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Mapping the distribution of micro nutrients in soils of Akola district: A spatial analysis

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Abstract
Soil nutrient mapping and analysis were conducted in the Akola district during 2023-2024 using grid sampling technique with grid of 5 km total 270 georeferenced surface soil samples (0-20) collected randomly with GPS assistance. The soil samples using GPS representing each square by dividing toposheet of district and from each square the representative soil sample was collected so that the sampling sites were well distributed in the district. The soil pH levels varied from 6.86 to 8.67, indicate that soils in Akola district neutral to strongly alkaline and the electrical conductivity ranged between 0.12 to 0.98 dSm^{-1}. The free $CaCO_3$ content was found to be between 0.50 to 20.00%, with higher levels observed in Akola and Telhara tehsils. Organic carbon content ranged from 1.76 to 15.15 g kg^{-1}, notably higher in Barshitakali (2.35 – 15.15 g kg^{-1}). Available zinc content ranged from 0.21 to 2.85 mg kg^{-1}, the zinc deficiency was recorded to the extent of 47.70% in soils of Akola. Available iron ranged from 0.40 to 16.37 mg kg^{-1}, the iron deficiency was recorded to the extent of 77.41% in soils of Akola. Available copper content ranged from 0.89 to 6.57 mg kg^{-1}, copper deficiency was not recorded to the extent of in soils of Akola. Available manganese content ranged from 2.55 to 42.72 mg kg^{-1}, the manganese deficiency was recorded to the extent of 4.82% in soils of Akola. Available Boron ranged from 0.03 to 6.95 mg kg^{-1} , the boron deficiency was recorded to the extent of 61.47% in soils of Akola .Nutrient indices indicated medium range for available zinc (4.00) and low range for iron (2.68) and boron (3.26), and high range for copper (5.99) and manganese (5.69). Overall, the soil fertility in the Akola district is characterized by medium zinc levels, low iron and boron, high copper and manganese availability.

Keywords: Micronutrients, GPS, nutrient indices, deficiency

1. Introduction

Application of fertilizers by farmers in fields without prior knowledge of soil fertility status might result in adverse effects on soils as well as crops, both in terms of micronutrient deficiency and toxicity, caused by inadequate or overuse of fertilizers. With the advent of modern technologies such as remote sensing, increasing population pressure and overexploitation of productive lands create serious problems with the lowering of soil fertility status, leading to soil deterioration. Nutrient deficiencies directly affect crop growth, resulting in poor crop response (Jagtap *et al.* 2018) [7]. Therefore, for the sustainability of the present agricultural system and for effective soil management, a comprehensive database regarding the fertility status of soils is required. Soil fertility is a dynamic natural attribute that can vary under the influence of natural and human-induced factors (Denis *et al.* 2017) [2] In conclusion, it is crucial to utilize modern technologies for monitoring soil fertility and crop health to ensure sustainable agricultural practices and mitigate the adverse effects of indiscriminate fertilizer application. Currently, Indian agriculture faces a critical challenge: enhancing food production and productivity while ensuring the sustainability of the agricultural sector as a whole. Several issues hinder these goals, raising serious concerns about national food security. These challenges include soil fertility deterioration, rising production costs, and a lack of diversity in production systems. The imperative for improved crop productivity has become more pressing due to population growth and the resulting pressures from competing land demands. Consequently, the land-man ratio has decreased, leading to smaller average farm sizes and soil fertility depletion from continuous or intensive cropping coupled with imbalanced fertilization practices.

Soil fertility decline stands as a major obstacle to achieving high productivity targets. In both rainfed and irrigated systems, nutrient replenishment through fertilizers and manures falls short of crop removal rates, resulting in the depletion of native nutrient reserves over time. Soil nutrient depletion carries significant implications. Geographic Information System (GIS), and Global Positioning System (GPS), it is now possible to monitor soil fertility and crop health through systematic surveys. This monitoring can help to track changes in the fertility status of the studied area and determine site-specific nutrient requirements for crops. It is anticipated that with higher yields and more intensive agriculture, the incidence of secondary and micronutrient deficiency will increase both in amount and extent (NAAS, 2018). The imbalanced and inadequate use of fertilizers, coupled with low use efficiency of other inputs, has led to a decline in the response efficiency of chemical fertilizers under intensive agriculture in recent years. Recognizing these challenges, the present study was taken up with the objectives to assess the status of micronutrients in soils and to identify areas of micronutrient deficiencies in Akola district Maharastra.

2. Materials and Methods

2.1 Study Area

The Akola district located at 20.7004° N, 77.1025° E Maharastra India. It is bounded on the north and east by Amaravati District, to the south by Washim District, and to the west by Buldhana, district, Washim was earlier a part of Akola till 1999.Akola district include seven takulas which are Akola, Akot, Telhara, Balapur ,Barshitakali, Murtizapur and Patur. Total area covered by Akola district is 5428 sq.Km. Akola district is bounded on the north by the southern foot-hill of the Gavilgarh range which, in turn forms a part of the Satpuda range of hills, whereas, on south, it is bounded by the Ajanta and Satmala hills. Akola has an average elevation of 287 metres (942 feet). The most fertile soils of the district are the rich soils of the Purna valley proper. Akola tahsil also possesses some black soil, though to the east of the Katepurna River the tract is stony. The two main rivers of the district are the Purna River and the Penganga River, the other less important rivers being the tributaries of these two rivers. They are the Katepurna, Morna, Mun, Nand, Man and Uma, which are the tributaries of the Purna, the Arna and the Pus which are the tributaries of the Penganga.

The northern fringe of the district is hilly and forms part of Satpuda Range. South of these hill ranges, covering almost entire north-central part constitutes the Alluvial plain. 4 Southern part of the district is characterized by hilly rugged terrain as a part of Deccan Plateau. Purna and Painganga the main river flowing through the district. Other important rivers are Man, Murna and Kate. Two types of soils have been observed in the district namely medium black soil occurring in plain central part of trap origin and deep black soil occurring in valley in northern part. The climate of the district is characterized by a hot summer and general dryness throughout the year except during the south-west monsoon season, i.e., June to September. The mean minimum temperature is 12.6 °C and means maximum temperature is 45.4 °C. The normal annual rainfall over the district varies from about 740 mm to 860 mm.

The grid survey of district was carried out, the soil samples from dominant cropping system in the summer season Random surface soil samples representing different soils were collected from six out of seven tehsil of Akola district. Akot tehsil was excluded due to having salt affected soil with the grid sampling method about 5 km range or distance from previous sample. From each taluka minimum of 45-50 surface soil samples (0 - 20 cm) total 270 samples in Akola district were collected. The record of surveyed fields latitude, longitude using GPS with mean sea level was maintained. Soil pH and EC were determined in soil: water suspensions (1:2.5 w/v) as described by Jackson (1973) [6]. Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black (Nelson and Sommers, 1982) [12]. Free $CaCO_3$ was determined by rapid titration method (Piper, 1966) [16]. The available zinc, iron, copper and manganese were extracted with 0.005M diethylene triamine penta acetic acid (DTPA) and the concentrations of nutrients were determined on Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978) [9]. The nutrient indices were calculated by using the formula given by Parker *et al.* (1951) [13] and Hadole *et al* (2024).

Formula for Nutrient Index:

$$\text{Nutrient index} = \frac{\text{\% samples acute x 1 + \% samples deficient x 2 + \% samples latent x 3 + \% samples marginal sufficient x 4 + \% samples adequate x 5 + \% samples high x 6}}{100}$$

3. Result and Discussion

3.1 Soil properties

The soil pH for Akola district, showing values ranging from 6.86 to 8.67, (Table 2) indicating a pH range from neutral to strongly alkaline. The highest pH of 8.67 was observed in soils of Akola tehsil, while the lowest pH of 6.86 was recorded in Telhara tehsil. The alkaline nature of the soil is likely attributed to the presence of adequate free lime content in the soil (Jibhakate *et al.* 2009) [8]. Soil electrical conductivity (EC) values ranging from 0.12 to 0.98 dSm^{-1}(Table 2). It shows that soils in Akola district are generally non-saline, making them suitable for healthy plant growth. EC exceeding 1.0 dSm^{-1} indicates the presence of soluble salts, posing a risk to plant cultivation. Jackson (1967) [5]. The calcium carbonate content ($CaCO_3$) range from the 0.50 to 20.00 percent (Table 2) which indicates that soil are non-calcareous to calcareous in nature. The highest content of calcium carbonate was recorded in Akola tehsil. High levels of calcium carbonate in soil can be detrimental, as they lower the availability of essential micronutrient cations. This reduction can lead to deficiencies in sensitive plants, impacting their health and growth (Deb *et al.* 2009) [1]. The organic carbon content varied from 1.76 to 15.15 g kg^{-1}(Table 2). The organic carbon variation could be noticed in every tehsil with highest content observed in Barshitakali tehsil and Telhara tehsil.

3.2 Status of micronutrient

All available micronutrient can be categories into acute deficient, deficient, latent deficient, marginal sufficient, adequate, high, categories. The available zinc in all over Akola district ranged from 0.21 to 2.85 mg kg^{-1}, with mean of 1.13 mg kg^{-1} (Table 3), shows the moderate available zinc content in soils of Akola and major soil sample were found in latent category (28.14%) of available zinc followed by adequate (20.00%), high (18.52%), marginal sufficient (17.78%) and deficient (14.82%) category. While acute deficiency was observed in only two sample each of them from Telhara and Akola tehsil. The zinc deficiency was recorded to the extent of 47.70% in soils of Akola. The Nutrient index (Table 3) value in all over the district was found medium range that is (4.00). Highest nutrient index was found in Patur tehsil (5.28) followed by Barshitakali tehsil (4.86). Patil and Kharche (2006) [15] reported widespread deficiency of zinc in intensively cultivated districts of Western Maharashtra having predominant alkaline, calcareous, black clayey soils. The available iron in Akola district ranged from 0.40 to 16.37 mg kg^{-1}, with mean of 4.80 mg kg^{-1} (Table 4), shows the moderate available iron content in soils of Akola. In all tehsil such as Akola, Murtizapur, Barshitakali, Patur, Balapur, Telhara soil sample were found in latent deficient (31.48%) category of available iron followed by deficient (27.78%), acute deficient (18.15%), marginal sufficient (14.08%) category, while in the adequate and high categories some sample was found (4.81%) and (3.70%). The iron deficiency was recorded to the extent of 77.41% in soils of Akola. The Nutrient index (Table 4) value in all over the district was found low range that is (2.68). Highest nutrient index was found in Balapur tehsil (3.42) followed by Barshitakali and Murtizapur tehsil (3.18) and (3.02) while lowest nutrient index was observed from Akola district in Patur tehsil (1.62).

Patil *et al*. (2004) [15] reported 40 and 34.7 per cent soils deficient in zinc and iron in Vidarbha. The available copper in Akola district ranged from 0.89 to 6.57 mg kg^{-1}, with mean of 2.40 mg kg^{-1} (Table 5), shows the very high available copper content in soils of Akola. Most of the soil sample were found in high (99.63%) category of available copper followed by only one sample found in adequate category (0.37%). In case of acute deficiency there was not observed in any tehsil of Akola district. The copper deficiency was not recorded in soils of Akola. The Nutrient index (Table 5) value in all over the district was found in high range that is (5.99). P. N. Magare 2023 [10] also reported that the available copper content in soils of Akola varied from 0.78 to 4.98 mg kg^{-1} with a mean value of 2.95 mg kg^{-1}. The available manganese in Akola district ranged from 2.55 to 42.72 mg kg^{-1}, with mean of 13.42 mg kg^{-1} (Table 6), shows the very high available manganese content in soils of Akola. Akola soils most of the sample were found in high (86.66%) category of available manganese. The manganese deficiency was recorded to the extent of 4.82% in soils of Akola. The Nutrient index (Table 6) value in all over the district was found in high range that is (5.69) Gajbhe *et. al*. (1976) [3] reported that available Mn content in surface soils of Marathwada ranged from 13.3 to 65.20 ppm. The available boron in Akola district ranged from 0.03 to 6.95 mg kg^{-1}, with mean of 0.87 mg kg^{-1} (Table 7), shows the moderate available boron content in soils of Akola. Acute deficiency of available boron were observed in Barshitakli (27.27%), Patur (23.08%), Telhara (17.07%), Murtizapur (13.04%), Balapur (6.67%) and Akola tehsil (5.45%). The boron deficiency was recorded to the extent of 61.47% in soils of Akola. The Nutrient index (Table 7) value in all over the district was found in low range that is (3.26). Highest nutrient index was found in Akola tehsil (4.75) followed by Murtizapur and Telhara tehsil (4.46). The deficiency of nutrients creates imbalance in soils which results into nutritional stress in plants (Malewar, 2005) [11]. Singh (2003) [18] also enclosed the heavy depletion of micronutrients with time, particularly under intensive cropping of rice-wheat, maize-wheat and rice-rice.

Table 1: Categories of micronutrients.

Categories / Nutrient	Acute Deficient	Deficient	Latent Deficient	Marginal Sufficient	Adequate	High
Zn (mg kg^{-1})	<0.30	0.31-0.60	0.61-0.90	0.91-1.2	1.21-1.80	>1.80
Fe (mg kg^{-1})	<2.50	2.50-4.50	4.51-6.50	6.51-8.50	8.51-10.50	>10.50
Cu (mg kg^{-1})	<0.20	0.20-0.40	0.41-0.60	0.61-0.80	0.81-1.0	>1.00
Mn (mg kg^{-1})	<1.0	1.10-3.0	3.10-5.0	5.0-7.0	7.10-9.0	>9.00
B (mg kg^{-1})	<0.20	0.20-0.50	0.50-0.70	0.70-0.90	0.90-1.10	>1.10
Categories of Nutrient Index Value (NIV).						
NIV	Low		Medium		High	
Index	<3.34		3.34-4.66		>4.66	

Categories for available macro and micronutrient in six tier system acute deficient, deficient, latent deficient, marginal sufficient, adequate and high is taken from (Shukla *et al.* 2024) [17] and nutrient index value interpreted according to the standards proposed by Hadole *et al.* (2024) [4]

Table 2: Chemical properties of soil in Akola district.

S. N.	Name of tehsil	pH (1:2.5)		EC (dS m^{-1})		$CaCO_3$ (%)		Org.carbon (g kg^{-1})	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Akola	7.32-8.67	8.03	0.19-0.98	0.37	2.88-19.75	14.08	2.76-12.09	7.24
2	Murtizapur	7.18-8.46	8.03	0.15-0.90	0.32	2.50-20.20	9.32	2.35-9.26	4.98
3	Barshitakali	7.22-8.37	7.91	0.12-0.55	0.29	1.13-17.25	8.02	2.35-15.15	9.39
4	Patur	6.93-8.44	7.87	0.15-0.98	0.36	0.50-12.50	3.89	1.76-9.12	5.78
5	Balapur	7.70-8.36	8.08	0.15-0.75	0.27	2.50-19.50	8.93	2.21-7.79	4.61
6	Telhara	6.86-8.48	7.93	0.19-0.88	0.38	2.13-17.13	10.01	5.00-13.53	7.83
	Akola district	6.86-8.67	7.97	0.12-0.98	0.33	0.50-20.00	9.04	1.76-15.15	6.63

Table 3: Tehsil wise status and nutrient indices of DTPA zinc in soils of Akola District

Tehsil	Range (mg kg^{-1})	Number of samples							NIV
		Mean	Acute	Deficient	Latent	Mar. Suf.	Ade	High	
Akola	0.21-2.01	0.85	1 (1.82)	13 (23.64)	25 (45.45	7 (12.73)	6 (10.91)	3 (5.45)	3.24
Murtizapur	0.48-1.62	0.89	0	7 (15.22)	22 (47.83)	10 (21.74)	7 (15.22)	0	3.37
Barshitakli	0.71-2.85	1.51	0	0	4 (9.09)	13 (29.55)	12 (27.27)	15 (34.09)	4.86
Balapur	0.58-1.96	1.14	0	3 (6.67)	12 (26.67)	6 (13.33)	13 (28.89)	11 (24.44)	4.38
Patur	0.67-2.52	1.63	0	0	3 (7.69)	4 (10.26)	11 (28.21)	21 (53.85)	5.28
Telhara	0.30-1.78	0.77	1 (2.44)	17 (41.46)	10 (24.39)	8 (19.51)	5 (12.20)	0	2.98
District	0.21-2.85	1.13	2 (0.74)	40 (14.82)	76 (28.14)	48 (17.78)	54 (20)	50 (18.52)	4.00

(Figures in parenthesis are percentage)

Table 4: Tehsil wise status and Nutrient indices of DTPA iron in soils of Akola

Tehsil	Range (mg kg^{-1})	Mean	Number of samples						NIV
			Acute	Deficient	Latent	Mar. Suf.	Ade	High	
Akola	2.32-10.18	3.99	5 (9.09)	23 (41.82)	15 (27.27)	11 (20.00)	1 (1.82)	0	2.20
Murtizapur	1.61-13.80	5.45	1 (2.17)	15 (32.61)	20 (43.48)	5 (10.87)	2 (4.35)	3 (6.52)	1.62
Barshitakli	2.25-16.37	6.35	4 (9.09)	15 (34.09)	8 (18.18)	9 (20.45)	2 (4.55)	6 (13.64)	3.02
Balapur	2.37-10.31	6.51	1 (2.22)	3 (6.67)	23 (51.11)	12 (26.67)	6 (13.33)	0	3.18
Patur	0.40-11.21	2.55	27 (69.23)	5 (12.82)	5 (12.82)	0	1 (2.56)	1 (2.56)	1.24
Telhara	1.34-8.69	3.96	11 (26.83)	14 (34.15)	14 (34.15)	1 (2.44)	1 (2.44)	0	3.42
District	0.40-16.37	4.80	49 (18.15)	75 (27.78)	85 (31.48)	38 (14.08)	13 (4.81)	10 (3.70)	2.68

(Figures in parenthesis are percentage)

Table 5: Tehsil wise status and Nutrient indices of DTPA copper in soils of Akola

Tehsil	Range (mg kg^{-1})	Mean	Number of samples						NIV
			Acute	Deficient	Latent	Mar. Suf.	Ade	High	
Akola	1.17-4.80	1.91	0	0	0	0	0	55 (100)	6.00
Murtizapur	0.89-5.17	2.51	0	0	0	0	1 (2.17)	45 (97.83)	5.98
Barshitakali	1.34-5.87	2.50	0	0	0	0	0	44 (100)	6.00
Balapur	1.30-4.07	2.07	0	0	0	0	0	45 (100)	6.00
Patur	1.72-6.57	2.93	0	0	0	0	0	39 (100)	6.00
Telhara	1.53-3.97	2.52	0	0	0	0	0	41 (100)	6.00
District	0.89-6.57	2.40	0	0	0	0	1 (0.37)	269 (99.63)	5.99

(Figures in parenthesis are percentage)

Table 6: Tehsil wise status and Nutrient indices of DTPA manganese in soils of Akola

Tehsil	Range (mg kg^{-1}) (mg	Mean	Number of samples						NIV
			Acute	Deficient	Latent	Mar. Suf.	Ade	High	
Akola	10.14-22.32	11.44	0	0	0	0	0	55 (100)	5.39
Murtizapur	9.06-42.72	15.72	0	0	0	0	0	46 (100)	4.90
Barshitakali	10.20-17.24	12.93	0	0	0	0	0	44 (100)	6.00
Balapur	4.35-29.44	15.92	0	0	1 (2.22)	1 (2.22)	1 (2.22)	42 (93.33)	6.00
Patur	3.51-28.10	9.86	0	0	7 (17.95)	7 (17.95)	8 (20.51)	17 (43.59)	3.76
Telhara	2.55-30.60	14.68	0	1 (2.44)	4 (9.76)	3 (7.32)	3 (7.32)	30 (73.17)	5.87
District	2.55-42.72	13.42	0	1 (0.37)	12 (4.45)	11 (4.07)	12 (4.45)	234 (86.66)	5.69

(Figures in parenthesis are percentage)

Table 7: Tehsil wise status and Nutrient indices of available boron in soils of Akola

Tehsil	Range (mg kg^{-1})	Mean	Number of samples						NIV
			Acute	Deficient	Latent	Mar. Suf.	Ade	High	
Akola	0.03-6.95	1.52	3 (5.45)	8 (14.55)	4 (7.27)	2 (3.64)	6 (10.91)	32 (58.18)	4.02
Murtizapur	0.12-6.43	1.52	6 (13.04)	4 (8.70)	5 (10.87)	2 (4.35)	6 (13.04)	23 (50)	2.00
Barshitakali	0.04-0.68	0.30	12 (27.27)	29 (65.91)	3 (6.82)	0	0	0	4.46
Balapur	0.07-1.00	0.49	3 (6.67)	24 (53.33)	11 (24.44)	5 (11.11)	2 (4.44)	0	1.80
Patur	0.06-0.95	0.34	9 (23.08)	24 (61.54)	4 (10.26)	1 (2.56)	1 (2.56)	0	2.04
Telhara	0.03-2.78	1.09	7 (17.07)	5 (12.20)	5 (12.20)	4 (9.76)	3 (7.32)	17 (41.46)	2.53
District	0.03-6.95	0.87	40 (14.81)	94 (34.81)	32 (11.85)	14 (5.18)	18 (6.66)	72 (26.66)	3.26

(Figures in parenthesis are percentage)

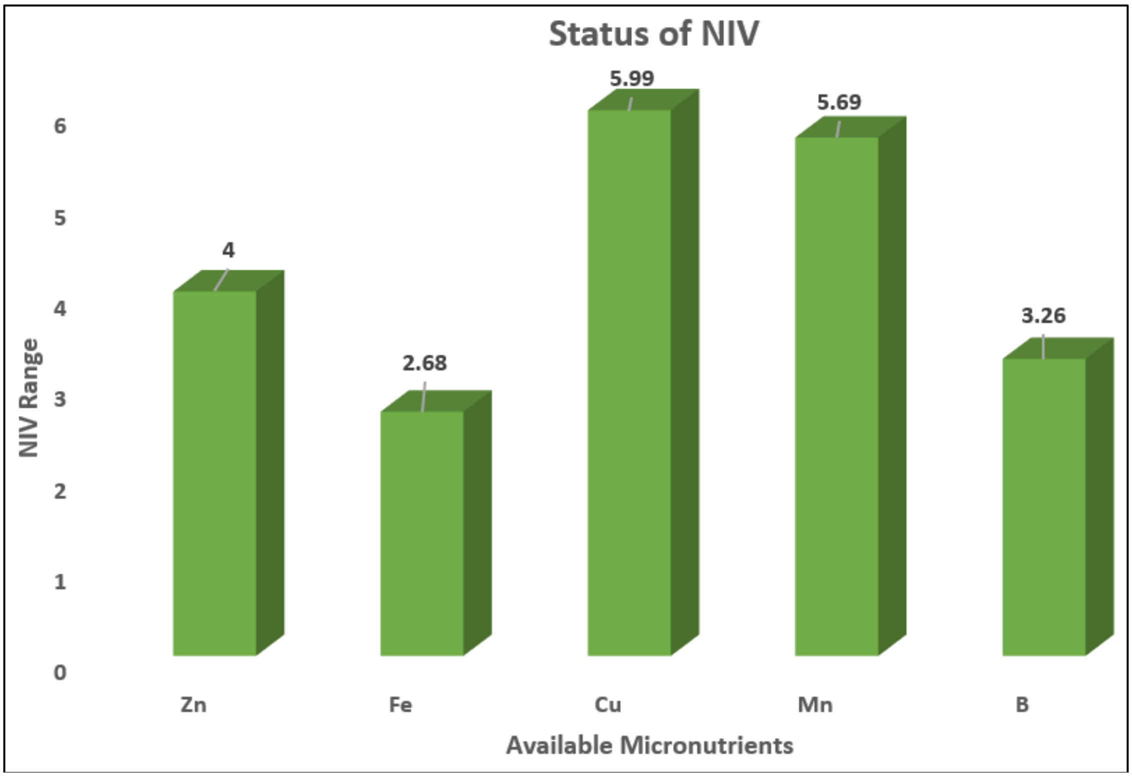

Fig 1: Status of nutrient index values in Akola district

4. Conclusion

The available Zn status in Akola district ranged from 0.21-2.85 mg kg^{-1}. The zinc deficiency was recorded to the extent of 47.70% in soils of Akola. The acute deficiency was observed in Telhara and Akola tehsils and the NIV is in medium range. The available Fe status in Akola district ranged from 0.40-16.37 mg kg^{-1}. The iron deficiency was recorded to the extent of 77.41% in soils of Akola. The acute deficiency was observed in Patur, Telhara, Akola, Barshitakali, Murtizapur and Balapur tehsils and the NIV is in low range. The available Cu status in Akola district ranged from 0.89 -6.57 mg kg^{-1}. The Copper deficiency was not recorded and NIV is in high range. The available Mn status in Akola district ranged from 2.55-42.72 mg kg^{-1}. The manganese deficiency was recorded to the extent of 4.82% and acute deficiency was not observed. The available B status in Akola district ranged from 0.03-6.95 mg kg^{-1}. The boron deficiency was recorded to the extent of 61.47% in soils of Akola. The acute deficiency was observed in Barshitakali, Patur, Telhara, Murtizapur, Balapur and Akola tehsils and the NIV is in low range.

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