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Status of B, Cu, Fe, Mo and Zn of Soils of Ethiopia for Maize Production: Greenhouse Assessment

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ABSTRACT

A greenhouse experiment using omission technique was conducted to evaluate the status of Fe, Cu, Zn, B and Mo in some Nitisols of Western Ethiopia and Rift Valley Andisols for maize production in order to confirm the results of the laboratory study. For each nutrient under study, a randomized complete block design with five treatments and four replications was employed. The treatments were: (1) control, no nutrient application; (2) application with low rates of all nutrients; (3) application with medium rates of all nutrients; (4) application with high rates of all nutrients; and (5) application with medium rates of all nutrients except the micronutrients under study. Considering the results of the present experiment and those in the previous laboratory assessment the following conclusions were drawn. Fe status of all of the Andisol was in the sufficient range whereas about 1.9% of the Nitisols was in the deficient range for maize production. The results of the present study did not support the critical level of 4.8 mg Fe kg^{-1} by AB-DTPA method reported by other authors. The results on of this experiment showed that the critical levels were lower than 4.56 mg Fe kg^{-1} in the case of Andisols and higher than 5.20 mg Fe kg^{-1} in the case of Nitisols. Cu status of all of the Andisols was in the deficient range whereas that of 5.6% of the Nitisols was in the deficient range for maize production. Zn status of all of the Nitisols was in the deficient range whereas that of all of the Andisols was in the sufficient range. B status of 31.9% of the Nitisols was in the deficient range whereas that of all of the Andisols was in the sufficient range. Mo status of all of the Andisols was in the sufficient range whereas that of 4.4% of the Nitisol was in the deficient range. The present results supported the critical levels for Cu, Zn, B and Mo found in the literature.

Key words: iron, molybdenum, copper, zinc, boron, greenhouse assessment, maize

INTRODUCTION

In Ethiopia maize is one of the most important crops among all cereals consumed by the people. According to Belay (1997) maize was the second major cereal crop in area coverage as well as in production in Ethiopia. Of the total potentially arable land, one million hectares are under maize cultivation and are mostly occupied by Nitisols and Andisols. Mesfin (1998) stated that Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia. The Rift Valley Andisols are also intensively used for cultivation of maize which is

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the main staple food crop grown by the farmers (Mesfin, 1998).

Desta (1983) stated that for a long time it was thought that under the existing farming system and fertilizing practices, the level of micronutrients in Ethiopian cultivated soils was adequate and that the problem of micronutrient deficiencies was not a serious one. Consequently, the study on the status of micronutrients in the country has received very little attention.

In general the role of micronutrients in crop production has not yet been studied systematically, except the study on micro and macro nutrient distribution in Ethiopian Vertisol landscape (Fisseha, 1992). The past investigations (Sillanpaa, 1982; Desta, 1983; Godfrey *et al*., 1987; Fekadu, 1987; Saleh *et al*., 1990) were either incidental or exploratory in nature, which made it difficult to obtain a real assessment of magnitude of micronutrient problems. The above-mentioned investigations were also not based on fertilizer recommendation approach. Moreover no attempts have been made to study the status of micronutrients on specific soil type and crop, which prevents extrapolation of the results to wider areas. Even though there is an excessive delay, it is important to investigate the limitation and advantage of micronutrients fertilizers on Nitisols of Western Ethiopia and Rift Valley Andisols.

According to Teklu *et al*. (2003 a, b) status of micronutrients in Nitisols of Western Ethiopia and Andisols of Rift Valley were evaluated by using three soil-testing methods and it was concluded as the following.

In Nitisols of Western Ethiopia Fe status was in the sufficient range as compared with critical levels found from the literature. Extractable Cu in all the samples was in the sufficient range by DTPA-TEA and AB-DTPA methods, but 5.6% of the samples were deficient by Mehlich-III method. Extractable Zn was mostly in the deficient range. The amounts of extractable B in 31.9%, and extractable Mo in 4.4% of the samples were in the deficient range.

In Andisols extractable Fe in 20 and 10% of the samples were in the deficient range by DTPA-TEA and AB-DTPA, respectively. The amount of extractable Cu in all of the samples using DTPA-TEA and in 45 and 55% of the sample using AB-DTPA and Mehlich-III methods, respectively, were in the deficient range. Mo extracted by ammonium acetate EDTA acid extraction was in deficient range by 20% of the samples while B was in sufficient range compared to critical level in the literature.

As the critical level which separate deficient from the non deficient soils may vary with kind of crop and soil conditions (Basal and Nayyar, 1990), the present investigation was undertaken to evaluate the sufficiency of the micronutrients in some selected Nitisols of Western Ethiopia and Rift Valley Andisols for maize production in order to confirm the result of the laboratory study.

MATERIALS AND METHODS

Soil selection and preparaion

From results of assessments of micronutrients status of Nitisols of Western Ethiopia and Andisols of Rift valley (Teklu *et al.*, 2003 a, b), tables were constructed for micronutrients (Mn, Fe, Cu, Zn, B and Mo) to show frequency distribution of soil samples in different ranges of extractable micronutrients. The samples having extractable levels of micronutrients lower or a little higher than critical levels of each nutrient found in the literature were selected for greenhouse experiment as shown in Table 1. Bulk samples of the selected soils were collected from the 0-15 cm surface layer. The soil samples were air-dried on plastic sheets and the clods were gently crushed, to pass through 2-mm sieve.

Design of the experiment and treatments

The experiment was carried out in the greenhouse at the National Soil Research Center, Addis Abeba, Ethiopia, from December 7, 2002 to March 4, 2003. For each soil a randomized complete block design with five treatments and four replications was employed. Following the techniques used by Asher *et al*. (1970) and Suwanarit *et al*. (1978) the treatments and their description were given in Table 2. According to the designed experiment all of the nutrients (Table 2) except nitrogen were mixed with 5-kg soil before potting. One half of the nitrogen fertilizer was mixed with the soil before potting and the balance was applied on the soil surface at one month after planting. The soils were moistened to moisture level slightly lower than field capacity, kept overnight and then gently mixed to create soil crumb before potting to a plastic pots with saucers which were free of micronutrients.

Maize planting and watering

Five seeds of maize (*Zea mays* L.) (BH-540) were sown in each pot and at four-leave stage two plants were left to grow. De-ionized water was liberally given to the plant via saucers. Spraying of water on the soil surface was applied only when necessary to keep the soil surface moist.

Table 1 Soil samples used for greenhouse experiment, nutrients under test, nutrient content of the soils and critical level of the nutrients.

Soil no.	Soil order	Nutrient under test	Method of extraction	Extracted nutrient mg kg^{-1}	Critical level	
					Analytical value mg kg^{-1} and method of assessment	Test organism and Reference
6	Andisols	Fe	AB-DTPA	4.56	4.80, AB-DTPA	Sorghum, Halvin & Soltanpour (1981)
108	Nitisols	Fe	Mehlich III	5.20	4.80, AB-DTPA	Sorghum, Halvin & Soltanpour (1981)
32	Andisols	Cu	AB-DTPA	0.50	0.50-0.60, AB-DTPA	Maize, Makarim & Cox (1983)
68	Nitisols	Cu	Mehlich III	0.32	0.37, Mehlich III	Maize, Makarim & Cox (1983)
102	Nitisols	Cu	Mehlich III	0.48	0.37, Mehlich III	Maize, Makarim & Cox (1983)
49	Nitisols	Zn	DTPA-TEA	0.34	0.80-0.90, DTPA-TEA	Sorghum, Lindsay & Norvell (1978)
100	Nitisols	Zn	DTPA-TEA	0.32	0.80-0.90, DTPA-TEA	Sorghum, Lindsay & Norvell (1978)
95	Nitisols	B	Hot water	0.46	0.50-1.00, Hot water	Rice, Ponnaperuma *et al*. (1981)
150	Nitisols	B	Hot water	0.38	0.50-1.00, Hot water	Rice, Ponnaperuma *et al*. (1981)
10	Andisols	Mo	NH_4Ac EDTA	0.10	0.10-0.30, ammonium oxalate	*Aspergillus niger*, Griggs (1953)
36	Andisols	Mo	NH_4Ac EDTA	1.30	0.10-0.30, ammonium oxalate	*Aspergillus niger*, Griggs (1953)
64	Nitisols	Mo	NH_4Ac EDTA	0.50	0.10-0.30, ammonium oxalate	*Aspergillus niger*, Griggs (1953)

Table 2 Description of treatments employed in the greenhouse experiment.

Treatment symbol	Description
C	No nutrient addition
L_{nu}	Application with all nutrient at low rates, namely, 300 kg N1/, 300 kg P2/, 100 kg K3/, 200 kg Ca4/, 35 kg Mg5/, 25 kg S6/, 15 kg Cl7/, 3 kg Fe8/, 3 kg Cu9/, 3 kg Zn10/, 5 kg Mn11/, 500 g B12/ and 150 g Mo13/ per ha
M_{nu}	As L_{nu} but the rates of Fe, Cu, Zn, B and Mo were twice of those of L_{nu}
H_{nu}	As L_{nu} but with 10 kg Fe, 10 kg Cu, 10 kg Zn, 15 kg Mn, 1.5 kg B and 450 g Mo per ha
-x	As M_{nu} but without application of micronutrient under test where x was the nutrient under study

1/: as urea. 2/: as triple super phosphate. 3/: as potassium chloride. 4/: as calcium chloride. 5/: as magnesium oxide. 6/: as copper, zinc and manganese sulfates fertilizers. 7/: as calcium chloride and potassium chloride. 8/: as FeEDTA. 9/: as copper sulfate. 10/: as zinc sulfate. 11/: as manganese sulfate. 12/: as boric acid. 13/: as ammonium molybdate

Collection of data, harvesting and plant sample preparation

Plant height was measured from the soil surface to the top of the uppermost leaf sheath at 30 and 45 days after planting and at 50% silking. Harvesting was done at 50% silking stage by cutting the plant just above the soil surface. The harvested maize shoots were washed several times in running water, followed by deionized water, dried first in the air and then oven-dried at 65 °C to constant weight for dry weight measurement. The shoots were then finely ground using stainless steel grinder for analysis of micronutrients.

Plant analysis

The analysis of micronutrients in plant samples was done using the dry ashing method (Sahlemedhin and Taye, 2000). The micronutrients Fe, Cu and Zn in the sample digests were determined using atomic absorption spectrophotometer. Boron was determined according to Walinga *et al.* (1995) and molybdenum by method of Cottenie *et al.* (1983) using spectrophotometer at appropriate wavelengths.

RESULTS

Height of maize plant at 30 days after planting

Height of maize at 30 days after planting obtained from different treatments and changes in height due to omission of nutrient were presented in Table 3.

In soil no. 6, omission of Fe fertilizer showed a non-significant trend of increase (11.6%) in height of maize. In soil no. 108, omission of Fe had a significant depressive effect on height of maize plant by 29.4%. Omission of Cu resulted in significant decrease in height by 20.8% in soil no. 32. In soil nos. 68 and 102, omission of Cu fertilizer showed a non-significant trend of decrease in height of maize plant. In soil no. 49, omission of Zn had a significant depressive effect on height of maize plant by 32.1%. In soil no. 100 the omission of Zn showed a non-significant trend of decrease in height of maize. In soil no. 150 omission of B had a significant depressive effect on height of maize plant by 17.9%. But in soil no. 95 the application of B showed a non-significant trend of increase (8.7%) in plant height. Omission of Mo resulted in significant decrease of height of maize plant by 19.0 and 9.8% in soil nos. 36 and 64, respectively. But in soil no. 10 the omission of Mo

Table 3 Height of maize (cm) at 30 days obtained from different treatments and increase in height due to omission of nutrient elements.

Soil no.	Soil classification	Missing nutrients	Treatments[2/] C	L_{nu}	M_{nu}	H_{nu}	-x	Change due to omission of the nutrient, (%) [1/]	C.V. %
6	Andisol	Fe	20.2^{b}	30.5^{a}	30.2^{a}	29.7^{a}	33.7^{a}	+11.6ns	11.5
108	Nitisol	Fe	13.4^{c}	31.8^{ab}	37.1^{a}	31.5^{ab}	26.2^{b}	-29.4*	12.9
32	Andisol	Cu	17.9^{c}	28.5^{ab}	31.3^{a}	31.5^{a}	24.8^{b}	-20.8*	10.0
68	Nitisol	Cu	13.3^{c}	32.2^{ab}	34.6^{ab}	36.5^{a}	30.1^{b}	-13.0ns	10.0
102	Nitisol	Cu	6.8^{b}	31.9^{a}	35.3^{a}	30.8^{a}	31.8^{a}	-9.9ns	10.5
49	Nitisol	Zn	7.4^{d}	36.9^{b}	39.0^{b}	43.8^{a}	26.5^{c}	-32.1*	8.6
100	Nitisol	Zn	7.0^{d}	36.9^{b}	34.4^{bc}	39.9^{a}	32.7^{c}	-4.9ns	5.8
95	Nitisol	B	9.5^{b}	38.0^{a}	39.3^{a}	40.2^{a}	35.9^{a}	-8.7ns	11.5
150	Nitisol	B	8.0^{c}	25.0^{b}	35.2^{a}	24.8^{b}	28.9^{b}	-17.9*	14.7
10	Andisol	Mo	22.1^{b}	33.7^{a}	31.5^{a}	29.4^{a}	29.1^{a}	-7.6ns	10.2
36	Andisol	Mo	22.2^{c}	39.7^{a}	38.4^{a}	37.6^{a}	31.1^{b}	-19.0*	4.8
64	Nitisol	Mo	5.5^{c}	31.7^{ab}	34.6^{a}	31.2^{b}	31.2^{b}	-9.8*	7.2

[1/] : 100 [(height of –x) – (height of M_{nu})] / (height of M_{nu}) ; ns, non-significant at the 5% level; *, significant at the 5% level
[2/] : Means followed by a common letter are not significantly different at the 5% level by DMRT.

showed a non-significant trend of decrease (7.6%) in plant height.

Height of maize plant at 45 days after planting

Height of maize at 45 days after planting obtained from different treatments and changes in height due to omission of nutrient were presented in Table 4.

In soil no. 6 omission of Fe had a significant response on height of maize by 13.2%. But in soil no. 108 the effect of omission of Fe had a significant depressive effect on height of maize plant by 12.3%. Omission of Cu resulted in significant decreases in the height of maize plant by 15.9 and 10.4% in soil nos. 32 and 68, respectively. In soil no. 102 the result showed a non-significant trend of decrease (2.0%) in height of maize. In soil no. 49, omission of Zn had a significant depressive effect on height of maize plant by 19.7%. Soil no. 100 showed a non-significant trend of increase (3.8%) than the Zn omission treatment. Omission of B fertilizer showed non-significant trends of decrease (2.5 and 7.4%, respectively) in height of maize plant in soil nos. 95 and 150 at 45 days after planting. Omission of Mo resulted in significant decrease of height of maize plant by 6.0% in soil no. 64. Omission of Mo fertilizer showed non-significant trends of decreases (6.6 and 5%, respectively) in height of maize plant in soil nos. 10 and 36.

Height of maize plant at 50% silking

Height of maize at 50% silking obtained from different treatments and changes in height due to omission of nutrient were presented in Table 5.

Table 4 Height of maize (cm) at 45 days obtained from different treatments and increase in height due to omission of nutrient elements[1/].

Soil no.	Soil classification	Missing nutrients	Treatments					Change due to omission of the nutrient, (%)	C.V. %
			C	L_{nu}	M_{nu}	H_{nu}	-x		
6	Andisol	Fe	44.5^{c}	70.1^{a}	63.0^{b}	62.4^{b}	71.3^{a}	+13.2*	6.2
108	Nitisol	Fe	28.4^{c}	67.5^{a}	68.5^{a}	60.1^{b}	60.1^{b}	-12.3*	3.9
32	Andisol	Cu	34.5^{d}	52.1^{bc}	57.3^{ab}	61.9^{a}	48.2^{c}	-15.9*	8.6
68	Nitisol	Cu	17.9^{c}	61.3^{a}	61.5^{a}	63.0^{a}	55.1^{b}	-10.4*	6.8
102	Nitisol	Cu	20.1^{b}	58.9^{a}	58.9^{a}	62.7^{a}	57.7^{a}	-2.0^{ns}	8.1
49	Nitisol	Zn	16.9^{d}	55.2^{b}	63.4^{a}	64.3^{a}	50.9^{c}	-19.7*	5.1
100	Nitisol	Zn	16.2^{b}	63.0^{a}	61.4^{a}	63.1^{a}	59.1^{a}	-3.8^{ns}	6.0
95	Nitisol	B	22.5^{c}	64.6^{ab}	65.1^{ab}	70.1^{a}	63.5^{b}	-2.5^{ns}	6.0
150	Nitisol	B	16.6^{b}	61.6^{a}	61.9^{a}	58.7^{a}	57.3^{a}	-7.4^{ns}	7.8
10	Andisol	Mo	48.4^{c}	75.0^{a}	72.6^{ab}	68.4^{b}	67.8^{b}	-6.6^{ns}	4.8
36	Andisol	Mo	41.7^{c}	63.4^{a}	62.0^{ab}	60.1^{ab}	58.9^{b}	-5.0^{ns}	4.2
64	Nitisol	Mo	10.6^{c}	64.6^{ab}	67.9^{a}	63.4b	63.8^{b}	-6.0*	4.3

[1/] : See Table 3 for captions

Table 5 Height of maize (cm) at 50% silking obtained from different treatments and increase in height due to omission of nutrient elements[1/].

Soil no.	Soil classification	Missing nutrients	Treatments					Change due to omission of the nutrient, (%)	C.V. %
			C	L_{nu}	M_{nu}	H_{nu}	-x		
6	Andisol	Fe	99.8^{d}	118.2^{a}	111.9^{a}	106.3^{c}	119.8^{a}	+7.1^{ns}	2.9
108	Nitisol	Fe	43.2^{d}	107.2^{b}	114.3^{a}	105.6^{b}	99.9^{c}	-12.6*	3.4
32	Andisol	Cu	82.9^{c}	109.9^{b}	113.5^{ab}	116.8^{a}	109.3^{b}	-3.7^{ns}	3.7
68	Nitisol	Cu	49.4^{d}	110.5^{b}	118.1^{a}	121.5^{a}	102.6^{c}	-13.1*	2.3
102	Nitisol	Cu	42.8^{c}	106.2^{a}	107.2^{a}	111.4^{a}	99.9^{b}	-6.8*	4.0
49	Nitisol	Zn	28.5^{d}	94.5^{c}	104.9^{b}	112.8^{a}	91.8^{c}	-12.5*	2.7
100	Nitisol	Zn	45.6^{d}	112.4^{b}	109.7^{b}	122.4^{a}	98.4^{c}	-10.3*	3.5
95	Nitisol	B	52.2^{c}	108.7^{b}	109.8^{b}	116.5^{a}	107.9^{b}	-1.7^{ns}	3.2
150	Nitisol	B	42.8^{c}	108.2^{a}	110.3^{a}	107.5^{a}	96.9^{b}	-12.2*	2.9
10	Andisol	Mo	100.6^{c}	124.3^{a}	121.1^{a}	120.8^{a}	114.2^{b}	-5.7*	2.0
36	Andisol	Mo	90.5^{c}	118.5^{a}	117.6^{a}	107.9^{b}	109.3^{b}	-7.1*	4.1
64	Nitisol	Mo	44.5^{b}	114.7^{a}	118.1^{a}	113.4^{a}	114.6^{a}	-3.0^{ns}	3.3

1/ : See Table 3 for captions

In soil no. 6 omission of Fe fertilizer showed non-significant trend of increase in height of maize by 7.1%. But in soil no. 108 the effect of omission of Fe had a significant depressive effect on plant height of maize by 12.6%. Omission of Cu resulted with a significant decrease in the plant height by 13.1 and 6.8% in soil nos. 68 and 102, respectively. In soil no. 32 there was non-significant response to application of Cu fertilizer. Omission of Zn had a significant depressive effect on plant height by 12.5 and 10.3% in soil nos. 49 and 100, respectively. Omission of B had a significant depressive effect on plant height by 12.2% in soil no. 150. In soil no. 95 the omission of B showed a non-significant trend of decrease (1.7%). Omission of Mo resulted in significant decrease of plant height by 5.7 and 7.1% in soil nos. 36 and 64, respectively. In soil no. 64 omission of Mo showed a non-significant trend of decrease (3.0%) in maize height.

Dry matter yield of maize

Dry matter yields of maize obtained from different treatments and changes in dry matter yield due to omission of nutrients were presented in Table 6.

In soil no. 6, omission of Fe had a significant response on dry matter yields of maize by 10.42%. But in soil no. 108 the effect of omission of Fe showed a non-significant trend of decrease (8.89%). Omission of Cu resulted with non-significant trends of decrease in the dry matter yields of maize by 1.9, 9.9 and 1.8% in soil nos. 32, 68 and 102, respectively. Omission of Zn had non-significant trends of decrease (4.85 and 5.78%, respectively) in dry matter yields of maize in soil nos. 49 and 100. Omission of B had a significant depressive effect on dry matter yield of maize by 10.02% in soil no. 150. In soil no. 95, omission of B showed a non-significant trend of decrease (5.66%) in dry

Table 6 Dry matter yield of maize (g pot^{-1}) obtained from different treatments and increase in dry matter due to omission of nutrient elements[1/].

Soil no.	Soil classification	Missing nutrients	Treatments					Change due to omission of the nutrient, (%)	C.V. %
			C	L_{nu}	M_{nu}	H_{nu}	-x		
6	Andisol	Fe	50.1^{d}	84.3^{c}	90.6^{b}	82.7^{c}	100.1^{a}	+10.42*	3.8
108	Nitisol	Fe	13.0^{b}	69.0^{a}	70.1^{a}	63.9^{a}	63.84^{a}	-8.89^{ns}	7.0
32	Andisol	Cu	23.6^{c}	73.9^{ab}	67.8^{ab}	78.4^{a}	66.6^{b}	-1.79^{ns}	11.2
68	Nitisol	Cu	9.2^{b}	67.2^{a}	68.5^{a}	64.6^{a}	61.7^{a}	-9.93^{ns}	9.5
102	Nitisol	Cu	8.1^{b}	57.9^{a}	57.7^{a}	63.5^{a}	56.7^{a}	-1.80^{ns}	8.7
49	Nitisol	Zn	4.3^{c}	62.3^{a}	59.3^{ab}	63.1^{a}	56.5^{b}	-4.85^{ns}	5.9
100	Nitisol	Zn	9.9^{b}	62.7^{a}	68.4^{a}	67.7^{a}	64.4^{a}	-5.78^{ns}	7.9
95	Nitisol	B	12.9^{c}	77.9^{b}	79.4^{ab}	82.7^{a}	74.9^{b}	-5.66^{ns}	4.3
150	Nitisol	B	8.0^{c}	71.0^{ab}	71.5^{a}	66.2^{ab}	64.4^{b}	-10.02*	7.7
10	Andisol	Mo	63.7^{b}	106.8^{a}	102.5^{a}	100.7^{a}	104.9^{a}	+2.39ns	8.4
36	Andisol	Mo	37.9^{b}	80.3^{a}	82.5^{a}	77.3^{a}	77.0^{a}	-6.68^{ns}	6.2
64	Nitisol	Mo	6.8^{b}	65.4^{a}	68.8^{a}	68.9^{a}	64.6^{a}	-6.18^{ns}	7.0

[1/] : See Table 3 for captions

matter yields of maize. Omission of Mo resulted in non-significant trends of decrease of dry matter yields of maize by 6.68 and 6.18% in soil nos. 36 and 64, respectively. In soil no. 10, omission of Mo fertilizer showed a non-significant trend of increase (2.39%) in dry matter yield.

Nutrient uptake of maize

Uptake of nutrients under study by maize obtained from different treatments and changes in uptake due to omission of nutrients were presented in Table 7.

In soil no. 6, omission of Fe fertilizer showed a significant positive response on uptake of Fe by maize by 27%. But in soil no. 108 omission of Fe had a significant depressive effect on uptake of Fe by maize by 21.8%. Omission of Cu resulted in significant decrease in the uptake of Cu by maize by 47.3, 12.2 and 20.9% in soil nos. 32, 68 and 102, respectively. Omission of Zn had a significant depressive effect on uptake of Zn by maize by 10.9, 25.8% in soil nos. 49 and 100, respectively. Omission of B had a significant depressive effect on uptake of B by maize by 37.7 and 43.4% in soil nos. 95 and 150, respectively. The omission of Mo had a significant depressive effect on uptake of Mo by maize by 72.9% in soil no. 64. In soil nos. 10 and 36, omission of Mo resulted with a non-significant trend of decrease of uptake by maize by 14.2, and 4.3%, respectively.

DISCUSSION

Application of Fe to soil no. 6, a Vitric Andisol, resulted in significant depressive effects on plant height, dry matter yield and Fe uptake by maize. Among the soil samples collected from Vitric Andisols, soil no. 6 had the lowest amount of extractable Fe (4.56 mg Fe kg^{-1}) which was below the critical level of 4.8 mg Fe kg^{-1} (Lindsay and Norvell, 1978; Halvin and Soltanpour, 1981). The greenhouse experiment therefore suggested

Table 7 Uptake of nutrient (mg pot^{-1}) under study by maize obtained from different treatments and increase in uptake due to omission of nutrient elements[1/].

Soil no.	Soil classification	Missing nutrients	Treatments C	L_{nu}	M_{nu}	H_{nu}	-x	Change due to omission of the nutrient, (%)	C.V. %
6	Andisol	Fe	1.97^{c}	3.96^{b}	3.85^{b}	3.68^{b}	4.89^{a}	+27.00*	5.2
108	Nitisol	Fe	0.78^{d}	4.27^{ab}	4.53^{a}	4.02^{b}	3.54^{c}	-21.83*	6.3
32	Andisol	Cu	0.051^{d}	0.108^{b}	0.148^{a}	0.160^{a}	0.078^{c}	-47.25*	13.1
68	Nitisol	Cu	0.037^{d}	0.322^{a}	0.305^{ab}	0.291^{bc}	0.268^{c}	-12.23*	7.8
102	Nitisol	Cu	0.025^{d}	0.218^{b}	0.238^{b}	0.274^{a}	0.189^{c}	-20.87*	10.0
49	Nitisol	Zn	0.099^{d}	0.887^{b}	0.935^{b}	1.025^{a}	0.834^{c}	-10.87*	4.4
100	Nitisol	Zn	0.127^{e}	0.502^{c}	0.562^{b}	0.650^{a}	0.417^{d}	-25.81*	6.6
95	Nitisol	B	0.217^{c}	1.103^{b}	1.417^{a}	1.552^{a}	0.883^{b}	-37.71*	4.6
150	Nitisol	B	0.117^{e}	1.026^{c}	1.132^{b}	1.226^{a}	0.637^{d}	-43.4*	5.4
10	Andisol	Mo	0.036^{c}	0.069^{a}	0.046^{b}	0.026^{d}	0.039^{bc}	-14.12^{ns}	10.1
36	Andisol	Mo	0.032^{d}	0.107^{a}	0.086^{b}	0.072^{c}	0.082^{b}	-4.26^{ns}	7.2
64	Nitisol	Mo	0.001^{e}	0.018^{c}	0.024^{b}	0.028^{a}	0.007^{d}	-72.96*	13.5

[1/] : See Table 3 for captions

that the critical level might be at 4.56 mg Fe kg^{-1} or lower in Andisols. Omission of Fe in soil no. 108, a Nitisol, resulted in significant depressive effects in plant height at all observed stages and in Fe uptake by maize and showed a non-significant trend of decrease in dry matter yield of maize. But the laboratory assessment indicated that extractable Fe in this soil was above the critical level. The greenhouse experiment showed that the critical level was above 5.20 mg Fe kg^{-1} in the Nitisols. These results did not therefore support the critical level of Lindsay and Norvell (1978) and Halvin and Soltanpour (1981). These might be due to differences in properties of the soils or plant species used. The result of the laboratory assessment and greenhouse experiment suggested that the status of Fe was sufficient in the Andisols while was deficient in 1.9% of the Nitisols.

Omission of Cu application to soil no. 32, a Mollic Andisol, resulted in significant decreases in plant height at 30 and 45 days after planting and in uptake of Cu by maize while showed non-significant trends of decrease in height at 50% silking and in dry matter yields. Basing on the critical levels reported by Makarim and Cox (1983), the laboratory assessment indicated that in all of the Mollic Andisols Cu was below the critical level (0.50-0.60 mg Cu kg^{-1}) and soil no. 32 had the highest amount of extractable Cu. The greenhouse experiment also showed mostly responses to application of Cu fertilizer. The results thus indicated that there was a need of application of Cu to all of the Andisols.

In the cases of Nitisols, the omission of Cu resulted in mostly significant decreases in soil no. 68 and trends of decrease in soil no. 102. Basing on the critical level (0.37 mg Cu kg^{-1}) reported by Makarim and Cox (1983), the laboratory assessment indicated that in all of the Nitisols amounts of extractable Cu were in sufficient range (0.37 mg Cu kg^{-1}) except soil no. 68. The greenhouse experiment also showed clearer responses to application of Cu to soil no. 68 than to soil no. 102 (with 0.48 mg kg^{-1} extractable Cu). Therefore, the results of the laboratory assessment and the greenhouse experiment supported the critical level reported by Makarim and Cox (1983). Accordingly there was a need of application of Cu to Nitisols having extractable Cu less than the critical level, which accounted for 5.6% of the samples.

For soil nos. 49 and 100, Nitisols, application of Zn resulted in significant responses in plant height and Zn uptake by maize and a non-significant trend of increase in dry matter yield. Compared to the critical level reported by Lindsay and Norvell (1978), the laboratory assessment indicated that in all of Nitisols extractable Zn was below the critical level using DTPA-TEA method. The greenhouse experiment also showed positive responses of maize to Zn application. The results of laboratory assessment and greenhouse experiment therefore supported the reported critical level. Accordingly, it might be concluded that there would be a need of application of Zn to all of the Nitisols for maize production. From the laboratory assessment and referring to the critical level the amounts of extractable Zn in all of the Andisols were in the sufficient range.

Application of B resulted in significant responses in height of maize at 30 days and at 50% silking stage, in dry matter yield and B uptake by maize in soil no. 150 (with 0.38 mg extractable B kg^{-1}) and non-significant trends of increase in soil no. 95 (with 0.46 mg extractable B kg^{-1}). The laboratory assessment and greenhouse experiment therefore supported the critical level (0.50-1.00 mg extractable B kg^{-1}) reported by Ponnaperuma *et al.* (1981). Basing on the critical level and the laboratory study, 31.9% of the Nitisols (having less than 0.8 mg extractable B kg^{-1}) were deficient in B. Therefore, it might be concluded that there would be a need of application of B to 31.9% of the Nitisols. Thus, the results were in agreement with those of Zada and Afzal (1997) and Asad and Rafigue (2002) reported that significant reduction in dry mass yield and plant height was obtained with B concentration below 0.8 mg extractable B kg^{-1} soil. From the laboratory assessment and referring to the critical level, the amounts of B in all of the Andisols were in the sufficient range.

The omission of Mo in soil no. 10, a Vitric Andisol, resulted in significant negative response in plant height at 50% silking stage and showed non-significant negative responses in the other parameters. The laboratory assessment indicated that all of the Vitric Andosols had Mo above the lower limit of the critical level including soil nos. 10 and 36 that had the lowest amounts of extractable Mo compared to the other soils. In soil no. 36, a Mollic Andisol, omission of Mo application resulted in non-significant response to application of Mo. The laboratory assessment also indicated that all of the samples of Mollic Andisols had Mo in the sufficient range. The results of laboratory assessment and greenhouse experiment therefore supported the critical level reported by Griggs (1953). Thus, the amounts of extractable Mo in all of the Andisols were in the sufficient range.

Omission of Mo in soil no. 64, a Nitisol, resulted in significant decreases in height of maize at 30 and 45 days after planting and in Mo uptake by Maize and non-significant trends of negative responses in plant height at 50% silking stage and dry mass yield of maize. The laboratory assessment and greenhouse experiment therefore supported the critical level reported by Griggs (1953). The laboratory assessment indicated that all, except 4.4%, of the Nitisols had Mo status higher than the critical level. Therefore, 4.4% of the Nitisols were deficient in Mo.

CONCLUSION

Considering the results of the present experiment as well as those in the previous laboratory assessment the following conclusion might be drawn. Fe status of all of the Andisol was in the sufficient range whereas that of about 1.9% of the Nitisols was in the deficient range for maize production. The results of the present study did not support the critical level of 4.8 mg Fe kg^{-1} by AB-DTPA method reported by other authors. The results on the other hand showed that the critical level were lower than 4.56 mg Fe kg^{-1} in the case of Andisols and higher than 5.20 mg Fe kg^{-1} in the case of Nitisols.

Cu status of all of the Andisols was in the deficient range whereas 5.6% of the Nitisols was in the deficient range for maize production.

Zn status of all of the Nitisols was in the deficient range whereas all of the Andisols was in the sufficient range.

B status of 31.9% of the Nitisols was in the deficient range whereas all of the Andisols was in the sufficient range.

Mo status of all of the Andisols was in the sufficient range whereas 4.4% of the Nitisol was in the deficient range.

The present results supported the critical levels for Cu, Zn, B and Mo found in the literature.

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