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Status and distribution of available micronutrients along a toposequence at Bazargaon plateau, Maharashtra

■ JAYA N. GIRI, NILIMA S. SADANSHIV AND PRAJAKTA M. METKARI

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MEMBERS OF RESEARCH FORUM:

Corresponding author :
JAYA N. GIRI, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, AKOLA (M.S) INDIA

Co-authors :
NILIMA S. SADANSHIV AND PRAJAKTA M. METKARI, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, AKOLA (M.S) INDIA
Email: nil.sadanshiv@gmail.com

Summary

A study was carried out to determine the status and distribution of extractable micronutrients zinc (Zn), cupper (Cu), iron (Fe) and manganese (Mn) along a toposequence at Nagpur district, Maharashtra. The twelve profile pits were dug along upper, mid and lower slope positions and soil samples taken from identified horizons were subjected to laboratory analysis. The results show that in toposequence-I, pH of soils ranged from 6.8 to 8.7 indicating slightly neutral to moderately alkaline soil reaction. The EC of the soils in toposequence-I varied from 0.14 to 0.34 dSm^{-1} and in toposequence-II, it varied from 0.10 to 0.46 dSm^{-1} indicating low soluble salt content. Organic carbon content in toposequence-I ranged from 3.10 to 18.77 g kg^{-1} while in toposequence-II, it ranged from 1.55 to 12.77 g kg^{-1} and gradually decreased with depth. Exchangeable cations followed the order: Ca^{2+}> Mg^{2+}> Na^{+}> K^{+} in all the pedons of both the toposequences indicating dominance of calcium bearing minerals in the parent material. Cation exchange capacity in toposequence-I varied from 35.6 to 69.0 cmol (p^{+}) kg^{-1} while in toposequence-II, it varied from 37.8 to 67.2 cmol (p^{+}) kg^{-1}. Base saturation of toposequence-I varied from 91 to 127 per cent while in toposequence-II, it varied from 89 to 105 per cent. The DTPA extractable micronutrients followed the order: Mn^{2+}>Fe^{2+}>Cu^{2+}>Zn^{2+} in toposequence-I and Fe^{2+}>Cu^{2+}>Mn^{2+}>Zn^{2+} in toposequence-II. Almost all the soils of both the toposequences were deficient in Zn^{2+}, respectively.

Key words : Toposequence, Micronutrients, Soil fertility

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Introduction

Soil fertility is an important factor which determines the growth and productivity of plants. It is determined by the presence or absence of macro or micronutrients. Iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) are essential micronutrients for plant growth. Through their involvement in various enzymes and other physiologically active molecules these micronutrients are important for gene expression, biosynthesis of proteins, nucleic acids, growth substances, chlorophyll and secondary metabolites, metabolism of carbohydrates and lipids, stress tolerance etc (Gao *et al.*, 2008 and Biwe, 2012).

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 and 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 (Zahedifar *et al*., 2010). 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 (Prasad and Gajbhiye, 1999 and Chinchmalatpure *et al.*,2000). Hence, an attempt was made to analyze the status of available soil micronutrient in agricultural soils of Nagpur district, Maharashtra for sustainable agriculture production and soil fertility management.

Resource and Research Methods

The study was conducted at Nagpur district in Maharashtra (India) representing hot, dry sub humid ecoregion. The Archean rocks of the Nagpur district have a very complex structural pattern comprising two distinct lithological groups *viz*., Sausar and Sakole series. As both these groups have suffered intense deformation and metamorphism, it is generally grouped together as unclassified metamorphic and crystalline series of the metasedimentaries (NBSS and LUP, 1990).The climate is characterized by medium rainfall, high temperature, and hot summer. The average rainfall is 1113 mm. The average annual temperature is 26.5^0C.

Two prominent toposequences with upper, mid and lower slope representing changes in slope gradient and soils characteristics were selected for present study from Nagpur district.Toposequence-I *i.e*. Bazargaon Plateau consist of two villages namely Panjra and Saonga of Hingna tahsil of Nagpur district. Panjra village (4024.6 ha) is placed on the top of the Basaltic Plateau and lies between $78^0$46'14''E longitude and $21^0$07'24''N latitude, mostly used for rainfed cultivation of cotton and redgram, while Saonga is at the lowermost portion comprising a valley, situated on back slope of the BorNala (NBSS and LUP, 1990).

Toposequence–II runs from North (Mandawghorar) to South (Salaimendha). Salaimendha village of Hingna tahsil of Nagpur district in Maharashtra (India) is located about 19 km south east of Nagpur and lies between $78^0$53'7.9''E longitude and $21^0$07'57.1''N latitude. The village has an area of about 1300 acres, mostly irrigated with wheat, sweet orange gardens, vegetables like brinjal, tomato and spinach on upper pediplains and interhill valley floors. A fairly dense cover of teak is on the hill ridges covered with more than 60 per cent surface stone cover. The two villages namely Mandawghorar and Salimendha covering a toposequence varying in slopes were selected for the present study (Savale, 2006).

Site selection and soil analysis :

Twelve pedons (six profiles from each toposequence) were dug on two prominent toposequences with upper, mid and lower slope representing changes in slope gradient was carried out (The soils in the upper slopes were expected to be shallow whereas in the lower slope the soils were expected to be deeper having well differentiated genetic horizons) these positions referred to as pedons 1, 2, 3, 4, 5 and 6, respectively. Soil samples were collected horizon-wise for analysis of physical and chemical properties. Collected soil samples were air dried, processed, passed through 2 mm sieve for analysis of nutrients. The pH and EC were measured in 1:2.5 soil water suspension using pH meter and EC meter, respectively. Soil organic carbon content was estimated by Walkley and Black (Jackson, 1979) method. Cation exchange capacity (CEC) was determined by sodium acetate (NaOAc) saturation and neutral ammonium acetate.The extractable micronutrients (Fe, Mn, Cu, Zn) from soils were extracted with 0.005 diethylene triamine penta acetic acid (DTPA) as per method out lined by Lindsey and Norvell (1978) on an atomic absorption spectrophotometer at appropriate wavelength.

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Soil reaction (pH) :

In toposequence-I, pH of soils ranged from 6.8 to 8.7 indicating slightly neutral to moderately alkaline soil reaction. In general, pH increased with depth in all the pedons with slight variations in intermediate layers and also across the slope of the toposequence. Comparatively

Table 1 : Chemical properties of soils

Depth (cm)	Horizon	pH (1:2) H_2O	EC (1:2) (dS m^{-1})	Org. C. (g kg^{-1})	Extractable bases Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Sum	CEC	BS (%)
					<-----------cmol (p^+) kg^{-1}----------->						
Toposequence-I : Bazargaon Plateau											
Pedon 1 : Panjra (Very fine,smectitic (cal), hyperthermic, LepticHaplusterts)											
0-18	Ap	7.7	0.23	7.93	47.4	5.6	0.4	1.1	54.5	44.7	122
18-43	Bw	7.9	0.17	7.74	44.5	5.9	0.3	0.7	51.4	45.9	112
43-69	Bss1	7.2	0.14	7.89	33.7	8.0	0.6	0.4	42.7	35.6	120
69-100	Bss2	8.1	0.22	7.74	44.1	7.9	0.4	0.8	53.2	44.3	120
100-117	Cr	<--------------------------------------Weathered basaltic material------------------------->									
Pedon 2 : Panjra (Fine, smectitic (cal), hyperthermic, TypicHaplusterts)											
0-16	Ap	8.1	0.22	6.77	39.0	8.2	0.7	0.9	48.8	39.7	123
16-35	Bw	8.3	0.20	5.42	38.5	9.2	1.3	0.8	49.8	40.5	123
35-58	Bss1	8.5	0.24	5.81	37.3	10.9	2.3	0.7	51.2	40.3	127
58-82	Bss2	8.6	0.27	4.84	36.6	12.5	2.9	0.7	52.7	52.2	101
82-102	Bss3	8.7	0.34	3.68	35.0	13.5	3.8	0.8	53.1	50.6	105
102-116	Cr	<--------------------------------------Weathered basaltic material------------------------->									
Pedon 3 : Panjra (Very fine, smectitic/mixed, hyperthermic, VerticHaplustepts)											
0-19	Ap	7.6	0.17	6.77	41.5	11.9	0.4	0.7	54.5	52.4	104
19-40	Bw	7.7	0.17	5.22	42.5	11.5	0.4	0.4	54.8	53.2	103
40-64	Cr	<--------------------------------------Weathered basaltic material------------------------->									
Pedon 4 : Panjra (Very fine, smectitic, hyperthermic, Lithic Haplusterts)											
0-13	A	6.9	0.22	18.77	34.8	19.1	0.4	0.4	54.7	56.4	97
13-26	Bw	6.8	0.27	16.25	33.9	20.9	0.6	0.4	55.8	58.1	96
26-44	Bss	7.5	0.17	6.39	37.7	12.0	0.4	0.8	50.9	55.9	91
Pedon 5 : Saonga (Very fine, smectitic, hyperthermic, LepticHaplusterts)											
0-12	Ap	8.1	0.23	6.19	50.6	5.1	0.4	0.8	56.9	59.9	95
12-27	Bw1	8.2	0.19	4.26	52.6	6.1	0.3	0.5	59.5	63.3	94
27-48	Bw2	8.0	0.21	3.10	51.4	9.4	0.3	0.5	61.6	62.9	98
48-84	Bss	8.2	0.21	4.06	45.4	11.2	0.4	0.5	57.5	59.9	96
84-100	Cr	<--------------------------------------Weathered basaltic material------------------------->									
Pedon 6 : Saonga (Fine loamy, mixed, hyperthermic, TypicUstorthents)											
0-15	Ap	8.0	0.24	9.48	49.6	8.2	0.5	0.9	59.2	58.6	101
15-30	AC	8.1	0.32	5.42	52.5	5.4	0.4	0.5	58.8	57.6	102
30-47	C1	8.2	0.21	3.70	41.9	4.0	0.4	0.3	46.6	45.2	103
47-67	C2	8.3	0.17	1.16	71.5	9.2	0.4	0.3	81.4	69.0	118
67-95	Cr	<--------------------------------------Weathered basaltic material------------------------->									
Toposequence-II: Mandawghorar-Salaimendha											
Pedon 1 : Mandawghorar (Very fine, smectitic, hyperthermic, TypicHaplusterts)											
0-17	Ap	8.1	0.32	8.13	49.4	12.2	0.5	0.6	62.7	64.0	98
17-30	Bw1	8.0	0.33	6.39	48.6	14.5	0.6	0.4	64.1	64.1	100
30-55	Bw2	8.0	0.35	5.61	48.4	16.6	0.6	0.4	66.0	66.7	99
55-76	Bss1	7.9	0.37	5.61	46.7	19.8	0.6	0.5	67.6	66.9	101
76-105	Bss2	8.1	0.37	5.03	45.5	22.4	0.6	0.6	69.1	65.8	105
105-122	Bss3	8.1	0.46	5.61	45.3	23.2	0.7	0.7	69.9	67.2	104
122-150	Bss4	8.2	0.32	5.42	43.5	22.4	0.7	0.6	67.2	64.0	105
Pedon 2 : Mandawghorar (Fine, mixed, hyperthermic, Calcic Haplusterts)											
0-15	Ap	8.2	0.26	6.00	33.3	5.9	0.4	0.3	39.9	42.4	94
15-31	Bw	8.2	0.22	6.00	37.0	5.3	0.3	0.2	42.8	43.2	99
31-63	Bk	8.3	0.15	6.19	40.8	4.0	0.3	0.2	45.3	47.2	96
63-89	Cr	<--------------------------------------Weathered basaltic material------------------------>									

Table 1 : Contd…………….

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Pedon 3 : Mandawghorar (Clayey skeletal, mixed, hyperthermic, Lithic Ustorthents)											
0-9	Ap	6.8	0.11	12.77	21.9	13.7	0.3	0.6	36.5	39.7	92
9-50	Bw	7.1	0.10	1.55	22.6	10.2	0.3	0.5	33.6	37.8	89
50+	Cr	<---------------------------------------Weathered basaltic material------------------------->									
Pedon 4 : Salaimendha (Fine, smectitic, hyperthermic, LepticHaplusterts)											
0-15	Ap	7.6	0.24	6.97	35.1	15.6	0.5	0.6	51.8	52.3	99
15-26	Bw	7.7	0.12	6.19	38.7	19.3	0.5	0.3	58.8	57.1	103
26-48	Bss	7.7	0.17	7.16	41.2	19.1	0.5	0.3	61.1	59.3	103
Pedon 5 : Salaimendha (Fine, smectitic, hyperthermic, LepticHaplusterts)											
0-16	Ap	7.7	0.19	12.60	39.5	15.5	0.5	1.0	56.5	54.9	103
16-34	Bw	7.9	0.17	9.10	40.3	17.0	0.5	0.5	58.3	58.3	100
34-59	Bss1	7.9	0.20	7.40	39.7	19.1	0.6	0.4	59.8	58.1	103
59-81	Bss2	8.0	0.26	5.40	34.1	18.6	0.6	0.4	53.7	51.6	104
81-140+	Cr	<---------------------------------------Weathered basaltic material------------------------->									
Pedon 6 : Salaimendha (Fine, smectitic, hyperthermic, TypicHaplustepts)											
0-23	Ap	7.6	0.19	11.6	37.1	13.0	0.4	0.6	51.1	51.6	99
23-43	Bw	7.1	0.22	11.2	35.8	13.2	0.3	0.7	50.0	53.2	94
43-70	Cr	<---------------------------------------Weathered basaltic material-------------------------->									

high pH was observed in pedon 2 which might be due to calcareous nature of such soils (Bharambe *et al.*, 1987). Soils of toposequence-II also followed the similar trend with respect to soil reaction and pH of soils ranged from 6.8 to 8.3. The high pH value 8.2 to 8.3 as observed in pedon 1 and 2 may be due to lower physiographic position where the accumulation of calcium carbonate, salts and bases from upper slope takes place (Murthy *et al.*, 1982 and Sharma *et al.*, 1994).

Electrical conductivity :

The electrical conductivity (EC) measures the salt content of soil. The EC of studied soils in toposequence-I ranged from 0.14 to 0.34 dS m^{-1} and in toposequence-II ranged from 0.10 to 0.46 dS m^{-1}, respectively indicating low soluble salt content and therefore, is not of much significance for growing crops.

Organic carbon :

Organic carbon content in toposequence-I ranged from 3.10 to 18.77 g kg^{-1} while in toposequence-II, it ranged from 1.55 to 12.77 g kg^{-1} and gradually decreased with depth. The uppermost pedons of both the toposequence had remarkably high amount of organic carbon which may be due to forest cover and virgin nature of the soil.

Exchangeable bases :

The exchangeable cations determine, to a large extent, the chemical and physical properties of soil. The data on exchangeable cations followed the order: Ca^{2+}> Mg^{2+}>Na^{+}>K^{+} in all the pedons of both the toposequences indicating dominance of calcium bearing minerals in the parent material. The exchangeable Na^{+} and K^{+} are low and their vertical distribution is more or less uniform in all the soils.

In toposequence-I, calcium ranged from 33.7 to 71.5 cmol (p^{+}) kg^{-1} followed by magnesium varying from 4.0 to 20.9 cmol (p^{+}) kg^{-1}. Exchangeable sodium varied from 0.3 to 2.9 cmol (p^{+}) kg^{-1} while exchangeable potassium varied from 0.3 to 1.1 cmol (p^{+}) $kg^{-1.}$ In toposequence-II, exchangeable calcium and magnesium ranged from 21.9 to 49.4 cmol (p^{+}) kg^{-1} and 4.0 to 23.2 cmol (p^{+}) kg^{-1}, respectively while exchangeable sodium and potassium varied from 0.3 to 0.7 cmol (p^{+}) kg^{-1} and 0.2 to 1.0 cmol (p^{+}) kg^{-1}, respectively.

Cation exchange capacity (CEC) :

The cation exchange capacity is an indicator of the nutrient storage capacity of soils. Cation exchange capacity in toposequence-I varied from 35.6 to 69.0 cmol (p^{+}) kg^{-1} with general tendency of decreasing down the depth of the pedons,except in pedon 2, 3 and 6 which showed irregular trend of CEC along the depth. Similarly, in toposequence-II, the CEC varied from 37.8 to 67.2 cmol (p^{+}) kg^{-1}. Significant positive correlation between CEC and clay was observed (r = 0.44**) while it was negatively correlated with sand (r = 0.37*).

Table 2 : DTPA extractable micronutrients of the soils

Depth (cm)	Cu^{2+}	Fe^{2+}	Mn^{2+}	Zn^{2+}
	<------------------------------------(mg kg^{-1})------------------------------->			
	Toposequence-I : Bazargaon Plateau			
	Pedon 1 : Panjra (Very fine,smectitic (cal), hyperthermic, LepticHaplusterts)			
0-18	1.98	7.11	27.00	0.42
18-43	1.78	7.41	23.20	0.22
43-69	4.34	7.92	15.20	0.18
69-100	2.08	7.18	13.20	0.14
100-117	<--------Weathered basaltic material------->			
	Pedon 2 : Panjra (Fine, smectitic (cal), hyperthermic, TypicHaplusterts)			
0-16	1.82	7.67	21.20	0.34
16-35	1.74	8.16	20.00	0.18
35-58	1.80	8.30	20.80	1.04
58-82	1.92	8.30	17.40	0.16
82-102	1.80	7.96	13.40	0.14
102-116	<--------Weathered basaltic material------->			
	Pedon 3 : Panjra (Very fine, smectitic/mixed, hyperthermic, VerticHaplustepts)			
0-19	2.90	16.64	60.00	0.42
19-40	2.34	12.54	41.20	0.34
40-64	<--------Weathered basaltic material------->			
	Pedon 4 : Panjra (Very fine, smectitic, hyperthermic, Lithic Haplusterts)			
0-13	9.56	50.32	78.60	1.06
13-26	6.64	25.82	47.60	0.40
26-44	2.64	15.09	55.40	0.42
	Pedon 5 : Saonga (Very fine, smectitic, hyperthermic, LepticHaplusterts)			
0-12	2.60	7.25	19.40	0.34
12-27	2.60	7.18	17.20	0.20
27-48	2.64	7.16	16.00	0.20
48-84	2.56	6.62	15.60	0.20
84-100	<--------Weathered basaltic material------->			
	Pedon 6 : Saonga (Fine loamy, mixed, hyperthermic, TypicUstorthents)			
0-15	3.24	7.38	2.58	0.48
15-30	3.20	8.62	2.98	0.30
30-47	1.32	11.34	1.44	0.20
47-67	0.94	12.72	1.24	0.28
67-95	<--------Weathered basaltic material------->			
	Toposequence-II: Mandawghorar-Salaimendha			
	Pedon 1 : Mandawghorar (Very fine, smectitic, hyperthermic, TypicHaplusterts)			
0-17	4.54	7.10	2.40	0.42
17-30	4.36	7.00	2.40	0.34
30-55	4.26	6.71	2.20	0.32
55-76	5.08	7.31	1.78	0.32
76-105	5.56	6.57	1.42	0.26
105-122	5.48	5.75	1.12	0.26
122-150	4.96	7.31	1.50	0.26
	Pedon 2 : Mandawghorar (Fine, mixed, hyperthermic, Calcic Haplusterts)			
0-15	2.86	8.27	1.9	0.46
15-31	3.02	8.24	1.9	0.34
31-63	3.22	7.29	1.98	0.22
63-89	<--------Weathered basaltic material------->			

Table 2 : Contd…………..

Table 2 : Contd………

Pedon 3 : Mandawghorar (Clayey skeletal, mixed, hyperthermic, Lithic Ustorthents)				
0-9	6.94	28.8	7.62	0.72
9-50	1.52	11.72	2.64	0.54
50+		<--------Weathered basaltic material------->		
Pedon 4 : Salaimendha (Fine, smectitic, hyperthermic, LepticHaplusterts)				
0-15	4.10	5.70	3.30	0.56
15-26	5.20	13.38	4.82	0.38
26-48	5.66	13.89	5.08	0.46
Pedon 5 : Salaimendha (Fine, smectitic, hyperthermic, LepticHaplusterts)				
0-16	7.38	9.39	4.10	0.64
16-34	7.38	9.58	4.14	0.50
34-59	7.22	8.60	3.08	0.44
59-81	6.30	7.78	1.62	1.30
81-140+		<--------Weathered basaltic material------->		
Pedon 6 : Salaimendha (Fine, smectitic, hyperthermic, TypicHaplustepts)				
0-23	7.86	12.07	6.10	0.66
23-43	8.20	6.49	7.04	0.40
43-70		<--------Weathered basaltic material------->		

DTPA extractable micronutrients:

Micronutrients are held within the mineral matter (Miller *et al.*, 1986) and finer fractions of soils (Follet and Lindsay, 1978 and Sharma *et al.*, 1999). The data on micronutrient status of the soils is presented in Table 2. The DTPA extractable micronutrients (available micronutrients) followed the order: Mn^{2+}> Fe^{2+}> Cu^{2+}> Zn^{2+} in toposequence-I and Fe^{2+}>Cu^{2+}>Mn^{2+}>Zn^{2+} in toposequence-II.

DTPA extractable micronutrients *viz.*, Zn^{2+}, Cu^{2+}, Fe^{2+} and Mn^{2+} in surface soils of toposequence-I and toposequence-II varied from 0.34 to 1.30 $mgkg^{-1}$,1.82 to 9.56 $mgkg^{-1}$, 5.70 to 50.32 $mgkg^{-1}$ and 1.90 to 78.60 mg kg^{-1}, respectively. Based on critical limits of DTPA-Cu^{2+}, Fe^{2+}, Mn^{2+} and Zn^{2+} in soils reported by Lindsay and Norvell (1978), all the soils of toposequence-I and toposequence- II were well above the critical limits of Cu, Fe and Mn except in pedon 6 (toposequence-I) and pedons 1 and 2 of toposequence-II which exhibited Mn deficiency. However, almost all the soils of both the toposequences were deficient in Zn^{2+} except surface horizon of pedon 1 (toposequence-I) and pedons 3, 5 and 6 (toposequence-II), perhaps due to formation of less soluble compounds of zinc or insoluble zincates (Mandal, 2007; Gupta, 1995 and Bassirani *et al.*, 2011). Very high concentration of Fe and Mn is observed throughout the soils of both the toposequences probably due to nature of archean rock (Deshpande, 1998). In general, surface horizons had higher concentrations of DTPA extractable micronutrients due to higher organic carbon and biological activity (Prasad and Gajbhiye, 1999) except pedon 6 of toposequence-I and pedons 1 and 4 of the toposeqeunce-II which showed reverse trend of Fe content possibly due to the nature of parent materials and deposition of the soluble cations on the lithic barrier (Sarkar *et al.*, 2000).

Conclusion:

The profile distributions of Fe, Mn, Cu and Zn in the study area 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.

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