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Status of Soil Micronutrients in Ethiopian Soils: A Review

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Abstract
Deficiencies of micronutrients have emerged as a new problem to crop productivity in Ethiopia. Particularly, deficiencies of Zn and Cu are widespread in different parts of the country. In some of the studies B and Mo deficiency were also reported. These problems are expected to increase in the future because of the increase in cropping intensity, the use of high-yielding varieties and the more extensive use of nitrogen, phosphorus and potassium fertilizers. Therefore, future research should focus on mapping of soil micronutrients and conducting extensive crop response studies using sensitive crops for the respective micronutrients. Moreover, Standardization of laboratory procedures and establishing the critical level of micronutrients for soils and crops in Ethiopia should be given due emphasis since contrasting results have been reported with different extractants.
Keywords: Critical level, Deficiency, Extractant, Micronutrient

Introduction

Seven plant nutrients, i.e., boron (B), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn), required by plants in very small quantities, are known as micronutrients (Rashid and Ryan, 2004). Although they are required in minute quantity but have the same agronomic importance as macro-nutrient have and play a vital role in the growth of plants. Soil micronutrient deficiencies not only reduce crop productivity, but also low micronutrient concentrations in plant food adversely affect human health and well-being (Graham and Welch, 2000). However, unlike major nutrient deficiencies, micronutrient problems are highly genotype-specific and location-specific (Rashid and Ryan, 2004).

Nitrogen (N) and phosphorus (P) in the form of urea and Di-ammonium phosphate are the major fertilizers applied by Ethiopian smallholder farmers. These fertilizers were introduced in 1967 following four years of trials carried out by the government, with the assistance from the Food and Agriculture Organization's (FAO's) Freedom from Hunger Campaign (FAO, 1995). Continuous application of N and P fertilizers without due consideration of other nutrients could led to deficiencies of other nutrients. According to Kayal and Randhawal (1983) two to six-times more of the micro-nutrients are being removed annually through crop harvest from the soil, than are applied to it when using high analysis fertilizers like DAP and Urea. Micronutrient problems are expected to increase in the future because of the increase in cropping intensity, the use of high-yielding varieties and the more extensive use of nitrogen, phosphorus and potassium fertilizers. As a result, some studies were conducted to assess the status of micronutrients in Ethiopian soils in the past two decades. While extensive reviews are available on geographic distribution of micronutrient problems and their correction in other parts of the world such information is rather limited for soils of Ethiopia. The aim of this paper is therefore to review the findings micronutrient assessment studies and propose future research directions.

Limitation of the study

Some of the research reviewed are not published but are in the form of technical reports. Moreover, critical values of micronutrients for soils and crops in Ethiopia were not established so far and hence ratings were based on critical values established for other regions. In addition, most of the researches reviewed here are based on small numbers of samples focusing on a given locality and hence making it difficult to generalize. Sampling depth, techniques and methods of extraction also differ between authors. Another serious concern is whether the laboratories provide reliable results with given analytical standards. Data from different laboratories in Ethiopia have shown differences so large-even with subsamples taken from the same bag-that analyses became inconclusive. Most of the laboratories in Ethiopia suffer from inconsistencies and only few of them are accredited so far.

Concentration of Micronutrients Soils and Plant Tissues

The worldwide study by Sillanpaeae (1982) provided data on micronutrient concentrations in selected soils of Africa. It illustrated that copper, zinc and molybdenum deficiencies are common in many coarse textured, acid soils of Ethiopia, Ghana, Malawi, Nigeria, Sierra Leone, Tanzania, and Zambia. Another study by Haque *et al.* (2000) showed that the decision depends on the type of extractant used indicating the need to identify the most suitable extractant (s).

A number of studies conducted so far showed that deficiency of Cu and Zn are widespread in many Ethiopian soils (table 1, 2 and 3). For instance, in an attempt to produce countrywide information on status of micronutrients, Asgelil *et al*. (2007) collected a number of soil and plant samples from different agro-ecologies and confirmed that Cu and Zn are deficient in both plant and soil samples (table 2 and 3). They reported that 65% and 89% of the soil samples were deficient in Cu and Zn, respectively. On the other hand, Fe and Mn in soils were found to be above the satisfactory limit and in some cases Mn toxicity were noted. In similar study, 75.4 and 43.3% maize leaf samples, 87.7 and 64.6% of tef leaf samples, 84.8 and 51.6% wheat leaf samples showed Cu and Zn deficiency, respectively. In line with this, different authors (Sahlemedhin *et al*., 2003; Demeke and Abayneh, 2003; Abayneh and Ashenafi, 2006; Abebe and Endalckachew, 2012) independently reported deficiency of Cu and Zn while Mn and Fe were above the critical limits in different parts of Ethiopia. Previously, Faye *et al* (1993) reported that there was widespread deficiency of Zn and Cu in forages and blood of domestic ruminants in Ethiopia, implying that these nutrients could be limiting forage production. Some preliminary results from recent EthioSIS survey also indicated that boron, zinc and copper are deficient micronutrients in most Ethiopian soils (Samuel, 2014).

Table 1 Soil micronutrients studied and reported to be deficient in some Ethiopia soils

Soil type	**Studied Micronutrients**	**Deficient micronutrient (s)***	**Study area**	**Source**
Dominantly Pellic Vertisols and Eutric Cambisols	Fe, Mn, Cu, Zn and B	B (97%), Zn (20%)	Gurage Zone (Cheha District), Southern Ethiopia	Mohammed *et al.* (2016)
Vertisols (saline soil) and Fluvisols (saline sodic and sodic)	Fe, Mn, Cu Zn, B and Mo	Fe, Zn, Mn and Cu	Amibara irrigation project, Gabiressu zone, Afar	Ashenafi *et al.* (2016)
Pellic & chromic Vertisols	Fe, Cu, Mn, Zn and B	B (100%)	Alicho-Woriro district (Northern Siltie Zone)	Eyob *et al.* (2016)
Vertisols	Fe, Mn, Cu Zn, B and Mo	Zn, B and Mo	Central highlands of Ethiopia	Hillette *et al.* (2015)
Not characterized	Fe, Cu, Zn & Mn	None	Abaya Chamo Lake Basin	Tuma *et al.* (2014)
Eutric Fluvisol, Salic Fluvisol and Eutric Vertisol	Fe, Cu, Zn & Mn	Zn (100%)	Middle Awash irrigated farms	Wondimagegne and Abere (2012)
Nitisols	Mn, Fe, Cu, Zn, B & Mo	Zn (100%), B (31.9%), Cu (5.6%), Mo (4.4%)	Western Ethiopia	Teklu *et al.* (2003a,b)
Vitric Andisols		Cu (100%), Mo (40%)	Rift Valley	Teklu *et al.* (2007)
Mollic Andisols		Cu (70%)		
Alfisols/Nitisols	Mn, Fe, Cu, Zn, B & Mo	Zn, B & Mo	Western Ethiopia, Bako	Wakene and Heluf (2003)
Alfisols/Nitisols	Mn, Fe, Cu, Zn, & B	Cu	Delbo Atwaro watershed, Wolaita	Wondwosen and Sheleme, 2011
Nitisols	Fe, Cu, Zn & Mn	Cu and Zn	Jimma Zone	Abebe and Endalkachew (2012)
Eutric Vertisols and Vertic Cambisols	Fe, Cu, Zn & Mn	Zn (100%)	Bale highlands	Yerima *et al.* (2013)
Vertisols	Fe, Cu, Zn & Mn	Zn (98%), Fe (96%), Mn (20%)	Central highlands	Yifru and Mesfin (2013)

* Values in the parenthesis in 3rd column indicate the percentage of samples reported to be deficient.

The study conducted at Amibara irrigation project area, Gabiressu zone of Afar regional state by Ashenafi *et al*, (2016) recently reported that DTPA extractable Fe, Zn and Mn were found to be deficient in all salt affected soils, whereas, Cu was deficient in saline sodic and sodic soil of Fluvisols but medium in non-saline, non-sodic soil and saline soil of Vertisols and Fluvisols.

The study in Bale highlands (Yerima *et al*., 2013), Nitisols of western Ethiopia (Teklu *et al*., 2003) and irrigated farms of Middle Awash (Wondimagegne and Abere, 2012) indicated that Zn deficiency is most common. This corroborates the findings of Bemnet *et al* (2012) which reported 47 percent Zn deficiency in the blood serum of school children in the northwest Ethiopia (Gondar) that could be an indication the deficiency of Zn in the soils.

Table 2 Status of some micronutrients in major Ethiopian soils (Asgelil *et al*. 2007)

Soil type	No. of soil samples collected & analyzed	Range, mean and percent of deficient samples	Micronutrient content (mg/kg)			
			Fe	Mn	Zn	Cu
Nitisols	386	Range	0.0-864.4	0.0-304.6	0.0-7.0	0.0-8.2
		Mean	22.9	53.7	1.3	1.8
		Deficient samples (%)	4.9	0.3	55.4	69.4
Vertisols	291	Range	1.7-109.2	0.0-205.5	0.0-10	0.1-24.8
		Mean	22.7	35.2	0.9	2.8
		Deficient samples (%)	3.4	0.7	78.4	51.6
Cambisols	109	Range	1.9-78.2	0.0-67.9	0.0-10.0	4.5-23.1
		Mean	15.6	25.4	1.5	1.8
		Deficient samples (%)	6.4	1.8	78	67
Fluvisols	8	Range	5.9-19.4	12.0-51.6	0.3-3.7	0.8-4.4
		Mean	12.6	28.4	1.1	2.0
		Deficient samples (%)	0	0	75	75

Globally, Zn deficiency is the most important micronutrient problem because of factors like alkaline soil pH, soil calcareousness, low soil organic matter, exposed subsoils (eroded or leveled), sandy texture, Zn-free fertilizers, accentuated Zn mining by high-yielding varieties, and/or flooding-induced electro-chemical changes (Rashid and Ryan, 2004). Zinc deficiency is believed to be accentuated by the addition of high levels of P fertilizers (Mortvedt *et al*., 1991)

Table 3 Status of some micronutrients in leaf samples from different crops grown in some Ethiopian soils (Modified from Asgelil *et al*., 2007)

Crop type	No. of plant samples collected & analyzed	Range, mean and percent of deficient samples	Micronutrient content (mg/kg)			
			Fe	Mn	Zn	Cu
Tef	386	Range	6.2-1412.7	10.4-396.6	4.0-417.1	0.1-604.7
		Mean	168.6	89.1	24.1	7.5
		Deficient samples (%)	10.3	36.9	64.6	87.7
		Satisfactory level	50-250	55-100	20-70	7-12
Maize	291	Range	18.3-1612.5	3.6-323.4	3.5-200.6	0.1-61.2
		Mean	232.4	68.2	39.9	6.8
		Deficient samples (%)	7.0	18.2	43.3	75.4
		Satisfactory level	50-250	25-150	20-70	6-20
Wheat	109	Range	0.1-635.6	1.08-255	0.1-157.5	0.1-84.3
		Mean	121.4	39.2	23.3	3.7
		Deficient samples (%)	8.5	80.6	51.6	84.8
		Satisfactory level	50-250	55-100	20-70	7-12
Citrus	8	Range	122.8-464.2	9.6-54	7.34-33.1	0.1-1001
		Mean	252	31.6	16.6	38.2
		Deficient samples (%)	0	10.8	30	54.1
		Satisfactory level	> 36	> 16	> 16.0	>3.0

A study conducted to assess the boron status of irrigated fields in semi arid north Ethiopia (Tigray region and Aba'ala district in Afar region) indicated that about 33.3 % of the samples have values less than 0.5 ppm (the critical value for soil Boron deficiency), implying that deficiency of Boron could limit production of irrigated crops in the area (Fassil and Hollington, 2010, table 4). Some recent studies by EthioSIS also reported that 70% of Tigray region is deficient in Boron (Hezekiel, 2014). Similarly, Teklu *et al* (2003a, b) reported that 31.9% of soil samples collected from Nitisols in western Ethiopia are Boron deficient. The deficiency of B was also reported in Nitisols of western Ethiopia by Wakene and Heluf (2003). Recent studies by IFDC in 2011 also revealed deficiency of B and Zn in the majority of Ethiopian soils (unpublished report). The study conducted by Hillette *et al*. (2015) also reported deficiency of Zn, Bo and Mo in Vertisols of the central highlands of Ethiopia. Some preliminary results generated by EthioSIS also indicated that 65% of the areas are deficient in Boron (Samuel, 2014).

Table 4 Hot water extractable B distribution in the soils of the irrigated fields on semi arid north Ethiopia (Fassil and Hollington, 2010)

Soil types	Distribution of B (%)					
	Mean	Range	< 0.5	0.5-1.0	1.0-1.5	1.5-2.0
Arenosols	0.19	0.14-0.24	100	0	0	0
Cambisols	0.96	0.58-1.29	0	33.3	66.7	0
Luvisols	0.79	0.19-2.35	50	0	50	0
Vertisols	0.67	0.33-1.52	33.2	49.8	17	0

Crop response studies

Crop response forms the ultimate measure of micronutrient deficiency and a dependable method for control of the deficiency. However, crops often vary in their response to micronutrients and sensitiveness to micronutrient deficiencies (table 5). Therefore, sensitive crops should be considered to study response of crops to micronutrients when they are found to be deficient.

Studies on response of crops to micronutrients in Ethiopia are rather limited. However, both response and lack of response of crops to micronutrient fertilizer applications were reported. For instance, the greenhouse study by Asgelil *et al* (2007) indicated lack of response of maize, wheat and tef to micronutrient applications despite low level of micronutrients in the soils. Bereket *et al.* (2011) on the other hand, reported an average increase of 14 and 15% in grain and straw yields of tef due to application of Zn at the rate of 8 kg Zn ha^{-1} on Vertisols around Ada (Oromia) and Laelay Michew and Alamata (Tigray region) under field condition. This proved the research finding by Asgelil *et al* (2007) which reported that 78.4% of soils samples collected from Vertisols in Ethiopia are deficient in Zn. Similarly, greenhouse study by Yirga (2012) reported increased pods per plant and above ground biomass of faba bean at maturity stage, although this was not reflected in grain yield.

Based on the results of EthioSIS soil fertility map, currently many studies were initiated to evaluate the response of crops to micronutrients and macronutrients like K and S. The results of these studies may recommend new fertilization schemes for Ethiopian soils.

Table 5 Relative response of selected crops to micronutrients (Modified from Vitosh *et al*.,1994)

Crop	Response to micronutrients					
	Mn	B	Cu	Zn	Mo	Fe
Alfalfa	Low	High	High	Low	Medium	
Barley	Medium	Low	Medium	Low	Low	Medium
Wheat	High	low	High	Low	Low	Low
Corn	Medium	Low	Medium	High	Low	Medium
Sorghum	High	Low	Medium	High	Low	High
Pea	High	Low	Low	Low	Medium	
Snap bean	High	Low	Low	High	Medium	High
Soybean	High	Low	Low	Medium	Medium	High
Broccoli	Medium	High	Medium		High	High
Cabbage	Medium	Medium	Medium	Low	Medium	Medium
Carrot	Medium	Medium	Medium	Low	Low	
Cauliflower	Medium	High	Medium		High	High
Potato	High	Low	Low	Medium	Low	
Lettuce	High	Medium	High	Medium	High	
Onion	High	Low	High	High	High	
Tomato	Medium	Medium	High	Medium	Medium	High
Spinach	High	Medium	High	High	High	High
Radish	High	Medium	Medium	Medium	Medium	

[1]highly responsive crops will often respond to micronutrient fertilizer additions and medium responsive are less likely to respond if the micronutrient concentration is low

Conclusion and Recommendations

The studies on the status of micronutrients in Ethiopia are very few and most of them focused on Cu, Zn, Fe and Mn. This review indicated that deficiency of micronutrients have emerged as a new problem to crop productivity in Ethiopia. Particularly, deficiencies of Zn and Cu in that order are widespread in different parts of the country. Deficiency of B is also common in different part of the country, whereas Fe and Mo deficiency can play a role locally. Manganese deficiencies are very rare and chlorine deficiency is not expected to occur in Ethiopia and is not a field problem in any part of the world.

Since low Zn content of soil affects the content in grain and forage crops, the low Zn soil values in most

Ethiopian soils present a matter of concern for human nutrition on a national scale. Deficiencies of micronutrients are likely to be accentuated in magnitude as well as in severity unless addressed adequately. Therefore, future research should focus on mapping of soil micronutrients and conducting crop response studies using sensitive crops for the deficient micronutrients. Moreover, Standardization of laboratory procedures and establishing the critical level of micronutrients for soils and crops in Ethiopia should be given due emphasis.

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