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Spatial Distribution and Mapping of Available Micro Nutrient Status in Relation to Soil Properties of Tomato Grown Soils of Chikkaballapura District, Karnataka

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Authors' contributions

This work was carried out in collaboration among all authors. Authors PNSP and CTS designed the study, performed the statistical analysis, wrote the protocol. Author PNSP wrote the first draft of the manuscript. Authors PNSP and CTS managed the analyses of the study. Author AS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

GPS based soil survey was conducted in the tomato growing areas of Chikkaballapura district, Karnataka to map the soil fertility status by using Arc GIS 10.4 software. Seventy five surface soil samples were taken from the tomato growing areas of the district and analysed for texture, pH, EC, OC and micronutrients (Zn, CU, Fe, Mn, B) and zinc content in plant samples. The results revealed that the soils under investigation were acidic to alkaline in reaction, non saline, medium to high in organic matter content. All the studied soils were sandy loam to sandy clay loam in texture. DTPA extractable Zn, Cu, Fe, Mn and HWS-B varied from 0.07 - 6.87, 0.41-4.59, 2.08-28.92, 1.37-27.08 and 0.24-2.13 mg kg^{-1} respectively. Plant zinc ranges from 14 - 98 mg kg^{-1} inferring low to high in zinc concentration. The nutrient index was calculated for all the micronutrients and it is found to be medium. Among the micronutrients 48, 21.33 and 30.67 per cent samples were categorized as low, medium and high in available zinc status. These results indicated that Zn is likely to constraint tomato crop production in Chikkaballapura.

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1. INTRODUCTION

Soil fertility is one of the important factors controlling yield of the crops. Soil characterization in relation to evaluation of fertility status of the soil of an area or region is an important aspect in the context of sustainable agricultural production because of imbalanced and inadequate fertilizer use coupled with low efficiency of other inputs. The response (production) efficiency of chemical fertilizer nutrients has declined tremendously under intensive agriculture in recent years [1]. Introduction of high yielding varieties in Indian Agriculture forced the farmers to use high dose of NPK without micronutrient fertilizers. This declined the level of some micronutrients in the soil at which productivity of crops cannot be sustained. The deficiencies of micronutrients have become major constraints to productivity, stability and sustainability of soils. Nutrients strength and their relationship with soil properties affect the soil health. Micronutrients play a vital role in maintaining soil health and also productivity of crops. These are needed in very small amounts. The soil must supply micronutrients for desired growth of plants and synthesis of human food.

In the present era of precision farming, the inputs such as fertilizer, crop varieties and management practices are matched precisely with the variability in soil and climatic conditions so that inputs are applied as per the location-specific requirements of the crop. The advent of information technology have provided tools like global positioning system (GPS), geographical information system (GIS) which helps in collecting a systematic set of georeferenced samples and generating the spatial data about the distribution of nutrients [2]. The maps generated through remote sensing helps in delineating the homogenous units to decide the sampling size and thereby saving a lot of time. This will also help to monitor the changes in micronutrient status over a period of time as georeferenced sampling sites can be revisited with the help of GPS which is otherwise difficult in the random sampling [3]. The availability of micronutrients to plants is influenced by certain soil characteristics. Keeping this in view, the present study was taken up in Chikkaballapura district of Karnataka to diagnose micronutrient related constraints to productivity by assessing micronutrient status of the soils and their spatial variability in soils and plants.

2. MATERIALS AND METHODS

2.1 SOil Sampling, Processing and Analysis

Surface (0-15 cm) soils are collected from tomato growing areas of Chikkaballapura district. All together a total of seventy five geo-referenced soil samples were collected from farmer's fields. The samples were air-dried, ground and passed through a 2 mm sieve for analysis of physical, chemical properties and micronutrient content of soil. Soil particle size distribution was determined by the Bouycous hydrometer method after destroying organic matter by using hydrogen peroxide (H_2O_2). The pH (potential of hydrogen) and EC (electrical conductivity) of the soils was determined in 1:2.5 soil water suspension using a glass electrode pH meter and EC meter as described by Jackson 1973 [4]. The Walkley and Black [5] wet digestion method was used to determine soil organic carbon (SOC) content. The available zinc (Zn), iron (Fe), copper (Cu) and manganese (Mn) in soil samples were estimated by atomic absorption spectrophotometer following DTPA extraction method (Lindsay and Norvell 1978). The deficiency and sufficiency areas were then delineated based on the critical limit given for Fe, Mn, Zn, Cu. Available boron was estimated by using Azomethine-H method. Plant samples were digested in diacid mixture and concentration was determined using AAS. The correlation analysis of data was computed in relation to available micronutrients content with different physicochemical properties of the soils as suggested by Panse and Sukhatme,1961 [6].

2.2 Nutient Index (NI)

Nutrients index (NI) was enumerated for surface soil samples as described by Motsara et al., 1982 [7].

$$\text{Nutrient index} = \frac{(\text{N}l \times 1) + (\text{N}m \times 2) + (\text{N}h \times 3)}{\text{N}t}$$

where,

N*t* = total number of samples analyzed for a nutrient in given area;

N*l* = number of samples falling in the low category of nutrient status;
N*m* = number of samples falling in the medium category of nutrient status; and
N*h*= number of samples falling in high category of nutrient status.

2.3 Preparation of Maps

Maps for soil sampling sites were generated based on x, y coordinates recorded in the field using GPS coordinated. Maps showing the spatial distribution of deficient and sufficient area for individual DTPA extractable micronutrients were also generated and digitized using the Arc GIS 10.4 software package.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Properties of the Soil

Soil texture of Chikkaballapura district surface samples ranges from sandy loam to sandy clay loam. The sand percent ranges from 65 - 79.12 with a mean of 75.38 percent and a median of 76 per cent with a standard deviation of 3. The silt percent ranges from 1.36 - 15.48 with a mean of 5.79 and a median of 4.36 with standard deviation of 4.14 where as clay percent ranges from 10.52 -24.52 with a mean of 18.83 and a median of 20.52 with a standard deviation 3.43. Out of 75 samples 49.33 percent samples are sandy loam and 50.67 samples are sandy clay loam in texture.

The pH of soil samples analyzed in the district ranged from 4.47 - 8.06 with a mean and median of 6.87 and 6.97 respectively with 0.78 as standard deviation. Thus, the soils of the district were categorized into acidic, neutral and alkaline. The electrical conductivity of analyzed soil samples were between 0.04 - 1.02 dS m^{-1} with a mean and median of 0.42 dS m^{-1} with a standard deviation of 0.32. It was observed that only four soils out of 75 were found to register EC more than 1 dS m^{-1} and otherwise the EC of district soils was very much suitable for growing the crop.

The organic carbon content of district soils was found to be in the range of 0.15 to 2.0 %. The mean and median of organic carbon content in the studied soils was 1.07 and 0.98 respectively, with standard deviation of 0.48. Out of 75 soil samples of the district, 20 % were found to be low in organic carbon content, 8 % were medium whereas most of the soils i.e., 72 % were found to be high in organic matter content where as 20% low organic carbon in the soils of Chikkaballapura district may be due to low input of organics and also rapid rate of decomposition because of high soil temperature prevailing in the district. The details of soil analytical values are presented in Table 1. The high content of organic carbon reported in the studied area might be due to addition of organic matter and its subsequent decomposition. These results are in confirmatory with results reported by Waikar et al., 2004 [8] and Sathish et al., 2017 [9].

3.2 DTPA Extractable Micronutrients

The DTPA extractable Zn, Fe, Mn, Cu, hot water extractable boron and plant zinc were analysed and the results were presented in Table 1.

Table 1. Descriptive statistics of analytical results of tomato growing areas of Chikkaballapura district

S.No	Parameter	Units	Maximum	Minimum	Mean	Median	Standard Deviation
1	pH		8.06	4.47	6.87	6.97	0.78
2	E.C	dS m^{-1}	1.02	0.04	0.42	0.26	0.32
3	O.C	%	2.00	0.15	1.07	0.98	0.48
4	Sand		79.12	65.00	75.38	76.00	3.00
5	Silt		15.48	1.36	5.79	4.36	4.14
6	Clay		24.52	10.52	18.83	20.52	3.43
7	Available Zinc	ppm	6.87	0.07	1.06	0.62	1.22
8	Available Manganese		27.08	1.37	7.2	5.16	5.36
9	Available Copper		4.59	0.41	1.7	1.65	0.68
10	Available Iron		28.92	2.08	9.17	6.48	6.49
11	Available Boron		2.13	0.24	0.74	0.64	0.34
12	Plant Zinc		98.00	14.00	33.23	27.00	20.15

3.2.1 Available zinc

The Zn status of soils of Chikkaballapura district ranged from 0.07 to 6.87 mg kg^{-1} with mean and median 1.06 and 0.62 mg kg^{-1} with standard deviation of 1.22. The studied soils of the district were fell down in low to high zinc category.

3.2.2 Available iron

The Fe status of soils of Chikkaballapura district ranged from 2.08 to 28.92 mg kg^{-1} with mean and median 9.17 and 6.48 mg kg^{-1} with standard deviation of 6.49. The studied soils of the district were fell down in low to high iron category. The data indicated that soils were deficient in an iron, it might be due to unavailability of iron under alkaline condition. The availability of iron is due to slightly acidic condition and organic matter content and in some cases due to lack of moisture. The similar trend of Fe was reported by Dwivedi et al. 2005 [10] in soils of Ladakh region (Jammu & Kashmir) and by Nagendran and Angayarkanni, 2010 [11] in soils of Cumbum valley, Tamilnadu.

3.2.3 Available manganese

The Mn status of soils of Chikkaballapura district ranged from 1.37 to 27.08 mg kg^{-1} with mean and median of 7.2 and 5.16 mg kg^{-1} with standard deviation of 5.36. The Mn in the studied soils were recorded as low to high in nutrient status. The sufficiency of available manganese might be due to high organic matter content under optimum soil reaction. Also the sufficient content of NPK is responsible for availability of manganese in soil. The similar results were supported by Hundal *et al.* 2006 [12] in soils of Punjab by [13] in soybean growing soils of Malwa Plateau, Madhya Pradesh.

3.2.4 Available copper

The Cu status of soils of Chikkaballapura district ranged from 0.41 to 4.59 mg kg^{-1} with mean and median 1.70 and 1.65 mg kg^{-1} with standard deviation of 0.68. The studied soils of the district were fell down in low to high in copper status. The higher amount of DTPA-Cu in surface layer might be due to higher biological activities and chelating effect [14]. Similar results were observed by [15] in soils of Malaprabha right bank command of Karnataka and [16] in soils of Mantagani village in north Karnataka.

3.2.5 Available boron

The boron status of soils of Chikkaballapura district ranged from 0.24 to 2.13 mg kg^{-1} with mean and median of 0.74 and 0.64 mg kg^{-1} with standard deviation of 0.34. The studied soils of the district were fell down in low to high in boron status. The data indicate that the majority of soils are found sufficient in available boron in soils might be due to increased level of soil organic matter and slight deficiency might be due to unavailability of boron in alkaline pH of soil.

3.2.6 Plant zinc

The Zinc content in the tomato plants were ranged from 14 to 98 mg kg^{-1} with mean and median of 33.23 and 27 mg kg^{-1} with a standard deviation of 20.15. The zinc content in the surveyed areas were low to high in zinc content. Therefore, it is advisable that Zn-fertilizers should be added in such soils for sustainable agricultural production. Analysis of both soil and plant samples showed that these soils are deficient in Zn but relatively higher percentage of deficiency of Zn was observed in plant samples. Similar reports were also made at Kupwara district in Kashmir [17].

3.3 Nutrient Index, Percent Distribution and Mapping of the Studied Soils

Keeping in view of the importance of pH in controlling availability of most of nutrients, the pH range in the district is divided into 5 categories. First category is in moderately acidic (5.5-6.0), slightly acidic (6.0-6.5), neutral (6.5-7.3), slightly alkaline (7.3-7.8) and moderately alkaline (7.8-8.4). It was overall found that about 36 per cent of district soils were acidic in nature, 34.67 per cent were found to be neutral and 29.33 percent soils are alkaline in nature. The electrical conductivity of soil is a measure of salt content. Soils having EC less than 0.8 dS m^{-1} are denoted as non saline. Out of surveyed samples 78.67 percent are very normal and 21.33 percent are medium in salt content. There is no salinity in the studied soils. The soil samples having < 0.5 percent are denoted as low, 0.5 to 0.75 percent as medium and > 0.75 per cent are considered as high in organic carbon status. Twenty percent samples are low in available carbon, 8 per cent in medium and 72 percent under high organic carbon content.

Out of 75 samples collected from various soil mapping units 48 percent soil samples were below the critical limit (>0.6 mg kg^{-1}) and 52 per cent samples were above the critical limits (>0.6 mg kg^{-1}). In detailed 48, 21.33 and 30.67 were categorized as low (>0.6 mg kg^{-1}), medium (>0.6 -1.2 mg kg^{-1}) and high zinc (>1.2 mg kg^{-1}) status respectively for Chikkaballapura district. The plant zinc < 19 mg kg^{-1} were considered as low, 20-50 mg kg^{-1} were considered as medium and > 50 mg kg^{-1} was considered as high. Out of studied samples, 34.15 per cent samples were low, 48.78 per cent samples were medium and 17.07 per cent samples were high in plant zinc respectively. Based on soil test and plant analysis, there is a need of zinc fertilization at regular intervals to maximize yields. Otherwise, the deficiency of Zn will gradually become a major constraint to productivity of crops. Similar findings were made by Wani et al., 2014 [17].

The available DTPA extractable Cu < 0.4 mg kg^{-1} is low, 0.4-0.8 mg kg^{-1} is medium and > 0.8 mg kg^{-1} is high. The studied samples fell down in two categories i.e., medium and high. Only 5.33 per cent samples are medium in Cu and the rest 94.67 samples are high in copper content. Manganese < 4 mg kg^{-1}, 4-8 mg kg^{-1} and > 8 mg kg^{-1} were considered as low, medium and high in Mn content respectively. The studied samples fell down in all three categories. Out of studied samples 29.33 per cent samples were in low, 38.67 per cent samples in medium and 32 per cent samples in high Mn content.

The available DTPA extractable Fe < 5.5 mg kg^{-1} is low, 5.5-9.5 is medium and > 9.5 is high. Out of studied soils 29.33 per cent soils were low, 33.33 percent soils were medium and 37.34 samples high in available Fe status respectively. Available boron < 0.5 mg kg^{-1} is low, 0.5- 1 mg kg^{-1} is medium and > 1 mg kg^{-1} is high respectively. The studied soils were fell down in all of these three categories. Among them 30.67 per cent was under low, 37.33 per cent was under medium and 32 per cent was under high. Similar studies were conducted [18]. The percent distribution of micronutrients of chikkaballapura district was presented in Table 2 and depicted in Fig. 1. The category in which micronutrients were present in Chikkaballapura district were shown in legend. As per categorization and availability of micronutrients, the status covered under each category shown by different colour legends which are depicted in Fig. 2.

Table 2. Percent distribution of tomato growing areas of Chikkaballapura district

S.No	Parameter	Low	Medium	High
1	pH	36 (Acidic)	34.67(Neutral)	29.33 (Alkaline)
2	E.C	78.67 (Normal)	21.33 (Medium)	0 (Saline)
3	O.C	20	8	72
4	Available Zinc	48	21.33	30.67
5	Available Manganese	29.33	38.67	32
6	Available Copper	0	5.33	94.67
7	Available Iron	29.33	33.33	37.34
8	Available Boron	30.67	37.33	32
9	Plant Zinc	34.15	48.78	17.07

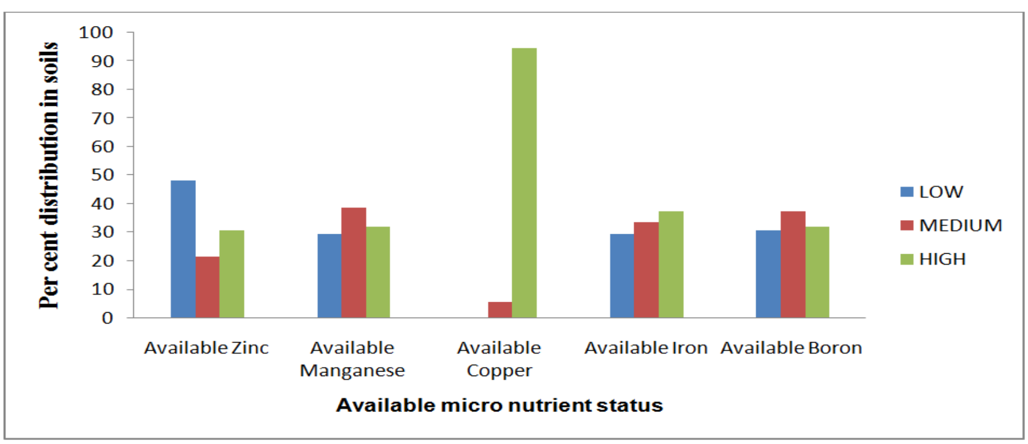
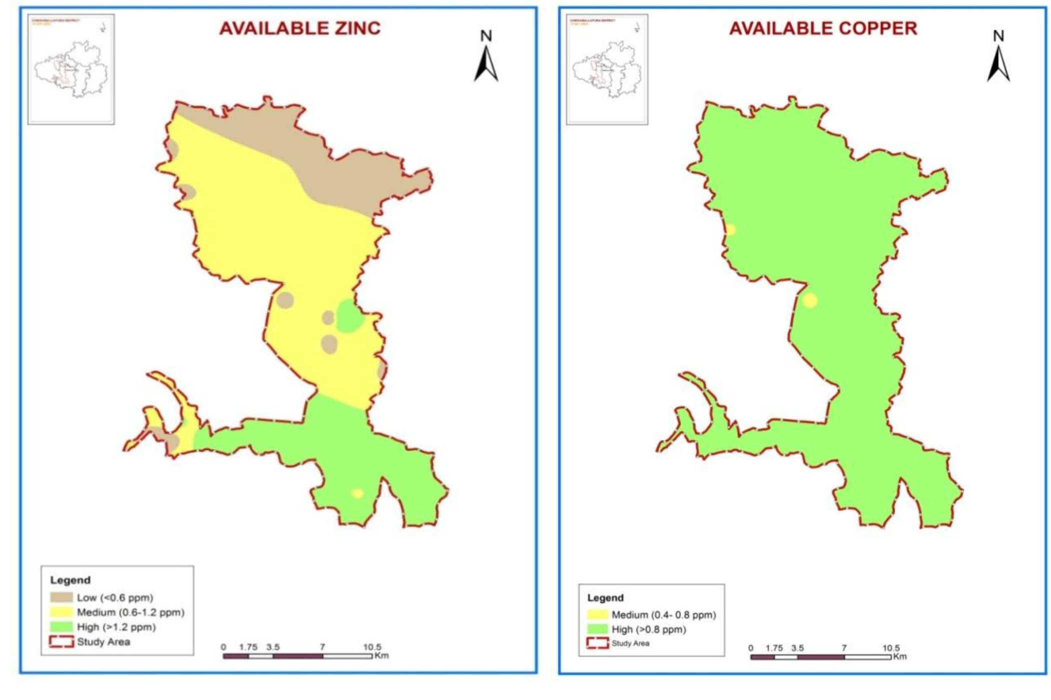


Fig. 1. Percent distribution of micronutrient content of tomato growing soils of Chikkaballapura district

A detailed survey of tomato growing soils of Chikkaballapur district reveals that nutrient index of available zinc, manganese, copper, iron, boron and plant zinc was medium (1.67-2.33) and organic carbon, was high (>2.33). The NI value for zinc status was found to be 1.83 with medium status. The manganese, copper, iron and boron NI values are 2.03, 2.95, 2.08, and 2.10 respectively and categorized as medium. The details are presented in Table 3. The overall nutrient index of the district was in conformity with the findings of Singh et al., 2016 [19]. In view of the above, it is concluded that the intensive soil management practices are required in the studied area for improvement of crop productivity and soil health.



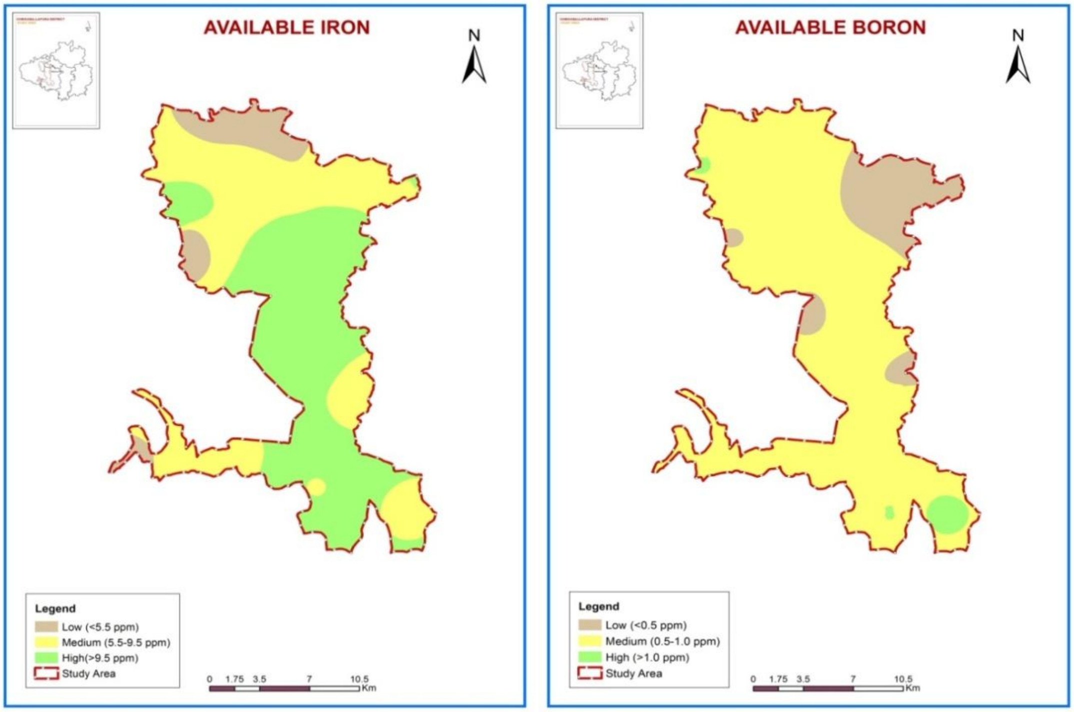


Fig. 2. Mapping of micro nutrient status in soils of Chikkaballapura district, Karnataka

Table 3. Nutrient index (N.I) of tomato growing areas of Chikkaballapura district

S.No	Parameter	Low	Medium	High	N.I	N.I Class
1	O.C	15	6	54	2.52	High
2	Available Zinc	36	16	23	1.83	Medium
3	Available Manganese	22	29	24	2.03	Medium
4	Available Copper	0	4	71	2.95	High
5	Available Iron	22	25	28	2.08	Medium
6	Available Boron	23	28	24	2.01	Medium
7	Plant Zinc	14	20	7	1.83	Medium

3.4 Correlation of the Micronutrients with Other Physico Chemical Properties

Among the soil properties, soil pH and organic carbon has been comprehensively identified as the most important soil factor controlling the availability of micronutrients in soil.

Soil pH is negatively correlated with the micronutrients Zn, Mn, Cu and B. Electrical Conductivity is positively correlated with all the micronutrients Zn, Mn, Cu, Fe and B. The mean available Zn, Cu, Fe and Mn contents decreased with increase in pH and increased with increase in organic carbon content of the soil. Similar trend was also observed by [20,21,22] reported that soil properties exercise greatest influence in controlling the micronutrient status of soils. Available Cu was negatively correlated (-0.040) with pH.

Negative significant correlations of available Mn with pH (-0.113) for Chikkaballapur soils. Similar results are reported in Lachimipur series of Jharkhand [23] which may be due to the formation of insoluble higher valent oxides of Mn. Organic carbon is positively correlated with Zn, Mn and positively significantly correlated with Cu and Fe, where as B is negatively correlated with organic carbon for Chikkaballapura soils. The details are presented in Table. 4. Similar results were also reported in Soils of Garikapadu of Krishna district of Andhra Pradesh [24].

The availability of micronutrients increase with organic matter content might be ascribed to

Table 4. Correlation (r) between soil physico chemical properties with micronutrients of tomato growing areas of Chikkaballapura district

	pH	EC	O.C	Sand	Clay	Silt
Zinc	-0.151	0.201	0.177	0.149	-0.266*	0.112
Manganese	-0.113	0.127	0.189	-0.041	-0.030	0.055
Copper	-0.040	0.049	0.297**	0.147	-0.218	0.074
Iron	0.103	0.060	0.298**	-0.077	-0.071	0.115
Boron	-0.061	0.075	-0.062	-0.084	-0.116	0.157

*** Significant at 0.01 level; * Significant at 0.05 level*

greater availability of chelating agents through organic matter. DTPA, being organic chelating agent, extracts micronutrient cations from different pools [25] and the higher amount of organic carbon coupled with low pH values is further likely to increase the solubility of micronutrient cations. This might be the reason for positive correlation with micronutrients. Similar findings have also been reported [26].

Positive correlation of Zn, Cu, Fe, Mn and B was observed with silt. It has been reported that adsorbed metal ions (Zn, Cu, Fe, Mn) are in equilibrium with the soil solution. Thus, a soil having greater surface is expected to adsorb greater amount of these ions and vice versa. Increase in the finer surface area for ion exchange and hence can contribute to greater DTPA-extractable forms of metal ions. Similar results were reported by Bhanwaria et al., 2011 [27].

4. CONCLUSION

The Zn, Fe, Mn, Cu and Boron content of tomato growing soils of Chikkaballapura district ranged from 0.07 to 6.87, 2.08 to 28.92, 1.37 to 27.08, 0.41 to 4.59 and 0.24 to 2.13 mg kg^{-1}, respectively and all micronutrients were recorded low to high in content. The zinc content in the tomato plants ranged from 14 to 98 mg kg^{-1} and was categorized as low to high in zinc content. About 48.00, 21.33 and 30.67 per cent are recorded as low, medium and high zinc status, respectively. Whereas plant zinc indicated 34.15 per cent samples as low, 48.78 per cent medium and 17.07 per cent was high),respectively. Available Cu status indicated that 5.33 per cent samples were medium and the rest 94.67 samples were high in copper content, where as 29.33, 38.67 and 32 per cent samples were in low, medium and high in Mn content. Available Fe status indicated that 29.33 per cent soils were low, 33.33 per cent soils were medium and 37.34 samples were high respectively, whereas for boron, 30.67 per cent was under low, 37.33 per cent was under medium and 32per cent was under high boron content. Soil fertility maps prepared were useful for proper planning of micronutrient fertilization, monitoring changes in fertility levels and helps in sustainable crop production by bringing good economic returns.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Yadav RL, Meena MC. Available micronutrients status and their relationship with soil properties of Degana soil series of Rajasthan. J. Indian Soc. Soil Sci.2009; 57(1):90-92.
2. Sharma BD, Arora H, Kumar R, Nayyar VK. Relationships between soil characteristics, total and DTPA-extractable micronutrients in Inceptisols of Punjab. Commun. Soil Sci. Pl. Analysis. 2004;35: 799-818.
3. Sood A, Sharma PK, Tur NS, Nayyar VK. Micronutrient status and spatial variability in soils of Muktsar district of Punjab- A GIS approach. J. Indian Society Soil Sci. 2009; 57(3):300-306.
4. Jackson ML. Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi;1973.

5. Walkley AJ, Black CA. Estimation of soil organic carbon by thechromic acid and titration method. Soil Sci.1934;37:29-38.
6. Panse VC, Sukhatme PV. Indian statistical methods for agricultural workers. I.C.A.R. New Delhi; 1978.
7. Motsara MR, Singh J, Verma KPS. Nutrients indexing system in soil fertility evaluation and fertilizer use in India. Fertilizer News. 1982;27:92-99.
8. Waikar SL, Malewar GU, More SD. Elemental composition of humicand fulvic acid in soils of Marathwada region of Maharashtra. J. Maharashtra Agri. Univ. 2004;29:127-129.
9. Sathish A, Ramachandrappa BK, Devaraja K, Savitha MS, Thimme Gowda MN, Prashanth KM. Assessment of spatial variability in fertility status and nutrient recommendation in Alanatha cluster villages, Kanakapura taluk, Ramanagara district, Karnataka Using GIS Techniques. Int. J. Curr. Microbiol. App. Sci. 2017;6(5): 211-224.
10. Dwivedi Sanjay K, Sharma VK, Vipin Bharadwaj. Status of available nutrients in soils of cold arid region of Ladakh. J. Indian Soc. Soil Sci. 2005; 53(3):421-423.
11. Nagendran, Angayarkanni A. Vertical distribution of DTPA-extractable micronutrients in soils of Cumbum valley, Tamil Nadu. Agric. Sci. Digest. 2010;30(2): 79-84.
12. Hundal HS, Rajkumar, Dhanwindar Singh, JS Machandra. Available nutrient and heavy metal status of soils of Punjab, North-west India. J. Indian Society of Soil Sci. 2006;54:50-56.
13. Karthikeyan K, Pushpanjali , Prasad J. Soil fertility status of soybean (*Glycine max L.)* growing soils of Malwa Plateau, Madhya Pradesh. J. Indian Soc. Soil Sci. 2014; 62(2):174-178.
14. Singh YP, Raghubanshi BPS, Rajbeer S, Tomar, Verma SK, Dubey SK. Soil fertility status and correlation of available macro and micronutrients in chambal region of Madhya Pradesh. J. Indian Soc. Soil Sci. 2014;62(4):369-375.
15. Ravikumar MA, Patil PL, Dasog GS. Mapping of nutrient status under 48A distributary in Malaprabha right bank command of Karnataka by geographic information system technique. Karnataka J. Agri. Sci.2007; 20:738-740.
16. Pulakeshi HBP, Patil PL, Dasog GS. Characterization and classification of soil resources derived from chlorite schist in northern transition zone of Karnataka. Karnataka J. Agric. Sci. 2014;27(1):14-21.
17. Wani A Mushtaq, Wani Zahid M, Nazir S. Spatial variability of DTPA Extractable Cationic Micronutrients in Northern part of lesser Himalayas using GIS Approach. Esri India User Conference. 2014;15:1-14.
18. Nayak AK, Chinchamalatpure, Anil R, Gururaja Rao G, Khandelwal MK, Tyagi NK. Spatial variability of DTPA extractable micronutrients in soils of Baratract of Sardar Sarovar canal command in Gujarat state India. J. Indian Soc. Soil Sci. 2006;42(1):137-145.
19. Singh SK, Dey P, Sharma PK, Singh YV, Latare AM, Singh Deelip Kumar CM, Omkar Kumar, Yadav SN, Varma SS. Primary and cationic micronutrient status of soils in few districts of eastern Uttar Pradesh. J. Indian Soc. Soil Sci. 2016; 64(4):319-332.
20. Rao BS, Patil DB, Puli MR, Jayalakshmi M. Delineation of copper (cu)and zinc (zn) status in soils of Central Research Station. Akola. J. Prog. Agriculture. 2013;4(1):131-134.
21. Ravi P, Raj GB, Rao C. Distribution of DTPA extractable micro nutrients in rice growing soils of Karimnagar district of Andhra Pradesh. Helix. 2014;1:494-497.
22. Reza S K, Baruah U, Sarkar D. Spatial variability of soil properties in Brahmaputra plains of north-eastern India: A geo statistical approach. J. Indian Soc. Soil Sci. 2012;60(2):108-115.
23. Rakesh Kumar AK, Sarkar KP, Agarwal BK, Karmaker S. Appraisal of available nutrient status in santlal paragacas region of Jharkhand. J. Indian Soc. Soil Sci. 2009;57(3):366-369.
24. Rajeswar M, Rao CS, Balaguravaiah D, Khan MAA. Distribution of available macro and micronutrients in soils garikapadu of krishna district of Andhra Pradesh. J. Indian Soc. Soil Sci. 2009;57(2):210-213.
25. Lindsay WL, Norvell WA. Development of DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. America. 1978; 42:421-428.
26. Kumar R, Sarkar AS, Singh KP, Agarwal B K, Karmakar S. Appraisal of available nutrients status in santhal paraganas region of Jharkhand. J. Indian Soc. Soil Sci. 2009;57(3):366-369.

27. Bhanwaria R, Kameriya PR, Yadav BL. Available micronutrient status and their relationship with soil properties of Mokala soil series of Rajasthan. J. Indian Soc. Soil Sci. 2011;59(4):392-396.

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