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Distribution of Micronutrients in Selected Pedons of Sugarcane Growing Vertisols in Northern Karnataka State of India

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Abstract

Micronutrients deficiency is a major limiting factor for increasing yield and productivity of major crops in India. Recent findings of multiple micronutrients interactions have evidenced the indispensable role played by micronutrients in plant nutrition. Though they are needed in smaller quantities, however, their availability in the Right amount, at the Right time, and for the Right crop has been a major limiting factor for improving the productivity and yield of Sugarcane in northern Karnataka state of India. This study was conducted to assess the level of Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn) deficiencies in Sugarcane growing Vertisols of six micro-watersheds in northern Karnataka. The six selected micro-watersheds were intensively traversed and six representative pedons of standard dimensions were dug and horizon-wise soil samples collected and analyzed for various micronutrients using standard analytical procedures. Based on the optimum critical levels of micronutrients, B, Fe and Zn were deficient, ranging from 0.15 - 0.64, 1.23 - 5.92 and 0.11 - 0.64 $mg \cdot kg^{-1}$ respectively while Cu and Mn were in excess, ranging from 1.54 - 7.62 and 1.22 - 7.03 $mg \cdot kg^{-1}$ respectively. The distribution of B, Fe and Zn were inversely proportional to soil depth whereas that of Cu and Mn were irregular, which is an indication of the influence of pedoturbation in these soils. With the current rate of agricultural intensification, unbalanced fertilizer application, depletion of nutrients and no replenishment by smallholders, the results reveal that the current deficiency levels may increase further if appropriate and timely actions are not taken. We therefore recommend the use of site-specific nutrient management, balanced fertilizer application and good agronomic practices. These can enhance nutrient use efficiency in the study area.

Keywords

Soil Fertility, Micronutrients, Boron, Copper, Iron, Manganese, Zinc, India

1. Introduction

Studies have shown that Indian soils are characterized by large-scale deficiencies of not only primary (*i.e.* Nitrogen (N), Phosphorus (P), Potassium (K)) and secondary nutrients (*i.e.* Sulphur (S), Calcium (Ca) and Magnesium (Mg)) but also micronutrients (*i.e.* Boron (B), Copper (Co), Iron (Fe), Manganese (Mn), Molybdenum (Mo) and Zinc (Zn)) [1]. Besides the primary and secondary nutrient deficiencies, crops also suffer from deficiencies of one or more micronutrients in these soils, which sometimes create nutrient imbalances in plant nutrition. These nutrient imbalances have caused greater mining of soil nutrient reserves and depletion of soil fertility in many states of India. The nature and extent of micronutrient deficiencies vary with many factors including ecological conditions, soil type, crop genotype, soil/fertilizer management practices. In an intensive cropping system, for example, the use of high-yielding crop varieties may exacerbate Fe, Mn and Zn deficiencies [2]. In Karnataka, micronutrient deficiencies have become a major limitation to increasing Sugarcane productivity. Studies conducted by various researchers including Wani *et al.* (2011), Shivakumar and Nagaraja (2016), Krishna *et al.* (2017), Sudhakar *et al.* (2018) and Doran (2019) [3] [4] [5] [6] [7] have indicated a decreasing trend in micronutrient status in soils of Karnataka.

According to Cooperative Sugar (2020) [8], sugarcane was cultivated in about 4.9 million ha of land, producing about 37.8 million tons of cane with an average productivity of 77.6 tonnes/ha. The prime concern of cane growers and the sugar industry is to achieve higher sugarcane yield. India is the largest consumer and second largest producer of sugar in the world. Hence, sugarcane is the most important commercial crop and source of sugar and ethanol in India. According to recent report by the Task Force on Sugarcane and Sugar Industry in India [9], India's average annual production of sugarcane stands at 35.6 million tonnes, with sugar production of around 3 million tonnes. Among these figures, Karnataka is the third largest sugarcane producing state in India after Uttar Pradesh and Maharashtra, accounting for 397,000 ha of land area under sugarcane production, with a productivity of 2,7378,000 tonnes and yield of 68,962 kg/ha.

Despite sugarcane being a major income crop for many smallholders in the district and beyond, however increasing its yield and quality has been constrained by not only deficiency of nutrients, but also the lack of quality information on the status of soil nutrients, that would guide farmers in selecting the best site for their crop. Huge information on primary and secondary nutrients is available for decision making across various cropping systems but there exist a wide gap in the availability of information on the status of micronutrients in northern Karnataka [5]. Regularly updated micronutrient status and soil fertility maps of sugarcane growing districts are not available for decision making process. Keeping this in view, the study was undertaken to ascertain the status of B, Cu, Fe, Mn and Zn in relation to sugarcane production in northern Karnataka. The information generated from this study would help to guide sugarcane growers in selecting suitable sites for their crop. Understanding the distribution and location specific variability of available micronutrients would help to establish a link between soil and available micronutrients and avoid the imbalances between fertilizer application rates and crop nutrient demand.

2. Materials and Methods

2.1. Study Area

Six representative micro-watersheds (*i.e.* Kesarakoppa, Shedbal and Marihal) covering major sugarcane growing areas of Bagalkot, Belgaum and Bijapur districts, respectively in northern dry zone (**Figure 1**) and Devihosur, Tadakod and Basavanadaddi covering major sugarcane growing areas of Haveri, Dharwad and Belgaum districts, respectively in northern transition zone (**Figure 2**) were selected for the study. All six districts are located on the eastern side of the Western Ghats, with Bagalkot, Belgaum and Bijapur districts lying on the bank of river Ghataprabha, Malaprabha and Krishna, respectively and Haveri, Dharwad and Belgaum districts being drained by the Tungabhdra, Ghataprabha, Malaprabha and Krishna rivers, respectively.

The districts of Bagalkot, Belgaum and Bijapur are located in the plateau region that is formed by basaltic lava flows, which represents the Deccan peneplain. These districts exhibit moderate to gently undulating topography having sparsely distributed knolls and tors. The average elevation is 540 m, 560 m and 650 m for Bagalkot, Bijapur and Begaum, respectively. The relief is normal, nearly level to very gently sloping and high to medium. The drainage pattern is parallel with very few tributaries flowing in the same direction towards the slope. The important parent materials include basalt, schist, limestone, sandstone and alluvium. The climate is semi-arid to arid, with summer season running from February to May and winter from November to February. Monsoon starts in June and ends in October. The average elevation is 623 m, 674 m and 650 m for Haveri, Dharwad and Belgaum respectively. The climate is transitional, with mean annual rainfall ranging from 619 to 1303 mm.

A wide diversity of natural vegetation including Peepal (*Ficus religiosa*), Kikar (*Prosopis cineraria*), Subabul (*Lucaena leucocephala*) and Neem (*Azadirachta indica*) are predominant. The land use is arable farming with sugarcane, sorghum, maize, soybean, wheat, green gram, sunflower, groundnut, millet, chickpea, onion, chilli, cucumber, tomato, brinjal, cabbage, coriander, radish and other leafy vegetables being the major crops. Among the commercial crops, sugarcane is prevalent and intensively cultivated in the study area, while banana, mango, grapes and pear are the important fruit crops.

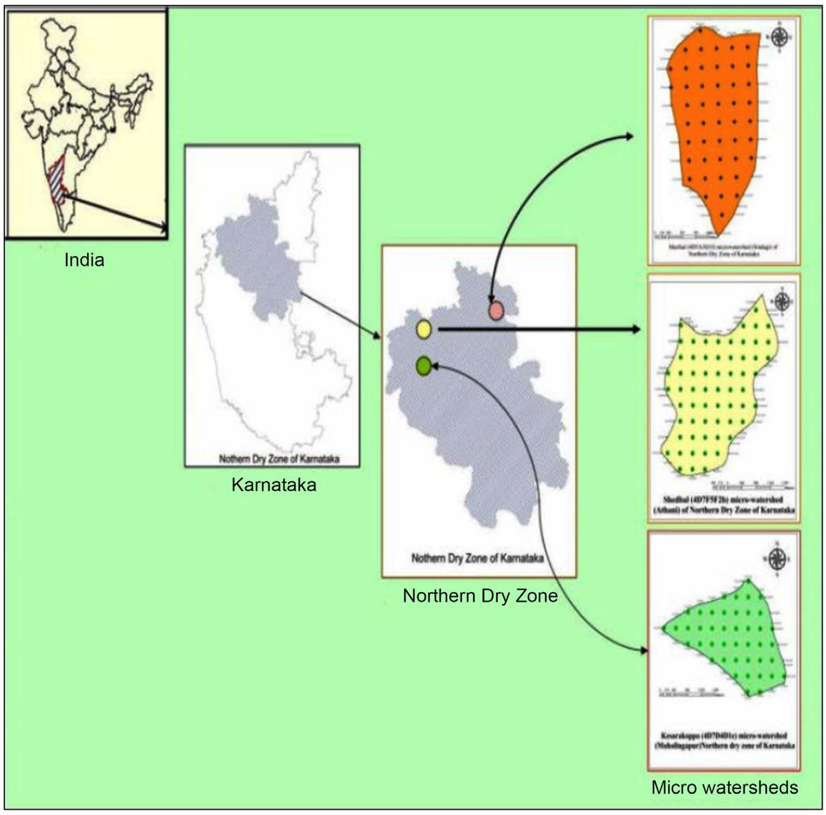

Figure 1. Representative micro-watersheds in northern dry zone of Karnataka.

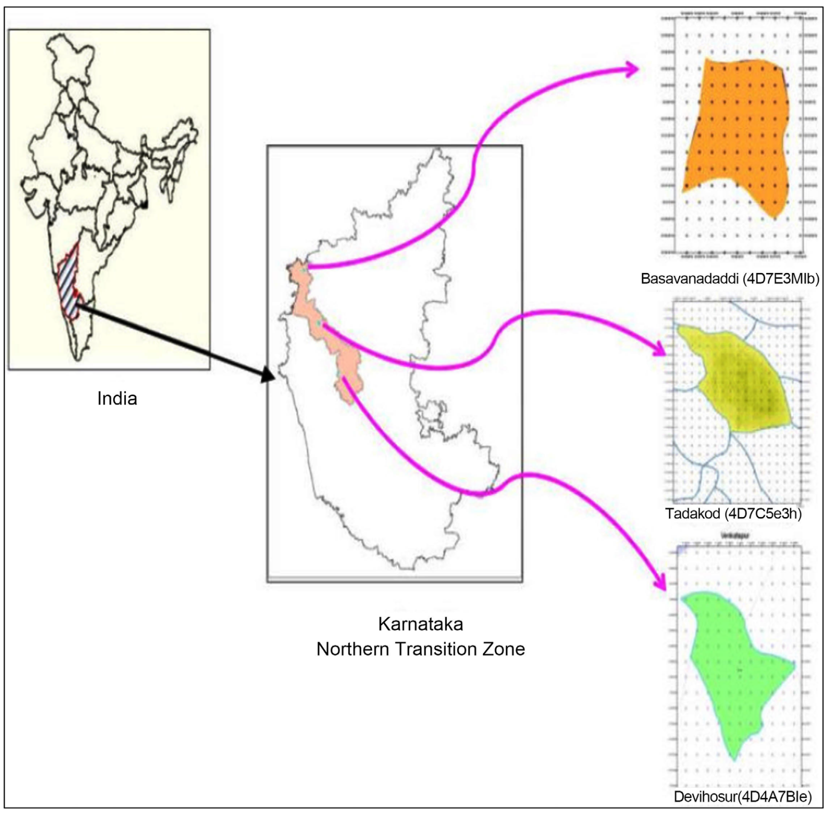

Figure 2. Representative micro-watersheds in northern transition zone of Karnataka.

2.2. Soil Sampling and Analysis

The six micro-watersheds were intensively traversed and six representative pedons with standard dimensions of 2 m long, 1.5 m wide, and 1.5 m (one for each micro-watershed) representing Vertisols, commonly referred to the deep black cotton soils in India, were dug and horizon-wise soil samples collected in zip lock bags. These samples were processed and analyzed at the Soil and Agricultural Chemistry Laboratory of the University of Agricultural Sciences, Dharwad. Available Cu, Fe, Mn and Zn were extracted using Diethylene Triamine Penta Acetic Acid extractant (0.005 DTPA + 0.1 M Triethanolamine and 0.01 M Ca Cl2 solution buffer) [10]. The concentrations of zinc, copper, iron and manganese in the soil-extracts were quantified using Atomic Absorption Spectrometer. For B, the soil was extracted with boiling water and then the amount of boron in the extractant was estimated by Azomethine-H method using spectrophotometer at 430 nm [11]. Critical limits used for interpretation of micronutrient status were 0.60 mg DTPA-extractable Zn kg^{-1} soil, 4.50 mg DTPA-extractable Fe kg^{-1} soil, 0.20 mg DTPA-extractable Cu kg^{-1} soil, 2.50 mg DTPA-extractable Mn kg^{-1} soil and 0.50 mg hot water-soluble B kg^{-1} soil [12].

3. Results

In the present study, the status of five micronutrient elements (B, Cu, Fe, Mn and Zn) in sugarcane growing Vertisols in northern Karnataka have been analyzed in order to ascertain whether these nutrients are in deficient, sufficient or excess quantities and the results are given in **Table 1** and **Table 2**.

In all pedons, the content of DTPA-extractable Zn decreased with depth but surface horizons recorded higher content than subsurface horizons. Pedons 1, 2 and 3 of Northern dry zone recorded higher micronutrient content especially in surface soils than their Northern transition zone counterparts (Profile 4, 5 & 6). The DTPA-extractable Zn content in Pedons 1, 2 and 3 decreased from 0.48 $mg·kg^{-1}$ in surface (Ap) horizon to 0.21 $mg·kg^{-1}$ in subsurface (BssCk) horizon; 0.54 $mg·kg^{-1}$ in surface (Ap) horizon to 0.30 $mg·kg^{-1}$ in subsurface (BssCk) horizon and 0.62 $mg·kg^{-1}$ in surface (Ap) horizon to 0.24 $mg·kg^{-1}$ in subsurface (BssCk) horizon, respectively. In pedons 4, 5 and 6, it decreased from 0.57 $mg·kg^{-1}$ in surface (Ap) horizon to 0.23 $mg·kg^{-1}$ in subsurface (BssCk) horizon; 0.52 $mg·kg^{-1}$ in surface (Ap) horizon to 0.14 $mg·kg^{-1}$ in subsurface (BssCk) horizon and 0.43 $mg·kg^{-1}$ in surface (Ap) horizon to 0.11 $mg·kg^{-1}$ in subsurface (BssCk) horizon, respectively.

Like the DTPA-extractable Zn, the content of DTPA-extractable Fe was observed to follow a decreasing trend with depth in all pedons, with surface horizons exhibiting higher values than subsurface horizons. In pedons 1, 2 and 3, it decreased from 3.12 $mg·kg^{-1}$ in surface (Ap) horizon to 1.23 $mg·kg^{-1}$ in subsurface (BssCk) horizon; 4.22 $mg·kg^{-1}$ in surface (Ap) horizon to 2.14 $mg·kg^{-1}$ in subsurface (BssCk) horizon and 3.23 $mg·kg^{-1}$ in surface (Ap) horizon to 1.28 $mg·kg^{-1}$ in subsurface (BssCk) horizon, respectively. In pedons 4, 5 and 6, the DTPA-extractable Fe content decreased from 5.92 $mg·kg^{-1}$ in surface (AP) horizon to 1.44 mg·kg^{-1} in subsurface (BssCk) horizon; 4.42 mg·kg^{-1} in surface (Ap) horizon to 2.11 in subsurface (Bss3) horizon and 4.88 mg·kg^{-1} in surface (Ap) horizon to 2.15 mg·kg^{-1} in subsurface (BssCk) horizon.

Table 1. DTPA and hot water extractable micronutrient status in selected pedons of northern Karnataka.

Pedon No.	Horizon	Depth (cm)	Zn	Fe	Cu	Mn	B
			(mg·kg^{-1})				
Northern dry zone of Karnataka							
Pedon 1	Ap	0 - 14	0.48	3.12	5.99	3.64	0.64
	A2	14 - 32	0.37	2.37	4.89	5.56	0.39
	Bss1k	32 - 72	0.29	2.02	5.23	4.23	0.35
	Bss2k	72 - 96	0.25	1.69	4.14	4.12	0.32
	BssCk	96 - 121+	0.21	1.23	3.65	3.15	0.23
Pedon 2	Ap	0 - 16	0.54	4.22	5.85	6.36	0.41
	A2	16 - 40	0.52	3.24	5.26	5.88	0.32
	Ap1	40 - 77	0.41	3.02	6.63	6.52	0.24
	Bss1k	77 - 102	0.33	2.41	6.97	4.85	0.21
	BssCk	102 - 142+	0.30	2.14	6.65	7.54	0.19
Pedon 3	Ap	0 - 19	0.62	3.23	4.42	4.16	0.49
	A2	19 - 41	0.53	2.46	4.33	2.14	0.48
	Bss1k	41 - 64	0.45	2.29	1.54	3.12	0.37
	Bss2k	64 - 98	0.38	1.61	4.02	3.54	0.34
	BssCk	98 - 122+	0.24	1.28	4.28	1.22	0.21
Northern transition zone of Karnataka							
Pedon 4	Ap	0 - 14	0.57	5.92	5.22	4.72	0.41
	A2	14 - 32	0.41	4.52	5.43	4.84	0.33
	A3	32 - 54	0.32	3.23	5.87	5.29	0.27
	Bss1	54 - 88	0.28	2.55	4.36	4.03	0.22
	Bss2	88 - 137+	0.23	1.44	4.24	3.81	0.21
Pedon 5	Ap	0 - 15	0.52	4.42	5.35	4.81	0.34
	A2	15 - 31	0.34	4.20	7.04	6.46	0.28
	Bss1	31 - 79	0.22	3.37	6.83	6.15	0.24
	Bss2	79 - 104	0.19	2.28	4.38	4.02	0.23
	Bss3	104 - 140+	0.14	2.11	5.21	4.83	0.22
Pedon 6	Ap	0 - 13	0.43	4.88	4.87	4.45	0.47
	A2	13 - 37	0.32	3.57	7.06	6.44	0.23
	Bss1	37 - 75	0.20	3.27	7.62	7.03	0.21
	Bss2	75 - 99	0.17	2.25	7.48	6.92	0.19
	Bss3	99 - 129+	0.11	2.15	4.35	3.69	0.15

Table 2. Status of micronutrient sufficiency and deficiencies in selected pedons of northern Karnataka.

Pedon No.	Horizon	Depth (cm)	Zn	Fe	Cu	Mn	B
			(mg·kg^{-1})				
Northern dry zone of Karnataka							
Pedon 1	Ap	0 - 14	−0.12	−1.38	+5.79	+1.14	+0.14
	A2	14 - 32	−0.23	−2.13	+4.69	+3.04	−0.11
	Bss1k	32 - 72	−0.31	−2.48	+5.03	+1.73	−0.15
	Bss2k	72 - 96	−0.35	−281	+3.94	+1.62	−0.18
	BssCk	96 - 121+	−0.39	−3.27	+3.45	+0.65	−0.27
Pedon 2	Ap	0 - 16	−0.06	−0.28	+5.65	+3.86	−0.09
	A2	16 - 40	−0.08	−1.26	+5.06	+3.38	−0.18
	Ap1	40 - 77	−0.19	−1.48	+6.43	+4.02	−0.26
	Bss1k	77 - 102	−0.27	−2.09	+6.77	+2.35	−0.29
	BssCk	102 - 142+	−0.30	−2.36	+6.45	+5.04	−0.31
Pedon 3	Ap	0 - 19	+0.02	−1.27	+4.22	+1.66	−0.01
	A2	19 - 41	−0.07	−2.04	+4.13	−0.36	−0.02
	Bss1k	41 - 64	−0.15	−2.21	+1.34	+0.62	−0.13
	Bss2k	64 - 98	−0.22	−2.89	+3.82	+1.04	−0.16
	BssCk	98 - 122+	−0.36	−3.22	+4.08	−1.28	−0.29
Northern transition zone of Karnataka							
Pedon 4	Ap	0 - 14	−0.03	−1.42	+5.02	+2.22	−0.09
	A2	14 - 32	−0.19	+0.02	+5.23	+2.34	−0.17
	A3	32 - 54	−0.28	−1.27	+5.67	+2.79	−0.23
	Bss1	54 - 88	−0.32	−1.95	+4.16	+1.53	−0.28
	Bss2	88 - 137+	−0.33	−3.06	+4.04	+1.31	−0.29
Pedon 5	Ap	0 - 15	−0.08	−0.08	+5.15	+2.31	−0.16
	A2	15 - 31	−0.26	−0.30	+6.84	+3.96	−0.22
	Bss1	31 - 79	−0.38	−1.13	+6.63	+3.65	−0.26
	Bss2	79 - 104	−0.41	−2.22	+4.18	+1.52	−0.27
	Bss3	104 - 140+	−0.46	−2.39	+5.01	+2.33	−0.28
Pedon 6	Ap	0 - 13	−0.17	−0.38	+4.67	+1.95	−0.03
	A2	13 - 37	−0.28	−0.93	+6.86	+3.94	−0.27
	Bss1	37 - 75	−0.40	−1.23	+7.42	+4.53	−0.29
	Bss2	75 - 99	−0.43	−2.25	+7.28	+4.42	−0.31
	Bss3	99 - 129+	−0.49	−2.35	+4.15	+1.19	−0.35

Note: The figures in brackets are the deviation from the critical levels (0.60 mg DTPA-extractable Zn kg^{-1} soil, 4.50 mg DTPA-extractable Fe kg^{-1} soil, 0.20 mg DTPA-extractable Cu kg^{-1} soil, 2.50 mg DTPA-extractable Mn kg^{-1} soil and 0.50 mg hot water-soluble B kg^{-1} soil). The positive sign denotes that the nutrient element is in excess and the negative sign denotes deficiency.

The distribution of Cu follows an irregular pattern in all pedons, with values higher in surface than subsurface horizons. In pedons 1, 2 and 3, the content of DTPA-extractable Cu decreased from 5.99 mg·kg^{-1} in surface (Ap) horizon to 3.65 mg·kg^{-1} in subsurface (BssCk) horizon; 6.97 mg·kg^{-1} in surface (Ap) horizon to 5.26 mg·kg^{-1} in subsurface (A2) horizon and 4.42 mg·kg^{-1} in surface (Ap) horizon to 1.54 mg·kg^{-1} in subsurface (Bss1) horizon, respectively. In pedons 4, 5 and 6, it decreased from 5.87 mg·kg^{-1} in subsurface (A3) horizon to 4.24 mg·kg^{-1} in subsurface (Bss2) horizon, 7.04 mg·kg^{-1} in surface (A2) horizon to 4.38 mg·kg^{-1} in subsurface (Bss2) horizon and 7.62 mg·kg^{-1} in subsurface (Bss1) horizon to 4.35 mg·kg^{-1} in subsurface (Bss3) horizons, respectively.

The DTPA-extractable Mn content in all pedons follows an indefinite pattern. However, pedons of northern transition zone recorded higher Mn content than those of northern dry zone. In pedons 1, 2 and 3, the DTPA-extractable Mn content was observed to decrease from 5.56 mg·kg^{-1} in subsurface (A2) horizon to 3.15 mg·kg^{-1} in subsurface (BssCk) horizon; 7.54 mg·kg^{-1} in subsurface (BssCk) horizon to 4.85 mg·kg^{-1} in subsurface (Bss1) horizon and 4.16 mg·kg^{-1} in surface (Ap) horizon to 1.22 mg·kg^{-1} in subsurface (BssCk) horizon, respectively. In pedons 4, 5 and 6 of northern transition zone, it decreased from 5.29 mg·kg^{-1} in surface (Ap) horizon to 3.81 mg·kg^{-1} in subsurface (Bss2) horizon; 6.46 mg·kg^{-1} in subsurface (A2) horizon to 4.02 mg·kg^{-1} in subsurface (Bss2) horizon and 7.03 mg·kg^{-1} in subsurface (Bss1) horizon to 3.69 mg·kg^{-1} in subsurface (BssCk) horizons, respectively.

The hot water extractable B decreased with depth in all pedons. In pedons 1, 2 and 3 of northern dry zone, the hot water extractable B content decreased from 0.64 mg·kg^{-1} in surface (Ap) horizon to 0.23 mg·kg^{-1} in subsurface (BssCk) horizon; 0.41 mg·kg^{-1} in surface (Ap) horizon to 0.19 mg·kg^{-1} in subsurface (BssCk) horizon and 0.49 mg·kg^{-1} in the surface (Ap) horizon to 0.21 mg·kg^{-1} in subsurface (BssCk) horizon, respectively. In pedons 4, 5 and 6 of northern transition zone, it decreased from 0.41 mg·kg^{-1} in surface (Ap) horizon to 0.12 mg·kg^{-1} in subsurface (Bss1) horizon; 0.34 mg·kg^{-1} in surface (Ap) horizon to 0.22 mg·kg^{-1} in subsurface (Bss3) horizon and 0.47 mg·kg^{-1} in surface (Ap) horizon to 0.15 mg·kg^{-1} in subsurface (BssCk) horizon, respectively.

4. Discussion

The distribution of B, Cu, Fe, Mn and Zn in soils (**Table 1**) and their sufficiency and deficiencies (**Table 2**) indicate that micronutrient content is inversely proportional to the soil depth in almost all pedons, with surface horizons having more micronutrients than subsurface horizons. The results further revealed a changing trend in the availability of micronutrients due to the wide variation in parent material and degree of weathering. According to Lal and Biswas (1974) and Venkatesh *et al.* (2001) [13] [14], parent material is a major pedogenic factor that influences the availability of micronutrient cations, especially in Vertisols. Based on the aging of parent materials, soils developed from shale parent materials generally show higher content of available micronutrient cations compared to those developed from granite or basaltic parent materials, hence, resulting to variation in micronutrients contents.

The trend in micronutrient deficiencies was much wider for Fe and Mn as compared to Zn and Cu. In general, Zn, Cu, Fe and Mn were more in the surface horizons than subsurface horizons, which may be due to the accumulation of these elements in the surface layer as a result of the regular turnover by plant and animal residues, higher content of organic carbon, lower calcium carbonate contents, better aeration and translocation of finer soil fractions leading to increase in the surface area for ion exchange. Similar observations were made by Venkatesh *et al.* (2001), Sharma *et al.* (2006) and Sharma and Chaudhary (2007) [14] [15] [16]. The distribution of micronutrients demonstrates overlapping domains of how genetic processes, isohyets, internal drainage, landform and particle size class have completely negated the influence of basaltic parent materials and root-induced redistribution. The irregular distribution of B, Cu and Mn with depth depicts the influence of argilli-, faunal-, and floral pedoturbation in these soils. In the cultivated soils of the Indo-Gangetic plain in the northern dry zone, Sharma *et al.* (2000) [17] noted lower content of micronutrient in the solum than in the C-horizons, which could be related to nutrient mining as a result of removal of these nutrients by the harvested crops. Although coarse clay and organic matter were present in small amounts, these data highlight their importance in understanding the distribution and management of micronutrient in these soils.

The distribution of hot water soluble B in all the pedons decreased with soil depth. Several studies have reported that B distribution in major soils of India especially Vertisols, decreases with soil depth. In the northern dry zone, hot water soluble B decreased from 0.42 $mg \cdot kg^{-1}$ in surface horizons to about 0.19 $mg \cdot kg^{-1}$ in subsurface horizons. Similarly in northern transition zone, it decreased from 0.54 $mg \cdot kg^{-1}$ in surface horizons to 0.18 $mg \cdot kg^{-1}$ in subsurface horizons. Gandhi and Mehta (1958 and Kanwar and Singh (1961) [18] [19] observed a decrease in hot water soluble B content with depth in saline soils of Saurastra and alkali soils of Punjab. Similarly in Rajasthan, Mathur *et al.* (1964) [20] observed a decrease in water soluble B content with depth in unirrigated soils, but after prolonged irrigation with well waters high in B, water soluble B increased with depth. In this study, surface horizon were more enriched with B than subsurface horizons, which may be due to the accumulation of B through irrigation waters. As most sugarcane growing Vertisols are irrigated in this area, the prolonged use of these brackish and irrigation waters might have resulted to the observed B variability in these soils. Similar pattern of distribution was reported by Bhargava *et al.* (1974), Sharma and Bajwa (1989) and Singh and Nayyar (1999) [21] [22] [23] for salt-affected and contiguous normal soils and alluvium-derived soils of Ferozepur and Faridkot districts of Punjab.

Based on the critical limit of micronutrients, the study reveals that the soils are deficient in B, Fe and Zn but excess in Cu and Mn. This is however at par with the findings of Behera and Shukla (2013) [24] which states that deficiency of Zn has declined in recent times as a result of regular application of Zn fertilizers but is in conformity with the statement that deficiencies of Cu and Mn are not widespread and therefore, sporadic crop response was expected.

5. Conclusion

Micronutrients deficiency is a major productivity-limiting factor in sugarcane growing Vertisols in India. The nature of the problem has over time become a cause for alarm in many sugarcane production systems and this has necessitated further probe into the matter in order to remedy the situation. For this purpose, a study was conducted to assess the level of Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn) deficiencies in Sugarcane growing Vertisols of six micro-watersheds in northern Karnataka. Soil data were collected and analyzed to understand the status of micronutrient deficiencies in the area. Our study has revealed that there is a changing trend in the availability of micronutrients, which is attributed to the wide variation in parent material and degree of weathering. Based on our analysis, we observed that the most critical micronutrients (otherwise referred to as deficient micronutrients) are B, Fe and Zn and those in excess amounts are Cu and Mn. In general, Zn, Cu, Fe and Mn were more in the surface horizons than subsurface horizons. We have ascribed this trend to the fact that to the accumulation of these elements in the surface layer may occur as a result of several factors including regular turnover by plant and animal residues, higher content of organic carbon, lower calcium carbonate contents, better aeration and translocation of finer soil fractions leading to increase in the surface area for ion exchange. Though Cu and Mn are in excess amounts, however, we suggest that special attention be accorded to these soils because any improper use of these soil resources may cause nutrient imbalances that would lead to severe deficiencies in future. The distribution of B, Fe and Zn were inversely proportional to soil depth but that of Cu and Mn were irregular, which is an indication of the influence of pedoturbation in these soils. Our study has also further informed the scientific audience that B, Fe and Zn distribution in major soils of India especially Vertisols decreases with soil depth, which is an indication of subsurface deficiency of nutrients. In this regard, we are of the view that the application of micronutrient fertilizers in appropriate quantities may ease the problem of deficiencies in these soils. Already, Cu and Mn are found to be in excess amounts. Therefore, we recommend that any application of micronutrient fertilizers should be restricted to B, Fe and Zn rather than Cu and Mn, in order to avoid toxicity of these micronutrients.

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Authors' Contributions

SAN development of research proposal, collection of soil samples, analysis of soil samples, interpretation of results and preparation of manuscript. DMKA development of research proposal, quality control checks, interpretation of results, editing and reviewing of manuscript. PLP provide laboratory facility, supervise soil sample collection, soil analysis and revised the manuscript. All authors have read and approved the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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