Pakistan J. Sci. Ind. Res., Vol. 29, No. 4, August 1986

MICRONUTRIENT STATUS OF THE SOILS OF THE FRONTIER REGION

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(Received September 19, 1985; revised April 8, 1986)

Surface soil samples collected from Swat, Dir and Malakand Agency of N.W.F.P were analysed for total and available (DTPA-extractable) contents of Zn, Fe, Mn and Cu. The micronutrient content was correlated with the soil parameters of pH, organic matter and calcium carbonate contents. The results showed that the available amounts of Fe, Mn and Cu were well above sufficiency levels for optimum crop production whereas the available Zn varied from deficient to sufficient. Twelve percent of the samples were deficient while another 33% were marginal in Zn. A highly significant positive correlation existed between the Zn and organic matter contents. Calcium carbonate appeared to have a dominant negative influence on Fe, but a positive influence on Mn. Except for Zn, the total content of micronutrients did not correlate significantly with their available content.

INTRODUCTION

With the introduction of high-yielding varieties of crops having high nutritional requirements coupled with the enhanced use of micronutrient-free fertilizers, the deficiency of micronutrients is likely to become a limiting factor for profitable crop production. Micronutrients play a vital role in plant growth [1] hence their deficiency has a depressing effect on yield despite the application of major elements in recommended quantities and following all cultural practices.

In Pakistan, fertilization with major elements has been a subject of concern to both scientists and farmers but very little attention has been paid to micronutrients. The deficiency of Zn and Cu has been reported in many parts of Pakistan [2]. The objective of this project was to determine the micronutrient status of major soil groups of the Frontier province. This information should serve as a guide to farmers for correcting the deficiency of micronutrients and for maintaining the fertility and productivity of their soils. In this paper the micronutrient status of the soils of Malakand, Swat and Dir is reported.

MATERIALS AND METHODS

Forty surface soil samples (0-15 cm), collected by the Directorate of Agricultural Extension from the progressive farms in the Malakand Agency and districts of Swat and Dir, were provided to NIFA. The sampling site lies between 34° 50′ and 35° 50′ latitude and 71° 50′ and 73° longitude. The height above sea level ranges from 650 to 1300 meters. The general cropping system in Swat consists of fruit orchards and wheat; in Dir, of apple orchards, wheat and rice, and in Malakand Agency of wheat, maize, sugarcane and vegetables.

The samples were air-dried, crushed with a wooden pestle and mortar (to avoid contamination), passed through a 2 mm sieve and stored in polythene jars. The samples were analysed for pH, electrical conductivity, organic matter and total carbonates. The soils were neutral in reaction, non-saline, and had organic matter content that ranged from 0.13 to 3.0 %. The $CaCO_3$ content was low and most of the soils ranged from slightly to moderately calcareous. Only one sample from Kota in Swat was strongly calcareous (15.37 % $CaCO_3$).

For the determination of available micronutrient content, the samples were extracted with diethylene triamine penta acetic acid (DTPA) solution (10 g soil + 20 ml, of extracting solution consisting of 0.005 M DTPA, 0.01 M $CaCl_2$ and 0.1 M triethanolamine (TEA) buffered at pH 7.3, shaken for 2 hr. and filtered) [3], and the extracts were analysed on a Hitachi Atomic Absorption Spectrophotometer (Model 170-10).

For the determination of the total content of the micronutrients, the samples were digested in a triacid mixture comprising HNO_3, H_2SO_4 and 70 % $HClO_4$ in the ratio of 10: 1: 4 [4]. Half a g. 40-mesh soil sample was predigested with 8 ml conc. HNO_3 in a 250-ml Pyrex beaker. Heated initially on a steam bath for 30 min and then to 200-285° until the soil turned to a caramelized mass. Now the triacid mixture was added and heating continued. The procedure was repeated until a clear solution or white suspension was attained. Deionized water was added and the resulting solution was filtered. The volume was made up 100 ml and analyzed on an Atomic Absorption Spectrophotometer.

RESULTS

Zinc. The DTPA-extractable Zn varied from 0.39 to 5.69 μg/g of soil with an overall mean value of 1.4 μg/g. The critical limit for DTPA-extractable zinc is 0.5 μg/g [5] therefore the soils ranged from very low to sufficient in Zn. Twelve percent of the samples were deficient while another 33 % of the samples were marginal in Zn (Table 1). Kausar *et al* [2] found 55 % of the soil samples from NWFP to be deficient in Zn. Liberal application of N and P fertilizer on soils having marginal concentration of Zn may induce or aggravate Zn deficiency in plants growing on such soils.

Table 1. Frequency distribution of DTPA-extractable Zn, Fe, Mn and Cu in the soils of Malakand Division.

	Zn		Fe		Mn		Cu	
Category	Critical limit (μg/g)	% of samples	Critical limit (μg/g)	% of samples	Critical limit (μg/g)	% of samples	Critical limit (μg/g)	% of samples
Deficient	<0.5	12.5	<2.5	0	<1.0	0	<0.2	0
Marginal	0.5-1.0	32.5	2.5-4.5	0	–	–	–	–
Adequate	>1.0	55.0	>4.5	100	>1.0	100	>0.2	100

Zinc content did not correlate with pH or $CaCO_3$ content but a highly significant positive correlation existed between Zn and organic matter content (Table 2). In studies by Kausar *et al* [2] also, Zn correlated significantly with soil organic matter in NWFP soils. Zinc forms stable complexes with soil organic matter components such as humic and fulvic acid which are very important in Zn adsorption [6].

The total content of Zn in the soils ranged from 40 to 207 μg/g of soil. This is within the normal range of 10-300 μg/g reported in literature [6]. The total Zn content correlated positively with the DTPA-extractable Zn at 5% level of statistical significance (Table 2).

Iron: The DTPA-extractable Fe varied from 22.5 to 39.9 μg/g of soil with the mean value of 34.0 μg/g. The critical level of Fe is 2.5 μg/g [5] therefor the Fe content of all the samples was above the sufficiency level (Table 1). A highly significant negative correlation was found between Fe and $CaCO_3$ contents (Table 2). This dominating negative influence of $CaCO_3$ appears to be due to the oxidation of ferrous (Fe^{2+}) to ferric (Fe^{3+}) oxide [7] which is insoluble under neutral and alkaline conditions. Joshi *et al* [8] also found a negative significant influence of $CaCO_3$ on DTPA-extractable Fe.

The total Fe content of the soils varied from 3,436 to 3,900 μg/g of soil. This is below the total Fe content of 10,000-100,000 μg/g normally encountered in mineral soils [6]. Also, there was no significant correlation between total and available (DTPA-extractable) Fe contents (Table 2).

Manganese. The DTPA-extractable Mn varied from 45.8 to 48.1 μg/g of soil with the mean value of 48.0 μg/g. One location in Swat (Shangwatai) contained very high amount of 78.0 μg/g. The cirtical limit of Mn is 1.0 μg/g [5] hence Mn content of all the soils was well above the sufficiency level (Table 1). A highly significant positive

Table 2. Correlation coefficients (r values) showing relationship between available (DTPA-extractable) micronutrients, soil parameters and total content of respective micronutrients.

Soil parameter	Available micronutrient			
	Zn	Cu	Fe	Mn
pH	–0.11	–0.15	0.14	–0.19
Organic matter	+0.553**	0.281	0.286	0.184
$CaCO_3$	0.06	–0.207	–0.475**	0.339*
Total contents	0.399*	0.025	0.022	0.280

*, ** = Significant at 5% and 1% levels, respectively.

correlation was found between extractable Mn and $CaCO_3$ content (Table 2).

The total Mn content of soils varied from 411 to 990 μg/g of soil. This is within the normal range of 20-3,000 μg/g found in most of the soils [6]. The total Mn content did not correlate significantly with the available Mn content (Table 2).

Copper: The DTPA-extractable Cu ranged from 2.0 to 14.8 μg/g of soil with the mean value of 7.6 μg/g. The critical limit for DTPA-extractable Cu as suggested by Viets and Lindsay [5] is 0.2 μg/g but Chaudhry and Sharif [9] reported 0.86 μg/g to be the critical limit in alkaline calcareous soils. Following even the limit of 0.86 μg/g, all of the soil samples were found to be sufficient in Cu. The Cu had no significant relationship with any of the soil parameters studied.

The total Cu content ranged between 9.9-127 μg/g of soil with four samples having Cu content in the range of 265-280 μg/g. The normal range reported for mineral soils is 10-80 μg/g [6]. Fifteen percent of the samples had total Cu higher than 80 μg/g of soil. The total Cu content did not correlate significantly with the available Cu content.

DISCUSSION

The data on available content showed that the amounts of Fe, Cu and Mn in the soil samples analysed were much above sufficiency levels whereas the amount of available Zn varied from deficient to sufficient. Forty-five percent of the samples were either deficient or marginal in Zn.

The data on total content showed that Mn and Zn were within the normal ranges encountered in mineral soils whereas Fe content was lower and Cu content of some of the samples was higher than the normal ranges. The total contents, with the exception of Zn, did not correlate significantly with their respective available contents. In case of zinc, although the total content was within the normal ranges reported for mineral soils, about half of the samples appeared to be deficient in available zinc to various degrees. The total analysis, therefore, can give little, if any, information on the availability of these elements to plants. They, at best, can give some indication on total reserves of the element and possible areas of extreme deficiency or toxicity. Factors such as leaching regime, pH, mechanical translocation and biological activity contribute to various concentrations of available micronutrients in soils.

The deficient soils are expected to respond to Zn application. For correcting Zn deficiency in these soils, only Zn fertilizer should be applied; the application of micronutrient-mix fertilizer which contains all the micronutrients may lead to accumulation of Fe, Mn and Cu to toxic levels in the soil.

REFERENCES

1. C.A. Price, H.E. Clark and E.A. Funkhouser *in "Micronutrients in Agriculture,"* ed. J.J. Mortvedt, P.M. Giordano and W.L. Lindsay, Soil Sci. Soc. Am. Inc., Wisconsin, pp 231-42 (1972).
2. M.A. Kauser, S.M. Alam, M. Sharif and M.I. Parvez, Pakistan J. Sci. Ind. Res., 22, 156 (1979).
3. W.L. Lindsay and W.A. Norwell, Soil Sci. Soc. Am. Proc., 42, 421 (1978).
4. D. Scott and H.H. Thomas, Soil Sci., 124, 329 (1977).
5. F.G. Viets, Jr. and W.L. Lindsay *in "Soil Testing and Plant Analysis",* ed. L.M. Walsh and J.D. Beaton, Soil Sci. Soc. Am., Wisconsin, pp 153-72 (1973).
6. B.D. Knezek and B.G. Ellis *in "Applied Soil Trace Elements",* ed. B.E. Davies, (John Wiley & Sons, New York, 1980). pp 259.
7. S.G. Mishra and P. Pande, J. Ind. Soc. Soil Sci., 23, 242 (1975).
8. D.C. Joshi, R.P. Dhir and B.S. Gupta, Plant and Soil, 72, 31 (1985).
9. F.M. Chaudhry and M. Sharif, *in* "Isotope-aided Micronutrient Studies in Rice Production with Special Reference to Zinc Deficiency, IAEA-72, Vienna, 1 (1975).