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Vertical distribution of soil available micronutrients and stock analysis under central mango belts of southern Karnataka, India

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ABSTRACT

Micronutrient deficiency due to exhaustive cultivation is an emerging threat to modern agriculture. Delineating spatial and vertical distribution of micronutrients along with site specific management for deep rooted crops is an effective strategy for sustainable agriculture. Current study was performed to investigate micronutrient distribution of soils under central mango belts region (CMB) of southern Karnataka, along with factors impacting its profile distribution. Six major taluks were selected on the basis of area production data, i.e. Sorab, Tarikere, Channagiri, Holalkere, Hunsur and Nagamangala. Soil profile analysis revealed, Sorab taluks under Hilly zone manifest the highest concentration of surface as well as control section micronutrient content. The micronutrient was found deficient in Nagamangala taluk under southern dry zone. Current study also delineated vertical distribution of micronutrient stock in soil where we have found Fe and Mn pools were dominated in surface soils (0-30 cm) and Cu and B pools were predominated in soil control section (30-100 cm). Soil boron stock impact the mango yields significantly for both the surface and control section. Correlation analysis revealed soil pH has the significant negative correlation with Fe, Mn, Cu and B whereas organic matter has the positive correlation with all the available micro nutrients. The measured soil properties and available micronutrients along with stocks correlations in CMB will be crucial for precise micronutrients management for sustaining yield and productivity.

Keywords: Micronutrients, Vertical and Spatial distribution, Micronutrient stock

INTRODUCTION

Soil degradation due to soil nutrient deficiency affects the global crop production and productivity in various parts of world, including Deccan Plateau of India (Lal, 2015; Bhattacharyya *et al.*, 2015; Biswas *et al.*, 2015). Alloway (2008) showed the wide-spread deficiencies of micro nutrients in world agricultural soils. Soil micronutrients like Zinc (Zn), Boron (B), Iron (Fe), Copper (Cu) and Manganese (Mn) deficiency in Indian soils due to intensive cultivation high yielding varieties reported by many researchers (Shukla *et al.*, 2014; 2015, 2016, & 2017). Soil inherent properties like parent material along with soil pH, organic carbon govern the availability of micronutrient pools in soils (Lindsay, 1979). Spatial and vertical variation of cationic micronutrients in soils is very much important specially for perineal deep-rooted crops like Mango. Karnataka is the third largest producer of mango in India and southern part of Karnataka is the major contributor for this huge production. Farmers from Central mango belts (CMB) under southern Karnataka have been introducing mango as a perineal land use to their land use systems from last two decades. Detailed knowledge of vertical distribution of different micronutrient pools is very much important to sustain and manage deep rooted cropping systems like Mango.

METHOD AND MATERIALS

Soil sampling was being carried out throughout the mango growing areas of central mango belts (CMB) under southern Karnataka. Our study covered five major agroclimatic zones, under six districts (Table 1). Sampling sites were chosen on the basis of area production data under CMB, the selected taluks were, Sorab, Tarikere, Channagiri, Holalkere, Hunsur and Nagamangala. Location details of the study areas along with climatic and soil moisture regime are given in Table 1.

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Table 1: Pedon location of the study areas

Agroclimatic zones	District	Pedon Location	Climatic Zone	Soil moisture regime (SMR)	Soil Order
Hilly zone (Hz)	Shimoga (Sorab)	14° 32' 48.1" N 75° 09' 48.0" E	Sub humid tropical (SHT)	Ustic	Alfisol
	Chikmagalur (Tarikere)	13° 39' 41.7" N; 75° 50' 05.4" E	Sub humid tropical (SHT)	Ustic	Alfisol
Central dry zone (CDz)	Davangere (Channagiri)	14° 10' 08.3" N 76° 03' 10.8" E	Semi-arid tropical (SAT)	Ustic	Alfisol
Northan transitional zone	Chitradurga (Holalkere)	14° 02' 59.8" N 76° 15' 58.4" E	Semi-arid tropical (SAT)	Ustic	Alfisol
Southern transitional zone	Mysore (Hunsur)	12° 17' 27.9" N; 76° 23' 37.0" E	Semi-arid tropical (SAT)	Ustic	Alfisol
Southern dry zone	Mandya (Nagamangala)	12° 54' 20.8" N 76° 44' 00.6" E	Semi-arid tropical (SAT)	Ustic	Inceptisol

Majority of the soils were classified under Alfisol except Nagamangala which came under Inceptisol. Soil profile were being digged upto the depth of the bedrock and from each identified horizons 2 kg soil sample were collected, processed and brought to lab for further analysis. Soil bulk density was measured through collecting the samples by core sampler and oven-dried at 105 °C. Soil pH was determined by using a glass electrode (1:2.5, soil/water ratio) and the following soils were used for measuring the electrical conductivity (EC). Soil organic carbon (SOC) was measured following the method of Walkley and Black (1934). Available Fe, Mn, Cu, and Zn in soil were extracted with 0.005M diethylene triamine penta acetic acid (DTPA), 0.1M $CaCl_2$, and 0.1M triethanolamine (TEA) with pH of 7.3, and determined by atomic adsorption spectrophotometer (Lindsay and Norvell, 1978). Boron is analysed through hot water extraction method. The obtained data were analysed with SPSS 20 statistical software, for correlation analysis. A significance level of $p<0.05$ and $p<0.01$ were chosen for detecting significant correlation. DTPA extractable soil micro nutrient pools were calculated by the following formula Jiang *et al.*, (2009):

$$MNs = \sum_{i=1}^{n} (MNi \times \rho i \times Ti)/10$$

where: *MNs* is DTPA-extractable Fe, Mn, Cu, or Zn pool (Mg/ha) at a given depths, *MN*i is the concentration of test micronutrient (g/kg) of layer i, *ρ*i is soil bulk density (g/cm^3) of layer i, *T*i is the thickness (cm) of layer i, and *n* is the number of layers.

RESULT AND DISCUSSION

Depth-wise distribution of DTPA extractable soil micro nutrients

In soil profile, micro nutrient concentration decreases with soil depth, highest concentration found in surface soils (Fig: 1). Fe concentration in soil profile followed the similar trend, except Nagamangala pedon. Average surface concentration was 45.57±39.85 ppm, highest found in Sorab soils (126.94 ppm) and lowest found in Nagamangala soils (5.98 ppm). Whereas average concentration of Fe in control section 11.6±10.76. Mn concentration followed the similar trend, decreased with depth. Average surface concentration 65.27±22.9 ppm whereas sub surface soils were having 20.95±10.04 ppm. Highest concentration was found in Sorab taluk (193.38 ppm), and lowest in Nagamangala taluk (6.66 ppm). Cu content was highest found in surface soils of Sorab (4.42 ppm) taluk, and lowest found in Nagamangala (1.08). Depth wise distribution found to be irregular for Channagiri, Holalkere and Nagamangala. Average Zn concentration for surface soils was 1.05±0.84 ppm and for control section was 0.19±0.09 ppm, highest found in the surface soils of Hunsur (2.74 ppm). B concentration reduced with the depth with a continuous process, surface and sub-surface concentration varied on an average 0.75±0.30 and 0.46±0.27 ppm, respectively. Critical limits of the cationic micronutrient for the soils were given in Table 2. Fe and Mn concentration for the surface soils were sufficient, except Nagamangala, which comes

Table 2: Critical limits of micronutrients in soil

Content	Micronutrients (ppm)			
	Fe	Mn	Cu	Zn
Deficit	<4.5	<2.5	<0.2	<0.6
Marginal	4.5-9.0	2.5-3.5	0.2-0.4	0.6-1.2
Sufficient	9.0-18.0	3.5-7.0	0.4-0.8	1.2-2.4
High	18-27	>7.0	0.8-1.6	>2.4
Very high	>27	-	>1.6	-

Source; Lindsay and Norvell, 1978

under marginal in concentration. The trend in higher micronutrient concentration in surface soils than the control section due to higher organic carbon accumulation and lower calcium carbonate contents (Venkatesh *et al.*, 2001; Sharma *et al.*, 2006; Sharma and Chaudhary, 2007; Nadaf *et al.*, 2022). Cu and Zn concentration was found to be sufficient but B content found to be deficient in the soils of Nagamangala and Holalkere taluks. Plant cycling was considered as the leading factor, and anthropogenic disturbance and leaching were the secondary factors that affecting the vertical distributions and topsoil accumulation of nutrients under different land uses (Jobbáge and Jackson 2001, Jiang *et al.*, 2006). Higher spatial variability of cationic micronutrient had been found for varied agroclimatic zones, which might be due to diversity of weathering regimes and pedogenic process (Bowen, 1979).

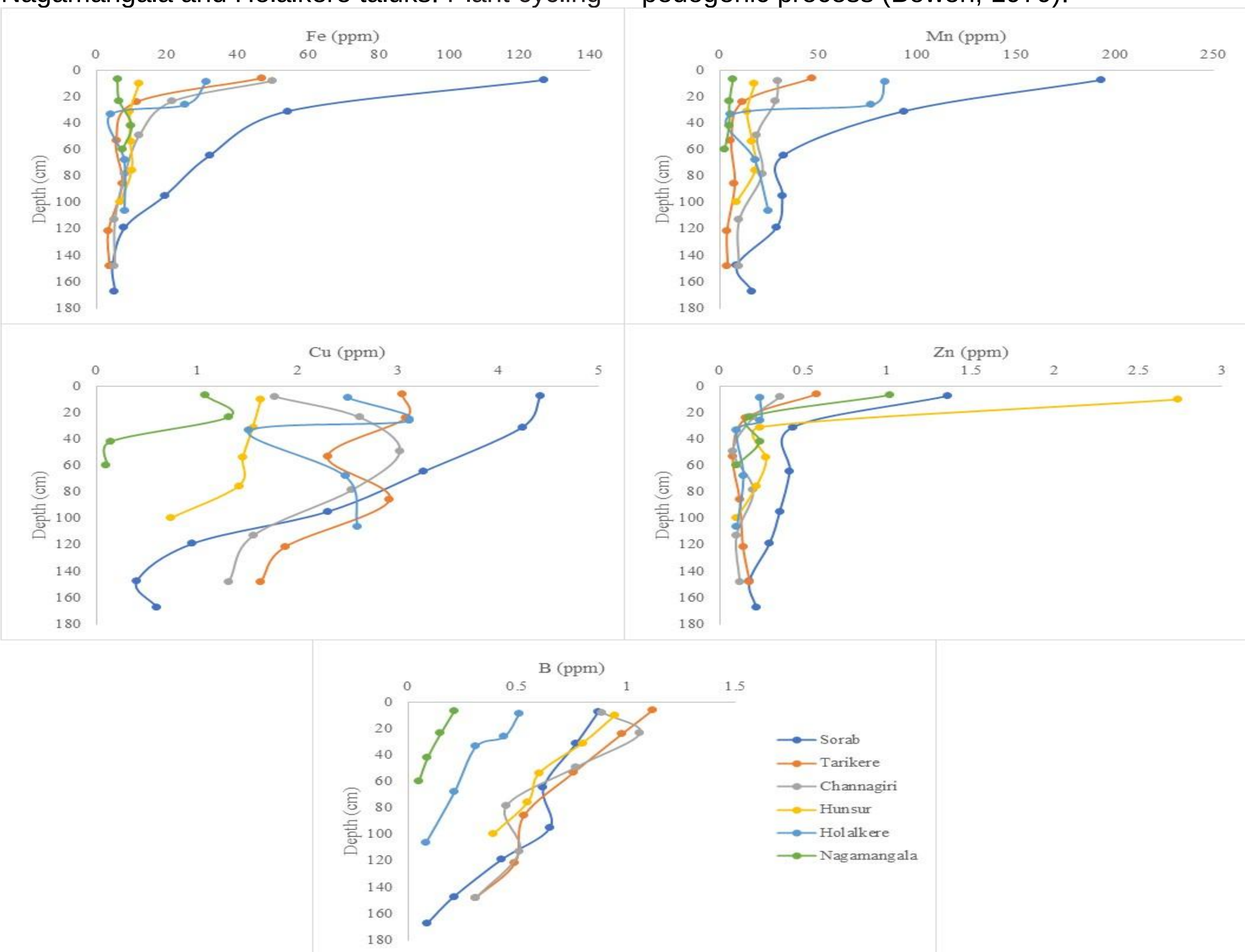

Fig 1: Vertical distribution of micronutrients (Fe, Mn, Cu, Zn and B) under different taluks of Central mango belts of southern Karnataka

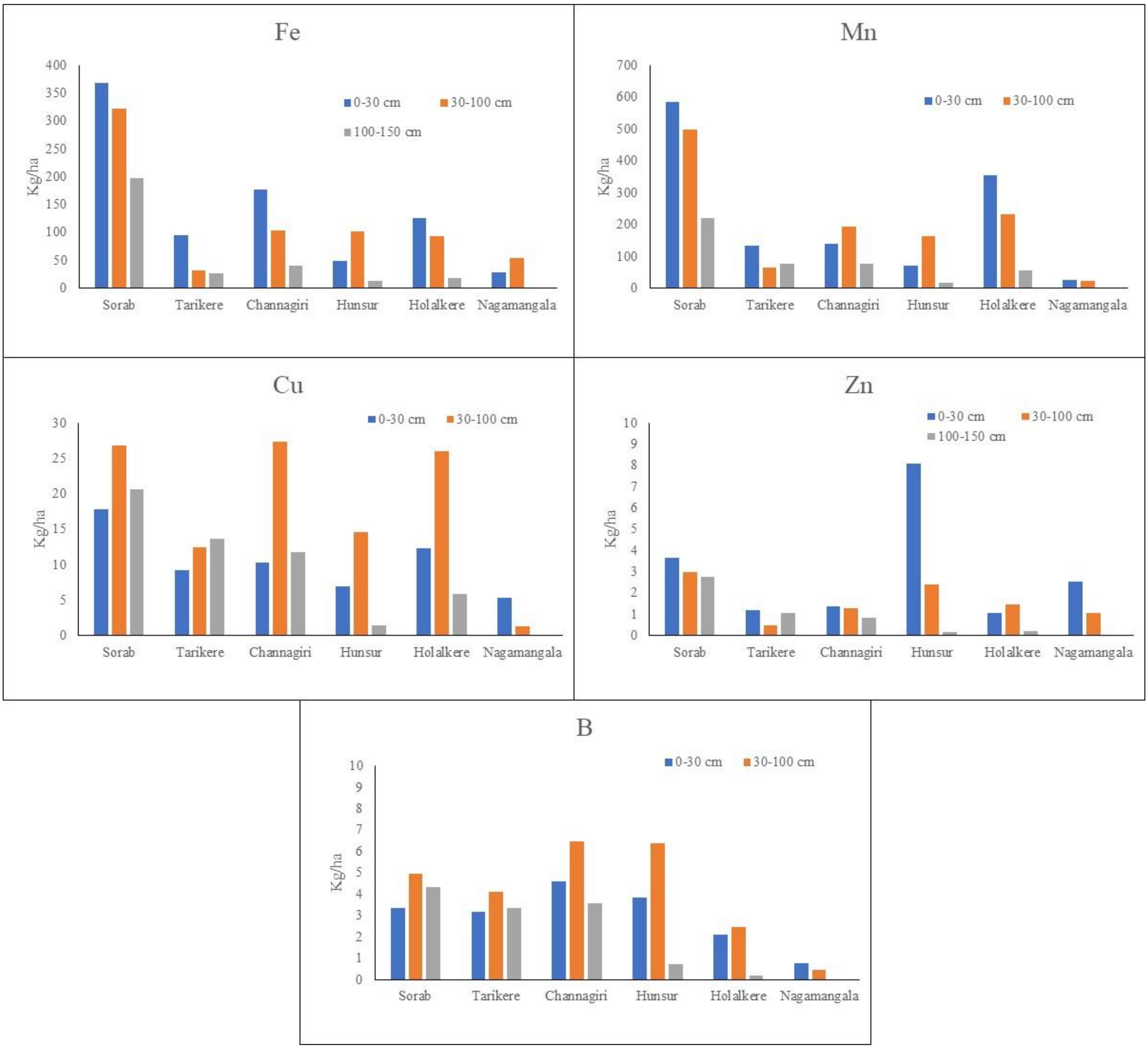

Fig 2: Vertical distribution of micronutrient stocks under different taluks of Central mango belts of southern Karnataka

Spatial and vertical distribution of DTPA-extractable soil micro nutrient pools

The differences of DTPA-extractable soil micro nutrient pools under varied climate and taluks were shown in Figure 2. For both Fe and Mn pools, Sorab taluk manifest highest concentration in surface soils; i. e., 368.13 kg/ha and 583 kg/ha respectively. Similarly, the lowest values were shown under Nagamangala taluk for both Fe and Mn pools; i.e. 27.82 kg/ha and 25.46 kg/ha, respectively. Depth distribution of Fe concentration had shown direct impact on Fe stock, where highest concentration was found in surface soils (0-30 cm) except Nagamangala and Hunsur. Whereas the similar trend followed for Mn pools, except Channagiri and Hunsur taluks. Cu stock highest found for soil control section (30-100 cm) for all the taluks except Nagamangala soils. Channagiri taluk found to be highest in total Cu pools (27.34 kg/ha), whereas Nagamangala manifest the lowest (1.29 kg/ha) within the taluks. Avarage Zn stock for the surface (0-30 cm) varied significantly varied within the taluks (2.97±2.21 kg/ha), highest found in Hunsur (8.08 kg/ha). Depth distribution of Zn and Cu found to be similar with the results of Jiang *et al.*, 2009. B stock found to be highest in sub surface soils (4.13±2.01 kg/ha) than the surface soils (2.98±1.24 kg/ha). Table 3 showed the relationship under different micronutrient pools with average yield of the taluks. Boron stock is found to be significantly co-related with both surface and sub-surface soils (r=0.90, $p<0.05$), manifest the importance of B for quality and production of Mango.

Table 3: Correlation study of soil micronutrient stock of surface (0-30 cm) and soil control section (30-100 cm) with average yield of different taluks

	Fe		Mn		Cu		Zn		B	
Depth (cm)	0-30	30-100	0-30	30-100	0-30	30-100	0-30	30-100	0-30	30-100
Correlation coefficient	0.53	0.30	0.23	0.37	0.43	0.59	-0.08	0.10	0.90*	0.84*

*(*Correlation coefficient significance at <0.05 level of significance)*

Relationships of soil micronutrients with other soil chemical properties

Table 4 shows the relationship between soil micronutrient with basic soil parameters. In surface horizon, distribution of soil micronutrient majorly controlled by soil pH, EC, organic carbon and so on (Jiang *et al.*, 2006). Our study confirms negatively and significantly correlation ($p<0.01$) between soil pH with all the cationic micronutrient and B except Zn. Similar relationship were showed by Jiang *et al.*, 2009, in surface soils (0-20cm) under different land uses. Under acidic soil environments, Fe, Mn, Cu, and Zn are the most soluble. Under continuous increase in soil alkalinity, Cationic micronutrients are changed first to the hydroxyl ions and finally to the insoluble hydroxides or oxides of the elements (Brady and Weil, 2002). For every unit increase in pH, solubility of cationic micronutrients may decrease from 100-fold for divalent Mn, Cu and Zn to 1000-fold for trivalent Fe (Rengel, 2001). Except Zn, our study confirms the similar tendency of micronutrient chemistry described by Rengel (2007) have also showed, Organic matter and residue applications affect the immediate and potential availability of micronutrient cations. Table 4 explains significant and positive relationship was found between organic matter content and all cationic and anionic micronutrients ($p<0.01$). Organic molecules form organometallic complexes with cationic micronutrients and get into soluble forms by forming chelates (Jiang *et al.*, 2009). These chelates can enhance the availability of the micronutrients and protect it from precipitation reactions (Brady and Weil, 2002). Positive and significant relationship were recorded between Fe vs Mn, Fe vs Cu, Fe vs B, Mn vs Cu, Cu vs B ($p<0.01$). Behera and Shukla (2013) have reported similar relationship in some Indian acid soils under cultivation. This indicates that similar sets of factors influence distribution of these metallic nutrients in soils in the study region.

Table 4: Correlation study of soil micronutrient content with basic soil properties

	pH	*EC*	*OC*	*Fe*	*Mn*	*Cu*	*Zn*	*B*
pH	1.00							
EC	0.70**	1.00						
OC	-0.57**	-0.07	1.00					
Fe	-0.70**	-0.16	0.67**	1.00				
Mn	-0.74**	-0.28	0.45**	0.82**	1.00			
Cu	-0.75**	-0.31	0.63**	0.63**	0.73**	1.00		
Zn	-0.05	0.36*	0.58**	0.37*	0.26	0.14	1.00	
B	-0.61**	-0.23	0.65**	0.48**	0.38*	0.60**	0.35*	1

*(Correlation coefficient at level of significance at *p<0.05; **p<0.01)*

The current study divulged vertical distribution of soil micro nutrients in central mango belts of southern Karnataka. Soil profile analysis revealed, Sorab taluk under Hilly zone manifested the highest concentration of surface as well as control section micronutrient content. Whereas, the micronutrient deficiency found for Nagamangala taluk under southern dry zone.

Addition of organic matter along with plant residues should be included with the package of practices to improve the micronutrient availability in soils. This study also explains vertical distribution of micronutrient stock in soil where we have found Fe and Mn pools were dominated in surface soils (0-30 cm) than the soil control section. Whereas, Cu and B pools were more dominated in soil control section (30-100 cm). Soil boron stock impact the mango yields significantly for both the surface and control section in Nagamangala taluk. Correlation analysis revealed soil pH has the significant negative correlation with Fe, Mn, Cu and B whereas organic matter has the positive correlation with all the available micro nutrients. Spatial and vertical distribution of micronutrient content along with pools and its correlation analysis gives an overall idea of the deficiency and sufficiency of micro nutrients and its management techniques for better mango production and quality.

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