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Vertical Distribution of Available Micronutrients in Some Pedons Situated at Undulated Hilly Terrain of Dangs District, Gujarat

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Abstract The present investigation was carried out in three villages named Motidabdar, Chikhalda and Daguniya in Waghai taluka of Dangs district in South Gujarat (GPS ranged from Lat. N 20°38´58.1´´ to N20°43´21.5´´, Long. E73°35´60.9´´ to E73°85´70.6´´ and Alt. 208 to 376 m). Lands are hilly undulating highly dissected piedmont plateau and escarpment slope are shallow with excessive relief. The soils are stony/gravelly in surface and moderate to severely eroded, non-calcareous and generally neutral to slightly acidic reaction, imperfect to well drained and highly permeable. The soil pH of different horizons of pedons at various physiographic positions of three villages varied from medium (5.78) to neutral (6.92) except Daguniya village in which varied from medium (5.76) to slightly acidic (6.39) in reaction. The electrical conductivity was very low ranged from 0.010 to 0.099 dS m^{-1}, which indicated that soils were normal in these villages. Soil organic carbon content widely varied from 1.00 to 15.00 g kg^{-1} in the pedons of three villages and also indicated the similar trend in all pedons, which gradually decreases with increasing in soil depth and elevation. Considering the critical limit 4.5 and 2.0 mg kg^{-1} in respect to Fe and Mn, all the soils of three villages were sufficient in available Fe and Mn content. Results also indicated that all the horizons were gradually decreased with increasing in soil depth in respect to Fe and Mn, but in case of Cu, majority pedons were showed similar trend closely resembles that of available Fe and Mn except only pedon 1 and 2 in Daguniya village, in which not found a definite trend with soil depth and which varied from low (0.03 mg kg^{-1}) to high (4.38 mg kg^{-1}). So far as DTPA extractable Zn status is concerned low to high status was observed in three villages, ranged varied from 0.36 mg kg^{-1} to 3.70 mg kg^{-1}. These micronutrients showed positive relationship with organic carbon content but were inversely related with soil pH.

Keywords Vertical distribution, Micronutrients, Pedons, Undulated land.

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Introduction

The pedosphere is a unique biologically active dynamic layer forming a continuous interface between the lithosphere, atmosphere, hydrosphere and biosphere. The soil layer or pedosphere is essentially the skin of the terrestrial earth, functioning as earth geomembrane, regulating the biogeochemical and hydrological cycling of matter and energy with terrestrial surfaces [1]. The pedospheric variations due to parent mterial, topography, climate lead to vertical variation of micronutrients in the soils [2]. Physiography influences soil formation through water, temperature, soil erosion and microclimate relations which in turn affects the pedogenic processes producing soils of varying nutrient supplying capacities [3]. Because, the stagnation in crop productivity is becoming a common phenomenon that can be widely attributed to the soil micronutrients deficiency due to intensive agriculture and indiscriminate and imbalanced fertilizer use by the farmers. Micronutrients have assumed increasing importance in crop production, stability and sustainability in many soils under modern agricultural technology. The availability of micronutrients to plants is influence by their distribution within the soil profile and other soil characteristic [4]. So, in order to advocate more scientific and site specific nutrient management strategies to farmers, an understanding of the vertical distribution of micronutrients cations in the soils is essential. Studies were conducted by many researchers [5, 6] to understand the content and distribution pattern of the micronutrients cations in different soil under different agro-climate condition and their relationship with soil physical and chemical properties. For an effective correction of a micronutrients deficiency in the field, it is necessary to understand the reasons of its deficiency in the soil.

The knowledge of vertical distribution of micronutrients cations in soil is helpful in understanding the inherent capacity of soil to supply these nutrients to plants and their downward movement in soil.Moreover, roots of many crop plants go beyond the surface layer and thus draw part of their nutrient requirement from sub surface layer of soil. Most of the work on micronutrients studies in southern part of Gujarat was confined to surface soil and therefore the present investigation was undertaking to study the depth wise vertical distribution of major and micro nutrients status in these coarse-textured and erosion-prone soils would be of highly importance in relation to proper soil nutrient management of hilly undulating terrain for higher crop production.

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Materials and Methods

The present investigation was carried out in three villages named Motidabdar, Chikhalda and Daguniya in Waghai taluka of Dangs district in South Gujarat. Motidabdar, Chikhada and Daguniya villages are situated at latitude and longitude of 20°42´33´´N and 73°35´58´´ E, 20°41´7´´ N and 73°35´50´´ E and 20°38´31´´N and 73°36´6´´E, respectively with their altitude varied from 275 to 355, 210 to 360 and 315 to 355 m above from the level. Villages receive an average annual rainfall of around 2500 mm and come under hyperthermic temperature and ustic moisture regime. Soils are hilly undulating highly dissected piedmont plateau and escarpment slope are shallow with excessive relief. The crops grown in the study area during *kharif*. Paddy and Miner millets followed by blackgram, groundnut, vari, pegeonpea, Niger, while groundnut, gram and vegetables are grown during *rabi* season. Depending upon varying physiographic position, slope, nine representative pedons were dug out and were examined by following standard procedures [7]. From the each of such pedons different layers were identified carefully, varying characteristics of pedons along with site characteristics were noted down. Collected of soil samples were done from different horizons and depths of all pedons as per standard procedure [7]. The soil samples from each layer was collected by scrapping equal width and thickness through the depth of layer. Scrapped soils were mixed well and homogenous samples of nearly one kilogram weight were packed in polythene bag with proper leveling. The collected soil samples were air-dried, ground in wooden plank and rollers, passed

Table 1. Some chemical properties and DTPA-extractable micronutrients in Motidabdar villages of Dangs district.

Profile location	Horizon	Depth (cm)	Texture (<2.00 mm fraction)	Structure	pH	EC (dS m^{-1})	OC (g kg^{-1})	Fe	Mn	Zn	Cu
									mg kg^{-1}		
Pedon-1											
N20°42´65.5´´	A3	0–15	C	m 2Sbk	6.17	0.088	15.90	40.86	39.84	1.36	0.52
E73°35´87.5´´	B1c	15–34	C	m 2Sbk	6.27	0.084	15.10	39.96	39.26	0.80	0.42
A279m MSL	B2c	34–64	Cl	m 2sbk	6.47	0.059	5.10	28.42	36.12	0.79	0.29
	C	64–90	Sic	m 2abk	6.84	0.031	1.90	26.46	13.44	0.36	0.03
Mean					6.44	0.070	9.50	33.17	32.16	0.83	0.32
Pedon-2											
N20°42´63.6´´	A3	0–22	C	m2 Sbk	6.53	0.066	11.50	56.92	53.52	1.51	2.15
E73°36´29.2´´	B1	22–42	C	Cl Sbk	6.08	0.059	9.30	55.14	51.94	1.41	1.58
A309m MSL	B2	42–58	C	Sbk	6.18	0.057	7.90	48.74	30.12	1.39	1.15
	C1	58–170	Cl	abk-sbk	6.12	0.044	3.70	47.74	28.84	0.99	1.07
	C2	170–200	C1	m 2abk	6.45	0.050	3.70	42.84	24.84	0.55	0.96
Mean					6.27	0.060	7.20	50.28	37.85	1.22	1.38
Pedon-3											
N20°43´21.5´´	A3	0–40	C	m2Sbk	5.88	0.056	6.70	61.46	62.14	1.86	1.36
E73°85´70.6´´	B1c	40–70	C	m 2Sbk	6.12	0.073	6.30	57.60	54.08	1.66	1.20
A352m MSL	B2c	70–83	C1	m 2Sbk	5.78	0.089	5.50	57.58	47.82	0.77	0.71
	C	83–98	Sc	m 2Sbk	5.80	0.078	5.40	50.72	26.94	0.48	0.57
Mean					5.90	0.070	6.00	57.09	47.75	1.19	0.09
Overall range					5.78-6.84	0.031-0.088	1.90-15.9	26.5-61.5	13.4-62.1	0.36-1.86	0.03-2.15
Mean					6.44	0.066	7.50	46.8	39.3	1.08	0.88

through a 2 mm stainless steel sieve and analyzed for various physico-chemical properties. The soil pH was measured in 1:2.5 ratio of soil and water suspension using glass electrode pH meters and EC was measured in 1:2.5 ratio of soil and water suspension solution with the help of electrical conductivity bridge [8]. The soil organic carbon was determined by following Walkley and Black rapid titration method [9]. The available micronutrient cations were extracted with a solution of 0.005 M DTPA, 0.01 M $CaCl_2$ and 0.1 M Tri-ethanolamine (adjusted to pH 7.3) as outlined by Lindsay and Norvell [10]. The concentration of these micronutrients in the extracts was determined using Atomic Absorption Spectrophotometer (Model-AAS 4141 A). The simple correlations among different parameters as per requirement were workout following standard method given by Panse and Sukhatme [11].

Results and Discussion

Physico-chemical properties

pH, electrical conductivity and organic carbon

In general, the soil of different horizons of nine pedones were medium acidic to neutral in reaction except Daguniya village soil which showed medium acidic to slightly acidic in reaction and observed pH range varied from 5.78 to 6.84, 5.87 to 6.92 and 5.76 to 6.39 with mean value of 6.20, 6.24 and 6.08 respectively in Motidabdar, Chikhalda and Daguniya villages of Dangs district of Gujarat. Moreover, the increase in soil reaction down the slope of this village could be due to leaching of bases from higher topography and getting deposited in lower elevations. An-

Table 2. Some chemical properties and DTPA-extractable micronutrients in Chikhalda villages of Dangs district.

Profile location	Horizon	Depth (cm)	Texture (<2.00 mm fraction)	Structure	pH	EC (dS m^{-1})	OC (g kg^{-1})	Fe	Mn	Zn	Cu
Pedon-1									mg kg^{-1}		
	A1	0–5	L	m 2Sbk	6.24	0.074	15.00	61.84	56.94	1.04	1.51
N20°41´51.8	B21	5–35	L	m 2Sbk	5.88	0.039	13.00	60.30	55.98	1.11	0.91
E73°35´65.2	B22	35–60	L	m 2abk	5.87	0.047	7.00	58.76	48.98	1.1	0.76
A208m MSL	B31	60–85	L	m 2abk	5.93	0.036	6.00	43.92	44.18	0.97	0.71
	C	86–120	S1	m 2abk	6.04	0.041	3.00	34.02	28.52	0.86	0.04
Mean					5.99	0.050	8.80	51.77	46.92	1.02	0.79
Pedon-2											
N20°41´54.8	A2	0–5	L	m 2Sbk	6.12	0.090	14.70	49.48	45.80	2.34	1.01
E73°35´65.2´´	B1c	5–52	Sc	m 2Sbk	6.08	0.040	11.00	38.34	40.48	1.19	0.73
A220m MSL	B2c	52–109	Cl	Sbk	5.99	0.050	2.60	38.04	37.76	1.16	0.67
	C1	109–120	C	m 2Sbk	6.00	0.040	1.80	26.28	32.00	1.05	0.32
					6.05	0.06	7.50	38.04	39.01	1.44	0.68
Mean								49.48	45.80	2.34	1.01
Pedon-3											
N20°41´50.7´´	A1	0–5	L	m 2Sbk	6.73	0.088	17.20	47.10	64.08	1.19	2.74
E73°35´60.9´´	B1c	5–42	L	cl Sbk	6.62	0.084	7.50	46.44	56.93	1.27	1.82
A226m MSL	B2c	42–62	L	m 2Sbk	6.52	0.059	6.00	34.32	49.24	1.37	1.19
	Cl	62–80	L	m 2abk	6.57	0.031	4.50	32.78	37.30	1.29	0.59
	C2	80–95	C	cl Sbk	6.72	0.071	2.20	32.16	34.42	1.41	0.55
	C3	95–110	C	cl Sbk	6.92	0.082	1.50	30.92	26.58	26.6	0.22
Mean					6.68	0.069	6.50	37.29	44.76	1.32	1.19
Overall range					5.87-6.92	0.036-0.090	1.50-17.20	26.28-61.84	26.58-64.08	0.86-2.34	0.04-2.74
Mean					6.24	0.059	7.6	42.36	43.56	1.26	0.88

other reason for low pH at pedons of higher elevations might be due to the leaching of bases on account of well-drained to excessively drained conditions that also supported by Patil and Prasad [12], Sitanggang et al. [13] and Singh et al. [14]. The electrical conductivity (EC) of soils were low which ranged from 0.013 to 0.089, 0.031 to 0.090 and 0.010 to 0.099 dS m^{-1} with mean values of 0.066, 0.059 and 0.050 respectively in Motidabdar, Chikhalda and Daguniya villages of Dangs district in Gujarat. There are not definite trend of EC was observed with soil of profiles. The results are strongly supported by the findings of Verma et al. [5] in north east of Punjab was also recorded decrease EC and OC with increase depth of pedon. The reason for decreasing EC with depth might be well drained to excessively drained condition which triggered off the removal of bases through percolating and drainage water particularly in soils of higher sloppy lands that also supported by Leelavathi et al. [15], Pati and Mukhopadhyay [16] and Shinde et al. [17]. In case of soil organic carbon (SOC) content were varied from high to low i.e., from 1.90 to 15.90, 1.50 to 17.20 and 1.00 to 14.40 g kg^{-1} with mean values of 7.56, 7.60 and 8.0 respectively in Motidabdar, Chikhalda and Daguniya villages. In general, SOC also showed decreasing trend with depth of soil in all the pedons of three villages. The major reason for decreasing SOC with depth of these pedons was degradation of organic matter at faster rate under the prevailing climatic condition. Results corroborated with the work done elsewhere by Gangopadhyay et al. [18], Pati and Mukhopadhyay [16] and Das and Shinde [19]. It was further noted that mean SOC content of pedons increased generally at higher elevation and

Table 3. Some chemical properties and DTPA-extractable micronutrients in Daguniya villages of Dangs district.

Profile location	Horizon	Depth (cm)	Texture (<2.00 mm fraction)	Structure	pH	EC (dS m^{-1})	OC (g kg^{-1})	Fe	Mn	Zn	Cu
Pedon-1									mg kg^{-1}		
	A1	0–10	C	m 2Sbk	6.22	0.065	14.40	63.76	66.78	1.66	1.24
N20°38´58.1´´	B1	10–42	C	cl Sbk	6.21	0.059	12.90	43.00	46.82	1.13	1.01
E73°35´95.0´´	B2	42–67	Cl	m 2Sbk	6.31	0.075	12.60	43.00	38.06	1.26	2.10
A320m MSL	B3	67–78	Cl	m 2Sbk	6.39	0.040	8.40	42.03	27.98	0.62	0.36
Mean					6.28	0.060	12.10	48.06	44.91	1.17	1.18
Pedon-2											
N20°38´63.8´´	A2	0–10	C	m 2Sbk	5.83	0.010	14.10	46.76	68.64	1.31	1.66
E73°36´22.0´´	B1	10–42	Cl	cl Sbk	5.85	0.099	10.50	46.76	51.28	1.31	1.13
A336m MSL	B2	42–62	Cl	m 2Sbk	5.96	0.076	4.60	36.28	48.42	0.99	1.26
	C1	62–80	Sc	Sbk	5.76	0.049	5.20	35.26	36.84	1.13	0.62
	C2	80–100	Sc	cl abk	6.25	0.037	1.00	16.96	17.04	1.26	1.17
Mean					5.93	0.054	7.10	46.76	44.44	1.26	1.17
Pedon-3											
N20°38´59.7´´	A2	0–10	Sic	m 2Sbs	5.88	0.040	11.50	46.76	44.69	3.70	4.38
E73°36´24.5´´	B1	10–30	C1	cl 2Sbk	5.98	0.042	5.80	42.84	42.22	3.26	3.23
A376m MSL	B2	30–60	C1	m 2Sbk	6.16	0.041	2.40	36.28	27.20	3.09	2.41
	Cl	60–90	Sc	Sbk	5.95	0.038	2.40	35.62	26.42	2.56	1.30
	C2	90–115	Sc	cl abk	6.18	0.029	1.90	30.78	22.80	1.44	1.04
Mean					6.03	0.038	4.80	38.46	32.66	2.81	2.47
Overall range					5.76-6.39	0.010-0.099	1.0-14.40	16.96-63.76	17.04-68.64	0.62-3.70	0.36-4.38
Mean					6.08	0.050	8.00	44.42	40.67	1.74	1.60

topography. The higher SOC content in surface soils of all the pedons could be attributed to high leaf-litter fall from vegetations and plantations and decay coupled with heavy rainfall in these three villages situated in undulating hilly terrain. Even though there was good vegetative cover in the mid or upper slope position of these villages, high rate of oxidation of organic matter by the prevailing high temperature coupled with coarse textured nature of soils were highly responsible for maintaining low to medium content of organic carbon in some soil horizons.

DTPA-extractable micronutrients

DTPA extractable micronutrients i.e., Fe, Mn, Cu and Zn content in different horizons of nine pedons of three villages named Motidabdar, Chikhalda and Daguniya in Waghai taluka of Dangs district, Gujarat were depicted in Tables 1, 2 and 3. The DTPA extractable Fe content in the soil of all pedons was ranged between 26.46 to 61.46, 26.28 to 61.84 and 16.96 to 63.76 mg kg^{-1}, respectively in Motidabdar, Chikhalda and Daguniya villages of Dangs district. Considering the critical limit of 4.5 mg kg^{-1} [10] for acidic soil, all the soils were sufficient in available Fe content. Results also indicated that the similar trend in all the pedons to accumulation of Fe was higher in surface horizon as compared to lower horizons. In general, DTPA-Fe decreased with increasing soil depth, which may be due to lower content of organic carbon in the subsurface soil than surface soil. These results get support from the finding of Verma et al. [20].

The vartical distribution of available Mn in the pedons of all soils closely resembles that of available Fe profile which might be due to similar reason discussed under Fe. The DTPA extractable Mn content in the soil of study areas varied from 13.44 to 62.14,

Table 4. Simple correlations among different parameters of Pedon 1, 2 and 3 of Motidabdar, Chikhalda and Daguniya village. **Significant at 1%, *Significant at 5%.

	pH	EC	OC	Fe	Mn	Zn	Cu
pH	1.00						
EC	0.171	1.000					
OC	-0.074	0.373*	1.000				
Fe	-0.344*	0.296	0.556**	1.000			
Mn	-0.208	0.294	0.674**	0.711**	1.000		
Zn	-0.200	-0.113	0.065	0.096	0.138	1.000	
Cu		-0.010	0.317*	0.292	0.371*	0.743**	1.000

26.58 to 64.08 and 17.04 to 68.64 mg kg^{-1} with mean values of 39.25, 43.56 and 40.67 mg kg^{-1} respectively in Motidabdar, Chikhalda and Daguniya villages of Dangs district. Considering the critical limit of 2.0 mg kg^{-1} [10] for acidic soil, all the soils were sufficient in available Mn content.

The DTPA extractable Cu content in different horizons of pedons varied from 0.03 to 2.15, 0.04 to 2.74 and o.36 to 4.38 mg kg^{-1}, respectively in Motidabdar, Chikhalda and Daguniya villages. As par critical limit of 0.2 mg kg^{-1} [10] for Cu in the acidic soil, the available Cu status was uniformly above the critical level in the soils except only in lower horizon of pedon 1 of Motidabdar (0.03 mg kg^{-1}) and Chikhada (0.04 mg kg^{-1}) villages soils, in which were deficient. In general, majority pedons were showed gradually decreased with increasing soil depth except pedon 1, 2 of Daguniya village in which was not found a definite trend with soil depth.

Considering the critical limit of 0.5 mg kg^{-1} for Zn in acidic soil [10], all the soils were sufficient in available Zn content except lower horizon of pedon 1 and 3 of Motidabdar village soil, in which were deficient. In general, gradually decreased with increasing soil depth except pedon 1 and 3 in Chikhalda and 1 and 2 of Daguniya villages in which was not found a definite trend with soil depth. The DTPA extractable Zn content in the pedons ranged from 036 to 1.86, 0.86 to 2.34 and 0.62 to 3.70 mg kg^{-1}, respectively in Motidabdar, Chikhalda and Daguniya villages of Dangs diatrict in Gujarat.

Results were in the same line as mentioned by Verma et al. [3] in relation to DTPA-extractable Fe, Zn and Cu for soils of north-east of Punjab and Sharma et al. [21] in case of increased availability of metal ions (Zn, Cu, Fe and Mn) with increase in organic matter content. Results also corroborated with the findings of Kannan et al. [22], Pati and Mukhopadhyay [16], Singh et al. [14] and Behera and Shukla [23] in soil of different areas on DTPA-extractable micronutrients.

Correlation among different parameters

Among the correlation of different parameters in Table 4, it was observed that the DTPA-Fe was either positively or negatively and significantly correlated with pH, OC and DTPA-Mn. DTPA-Mn was positively and significantly correlated with OC, and DTPA-Fe and Cu. Similarly, DTPA-Cu was positively and significantly correlated with OC, DTPA-Mn and Zn either at 1% or 5% level of significance. Further, OC was positively and significantly correlated with EC, DTPA-Fe, Mn and Cu either 1% or 5% level of significance. Results of significantly and/or negative correlations of all or some micronutrients with pH were supported by Sharma et al. [21, Verma et al. [5], Iratkar et al. [24], Meena et al. [25]. Results of positive and significant simple correlations among DTPA- micronutrients and DTPA-micronutrients with other parameters like OC and EC, were similar with the findings of Bahera and Shukla [23] and Wani et al. [26].

Conclusion

Surface soils of all pedons contained higher SOC (11.50 to 17.20 g kg^{-1}), but the content decreased gradually with depth of pedon. Soils of all the pedons were high in DTPA-Fe, Mn, Zn and Cu with exception

of one or two horizons in Zn and Cu. DTPA-Fe, Mn, Zn and Cu in all pedon-soils decreased gradually with depth and was found positively and significantly correlated with SOC.

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