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Status of Available Micronutrient Cations and their Relationship with Soil Properties in Nagpur District, Maharashtra

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ABSTRACT: Two hundred surface soil samples representing different soil series and associated soils from different tehsils of Nagpur district were collected and analyzed for relevant physical, chemical soil properties and DTPA-extractable micronutrients. The results revealed that soils were sufficient in DTPA-extractable micronutrient cations except zinc which was found deficient in nearly 62% of the samples. Pearson correlation coefficients indicated positive correlation of DTPA-extractable micronutrient cations with organic carbon and negative correlation with pH, EC, $CaCO_3$, CEC, base saturation and clay content. Based on soil nutrient indexing approach, different tehsils of Nagpur district were classified under adequate, marginal and deficient zones of available micronutrients for soil fertility management.

Key words: Soil fertility, micronutrients, nutrient index, shrink-swell soils

Micronutrients play a vital role in maintaining the soil health and in-turn crop productivity. The main sources of micronutrients are parent material, sewage sludge, town refuse, farmyard manure (FYM) and organic matter. The availability of native micronutrients in soil is governed by several soil properties *viz.* organic matter, soil pH (Dahiya *et al*., 2005; Perez-Novo *et al*., 2011), $CaCO_3$, sand, silt, clay and cation exchange capacity, etc. (Hamza *et al.,* 2009). The adsorption of metal cations to oxide and clay mineral surfaces is strongly pH dependent (Dahiya *et al*., 2005; Zahedifar *et al*., 2010; Perez-Novo *et al*., 2011). Increased removal of micronutrients from soil due to intensive cropping of HYVs decrease micronutrients to below the normal range at which productivity of crops is severely affected and Nagpur district is not an exception (Jagdish Prasad and Gajbhiye, 1999; Chinchmalatpure *et al.,* 2000). Hence, an attempt was made to analyze the status of available soil micronutrient cations and the factors affecting their availability in agricultural soils of Nagpur district, Maharashtra for sustainable agriculture production and soil fertility management.

Materials and Methods

Nagpur district having an area of 9931 km^2 (20^{o}30' to 25^{o}45'N; 78^{o}15' to 79^{o}40'E) is located in the Vidarbha region of Maharashtra at an elevation ranging from 150 and 600 m above msl. The major geological formations are Deccan traps in west and south, and granite-gneisses in the eastern part of the district. The climate is dry sub-humid with a mean annual temperature of 26.8^{o}C and mean annual rainfall of about 1127 mm. The soil temperature and moisture regimes are *hyperthermic* and *ustic*, respectively. Physiographically, the district covers hills and ridges, isolated hillocks, intervening valleys, upper and lower plateau, mesa and butte and alluvial plains.

The soils, in general, have hue of 2.5YR, 5YR, 10YR (dominant) and 2.5Y with values 2 to 4 and chroma 1 to 6. Majority of the soils are rich in clay content (> 30%) and, in general, smectite is the dominant clay mineral. The soils of plateau and subdued hills, in general, are very shallow to moderately deep, well to excessively drained, loamy to very-fine textural family class whereas, those occurring in valleys and alluvial plains are moderately deep to very deep, moderately well to well drained fine-loamy to very-fine textural family. The soils have been classified under Typic and Lithic subgroups of Entisol order; Typic, Lithic, Vertic and Fluventic subgroups of Inceptisol order and Typic subgroup of Vertisol order (NBSS&LUP, 1990).

The natural vegetation consists of *Acacia arabica*, *Zizyphus jujuba*, *Butea frondosa*, *Azadirachta indica*, *Tectona grandis*, etc. The dominant *kharif* crops are cotton, soybean, paddy (in north eastern part), pigeonpea, sorghum and cowpea, while wheat and gram are major *rabi* crops. Nagpur Mandarin (*Citrus reticulata*) is an important horticultural crop in western part but is transcending towards eastern part owing to better pedo-edaphic environment (Likhar and Jagdish Prasad, 2011).

Soil sampling and analysis

A total of 200 surface soil samples (0-15 cm) representing identified soil series and associated soils from 13 tehsils of Nagpur district were collected in the month of April, 2007. The samples were processed and analyzed for sand, silt, clay, pH, organic carbon, calcium carbonate ($CaCO_3$) and cation exchange capacity (CEC) following standard methods. The available Fe, Mn, Zn and Cu in soil samples were extracted with DTPA (diethelene penta acetic acid) solution (Lindsay and Norvell, 1978) and the concentration of micronutrient cations in the extract was determined by using atomic absorption spectrophotometer (Perkin Elmer Analyst-100). The correlation coefficients between micronutrient cations and different soil properties were worked out as per Gomez and Gomez (1984). The soils were classified into three groups *viz.* deficient, marginal and adequate as per Shukla *et al*. (2012) (Table 1).

Table 1 : Nutrient levels used for classifying soils

Nutrient	Deficient	Marginal	Adequate
DTPA-Fe	<4.5	4.5-7.5	>7.5
DTPA-Mn	<1.0	1.0-2.0	>2.0
DTPA-Zn	<0.6	0.6-1.0	>1.0
DTPA-Cu	<0.2	0.2-0.5	>0.5

The soil nutrient index was worked out using the equation [NI = ((ND x 1) + (NM x 2) + (NA x 3)/NT] as given by Parker *et al.* (1951) where, NI is the nutrient index, ND, NM and NA are the number of soil samples falling in deficient, marginal and adequate categories, respectively and NT represents the total number of samples analyzed. The limits of nutrient index used for deficient, marginal and adequate class are <1.67, 1.67 to 2.33 and >2.33, respectively (Ramamoorthy and Bajaj, 1969).

Results and Discussion

More than 75% soils had pH ≥7.0 and soil EC <0.77 dS/m in all the samples (Table 2). The organic carbon content of soils ranged from 1.14 to 29.41g/kg and $CaCO_3$ content from 0.25 to 17.04%. The CEC of soils varied from 11.3 to 75.7 cmol (+)/kg and base saturation from 68.5 to 122.5% owing to presence of zeolite (Lingade *et al*., 2008), respectively. In general, more than 75% soils were clayey due to their development from basaltic parent material. Sand, silt and clay contents in the soils ranged from 1.2 to 91.1, 4.6 to 60.4 and 4.4 to 75.0%, respectively.

The data on available micronutrients (Table 2) indicate that DTPA-extractable Fe, Mn, Zn and Cu contents in soil varied from 2.53 to 71.31, 1.12 to 95.96, 0.13 to 2.42 and 0.48 to 16.28 mg/kg, respectively. It was observed that the DTPA-Fe, Mn and Cu were above the critical levels of 4.5 mg/kg, 1.0 mg/kg and 0.2 mg/kg (Shukla *et al.,* 2012), respectively in the soil samples. However, DTPA-Zn was found deficient in 62% of the samples against critical level 0.6 mg/kg.

Tehsil-wise spatial distribution of micronutrients

The highest mean DTPA-Fe content was found in soils of Katol (20.88 mg/kg) whereas, the lowest value (6.59 mg/kg) was found in soils of Kuhi owing to varied geological formation and land uses (Table 3). The mean DTPA-Mn content was the highest in soils of Katol (34.95 mg/kg) whereas, the lowest value (2.91 mg/kg) was recorded in soils of Hingna. The mean DTPA-Zn varied from 0.32 to 0.97 mg/kg and was found below the critical level (0.6 mg/kg) in Hingna, Kalmeshwar, Kuhi, Nagpur, Kamthi, Parshivni, Ramtek, Saoner and Umred. The lowest values of DTPA-Zn have been found in the soils of Ramtek which could be due to intensive cultivation of paddy in *kharif* and thereafter oilseeds or vegetables. The mean DTPA-Cu content was highest in soils of Katol (6.64 mg/kg) whereas the soils of Parshivni had the lowest value (1.25 mg/kg). The lowest mean contents of DTPA-Fe (Kuhi), DTPA-Mn (Hingna), DTPA-Zn and Cu (Parshivni) in the soils might be due to the presence of high amount of $CaCO_3$ in these soils that reduces the availability of micronutrients (Kadao *et al.,* 2002).

Table 2 : Descriptive statistical parameters of physical and chemical properties of soils

Soil property	No. of soil samples	Range	Mean	SD	Percentiles				
					10	25	50	75	90
pH (1:2 soil:water)	200	4.87-8.67	7.49	0.71	6.53	6.95	7.70	8.01	8.20
EC (dS/m)	200	0.03-0.77	0.21	0.12	0.07	0.13	0.19	0.26	0.36
Organic C (g/kg)	200	1.14-29.41	8.72	4.12	4.75	6.06	7.93	10.24	14.09
$CaCO_3$ (%)	159	0.25-17.04	5.45	4.01	1.54	2.42	4.22	7.91	11.34
CEC (cmol (+)/kg)	200	11.33-75.65	48.16	14.64	21.33	38.77	52.06	59.00	65.00
BS (%)	195	68.48-122.48	91.67	8.72	78.91	86.42	92.35	96.37	102.10
Sand (%)	200	1.20-91.09	23.75	20.09	4.14	7.64	18.14	33.60	54.98
Silt (%)	200	4.55-60.43	30.41	8.93	18.89	26.66	31.10	35.56	39.67
Clay (%)	200	4.36-75.00	45.84	16.85	20.01	35.35	51.45	58.53	64.65
DTPA-Fe (mg/kg)	197	2.53-71.31	14.21	12.11	5.26	6.50	9.52	16.50	34.21
DTPA-Mn (mg/kg)	190	1.12-95.96	19.72	20.12	2.03	3.29	12.80	29.16	49.64
DTPA-Zn (mg/kg)	199	0.13-2.42	0.59	0.34	0.27	0.37	0.49	0.75	1.00
DTPA-Cu (mg/kg)	193	0.48-16.28	3.80	2.87	1.18	1.78	2.82	4.96	7.89

EC: Electrical conductivity; BS: Base saturation; CEC: Cation exchange capacity; SD: Standard deviation

Table 3 : Tehsil-wise spatial distribution of micronutrients in soils

Tehsil	Dominant soil series	No. of samples	Range			
			DTPA-Fe	DTPA-Mn	DTPA-Zn	DTPA-Cu
Bhiwapur	Linga, Panjra	10	5.42-46.86 (18.73)	8.56-63.76 (29.19)	0.32-2.20 (0.85)	0.80-10.16 (4.33)
Hingna	Muserkhapa, Yenwa, Karla, Chankapur, Malegaon	54	2.53-36.95 (10.26)	1.12-5.93 (2.91)	0.22-1.19 (0.58)	1.00-11.75 (3.51)
Kalmeshwar	Linga, Muserkhapa	21	4.69-32.26 (11.63)	3.59-57.04 (21.30)	0.29-1.06 (0.54)	1.77-5.08 (2.95)
Katol	Yenwa, Muserkhapa, Linga, Khapri, Semda	44	2.92-71.31 (20.88)	1.31-95.96 (34.95)	0.20-1.77 (0.67)	1.24-16.28 (6.64)
Kuhi	Kirnapur, Aroli, Wadhona, Gaimukh, Jam	4	5.66-7.36 (6.59)	2.32-11.20 (4.69)	0.21-0.55 (0.43)	0.76-2.20 (1.40)
Mauda	Kirnapur, Aroli	6	5.12-35.55 (16.20)	9.64-59.12 (34.15)	0.22-2.42 (0.97)	0.94-3.07 (1.77)
Nagpur & Kamthi	Aroli, Wadhona, Muserkhapa	8	4.72-46.48 (16.09)	2.06-65.91 (21.06)	0.41-0.75 (0.53)	1.17-9.42 (3.57)
Narkhed	Linga, Panjra, Muserkhapa	9	5.85-18.07 (10.68)	10.86-50.59 (25.26)	0.23-1.08 (0.60)	1.33-4.10 (2.72)
Parshivni	Sewadoli, Aroli, Kirnapur, Bagbori	7	5.97-11.31 (9.20)	7.90-27.86 (13.28)	0.18-0.74 (0.32)	0.93-1.45 (1.25)
Ramtek	Sewadoli, Chankapur, Magarli, Devadipar, Gunjepar, Ramtek, Rongha, Borgaon	16	7.40-43.15 (19.03)	6.61-46.10 (23.31)	0.13-1.16 (0.52)	0.70-2.34 (1.44)
Saoner	Wadhona, Linga, Sur	8	4.29-34.91 (9.59)	9.62-37.07 (19.61)	0.17-1.20 (0.50)	0.48-11.31 (2.97)
Umred	Muserkhapa, Yenwa, Karla, Pardi	13	4.27-45.82 (12.15)	2.25-81.72 (28.41)	0.27-0.65 (0.44)	0.88-6.42 (2.61)

Figures in parentheses indicate mean values

Correlation studies

Pearson correlation coefficients were worked out between DTPA-extractable Fe, Mn, Zn, Cu and various physical and chemical characteristics (Table 4) using SPSS v. 11.5 software, to understand the relationship between them. DTPA-Fe showed significant negative correlation with soil pH. The positive correlation between DTPA-Fe and organic carbon may be due to chelation of micronutrient cations with the formation of organic complexes that protects it from leaching. (Goldberg *et al.,* 2002). The data revealed a significant negative correlation of DTPA-Fe with clay, cation exchange, base saturation and $CaCO_3$. These results are in agreement with the findings of Chinchmalatpure *et al.* (2000) and Hamza *et al.* (2009).

Table 4 : Correlation coefficients between available micronutrients and soil properties

Soil property	DTPA-Fe	DTPA-Mn	DTPA-Zn	DTPA-Cu
pH (1:2 soil:water)	-.627**	-.437**	-.333**	-.417**
EC (dS/m)	-.409**	-.228**	0.101	-.233**
Organic C (g/kg)	.408**	.191**	.414**	.551**
$CaCO_3$ (%)	-.395**	-.322**	-.245**	-0.122
CEC (cmol (+)/kg)	-.402**	-0.129	-0.047	0.031
BS (%)	-.325**	-.146*	-0.053	-0.051
Sand (%)	.419**	0.131	-0.008	-0.019
Silt (%)	0.033	0.036	0.139	.163*
Clay (%)	-.514**	-.174*	-0.064	-0.065

**Significant at 0.01 level; * at 0.05 level; EC: Electrical conductivity; BS: Base saturation; CEC: Cation exchange capacity

DTPA-Mn showed significant negative correlation with soil pH, $CaCO_3$, EC, base saturation and clay whereas, it showed a positive correlation with organic carbon. However, no significant correlation of DTPA-Mn was observed with sand, silt and CEC. The DTPA-Zn had negative correlation with soil pH and $CaCO_3$ and positively correlated with organic carbon. Jagdish Prasad and Gajbhiye (1999) also reported similar findings. However, no significant relationship of DTPA-Zn was found with EC, CEC, base saturation, sand, silt and clay. The DTPA-Cu showed significant negative correlation with soil pH and EC and positive correlation with organic carbon and silt content. However, no significant relationship of DTPA-Cu was found with CEC, $CaCO_3$, sand and clay contents.

Soil micronutrients index

The grouping of available micronutrients into deficient, marginal and adequate categories facilitates in understanding the status of soil fertility and for making fertilizer recommendation. Zn was found deficient (Table 5) in soils of nine tehsils *viz.* Hingna, Kalmeshwar, Kuhi, Nagpur, Kamthi, Parshivni, Ramtek, Saoner and Umred and marginal in all other tehsils. DTPA-Fe was adequate in all the tehsils barring Kuhi and Saoner tehsils where it was marginal. DTPA-Mn and Cu were adequate in all soils.

Table 5 : Tehsil-wise soil nutrient index of micronutrients

Tehsil	DTPA-Fe	DTPA-Mn	DTPA-Zn	DTPA-Cu
Bhiwapur	A	A	M	A
Hingna	A	A	D	A
Kalmeshwar	A	A	D	A
Katol	A	A	M	A
Kuhi	M	A	D	A
Mauda	A	A	M	A
Nagpur and Kamthi	A	A	D	A
Narkhed	A	A	M	A
Parshivni	A	A	D	A
Ramtek	A	A	D	A
Saoner	M	A	D	A
Umred	A	A	D	A

A: Adequate; M: Marginal; D: Deficient

The district is pre-dominantly under rainfed farming with erratic rainfall associated with low crop productivity of major crops *viz*. cotton (265 kg/ha), soybean (1184 kg/ha), paddy (983 kg/ha), sorghum (736 kg/ha), wheat (1469 kg/ha) and chickpea (879 kg/ha) compared to the State average productivity of cotton (322 kg/ha), soybean (1581 kg/ha), paddy (1770 kg/ha), sorghum (1325 kg/ha), wheat (1700 kg/ha) and gram (914 kg/ha). This baseline database on availability of soil micronutrients may help in judicious application of micronutrient fertilizers for enhancing the agricultural productivity and also the quality of the food grains produced. The Zn, in particular and other micronutrients should be applied externally through organics and inorganics on soil test basis to boost the productivity and quality at desired level of these crops without deteriorating the resource base. However, Shukla *et al*. (2012) recommended soil application of zinc sulphate @ 50 kg/ha to every fourth crop of cotton, 25 kg/ha to every third crop of rice, 17.5 kg/ha/yr to wheat and soybean, 15 kg/ha/yr to pigeonpea and 10 kg/ha/yr to *kharif* sorghum for Zn-deficient black soils of Maharashtra.

Conclusion

The baseline information may help in judicious application and utilization of micronutrient fertilizers for enhancing agricultural productivity in the region.

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