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DTPA-Extractable Micronutrients and Their Correlation of Soil Properties of Waghodia, Vadodara District, Gujarat

K. R. Malode[1*]
Department of Soil Science and Agricultural Chemistry,
COA, Parul University, Vadodara Gujarat, India.
Patel K.G[2]
Dean, and Principal,
College of Agriculture, Parul University, Waghodia, Gujarat.
Swati Patel[3]
Department of Soil Science and Agricultural Chemistry,
COA, Parul University, Vadodara Gujarat, India.
Parmar V.P[4]
Department of Soil Science and Agricultural Chemistry,
COA, Parul University, Vadodara Gujarat, India.
Saiyed Sakil Ahemad[5]
Department of Agroforestry,
COA, Parul University, Vadodara Gujarat, India.
Mustapure S.N.[6]
Department of Agricultural Engineering,
PIT, Parul University, Vadodara Gujarat, India.

Abstract:

Seventy-five soil samples from five pedons of the Instructional Farm, Parul University, Waghodia (Vadodara), were evaluated to determine the vertical distribution of DTPA-extractable micronutrients (Zn, Cu, Fe, Mn, and B) and their association with major soil properties. Soil pH, $CaCO_3$, organic carbon, and texture significantly influenced micronutrient availability. Zinc ranged from 0.01–0.27 mg kg^{-1}, with more than 80% of surface horizons deficient (<0.6 mg kg^{-1}), showing a clear decrease with depth. Copper (0.20–2.10 mg kg^{-1}) remained adequate in all pedons, while iron (0.97–23.89 mg kg^{-1}) was also largely sufficient relative to the 4.5 mg kg^{-1} critical limit. Manganese (2.90–53.36 mg kg^{-1}) was adequate in most pedons except P5, whereas boron (0.02–0.12 mg kg^{-1}) showed widespread deficiency, with over 85% of samples below the 0.5 mg kg^{-1} threshold.

Micronutrient availability generally declined with depth and was strongly negatively correlated with soil pH and $CaCO_3$, indicating reduced solubility under alkaline conditions. Organic carbon and clay exhibited positive correlations with most micronutrients, highlighting their role in complexation and retention. Overall, the soils were moderately to strongly alkaline, varied from sandy loam to clay in texture, and displayed deficient levels of Zn and B, indicating the need for targeted micronutrient management for sustainable crop production.

Keywords: Correlation, micronutrients, soils of Vadodara.

INTRODUCTION

Micronutrient deficiency in soil has become wide spread in recent years and has resulted in low crop yields, more so after the introduction of high yielding crop varieties coupled with the use of high analysis fertilizer and increased cropping intensity. Soil surveying and mapping provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for maximizing crop yields. Soil fertility maps are meant for highlighting the nutrient needs, based. It is known that micronutrients are held within the mineral matter (Miller *et al*., 1986) and finer fractions of soils (Sharma *et al*., 2006). The availability of micronutrients is sensitive to changes in soil environment as well as physiographic; however, land use and landscape position may be the dominant factors of soil properties. Traditionally status of micronutrients was studied in only surface horizons (Takkar *et al*., 1989). The sub-soil micronutrient status, which varies in the soil profile depending upon parent materials, landforms, climatic conditions, natural vegetation, and land use pattern (Deka *et al.*,1996), is an important characteristic of knowing the soil resources, especially for crop nutrition practices. The micronutrients essential for plants are also indispensable for human beings, Zn and Fe are the most important nutrients and nearly half of the Indian soils are deficient in Zn and 15% in Fe. Available zinc in Gujarat soils ranges between 0.25 to 2.58 mg kg^{-1}. Nearly 24% soils of Gujarat state are Zn deficient and 58% soils of North Gujarat are found deficient to medium in available zinc status (Dangarwala *et. al*., 1983). These soils are commonly found in areas of Vertisols and. associated soils covering 4.9 M ha in Gujarat (NBSS Staff 1988).

Micronutrients are important for maintaining soil health and also increasing the productivity of crops as they play vital roles in plant metabolism. These are needed in very small amounts. The deficiencies of micronutrients have become major constraints to the productivity, stability, and sustainability of soils. The availability of micronutrients is influenced by their distribution in soil and other physio-chemical properties of soil. Soils with finer particles and with higher organic matter can generally provide a great reserve of these elements whereas coarse-textured soils such as sand have fewer reserves and tend to get depleted rather quickly (Bhanwaria *et al.* 2011).

MATERIALS AND METHODS

Study area Waghodia Taluka is located in the Vadodara district. Geographically the area lies between 73°17' to 73°33'E longitude and 22°12'to 22°21'N latitude. The total geographical area of the Taluka is 585.12km.

The mean annual temperature is 27.9°C with a mean summer temperature of 31.1°C and a mean winter temperature of 23.3°C. May is the hottest month with 39.5°C mean daily maximum temperature and January is the coldest month with 12.7°C mean daily minimum temperature. The mean annual rainfall of the area is around 869 mm, received mainly during the southwest monsoon from June to September. Major crops grown in this area are pigeon pea (*Cajanuscajan*), maize (*Zea mays*), cotton (*Gossypiumhirsutum*), sugarcane (*Saccharumofficinarum*), wheat (*Triticumaestivum*) and green gram (*Vignaradiata*) with 90

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to 120 days of length of growing period (LGP). The natural vegetation of the area comprised of *Azadirachtaindica*, Prosopisjuliflora, Prosopis cineraria, Doob(*Cynodondactylon*) , Babool (*Acacia arabica*), Peepal(*Ficus religious*).

The site and morphological characteristics of these soils were recorded and horizon-wise soil samples were collected (Soil Survey Division Staff 1995). The mechanical composition of soils was estimated by following the international pipette method (Piper 1966). For estimation of saturated hydraulic conductivity, 200 g of air-dry sample (2 mm) was dumped in one motion in the permeameter that was fitted with a screen and filter paper. The permeameter was then tapped 100 times to attain a uniform bulk density. After saturating the soil with distilled water, the saturated hydraulic conductivity was measured using the constant head method of Richards (1954).Calcium carbonate (Piper 1966), soil organic carbon (Walkley and Black 1934), pH, electrical conductivity Jackson (1973), Available Nitrogen was determined by Subbaiah and Asija (1956). Available phosphorus was estimated calorimetrically as per the method given by Jackson (1973).while Available potassium by Jackson (1973).Micronutrient content with physicochemical properties of the soils as suggested n (Lindsay and Norvell, 1978) and analyzed with the help of Atomic Absorption Spectrophotometer. Available forms of B was extracted using 0.02 (M) hot calcium chloride ($CaCl_2$) (HCC) (Parker and Gardner 1981). Extracted B in the clear filtrate was estimated calorimetrically using azomethine-H-method (Jakson, 1973).

RESULTS AND DISCUSSION

Soil site characteristics of Waghodia of Vadodara

The characteristics of the five soil pedons are presented in excavated the representative soil profile. The details about the location of the soil profile, name of soil series latitude and longitude, Mean Annual Rainfall (MAR), Mean Annual Temperature (MAT) (^{0}C) and topography, etc. are given in Table 1.

Table 1 Soil- site Characteristics of Waghodia, of Vadodara District, Gujrat state.

Location	Latitude	Longitude	MAR (mm)	MAT (0ᶜ)	Topography	Drainage	Slope (%)	Erosion	Natural vegetation
Patiyapura	22˚ 16'.32.2 "	73˚ 25' 29".8	869	30 ^{0}C	Plateau and uneven slope land	well	1-2	Nil	Mango (Mangiferaindica), Doob (Cynodondactylon), Babool (Acacia Arabica), Neem (Meliaaradirachata), Gumma (Leucasaspera), Peepal (Ficus religious)
Tawara	22˚ 16'.44.0 "	73˚ 25' 01".7	869	35 ^{0}C	Plateau	well	1-3	Nil	Mango (Mangiferaindica), Gumma (Leucasaspera), Palm (Borassusflabellifer), Gorkhul (Tribulusterrestr)
Limbda	22˚ 29'.24.6 "	73˚ 36' 34".5	750	36 ^{0}C	Plateau	M. well	1-2	Nil	Doob (cynodondactylon), Babool (Acacia Arabica),

(MAR- Marginal annual rainfall, MAT- Marginal annual temperature)*

The soils of Patiyapura P1 and P2 are observed to be Plateau and uneven slope lands in topography to be slightly undulating, that of Tawara pedon P3, P4, and Limda P5 were Plateau. The slope and drainage were recorded to be 1-2 percent except for pedons P3 and P4, medium and Imperfect of all pedons. The Erosion is nil to all pedons of receptivity variation in morphological characteristics of five profiles indicating that the soil varies in depth and color considerably depending upon the topographic situation. The morphological characteristics showed considerable variation in the nature and degree of horizon development reported by Raina (2008).The morphology of the Vertisols indicated that the soils were deep to very deep (more than 90 cm) Abhishek Jangir(2018). The cracks were 2 to 10 cm wide at the surface and extended up to a depth of 50 cm. The pressure faces were observed in all the profiles. Slicken sides were well developed and were tilted to an angle of 45-60 degrees from the horizontal. In pedons 1, 2, 3, and 4 the effervescence (with 10% HCl) was slight whereas in pedons 5, it was strong to violent which attributed the process of diffuse powdery from of CaCO3. Calcium carbonate was observed throughout the depth of all soils. Malode and Patil (2014).

Physico-Chemical Properties and DTPA-Extractable Micronutrient Cations (mg kg^{-1}) in Soils of Waghodia, Vadodara District, Gujarat.

The Soil texture is an inherent property of soil that determines the makeup of primary particles and it controls mainly air, water and nutrient availability to the plant. It could be judged considering sand (%), silt (%) and clay (%). The data indicated that all the soils were sandy Lome to clayey in texture. Per cent clay ranged from 69.1 per cent (pedon 5) to 52.7 per cent (pedon 1), whereas the sand per cent ranged from 24.9 (pedon 1) to 13.1 (pedon 5) of Limda and that of silt per cent ranged from 26.2 (pedon 5) to 17.2 (pedon 5). It is also observed that the clay distribution below the profile for all soils was almost uniform, suggesting of their development from their same kind of parent material under same climatic condition. Macro topography must have been played key role in the profile development (Pal *et al.*, 2000). The uniformity in clay distribution is attributed to the movement of finer soil particles along with runoff water from higher topographic position to lower situation and pedoturbation in vertisol (Sharma and Raychoudhari, 1988), (Malode and Patil 2014) Table 2.

Table 2. Physico-Chemical Properties and DTPA-Extractable Micronutrient Cations (mg kg⁻¹) in Soils of Waghodia, Vadodara District, Gujarat.

Location	Horizon	Depth (cm)	pH	EC (d Sm^{-3})	Soil Texture			Available Micro Nutrient status (mg kg^{-1})					OC (%)	$CaCO_3$ (%)
					Sand (%)	Silt (%)	Clay (%)	Cu	Fe	Mn	Zn	B		
Patiyapura-1 Fine, Semectitic, hyperthermic Vertic Haplustepts														
Patiyapura P 1	AP	0-15	6.90	0.48	24.9	22.4	52.7	0.32	8.53	48.40	0.16	0.11	0.40	11.33
	A	15-27	7.52	0.46	23.1	20.8	56.1	0.30	7.22	41.20	0.09	0.12	0.34	10.01
	Bw	27-40	7.60	0.42	21.2	19.3	59.4	0.25	6.01	33.3	0.02	0.07	0.21	09.23
	Bssk	40-70	7.57	0.41	19.3	18.2	62.5	0.20	4.21	21.01	0.02	0.02	0.01	07.03
Patiyapura-2 Fine, Semectitic, hyperthermic Vertic Haplustepts														
Patiyapura P2	AP	0-15	7.30	0.44	23.9	22.1	53.9	0.44	23.89	48.40	0.16	0.10	0.40	11.97
	A	15-25	7.87	0.42	22.2	21.2	56.6	0.40	19.27	41.01	0.09	0.06	0.31	11.07
	Bw	25-65	7.88	0.41	19.1	19.3	61.6	0.24	17.22	32.2	0.01	0.03	0.21	09.73
Tawara-1 Fine- loamy, mixed hyperthermic Typic Haplustepts														
Tawra P3	AP	0-15	7.00	0.49	24.1	22.1	53.8	0.41	17.82	7.45	0.20	0.09	0.80	09.41
	A	15-30	7.48	0.55	22.8	20.2	56.8	0.33	14.81	5.02	0.19	0.08	0.62	09.21
	Bw	30-65	7.5	0.47	21.2	19.1	59.6	0.21	11.32	2.90	0.11	0.07	0.41	08.43
Tawara-2 Fine- loamy, mixed hyperthermic Typic Haplustepts														
Tawra P4	AP	0-15	6.80	0.44	21.9	20.8	57.3	0.39	15.44	53.36	0.27	0.08	0.50	09.92
	A	15-30	7.22	0.41	19.3	19.1	61.6	0.31	11.00	41.50	0.20	0.05	0.51	07.73
	Bw	30-77	7.63	0.40	18.6	17.5	63.9	0.20	06.02	30.30	0.17	0.02	0.32	07.10
Limda-1 Very Fine Smectitic, hyperthermic Typic Haplusteps														
Limda P5	AP	0-15	8.02	0.85	17.8	26.2	63.9	2.10	03.94	07.24	0.21	--	0.54	13.3
	A	15-30	8.21	0.60	16.3	21.9	61.8	1.72	02.63	06.10	0.13	--	0.30	11.2
	Bw	30-49	8.36	0.42	14.4	19.7	65.9	1.42	01.92	02.91	0.07	--	0.19	07.91
	Bssk	49-75	8.40	0.42	13.1	17.2	69.1	0.94	0.97	02.97	0.01	0.02	0.09	07.10

The pH data indicated that the soil were generally moderate to strongly alkaline in reaction with pH varying between 6.80 (P2) to 8.4 (P5). The increase in soil pH below the slop and at lower depth may be attributed to the accumulation of the alkaline earth salts. It may be further stated that calcareousness of soil might be due to its formation form basalt rich in calcium (Ca++) and high or moderately alkaline earth, which leads to neutral to alkaline conditional as reported by Kaushal *et al.* (1986). Slight variation in electric conductivity (1:2.5 soil: water suspension) was observed with increase in depth i.e. the subsurface horizon. This might be due to leaching of salts from surface to down below through the percolating water, followed by evapotranspiration resulting in the salt accumulation at the subsurface horizon. Similar to this observation Rajankar (1990), Malode and Patil (2014) and Anonymous (1994) also reported that increase in depth i.e the surface horizon is associated with variation in electric conductivity. The organic carbon data indicated that, organic carbon content decreased with depth in all studied soils. This content ranged from 0.09 per cent (P5) to 0.8 per cent (P3). This might be due to sieving effect and adsorption of fine organic particles and water soluble organic matter respectively by soil particles. The calcium carbonate content varied from 07.03 per cent (P1) to 13.3 per cent (P5). The high calcium carbonate in soil affect the water holding capacity of soil which has great bearing on crop production under rainfed condition. Calcium carbonate affects the physical and chemical characteristics of soil and may prevent root penetration (Sys, 1985).

Available Zinc

DTPA-extractable zinc content in soils varied from 0.01 to0.27 mg $kg^{-1.}$ Table 2. More than 80% of the surface soil samples could be rated as deficient in available zinc out of seventy-five soil samples from five pedons of Waghodiya of Vadodara Gujarat, below the critical limit of 0.6 mg kg^{-1}(Katyal, 1985). Pedon1 to 5 appeared to be deficient in zinc, while others of surface soils were above the critical level. All the pedons were available zinc showe decreasing trend with increasing soil depth. The lower content of zinc in black soils is due to its fixation by clay (Manohar,1974)or due to high pH values which have resulted in the formation of in soluble compounds of zinc (Tandon, 1995). Available Zn content was significantly and negatively correlated (r = - 0.60**) with calcium carbonate. Sand and silt contents of soil also had a negative correlation but organic carbon and clay had a positive correlation with DTPA extractable Zn content of the soils.

Available Copper

The DTPA extractable copper in these soils ranged from 0.20 to 2.10 mg $kg^{-1}$with a mean value of 0.67 mg kg^{-1} Table 2. Considering the critical limit of 0.2 mg $kg^{-1}$for Cu for normal plant growth (KatyalandRandha,1983), the soils are rated adequate in available Cu. Soil pH and $CaCO_3$ content had a negative correlation with copper but organic carbon (r=0.50**) and clay(r=0.39*) had a significantly positive relation with Cu content (Table 3).These findings collaborate with the results of Patil and Mukhopadhyay (2011); and Thakur *et al.* (2011).

Table 3: Correlation between Soil Properties and Available Micronutrients in the Soils of Waghodia, Vadodara District, Gujarat

Soil characteristics	DTPA- Zn	DTPA- Cu	DTPA- Fe	DTPA- Mn	DTPA- B
pH	-0.587	0.620	-0.546	-0.589	-0.556
EC	0.396	0.736	-0.211	-0.395	0.329
OC	0.831	-0.007	0.489	-0.005	0.673
$CaCO_3$	0.358	0.405	0.331	0.238	0.332

Available Iron

These soils' DTPA extractable iron content varied between 0.97 to 23.89 mg kg^{-1}. Considering the critical limit of 4.5 mg $kg^{-1}$for Fe (Lindsay and Norvell, 1978, Ramamurthy and Bajaj 1969), the soils are rated adequate in available Fe. Available Fe content was significantly and negatively correlated with calcium carbonate and soil reaction. These results agree with the findings of Patel *et al.* (2016), Satyavathi and Reddy (2004).

Available Manganese

The DTPA extractable manganese content of these soils varied from 2.90 to 53.36 mg kg-1. Table 2. Considering the critical limit of 3 mg kg-1for manganese as suggested by Takkar *et al.*(1989), pedons P5are deficient in Mn. Available Mn content was significantly and positively correlated with calcium carbonate (r = 0.32**) and clay (r = 0.36**) content of the soil (Table 3).In general, calcium carbonated increased the availability of micronutrients to the formation of their soluble hydroxides at higher pH (Sahoo *et. al.*, 1995). Contrary to this, organic carbon had positive influence on DTPA-micronutrients due to complexation (Thampatti and Jose, 2006).

Available Boron

These soils' DTPA extractable Boron content varied between 0.12 to 0.02 mg kg^{-1} (Table 2.). Considering the critical limit of 0.5 mg $kg^{-1}$for B the soils are rated adequate in available B. Pedon1 to 5 appeared to be deficient in Boron, while others of surface soils were above the critical level. All the pedons were available Boron showed decreasing trend with increasing soil depth. More than 85 % of the surface soil samples could be rated as deficient in available Boron out of seventy-five soil samples from five pedons of Waghodiya of Vadodara Gujarat, (Singh, 1999; Singh 2006). Available B content was significantly and negatively correlated with calcium carbonate and soil reaction. These results agree with the findings of Thakor, K. M and *et.al.* (2014).

CONCLUSION

The DTPA extractable micronutrient captions distribution in soils of Waghodia of Vadodara showed nutrient stats of soils with profile P1 to P5. The surface soil pedons were Very low to low in available Zn, however, all the Pedon P1 to P5 showed low status. The available Zn content in soil profiles showed a decreasing trend with soil depth. All the soil horizons showed sufficiency in available copper. Available iron content was sufficient in surface and deficient in subsurface particularly in soils having CaCO3. Available Mn was sufficient in all the soil profiles. Soil properties such as pH, and $CaCO_3$ showed negative correlations and organic carbon and texture showed positive correlations with available micronutrients.

These observations point out those 75 and 85 % soil samples of Waghodia of the Vadodara district of Gujarat are deficient in DTPA- Zn and Fe respectively and need zinc fertilization for sustainable crop production. Higher amounts of these micronutrient cations were found in surface layers. The soil properties had a definite influence on their availability. And for Boron also ensure 20 kg ha-^{1}would be optimum for getting smart managements.

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