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MICRONUTRIENT STATUS OF PAKISTAN SOILS

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One hundred and fifty-two surface soil samples representing different soil series of the four provinces were collected and analysed for their available micronutrients (Zn, Cu, Fe, Mn) by atomic absorption spectrophotometry after extraction with DTPA (diethylenetriaminepentaacetic acid). Zinc appeared to be the most limiting micronutrient element in these soils, as 85% of the samples contained marginal to deficient concentrations of available Zn; the deficiencies were in the order: Baluchistan (69%), N.W.F.P. (55%), Punjab (45%) and Sind (17%). Copper deficiency was less in magnitude as only 28, 15, 5 and 14% samples in the respective provinces contained deficient concentrations. However, sufficient concentrations of Fe and Mn were detected in all the soils.

Soil pH, organic matter and $CaCO_3$ contents were correlated with available micronutrients. Organic matter showed positive correlation with Zn in N.W.F.P. (r 0.77**) and Sind (r 0.82**) soils. In N.W.F.P. soils it also correlated with Cu (r 0.63**), Fe (r 0.89**) and Mn (r 0.44**). Soil pH gave negative correlation with Zn in the Punjab (r −0.78**) and N.W.F.P. (r −0.72**). Similarly, negative correlation was also found with Cu (r −0.46**) and Fe (r −0.83**) in N.W.F.P. soils. Calcium carbonate content was negatively correlated with Cu (r −0.85**) and Fe (r −0.44*) in Sind soils.

INTRODUCTION

Micronutrient deficiencies in Pakistan soils have been well recognised during the recent years [5, 6, 13, 19, 26, 32]. These deficiencies may be attributed to intensive cultivation, introduction of high yielding varieties, enhanced use of micronutrient-free fertilizers and certain soil conditions [13, 24]. In the years to come, micronutrient disorders may become a serious problem for successful crop production. It is, therefore, imperative to know the micronutrient status of our soils. The present study was undertaken to have an idea about the micronutrient (available) status of different regions of the country. This sort of information would not only help in delineating micronutrient deficient areas but may also be utilized for planning the production and distribution programme of fertilizers containing micronutrients.

MATERIALS AND METHODS

Surface soil samples (0–15 cm) representing different soil series of the four provinces were provided by the Soil Survey of Pakistan. Organic matter (O.M.) and $CaCO_3$ contents were determined by Walkley and Black's and by Puri's methods respectively while pH was determined in 1:1 soil–water suspension. Most of the soils contained less than 1% organic matter and were alkaline in reaction with varying amounts of $CaCO_3$. Micronutrients of the soils were determined after extraction with DTPA [14]. The extractant consisted of 0.005*M* DTPA, 0.01*M* $CaCl_2$ and 0.1*M* TEA (triethanolamine) buffered at pH 7.3. Ten grams of soil were shaken with 20 ml of extractant for 2 hr and filtered. Concentrations of Zn, Cu, Fe and Mn in the filtrate were determined with atomic absorption spectrophotometer (Beckman, model 485). The number of soil samples from each province, their soil properties and micronutrient contents together with their mean values are given in Table 1.

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RESULTS AND DISCUSSION

Many research workers have shown the superiority of the DTPA extraction procedure over other methods for having its higher predictive value to separate deficient from nondeficient soils and for its strong relationship with micronutrient contents in plants. Moreover, this method has an added advantage that Zn, Cu, Fe and Mn can be determined in the same extract [2, 5, 10, 12, 14].

Zinc Contents of the Soils. Different critical levels (minimum level for normal crop growth) of DTPA–extractable Zn in soils have been reported. For example Brown *et al.* [2] while working on different micronutrient soil tests found DTPA the best extractant for soil-available Zn. They proposed 0.5 ppm Zn as the critical level in the soil. Viets and Lindsay [30] reported <0.5, 0.5–1.0 and >1.0 ppm

Table1. Soil properties and available micronutrient in soils of various regions of Pakistan.

Series	Location	pH (1:1)	O.M. (%)	CaCO (%)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
Punjab								
Bhalwal	Lahore, near Choong	8.70	0.20	-	0.29	1.46	16.2	60.0
-	Sheikhupura	8.50	0.54	4.58	4.30	7.20	60.0	-
Hafizabad	Lahore, Changa Manga	8.05	0.82	1.15	0.91	1.24	11.2	106.8
Matli	Multan, Qureshi Farm	8.20	0.63	-	0.49	4.20	38.8	113.4
Bhalwal	Lahore, Choong	8.50	0.31	-	0.29	1.75	18.4	-
Miani	Multan, Qureshi Farm	8.15	0.43	-	0.47	2.15	24.4	69.6
Bhalwal	Lahore, near Muridke	8.60	0.37	0.75	0.42	1.89	22.2	86.4
Nabipur	Multan, Agri. Farm	8.20	0.34	-	0.31	1.24	9.0	49.2
Miani	Multan, Ghulam Mohd Farm	8.20	0.82	-	1.79	-	70.0	145.0
Sindwan	Lahore, Choong	8.40	0.31	5.36	0.26	1.53	17.0	66.0
Mirzawala	Cholistan	8.50	0.55	-	2.00	1.53	12.0	42.0
Bhalwal	Lahore, Choong	8.20	0.75	0.90	0.88	1.75	25.2	150.0
Hafizabad	Sheikhupura	9.00	0.36	1.90	0.55	2.07	39.2	73.2
Miani	Multan, Agri. Farm	8.30	0.47	4.93	0.62	1.97	12.0	79.8
Pindorian	Lahore, Changa Manga	7.35	1.34	1.65	0.94	1.02	16.0	144.0
Miani	Multan, Pullwala	8.30	0.41	5.89	0.52	6.60	13.6	32.4
	Sheikhupura	8.90	0.44	1.75	0.36	3.15	34.8	33.6
Sultanpur	Multan, Qureshi Farm	6.80	0.20	-	0.60	1.90	7.8	24.6
Lyallpur	Sheikhupura	8.35	0.46	4.28	0.68	2.44	18.4	42.0
Hafizabad	Sheikhupura	9.60	0.35	-	0.45	2.53	17.8	57.6
Bhalwal	Lahore, Changa Manga	8.15	0.50	1.73	0.52	1.55	7.2	33.6
Shujaabad	Multan, Cott. Res. Inst.	8.20	0.74	-	0.86	2.40	11.2	50.4
Matli	Saleem, Chaman Farm	8.30	0.72	6.20	0.68	12.00	17.8	50.4
Moruwala	Cholistan	9.00	0.03	-	0.62	0.18	18.4	3.0
Hafizabad	Sheikhupura	9.50	0.22	3.05	0.23	1.64	11.2	21.6
Bhalwal	Sheikhupura	9.40	0.72	6.20	0.62	3.15	17.8	57.6
Gajiana	Lahore, Choong	8.20	0.25	3.50	0.18	1.55	11.2	21.0
-	Sheikhupura	8.90	2.33	8.35	0.83	3.42	17.8	19.8
Hafizabad	Sheikhupura	9.60	0.25	1.83	0.29	1.33	13.6	15.4
Bhalwal	Lahore, Pawaulta village	8.10	0.48	2.15	0.42	-	6.6	25.2
Sagheerwala	Cholistan	8.85	0.13	6.55	0.60	0.80	9.0	12.0
Matli	Multan Cott. Res. Inst	8.10	0.57	4.50	0.68	2.00	8.4	17.4
Gajiana	Lahore	9.00	0.15	3.45	0.13	1.38	9.0	14.4
Gujranwa a	Lahore, near Choong	8.00	0.48	1.21	2.52	14.40	9.0	13.2
Bhalwal	Sheikhupura	9.70	0.10	1.85	0.39	1.91	8.4	15.6
-	Sheikhupura	9.25	0.35	7.33	0.36	3.06	27.4	25.2
Bhalwal	Lahore Near Changa Manga	8.00	0.67	2.18	1.17	2.35	8.4	21.0
Bhalwal	Lahore near Choong	8.10	0.27	1.50	1.66	1.64	7.2	-
Hafizabad	Sheikhupura	9.30	0.36	2.23	0.42	1.91	9.6	19.8
Lyallpur	Sheikhupura	9.15	0.32	4.70	0.34	1.42	6.6	-
Mean		8.54	0.49	3.51	0.77	2.78	18.2	50.34
N.W.F.P.								
Ghara	Peshawar , Pir Sabak Farm	8.45	0.28	-	0.25	1.35	16.2	22.8
Bhalwal	Bannu, near Laki	8.40	0.57	-	0.35	2.26	16.2	117.0
Mughalki	Peshawar, Pir Sabak	8.60	0.42	-	0.39	3.20	-	-
Spenkanra	Peshawar, Pir Sabak	8.45	0.26	-	0.16	1.89	18.4	36.6
Minakhel	Bannu, near Laki	8.60	0.05	-	0.13	0.25	11.2	22.8
Tochi	Bannu	8.50	0.61	12.20	0.39	2.62	28.2	113.4
Changhaus	Bannu, near Laki	8.50	0.39	9.63	0.26	0.98	7.8	36.6
Misri	Peshawar, Pir Sabak Farm	8.80	0.23	-	0.81	1 13	12.0	18.0
Baran	Bannu	8.50	0.77	-	0.52	3.89	42.0	180.0
Kaghan	Kaghan Valley	7.30	2.54	-	8.30	2.44	156.0	-
Kaghan	Kaghan Valley	7.00	1.80	0.68	4.00	3.75	120.0	60.0
Kashu	Bannu	8.40	0.39	12.08	0.75	1.02	6.6	33.6

(Table 1 continued)

Turtola	Bannu, near Laki	8.70	0.12	-	0.52	1.29	7.80	14.4
Bannu	Bannu, near Laki	8.45	0.80	-	0.62	3.51	19.4	66.0
Pir Sabak	Peshawar, Pir Sabak Farm	8.30	0.33	7.80	0.23	1.90	9.8	13.2
Poriwala	Bannu	8.70	0.40	12.25	0.70	1.55	9.0	28.2
V. Brownak	Peshawar	8.70	0.17	-	0.18	0.75	11.2	13.0
Kattikhel	Peshawar, Pir Sabak Farm	8.50	0.08	-	0.18	1.64	9.8	16.8
Takhtikhel	Bannu	8.10	0.03	-	0.18	0.67	5.4	18.0
Tajari	Bannu	8.50	0.43	12.14	0.34	1.02	7.8	48.0
Talibwala	Bannu	8.30	0.29	-	0.68	1.02	7.2	28.2
Toru	Peshawar, Tarnab	8.60	0.42	12.38	0.62	1.91	12.0	15.6
Matli	Bannu,near Laki	8.20	1.00	12.38	0.55	4.13	21.2	27.0
Thatti	Bannu	8.50	0.28	9.98	0.18	0.93	6.0	9.0
Malik Shahi	Bannu	8.40	0.48	12.41	0.44	2.22	7.2	14.4
Tarnab	Peshawar, Tarnab	8.15	0.58	12.38	0.94	6.80	18.4	15.6
Pacca	Bannu	8.0	2.18	7.48	0.88	7.80	30.8	24.0
Burhan	Peshawar, Pir Sabak Farm	8.30	0.15	5.80	0.34	1.24	6.6	10.8
Sultanpur	Bannu	8.25	0.60	12.40	0.31	1.33	4.8	34.8
Katchkot	Bannu	8.20	1.01	12.33	0.52	3.55	38.0	28.8
Zaramina	Peshawar, Pir Sabak Farm	8.30	0.46	5.88	0.29	3.51	8.40	18.0
Kalpani	Peshawar, Pir Sabak Farm	8.10	0.37	5.60	0.31	1.24	8.40	12.0
Toru	Peshawar, Tarnab	7.80	0.72	12.35	1.38	5.40	6.00	24.0
Laki	Bannu	9.00	-	2.60	0.16	0.13	11.20	4.8
Misri	Peshawar, Pir Sabak Farm	8.30	0.32	7.38	0.23	1.91	9.0	12.0
Abbakhel	Bannu	8.30	0.02	4.45	0.13	0.18	9.0	4.8
Mughalki	Peshawar,Pir Sabak Farm	8.70	0.22	7.80	0.16	1.86	9.0	6.0
Missa	Peshawar, Pir Sabak Farm	8.55	0.19	6.10	0.44	0.80	8.4	11.4
Khujak	Bannu	8.70	0.21	8.47	0.18	0.53	4.2	6.0
Mean		8.32	0.60	9.12	0.72	2.14	22.98	33.58
Baluchistan								
Pinakai	Quetta	8.50	0.23	12.03	0.36	1.24	10.4	44.4
Balri	Quetta, near Malezai vill.	8.45	0.17	-	0.42	0.47	16.2	36.6
Sago Bhago	Quetta	8.45	0.60	2.44	0.36	2.18	-	-
Azim	Quetta	8.50	0.35	-	0.34	1.38	8.4	54.6
Babak	Quetta	8.20	0.43	12.38	0.26	0.80	9.0	33.6
Lak	Quetta	8.60	0.58	-	0.73	2.04	7.8	-
Pinakai	Quetta	8.70	0.19	-	0.26	0.51	9.6	25.8
Chaman	Quetta	8.60	0.20	12.28	0.29	1.02	7.8	32.4
Baghai	Quetta, Pinakai Valley	8.30	0.40	12.40	0.16	1.60	6.6	42.0
Baghai	Quetta	8.30	0.82	-	0.72	0.80	26.4	91.2
Babak	Quetta	8.70	0.17	12.39	0.26	0.47	9.0	31.2
-	Tariq Estate	8.20	0.47	-	1.17	14.40	41.0	113.4
Muslakh	Quetta	8.50	0.31	12.40	0.29	0.55	9.0	36.6
Muslakh	Quetta	8.60	0.38	-	0.44	0.91	9.0	39.0
Karbala	Quetta, Chaman Road	8.25	1.01	-	0.75	1.35	7.8	13.2
Baleli	Quetta	8.90	0.24	12.45	0.36	1.35	7.8	21.6
Taleri	Quetta	8.60	0.26	-	0.29	0.84	9;0	32.4
Samungli	Quetta	8.90	0.33	-	0.34	1.73	6.6	13.2
Shamozai	Quetta	8.30	0.25	-	0.34	1.95	6.6	22.8
Lak	Quetta	8.45	0.84	-	0.44	1.69	6.0	33.6
Babak	quetta	8.30	0.35	3.96	0.75	0.93	4.8	24.6
Khamat	Quetta	8.80	0.32	-	0.29	1.15	7.2	22.8
Popalzai	Quetta	9.00	0.85	12.0	0.94	1.69	6.0	24.0
Sariab	Quetta, Muslakh Valley	8.30	0.28	7.48	1.46	0.75	5.4	17.4
Pishin	Quetta	8.70	0.15	-	0.26	0.36	9.0	12.0
Karak	Quetta	8.40	0.23	-	0.23	0.93	3.0	12.0
Malezai	Quetta,near Malezai Vill.	8.80	0.35	-	0.18	1.42	6.0	5.4
Azim	Quetta	8.10	0.73	7.23	0.78	3.60	13.6	19.8
Majak	Quetta	10.05	0.33	12.18	0.75	2.22	8.0	10.8
Quetta	Quetta	8.40	0.37	6.19	0.29	1.73	9.6	15.6
Panjpani	Quetta	8.60	0.15	12.41	0.23	0.49	9.0	9.0
Kandil	Quetta, Chaman Road	8.70	0.63	11.40	0.57	1.55	6.0	10.6
Lajwar	Quetta	8.55	0.68	12.21	0.47	1.73	7.2	21.0

(Table 1 continued)

Majak	Quetta	8.20	0.28	-	0.44	1.20	5.4	15.6
Baghai	Quetta, Pinakai Valley	8.35	0.55	12.27	0.31	0.67	6.6	15.6
Pishin	Quetta	8.70	0.28	-	0.75	0.93	8.0	14.4
Quetta	Quetta	6.80	3.12	12.15	-	-	156.0	110.4
Mean		8.55	0.41	10.34	0.48	1.63	9.39	28.48
Sind								
Larkana	Larkana, Rattodoro	-	-	-	0.52	8.40	74.4	79.8
Kabil	Larkana, Kirthar minor	8.50	0.21	-	0.44	0.80	7.8	-
Kamber	Dadu	7.55	1.20	7.35	1.27	2.58	18.4	44.4
Lodra	Larkana, near Mohanjo Daro	9.70	0.55	-	0.99	5.00	32.6	18.0
Chimni	Dadu	7.70	0.08	12.48	0.60	0.51	13.6	18.0
Kasur	Larkana, near Dokri Canal	9.25	0.46	-	1.12	3.64	7.8	19.2
Dlengi	Dadu	7.60	1.06	12.33	2.13	3.09	32.6	49.2
Lodra	Larkana , near Mohanjo Daro	10.10	0.28	9.40	0.68	2.73	28.4	16.8
Jhatpat	Larkana	-	0.87	0.55	0.94	6.00	120.0	103.2
Miani	Dadu	8.30	0.65	-	0.62	3.06	16.0	60.0
Rattodero	Larkana, near Bakrani	8.40	1.09	-	0.81	-	-	6.84
Kashmore	Larkana	7.35	1.08	12.27	1.69	1.42	26.4	-
Kundi	Dadu	8.20	0.77	12.20	1.07	4.04	44.4	-
Naudero	Dadu	7.85	0.92	9.20	0.68	2.73	26.4	156.0
Gudu	Dadu	8.00	0.75	-	0.52	7.80	80.4	48.0
Rattodero	Dadu	-	0.68	-	1.20	2.06	22.2	25.8
Kandhot	Larkana	8.10	1.24	12.03	0.65	7.80	76.8	24.0
Mirzapur	Larkana	7.70	0.63	-	0.78	2.35	13.6	30.0
Jhatpat	Larkana	7.90	0.24	12.33	0.52	1.20	5.4	14.4
Shahdara	Dadu	8.00	0.59	12.30	0.36	2.13	8.0	6.6
Phulji	Dadu	7.30	0.65	12.40	1.61	1.33	9.6	22.2
Kithar	Larkana, Kirthar minor	8.00	0.59	-	0.65	3.15	17.0	9.0
Kabil	Larkana, Piedment area	7.10	3.31	10.25	10.00	2.00	37.0	52.8
Jhatpat	Larkana	7.60	0.35	-	0.94	1.51	5.4	21.0
Manchar	Dadu	8.00	0.80	8.98	0.55	5.40	41.0	10.8
Kamber	Larkana, Kamber Road	8.50	0.20	5.75	0.34	1.64	4.0	4.8
Bolari	Dadu	8.70	0.10	-	1.46	0.58	7.2	6.0
Kamber	Larkana	7.30	0.74	5.50	0.57	2.71	6.0	6.0
Kashmore	Larkana	7.50	0.59	12.39	0.96	1.33	8.4	18.0
Sultanpur	Dadu	8.20	0.40	11.27	0.34	1.60	10.4	10.8
Rattodero	Larkana, Bakrani Sitajan Road	8.65	0.42	-	0.42	1.60	6.0	3.6
Pandhi	Dadu	8.20	0.29	7.95	0.70	0.71	6.0	19.8
Petaro	Dadu	8.60	0.07	12.43	1.50	0.36	8.4	-
Larkana	Dadu	8.05	0.58	8.96	0.29	4.80	40.0	9.0
Miani	Dadu	8.20	0.88	10.61	0.83	3.20	10.4	13.2
Mean		8.13	0.69	9.95	1.11	2.92	25.6	30.3

DTPA-Zn in the soil as the deficient, marginal and adequate concentrations for crop growth. Research workers from India suggested critical levels ranging from 0.5 to 1.0 ppm Zn for different soils [24, 25]. Chaudhry and Sharif [5] working with calcareous soils of Pakistan reported 0.34 ppm Zn in the soils as the critical level using wheat as test crop. However, to remain on the safe side the ranges proposed by Viets and Lindsay were followed in this study to separate deficient from nondeficient soils.

Available Zn ranged from 0.13 to 4.3, 0.13 to 8.30, 0.16 to 1.46 and 0.29 to 10.00 ppm in the Punjab, N.W.F.P., Baluchistan and Sind soils respectively (Table 1). It was observed that 69% soil samples from Baluchistan, 55% from N.W.F.P. 45% from the Punjab and 17% from Sind may be classed as deficient in available Zn(< 0.5 ppm Zn). On the whole, only 15% samples contained adequate Zn (>1.00 ppm Zn) while 85% had marginal to deficient amounts (<1.00 ppm) in their surface horizons.

Research workers have noted a decrease in available Zn with an increase in the depth of the soil profile [9, 15, 22], hence for crops or trees with deeper root system, the problem may be even more serious. This is suspected that citrus requires Zn fertilization in some form almost everywhere it is grown [29].

Liberal applications of N and P on soils having marginal concentration of available Zn may not prove beneficial. These added nutrients may induce or aggravate Zn deficiency in plants growing on such marginal soils. Indeed in certain situations, adverse results of adding N and P to crops have been recorded [3, 8, 27]. Phosphorus-induced Zn deficiency has been reported to be common disorder in upland crops. Olsen [20] has made a comprehensive review of the problem.

Soils from Sind had higher concentrations of available Zn followed by the Punjab, N.W.F.P. and Balushistan. Similar trend in case of organic matter was found. These results support the earlier findings [9, 17] that available Zn concentrations were correlated with soil organic matter. In the present study (Table 2) Zn correlated significantly with the soil organic matter in Sind (r 0.82**), N.W.F.P. (r 0.77**) and Baluchistan (r 0.36*) soils. The reason for the lack of correlation in the Punjab could not be ascertained. Available-Zn had negative correlation with pH in the Punjab (r 0.78**) and N.W.F.P. (r 0.72**) soils. A decrease in Zn availability with an increase in soil pH has been reported by many workers [1, 11, 16, 18]. DTPA-Zn had no relationship with $CaCO_3$ in soils of any region. Udo *et al.* [28] also could not find any significant correlation between them.

Copper Contents of the Soils. The DTPA-Cu ranged from 0.18 to 12.0, 0.18 to 7.80, 0.36 to 14.40 and 0.36 to 8.40 ppm in the Punjab, N.W.F.P.,Baluchistan and Sind soils respectively (Table 1). Viets and Lindsay [30] reported a concentration of <0.2 ppm DTPA-Cu in the soils as deficient and >0.2 ppm DTPA-Cu as adequate for crop growth. Chaudhry and Sharif [5] on the other hand reported 0.86 ppm DTPA-Cu as the critical limit in the alkaline calcareous soils. If the ranges suggested by the formers are followed, only a few samples would appear deficient in available Cu. But the value of 0.2 ppm as critical limit appears to be too low for our soils because workers did get response in crop yields rather frequently by Cu applicaion [13, 19, 26] even on soils that contained more than 0.2 ppm Cu. Therefore, following critical limit of 0.86 ppm [5], 28% soil samples of Baluchistan, 15% of N.W.F.P., 14% of Sind and 5% of the Punjab appeared to be deficient in available Cu. This indicates that Cu deficiency in the soils of Pakistan is less in magnitude as compared to that of Zn. However, while emphasizing the need of micronutrients to make up their deficiencies, particularly of Zn, the suspected induced Cu deficiency in the crops must not be overlooked [4, 20].

Correlation studies indicated that available Cu in soils correlated with organic matter content of N.W.F.P. (r 0.63**) soils while it had negative correlation with $CaCO_3$ (r −0.85**) and pH (r −0.46**) in Sind and B: N.W.F.P. soils respectively (Table 2).

Table 2. Correlation coefficients between available micronutrients and soil properties in different regions of Pakistan.

Soil properties	Zn	Cu	Fe^{3}	Mn
Punjab				
pH	−0.78**	−0.14	0.07	−0.34*
O.M.	0.21	0.16	0.15	0.33*
$CaCO_3$	−0.06	0.26	0.06	0.31
N.W.F.P.				
pH	−0.72**	−0.46**	−0.83**	−0.28**
O.M.	0.77**	0.63**	0.89**	0.44**
$CaCO_3$	−0.28	0.17	−0.11	0.30
Baluchistan				
pH	−0.04	−0.15	−0.23	0.31
O.M.	0.36*	0.18	0.15	0.16
$CaCO_3$	−0.32	−0.35	0.03	0.24
Sind				
pH	0.31	0.08	0.02	−0.22
O.M.	0.82**	0.27	0.35*	0.32
$CaCO_3$	0.09	−0.85**	−0.44*	0.31

* Significant at 5% probablity level
** Significant at 1% probablity level.

Iron Contents of the Soils. The DTPA-Fe varied from 6.6 to 70.0, 4.2 to 15.6, 3.0 to 41.0 and 4.0 to 120.0 ppm in the Punjab, N.W.F.P., Baluchistan and Sind soil samples (Table 1). Viets and Lindsay [30] reported 2.5 ppm DTPA-Fe in the soil as critical limit. As far as we know, critical limit for iron in soils has never been reported in the subcontinent. So keeping in view the critical limit reported by Viets and Lindsay, all the samples analysed appeared to contain adequate concentrations of available Fe in them. However, in the past, people have been obtaining response of Fe application to soils in various crops [6, 19]. This indicates that the behaviour of Fe in the soil needs to be investigated and understood more thoroughly.

DTPA-Fe was found to be correlated with soil organic matter content in N.W.F.P. (r 0.89**) and Sind (r 0.35*) soils, while it had negative correlation with pH (r −0.83**) and $CaCO_3$ contents (r −0.44**) in N.W.F.P. and Sind soils respectively (Table 2).

Manganese Contents of the Soils. The DTPA-Mn ranged from 3.0 to 145.0, 4.8 to 117.0, 5.4 to 113.4 and 6.6 to 156.0 ppm in the soil samples from the Punjab, N.W.F.P. Baluchistan and Sind respectively (Table 1). Depending

upon the critical limit of 1.00 ppm DTPA-Mn as suggested by Viets and Lindsay, it appeared that Mn was present in sufficient amounts in the soils. DTPA-Mn had significant correlation with organic matter in the N.W.F.P. (r 0.44**) and the Punjab (r 0.33*) soils while it had negative correlation with pH in the Punjab (r −0.34*) and N.W.F.P. (r −0.28**) soils (Table 2).

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REFERENCES

1. L.C. Boawn, F.G. Viets Jr., C.L. Crawford and J.L. Nelson, Soil Sci., **90**, 329 (1960).
2. A.L. Brown, J. Quirk and J.L. Eddings, Soil Sci. Soc. Am. Proc., **35**, 105 (1971).
3. C.A. Burleson, A.D. Dacus and C.J. Gerard, Soil Sci. Soc. Am. Proc., **25**, 365 (1961).
4. F.M. Chaudhry, M. Sharif, A. Latif and R.H. Qureshi, Plant Soil, **38**, 573 (1973).
5. F.M. Chaudhry and M. Sharif, IAEA-172, 1 (1975).
6. F.M. Chaudhry, A. Latif, A. Rashid and S.M. Alam, Pakistan J. Sci. Ind. Res., **19**, 134 (1976).
7. F.M. Chaudhry, S.M. Alam, A. Rashid and A. Latif, Plant Soil, **46**, 637 (1977).
8. M.R. Chaudhry, M. Ibrahim and M.R. Chaudhry *in* 'Proc. Rice Production Seminar', (ESSO Chemicals, Pakistan, 1976), p. 34..
9. R.H. Follett and W.L. Lindsay, Colo. Exptl. Sta. Tech. Bull., **110**, 79 (1970).
10. R.H. Follett and W.L. Lindsay, Soil Sci. Soc. Am. Proc., **35**, 600 (1971).
11. P.M. Giordano, IAEA-172, 177 (1975).
12. P.M, Giordano, Plant Soil, **48**, 673 (1977).
13. M.A. Kausar, F.M. Chaudhry, A. Rashid, A. Latif and S.M. Alam, Plant Soil, **45**, 397 (1976).
14. W.L. Lindsay and W.A. Norvell, Soil Sci. Soc. Am. J., **42**, 421 (1978).
15. W.L. Lindsay, Advan. Agron., **24**, 147 (1972).
16. W.L. Lindsay, *in* 'Micronutrients in Agriculture', eidted by J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay, Soil Sci. Soc. Am., Madison, Wisconsin, p. 41 (1972).
17. D.C. Martens, G. Clusters and L.A. Peterson, Soil Sci. Soc. Am. Proc., **30**, 67 (1966).
18. H.F. Massey, Soil Sci., **83**, 123 (1957).
19. Nuclear Institute for Agriculture and Biology (NIAB), Annual Report (1974–75).
20. S.R. Olsen, *in* 'Micronutrients in Agriculture', edited by J.J. Mortvedt, P.M. Giordano and W.L. Lindsay, Soil Sci. Soc. Am.,Madison, Wisconsin, p. 243, (1972).
21. A.N. Puri, Soil Sci., **31**,275 (1931).
22. R.H. Qureshi and M.Q. Anjum, J. Agri. Res., **15**, 63 (1977).
23. Rahmatullah, F.M. Chaudhry and A. Rashid, Plant Soil, **45**, 411 (1976).
24. N.S. Randhawa, P.N. Takkar and C.S. Venkata Ram, *in* 'Zinc in Crop Nutrition'. (International Lead Zinc Research Organization and Zinc Institute, New York, and the Indian Zinc Information Centre, New Delhi, 1974).
25. N.S. Randhawa and P.N. Takkar, Fertilizer News, May (1975).
26. A. Rashid, Rahmatullah, F. Hussain, A. Latif and M. Sharif, Pakistan J. Sci. Ind. Res., (in press) (1978).
27. A. Tanaka and S. Yoshida, IRRI Tech. Bull. No. 10 (1970).
28. E.J. Udo, H.L. Bohn and T.C. Tucker, Soil Sci. Soc. Am. Proc., **34**, 405 (1970).
29. F.G. Viets Jr., *in 'Sinc Metabolism'* edited by A.Prasad, (Thomas, Springfield, Illinois, 1966), p. 90.
30. F.G. Viets, Jr. and W.L. Lindsay, *in* 'Soil Testing and Plant Analysis' edited by L.M. Walsh and J.D. Beaton, Soil Sci. Soc. Am., Madison, Wisconsin, p. 153 (1973).
31. A. Walkley and I.A. Black, Soil Sci., **37**, 29 (1934).
32. S. Yoshida and A. Tanaka, Soil Sci. Plant Nutr., **15**, 75 (1969).