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Metal Nutrient Distribution and Availability in Vegetable Growing Soils of Coimbatore District, Tamil Nadu

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Knowledge about distribution and bio availability of micronutrients is critically needed for better production of agricultural products both quantitatively and qualitatively. The study intended to evaluate the micronutrient status, availability and its interaction with soil properties in the vegetable ecosystem. This study looks at the availability of micronutrient metal cation with their diversified soil properties. A total number of 25 surface soil samples were collected from major vegetable growing areas and basic soil parameters such as pH, electrical conductivity, organic carbon, clay, cation exchange capacity, and free $CaCO_3$ were examined. Micronutrients, both total and accessible,

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were also determined in soil. Zn and Fe deficiencies were found to a tune of 36 and 24 percent respectively in the overall soil samples, respectively. Deficiencies in Mn and Cu were found in extremely small quantities. Calcareous soils contribute to 40% of the soils analysed. Among the different soil properties, pH and $CaCO_3$ showed a significant negative impact on micronutrient bioavailability whereas organic carbon and clay enhances the availability of micronutrients. The total micronutrient was not significantly correlated with the bioavailability of their respective nutrients.

Keywords: Micronutrients; calcareous; soil; deficiency; availability; cation.

1. INTRODUCTION

The role of micronutrients in human, plant and animals are irreplaceable to complete their life cycle. The deficiency out break shows in plants especially iron (inter veinal chlorosis) and Zinc (stunted growth), in animals Manganese (skeletal defects) finally in humans Fe deficiency (anaemia) etc. The wellspring of these deficiencies was the cyclic process as it starts from the soil. The bioavailability and distribution of micronutrients in soil is governed by the characteristics of soil, climate, physiographic landform, nature of crop grown and soil developmental process. The soil temperature and moisture regimes highly influence the distribution of micronutrients [1]. The combined influence of above factors both increase and decrease the micronutrient availability. An arid climate alters the soil property mainly the pH and organic carbon content of the soil which affects the dissolution and availability of micronutrient [2].Pursuant to moisture regime, DTPA- zinc, iron, copper and manganese availability is higher in aquic regime than ustic and aridic moisture regime [1]. Cold climate condition also impacts the bio accessibility of micronutrients (especially zinc) due to its reduced diffusion to rhizosphere [3]. An unmediated relationship of soil properties with micronutrients availability starts from texture, organic carbon, pH, CEC, EC, moisture, Free $CaCO_3$and other oxide fixation surfaces both crystalline and amorphous.

Organic matter plays both direct and indirect roles on the availability of micronutrients. The indirect relationships of organic matter were modified the structure and aeration of soil which governs the micronutrient availability. The direct relationships were organic complexing agents which reduces the oxidation and precipitation of micronutrients. The nature and intensity of crop also influences the nutrient availability of soils. A vigorous vegetable cultivation with improved nutrient receptive varieties leads to inordinate withdrawal of nutrients cause deficiency of micronutrients. The improper nutrient management has, led to emergence of multi nutrient deficiencies in the Indian soils [4]. Right assessment and monitoring of bio accessible nutrient status in arable soil is highly significant to maintain the productivity and fertility of soils. Ceaseless suck up of micronutrients leads to decline in soil potentiality. Considering the relationship between soil properties and micronutrients availability, the present study was carried out to analyse the influence of different soil properties on micronutrients availability for better land use management of especially vegetable growing soils of Coimbatore district as the information on above aspects is rather scare and scanty.

2. MATERIALS AND METHODS

2.1 Study Area

The study area covered the western part of Tamil Nadu, India. It is situated between latitude and longitude of 11.0168° N, 76.9558° E respectively with an altitude of +411m above mean sea level. The study area had a mean annual temperature of 25.4ºC ± 5.8ºC with an average rainfall of 694 mm that comes under the western agro climatic zone of Tamil Nadu [5] Mainly bhendi, tomato, onion and brinjal were the major vegetables predominately cultivated in the study area.

2.2 Soil Analysis

The surface soil samples of 0-30 cm in depth were collected from 25 different locations (25 samples) in major vegetable especially Bhendi growing areas of Coimbatore district. The collected soils were air dried, sieved (2 mm) and stored in plastic container. The soil properties namely pH [6], EC [6], organic carbon [7], cation exchange capacity [6], soil texture [9] CaCO3 [8], total and available micronutrients [10] namely Zn, Fe, Cu and Mn were analysed in each samples by following standard procedures.

Table 1. Method of analysis of soil properties

S.No	Soil property	Reference
1.	pH	Potentiometry (Jackson,1973) [6]
2.	EC (dS m-1)	Conductometry (Jackson, 1973) [6]
3.	Organic carbon (%)	Chromic acid wet digestion (Walkey and Black,
4.	Free CaCO3 (%)	1936)[7]
5.	CEC (Cmol (p+)kg-1)	Rapid titration (Piper, 1966) [8]
6.	Clay (%)	Neural Normal NH4OAc- (Jackson, 1973) [5]
7.	Available micronutrients (mg kg-	International pipette (Piper, 1966) [8]
8.	1)	DTPA extract – AAS (Lindsay and Norvell, 1978)
	Total micronutrients (mg kg-1)	[9]
		Triple acid extract –AAS (Lindsay and Norvell,
		1978) [9]

2.3 Data Analysis

The results of the laboratory analysis of soil samples were statistically scrutinized as explained by Gomez et al., 1985 [10] to find out the correlation between the micronutrients with their soil properties.

3. RESULTS AND DISCUSSION

3.1 Soil Properties

The data showed that the soil pH was mainly neutral to alkaline in reaction ranged from 7.12 – 8.66 and a significant positive correlation was observed with $CaCO_3$. The calcareousness of the soil is stretched from non-calcareous to highly calcareous with a range value of 0.50-12.5 per cent with a mean value of 4.10 per cent. Only around 32% of collected soils were calcareous in nature. The $CaCO_3$ is the most important parameter to assess the extent of nutrient availability and their releasing pattern. The calcareousness of 32 per cent of soils might be due to the lesser water availability for leaching of insoluble carbonates and bicarbonates of calcium and increased evapotranspiration [11.12]. Among the samples, 60 per cent of the soil samples were high in organic carbon content whereas 40 per cent of the soils were medium and deficient in organic carbon. The values of organic carbon were significantly positively correlated with clay content and negatively correlated with calcium carbonate content. The low organic carbon content may be due to high rate of organic matter decomposition. The ranges of clay content was from 16.4 to 31.5 per cent. The electrical conductivity ranged from 0.26 to 0.67 dS m^{-1}. The organic carbon content showed a considerable variation with types and topography of the soil.

The positive relationship of pH and $CaCO_3$ may be due to the solubility of $CaCO_3$ which in turn increase the CO_3, HCO_3^- concentration in solution leads to the formation of OH^- ions which raises the soil pH. The sparingly soluble of $CaCO_3$ buffers the pH around 7.5 – 8.5. The change in $CaCO_3$ leads to change in pH [13,14,15]. The presence of $CaCO_3^-$ maintains the soil pH at slightly alkaline 7.5 – 8.5 which enhances higher microbial activity that cause quick oxidation of organic matter [16].

3.2 Available Micronutrients

3.2.1 DTPA-Zn

The soil available zinc ranged from 0.24 -3.31 mg kg^{-1} with a mean value of 1.32 mg kg^{-1}. The availability of zinc significantly positively correlated with organic carbon and clay content. The negative correlation were observed with pH and $CaCO_3$ content. It conveys that the available zinc increases with increase in organic carbon and clay content and diminishes with increase in pH and $CaCO_3$ content. Among the collected soil samples, 36% of the samples were deficient in zinc. The results were line with the outcome of [17,18]. The inverse proportion of pH with zinc might be due to a) high adsorption capacityof soil due to raise in pH dependent charge, b) increase in precipitation of zinc as $Zn(OH)_2$ [19]. Soluble organics complexes with zinc maintains solution concentration of zinc [20]. $CaCO_3$ exhibited highly significant negative correlation with solution zinc concentration [1].

Table 2. Physicochemical properties and nutrient status of the soil

Soil Properties	Range	Mean	Standard deviation	CV
pH	7.12 - 8.66	8.02	0.414	0.051
EC (dS m^{-1})	0.26 - 0.67	0.47	0.115	0.245
Organic carbon (%)	0.23 - 1.52	0.83	0.325	0.394
Free $CaCO_3$ (%)	0.50 - 12.50	4.10	3.815	0.930
CEC (Cmol $(p^+)kg^{-1}$)	11 - 26	18.52	4.099	0.221
Clay (%)	16.4 - 31.5	23.57	4.143	0.175
DTPA – Zn (mg kg^{-1})	0.24 - 3.31	1.32	0.841	0.637
DTPA – Fe (mg kg^{-1})	2.68 - 22.31	10.29	5.448	0.529
DTPA – Cu (mg kg^{-1})	0.85 - 7.11	3.57	2.095	0.586
DTPA – Mn (mg kg^{-1})	1.19 - 24.56	10.72	6.286	0.586
Total Zn (mg kg^{-1})	15.61 - 46.12	26.86	7.599	0.282
Total Fe (mg kg^{-1})	30.69 - 15.24	52.28	14.616	0.279
Total Cu (mg kg^{-1})	15.24 - 41.68	28.18	7.650	0.270
Total Mn (mg kg^{-1})	40.20 - 78.62	59.73	10.821	0.181

Number of samples = 25 ; CV = coefficient of variation

3.2.2 DTPA-Fe

The DTPA-Fe content in soil was ranged from 2.68-22.31 mg kg^{-1} with a mean value of 10.29 mg kg^{-1}. The data indicated that 24 per cent of collected samples were deficient in Fe. The iron content were significantly and positively correlated with organic carbon and clay content of the soil. The results follows the line of Mondal *et al*. [21]. Fe availability greatly affected by pH and $CaCO_3$ content. The increase in pH results in Fe precipitation as $Fe(OH)_3$ and $CaCO_3$ favours the oxidation of Fe from Fe^{2+} to Fe^{3+} by CO_3^- and also precipitation of Fe as $FeCO_3$. Adsorption of Fe on surface of $CaCO_3$ is also the reason for reduction in zinc concentration in soil [22,23]. The organic matter positive correlation may due to higher microbial activity, higher dissolution of Fe increase in solution concentration and complexation of Fe leads to reduce the adsorption precipitation, oxidation and crystallization of Fe compounds [24,25].

3.2.3 DTPA-Cu

The soil available copper (DTPA-Cu) was observed to lie in the range between 0.85 and 7.11 mg kg^{-1} with a mean value of 3.57 mg kg^{-1}. The pH and $CaCO_3$ showed a significant negative correlation with DTPA-Cu content. The positive correlation were observed with organic carbon and clay content. The results of Sharma et al., [26] and Meena et al., [27] showed identical results with the results of the current study. The high negative influence of pH towards available copper might be due to be adsorption, fixation and precipitation. When pH increase more than 6, Cu starts precipitating as Cu(OH)n or CuO. The binding attraction of copper with inorganic and organic matter depends on pH, oxidation reduction potential of the local environment. Carbonate involves in the fixation of Cu as $Cu_2(CO_3)(OH)_2$ and $Cu_3(CO_3)_2(OH)_2$. [28]. In many cases, organic matter content reduces the copper availability due to higher affinity of Cu towards the organic matter (humic acids) but increase in organic matter, subsequent increase in dissolved organic carbon which captures the copper in solution and reduces the adsorption and precipitation [29].

3.2.4 DTPA-Mn

Regarding manganese, the DTPA-Mn ranged from to 1.19 to 24.56 mg kg^{-1}. Mn had a significant positive correlation with clay content of the soil whereas the negative correlation was observed with pH. The results were in line with the outcome of Sharma et al. [30] and Chinchmalatpure et al. [31]. Mn were prone to leaching in water saturated coarse grained soils. In fine textured soils, Mn retention increases with increase in clay content Meena et al., [32]. Clay act as a site for nutrient holding. At elevated $CaCO_3$ and pH formation of low solubility of compounds like $MnCO_3$ or $Mn(OH)_2$ will be formed. The higher pH favours the formation of less soluble organic complexes of Mn, which reduces the availability of Mn [33].

Table 3. Correlation between available micronutrients and soil properties

Soil Properties	**Zn**	**Fe**	**Cu**	**Mn**	**Soil Properties**	**Zn**	**Fe**	**Cu**	**Mn**
pH	-0.473^{*}	-0.600^{**}	-0.709^{**}	-0.585^{**}	Avail. Fe	0.497^{*}	1	0.481^{*}	0.543^{**}
EC	-0.228	-0.228	-0.204	-0.174	Avail. Cu	0.313	0.481^{*}	1	0.236
OC	0.645^{**}	0.489^{*}	0.516^{**}	0.469^{*}	Avail. Mn	0.522^{**}	0.543^{**}	0.236	1
$CaCO_3$	-0.548^{**}	-0.601^{**}	-0.415^{*}	-0.317	Total Cu	-0.09	0.123	-0.112	-0.114
CEC	0.131	0.39	0.302	0.483^{*}	Total Fe	-0.197	-0.223	-0.057	-0.017
Clay	0.515^{**}	0.480^{*}	0.439^{*}	0.654^{**}	Total Zn	0.02	0.073	-0.148	-0.356
Avail. Zn	1	0.497^{*}	0.313	0.522^{**}	Total Mn	0.401^{*}	0.454^{*}	0.043	0.368

**. Correlation is significant at the 0.01 level   **. Correlation is significant at the 0.05 level*

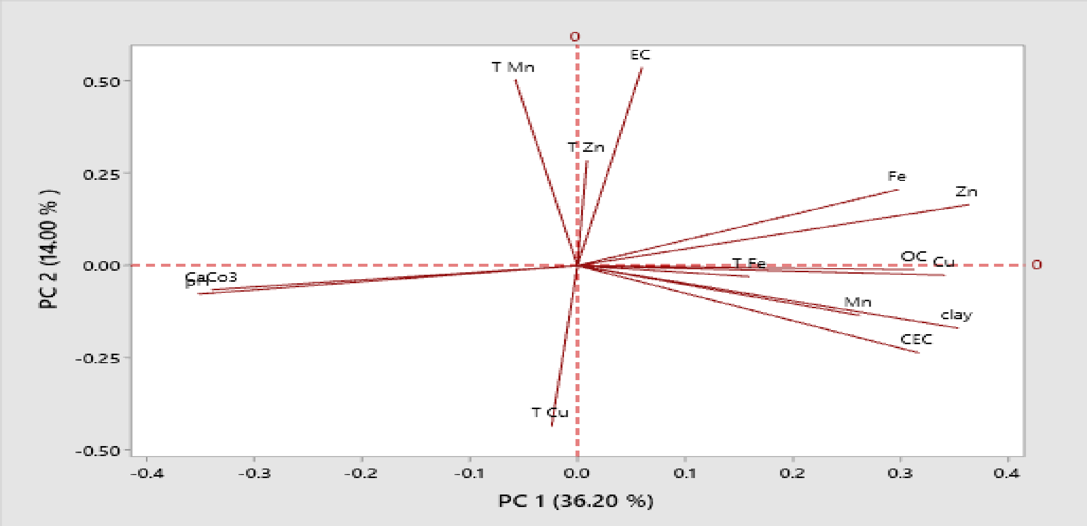

Fig. 1. PCA Results for relationship between micronutrient content and soil properties

The results of principle component analysis confirms the above results that pH and $CaCO_3$ content of soil showed a significant negative relationship especially observed with available micronutrients (Fig. 1). There is a feeble relationship between total and available micronutrients. With two principle component (PC 1- 36.02 and PC 2 -14.0) shows the cumulative variability 50.02 per cent. Among the soil properties, highly influencing variables were pH, $CaCO_3$, OC, Clay and CEC.

4. CONCLUSION

The outcome of present study showed that there is a significant relationship between the inherent soil factors to the bioavailability and distribution of micronutrient cations. Soil pH act as a major driving factor which greatly reduces the availability of micronutrients whereas organic carbon enhances the availability of micronutrients. Electrical conductivity was non-significant with the availability of micronutrients in the surveyed soils. To conclude that the bioavailability of micronutrient can be predicted by soil inherent properties to a certain extent possible. In order to get a accurate prediction, other climatic and environmental factors also to be considered.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Najafi-Ghiri M, Ghasemi-Fasaei R, Farrokhnejad E. Factors affecting micronutrient availability in calcareous soils of Southern Iran. Arid Land Research and Management. 2013;27(3):203-15.
2. Moreno-Jiménez E, Plaza C, Saiz H, Manzano R, Flagmeier M, Maestre FT. Aridity and reduced soil micronutrient availability in global drylands. Nature sustainability. 2019;2(5):371-7.
3. Neenu S, Ramesh K. Weather–Micronutrient Interactions in Soil and Plants–A Critical Review.
4. Singh MV. Micronutrient deficiencies in crops and soils in India. InMicronutrient deficiencies in global crop production Springer, Dordrecht. 2008; 93-125.
5. Selvaraj, KN, Ramasamy, C. Drought, agricultural risk and rural income: Case of a water limiting rice production environment, Tamil Nadu. Economic and Political Weekly. 2006;2739-2746.
6. Jackson ML. Soil chemical analysis prentice hall of India. Pvt. Ltd. New Delhi. 1973;498.
7. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed

modification of the chromic acid titration method. Soil Science. 1934;37(1):29-38.
8. Piper CS. Soil and plant analysis, Hans. Pub. Bombay. Asian Ed. 1966:368-74.
9. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Science Society of America Journal. 1978;42(3):421-428.
10. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John Wiley & Sons; 1984.
11. Lal R, Eswaran H, Kimble JM, Stewart BA. Global climate change: Cold region ecosystems. Ohio State Univ., Columbus, OH (US); 2000.
12. Li Y, Zhang W, Aydin A, Deng X. Formation of calcareous nodules in loess–paleosol sequences: Reviews of existing models with a proposed new per evapotranspiration model. Journal of Asian Earth Sciences. 2018;154:8-16.
13. IMAS P. Nutrient Management for Sustaining Crop Yields in Calcareous Soils. Balanced Nutrition of Groundnut and Other Field Crops Grown in Calcareous Soils of India. 2000;151.
14. Bowman WD, Cleveland CC, Halada Ĺ, Hreško J, Baron JS. Negative impact of nitrogen deposition on soil buffering capacity. Nature Geoscience. 2008; 1(11):767-70.
15. Najafi S, Jalali M. Effect of heavy metals on pH buffering capacity and solubility of Ca, Mg, K, and P in non-spiked and heavy metal-spiked soils. Environmental monitoring and assessment. 2016 Jun 1;188(6):342.
16. Grover SP, Butterly CR, Wang X, Tang C. The short-term effects of liming on organic carbon mineralisation in two acidic soils as affected by different rates and application depths of lime. Biology and Fertility of Soils. 2017;53(4):431-43.
17. Sharma BD, Arora H, Kumar R, Nayyar VK. Relationships between soil characteristics and total and DTPA-extractable micronutrients in Inceptisols of Punjab. Communications in Soil Science and Plant Analysis. 2004;35(5-6):799-818.
18. Rutkowska B, Szulc W, Bomze K, Gozdowski D, Spychaj-Fabisiak E. Soil factors affecting solubility and mobility of zinc in contaminated soils. International Journal of Environmental Science and Technology. 2015;12(5):1687-94.
19. Alloway BJ. Soil factors associated with zinc deficiency in crops and humans. Environmental Geochemistry and Health. 2009;31(5):537-48.
20. Stephan CH, Courchesne F, Hendershot WH, McGrath SP, Chaudri AM, Sappin-Didier V, Sauvé S. Speciation of zinc in contaminated soils. Environmental Pollution. 2008;155(2):208-16.
21. Mondal AK, Rai AP, Wali P, Kumar M. Available micronutrient status and their relationship with soil properties of vegetable growing area of Jammu district. Progressive Horticulture. 2015;47(1):95-8.
22. Sharma RÁ, Singh M, Sharma JÁ. Correlation studies on micronutrients vis-à-vis soil properties in some soils of Nagaur district in semi-arid region of Rajasthan. Journal of the Indian society of soil science. 2003;51(4):522-7.
23. Tao R, Fei Y. Recycled calcium carbonate is an efficient oxidation agent under deep upper mantle conditions. Communications Earth & Environment. 2021;2(1):1-8.
24. Zanelli R, Egli M, Mirabella A, Giaccai D, Abdelmoula M. Vegetation effects on pedogenetic forms of Fe, Al and Si and on clay minerals in soils in southern Switzerland and northern Italy. Geoderma. 2007;141(1-2):119-29.
25. Inda AV, Torrent J, Barrón V, Bayer C, Fink JR. Iron oxides dynamics in a subtropical Brazilian Paleudult under long-term no-tillage management. Scientia Agricola. 2013;70:48-54.
26. Sharma BD, Brar JS, Chanay JK, Sharma P, Singh PK. Distribution of forms of copper and their association with soil properties and uptake in major soil orders in semi-arid soils of Punjab, India. Communications in Soil Science and Plant Analysis. 2015;46(4):511-27.
27. Sharma BD, Brar JS, Chanay JK, Sharma P, Singh PK. Distribution of forms of copper and their association with soil properties and uptake in major soil orders in semi-arid soils of Punjab, India. Communications in Soil Science and Plant Analysis. 2015;46(4):511-27.
28. Alloway BJ, editor. Heavy metals in soils: trace metals and metalloids in soils and their bioavailability. Springer Science & Business Media; 2012 Jul 18.
29. Dierkes C, Geiger WF. Pollution retention capabilities of roadside soils. Water Science and Technology. 1999;39(2):201-8.

30. Sharma BD, Choudhary OP, Chanay JK, Singh PK. Forms and uptake of manganese in relation to soil taxonomic orders in alluvial soils of Punjab, India. Communications in Soil Science and Plant Analysis. 2016;47(3):313-27.
31. Chinchmalatpure AR, Brij L, Challa O, Sehgal J. Available micronutrient status of soils on different parent materials and landforms in a micro-watershed of Wunna catchment near Nagpur (Maharashtra). Agropedology. 2000;10(1):53-8.
32. Meena RS, Rao SS, Natarajan A, Hegde R, Singh SK. Available micronutrients in soils of chikkarsinkere hobli of maddur taluk, mandya district of karnataka. Journal of Plant Development Sciences. 2017; 9(3):229-33.
33. Singh DP, Yadav KK, Qureshi FM. Available micronutrient status, their relationship with soil physico-chemical properties and content in wheat crop of semi-arid eastern plain zone of Rajasthan. Green Farm. 2013;4:137-42.

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