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Status of Cu, Zn, B and Mo in Agricultural Soils of Western Ethiopia: Laboratory Assessment

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ABSTRACT

One hundred and sixty soil samples of Nitisols of Western Ethiopia were collected following three elevational positions and two farming practices. The objectives of the study were to assess the status of copper, zinc, boron and molybdenum in the soils and to examine effects of altitude and farming practices on status of the nutrients. The status of copper and zinc were determined by diethylene triamine pentaacetic acid-triethanolamine (DTPA-TEA), ammonium bicarbonate diethylene triamine pentaacetic acid (AB-DTPA) and Mehlich-III methods using atomic absorption spectrophotometer. Boron was analyzed by hot water extraction method and molybdenum by ammonium acetate EDTA extraction method using spectrophotometer. The contents of extractable copper were in the sufficient ranges by DTPA-TEA and AB-DTPA methods. However, by Mehlich-III method the amounts of extractable copper of 18, 3.6 and 1.8% of the samples were below the critical level in low, mid and high altitudes, respectively. The contents of extractable Zn were all in the deficient ranges in low and mid altitudes by DTPA-TEA and Mehlich-III methods. However, by AB-DTPA method, the contents of 72 and 51% of the samples were below critical level in low and mid altitudes, respectively. The contents of extractable Zn were in the deficient range in high altitude by 73, 9 and 71% of the samples using DTPA-TEA, AB-DTPA and Mehlich-III, respectively. The contents of extractable boron in 30, 38 and 27% of the samples and the contents of molybdenum in 6, 2 and 6% of the samples were in the deficient range in low, mid and high altitudes, respectively. The contents of copper were higher in traditional farms than in intensive farms in low altitude, while the contents were mostly higher in intensive farms than in traditional farms in mid and high altitudes.

The amounts of extractable zinc were higher in intensive farms than traditional farms. The values of extractable boron and extractable molybdenum mostly were higher in traditional farms than in intensive farms in all altitudes. The amounts of copper and zinc by Mehlich-III and AB-DTPA methods increased with increase in altitudes. Boron and molybdenum did not show consistency in the effects of altitudes.

Key words: altitude, copper, zinc, boron, molybdenum

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INTRODUCTION

Incidents of micronutrient deficiencies are widespread in the world and are receiving attention in recent times in areas where intensive agriculture is practiced. According to Graham and Welch (1996) about 50% of the soils used for cereal production in the world contain low levels of plant available Zn, which reduces not only grain yield, but also nutritional quality.

Recent investigations together with practical field experience have indicated clearly the importance of micronutrients in crop production. But until now most of the soil fertility work in Ethiopia has been centered on N and P, the two most limiting nutrients with the increase of intensive cultivation which was associated with increased dependence on chemically pure fertilizer compounds with decreasing emphasis on the use of organic manures (Heathcote and Stockinger, 1970). In addition, depletion of micronutrients has been accelerated by high demands of the high yielding varieties.

In Ethiopia, information on micronutrient levels in soils is lacking. A number of workers have however reported cases of micronutrient deficiencies (Sillanpaa, 1982; Desta, 1983; Fekadu, 1987; Godfrey *et al*., 1987; Saleh *et al*., 1990; Fisseha, 1992), but they were either incidental or exploratory in nature, which made it difficult to obtain a real assessment of magnitude of micronutrient problems. Due to these factors, there is no or very little information available on the agricultural status of Cu, Zn, B and Mo in different altitudes and farming practices in the country. It seems important at this time to know more about the status of these micronutrients in soils of Ethiopia, particularly, in Nitisols, the most intensively cultivated soil with area coverage of 12% of the total area of the country, rank first (23%), in terms of area coverage of arable lands (FAO, 1984), which will be an aid in predicting sufficiency or deficiency.

Therefore, the objectives of the present study were to assess the status of Cu, Zn, B and Mo in Nitisols, to examine effects of altitude and farming practices on the nutrients status and to examine relationship of the status with soil properties.

MATERIALS AND METHODS

Collection and preparation of soil samples

One hundred and sixty composite soil samples at 0-15 cm depth from a total area of 247 hectares were collected from Western Ethiopia farmers' field. Two farming practices were considered (intensive and traditional farmings) following three elevational positions, i.e. 25 soil samples each from intensive and traditional farms from low altitude at 1300 meter above sea level and 25 soil samples each from intensive farms and 30 soil samples each from traditional farms, from mid and high altitudes at 1800 and 2300 meter above sea level, respectively. Samples from each field were taken using auger (made from stainless steel) from twelve different spots at 0-15 cm depth. They were mixed very well in a plastic container and a composite sample was taken in a plastic bag for laboratory analysis.

The collected soils were air-dried on plastic trays, gently crushed using pestle and mortar and passed through a 2- mm sieve.

Analytical procedure

Particle size analysis was determined using hydrometric method according to Van Reeuwijk, (1992). pH measurements were made in water and in 1*M* KCl in 1: 2.5 soil: water or solution suspension using a digital pH meter. Electrical conductivity was measured from 1: 2.5 soil: water suspension using digital electrical conductivity meter. Organic carbon was determined using Walkley-Black's method (1934). Available phosphorus was determined according to Olsen *et al*. (1982) and Bray II method of Bray and Kurtz

(1945). Extractable copper and zinc were determined using three extractants namely, diethylene triamine pentaacetic acid-triethanolamine (DTPA-TEA) (Lindsay and Norvell, 1978), ammonium bicarbonate diethylene triamine pentaacetic acid (AB-DTPA) (Halvin and Soltanpour, 1981) and Mehlich-III (Mehlich, 1984) using atomic absorption spectrophotometer. Boron was analyzed by hot water extractable method (Wear, 1965) and molybdenum by ammonium acetate EDTA acid extraction method (Cottenie *et al*., 1983) using spectrophotometer. These methods were selected from summarizing findings from research, which had been conducted by different authors to evaluate the reliability of various soil testing methods for individual micronutrients using acid or base extractions, chelating and complexing agents and simultaneous extraction. The most superior were selected for determination of Cu, Zn, B and Mo for the soil under investigation.

RESULTS AND DISCUSSION

Statistical variation in soil pH, organic carbon and phosphorus contents of one hundred and sixty soil samples used in the study is presented in Table 1. Soil pH ranged from 4.24-6.21 with standard deviation of 0.403, indicating wide range from extremely acidic to slightly acidic. Mean percent organic carbon of the soils was 3.24% (range 1.46-5.75%) with a standard deviation of 1.15. Available phosphorus ranged from 0.60-15.0 ppm. Sixty four percent of the soil samples were low in available phosphorus. There was no textural variation of the sampled areas and all the samples were classified in the clay textural class (14-22% sand, 24-32% silt and 50-61% clay).

Cu status

From the frequency distribution (Table 2), the contents of extractable Cu were in the sufficient ranges by DTPA-TEA and AB-DTPA methods. However, by Mehlich-III and referring to the critical level (0.5-0.6 mg kg^{-1}) reported by Makarim and Cox, (1983), the samples were in the deficient range by 18.0%, 3.6% and 2.0% in low, mid and high altitudes, respectively.

The amounts of extractable Cu in low altitude Nitisols were in the ranges of 1.0-3.0, 1.0-4.0 and 0.4-0.9 mg kg^{-1} in intensive farms using DTPA-TEA, AB-DTPA and Mehlich-III, respectively. In traditional farms the distribution was in the ranges 1.0-4.0, 2.0-7.0, and 0.3-2.0 mg kg^{-1}, using DTPA-TEA, AB-DTPA and Mehlich-III, respectively (Table 2). The mean values of extractable Cu were 1.6, 2.5 and 0.7 mg kg^{-1} in intensive farms and were 2.4, 3.4 and 1.0 mg kg^{-1} in traditional farms for DTPA-TEA, AB-DTPA and Mehlich-III, respectively. The results indicated that, by using the three methods the extractable Cu status was higher in traditional farms than in

Table 1 Characterization of pH, organic carbon and phosphorus of the samples.

Statistics	pH in H_2O	pH in 1*M* KCl	Organic carbon, %	Available P, ppm (Olsen method)
Mean	5.23	4.21	3.24	3.76
Median	5.21	4.20	2.90	3.40
Mode	5.03	3.92	1.60	3.00
Maximum	6.21	4.99	5.75	15.00
Minimum	4.24	3.43	1.46	0.60
Standard deviation	0.403	0.347	1.15	2.03

Table 2 Frequency distribution of soil samples with different ranges in the amounts of Cu extracted by the three methods of extraction for Nitisols in low, mid and high altitudes.

Extractable Cu mg kg-1	Sufficiency[1/]	Low altitude Nitisol						Mid altitude Nitisol						High altitude Nitisol					
		DTPA-TEA		AB-DTPA		Mehlich III		DTPA-TEA		AB-DTPA		Mehlich III		DTPA-TEA		AB-DTPA		Mehlich III	
		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples	
		I[2/]	T[3/]	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T
0.0-0.3	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.3-0.4	D	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
0.4-0.5	D	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0
0.5-0.6	D	0	0	0	0	2	3	0	0	0	0	1	0	0	0	0	0	1	0
0.6-0.7	S	0	0	0	0	10	0	0	0	0	0	0	0	1	0	1	0	0	1
0.7-0.8	S	0	0	0	0	11	2	0	0	0	0	1	0	1	0	1	0	0	7
0.8-0.9	S	0	0	0	0	1	3	0	0	0	0	3	7	4	0	4	0	1	4
0.9-1.0	S	0	0	0	0	0	3	1	0	0	0	4	9	2	0	2	0	6	2
1.0-2.0	S	19	7	1	0	0	11	15	28	0	0	15	14	12	4	12	4	17	16
2.1-3.0	S	6	14	21	14	0	0	9	2	0	0	0	0	5	25	5	25	0	0
3.1-4.0	S	0	4	3	3	0	0	0	0	2	0	0	0	0	1	0	1	0	0
4.1-5.0	S	0	0	0	4	0	0	0	0	2	7	0	0	0	0	0	0	0	0
5.1-6.0	S	0	0	0	2	0	0	0	0	21	16	0	0	0	0	0	0	0	0
6.1-7.0	S	0	0	0	2	0	0	0	0	0	7	0	0	0	0	0	0	0	0
7.1-8.0	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		25	25	25	25	25	25	25	30	25	30	25	30	25	30	25	30	25	30

[1/] D = deficient, S = sufficient; [2/] I = Intensive farms, [3/] T = Traditional farms intensive farms in low altitude Nitisols (Table 6). Thus, the statistical analyses of the results are agreeable with the frequency distribution (Table 2), except with Mehlich-III method in which the Cu status in the frequency distribution was lower in traditional farms.

In mid altitude Nitisols, the amounts of extractable Cu were in the ranges of 0.9-3.0, 3.0-6.0 and 0.4-2.0 mg kg^{-1} by DTPA-TEA, AB-DTPA and Mehlich-III, respectively in intensive farms and in the ranges of 1.0-3.0, 4.0-7.0 and 0.8-2.0 mg kg^{-1} by DTPA-TEA, AB-DTPA and Mehlich-III, respectively in traditional farms. The mean values of extractable Cu for mid altitude Nitisols were 1.9, 5.4 and 1.0 mg kg^{-1} in intensive farms and 1.2, 5.5 and 1.0 mg kg^{-1} in traditional farms by DTPA-TEA, AB-DTPA and Mehlich-III, respectively (Table 6). Accordingly, the result indicated that amounts of extractable Cu in intensive farms were higher than those in traditional farms by DTPA-TEA method. By AB-DTPA and Mehlich-III methods the amounts of extractable Cu were similar in both farming systems. The statistical analysis of the results were not agreeable with the frequency distribution of the samples, which showed lower levels of Cu in intensive farms by all the three methods.

In high altitude Nitisols the amounts of extractable Cu ranged from 0.6-3.0, 2.1-8.0 and 0.5-2.0 mg kg^{-1} for intensive farms and 1.0-4.0, 3.0-5.0 and 0.6-2.0 mg kg^{-1} in traditional farms using DTPA-TEA, AB-DTPA and Mehlich-III, respectively. The mean values of extractable Cu for high altitude Nitisols were 1.3, 5.8 and 1.1 mg kg^{-1} in intensive farms and 2.4, 3.9 and 1.0 mg kg^{-1} in traditional farms by DTPA-TEA, AB-DTPA and Mehlich-III, respectively (Table 6). The results indicated that, by AB-DTPA and Mehlich-III methods, the status of Cu was higher in intensive farms than in traditional farms. On the other hand, DTPA-TEA method indicated that, content of extractable Cu in traditional farms was higher than intensive farms. In high altitude Nitisols the frequency distribution agreed with DTPA-TEA and Mehlich-III methods.

The means for amounts of extractable Cu, irrespective of farming practices were 2.0, 1.6 and 2.0 mg kg^{-1} by DTPA-TEA method, 3.0, 5.4 and 4.9 mg kg^{-1} using AB-DTPA method and 0.8, 1.0 and 1.1 mg kg^{-1} using Mehlich-III in low, mid and high altitudes, respectively. Accordingly, the contents of extractable Cu were not significantly affected by altitude.

Zn status

From the frequency distribution table (Table 3) and referring the critical level (0.8-0.9 mg kg^{-1}) reported by Halvin and Soltanpour, (1981), the contents of extractable Zn of all of the samples were in the deficient ranges by DTPA-TEA and Mehlich-III methods, in low and mid altitudes, while those of 28% and 44% of the samples (from low and mid altitudes, respectively) were in the sufficient ranges by AB-DTPA method. In high altitude, the contents of extractable Zn were in the deficient ranges by 73%, 9% and 71% by DTPA-TEA, AB-DTPA and Mehlich-III methods, respectively.

The frequency distribution of Zn (Table 3) showed that in low altitude Nitisols the amounts of extractable Zn ranged from 0.0-0.5 and 0.1-0.5 mg kg^{-1} by DTPA-TEA method and 0.3-2.0 and 0.4-1.5 mg kg^{-1} by AB-DTPA method, while those by Mehlich-III were in the ranges 0.2-0.8 and 0.1-0.5 mg kg^{-1} in intensive farms and traditional farms, respectively**.** The mean values of extractable Zn in low altitude were 0.19, 0.85 and 0.41 mg kg^{-1} in intensive farms and 0.28, 0.73 and 0.35 mg kg^{-1} in traditional farms using DTPA-TEA, AB-DTPA and Mehlich-III methods, respectively (Table 6). The results indicated that the Zn status by AB-DTPA and Mehlich-III was higher in intensive farms than in traditional farms. Thus, the statistical analysis of the results agreed with frequency distribution of the samples.

In mid altitude Nitisols the amounts of

Table 3 Frequency distribution of soil samples with different ranges in the amounts of Zn extracted by the three methods of extraction for Nitisols in low, mid and high altitudes.

Extractable Zn mg kg-1	Sufficiency[1/]	Low altitude Nitisol						Mid altitude Nitisol						High altitude Nitisol					
		DTPA-TEA		AB-DTPA		Mehlich III		DTPA-TEA		AB-DTPA		Mehlich III		DTPA-TEA		AB-DTPA		Mehlich III	
		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples		No.of samples	
		I[2/]	T[3/]	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T
0.0-0.1	D	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
0.1-0.2	D	15	3	0	0	0	2	13	16	0	0	18	19	0	0	0	0	0	1
0.2-0.3	D	8	12	0	1	2	3	8	8	0	1	3	9	0	1	0	0	0	0
0.3-0.4	D	0	9	3	0	14	14	2	4	0	3	3	2	1	3	0	0	0	1
0.4-0.5	D	1	1	0	1	6	6	1	1	0	9	0	0	1	4	0	0	0	3
0.5-0.6	D	0	0	1	2	2	0	0	0	0	7	0	0	2	5	0	1	4	5
0.6-0.7	D	0	0	5	10	0	0	0	0	1	2	0	0	0	7	0	1	1	5
0.7-0.8	D	0	0	1	3	1	0	0	0	1	0	0	0	6	4	0	1	5	4
0.8-0.9	D	0	0	4	5	0	0	0	0	2	2	0	0	5	1	1	1	6	4
0.9-1.0	S	0	0	4	2	0	0	0	0	1	1	0	0	4	1	1	2	4	1
1.0-1.5	S	0	0	6	1	0	0	1	0	11	4	0	0	5	4	17	18	5	4
1.5-2.0	S	0	0	1	0	0	0	0	0	8	1	0	0	1	0	4	5	0	2
2.0-2.5	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
2.5-3.0	S	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Total		25	25	25	25	25	25	25	30	25	30	25	30	25	30	25	30	25	30

[1/]D = deficient, S = sufficient; [2/] I = Intensive farms, [3/] T = Traditional farms extractable Zn were in the ranges of 0.1-0.5 and 0.0-0.5 mg kg^{-1} in intensive and traditional farms using DTPA-TEA method. By AB-DTPA the ranges were 0.6-3.0 and 0.2-2.0 mg kg^{-1}, while by Mehlich-III the ranges were 0.0-0.4 and 0.1-0.4 mg kg^{-1} for intensive and traditional farms, respectively. The mean values of extractable Zn in mid altitude Nitisols were 0.25, 1.37 and 0.19 in intensive farms and 0.23, 0.66 and 0.20 mg kg^{-1} in traditional farms using DTPA-TEA, AB-DTPA and Mehlich-III methods, respectively (Table 6). The results indicated that the contents of extractable Zn was higher in intensive farms than in traditional farms using DTPA-TEA and AB-DTPA methods, while by Mehlich-III method there is a tendency of higher amounts of extractable Zn in traditional farms. Thus, the statistical analyses of the results were agreeable with the frequency distribution of the samples (Table 3).

In high altitude Nitisols the amounts of extractable Zn were in the ranges 0.3-2.0, 0.8-3.0, 0.5-1.5 mg kg^{-1} in intensive farms and 0.2-1.5, 0.5-2.5, 0.1-2.0 mg kg^{-1} in traditional farms using DTPA-TEA, AB-DTPA and Mehlich-III methods, respectively (Table 3). The mean values of extractable Zn in high altitude Nitisols were 0.9, 1.5 and 0.9 mg kg^{-1} in intensive farms and 0.7, 1.3 and 0.8 mg kg^{-1} in traditional farms by DTPA-TEA, AB-DTPA and Mehlich-III, respectively (Table 6). The results showed that Zn status was higher in intensive farms than in traditional farms on high altitude Nitisols. The results agreed with the frequency distribution of extractable Zn in high altitude.

The means for amounts of extractable Zn, irrespective of farming practices were 0.24, 0.24 and 0.78 by DTPA-TEA, 0.79, 1.10 and 1.37 mg kg^{-1} by AB-DTPA and using Mehlich-III, were 0.38, 0.2 and 0.83 mg kg^{-1} in low, mid and high altitudes, respectively. Only AB-DTPA method showed increase in the contents of extractable Zn with increase in altitude.

The contents of Cu by Mehlich III method and those of Zn by AB-DTPA methods increased with the increase in altitude, which were supported by the findings of Cottenie *et al.* (1981) who had shown that the position of a profile in the toposequence has a strong influence on the micronutrients status and that upper slope profiles had higher Cu and Zn status than did lower members of the toposequence.

By comparing the mean values of analytical results of Cu and Zn (Cu-DTPA-TEA with Zn-DTPA-TEA, Cu- AB-DTPA with Zn-AB-DTPA and Cu-Mehlich-III with Zn-Mehlich-III) it was clear that the amounts of extractable Cu was higher than those of Zn in all the three altitudes using the three methods. These results were supported by the finding of Xiaofu and Selmer-Olsen (1992) and Haque *et al*. (2000), in which the amounts of DTPA-extractable Cu were higher than those of Zn.

Boron status

From the frequency distribution (Table 4), and referring to the critical level (0.50-1.0 mg kg^{-1}) according to Ponnamperuma *et al.* (1981) the amounts of extractable B were below the sufficiency range by 30, 38 and 27% in low, mid and high altitudes, respectively.

The amounts of extractable B ranged 0-2.5, 0-2.5 and 0.50-3.0 mg kg^{-1} in intensive farms and 1.5-2.5, 0.0-2.0 and 0.50-3.0 mg kg^{-1} in traditional farms in low, mid and high altitudes, respectively (Table 4). The mean values of extractable B were 1.0 and 2.0 in low altitude, 0.7 and 1.32 mg kg^{-1} in mid altitude and 1.5 and 1.3 mg kg^{-1} in high altitude in intensive farms and traditional farms, respectively. The values of B were higher in traditional farms than in intensive farms in low and mid altitudes; on the other hand, the values were higher in intensive farms of high altitude. The analytical results were agreeable with the frequency distribution of B in low, mid and high altitudes. The means for amounts of extractable B irrespective of farming practices were 1.5, 1.0, and 1.4 mg kg^{-1} B in low, mid and high altitudes, respectively. The results indicated that there was no consistency in the effects of altitude.

Molybdenum status

From the frequency distribution (Table 5), and referring to the critical level (0.1-0.5 mg kg^{-1}) according to Grigg (1953) of all of the samples the amounts of extractable Mo were in the deficiency range by 6, 2, and 6% in low, mid and high altitudes, respectively. The frequency distribution of Mo (Table 5) showed that extractable Mo ranged

Table 4 Frequency distribution of soil samples with the amounts of B extracted by hot water extraction method in different ranges for Nitisols in low, mid and high altitudes.

Extractable B mg kg^{-1}	Sufficiency[1/]	Nitisol					
		Low altitude		Mid-altitude		High altitude	
		Intensive[2/]	Traditional[3/]	Intensive	Traditional	Intensive	Traditional
0.0-0.5	D	6	0	9	3	0	0
0.5-1.0	D	9	0	9	0	2	13
1.0-1.5	S	3	0	6	18	13	6
1.5-2.0	S	3	11	0	8	9	7
2.0-2.5	S	4	14	1	0	1	2
2.5-3.0	S	0	0	0	1	0	2
Total		25	25	25	30	25	30

[1/] D = deficient S = sufficient [2/] Intensive = Intensive farms; [3/]Traditional = Traditional farms

Table 5 Frequency distribution of soil samples with the amounts of Mo extracted by ammonium acetate EDTA method in different ranges for Nitisols in low, mid and high altitudes.

Extractable Mo mg kg^{-1}	Sufficiency[1/]	Nitisol					
		Low altitude		Mid-altitude		High altitude	
		Intensive[2/]	Traditional[3/]	Intensive	Traditional	Intensive	Traditional
0.00-0.50	D	0	3	1	0	1	2
0.51-1.00	S	11	0	0	1	7	4
1.01-1.50	S	7	10	6	4	11	16
1.51-2.00	S	5	6	9	7	5	7
2.01-2.50	S	2	3	5	10	0	1
2.51-3.00	S	0	3	2	5	0	0
3.01-3.50	S	0	0	1	1	1	0
3.51-4.00	S	0	0	0	1	0	0
4.01-4.50	S	0	0	1	1	0	0
Total		25	25	25	30	25	30

[1/] D = deficient S = sufficient [2/] Intensive = Intensive farms; [3/]Traditional = Traditional farms

0.5-2.5 and 0.0-3.0 mg kg $^{-1}$ in low altitude, 0-4.5 and 0.5-4.5 mg kg $^{-1}$ in mid altitude, 0-3.5 and 0-2.5 mg kg $^{-1}$ in high altitude in intensive and traditional farms, respectively. The mean values of extractable Mo (Table 6) were 1.2, 1.9 and 1.3 mg kg $^{-1}$ in intensive farms and 1.5, 2.2 and 1.3 mg kg $^{-1}$ in traditional farms in low, mid and high altitudes, respectively. The results showed that

Table 6 Maximum, minimum and mean values of Cu and Zn as obtained from three different methods of extraction, B by hot water extraction method and Mo by ammonium acetate EDTA method in low, mid and high altitudes Nitisols (mg kg $^{-1}$).

Elements and methods of extraction	Intensive farming			Traditional farming		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
			Low altitude			
Cu-DTPA-TEA	2.56	1.16	1.60	3.72	1.64	2.41
Cu-AB-DTPA	3.34	1.98	2.51	6.46	2.16	3.41
Cu-Mehlich-III	0.88	0.48	0.67	1.92	0.32	1.01
Zn-DTPA-TEA	0.46	0.08	0.19	0.44	0.14	0.28
Zn-AB-DTPA	1.62	0.32	0.85	1.26	0.28	0.73
Zn-Mehlich-III	0.76	0.28	0.41	0.48	0.16	0.35
B-Hot water	2.26	0.00	1.02	2.40	1.52	2.02
Mo-Ammonium Acetate EDTA	2.30	0.60	1.22	3.00	0.00	1.53
			Mid altitude			
Cu-DTPA-TEA	2.96	0.94	1.87	2.10	1.02	1.23
Cu-AB-DTPA	5.98	3.14	5.36	6.98	4.38	5.51
Cu-Mehlich-III	1.56	0.48	1.03	1.40	0.88	1.02
Zn-DTPA-TEA	1.14	0.12	0.25	0.50	0.10	0.23
Zn-AB-DTPA	2.62	0.64	1.37	1.66	0.30	0.66
Zn-Mehlich-III	0.40	0.08	0.19	0.36	0.12	0.20
B-Hot water	2.34	0.06	0.70	2.98	0.08	1.32
Mo-Ammonium Acetate EDTA	4.40	0.14	1.92	4.05	0.85	2.16
			High altitude			
Cu-DTPA-TEA	2.48	0.70	1.29	3.02	1.90	2.35
Cu-AB-DTPA	7.38	2.80	5.84	4.90	3.12	3.86
Cu-Mehlich-III	1.36	0.60	1.08	1.36	0.68	1.01
Zn-DTPA-TEA	1.58	0.34	0.88	1.18	0.28	0.67
Zn-AB-DTPA	2.72	0.88	1.45	2.06	0.52	1.28
Zn-Mehlich-III	1.44	0.52	0.87	1.56	0.20	0.80
B-Hot water	2.42	1.00	1.49	2.80	0.58	1.33
Mo-Ammonium Acetate EDTA	3.10	0.50	1.27	2.50	0.30	1.29

extractable Mo status were mostly higher in traditional farms than in intensive farms. The analytical results were agreeable with the frequency distribution of Mo in mid altitude Nitisols in which the contents of Mo were low in intensive farms than in traditional ones. The means for amounts of extractable Mo, irrespective of farming practices, were 1.4, 2.0 and 1.3 in low, mid and high altitudes. The result indicated that there was no consistency in the effects of altitude.

Correlation between methods and their efficiency in extracting power

Correlation among the amounts of Cu, Zn, B and Mo extracted by using different methods (Table 7) showed that 42.9% of the methods were significant and positively correlated and 10.7% were significant and negatively correlated at 0.01 levels. 7.1% of the methods were significant and positively correlated, while 3.6% were significant and negatively correlated at 0.05 levels. The rest 35.7% were not significant. Comparing the extracting power of the methods for determination of Cu and Zn, the results showed that AB-DTPA was superior to the others followed by DTPA-TEA and Mehlich-III.

Relationship of copper, zinc, boron and molybdenum with soil properties

An attempt was made to examine the relationship between copper, zinc, boron and molybdenum and some soil properties (pH, organic carbon and extractable phosphorus) by simple correlation analysis (Table 8), to identify the soil factors involved in regulation of amounts of extractable Cu, Zn, B and Mo in soils. The amounts of Cu-DTPA-TEA, Zn-DTPA-TEA, Zn-Mehlich-III and B-hot water were highly significantly (P>0.01) correlated with pH and the relation was positive. The amounts of Cu-AB-DTPA and Mo-Ammonium acetate EDTA were highly significantly (P>0.01) correlated with pH and the relation was negative. Organic carbon was highly significantly correlated with Cu-DTPA-TEA and Zn-DTPA-TEA, Zn-Mehlich-III and B-hot water and the relation was negative. The value of Mo-Ammonium acetate EDTA was highly significantly (P>0.01) correlated with organic carbon and the relation was positive. The amounts of Zn with all the three methods and Cu-DTPA-TEA were highly significantly (P>0.01) correlated with Olsen-P and the relationship was positive. The values of Cu-AB-DTPA and Mo-Ammonium acetate EDTA

Table 7 Correlation matrix of the amounts of nutrients extracted by different methods.

Elements and methods of extraction	Elements and methods of extraction						
	Cu-DTPA-TEA	Cu-AB-DTPA	Cu-Mehlich-III	Zn-DTPA-TEA	Zn-AB-DTPA	Zn-Mehlich-III	B-Hot water
Cu-AB-DTPA	0.079^{ns}						
Cu-Mehlich-III	0.260**	0.559**					
Zn-DTPA-TEA	0.111^{ns}	0.326**	0.307**				
Zn-AB-DTPA	0.196*	0.304**	0.229**	0.600**			
Zn-Mehlich-III	0.207**	0.113^{ns}	0.130^{ns}	0.873**	0.465**		
B-Hot water	0.155 ^{ns}	-0.121 ^{ns}	0.200*	0.120 ^{ns}	-0.346**	0.083 ^{ns}	
Mo-Ammonium Acetate EDTA	-0.101 ^{ns}	0.288**	0.209**	-0.219**	-0.047 ^{ns}	-0.271**	-0.178*

** significant at the 0.01 levels, * significant at the 0.05 levels, ^{ns} Non significant at the 0.05 levels.

were highly significantly (P>0.01) correlated with Bray II-P and the relation was positive.

CONCLUSIONS AND RECOMMENDATION

This study has shown that the contents of extractable Cu were in the sufficient ranges by DTPA-TEA and AB-DTPA methods. But by Mehlich-III method 18.0, 3.6 and 1.8% of the samples were below the critical level in low, mid and high altitudes, respectively. The contents of extractable Zn were all in the deficient range in low and mid altitudes by DTPA-TEA and Mehlich-III methods. However, by AB-DTPA method, 72% and 51% of the samples were below the critical level in low and mid altitudes, respectively. In high altitude the contents of extractable Zn were in the deficient range by 73, 9, and 71% using DTPA-TEA, AB-DTPA and Mehlich-III methods, respectively. The amount of extractable B in 30, 38 and 27% of the samples and amounts of extractable Mo in 6, 2 and 6% of the samples were in the deficient range, in low, mid and high altitudes respectively. Since many factors may affect response of plants to nutrient addition, calibration with planting on some of the soils is needed to support this conclusion.

The contents of extractable Cu were not significantly affected by farming systems and altitudes. The contents of extractable Zn were mostly higher in intensive farms in all altitudes. The contents of extractable B and extractable Mo showed a tendency to be higher in traditional farms than in intensive farms in the altitudes. The contents of extractable Zn, B and Mo were not affected by altitudes.

The relationship between the amounts of extractable Cu, Zn, B and Mo with soil properties indicated that Cu-DTPA-TEA, Zn-DTPA-TEA, Zn-Mehlich-III and B-hot water were highly positively correlated and Cu-AB-DTPA and Mo-ammonium acetate EDTA were highly negatively correlated with pH. The values of Cu-DTPA-TEA, Zn-DTPA-TEA, Zn-Mehlich-III and B-hot water were highly negatively correlated and those of Mo-ammonium acetate EDTA were highly positively correlated with organic carbon. Olsen-P was positively correlated with Zn with all the three methods and with Cu-DTPA-TEA. Bray II-P was highly positively correlated with Cu-AB-DTPA and Mo-ammonium acetate EDTA.

Table 8 Correlation of some soil properties with micronutrients tests.

Micronutrients	pH in H_2O	pH in 1*M* KCl	Organic C	Olsen P	BrayII P
Cu-DTPA-TEA	0.298**	0.328**	-0.245**	0.384**	-0.108 ^{ns}
Cu-AB-DTPA	-0.447**	-0.458**	0.136 ^{ns}	-0.063 ^{ns}	0.389**
Cu-Mehlich III	-0.126 ^{ns}	-0.104 ^{ns}	-0.022 ^{ns}	0.068 ^{ns}	0.183*
Zn-DTPA-TEA	0.210**	0.234**	-0.499**	0.237**	0.024 ^{ns}
Zn-AB-DTPA	-0.071 ^{ns}	0.005 ^{ns}	-0.095 ^{ns}	0.324**	0.197*
Zn-Mehlich-III	0.419**	0.450**	-0.508**	0.281**	-0.114 ^{ns}
B-Hot water	0.283**	0.225**	-0.347**	-0.019 ^{ns}	-0.221**
Mo-Ammonium Acetate EDTA	-0.366**	-0.367**	0.442**	-0.094 ^{ns}	0.278**

** Correlation is significant at the 0.01 levels, * Correlation is significant at the 0.05 levels, ^{ns} Non significant at the 0.05 levels.

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