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Characterization of salt affected soils of Dholka taluka of *Bhal* region in Gujarat

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Abstract
Ten representing pedons of salt affected soils *viz*., Simej, Ambareli, Khatripur, Koth, Javaraj, Arnej, Bhetawada, Dholi, Anandpura and Vataman of *Bhal* region of Dholka taluka in Gujarat state (India) were selected for their physical and chemical properties. The soil texture of these pedons varied from clay to loam clay. The bulk density of different pedons ranged from 1.16 to 1.47 Mg m^{-3}. The bulk density was slightly increased with increase in depth of all pedons. No definite trend was observed in case of particle density, porosity and maximum water holding capacity and it was ranged from 2.31 to 2.57 Mg m^{-3}, 38.5 to 52.1% and 24.8 to 48.3%, respectively. In all pedons, pH of soil increased with depth of soil and it ranged from 7.48 to 9.08. *i.e.*, mildly alkaline to very strongly alkaline in nature. Electrical conductivity (EC) varies from 0.17 to 5.3 dS m^{-1}**,** normal to highly saline in nature. Organic carbon (OC) ranged from 0.10 to 0.75% in different horizons and decreasing trend was noticed with depth in all pedons. The dominating cations on the soil exchangeable complex were Na^{+} followed by Ca^{++} and Mg^{++}. Exchangeable Na^{+} was increased with depth in all pedons. Available macronutrients (N, P, K and S) were deficient, low to medium, medium to high and low to medium, respectively, and decreased with depth in all pedons. In case of micronutrients status, no definite trend was observed.

Keywords: Available nutrients, pedons, physical and chemical properties, salt affected soil

1. Introduction
The demand of food, fodder and fuel is increasing for growing population but agricultural land is decreasing day by day due to conversion of non- agricultural uses and increase in extent of problematic soils (salinity/alkalinity/acidity/erodibility). The salt-affected soils are more prominently witnessed in the arid, semi-arid areas and many coastal areas in the humid climate are also affected due to ingress of seawater. According to an estimate, about 7.54 million hectare (Mha) of land is covered with salt affected soils in India (Mandal *et al*., 2010) [7]. Salt affected soils are quite prevalent in Bhal region of Gujarat. Salinity in this area is due to (i) weathering of the mineral either in situ or elsewhere and subsequent transport and accumulations, (ii) inherent salinity, as this area remained under the sea for a long period and high saline water table has made the agricultural lands saline and (iii) lateral sea water intrusion in the lower aquifer. Presently, the crops *viz.*, cotton and sorghum are sown on upland and the low lying area are kept for *rabi* crops like wheat and gram on conserved moisture. This area will shortly be irrigated by Narmada canal which will bring changes in the soil and water situations. In view of the above scenario, the present study was undertaken to generate the information on the characteristics of soil with respect to constraints *viz.*, soil salinity for crop production. The study would help in planning strategies for different farming practices and irrigation management for improving the agricultural productivity and to check further degradation of the soils.

2. Materials and Methods
The Dholka taluka situated between $22^{0}25'$-$22^{0}60'$ N latitude and $72^{0}32'$ – $72^{0}50'$ E longitude in the very popular flat area known as *Bhal* track in the middle of Gujarat state. The climate of this track can be classified as a *hot steppe* one characterized by a distinct monsoon period. The rainfall is primarily received during monsoon (400-800 mm), through a few occasional showered during May and October is not an uncommon behaviour. The average rainfall is about 600 mm. The annual mean maximum temperature is 42 ºC, and minimum temperature 10 ºC. Mean relative humidity is 35 per cent. January and February are the coldest months while May and June are the hottest months. During the summer months, hot wind with dust storms is the characteristics feature of this area. This area has the *ustic* soil moisture regime.

In general, the ground water in the area is found at shallow soil depth. However, the depth varies from one place to another. Ground water in the Dholka taluka occurs under confined and unconfined aquifers. The North-East portion of the taluka is more suitable for groundwater development while water in southern and western area is saline and unsuitable for irrigation. The aquifer above 70 meters is saline and has TDS 2500-3300 ppm. The value of transmissibility varies from 3.9 to 9.2 m day^{-1}. The major crops grown in this area are cotton, jowar, bajara (on a smaller scale) and wheat (mainly dry '*Chhasiya*' wheat). In scanty rainfall years, sorghum crop is grown for fodder.

Ten pedons namely, Simej, Ambareli, Khatripur, Koth, Javaraj, Arnej, Bhetawada, Dholi, Anandpura and Vataman of *Bhal* region of Dholka taluka were studied for their physical and chemical properties. Depth wise soil samples were collected and analysed in the laboratory as per standard methods of Rechards (1954) [12]. Soils were classified as per USDA system. Processed soil samples were analysed for particle size distribution by using method given by Piper (1968) [9]. The organic carbon, electrical conductivity, pH, available N, P, K and S were determined as per methods described by Jackson (1973) [4]. The available micronutrients were extracted with DTPA (0.005 *M* DTPA + 0.01 *M* $CaCl_2$ + 0.1 *M* triethanolamine, pH 7.3) as per method described by Lindsay and Norvell (1978) [6].

3. Results and Discussion

3.1. Physical properties

The bulk density of soil was ranged from 1.16 to 1.47 Mg m^{-3} in all pedons (Table 1). A lower value of bulk density was observed on surface soil (0-30 cm) in comparison with sub-surface soil (30-60 cm) in all pedons. Maximum values of bulk density were found in sub-surface area in comparison with all surface area. Similar findings were reported by Singh and Agrawal (2005) [13]. The values of particle density were varied from 2.31 to 2.57 Mg m^{-3}. No specific trend was observed in different depth of all pedons.

The porosity of soil in all pedons ranged from 38.5 to 52.1% and no definite trend was observed with increasing in depth of soil. Except, Arnej and Anandpura, there was decreasing trend was observed with increasing depth of soils. In case of maximum water holding capacity (MWHC) of soil, it ranged from 24.88 to 48.31% in all pedons. In Simej and Khatripur villages MWHC was decreased and increased, respectively with increas in depth of pedons. No specific trend was observed for other pedons.

The soil texture of pedons of Javaraj, Arnej, Anandpura, Koth, Ambareli and Dholi comes under clay textural class. Soils of Vataman and Simej comes under clay loam and clay

Table 1: Physical properties of soil profile samples

Soil depth	BD	PD	Porosity (%)	MWHC (%)	Textural composition (%)				Soil depth	BD	PD	Porosity (%)	MWHC (%)	Textural composition (%)			
	Mg m^{-3}				Coarse sand	Fine sand	Silt	Clay		Mg m^{-3}				Coarse sand	Fine sand	Silt	Clay
Pedon 1 (Simej)									**Pedon 6 (Arnej)**								
1	1.28	2.41	46.8	41.04	2.66	35.4	31.8	30.1	1	1.16	2.43	52.1	39.22	3.35	13.8	37.9	44.9
2	1.31	2.36	44.2	37.20	0.96	31.6	37.3	30.1	2	1.19	2.38	50.0	42.32	4.09	13.4	36.7	45.9
3	1.35	2.48	45.5	36.59	1.02	19.7	37.4	41.9	3	1.22	2.31	47.2	34.99	3.12	19.9	30.2	46.8
4	1.35	2.43	44.4	33.92	1.82	17.6	38.5	42.0	4	1.28	2.43	47.2	42.73	3.22	9.8	37.1	49.8
5	1.38	2.48	44.0	38.75	6.28	11.1	39.7	42.9	5	1.35	2.36	42.7	40.04	2.88	19.8	31.8	45.5
Pedon 2 (Ambareli)									Pedon 7 (Bhetawada)								
1	1.20	2.37	49.2	37.27	4.59	17.5	36.3	40.7	1	1.33	2.37	43.7	42.00	8.67	21.3	43.9	25.4
2	1.28	2.36	45.7	36.72	4.80	11.0	37.3	46.9	2	1.37	2.36	42.0	39.22	9.23	23.8	45.8	21.6
3	1.31	2.49	47.2	42.41	13.00	10.0	29.9	47.2	3	1.41	2.49	43.4	37.86	6.21	25.7	44.8	22.0
4	1.31	2.51	47.6	41.62	3.08	8.0	39.0	49.9	4	1.41	2.51	43.9	42.41	2.16	25.8	46.5	25.5
5	1.35	2.39	43.5	42.28	2.75	11.4	35.8	50.0	5	1.47	2.39	38.5	41.58	2.54	26.1	45.9	25.4
Pedon 3 (Khatripur)									Pedon 8 (Dholi)								
1	1.25	2.48	49.6	40.56	9.76	20.7	46.9	22.6	1	1.25	2.37	47.3	41.30	18.82	20.9	14.4	45.9
2	1.29	2.43	46.6	41.40	11.23	21.5	44.6	22.7	2	1.30	2.36	45.0	43.86	6.01	14.6	33.6	45.9
3	1.31	2.48	46.9	42.75	8.12	25.0	43.8	23.1	3	1.33	2.49	46.5	43.45	10.20	8.2	33.2	48.4
4	1.36	2.43	43.6	43.40	2.16	25.8	47.5	24.1	4	1.35	2.51	46.2	42.66	13.20	7.5	30.9	48.4
5	1.36	2.51	45.4	45.11	2.45	25.8	44.8	26.6	5	1.35	2.39	43.5	43.52	14.25	9.4	22.0	53.5
Pedon 4 (Koth)									Pedon 9 (Anandpura)								
1	1.38	2.37	41.4	31.05	7.98	18.9	30.9	42.2	1	1.30	2.41	46.1	42.51	5.6	12.3	30.1	49.9
2	1.38	2.36	41.1	34.70	4.52	19.9	32.5	43.0	2	1.33	2.48	46.2	42.66	4.8	9.9	35.3	50.0
3	1.42	2.49	42.6	33.10	4.00	21.6	29.5	44.9	3	1.37	2.48	44.8	43.81	4.1	10.4	32.4	52.9
4	1.47	2.51	41.4	24.88	4.05	17.6	30.0	48.4	4	1.37	2.57	46.7	42.55	3.9	10.0	29.5	56.6
5	1.47	2.39	38.5	27.69	4.08	17.6	27.4	50.9	5	1.39	2.37	41.4	41.50	3.1	9.8	28.9	58.2
Pedon 5 (Javaraj)									Pedon 10 (Vataman)								
1	1.27	2.36	46.4	39.89	4.52	16.5	38.4	40.7	1	1.27	2.43	47.9	48.31	10.92	20.3	33.7	35.2
2	1.28	2.48	48.3	41.29	1.82	8.5	39.1	50.7	2	1.30	2.36	45.0	45.12	8.52	13.5	39.6	38.4
3	1.28	2.43	47.2	42.73	2.04	14.1	33.1	50.7	3	1.32	2.38	44.7	46.96	7.52	9.8	41.8	41.2
4	1.32	2.48	46.9	40.04	2.31	10.1	36.4	50.7	4	1.33	2.31	42.3	47.06	6.92	10.8	34.1	48.2
5	1.35	2.43	44.4	39.94	5.15	24.6	22.4	47.8	5	1.37	2.43	43.6	45.12	6.52	12.8	42.2	38.4

1= 0-30 cm, 2= 30-60 cm, 3= 60-90 cm, 4= 90-120 cm, 5= 120-150 cm

textural class whereas, loam textural class was observed in case of Khatripur and Bhetawada soils. Clay content in soil was varied from 21.6 to 58.2% and was increased in lower depth compared with upper depth of all pedons due to weathering of parent material. Silt content, in general, exhibited an irregular trend with depth; this irregular distribution of silt might be due to variation in weathering of parent material or *in-situ* formation (Kumar and Naidu, 2012)

[5]. The sand content in soil was varied from 7.5 to 35.4% in all pedons. It was decreased with increasing soil depth in Simej, Ambareli, Dholi, Anandpura and Vataman, whereas irregular trend was observed in other pedons.

3.2. Chemical properties

The soil pH was found to be increased with depth of soil and it ranged from 7.48 to 9.08. *i.e.,* mildly alkaline to very strongly alkaline in nature. In Simej, Ambareli, Khatripur, Koth, Javaraj and Bhetawada pedons soil pH was increased with definite trend, but for remaining pedons no definite trend was observed (Table 2). Electrical conductivity (EC) of soil varies from 0.17 to 5.3 dS m^{-1} **(**normal to highly saline) in all pedons. EC of Simej, Ambareli, Khatripur, Koth and Bhetawada' pedons was increased with depth of soil but in case of Anandpura village it was decreased with increasing in soil depth. For remaining pedons no definite trend was observed.

Organic carbon was ranged from 0.10 to 0.75% in all pedons. Khatripur showed higher organic carbon values at surface depth as compared to other pedons. A decreasing trend was observed in organic carbon and magnitude of decrease was higher in all pedons (Bhasker *et al.,* 2004) [1].

The exchangeable cations *i.e.,* Ca^{++}, Mg^{++}, K^{+} and Na^{+} recorded in the range of 11.1 to 22.4 Cmol(p^{+})kg^{-1}, 5.4 to 20.1 Cmol(p^{+})kg^{-1}, 0.21 to 1.0 Cmol(p^{+})kg^{-1} and 3.1 to 23.7 Cmol(p^{+})kg^{-1}, respectively. In all pedons, exchangeable Na^{+} content was increased with increase in depth of soil. However, exchangeable Ca^{++} in Javaraj and Arnej, exchangeable Mg^{++} in Koth, Anandpura and Vataman and while exchangeable K^{+} in Koth and Anandpura were increased with depth of soil. The dominating cations on the exchangeable complex were Na^{+} followed by Ca^{++} and Mg^{++}. Similar results were reported by Wilding *et al*. (1983) [15], Raghuwanshi *et al*. (2011) [11] and Geetha and Naidu (2013) [2].

3.3. Nutrient Status

3.3.1. Macronutrients

Status of macronutrients of different pedons showed the decreasing trend with increasing depth of soil profile (Table 3). The values of available N content varied from 78 to 204 kg ha^{-1} in all pedons. On the basis of the rating suggested by Subbaiah and Asija (1956) [14], available N content was found deficient (< 250 kg N ha^{-1}) in all soil pedons. Available N content was higher in surface horizons and decreased regularly with soil depth which may be due to decreasing trend of organic carbon.

The available P in all pedons varied from 2.2 to 46.3 kg ha^{-1} in different pedons (Table 3). On the basis of the limits suggested by Muhr *et al.* (1963) [8], the available P_2O_5 was rated low (< 10 kg P_2O_5 ha^{-1}) to high (>25 kg P_2O_5 ha^{-1}) in all soils. However, the highest available P content was observed in the surface horizon and was decreased with depth of soil. It might be due to the confinement of crop cultivation to the rhizosphere and supplementing the depleted

Table 2: Chemical properties of soil profile samples

Soil depth	pH	EC (dS m^{-1})	OC (%)	Exchangeable cations [Cmol(p^{+}) kg^{-1}]				Soil depth	pH	EC (dS m^{-1})	OC (%)	Exchangeable cations [Cmol(p^{+}) kg^{-1}]			
				Ca^{++}	Mg^{++}	K^{+}	Na^{+}					Ca^{++}	Mg^{++}	K^{+}	Na^{+}
Pedon 1 (Simej)								**Pedon 6 (Arnej)**							
1	7.48	2.21	0.33	14.0	12.1	0.52	5.9	1	8.02	0.21	0.43	13.7	15.9	0.66	10.2
2	7.52	2.24	0.34	14.9	14.7	0.45	6.3	2	7.86	0.38	0.39	14.8	14.1	0.54	10.7
3	8.13	2.62	0.29	13.8	18.6	0.44	9.2	3	8.01	0.17	0.31	16.6	17.2	0.46	13.1
4	8.42	2.73	0.11	13.8	15.9	0.40	9.8	4	7.95	0.44	0.21	17.1	17.8	0.42	15.2
5	8.48	3.14	0.10	13.3	16.1	0.40	9.7	5	9.05	0.37	0.19	13.5	17.9	0.43	15.7
Pedon 2 (Ambareli)								Pedon 7 (Bhetawada)							
1	8.68	0.21	0.34	14.8	12.8	0.47	4.6	1	7.84	0.87	0.48	11.9	7.2	0.43	3.1
2	8.61	0.19	0.29	14.6	15.9	0.27	4.8	2	8.18	0.25	0.41	13.1	8.6	0.42	5.6
3	8.85	0.21	0.17	13.9	18.7	0.44	8.5	3	8.80	0.57	0.27	11.9	8.6	0.42	7.7
4	9.05	0.38	0.12	13.8	16.7	0.45	8.6	4	7.68	0.87	0.21	11.3	6.1	0.45	9.3
5	9.05	0.44	0.10	13.6	17.7	0.39	8.5	5	8.14	0.91	0.13	11.1	5.4	0.39	10.9
Pedon 3 (Khatripur)								Pedon 8 (Dholi)							
1	7.93	4.20	0.75	11.3	6.9	0.50	3.1	1	8.10	0.39	0.54	19.3	12.2	0.50	8.4
2	8.71	3.90	0.55	14.7	9.2	0.44	4.5	2	8.07	0.26	0.56	21.4	14.1	0.43	6.6
3	8.79	4.20	0.31	12.4	9.7	0.21	6.2	3	8.93	0.41	0.49	20.2	14.9	0.41	6.9
4	9.08	5.30	0.11	11.4	7.5	0.38	7.9	4	8.78	1.38	0.21	19.7	15.6	0.40	7.6
5	9.06	5.30	0.11	11.9	6.9	0.38	9.4	5	7.70	1.53	0.19	19.2	20.1	0.56	8.2
Pedon 4 (Koth)								Pedon 9 (Anandpura)							
1	8.31	0.74	0.39	21.1	11.6	0.41	7.6	1	8.16	1.42	0.56	12.2	15.0	0.51	16.1
2	9.03	0.56	0.36	20.8	13.4	0.42	7.9	2	8.72	1.37	0.56	13.4	17.1	0.47	16.9
3	8.86	0.37	0.24	19.1	13.7	0.54	8.2	3	8.15	1.11	0.48	13.9	17.6	0.49	19.2
4	8.13	0.54	0.21	21.1	14.9	0.58	7.9	4	8.63	0.76	0.48	12.8	18.4	0.52	23.4
5	8.09	0.51	0.16	17.1	19.7	0.60	9.3	5	8.67	1.21	0.41	11.1	17.1	0.55	23.7
Pedon 5 (Javaraj)								Pedon 10 (Vataman)							
1	8.43	0.21	0.45	13.6	15.2	0.32	11.6	1	7.66	1.42	0.48	21.4	10.1	0.86	6.2
2	9.04	0.25	0.45	14.2	14.8	0.40	11.5	2	7.59	1.30	0.45	20.2	11.7	1.00	8.8
3	8.64	0.24	0.37	16.3	19.2	0.43	13.7	3	7.51	1.32	0.29	22.4	14.2	0.80	10.6
4	8.98	0.28	0.32	17.6	19.6	0.25	14.2	4	7.60	1.26	0.29	21.1	14.0	0.74	12.4
5	8.85	0.25	0.19	13.7	19.7	0.26	14.9	5	7.76	1.52	0.13	21.6	16.9	0.87	15.1

1= 0-30 cm, 2= 30-60 cm, 3= 60-90 cm, 4= 90-120 cm, 5= 120-150 cm

Table 3: Available macro and micronutrients of soil profiles

Soil depth	Available macronutrients (kg ha^{-1})				Available micronutrients (ppm)				Soil depth	Available macronutrients (kg ha^{-1})				Available micronutrients (ppm)			
	N	P	K	S	Fe	Mn	Zn	Cu		N	P	K	S	Fe	Mn	Zn	Cu
Pedon 1 (Simej)									**Pedon 6 (Arnej)**								
1	172	33.8	268	9.4	5.8	18.7	2.68	1.12	1	172	18.9	237	3.5	7.3	5.5	0.76	1.22
2	157	29.0	238	9.0	5.6	18.4	2.42	0.88	2	125	18.0	227	2.6	6.9	4.9	0.34	0.80
3	157	25.4	233	8.8	4.8	14.5	1.34	0.88	3	110	17.9	227	1.7	6.5	4.6	0.46	0.70
4	141	21.7	219	5.7	5.1	14.6	1.30	0.82	4	110	15.9	207	1.1	7.0	5.4	0.36	0.82
5	141	15.8	211	6.6	4.4	12.2	1.42	0.84	5	78	15.1	205	1.4	6.8	4.9	0.56	0.88
Pedon 2 (Ambareli)									**Pedon 7 (Bhetawada)**								
1	188	23.2	228	5.3	11.5	4.9	1.34	0.76	1	188	16.2	246	6.7	5.9	25.6	0.58	1.36
2	141	21.4	225	5.0	11.9	6.2	1.32	0.84	2	141	13.4	229	5.9	10.9	27.6	0.50	1.98
3	125	21.1	200	4.3	11.2	4.7	1.34	0.64	3	110	12.5	217	3.4	7.8	26.6	0.22	1.54
4	125	19.8	216	3.6	11.8	4.9	1.30	0.82	4	94	10.3	217	2.0	6.8	28.8	0.46	1.50
5	110	17.3	192	4.1	11.9	8.5	1.40	0.82	5	78	6.2	213	2.4	6.1	32.1	0.62	1.64
Pedon 3 (Khatripur)									**Pedon 8 (Dholi)**								
1	188	8.0	263	4.8	8.6	6.2	1.02	1.22	1	204	22.7	254	8.3	10.9	9.9	0.82	1.8
2	110	8.9	217	5.5	8.1	5.2	0.68	0.92	2	141	19.8	232	6.9	10.2	9.1	0.64	2.0
3	94	3.1	190	2.5	6.8	7.5	0.52	0.84	3	141	19.8	211	4.8	7.1	8.5	0.46	2.0
4	94	2.7	178	1.6	7.0	5.4	0.46	0.82	4	110	17.1	193	4.4	5.1	9.6	0.34	1.3
5	94	2.2	164	1.8	6.5	7.4	0.50	0.88	5	110	12.7	187	3.7	11.8	6.1	0.88	1.7
Pedon 4 (Koth)									**Pedon 9 (Anandpura)**								
1	204	16.4	262	3.4	11.5	9.5	0.44	1.56	1	172	21.7	278	7.6	9.7	8.9	1.16	1.64
2	110	12.2	256	2.5	5.5	5.7	0.38	1.36	2	141	19.1	255	7.3	11.8	5.8	0.48	1.70
3	110	11.8	198	1.8	5.2	7.7	0.20	1.36	3	94	16.7	215	6.5	7.7	7.1	0.48	2.02
4	78	11.3	172	1.8	4.7	5.8	0.32	0.98	4	94	11.1	187	4.4	6.8	6.0	0.48	1.48
5	78	10.2	166	1.7	3.8	7.2	0.29	0.78	5	110	8.8	147	3.6	7.5	8.1	0.42	1.62
Pedon 5 (Javaraj)									**Pedon 10 (Vataman)**								
1	204	45.3	289	15.6	7.4	9.1	0.61	1.12	1	204	46.3	290	16.3	21.0	14.3	1.72	3.68
2	172	39.8	262	14.8	8.4	4.2	0.48	1.06	2	172	36.4	269	14.4	18.0	16.9	1.72	3.56
3	141	39.4	222	11.2	6.5	4.8	0.52	0.86	3	141	24.3	221	11.6	21.1	13.8	1.56	3.28
4	94	20.3	222	9.2	7.2	6.7	0.64	0.78	4	141	14.3	186	11.5	21.7	11.7	1.46	2.92
5	110	15.8	199	10.6	6.4	6.1	0.42	0.88	5	110	11.6	155	9.9	21.7	11.4	1.40	2.92

1= 0-30 cm, 2= 30-60 cm, 3= 60-90 cm, 4= 90-120 cm, 5= 120-150 cm

P by external source *i.e*., fertilizers. The lower P content in lower depth compared to upper depth was due to the fixation of released P by clay minerals and oxides of iron and aluminium.

The available K_2O content of soils was varies from 147 to 290 kg ha^{-1}. The highest available K_2O content was noticed on surface horizon of pedon of Vataman in comparison with all pedons (Table 3). According to rating limit of K_2O [low (< 135 kg K_2O ha^{-1}), medium (135 to 280 kg K_2O ha^{-1}) and high (> 280 kg K_2O ha^{-1})] Muhr *et al.*, (1963) [8], low to medium, medium and medium to high were recorded. This might be due to more intense weathering, release of labile K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary rise. The available S in soils was varied from 1.1 to 16.3 ppm. The maximum values of available S were noticed on surface horizons and decreased with increasing depth of soil horizons in all pedons. It might be attributed to more amount of organic matter in surface layers than deeper layers. On the basis of the rating suggested by Hariram and Dwivedi (1994) [3], available S was low (< 10 ppm) to medium (10 to 20 ppm) in all horizons of different pedons.

3.3.2. Micronutrients

The DTPA-extractable Zn was ranged from 0.20 to 2.68 ppm in different pedons. Distribution of available Zn exhibited little variations with depth of soil (Table 3). Considering 0.60 ppm as critical level (Lindsay and Norvell, 1978) [6], deficiency of available Zn was found in all horizons, except in surface horizon of pedon Vataman. The low available Zn in soil was possibly due to high pH values which might be resulted in the formation of insoluble compounds of Zn or insoluble calcium zincate (Prasad *et al*., 2009) [10]. The DTPA-extractable Fe content was varied from 3.8 to 21.7 ppm in different soil depth of pedons. The trend of available Fe was not clear in different pedons, whereas decreasing trend with increasing soil depth of pedon was observed in Simej and Koth pedon. Considering the critical limits (< 4.5 ppm) proposed by Lindsay and Norvell (1978) [6], no deficiency of available Fe was observed in case of all pedon.

All the pedons found to be sufficient in available Cu (0.64 to 3.68 ppm) and no specific trends were observed with the depth of soil (Table 3). Considering critical limits (< 0.2 ppm) as suggested by Lindsay and Norvell (1978) [6], none of the samples of all soil horizons were found deficient. In all pedons, available Mn was varied from 4.2 to 32.1 ppm. Considering critical limit (<2 ppm) as suggested by Lindsay and Norvell (1978) [6], no deficiency was observed in case of available Mn. The decreasing trend of available Mn with soil depth was observed in Simej pedon.

4. Conclusions

The bulk density was slightly higher in sub-surface horizon (30 to 60 cm) in comparison with surface horizon (0 to 30 cm) and lower horizons of all pedons. All the soil pedons comes under clay to loam textural class. It is evident from the data that the dominating cations were Na^+ followed by Ca^{++}, Mg^{++} and K^+. The increasing trends of pH and electrical conductivity was observed with increasing depth of horizon, whereas reverse trend was observed in case of organic carbon of soil. The values of available N (deficient), P_2O_5 (low to medium), K_2O (medium to high) and S (low to medium) were

decreased with increasing depth, whereas available Zn, Fe, Cu and Mn were varied with depth of all horizons.

5. References

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