RESEARCH ARTICLE

Geospatial Distribution of Copper in the Intensively Rice Growing Soils of Madurai District, Tamil Nadu

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Abstract

The present study was undertaken to assess the status of available copper (Cu) in the intensively rice growing soils of Madurai district, Tamil Nadu. A total of 235 geo referenced surface soil samples were collected and analysed for plant available Cu and simple correlation was worked out to ascertain the degree of relationship between soil properties and available Cu content of soils of the study area. Plant available Cu in the entire rice growing soils ranged from 0.08 to 9.50 mg kg^{-1}. Out of two hundred and thirty five locations of rice growing soils of Madurai district collected for the purpose of delineation of copper, 29.78 per cent of the soils were deficient in Cu status while 31.91 and 38.29 per cent areas were medium and high in available Cu. Among the soil properties, clay, silt and CEC had a positive influence on the availability of Cu whereas, sand, pH, OC and $CaCO_3$ content had negative influence on available copper. The step-wise multiple regression equation in general indicated that the pH, CEC, OC and sand accounted for 54.50 per cent variation in available Cu in the soils of study area.

Keywords: *Available copper, Soil physico-chemical properties, Correlation and Multiple Regression*

Introduction

Rice is the most important food crop in India, covering about one-fourth of the total crop area and providing food to about half of the Indian population. Micronutrients play a vital role in crop growth, crop productivity, soil fertility and human nutrition. Among the micronutrients, Cu plays an important role in the crop growth by increasing tillering and pollen viability of the crop (Das, 2014). Copper serves as effector, stabilizer and inhibitor, and also as catalyst of oxidation reaction. It is particularly important for N, proteins and hormone metabolism. At the same time, it is involved in photosynthesis and respiration mechanisms, which ultimately affect pollen formation and fertilization. The total Cu content in Indian soils ranged from 45 to 69 mg kg^{-1} and the available Cu content ranged from 0.10 to 378 mg kg^{-1}. In Tamil Nadu, soils were recorded more than 25 per cent of copper deficiency (Shukla *et al.*, 2014). Rice plants grown in soils under submergence often suffer from Cu deficiency (Ponnamperuma *et al.*, 1981). Therefore, this research examined the distribution and primary factors influencing Cu deficiency in the rice growing soils of Madurai district.

Material and Methods

Soil Analysis

The study was undertaken in rice growing soils of Madurai district of Tamil Nadu. It geographically lies between 78.12° longitude and 9.93°latitude. The climate of this region is semi-arid with an annual rainfall of 832 mm. The soils of Madurai district comprise of red, black and alluvial soil groups with rice, pulses, cotton and other millets as major crops. A total of 235 geo-referenced soil samples (0-15 cm) covering all rice growing villages in eight blocks (Alanganallur, Madurai east, Madurai west, Melur, Sedapatti, Thirumangalam, Usilampatti and Vadipatti) were collected during 2017 using Garmin GPS instrument (Fig.1). The soil samples were air dried, gently powdered with wooden mallet and sieved through 2mm plastic sieve. The processed soil samples were analyzed for pH, EC (1:2.5 soil-water suspension), texture (International Pipette method), Organic carbon (Walkley and Black method), $CaCO_3$ (Piper method), CEC (NH_4OAc extraction method) following the standard procedures given by Jackson (1973).

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Extraction of copper

The available Cu status in the soil was determined through DTPA extractable method proposed by Lindsay and Norvell (1978). By adopting the critical levels of available copper less than 1.2, 1.2-1.8 and more than 1.8 mg kg^{-1} (AICRP Report, 2003), the soils were categorized into low, medium and high, respectively.

Statistical and Spatial Analysis

The pearson correlation coefficients were estimated for all possible paired combinations of the response variables to generate a correlation coefficient matrix. These statistical parameters were calculated with SPSS 16.0® software (SPSS Inc., Chicago, Ill., USA). The multiple regression equations were also arrived at as per the method described by Fisher (1936). The study area boundary was digitized from base map using ArcGIS-10 environment and polygonized. The geo coordinates of sampling sites with copper status database was fed into the Arc GIS environment and point feature shape file was created. Finally the point feature shape file was transformed in to thematic map by spatial interpolation technique of kriging.

Results and Discussion

Particle size distribution

The soil properties of rice growing soils of Madurai district are given in the table 1. Out of 235 villages selected in eight blocks, 71 villages belonged to fine textured (clay loam) and rest of the villages fell under moderately fine textured group (sandy clay loam).

Table 1.Soil properties of rice growing soils of Madurai district

Block name	pH (1:2.5)	EC (dS m^{-1})	CEC (cmol(p+) kg^{-1})	OC (g kg^{-1})	CaCO3 (%)	Sand (%)	Silt (%)	Clay (%)	Texture
Alanganallur (30)*	6.17-8.69 (7.52)	0.03-0.73 (0.16)	10.4-30.58 (20.02)	0.08-0.45 (0.29)	0.23-3.05 (1.59)	28.75-51.89 (43.08)	15.72-34.71 (23.48)	28.12-37.58 (32.36)	SCL(18)*, CL(12)*
Madurai east (34)*	6.30-8.61 (7.51)	0.1-0.86 (0.22)	10.4-30.58 (19.98)	0.03-0.45 (0.23)	0.55-2.58 (1.52)	25.56-51.72 (45.05)	16.46-37.51 (22.68)	27.46-36.85 (31.03)	SCL(26)*, CL(8)*
Madurai west (26)*	6.55-8.88 (7.45)	0.1-0.70 (0.26)	8.33-23.82 (16.74)	0.05-0.43 (0.23)	0.53-2.60 (1.47)	31.56-60.98 (49.48)	8.78-30.45 (18.07)	25.14-37.57 (31.16)	SCL(20)*, CL(6)*
Melur (31)*	6.60-8.76 (7.53)	0.1-0.66 (0.19)	7.45-27.22 (19.23)	0.05-0.44 (0.21)	0.72-2.62 (1.54)	32.57-65.02 (51.78)	9.83-29.28 (17.33)	19.45-37.46 (29.73)	SCL(26)*, CL(5)8
Sedapatti (28)*	6.50-8.45 (7.67)	0.1-0.40 (0.18)	8.25-36.47 (20.94)	0.03-0.71 (0.19)	0.64-2.41 (1.70)	30.25-54.78 (43.37)	14.67-31.67 (22.58)	28.09-36.85 (32.86)	SCL(16)*, CL(12)*
Thirumangalam (36)*	6.71-8.40 (7.54)	0.1-0.50 (0.18)	11.20-36.47 (23.35)	0.03-0.44 (0.22)	0.78-2.45 (1.59)	30.2651.72 (44.08)	15.78-32.56 (22.75)	27.89-37.56 (31.70)	SCL(24)*, CL(12)*
Usilampatti (24)*	6.59-8.82 (7.68)	0.1-0.49 (0.22)	10.26-36.40 (21.54)	0.03-0.36 (0.17)	0.73-2.67 (1.63)	30.35-51.85 (43.75)	14.67-32.45 (23.18)	28.63-36.34 (31.93)	SCL(15)*, CL(9)*
Vadipatti (26)*	6.81-8.60 (7.58)	0.1-0.6 (0.26)	12.18-30.36 (19.71)	0.03-0.44 (0.28)	0.85-2.54 (1.59)	32.28-58.96 (46.67)	9.17-30.56 (20.90)	27.89-36.85 (31.33)	SCL(19)*, CL(7)*
SD	0.08	0.04	1.91	0.40	0.07	3.18	2.40	0.95	
CV (%)	1.05	18.00	9.45	18.01	4.45	6.94	11.22	3.01	

Values within parenthesis are average values. *Values within parenthesis are number of villages.

The overall variation in texture of these soils from moderately fine texture to fine texture could be attributed to the variations in the intensities of weathering processes and also due to the nature of the parent materials from which such textural particles are generated.

The DTPA extractable Cu increased with increasing clay content and a significant positive correlation with silt and clay also supported these results. Thus, a soil having greater surface is expected to adsorb greater amount of Cu and *vice-versa*. Increase in the finer fraction of the soil leads to increase in the surface area for ion exchange and hence can contribute to greater DTPA extractable Cu. In addition to clay minerals, organic and inorganic soil colloids also provide the exchange sites that retain the plant nutrient elements. The positive relationship of micronutrients and clay observed by Sharma *et al*. (2006) and Bhanwaria *et al*. (2011) lend support to the present work.

Physico-chemical properties

Soil pH regulates the solubility of nutrients and thus has a pronounced effect on its availability to the growing plants. The soil pH is slightly acidic to slightly alkaline in reaction (6.17 and 8.88) in the entire rice growing blocks of Madurai district.

Table 2. Available copper status in rice growing soils of Madurai district

Block name	Available Cu (mg kg^{-1})		
	Min.	Max.	Mean
Alanganallur (30)	0.31	5.04	1.73
Madurai east (34)	0.73	6.94	2.90
Madurai west (26)	0.73	2.64	1.44
Melur (31)	0.22	6.36	1.82
Sedapatti (28)	0.62	5.36	1.67
Thirumangalam (36)	0.19	4.64	0.92
Usilampatti (24)	0.65	5.50	2.12
Vadipatti (26)	0.08	9.50	1.99
Mean	0.44	5.75	1.82
	SD		0.57
	CV (%)		31.23

Values within parenthesis are number of villages.

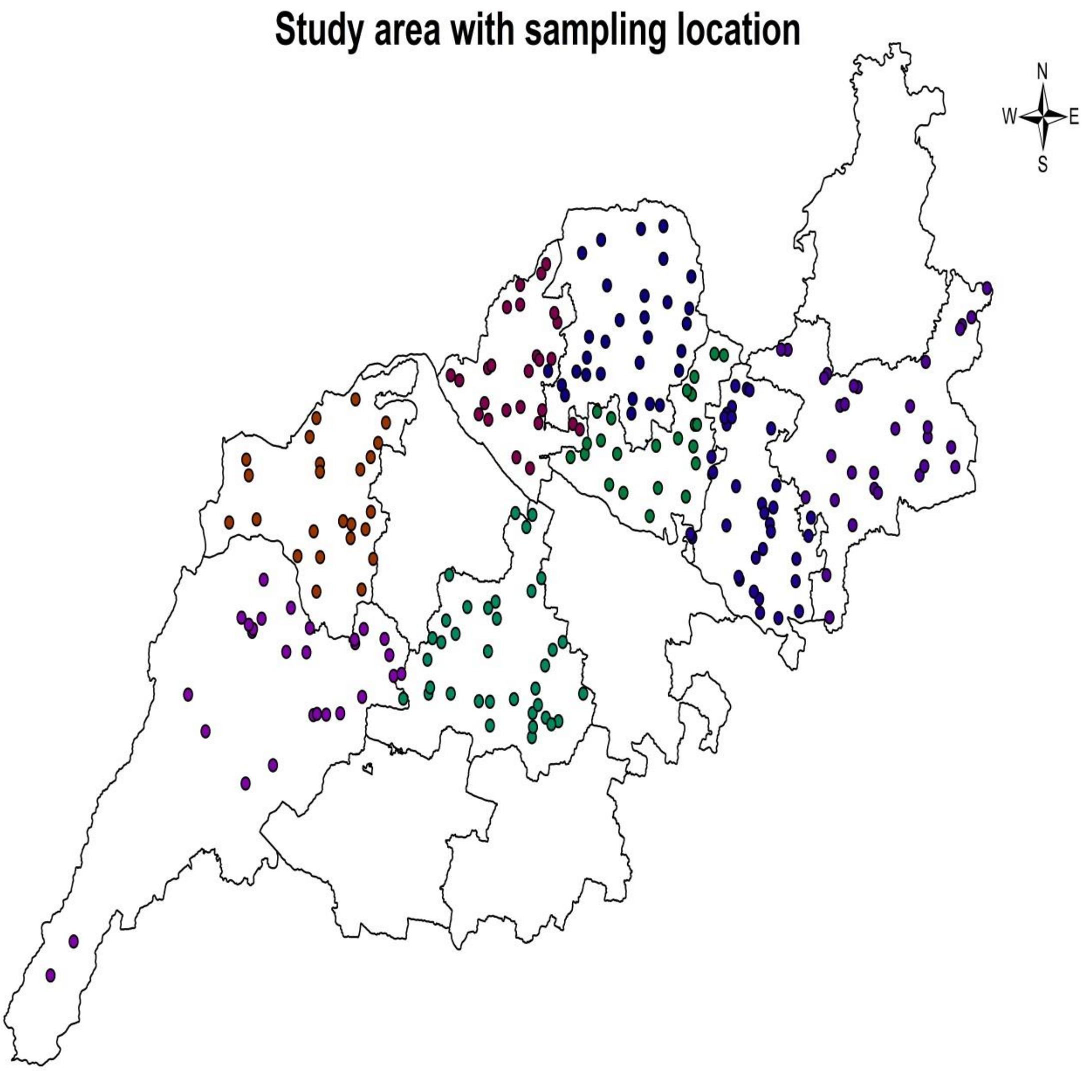
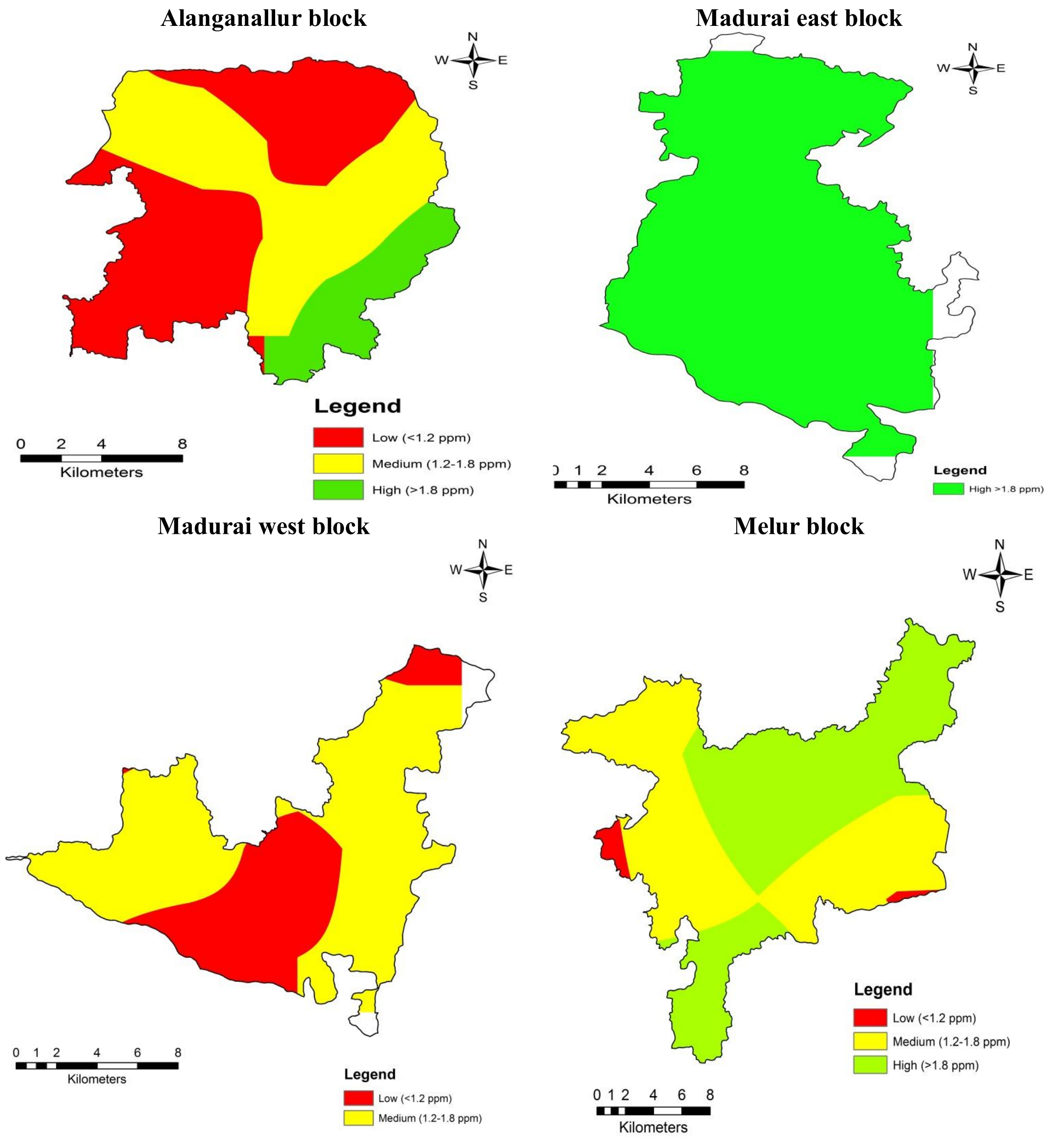


Fig.1. Study area with sampling location

Table 3. Correlation between the soil properties and soil available copper

	Cu	pH	EC	CEC	OC	CaCO3	Sand	Silt	Clay
Cu	1.00**								
pH	-0.57**	1.00							
EC	0.00	0.01	1.00						
CEC	0.51**	-0.39**	-0.09	1.00					
OC	-0.44**	0.35**	0.07	-0.33**	1.00				
CaCO3	-0.48**	0.89**	-0.02	-0.32**	0.27**	1.00			
Sand	-0.47**	0.19**	-0.04	-0.37**	0.15*	0.16*	1.00		
Silt	0.46**	-0.18**	0.03	0.39**	-0.15*	-0.15*	-0.96**	1.00	
Clay	0.41**	-0.16**	0.05	0.28**	-0.12	-0.13*	-0.86**	0.70*	1.00

**Significant at 0.01 level
*Significant at 0.05 level



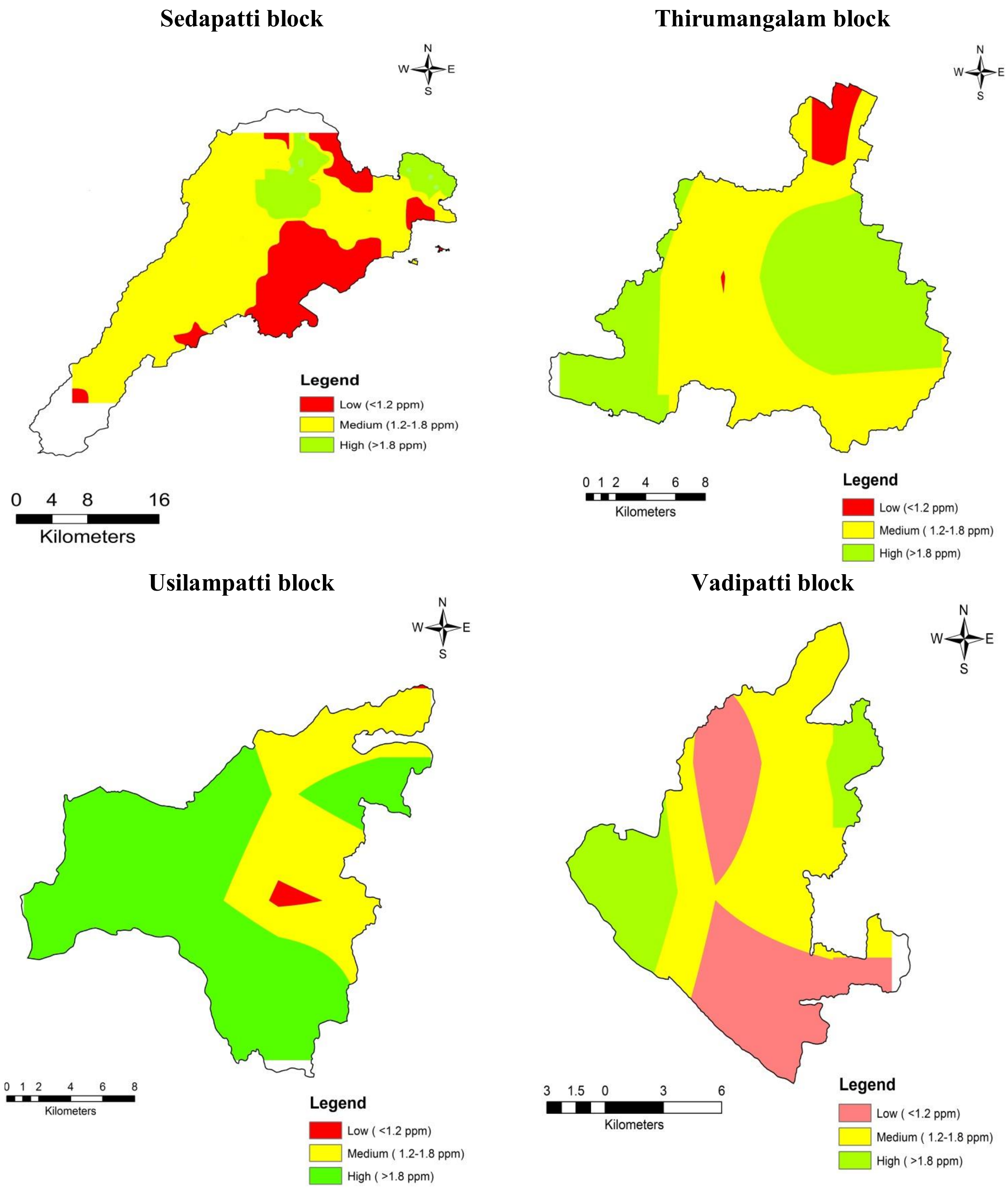


Fig.2. Available copper status in the intensively rice growing soils of Madurai district

Most of the sampling soils were non-saline with EC values varied from 0.03 to 0.86 dS m^{-1} in the entire rice growing blocks. The cation exchange capacity (CEC) of the soils varied from 7.45 to 31.47 cmolp(+) kg^{-1} in the rice growing blocks of Madurai district. Among the eight blocks, Thirumangalam and Madurai west blocks recorded the highest and lowest CEC of 23.35 and 16.74 cmolp(+)kg^{-1} respectively. Similar observation was also reported by Chaudhari *et al*. (2012).

Chemical properties

The soil organic carbon (SOC) content in the rice growing blocks of Madurai district varied from 0.3 to 7.1 g kg^{-1}. Most of soil samples under study were found to be low in OC content. The low OC content of these soils may be attributed to the high temperature in the study area during summer season, which is responsible for hastening the rate of oxidation of carbon. These results are in conformity with the views of Tur *et al*. (2005).The $CaCO_3$ content of the soils of varied from 0.23 and 3.05% in the entire rice growing blocks of Madurai district. Higher accumulation of $CaCO_3$ might be due to low intensity of rainfall leading to poor leaching of the initially precipitated $CaCO_3$ in heavy textured soils and low values of $CaCO_3$ content in moderately coarse textured soils could be attributed to the erosion of $CaCO_3$ by the percolating water (Mayalagu ,1971).

DTPA extractable Cu

Range and mean value of DTPA extractable copper of soils are given in the table 2. The available copper content varied from 0.08 to 9.50 mg kg^{-1} in the entire rice growing blocks of Madurai district. The wide variability in Cu content in the experimental area is mainly due to variation in soil reaction, organic carbon, calcium carbonate and clay contents. The highest mean DTPA-Cu was observed in the soils of Madurai east (2.9 mg kg^{-1}) followed by Usilampatti (2.12 mg kg^{-1}), Vadipatti (1.99 mg kg^{-1}), Melur (1.82 mg kg^{-1}), Alanganallur (1.73 mg kg^{-1}), Sedapatti (1.67 mg kg^{-1}), Madurai west (1.44 mg kg^{-1}) and Thirumangalam (0.92 mg kg^{-1}). The natural concentration of Cu in soils depends upon primarily on the geochemistry of the parent material and exhibited high spatial variability over heterogeneous lithologies (Mico *et al.,* 2006). Concentration of Cu in the soil can be influenced by soil properties, such as pH, organic matter, CEC, content of clay, fine silt, and coarse sand and variation of these properties in the villages of study area might be the reason for varied concentration of copper.

Considering the critical limit of Cu (<1.2 mg kg^{-1}) suggested for Tamil Nadu soils (Shukla *et al.*, 2014), the highest per cent deficiency of DTPA-Cu in soils was noticed in Sedapatti block (42.8%) followed by Madurai west (34.6%), Melur (32.3%), Vadipatti (30.8%), Usilampatti (29.2%), Thirumangalam (25.0%), Madurai east (23.5%) and Alanganallur (23.3%) (Fig.2). It was observed that high CaCO3 content and high pH could be the reason for deficiency of Cu in these soil samples. Decreased availability of Cu at high pH might be due to precipitation of Cu as its hydroxides and carbonates (Ibrahim and Umar, 2012).

Out of the two hundred and thirty five locations of rice growing soils of Madurai district from where surface soil samples were collected for the purpose of delineation of copper deficient areas, 29.78 per cent of the soils were deficient in Cu status while 31.91 and 38.29 per cent areas were medium and high in available Cu, respectively indicating the major problem of Cu deficiency in these soils. There is a need for Cu fertilization at regular interval to maximize yield. Otherwise, the deficiency of Cu will gradually become a major constraint to the productivity of crops. The results resembles to the findings of Sharma *et al*. (2006).

Copper and its relationship with soil characteristics

A simple correlation was worked out to ascertain the degree of relationship between soil properties and DTPA extractable Cu of the study area were given in table 3. The correlation studies revealed that the copper content in the soil was significant negatively correlated with the soil parameters *viz*. pH (r=-0.57), OC (r=-0.44), organic matter (r=-0.44), $CaCO_3$ (r=-0.48) and sand (r=-0.47) and positively correlated with CEC (r=0.51), silt (r=0.46) and clay (r=0.41). Similar findings were reported by Sharma *et al*. (2005).

The multiple regression coefficients and step-down regression analysis were carried out to study the effect of soil properties on predictability of DTPA extractable copper. The dependence of DTPA- Cu on the soil properties is shown in the following equation:

$10.517-0.907X_1+0.041X_3-2.212X_4-0.045X_6$ with $R^2=0.545$....(1)

$12.741-1.030X_1-2.595X_4-0.053X_6$ with $R^2=0.520$....(2)

$13.751-0.056X_1-1.223X_6$ with $R^2=0.469$....(3)

$12.492-1.397X_1$ with $R^2=0.330$....(4)

Where X_1-pH, X_2-EC, X_3-CEC, X_4-OC, X_5-$CaCO_3$,X_6-Sand,X_7- Silt,, X_8-Clay

The multiple regression study indicated that the available Cu showed significant negative regression coefficients with pH, OC, sand and positive correlation with CEC. The step-wise multiple regression equation indicated that 33.00 per cent variation in available Cu was observed due to pH. On inclusion of CEC, OC and sand parameters increased the R^2 value to 54.50 per cent.

Conclusion

The present investigation revealed that the rice growing soils of study area were moderately fine textured to fine textured with nearly neutral to alkaline in reaction. In general, the soils were very low in soluble salts and organic carbon. Higher accumulation of $CaCO_3$ in heavy textured soils induced alkalinity problem in soils. The available Cu in the rice soils of the study area ranged from 0.08 to 9.50 mg kg^{-1}. Out of two hundred and thirty five locations of rice growing soils of Madurai district collected for the purpose of delineation of copper, 29.78 per cent of the soils were deficient in Cu status while 31.91 and 38.29 per cent areas were medium and high in available Cu based on existing low (< 1.2 mg kg^{-1}), medium (1.2-1.80 mg kg^{-1}) and high (>1.80 mg kg^{-1}) classification respectively. Geospatial distribution of copper for soil observed in this study will be highly useful for guiding the rice growing farmers to decide the optimum amount of copper to be applied for getting high yield and economic returns. Further, the findings of the present investigation underlines the importance of complete soil testing for micronutrient along with macronutrients which will pave the way for adoption of site specific micronutrient management for rice.

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