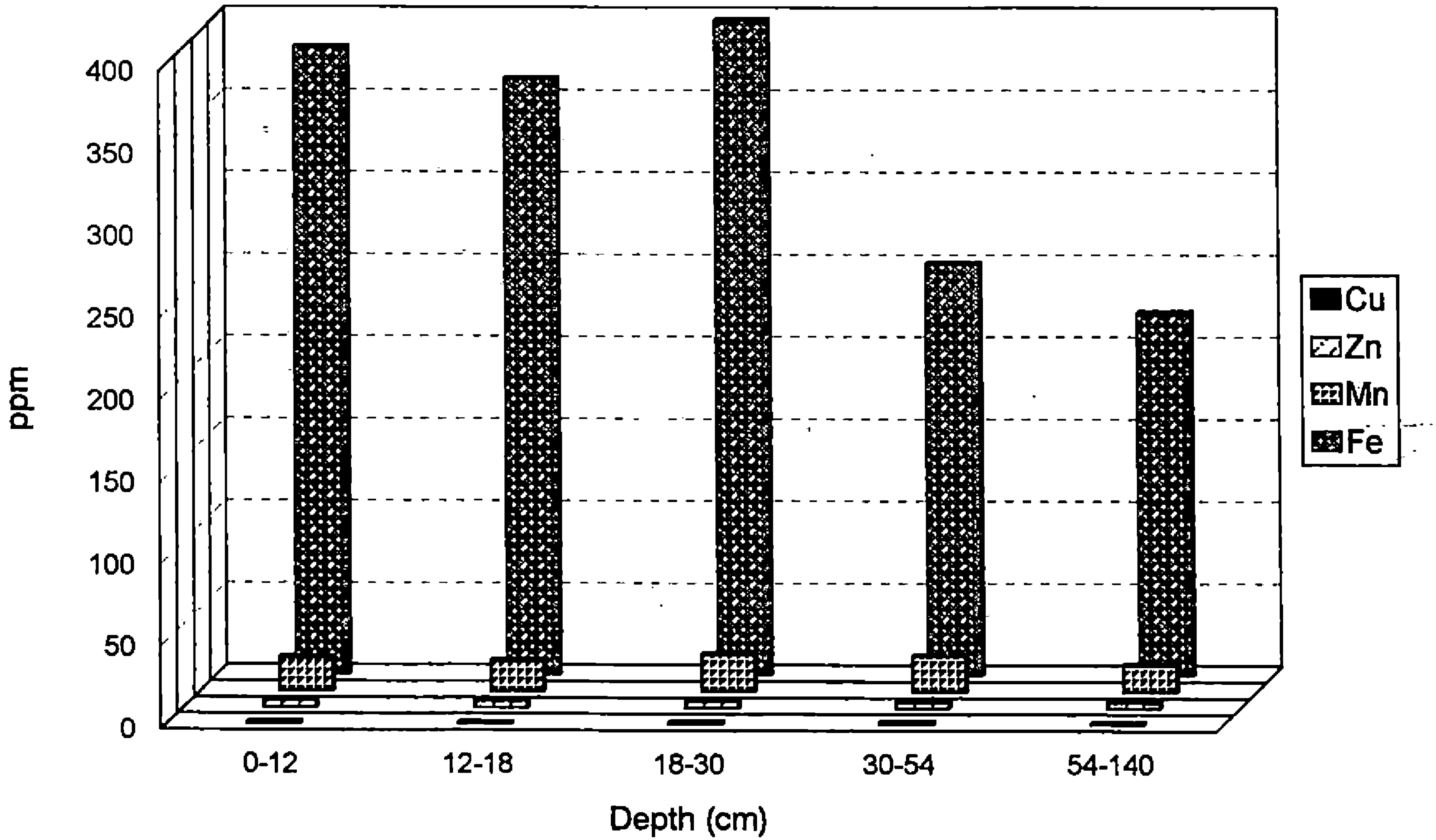
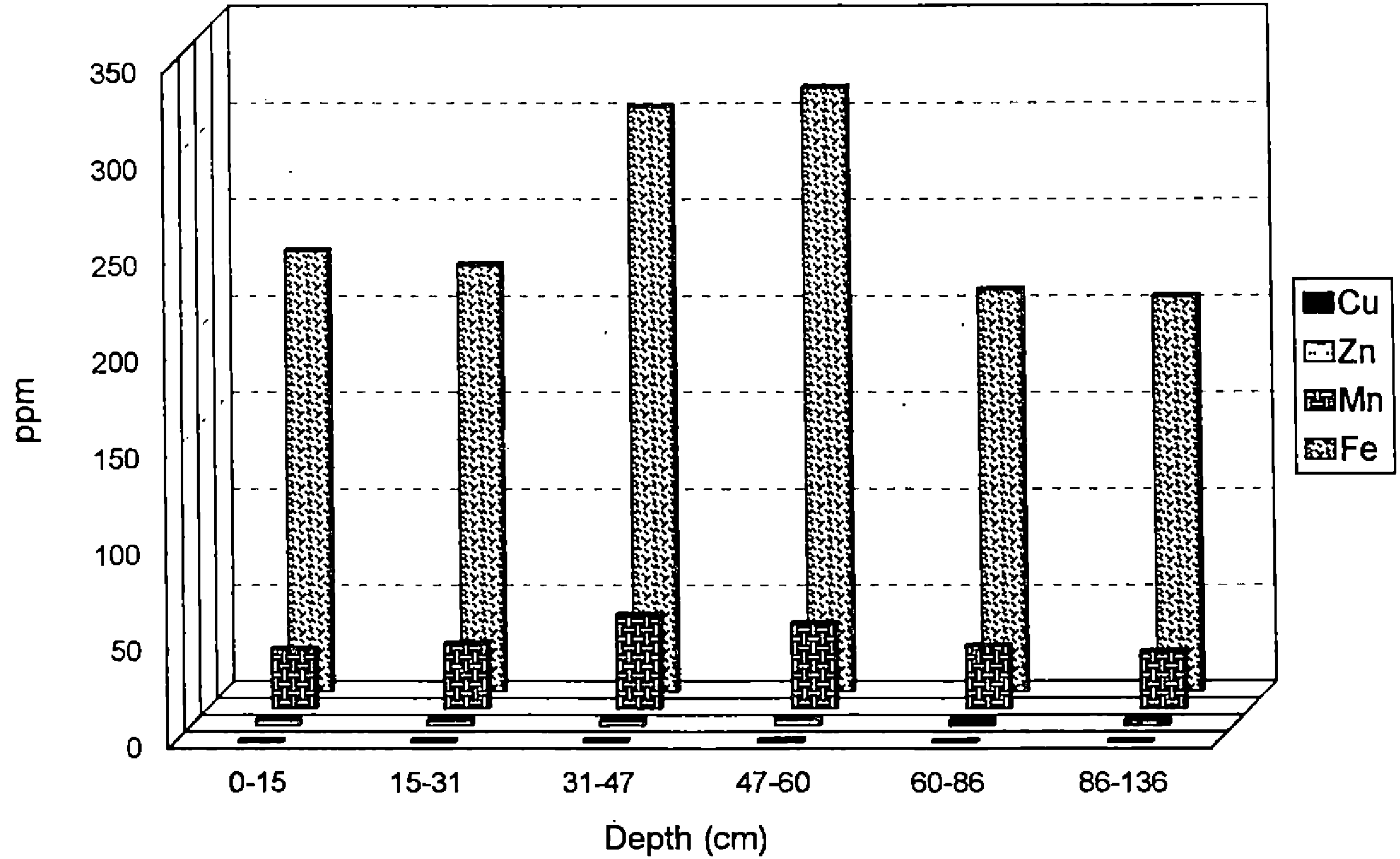


Fig 5.8 Ammonium acetate extractable micronutrient status in D-Block Series



a value of 3.21 ppm in the lowest layer. The surface layer showed a maximum content (2.61 ppm) of ammonium acetate extractable zinc, whereas it was least (1.82 ppm) in the bottom layer analysed. The ammonium acetate extractable copper content was maximum in the bottom layer with 0.52 ppm and least in the surface layer with 0.20 ppm.

In the Mannar series the ammonium acetate extractable iron cotent was observed to be highest in the top most layer (8.8 ppm) and it was least in the lowest layer (4.8 ppm). The surface layer showed the highest content of ammonium acetate extractable manganese (1.21 ppm), whereas it was least with 0.30 ppm in the bottom layer. The ammonium acetate extractable zinc content was maximum in the surface layer with 1.21 ppm , while it was least in the lowest layer with 0.75 ppm. The ammonium acetate extractable copper content was maximum in the surface layer (0.40 ppm) and it was least in the bottom layer (0.28 ppm) (Table No: 5).

In the Thakazhy series the ammonium acetate extractable iron content was highest in the third layer (398.1 ppm) and it was lowest in the bottom layer (220.5 ppm). A maximum ammonium acetate extractable manganese content of 22.73 ppm was observed in the third layer and it was least in the lowest layer with 15.92 ppm. The ammonium acetate extractable zinc content was highest in the surface layer and lowest in the bottom layer with values of 4.12 ppm and 3.26 ppm respectively. The ammonium acetate extractable copper was maximum in the third layer (0.82 ppm) and it was minimum (0.29 ppm) in the lowest layer (Table No: 5).

In the Ramankary series the ammonium acetate extractable iron content was observed to be highest in the surface layer with 485.1 ppm and it was minimum (387.2 ppm) in the second layer. The ammonium acetate extractable manganese content was highest (16.51 ppm) in the lowest layer, while it was least in the second layer with 16.51 ppm. The surface layer showed the highest content of ammonium acetate extractable copper content having 1.82 ppm, while it was least in the bottom layer with 1.31 ppm.

In the D-Block series the ammonium acetate extractable iron content was maximum in the fourth layer with 313.1 ppm and least in the bottom layer with 204.8 ppm. The ammonium acetate extractable manganese content was highest in the third layer with 48.2 ppm and minimum in the bottom layer (29.14 ppm). The fourth layer showed a maximum content of ammonium acetate extractable zinc (2.89 ppm), whereas it was least in the lower most layer with 2.08 ppm. A maximum copper content was noticed in the third layer having 0.87 ppm and lowest in the bottom layer with 0.22 ppm (Table No:5).

In the Palode, Vellayani, Trivandrum, Kottarakkara and Mannar series, in general a decreasing trend in the vertical distribution of micronutrient was observed. In Palode series, the maximum ammonium acetate extractable manganese content was observed in the second depth. The highest amount ot ammonium acetate zinc was obtained in the second layer of the profile in the Trivandrum series. But the trend was a decrease in the zinc content with depth. In the Kottarakkara series the ammonium accetate copper alone was found to follow an erratic trend with the maximum amount appearing in the lowest layer, while the least amount was obtained in the surface layer. In the Thakazhy series, the ammonium acetate Fe, Mn and Cu was found to be present in maximum quantity, in the third layer and there after decreased with depth in an orderly manner. In these sereies the zinc was found to increase with increase in depth.

In the Ramankary series where only three layers could be examined due to the presence of subsurface water, ammonium acetate-Fe was highest in the surface layer follwed by the third layer and then the second layer. Here the ammonium acetate extractable-Mn was found to be increase with depth while Zn and Cu was found to decrease with depth.

In D-Block (kayal) series, the ammonium acetate-Fe and Zn were found in maximum quantity in the fourth layer while Mn and Cu were highest in the third layer of the profile. In the succeeding layers, the micronutrients decreased with depth in an orderly manner.

The maximum quantity of ammonium acetate extractable Fe,Mn and Cu were found in the surface layer of the Ramankary profile (485.1, 12.28 and 1.82 ppm respectively).

The highest amount of ammonium acetate Mn was 48.2 ppm, observed in the third layer of the D-Block (*Kayal*) series. In Ramankary and D-Block series the higher availability may be due to the lower pH observed. Srivastava and Srivastava(1994) found that ammonium acetate extractable Mn content reduced substantially with increase in pH in soils of Uttar Pradesh. Similar observation were done in case of zinc by Mandal *et al* (1992) in West Bengal soils.

As in the case of other extractants this fraction was also found to be distributed erratically in the profiles of Thakazhy, Ramankary and D-Block series.

4.5 EDTA extractable micronutrient status in soils

In the Palode series the EDTA-Fe content was highest in the surface layer (95 ppm) and lowest in the bottom layer (68.9 ppm). A maximum content of EDTA-Mn content was observed in the top most level with 10.1 ppm, while it was least in the lower most layer with 1.60 ppm. The EDTA-Zn content was maximum in the surface layer (2.9 ppm), whereas it was least in the bottom layer (0.30 ppm). The EDTA-Cu was maximum in the surface layer with 1.60 ppm and it was least in the bottom layer having 1.15 ppm (Table No:6).

In the Vellayani series the EDTA-Fe content was present in the maximum quantity of 137.5 ppm in the surface layer, while it was minimum in the bottom layer (129.3 ppm). The EDTA-Mn content was highest in the surface layer with 40.33 ppm and lowest in the bottom layer with 5.90 ppm. The EDTA-

Zn showed a maximum content (16.1 ppm) in the surface layer, whereas it was minimum (14 ppm) in the lowest layer. The EDTA-Cu was also observed to be highest in the surface layer with 4.10 ppm, and least in the bottom layer 3.63 ppm (Table No:6).

In the Trivandrum series the EDTA-Fe content was highest in the third layer (292.5 ppm) and least in the surface layer (85 ppm). The presence of EDTA-Mn content was highest in the surface layer (34.2 ppm) and lowest in the bottom layer (22.1 ppm). A maximum content of EDTA-Zn was observed in the top most layer (1.61 ppm) and it was least in the bottom layer (0.29 ppm). The EDTA-Cu content was also highest in the surface layer with 2 ppm and lowest in the bottom layer with 1 ppm (Table.No:6).

In the Kottarakkara series the EDTA-Fe content was highest in the surface layer with 377.5 ppm and least in the bottom layer 119.3 ppm. The EDTA-Mn content was present in the maximum quantity (12.3ppm) in the surface layer, while it was minimum (5.2 ppm) in the lowest layer analysed. The surface layer showed a maximum content of 9.7 ppm of EDTA-Zn, whereas it was least in the bottom layer the value being 6.2 ppm. The EDTA-Cu content was highest in the surface layer with 8.1 ppm, while it was least in the lowest layer with 1.9 ppm (Table.No:6).

In the Mannar series the EDTA-Fe content was maximum in the third layer with 152.5 ppm and it was least in the lowest layer having 108.2 ppm. The

Table.No:6. EDTA extractable micronutrient status

Sl. No	Name of Series	Depth in cm	ppm			
			Fe	Mn	Zn	Cu
1.	Palode	0-10	95.0	10.1	2.90	1.60
		10-28	93.8	8.8	2.50	1.40
		28-47	87.5	3.5	0.60	1.30
		47-93	70.3	1.8	0.40	1.21
		93-170	68.9	1.6	0.30	1.15
2.	Vellayani	0-21	137.5	40.33	16.1	4.10
		21-52	134.2	38.50	15.8	4.03
		52-125	132.3	19.71	15.3	3.98
		125-150	129.3	5.90	14.0	3.63
3.	Trivandrum	0-15	85.0	34.2	1.61	2.00
		15-24	101.8	33.1	1.13	1.30
		24-57	292.5	31.5	0.60	1.20
		57-86	212.5	28.6	0.40	1 10
		86-114	98.9	25.3	0.30	1.20
		114-165	96.5	22.1	0.29	1.00
4.	Kottarakkra	0-5	377.5	12.3	9.7	8.1
		5-30	312.5	11.9	8.8	7.9
		30-57	298.9	10.8	8.5	6.5
		57-90	275.2	8.9	8.1	5.2
		90-130	162.3	6.8	7.8	3.2
		130-165	119 3	5.2	6.2	1.9

Sl. No.	Name of Series	Depth in cm	EDTA-Fe (ppm)	EDTA-Mn (ppm)	EDTA-Zn (ppm)	EDTA-Cu (ppm)
5.	Mannar	0-25	120.1	19.7	4.7	2.40
		25-74	130.3	18.5	4.8	1.90
		74-125	152.5	17.8	4.9	1.80
		125-155	130.6	16.5	5.7	1.60
		155-180	108.2	10.1	4.2	1.50
6.	Thakazhy	0-12	2125.0	6.9	2.11	6.8
		12-18	1785.0	10.1	2.18	5.3
		18-30	1235.0	19.1	3.10	4.8
		30-54	1125.0	12.1	1.98	2.2
		54-140	1089.0	11.2	1.71	1.9
7.	Ramankary	0-15	2845;0	29.80	33.2	11.12
		15-41	3265.0	88.50	15.1	6.15
		41-130	5072.5	120.91	4.6	3.80
8.	D-Block	0-15	4375	105.2	4.6	3.10
		15-31	3281	112.2	4.9	2.60
		31-47	7081	270.2	5.7	2.13
		47-60	5072	210.5	9.9	2.68
		60-86	3821	105.1	5.8	2.01
		86-136	3752	97.3	4.9	1.98

Fig 6.1 EDTA extractable micronutrient status in Palode Series

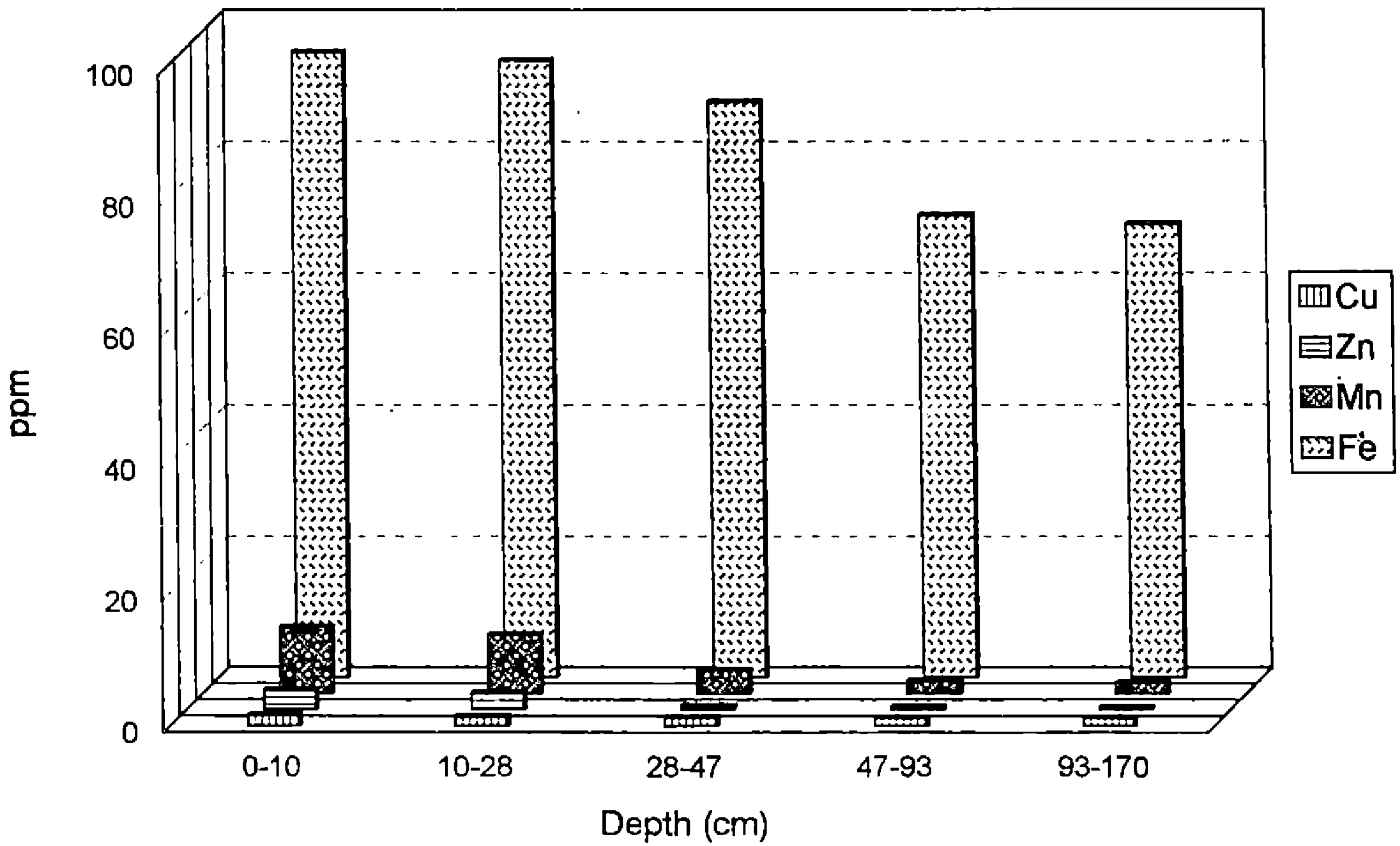


Fig 6.2 EDTA extractable micronutrient status in Vellayani Series

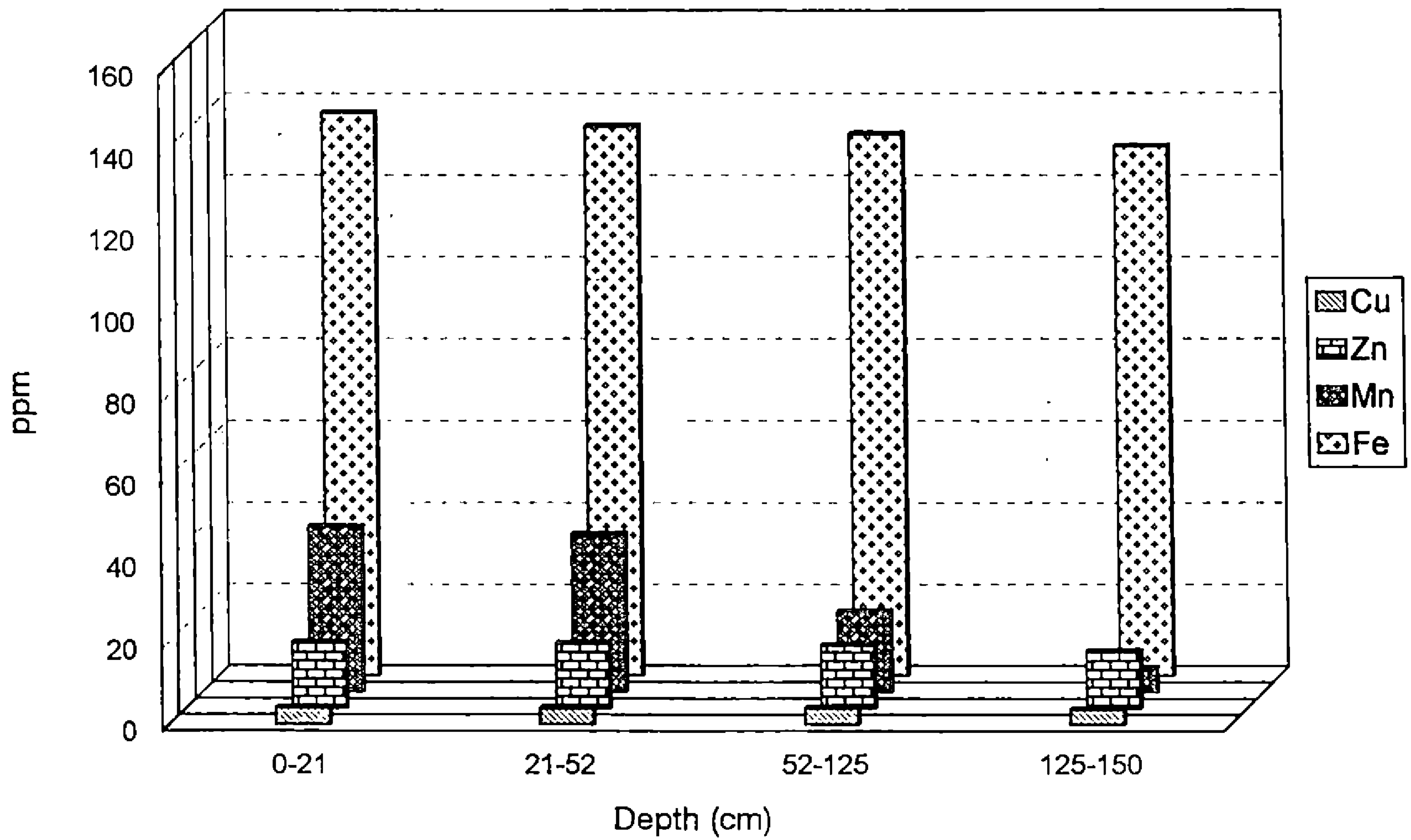


Fig 6.3 EDTA extractable micronutrient status in Trivandrum Series

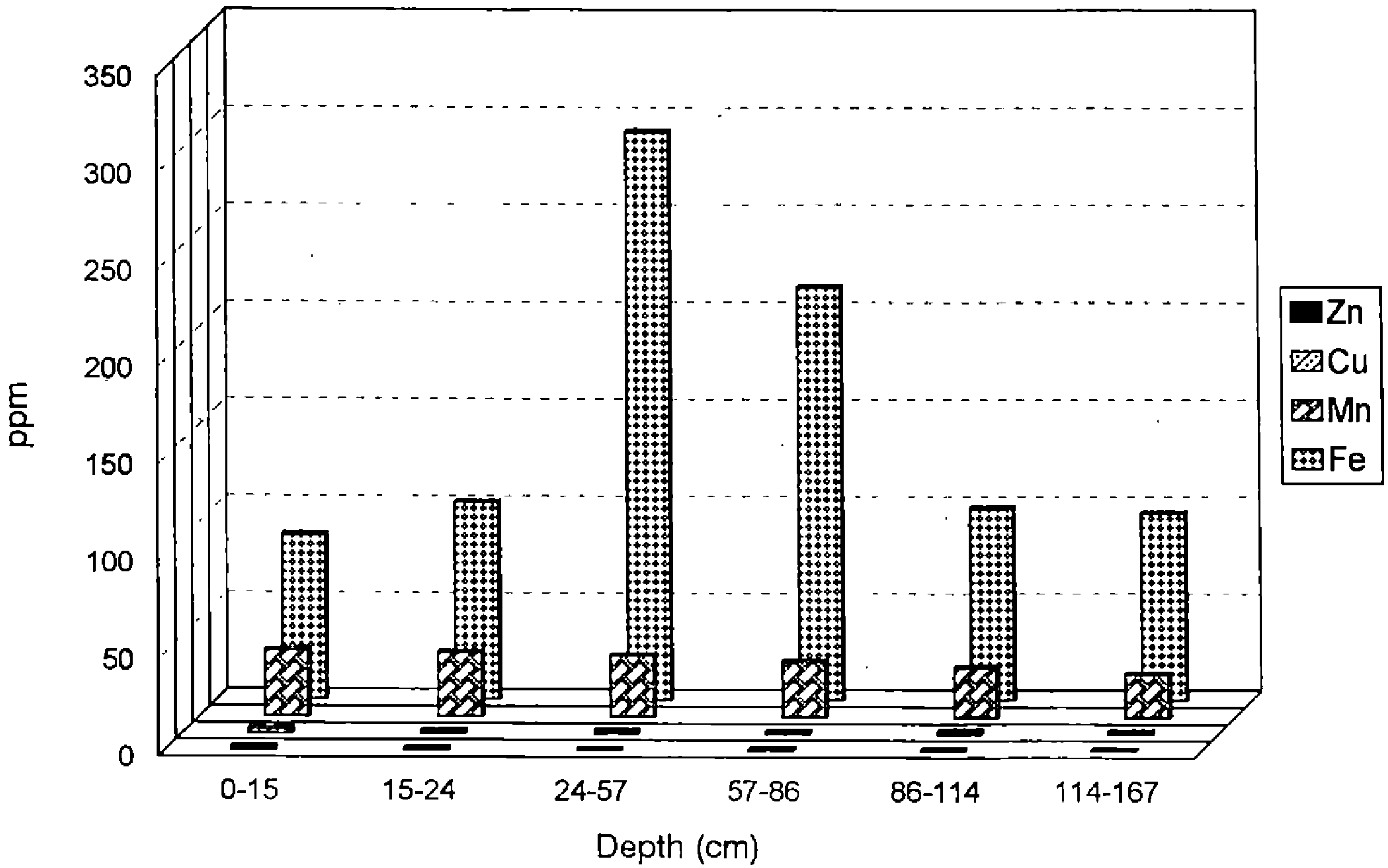


Fig 6.4 EDTA extractable micronutrient status in Kottarakkara Series

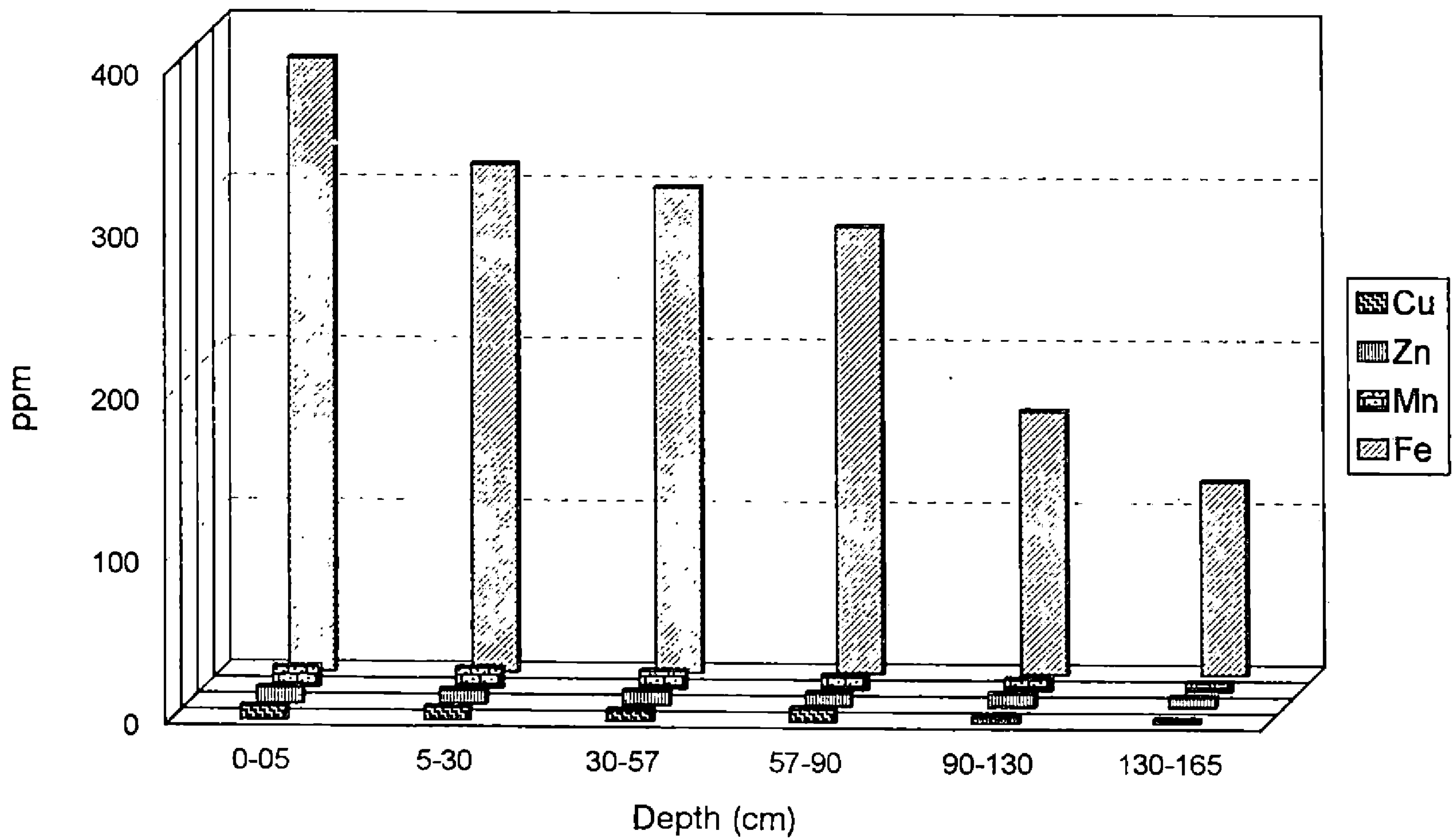


Fig 6.5 EDTA extractable micronutrient status in Mannar Series

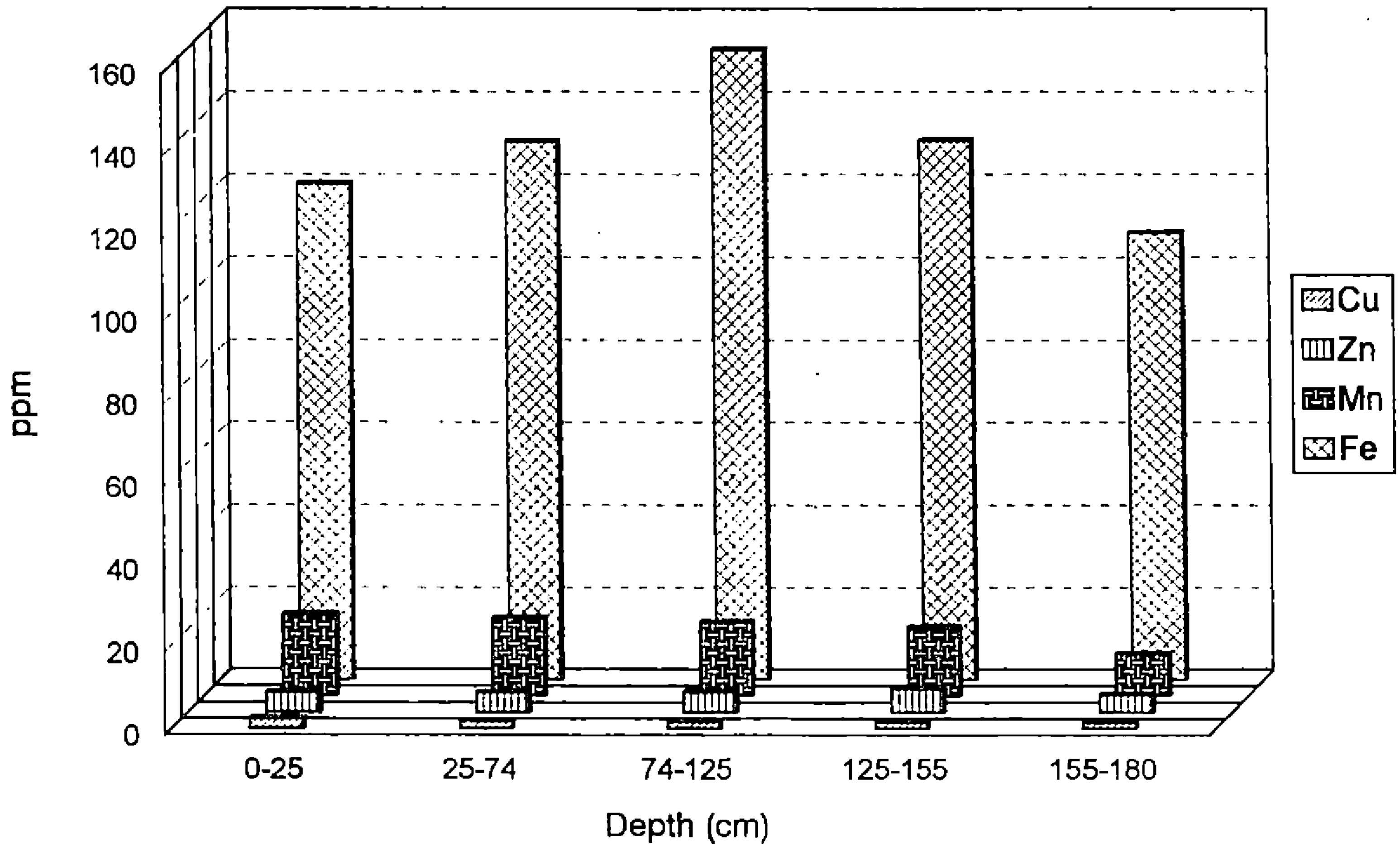


Fig 6.6 EDTA extractable micronutrient status in Thakazhy Series

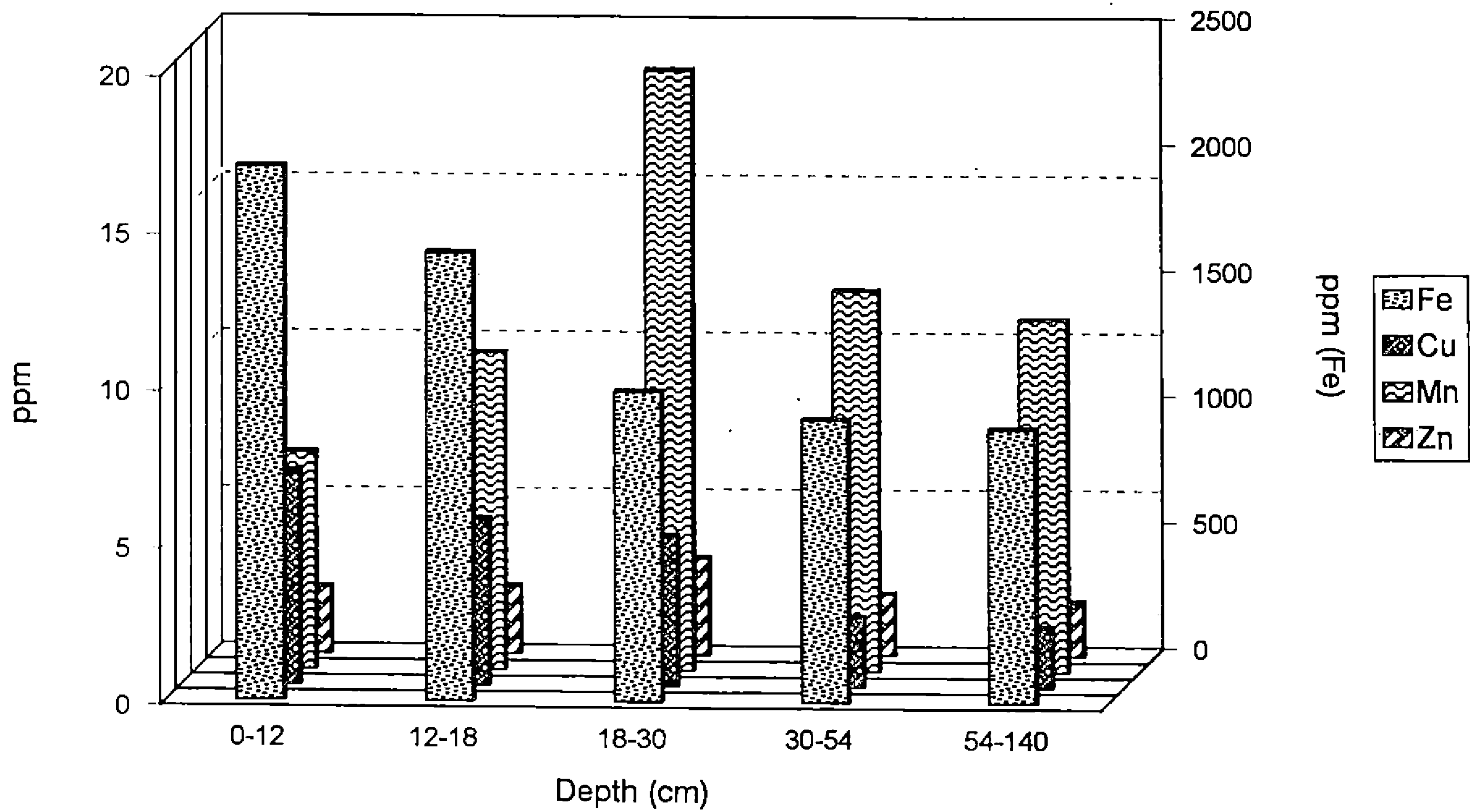


Fig 6.7 EDTA extractable micronutrient status in Ramankary Series

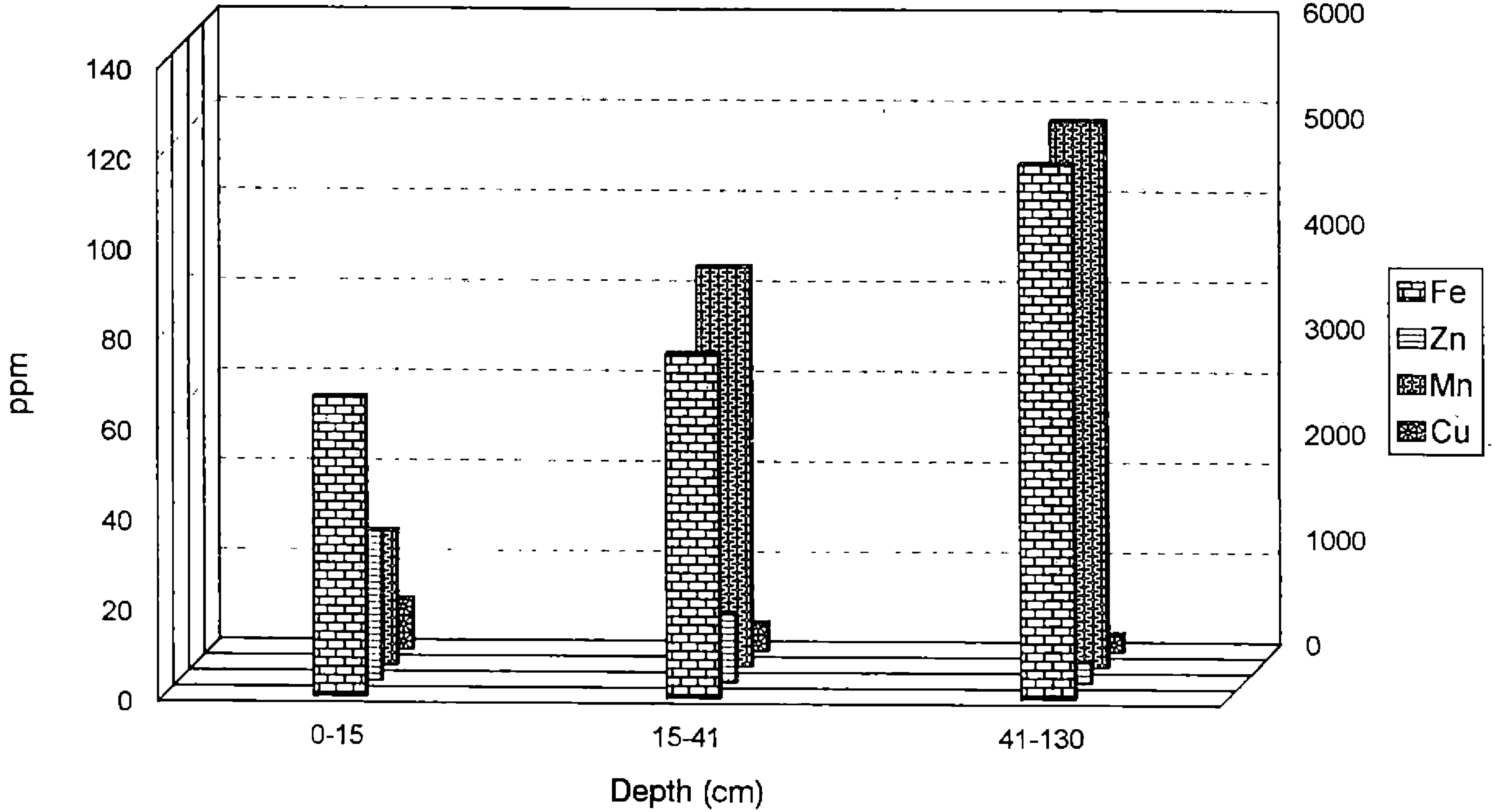
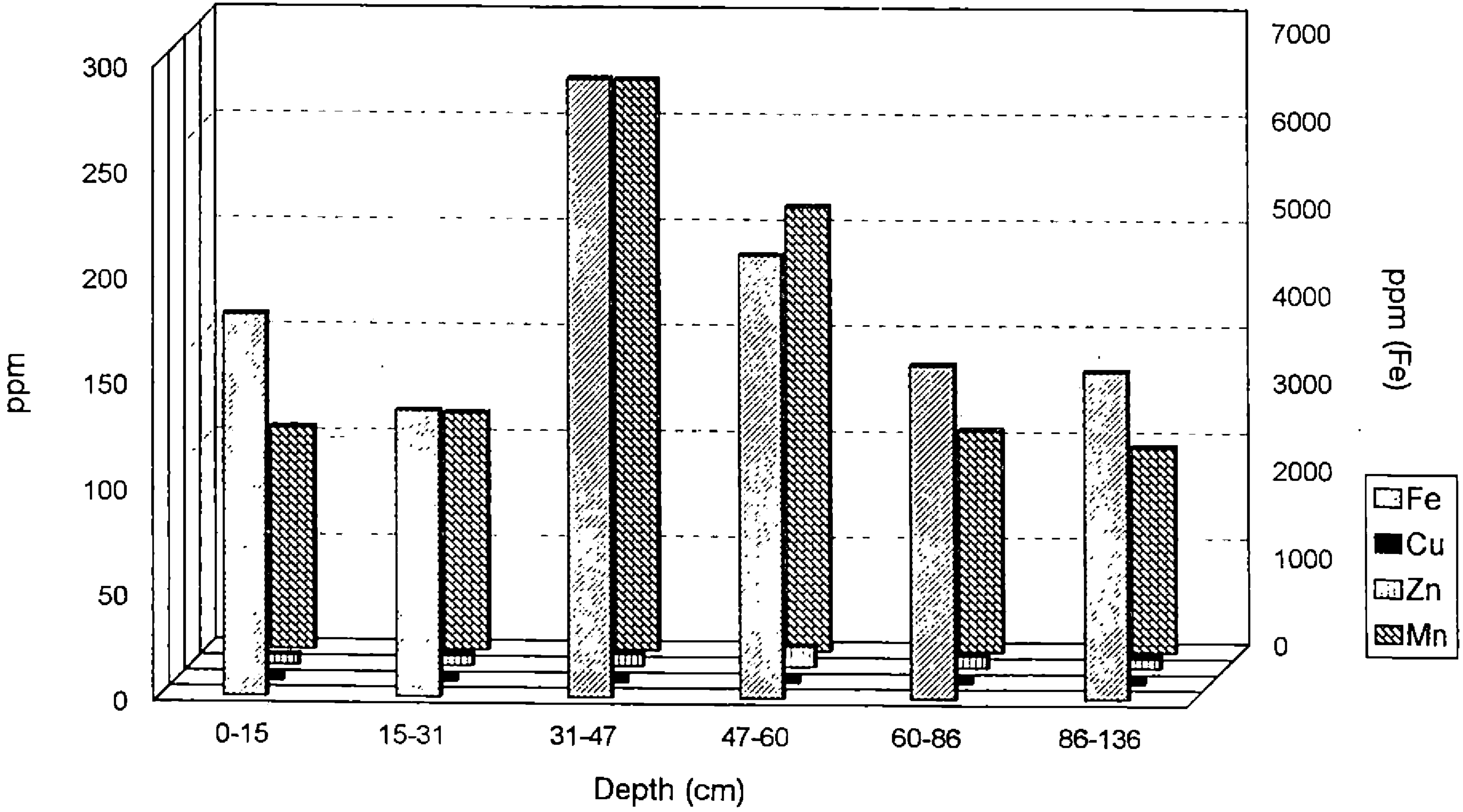


Fig 6.8 EDTA extractable micronutrient status in D-Block Series



surface layer showed the highest content of 19.7 ppm EDTA-Mn content, whereas it was minimum (10.1 ppm) in the lowest layer. The EDTA-Zn content was maximum (5.7 ppm) in the fourth layer, while it was least in the bottom layer (4.2 ppm). The EDTA-Cu content was highest in the surface layer with 2.40 ppm, and lowest in the bottom layer having 1.50 ppm (Table.No:6).

In the Thakazhy series the EDTA-Fe content was highest in the surface layer (2125 ppm) and least in the lowest layer (1089 ppm). A maximum EDTA-Mn was observed in the third layer (19.1 ppm) and lowest in the surface layer (6.9 ppm). The third layer showed a highest content of 3.1 ppm EDTA-Zn, whereas it was least in the bottom layer having 1.71 ppm. The EDTA-Cu content was maximum in the surface layer (6.8 ppm) and it was minimum in the lowest layer with 1.9 ppm (Table.No:6).

In the Ramankary series the EDTA-Fe content was observed to be highest in the bottom layer (5072.5 ppm) and it was minimum (2845 ppm) in the surface layer. A maximum EDTA-Mn content was noticed in the lowest layer with 120.91 ppm, and it was least in the surface layer having 29.8 ppm. The surface layer showed a maximum content of EDTA-Zn (33.2 ppm), whereas it was least in the bottom layer with 4.6 ppm. The EDTA-Cu content was also highest in the surface layer (11.12 ppm), while it was minimum with 3.80 ppm in the lowest layer (Table.No:6).

In the D-Block series the highest EDTA-Fe content was observed in the third layer (7081 ppm) and it was least in the second layer (3281 ppm). The EDTA-

Mn content showed a maximum value in the third layer with 270.2 ppm, while it was least in the bottom layer with 97.3 ppm. The fourth layer showed the highest EDTA-Zn content (9.9 ppm), whereas it was least in the surface layer (4.6 ppm). A maximum EDTA-Cu content was noticed in the surface layer (3.10 ppm) and lowest in the bottom layer (1.98 ppm).

The EDTA extractable micronutrients showed a decreasing trend with depth in the case of Palode, Vellayani, Trivandrum, Kottarakkara and Mannar series with exception in EDTA-Fe content alone in Trivandrum and Mannar series and EDTA-Zn in the Mannar Series. The highest EDTA-Fe was observed in the third depth. The maximum EDTA-Zn content was obtained in the fourth layer of Mannar series.

In the Ramankary series the highest EDTA-Fe was noticed in the bottom layer (3 rd layer) while it was highest in the third depth in D-Block (Kayal) series. The least EDTA-Fe was found in the surface layer of Ramankary series and bottom layer in D-Block (Kayal) series. In the Thakazhy series the highest EDTA-Fe content was obtained in the surface layer and the least content in the bottom layer.

The EDTA extractable manganese content in the Thakazhy, Ramankary and D-Block series was highest in the third layer. The maximum content of EDTA-Zn was found in third layer of Thakazhy series in the fourth layer of D-Block series, and in the surface layer of Ramankary series. The maximum content of EDTA-Cu was found in the surface layer and the least content in the bottom layer in all the profiles, but its distribution did not follow any trend in the middle layers in the D-Block series only.

As in the case of other extractants, the EDTA extractable micronutrients in Palode, Vellayani, Trivandrum, Kottarakkara and Mannar series were maximum in the surface layers, where the organic carbon content was also maximum. The erratic distribution of the micronutrients in the profiles of Thakazhy, Ramankary and D-Block series may be due to the geographical position, fluctuating water table, and consequent oxidation-reduction conditions existing there. Prasad and Sakal (1991) while studying the availability of iron in calcareous soils of Bihar found a greater influence of organic carbon on the EDTA-Fe content. Similar observations was done in the case of EDTA-Zn in West Bengal soils by Mandal *et al* (1992).

The maximum value for Fe and Mn (7081 ppm, 270.2 ppm) were observed in the third layer of D-Block series and EDTA-Zn & EDTA-Cu were highest in the surface layer of Ramankary series (33.2 ppm & 11.12 ppm respectively). The highly aciditic conditions (pH 4.5) existing in the profiles might be the reason for the higher availability of micronutrients in these profiles.

4.6 Total micronutrient status in soils.

In the Palode series total iron content was highest in the surface layer with 29625 ppm, and least in the bottom layer with 21915 ppm. A maximum total manganese content was observed in the surface layer (80 ppm) and it was least in the bottom layer (42.30 ppm). The total zinc content was maximum in the surface layer with 16 ppm, whereas it was least in the lowest layer with 8.90 ppm. The total copper content showed a maximum value in the surface layer (95.50 ppm), whereas it was minimum in the lowest layer with 26.50 ppm. (Table No.7).

In the Vellayani series the total iron content was present in the maximum quantity (15150 ppm) in the surface layer, while it was minimum in the bottom layer having 4569 ppm. The total manganese content was highest in the surface layer with 71.5 ppm, and lowest in the bottom layer having 63.8 ppm. The total zinc content showed a maximum value in the surface layer (84.10 ppm), and it was present in the least quantity in the bottom layer (52.3 ppm). The highest total copper content was also observed in the surface layer with 20.50 ppm and least in the lowest layer having 10.90 ppm (Table.No:7).

In the Trivandrum series the total iron content was highest in the surface layer 15625 ppm and least in the bottom layer having 2750 ppm. The presence of total manganese content was highest in the surface layer (91.5 ppm) and lowest in the bottom layer (29.3 ppm). A maximum content of total zinc was noticed in the surface layer with 17.5 ppm, and it was minimum in the bottom layer having 6.3 ppm. The total copper content was observed to be highest in the surface layer (20.5 ppm) and lowest in the bottom layer (10.2 ppm) analysed (Table.No:7).

Table No. 7 **Total micronutrient status**

Sl. No.	Name of Series	Depth in cm	ppm Fe	Mn	Zn	Cu
1.	Palode	0-10	29625	80.00	16.0	95.50
		10-28	25600	60.50	15.5	65.80
		28-47	25200	48.00	13.4	40.10
		47-93	22800	45.60	10.5	29.80
		93-170	21915	42.30	8.9	26.50
2.	Vellayani	0-21	15150	71.5	84.1	20.50
		21-52	13550	68.0	80.5	18.90
		52-125	7585	65.5	77.9	15.40
		125-150	4569	63.8	52.3	10.90
3.	Trivandrum	0-15	15625	91.5	17.5	20.5
		15-24	14325	86.3	15.4	18.8
		24-57	4802	78.4	12.3	18.5
		57-86	3562	60.3	10.1	16.5
		86-114	3050	50.1	8.2	15.8
		114-165	2750	29.3	6.3	10.2
4.	Kottarakkara	0-5	16875	109.5	10.5	21.5
		5-30	16800	89.1	8.5	18.9
		30-57	15600	78.9	7.8	15.3
		57-90	13200	69.8	6.9	13.2
		90-130	12700	53.1	5.8	12.8
		130-165	11600	45.9	4.9	10.9

Table No. 7 Contd.....

Sl. No.	Name of Series	Depth in cm	ppm			
			Fe	Mn	Zn	Cu
5.	Mannar	0-25	3750	25	8.5	11.5
		25-74	3890	16.3	7.8	10.8
		74-125	2850	10.8	6.9	10.5
		125-155	2453	8.5	6.3	8.5
		155-180	2451	6.3	5.8	5.8
6.	Thakazhy	0-12	19900	170.5	37.0	29.5
		12-18	25800	173.5	35.0	27.3
		18-30	35600	182.9	38.2	15.6
		30-54	20300	179.5	40.1	13.2
		54-140	15300	151.5	29.3	12.1
7.	Ramankary	0-15	20175	219.0	20.1	30.9
		15-41	30500	225.0	17.8	26.50
		41-130	37400	562.5	15.5	22.3
8.	D-Block	0-15	33800	232.6	44.0	41.2
		15-31	36600	198.1	42.0	40.8
		31-47	39800	894.8	38.9	39.2
		47-60	30600	802.0	42.3	29.5
		60-86	22300	192.5	32.1	20.8
		86-136	15600	181.5	29.8	15.9

In the Kottarakkara series the total iron content was highest in the surface layer with 16875 ppm, and least in the bottom layer with 11600 ppm. The total manganese content was present in the maximum quantity (109.5 ppm) in the surface layer, while it was minimum in the lowest layer (45.9 ppm). The surface layer showed a maximum content of 10.5 ppm total zinc and it was least in the bottom layer having 4.9 ppm. The total copper content was found to be highest in the surface layer (21.5 ppm), whereas it was least in the lowest layer having 10.9 ppm (Table No:7).

In the Mannar series the total iron content was observed to be maximum in the second layer (3890 ppm) and it was least in the lowest layer with 2451 ppm. The surface layer showed the highest content of total manganese (25 ppm), whereas it was least in the lowest layer (6.3 ppm) analysed. The total zinc content was maximum in the surface layer with 8.5 ppm, and it was least in the lowest layer with 5.8 ppm. The total copper content was highest in the surface layer (11.5 ppm) and lowest in the bottom layer (5.8 ppm) analysed. (Table.No:7).

In the Thakazhy series the total iron content was highest in the third layer with 35600 ppm, while it was least in the lowest layer with 15300 ppm. A maximum total manganese was observed in the third layer (182.9 ppm) and least in the bottom layer with 151.5 ppm. The fourth layer showed the highest content of total zinc (40.1 ppm), whereas it was least in the bottom layer (29.3 ppm). The total copper content was maximum in the surface layer with 29.5 ppm, and it was minimum in the lowest layer having 12.1 ppm (Table.No:7).

In the Ramankary series the total iron content was highest in the lowest layer with 37400 ppm, and least in the surface layer with 20175 ppm. A maximum total manganese content was noticed in the lowest level (562.5 ppm) and a minimum content in the surface layer (219 ppm). The surface layer showed a maximum total zinc content (20.1 ppm), whereas it was least in the lowest layer (15.50 ppm). The total copper content was also highest in the surface layer with 30.9 ppm, while it was minimum in the bottom layer with 22.3 ppm. (Table No:7).

In the D-Block series the maximum total iron content was noticed in the third layer with 39800 ppm and it was least in the lowest layer with 15600 ppm. The total manganese content was highest in the third layer with 894.8 ppm and minimum in the lowest layer having 181.5 ppm. The surface soil showed the maximum total zinc content (44 ppm), and it was least in the bottom layer (29.8 ppm). The total copper content was also highest in the surface layer (41.2 ppm) and minimum in the bottom layer having 15.9 ppm (Table.No.7).

In the Palode, Vellayani, Trivandrum, Kottarakkara series with one exception of total iron in Manner series, the total micronutrient content decreased with depth. In the case of total iron content in the Mannar series it was highest in the second layer and then decreased with depth. The highest amount of total iron (39,800 ppm) was obtained in the D-Block (*Kayal*) series while the least content was met within the lowest layer of Mannar series (245 ppm). Pisharody (1965) while investigating the iron status of Kerala soil found that it ranged between 16,000 to 1,32,000 ppm. Generally the water logged soil series of Thakazhy, Ramamkary and D-Block series contained very high amount of total iron.

In the forest profile of Palode series also the total iron content was comparatively high (29625 ppm). In the Palode, Trivandrum and Kottarakkara series, the highest total iron content was encountered in the surface layer of the profiles. In the Mannar series, the total iron content registered the highest value in the second layer. The maximum total iron content was encountered in the third layers of Thakazhy, Ramankary and D-Block (*Kayal*) series. The DTPA and ammonium accetate extractable iron content in the Thakazhy profile, DTPA and EDTA extractable iron in Ramankary and D-Block (*Kayal*) profiles were also found to be highest in the third layer.

The total manganese, zinc and copper content in the Palode, Vellayani, Trivandrum, Kottarakkara and Mannar series were found in maximum quantity in the surface which decreased regularly with depth. The highest manganese content of 894.8 ppm was encountered in the third layer of D-Block (*Kayal*) profile while the least content was observed in the bottom layer of Mannar series (6.3 ppm). The total Zn content was found to be highest in the surface layer of D-Block series (44 ppm) and the lowest value was observed in the bottom layer of Mannar series

(5.8 ppm). In the case of copper the maximum amount of total Cu (41.2 ppm) was observed in the surface layer of D-Block series and the minimum (5.8 ppm) was obtained inthe lowest layer of Mannar profile. As in the case of total Fe, total Mn also was present in highest quantity in the third layer of Thakazhy, Ramankary and D-Block series. Here also the available DTPA, EDTA and Ammonium accetate extractable manganese were highest in the third layer of these three series. Rajendran (1981) on studying the manganese status of the rice soils of Kerala noticed a higher total manganese content in *Kari*, *Kayal* and *Karappadam* soil series.

In the case of Thakazhy series the maximum amount of total Zn was observed in the fourth depth of the profile, while it was highest in the surface layer of Ramankary and D-Block series. The DTPA extractable zinc was also highest in the fourth layer of the Thakazhy series as was in the in case of total iron. Total zinc and copper were found in the maximum quantity in the surface layer of Ramankary and D-Block series. In the Ramankary profile (karappadam), alone the DTPA, EDTA and ammonium acetate extractable Cu were found to exist in the highest quantity in the surface layer as in the case of total copper. No such similarity was noticed between total copper and DTPA, EDTA and Ammonium acetate extractable copper in the D-Block (*Kayal*) series.

4.8 DTPA, EDTA and ammonium acetate extractable micronutrients in surface soil samples

4.8.1 DTPA extractable iron in surface samples.

The DTPA extractable iron in the surface samples of Palode series ranged between 38.89 to 39.56 ppm, with a mean value of 39.18 ppm. The range of this fraction of Fe in the Vellayani series was between 9.03 and 9.89 ppm, the value for the mean being 9.41 ppm. The DTPA iron in the Trivandrum series ranged between 15.83 to 16.13 ppm with a mean value of 16.00 ppm. This fraction of iron in the Kottarakkara series varied from 19.5 ppm to 21.5 ppm, the mean being 20.70 ppm. In the Mannar series the DTPA iron ranged between 12.82 ppm and 13.30 ppm with a mean of 13.02 ppm. The range was between 283.22 and 296.31 ppm (mean 291.02 ppm) in the Thakazhy series. In the Ramankary series DTPA-Fe varied from 253.20 to 270.2 ppm. The mean value in this case was recorded as 265.36 ppm. In the D-Block surface soils DTPA-Fe was found in concentrations of 139.2 to 147.7 ppm, with a mean value of 144.98 ppm. (Table No: 8)

On the whole wide variations in DTPA-Fe was not evident among soils of the same series, but between the different soil series investigated significant variation was noticed in the DTPA-Fe content.

4.8.2 EDTA extractable iron in surface samples.

The EDTA extractable iron in the surface samples of Palode series ranged between 94.20 to 96.50 ppm, with a mean value of 94.38 ppm. The range of this fraction of Fe in the Vellayani series was between 135.80 and 139.80ppm, the value for the mean being 137.53 ppm. The EDTA iron in the Trivandrum series ranged between 84.30 to 86.30 ppm with a mean value of 85.23 ppm. This fraction of iron in the Kottarakkara series varied from 367.30 ppm to 379.40 ppm, the mean being 374.20 ppm. In the Mannar series the EDTA iron ranged between 119.50 ppm to 121.90 ppm with a mean of 120.69 ppm. The range of the concentration of this fraction was between 2076.20 to 2138.20 ppm (mean 2123.21 ppm) in the Thakazhy series. In the Ramankary series EDTA-Fe varied from 2830.20 to 2859.40ppm. The mean value in this case was recorded as 2849.30 ppm. In the D-Block surface soils EDTA-Fe was found in concentrations of 4372.20 to 4381.30 ppm, with a mean value of 4376.75 ppm.(Table No: 8)

On the whole wide variations in EDTA-Fe was not evident among soils of the same series, but between the different soil series investigated significant variation was noticed in the EDTA-Fe content.

4.8.3 Ammonium acetate extractable iron in surface samples.

The ammonium acetate extractable iron in the surface samples of Palode series ranged between 10.28 to 11.50 ppm, with a mean value of 11.09 ppm. The range of this fraction of Fe in the Vellayani series was between 7.23 and 7.62 ppm, the value for the mean being 7.36 ppm. The ammonium acetate iron in the Trivandrum series ranged between 9.89 to 10.71 ppm with a mean value of 10.42

ppm. This fraction of iron in the Kottarakkara series varied from 13.35 ppm to 14.81 ppm, the mean being 14.39 ppm. In the Mannar series the ammonium acetate iron ranged between 7.89 ppm to 8.81 ppm with a mean of 8.30 ppm. The range was between 275.30 to 382.90 ppm (mean 353.31 ppm) in the Thakazhy series. In the Ramankary series ammonium acetate Fe varied from 469.80 to 489.30 ppm. The mean value in this case was recorded as 475.20 ppm. In the D-Block surface soils ammonium acetate Fe was found in concentrations of 226.30 to 229.80 ppm, with a mean value of 228.09 ppm.(Table No: 8)

In the profiles studied wide variation in the ammonium acetate extractable Fe was not evident among soils of the same series except in Thakazhy series which showed some variation. (275.3 ppm to 382.90 ppm). But between the soil series investigated significant and wide variation was noticed in the ammonium acetate extractable iron content.

4.9.2 DTPA extractable manganese in surface samples.

The DTPA extractable manganese in the surface samples of Palode series ranged between 4.06 to 4.56 ppm, with a mean value of 4.33 ppm. The range of this fraction of Mn in the Vellayani series was between 18.53 and 22.76 ppm, the value for the mean being 19.55 ppm. The DTPA manganese in the Trivandrum series ranged between 18.53 to 19.74 ppm with a mean value of 19.21 ppm. This fraction of manganese in the Kottarakkara series varied from 6.98 ppm to 7.28 ppm, the mean being 7.13 ppm. In the Mannar series the DTPA manganese ranged between 3.09 ppm to 3.28 ppm with a mean of 3.15 ppm. The range was between 30.08 and 31.33 ppm (mean 30.97 ppm) in the Thakazhy series. In the Ramankary series DTPA-Mn varied from 46.77 to 50.31 ppm. The mean value in this case was recorded as 48.02 ppm. In the D-Block surface soils DTPA-Mn was found in concentrations of 45.68 to 50.31 ppm, with a mean value of 47.62 ppm.(Table No: 9).

On the whole wide variations in DTPA-Mn was not evident among soils of the same series, but between the different soil series investigated significant variation was noticed in the DTPA-Mn content.

4.9.2 EDTA extractable manganese in surface samples.

The EDTA extractable manganese in the surface samples of Palode series ranged between 8.90 and 10.70 ppm, with a mean value of 10.14 ppm. The range of this fraction of Mn in the Vellayani series was between 39.05 and 41.08 ppm, the value for the mean being 40.11 ppm. The EDTA manganese in the Trivandrum series ranged between 32.09 to 34.63 ppm with a mean value of 33.89 ppm. This fraction of manganese in the Kottarakkara series varied from 11.20 ppm to 12.80 ppm, the mean being 12.21 ppm. In the Mannar series the EDTA manganese ranged between 19.09 ppm and 19.73 ppm with a mean of 19.55 ppm. The range was between 5.98 to 6.93 ppm (mean 6.58 ppm) in the Thakazhy series. In the Ramankary series EDTA-Mn varied from 28.30 to 29.90 ppm. The mean value in this case was recorded as 28.89 ppm. In the D-Block surface soils EDTA-Mn was found in concentrations of 103.80 to 105.90 ppm, with a mean value of 105.10 ppm.(Table No: 9)

In the surface samples studied wide variation was not evident among the soils of the same series. But between the different soil series investigated significant variation was noticed in the EDTA Mn content.

4.9.3 Ammonium acetate extractable manganese in surface samples.

The ammonium acetate extractable manganese in the surface samples of Palode series ranged between 1.96 and 2.85 ppm, with a mean value of 2.62 ppm. The range of this fraction of Mn in the Vellayani series was between 17.62 and 18.53 ppm, the value for the mean being 18.21 ppm. The ammonium acetate manganese in the Trivandrum series ranged between 2.09 to 2.51 ppm with a mean value of 2.37ppm. This fraction of manganese in the Kottarakkara series varied from 5.91 ppm to 6.10 ppm, the mean being 6.01 ppm. In the Mannar series the ammonium acetate manganese ranged between 1.13 ppm and 1.41 ppm with a mean of 1.22 ppm. The range was between 18.95 and 20.89 ppm (mean 20.01 ppm) in the Thakazhy series. In the Ramankary series ammonium acetate Mn varied from 13.12 to 14.09 ppm. The mean value in this case was recorded as 13.37 ppm. In the D-Block surface soils ammonium acetate Mn was found in concentrations of 29.42 to 31.50 ppm, with a mean value of 29.93 ppm.(Table No: 9)

On the whole, wide variation in the ammonium acetate extractable Mn was not evident among the soils of the same series. But between the different soil series investigated significant variation was noticed in this fraction in the surface samples.

5.1.1 DTPA extractable zinc content in the surface samples.

The DTPA extractable zinc in the surface samples of Palode series ranged between 0.33 and 0.41 ppm, with a mean value of 0.37 ppm. The range of this fraction of Zn in the Vellayani series was between 5.79 and 6.28 ppm, the value for the mean being 6.05 ppm. The DTPA zinc in the Trivandrum series ranged between 0.48 to 0.60 ppm with a mean value of 0.51 ppm. This fraction of zinc in the Kottarakkara series varied from 0.77 ppm to 0.95 ppm, the mean being 0.84 ppm. In the Mannar series the DTPA zinc ranged between 0.46 ppm to 0.56 ppm with a mean of 0.52 ppm. The range was between 5.63 to 5.91 ppm (mean 5.79 ppm) in the Thakazhy series. In the Ramankary series DTPA-Zn varied from 11.92 to 12.61 ppm. The mean value in this case was recorded as 12.25 ppm. In the D-Block surface soils DTPA-Zn was found in concentrations of 3.05 to 3.94 ppm, with a mean value of 3.66 ppm.(Table No: 10)

In the surface samples of the profiles studied wide variation in the DTPA Zn content was not evident among the soils of the same series. But between the different soil series investigated, wide variation was noticed in the DTPA-Zn content.

Table No : 8

Extractable iron in the surface soil samples.

1	2	3	4	5
Series	Sample No:	ppm		
		DTPA-Fe	EDTA-Fe	NH_4OAc - Fe
Palode	1	39.56	95.10	11.50
	2	39.38	93.20	11.32
	3	38.89	96.50	11.50
	4	38.98	93.80	11.39
	5	39.03	93.80	10.28
	6	39.11	94.20	10.99
	7	39.12	93.80	10.32
	8	39.14	94.30	11.12
	9	39.32	95.10	11.15
	10	39.33	94.10	11.33
	Mean	39.18	94.38	11.09
	Range	38.89-39.56	94.20-96.50	10.28-11.50
Vellayani	1	9.52	137.50	7.32
	2	9.03	136.80	7.30
	3	9.62	135.80	7.23
	4	9.39	139.20	7.28
	5	9.43	138.50	7.30
	6	9.89	135.90	7.29
	7	9.52	136.30	7.32
	8	9.33	139.80	7.43
	9	9.28	137.90	7.49
	10.	9.12	137.60	7.62
	Mean	9.41	137.53	7.36
	Range	9.03-9.89	135.80-139.80	7.23-7.62

1	2	3	4	5
Trivandrum	1	16.05	85.10	10.51
	2	16.13	84.30	10.62
	3	16.12	85.90	10.71
	4	15.89	86.30	9.89
	5	15.99	85.20	10.32
	6	15.83	84.30	10.32
	7	15.92	84.90	10.34
	8	15.93	84.60	10.42
	9	16.09	85.90	10.51
	10	16.09	85.80	10.52
	Mean	16.00	85.23	10.42
	Range	15.83-16.13	84.30-86.30	9.89-10.62
Kottarakkara	1	21.5	377.50	14.50
	2	20.80	376.30	14.81
	3	21.20	367.30	14.32
	4	20.90	373.40	13.80
	5	21.20	368.90	13.75
	6	21.30	372.50	14.32
	7	20.30	375.50	14.61
	8	19.80	374.90	14.58
	9	19.50	376.30	14.52
	10	20.50	379.40	14.65
	Mean	20.70	374.20	14.39
	Range	19.50-21.50	367.30-379.40	13.75-14.81
Mannar	1	13.30	120.10	8.81
	2	12.90	121.80	8.42
	3	12.82	120.90	8.32
	4	12.99	119.30	8.09
	5.	13.21	118.90	7.89
	6	13.25	120.30	7.98
	7	13.09	120.30	7.96
	8	12.82	121.40	8.41
	9	12.94	122.00	8.52
	10.	12.88	121.90	8.56
	Mean	13.02	120.69	8.30
	Range	12.82-13.30	119.5-121.9	7.89-8.81

1	2	3	4	5
Thakazhy	1	296.31	2125.5	381.5
	2	289.40	2076.20	380.20
	3	293.20	2138.20	279.40
	4	289.43	2122.30	275.30
	5	292.21	2122.40	380.40
	6	286.51	2132.50	380.80
	7	283.22	2128.90	381.50
	8	289.79	2129.60	382.30
	9	294.80	2125.30	382.40
	10	295.30	2131.20	382.90
	Mean	291.02	2123.21	360.67
	Range	283.22-296.31	2076.20-2138.20	275.3-382.9
Ramankary	1	267.50	2845.30	485.20
	2	266.30	2830.20	482.30
	3	268.20	2863.20	483.20
	4	270.20	2843.20	484.10
	5	253.20	2844.30	432.40
	6	258.90	2845.40	454.20
	7	264.30	2853.60	469.80
	8	265.90	2859.40	489.30
	9	269.20	2863.20	486.20
	10	269.90	2845.20	485.30
	Mean	265.36	2849.30	475.20
	Range	253.20-270.20	2830.20-2859.40	469.80-489.30

1	2	3	4	5
D-Block	1	147.50	4375.20	228.50
	2	139.20	4372.20	227.20
	3	147.30	4381.30	229.30
	4	145.40	4381.30	226.30
	5	146.20	4378.50	227.20
	6	147.90	4374.20	228.40
	7	142.20	4379.80	227.30
	8	143.30	4376.30	229.80
	9	144.50	4375.20	228.50
	10	146.30	4373.50	228.30
	Mean	144.98	4376.75	228.08
	Range	253.20-270.20	4372.20-4381.30	226.30-229.80

Table No: 9 **Extractable manganese in the surface soil samples**

1	2	3	4	5
Series	Sample No:	ppm		
		DTPA-Mn	EDTA-Mn	NH_4OAc- Mn
Palode	1	4.56	10.10	2.82
	2	4.36	10.30	2.80
	3	4.28	9.80	2.85
	4	4.33	9.70	1.96
	5	4.32	8.90	2.42
	6	4.06	10.40	2.43
	7	4.09	10.70	2.46
	8	4.32	10.50	2.75
	9	4.48	10.70	2.83
	10	4.49	10.30	2.85
	Mean	4.33	10.14	2.62
	Range	4.06-4.56	8.90-10.70	1.96-2.85
Vellayani	1	22.76	40.42	18.42
	2	19.09	40.49	18.31
	3	19.72	40.33	18.40
	4	19.02	40.99	18.33
	5	19.09	41.08	18.28
	6	18.53	39.05	18.29
	7.	18.69	39.83	18.53
	8	19.52	39.41	17.89
	9	19.48	39.63	17.98
	10	19.56	39.89	17.62
	Mean	19.55	40.11	18.21
	Range	18.53-22.76	39.05-41.08	17.62-18.53

Trivandrum	1	19.74	34.51	2.51
	2	18.73	34.42	2.32
	3	19.72	32.09	2.41
	4	19.02	32.32	2.51
	5	19.09	33.41	2.33
	6	18.53	34.63	2.42
	7	18.69	34.42	2.48
	8	19.52	34.69	2.13
	9	19.48	34.03	2.09
	10	19.56	34.42	2.50
	Mean	19.21	33.89	2.37
	Range	18.53-19.74	32.09-34.63	2.09-2.51
Kottarakkara	1	7.28	12.30	6.10
	2	6.98	12.10	6.08
	3	7.13	11.90	6.05
	4	7.12	12.80	6.09
	5	7.09	12.40	6.01
	6	7.08	12.20	5.99
	7	7.17	11.90	5.98
	8	7.12	13.80	5.91
	9	7.14	11.50	5.95
	10	7.15	11.20	5.96
	Mean	7.13	12.21	6.01
	Range	6.98-7.28	11.20-12.80	5.91-6.10
Mannar	1	3.28	19.71	1.21
	2	3.21	19.09	1.18
	3	3.18	19.61	1.19
	4	3.19	19.52	1.14
	5	3.15	19.22	1.13
	6	3.15	19.73	1.41
	7	3.09	19.71	1.23
	8	3.14	19.61	1.24
	9	3.03	19.63	1.23
	10	3.12	19.67	1.21
	Mean	3.15	19.55	1.22
	Range	3.09-3.28	19.09-19.73	1.13-1.41

Thakazhy	1	30.08	6.91	20.10
	2	31.20	6.93	20.09
	3	30.90	6.84	18.95
	4	31.08	5.98	19.89
	5	30.91	6.12	19.63
	6	30.99	6.43	19.42
	7	30.98	6.79	20.21
	8	31.24	6.48	20.89
	9	30.99	6.73	20.73
	10	31.33	6.58	20.14
	Mean	30.97	6.58	20.01
	Range	30.08-31.33	5.98-6.93	18.95-20.89
Ramankary	1	48.50	29.80	13.12
	2	48.39	28.50	13.21
	3	47.38	28.30	12.81
	4	46.58	29.40	12.90
	5	45.68	29.10	13.52
	6	48.91	29.50	13.21
	7	49.91	29.40	13.29
	8	50.31	29.60	14.09
	9	46.77	29.90	14 02
	10	47.77	29.10	13.53
	Mean	48.02	29.26	13.37
	Range	46.77-50.31	28.30-29.90	13.12-14.09
D-Block	1	46.51	105.20	30.72
	2	46.33	105.40	31.50
	3	47.38	104.80	30.16
	4	46.58	104.90	30.13
	5	45.68	104.90	29.89
	6	48.91	103.80	29.95
	7	49.91	105.60	29.63
	8	50.31	105.10	29.81
	9	46.77	105.20	28.13
	10	47.77	105.30	29.42
	Mean	47.61	101.10	29.93
	Range	45.68-50.31	103.80-105.90	29.42-31.50

Table No : 10 **Extractable zinc in the surface soil samples**

1	2	3	4	5
Series	Sample No:	ppm		
		DTPA-Zn	EDTA-Zn	NH_4OAc- Zn
Palode	1	0.35	2.12	4.91
	2	0.38	1.81	3.81
	3	0.34	1.92	3.98
	4	0.39	1.85	4.83
	5	0.40	1.86	4.85
	6	0.35	1.93	4.75
	7	0.36	1.87	4.70
	8	0.37	1.79	4.63
	9	0.41	2.15	4.69
	10	0.33	2.08	4.73
	Mean	0.37	1.94	4.59
	Range	0.33-0.41	1.79-2.15	3.81-4.91
Vellayani	1	6.28	16.10	3.41
	2	5.98	15.80	3.43
	3	5.85	15.70	3.79
	4	6.30	16.30	3.89
	5	6.11	16.20	3.63
	6	6.09	16.40	3.31
	7	6.03	16.80	3.25
	8	5.79	16.90	3.32
	9	5.85	14.90	3.41
	10	6.22	15.80	3.32
	Mean	6.05	16.09	3.48
	Range	5.79-6.28	14.90-16.90	3.25-3.89

1	2	3	4	5
Trivandrum	1	0.53	1.61	2.51
	2	0.60	1.43	2.48
	3	0.49	1.58	2.62
	4	0.43	1.48	2.54
	5	0.52	1.62	2.51
	6	0.53	1.63	2.49
	7	0.52	1.29	2.38
	8	0.49	1.58	2.39
	9	0.48	1.63	2.43
	10	0.50	1.79	2.51
	Mean	0.51	1.56	2.49
	Range	0.48-0.60	1.29-1.63	2.38-2.54
Kottarakkara	1	0.83	9.71	2.41
	2	0.84	9.82	2.43
	3	0.92	9.51	2.48
	4	0.95	9.58	2.49
	5	0.85	9.28	2.46
	6	0.82	9.52	2.42
	7	0.87	9.53	2.45
	8.	0.77	9.63	2.49
	9	0.78	9.89	2.42
	10	0.79	9.63	2.43
	Mean	0.84	9.62	2.45
	Range	0.77-0.95	9.28-9.89	2.41-2.49
Mannar	1	0.54	4.71	4.21
	2	0.53	4.81	4.18
	3	0.48	4.75	4.19
	4	0.49	4.77	4.20
	5	0.46	4.65	4.17
	6	0.52	4.66	4.20
	7	0.51	4.33	4.22
	8	0.54	4.89	4.23
	9	0.56	4.72	4.20
	10	0.53	4.79	4.18
	Mean	0.52	4.71	4.20
	Range	0.46-0.56	4.65-4.89	4.17-4.23

1	2	3	4	5
Thakazhy	1	5.91	2.11	4.12
	2	5.83	2.23	4.13
	3	5.98	2.24	4.09
	4	5.88	2.81	4.21
	5	5.63	2.62	4.12
	6	5.82	2.32	4.21
	7	5.75	2.12	4.09
	8	5.77	2.22	4.08
	9	5.73	2.08	4.12
	10	5.64	2.09	4.13
	Mean	5.79	2.28	4.13
	Range	5.63-5.91	2.08-2.81	4.09-4.21
Ramankary	1	12.61	34.61	12.61
	2	11.98	34.40	12.60
	3	11.99	34.32	12.58
	4	12.53	33.21	12.59
	5	12.32	32.28	12.48
	6	12.41	34.12	12.59
	7	11.92	33.19	12.53
	8	12.01	35.16	12.48
	9	12.30	32.13	12.53
	10	12.41	33.19	12.42
	Mean	12.25	33.67	12.54
	Range	11.92-12.61	32.13-34.61	12.42-12.61

D-Block	1	3.80	4.31	2.46
	2	3.94	4.46	2.38
	3	3.05	4.62	2.39
	4	3.81	4.38	2.35
	5	3.63	4.49	2.42
	6	3.53	4.73	2.43
	7	3.60	4.62	2.35
	8	3.78	4.48	2.34
	9	3.69	4.39	2.28
	10	3.77	4.58	2.29
	Mean	3.66	4.51	2.37
	Range	3.05-3.94	4.31-4.73	2.28-2.46

Table No : 11 Extractable copper in the surface soil samples

1	2	3	4	5
Series	Sample No:		ppm	
		DTPA-Cu	EDTA-Cu	NH_4OAc- Cu
Palode	1	4.10	1.60	0.90
	2	4.08	1.58	0.91
	3	3.98	1.49	0.89
	4	4.03	1.38	0.85
	5	4.05	1.62	0.84
	6	3.79	1.65	0.89
	7	4.52	1.72	0.87
	8	4.03	1.55	0.83
	9	3.99	1.59	0.84
	10	4.09	1.68	0.85
	Mean	4.07	1.59	0.87
	Range	3.79-4.52	1.38-1.68	0.83-0.91
Vellayani	1	4.01	4.10	1.41
	2	4.08	4.09	1.42
	3	3.98	4.62	1.39
	4	3.73	4.31	1.38
	5	3.89	4.28	1.42
	6	3.93	4.29	1.35
	7	3.62	4.18	1.36
	8	4.11	4.03	1.28
	9	4.13	4.09	1.29
	10	4.14	4.08	1.33
	Mean	3.96	4.21	1.36
	Range	3.62-4.14	4.03-4.62	1.28-1.42

Trivandrum	1	0.52	1.31	0.62
	2	0.51	1.42	0.61
	3	0.48	1.83	0.58
	4	0.49	1.94	0.59
	5	0.50	1.22	0.57
	6	0.52	1.63	0.61
	7	0.53	1.79	0.63
	8	0.56	1.82	0.62
	9	0.59	1.92	0.64
	10	0.48	1.81	0.63
	Mean	0.52	1.67	0.61
	Range	0.48-0.59	1.22-1.94	0.58-0.64
Kottarakkara	1	0.61	8.14	0.20
	2	0.62	8.33	0.21
	3	0.63	7.92	0.23
	4	0.58	7.81	0.22
	5	0.59	7.81	0.18
	6	0.64	7.93	0.19
	7	0.63	7.62	0.23
	8	0.59	8.21	0.24
	9	0.58	8.18	0.21
	10	0.57	8.19	0.23
	Mean	0.60	8.01	0.21
	Range	0.58-0.63	7.62-8.33	0.18-0.24
Mannar	1	1.44	2.40	0.40
	2	1.42	2.42	0.39
	3	1.43	2.09	0.38
	4	1.39	2.63	0.35
	5	1.38	2.19	0.39
	6	1.40	2.82	0.42
	7	1.39	2.79	0.36
	8	1.38	2.18	0.38
	9	1.42	2.40	0.42
	10	1.43	2.13	0.41
	Mean	1.41	2.41	0.39
	Range	1.38-1.44	2.09-2.82	0.35-0.42

Thakazhy	1	1.20	6.81	0.58
	2	1.08	6.72	0.59
	3	1.11	7.92	0.56
	4	1.12	7.81	0.53
	5	1.06	7.80	0.52
	6	1.07	7.93	.0.48
	7	1.09	7.62	0.49
	8	1.10	8.21	0.49
	9	1.13	8.18	0.53
	10	1.14	8.19	0.54
	Mean	1.11	7.72	0.53
	Range	1.06-1.20	6.72-8.21	0.48-0.59
Ramankary	1	5.79	11.12	1.82
	2	5.73	11.09	1.83
	3	5.62	11.63	1.84
	4	4.89	11.42	1.78
	5	4.90	11.09	1.79
	6	5.13	10.98	1.85
	7	5.12	10.99	1.82
	8	5.22	10.53	1.83
	9	5.23	11.32	1.84
	10	5.21	11.52	1.75
	Mean	5.28	11.17	1.82
	Range	5.12-5.79	10.53-11.52	1.75-1.84
D-Block	1	1.01	3.10	0.52
	2	0.97	3.09	0.53
	3	0.98	3.30	0.54
	4	1.10	3.41	0.48
	5	1.09	3.82	0.49
	6	1.08	3.09	0.45
	7	1.06	3.63	0.51
	8	1.10	3.79	0.52
	9	1.09	3.42	0.54
	10	1.08	3.63	0.55
	Mean	1.06	3.43	0.51
	Range	0.98-1.10	3.09-3.82	0.45-0.55

5.1.2 EDTA extractable zinc content in the surface samples.

The EDTA extractable zinc in the surface samples of Palode series ranged between 1.79 and 2.15 ppm, with a mean value of 1.94 ppm. The range of this fraction of Zn in the Vellayani series was between 14.90 and 16.90 ppm, the value for the mean being 16.09 ppm. The EDTA zinc in the Trivandrum series ranged between 1.29 to 1.63 ppm with a mean value of 1.56 ppm. This fraction of zinc in the Kottarakkara series varied from 9.28 ppm to 9.89 ppm, the mean being 9.62 ppm. In the Mannar series the EDTA zinc ranged between 4.65 ppm to 4.89 ppm with a mean of 4.71 ppm. The range was between 2.08 and 2.81 ppm (mean 2.28 ppm) in the Thakazhy series. In the Ramankary series EDTA-Zn varied from 32.13 to 34.61 ppm. The mean value in this case was recorded as 33.67 ppm. In the D-Block surface soils EDTA-Zn was found in concentrations of 4.31 to 4.73 ppm, with a mean value of 4.51 ppm.(Table No: 10)

On the whole wide variation in the EDTA-Zn was not evident among the soil of the same series. But between the different soil series investigated wide variation was noticed in the EDTA-Zn content.

5.1.3 Ammonium acetate extractable zinc content in the surface samples.

The ammonium acetate extractable zinc in the surface samples of Palode series ranged between 3.81 and 4.91 ppm, with a mean value of 4.59 ppm. The range of this fraction of Zn in the Vellayani series was between 3.25 and 3.89

ppm, the value for the mean being 3.48 ppm. The ammonium acetate zinc in the Trivandrum series ranged between 2.38 to 2.54 ppm with a mean value of 2.49 ppm. This fraction of zinc in the Kottarakkara series varied from 2.41 ppm to 2.49 ppm, the mean being 2.45 ppm. In the Mannar series the ammonium acetate zinc ranged between 4.17 ppm to 4.23 ppm with a mean of 4.20 ppm. The range was between 4.09 and 4.21 ppm (mean 4.13 ppm) in the Thakazhy series. In the Ramankary series ammonium acetate Zn varied from 12.42 to 12.61 ppm. The mean value in this case was recorded as 12.54 ppm. In the D-Block surface soils ammonium acetate Zn was found in concentrations of 2.28 to 2.46 ppm, with a mean value of 2.37 ppm.(Table No: 10)

On the whole wide variation in the ammonium accetate extractable zinc was not observed among the soils of the same series. But between the different soil series investigated wide variations in this fraction was noticed.

5.2.1 DTPA extractable copper content in the surface samples.

The DTPA extractable copper in the surface samples of Palode series ranged between 3.79 to 4.52 ppm, with a mean value of 4.07 ppm. The range of this fraction of Cu in the Vellayani series was between 3.62 and 4.14 ppm, the value for the mean being 3.96 ppm. The DTPA copper in the Trivandrum series ranged between 0.48 to 0.59 ppm with a mean value of 0.52 ppm. This fraction of copper in the Kottarakkara series varied from 0.58 ppm to 0.63 ppm, the mean being 0.60 ppm. In the Mannar series the DTPA copper ranged between 1.38 ppm to 1.44 ppm with a mean of 1.41 ppm. The range was between 1.06 and 1.20 ppm (mean 1.11 ppm) in the Thakazhy series. In the Ramankary series DTPA-Cu varied from 5.12 to 5.79 ppm. The mean value in this case was recorded as 5.28 ppm. In the D-Block surface soils DTPA-Cu was found in concentrations of 0.98 to 1.10 ppm, with a mean value of 1.06 ppm.(Table No: 11)

In the various soil series studied wide variation in the DTPA-Cu content was not observed among the soil samples of the same series. But between different soil series investigated significant variation was noticed.

5.2.2 EDTA extractable copper content in the surface samples.

The EDTA extractable copper in the surface samples of Palode series ranged between 1.38 and 1.68 ppm, with a mean value of 1.59 ppm. The range of this fraction of Cu in the Vellayani series was between 4.03 and 4.62 ppm, the value for the mean being 4.21 ppm. The EDTA copper in the Trivandrum series ranged between 1.22 to 1.94 ppm with a mean value of 1.67 ppm. This fraction of copper in the Kottarakkara series varied from 7.62 ppm to 8.33 ppm, the mean being 8.01 ppm. In the Mannar series the EDTA copper ranged between 2.09 ppm to 2.82 ppm with a mean of 2.41 ppm. The range was between 6.72 to 8.21 ppm (mean 7.72 ppm) in the Thakazhy series. In the Ramankary series EDTA-Cu varied from 10.53 to 11.52 ppm. The mean value in this case was recorded as 11.17 ppm.

In the D-Block surface soils EDTA-Cu was found in concentrations of 3.09 to 3.82 ppm, with a mean value of 3.43 ppm.(Table No: 11)

On the whoie wide variations in the EDTA copper was not evident among the soils of the same series. But between the different soil profiles investigaed wide variation was noticed in this fraction in the surface samples.

5.2.3 Ammonium acetate extractable copper content in the surface samples.

The ammonium acetate extractable copper in the surface samples of Palode series ranged between 0.83 to 0.91 ppm, with a mean value of 0.87 ppm. The range of this fraction of Cu in the Vellayani series was between 1.28 and 1.42 ppm, the value for the mean being 1.36 ppm. The ammonium acetate copper in the Trivandrum series ranged between 0.58 to 0.64 ppm with a mean value of 0.61 ppm. This fraction of copper in the Kottarakkara series varied from 0.18 ppm to 0.24 ppm, the mean being 0.21 ppm. In the Mannar series the ammonium acetate copper ranged between 0.35 ppm to 0.42 ppm with a mean of 0.39 ppm. The range was between 0.48 to 0.59 ppm (mean 0.53 ppm) in the Thakazhy series. In the Ramankary series ammonium acetate Cu varied from 1.75 to 1.84 ppm. The mean value in this case was recorded as 1.82 ppm. In the D-Block surface soils ammonium acetate Cu was found in concentrations of 0.45 to 0.55 ppm, with a mean value of 0.51 ppm.(Table No: 11)

In the surface samples of the soil series studied the ammonium acetate extractable copper content did not show significant a wide variation among the soils of the same series. But between the different soil series investigated greater variation was noticed in the ammonium acetate extractable Cu content in the surface samples.

6.0 Hot water extractable boron status

The hot water extractable boron content showed a decreasing trend with depth in all the profiles studies. In Palode series the highest content was in the surface layer with 0.83 ppm and lowest in the bottom layer with 0.29 ppm. A maximum content of hot water extractable boron was noticed in the surface layer of Vellayani series (0.82 ppm) and least in the lowest layer (0.32 ppm). In Trivandrum series the hot water extractable boron showed a highest content in the surface layer with 0.96 ppm and lowest in the bottom layer having 0.42 ppm. In Kottarakkara series, the boron content was present in the maximum quantity in the surface layer (0.73 ppm) and least in the lowest layer (0.29 ppm). In Mannar series, the hot water extractable boron showed a maximum content in the surface layer (0.56 ppm) and least in the bottom layer (0.28 ppm) analysed. In Thakazhy series the surface layer had the maximum content of boron (0.68 ppm) and minimum in the lowest layer (0.30 ppm). In Ramankary series it ranged between 0.78 ppm and 0.43 ppm. In D- Block series, the presence of boron was maximum in the surface layer (0.59 ppm) and least in the bottom layer with 0.31 ppm (Table No:12). The higher content of available boron may be due to the higher organic matter content

Table No: 12 Hot water extractable boron status

Name of the Series	Depth cm	Boron ppm	Name of the Series	Depth cm	Boron ppm
Palode	0-10	0.83	Mannar	0-25	0.56
	10-28	0.63		25-74	0.47
	28-47	0.41		74-125	0.33
	47-93	0.32		125-155	0.30
	93-170	0.29		155-180	0.28
Vellayani	0-21	0.82	Thakazhy	0-12	0.68
	21-52	0.63		12-18	0.59
	52-125	0.41		18-30	0.45
	125-150	0.32		30-54	0.32
				54-140	0.30
Trivandrum	0-15	0.96	Ramankary	0-15	0.78
	15-24	0.93		15-41	0.52
	24-57	0.81		41-130	0.43
	57-86	0.76			
	86-114	0.58			
	114-165	0.42			
Kottarakkara	0-5	0.73	D-Block	0-15	0.59
	5-30	0.68		15-31	0.48
	30-57	0.52		31-47	0.42
	57-90	0.48		47-60	0.39
	90-130	0.33		60-86	0.32
	130-165	0.29		86-136	0.31

in the surface layer. Suresh (1985) observed a positive correlation between availbale boron and organic matter in the sandy soils of Kerala. Similar observations were done by Sheeja *et al* (1993).

Among the profiles studied, the boron content was highest in the surface layer of Trivandurm series with 0.96 ppm in the surface layer and least in the bottom layer of Mannar series with 0.28 ppm (Table No: 12).

7.0 Available micronutrients by Neubauer seedling technique.

The plant available micronutrients were determined by Neubauer seedling technique in the eight soil series studied. The availability showed greater variation in the profiles studied. The maximum plant available Fe content was noticed in the Thakazhy series with 4.753 mg /100 g soil. The availability was lowest in the Vellayani series with 1.443 mg /100 g soil. The plant available Mn content was also highest in the Thakazhy series (1.039 mg /100 g soil) and least availability was found in the Palode series (0.279 mg /100 g soil). The availability of Zn was maximum in the Thakazhy and Ramankary series with 0.125 mg /100 g soil. The lowest availability was found in the Kottarakkara series with 0.057 mg / 100 g soil. In the case of Cu also the highest availability was noticed in the Thakazhy series having 0.143 mg /100 g soil, while the availability was least in the Kottarakkara series (0.041 mg /100 g soil). From the observations it was found that the availability was highest in the Thakazhy (*Kari*), Ramankary (*Karappadom*)

Table No:13

Available micronutrients determined by Neubauer seedling technique (mg/100g soil)

Name of soil series	mg/100g soil			
	Fe	Mn	Zn	Cu
Palode	2.602	0.279	0.069	0.063
Vellayani	1.443	0.489	0.063	0.068
Trivandrum	2.051	0.772	0.066	0.046
Kottarakkara	1.532	0.808	0.057	0.041
Mannar	2.149	0.207	0.068	0.049
Thakazhy	4.753	1.039	0.125	0.143
Ramankary	4.196	0.388	0.125	0.085
D-Block	3.593	0.647	0.116	0.106

and D-Block (*Kayal*) soil series. Similar type of higher micronutrient content was estimated by Rajendran (1981), in these types of soils while studying the Mn and Zn status in the rice soils of Kerala.

7.0 Correlation Studies

7.1 DTPA extractable micronutrients with soil properties:

The DTPA extractable micronutrients were influenced significantly by the soil properties like pH, organic carbon, cation exchange capacity, and clay content in all the soil profiles studied. These factors had a greater role in the availability of micronutrients in the soils. From the studies it was observed that the DTPA extractable micronutrients were significantly and negatively correlated with pH. The properties like organic carbon content, CEC and clay content were significantly and positively correlated with available micronutrient status.(Table No: 14).

The DTPA extractable iron, manganese and zinc were significantly and negatively correlated with pH (r = - 0.532 for Fe, r = - 0.395 for Mn, r = -0.432 for Zn). From the statistical analysis, it was noticed that the DTPA extractable Fe, Mn and Zn were significantly and positively correlated with organic carbon content (r = 0.717 for Fe, r = 0.472 for Mn and r = 0.600 for Zn). Similarly this fraction of micronutrients was found to have a significant and positive correlation with cation exchange capacity. (r = 0.763 for Fe, r= 0.5414 for Mn, and r = 0.613 for

Zn). The clay fraction also had a positive and significant correlation with DTPA extractable micronutrients (r = 0.524 for Fe, r = 0.393 for Mn, r = 0.485 for Zn) In the case of DTPA-Cu, no significant correlation was noticed between organic carbon, CEC and clay content.

The analysis, revealed that the pH, organic carbon, CEC and clay content had considerable influence on the availability of micronutrients. Increase in pH was found to be associated with decrease in the DTPA extractable micronutrients. Rajagopal (1977) found a significant negative correlation between available iron and pH. Similar correlations were also obtained by Mondal and Mete (1991) and Sheeja *et al* (1993).

The positive correlation with organic carbon, CEC and clay content of the soils with DTPA extractable micronutrients is an indication of the increase in their availability with an increase in these fractions. Valsaji (1972) found a significant positive correlation between available copper and organic carbon in the Amaravila and Marukil soil series of Trivandrum district. Mariam (1989) also found a significant positive correlation between DTPA extractable Zn and organic carbon in Kayal soils of Kerala. Similarly Appavu and Ramulu (1990) observed a positive correlation between DTPA extractable Mn and clay in the several soil series of Tamilnadu. Sheeja *et al* (1996) on studying the micronutrient status in sweet potato growing soils of India obtained a significant positive correlation with DTPA extractable micronutrients and organic carbon.

Table No: 14

Correlation of DTPA extractable micronutrients with soil properties

DTPA extractable Micronutrients	pH	Organic Carbon	CEC	Clay
Iron	-0.532**	0.717**	0.763**	0.524**
Manganese	-0.395**	0.472**	0.541**	0.393*
Zinc	-0.432**	0.600**	0.613**	0.485**
Copper	-0.176	0.142	0.052	0.090

**Significant at 1% level
* Significant at 5% level

Table No:15

Correlation of ammonium acetate extractable micronutrients with soil properties

Ammonium Acetate Extractable Micronutrients	pH	Organic Carbon	CEC	Clay
Iron	-0.583**	0.796**	0.878**	0.576**
Manganese	-0.339*	0.586**	0.693**	0.474**
Zinc	-0.432*	0.427*	0.400*	0.443**
Copper	-0.302	0.174	0.113	0.298

**Significant at 1% level
* Significant at 5% level

Table No:16

Correlation of EDTA extractable micronutients with soil properties

EDTA Extractable Micronutrients	pH	Organic Carbon	CEC	Clay
Iron	-0.361*	0.529**	0.643**	0.381*
Manganese	-0.251	0.270	0.375*	0.223
Zinc	0.253	-0.127	-0.081	-0.016
Copper	-0.100	0.227	0.260	0.283

**Significant at 1% level

* Significant at 5% level

in their availability with an increase in these fractions. Valsaji (1972) found a significant positive correlation between available copper and organic carbon in the Amaravila and Marukil soil series of Trivandrum district. Mariam (1989) also found a significant positive correlation between DTPA extractable Zn and organic carbon in Kayal soils of Kerala. Similarly Appavu and Ramulu (1990) observed a positive correlation between DTPA extractable Mn and clay in the several soil series of Tamilnadu. Sheeja *et al* (1996) on studying the micronutrient status in sweet potato growing soils of India obtained a significant positive correlation with DTPA extractable micronutrients and organic carbon.

7.2 Ammonium acetate extractable micronutrients with soil properties.

Statistical analysis of the data revealed that ammonium acetate extractable micronutrients were significantly and negatively correlated with pH (r = - 0.583 for Fe, r = - 0.339 for Mn, r = - 0.432 for Zn) while it was positively correlated with organic carbon (r = 0.796 for Fe, r = 0.586 for Mn and r = 0.427 for Zn). CEC was positively and significantly correlated with NH_4OAc extractable micronutrients (r = 0.878 for Fe, r = 0.693 for Mn and r = 0.400 for Zn). The clay content also exhibited the same trend (r = 0.576 for Fe, r = 0.474 for Mn and r = 0.443 for Zn). In the case of copper no significant positive correlation was observed (Table No: 15). From the results it was observed that the pH, organic carbon, CEC and clay had a greater influence on the availability of micronutrients in the soils. These results obtained were in general agreement with the correlation studies conducted by Rajendran (1981) and Prasad and Sakal (1991).

7.3 EDTA extractable micronutrient with soil properties.

In case of EDTA extractable micronutrient, EDTA-Fe only showed a significant negative correlation with pH (r = - 0.361) and positively correlated with organic carbon (r = 0.529), CEC (r = 0.643) and also with clay content (r = 0.381). In the case of EDTA-Mn only CEC showed significant positive correlation with it, while EDTA-Zn and EDTA-Cu did not show significant correlation with soil properties. (Table No: 16). Consistant general behaviour of the micronutrient availability in relation to soil physical properties could not be predicted when the soils were extracted with EDTA.

Summary and Conclusions

SUMMARY AND CONCLUSIONS

The study was taken up with a view to.assessing the micronutrient distribution, both vertically and spatially in the selected major land resource areas (MLRAs) of Kerala. The total and available micronutrients in the soil samples were determined and correlated with important physico-chemical properties. The salient conclusions drawn from the experiment are summarised below:-

1. All the profiles analysed were acidic in reaction except Mannar series which showed a nearly neutral pH.
2. The least pH values were observed in the Thakazhy series (*Kari* soils) and it was highly acidic in reaction.
3. Among all the profiles analysed, the highest clay content was noticed in Thakazhy series followed by D-Block (*Kayal*) series and Ramankary series (*Karappadom* soils).
4. The electrical conductivity did not show greater variation among the profiles except in Thakazhy and Ramankary series which exhibited higher EC values.
5. The cation exchange capacity was highest in the Thakazhy series followed by D- Block and Ramankary series.
6. The cation exchange capacity was found to decrease with depth in the Palode, Vellayani, Trivandrum,Kottarakkara and Mannar series while in the case of

Thakazhy, Ramankary and D-Block series, it did not follow regular pattern with depth.

7. The organic carbon was found to decrease with depth except in waterlogged profiles like Thakazhy, Ramankary and D-Block series which did not follow any consistent trend with depth.
8. The exchangable cations like sodium,potassium,calcium and magnesium were maximum in the Thakazhy series (*Kari* soils) in which the CEC was also found to be highest.
9. The DTPA extractable micronutrients found to decrease with depth except in Thakazhy, Ramankary and D-Block series.
10. The highest DTPA extractable iron content was observed in the third depth of Ramankary series, while the maximum content of DTPA extractable Mn content was noticed in the third depth of D-Block series.
11. The greatest quantity of DTPA-Zn and DTPA-Cu were observed in the surface layer of Ramankary series.
12. The waterlogged profiles namely Ramankary (*Karappadom*) series, Thakazhy series (*Kari* soils) and D-Block series (*Kayal* soils) were well supplied with all the micronutrient cations.
13. The ammonium acetate extractable micronutrients showed a decreasing pattern with depth except in Ramankary, Thakazhy and D-Block series where it showed an erratic trend with depth.

14. The maximum quantity of ammonium acetate extractable Fe, Zn and Cu content were found in the surface layer of Ramankary series, while the Mn content was highest in the third layer of D-Block series.
15. The maximum EDTA-Fe content was noticed in the bottom layer of Ramankary series, while the EDTA-Cu and Zn were maximum in the surface layer of Ramankary series.
16. In the D-Block, Ramankary and *Kayal* series higher content of EDTA extractable micronutrients were observed due to the peculiar hydrologic conditions existing in these soils.
17. The total micronutrients also showed greater variations in all the profiles studied. The total micronutrients were found to be highest in the D-Block series.
18. The total micronutrient content showed a decreasing pattern with depth in Palode, Vellayani, Trivandrum, Kottakara and Mannar series.
19. The hot water extractable boron content was found to decrease with depth in all the profiles studied and the highest content was observed in the surface layer of Trivandrum series.
20. The micronutrient contents from the surface samples analysed also showed grater variations among the profiles studied and the higher availability was noticed in Ramankary, D-Block and Thakazhy series.

21. The plant available micronutrients were determined by Neubauer seedling technique in all the profiles studied and their contents were higher in Ramankary, D-Block and Thakazhy series.

22. From the correlation studies conducted, the DTPA extractable micronutrients like Fe, Mn and Zn showed significant correlation with pH, organic carbon, CEC and clay content.

23. The ammonium acetate extractable micronutrients also showed similar significant correlations with pH, organic carbon, CEC and clay content.

24. In the case of EDTA extractable micronutrients only EDTA-Fe showed significant correlation with pH, organic carbon, CEC and clay content.

25. In all the profiles studied iron and manganese were well supplied and the higher contents were noticed in the waterlogged soils of D-Block, Thakazhy and Ramankary series.

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DISTRIBUTION OF EXTRACTABLE MICRONUTRIENTS IN SOILS OF SELECTED MAJOR LAND RESOURCE AREAS OF KERALA

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The investigation was carried out to assess the total and available micronutrients in soils of selected major land resource areas (MLRAs) of Kerala. The micronutrients investigated in the present study were iron, manganese, zinc, copper and boron. The study was intended to establish the pattern of the distribution of micronutrients both vertically and spatially in eight MLRAs viz, Palode, Vellayani, Trivandrum, Mannar, Kottarakkara, Thakazhy, Ramankary and D-Block soil series of Kerala.

Three extractables viz DTPA, EDTA and ammonium acetate were used in the analysis. The available boron content in these soils was also determined by hot water extraction method. All the micronutrients showed great variation in their distribution in the various horizons of the profiles. The micronutrients content of the soils estimated were correlated with soil properties like pH, organic carbon, CEC and clay content. They were found to be positively and significantly correlated with organic carbon, CEC and clay content while it was significantly and negatively correlated with pH. The significant correlations revealed that the micronutrient availability in these soils were influenced greatly by the soil properties mentioned above.

From the results obtained, it was observed that micronutrients like iron and manganese were well supplied in all the profiles studied. The micronutrients

were found to decrease with depth except in Ramankary, D-Block and Thakazhy series where it showed an irregular trend with depth due to the peculiar hydrologic and oxidation-reduction conditions existing in these soil series.

The available and total micronutrients content in the surface soils from places around the profile sites did not show any significant variation among places. In almost all the samples very high iron content was recorded.

APPENDICES

APPENDIX

1. PALODE SERIES:

Location: Tropical Botanical Gardens and Research Institute, Palode which represents the typical Palode series.

Horizon	Depth cm.	Profile description
Ao	0-10	10YR 3/1 gravelly, sandy clay loam, weak fine to medium granular to subangular blocky, coarse slightly sticky, non plastic, many fine roots between peds.
Ah	10-28	10YR 2/2, gravelly clay loam, weak to moderate, fine to medium, subangular blocky, friable structure, sticky, non plastic, moderately porous, gradual smooth boundary.
AB	28-47	10YR 3/4, gravelly clay loam, moderate medium to coarse, subangular blocky, friable slightly sticky, common fine roots through out.
Bt_1	47-93	10YR 5/6, gravelly clay, moderate, strong medium to coarse, subangular blocky, very sticky, plastic, firm, few root throughout, moderately porous, diffuse smooth boundary.

Bt2	93-170	7.5YR 5/8, gravelly clay, moderate, strong, medium to coarse, subangular blocky, very sticky, plastic, firm highly porous, patchy thin clay cutans.

2. VELLAYANI SERIES

Location: Near College of Agricultüre Vellayani Campus. Poonkulam. which represents typical Vellayani Series.

Horizon	Depth cm.	Profile description
Ap	0-21	2.5 YR 5/6 moist. sandy loam, very fine. very weak granular. non sticky, non plastic, friable. many fine pores. clear smooth boundary.
AB	21-52	2.5YR 4/8 moist. sandy loam, fine to medium. granualr. non sticky, non plastic, friable. few fine roots. diffused wavy boundary.
Bt_1	52-125	2.5YR 3/6 moist. clay loam. fine to medium. granular. slightly sticky, non plastic, friable, few fine roots. diffused smooth boundary.
Bt_2	125-150	2.5YR 3/6. Clay loam, fine to medium. granular. slightly sticky, non plastic, friable. few fine roots.

3. TRIVANDRUM SERIES

Location: Central Tuber Crops Research Institute, Sreekaryam, Trivandrum. which represents typical Trivandrum Series.

Horizon	Depth cm.	Profile description
Ap	0-15	5YR 5/4, dry, 5YR 4/4 moisture, gravelly clay loam, weak to moderate, medium to coarse, sub angular blocky, soft, friable, slightly sticky, non plastic.
E	15-24	5YR 6/6 dry, 5YR 5/8 moist, gravelly clay loam. moderate coarse, subangular blocky, slightly hard, sticky, non plastic, common fine to medium roots, gradual wavy boundary.
Bt_1	24-57	5YR 5/8 dry, 5YR 6/8 moisture, gravelly, dry, slightly dry, slightly sticky, non plastic.
Bt_2	57-86	5YR 6/8 dry, 5YR 6/8 moist, gravelly clay, sub angular blocky hard, very firm slightly sticky. many fine random discontinuous pores.
Bt_3	86-114	5YR 5/8 dry, 5YR 6/8 moist, gravelly clay. strong very coarse, sub angular blocky, very hard, firm. sticky, slightly plastic, fine random discontinuos pores throughout.

4. KOTTARAKKARA SERIES

Location : NARP Special Station, Sadanadapuram, Kottarakkara, which represents the typical Kottarakkara Series.

Horizon	Depth cm.	Profile description
Ap	0-5	Dark brown (7.5YR 4/5), clay loam texture. weak medium granular to crumby structure. moist slightly firm, slightly plastic.
Ap_2	6-30	Dark Brown (7.5YR 4/4), clay loam texture. crumby structure, moist slightly firm, slightly sticky, slightly plastic.
B_1	58-130	Yellowish red (5YR 4/6), clay loam texture. medium subangular blocky structure, moist firm. sticky and plastic.
B_2	130-165	7.5YR 4/3 moist, clay, very gravelly, very coarse. strong subangular blocky, slightly sticky. slightly plastic, very few fine diffused mottles.

5. MANNAR SERIES

Location : Profile taken from Karunagappally Taluk, which represents the typical Mannar Series.

Horizon	Depth	Profile description
Ap	0-25	10YR 4/1 moist, loamy sand, herbaceous fragments, highly decomposed, nonsticky, nonplastic, few fine roots through out.

C_1	25-74	10YR 4/3 moist, loamy sand, fine non sticky, non plastic, loose, few fine roots between peds.
Cg_1	74-125	10YR 5/8 loamy sand, fine to medium, non sticky, non plastic, few fine mottles, moderately porous.
Cg_2	125-155	5Y 6/1 moist, loamy sand, decomposed, fine to medium, non plastic, non sticky.
Cg_3	155-180	5Y 6/1 moist, loamy sand, fine to medium, coherant single grain, faint diffused mottles, non sticky, non-plastic.

6. THAKAZHY SERIES

Location: Thakazhy, Kuttanad, Alappuzha. which represents the typical Thakazhy series.

Horizon	Depth cm.	Profile description
Ap_1	0-12	Olive brown 2.5Y 4/4 moist, and light olive brown 2.5Y 5/4 dry, sandy clay loam, moderate fine granular. slightly sticky and slightly plastic, many few fine roots, inside the peds.
Ap_2	12-18	Very dark gray brown 2.5Y 3/2, moist and greenish brown 2.5Y 5/2 dry, sandy clay, moderate fine

granualr slightly and slightly plastic, few roots many fine tubular pores.

Ag	18-30	Very dark greyish brown 2.5Y 3/2 moisture, and dark greyish brown 2.5Y 4/2 dry, sandy clay moderate coarse granular, sticky and plastic.
C_1	30-54	Very dark grey 2.5Y 3/N moist, and very dark greyish brown 2.5Y 3/2 dry, clay, coarse granular. sticky and plastic.
C_2	54-140	Black 2.5Y N/2 moist and very dark greyish brown 2.5Y 3/2 dry, clay, massive, sticky and plastic. roots nil. many tubular pores.

7. RAMANKARY SERIES

Location : Near Rice Researh Station, Mancompu. which represents the typical Ramankary Series.

Horizon	Depth cm.	Profile description
Ap1	0-15	2.5 YR 2/2 moist. slightly clay loam. coarse. prismatic, wet dry sticky and plastic. many fine and medium roots.
Ap2	15- 41	10 YR 2/2 moist, sticky clay loam, coarse, prismatic, very sticky and plastic, few fine

		discontinuous horizondal oblique inped and exped vesicular open and closed pores, fine medium roots, gradual smooth boundary to.
Ag	41- 130	2.5 YR 2/2 moist, slightly clay, moderate, medium sub angular blocky, very sticky and plastic, few fine and medium roots, jarosite mottles, pyrite, gradual smooth boundary to.

D- BLOCK SERIES

Location : D-Block, Kuttanad, Alappuzha, which represents the typical D-Block series.

Horizon	Depth cm.	Profile description
Ap1	0- 15	Dark greyish brown, 2.5Y 4/2 moist and light olive brown, 2.5YR 5/6 dry, sandy clay, moderate granular.
Ap2	15- 30	Dark greyish brown, 2.5YR 4/2 moist and light olive brown, 2.5Y 5/4 dry, clay, moderate granular, weak, slightly plastic, slightly sticky.
C1G	31 - 47	Olive brown 2.5Y 4/4 moist and dark greyish brown 2.5Y 4/2 dry, few faint mottles, clay, massive, many fine tubular pores.

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C2G	47 - 60	Olive brown 2.5Y 4/4 moist and olive brown 2.5Y 5/2 dry, clay, massive, sticky, plastic, smooth boundary to.
C3G	60 - 86	Very dark greyish brown 2.5Y 3/2 moist and black, 2.5Y N/2 dry, fine distinct reddish and yellowish mottles, clay massive sticky.
C4G	86 - 136	Black 2.5Y N/2 moist, and very dark greyish. 2.5 Y N/3 dry, few fine distinct mottles, clay, massive. sticky, plastic, fine irregular pores with smooth boundary to.