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Full Length Research Paper

Assessment on the Status of Some Micronutrients in Vertisols of the Central Highlands of Ethiopia

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Abstract

Although the role of micronutrients in balanced plant nutrition is well established, information regarding their status in most Ethiopian soils is scanty. Even, the current fertilizer recommendation for major crops in Ethiopia is only for macronutrients; continuous application of one or two macronutrients may in due course deplete the soil reserve of other nutrients and limit the crop yield. In order to assess the status of Manganese (Mn), Iron (Fe), Copper (Cu) and Zinc (Zn) in the Vertisols of the central highlands of Ethiopia, fifty representative composite surface soil samples (0-30 cm depth) were collected from five districts viz., Akaki, Gimbichu, Ada'a, Lume and Minjar-Shenkora. These micronutrients were extracted using diethylenetriamine-penta-acetic acid (DTPA) and their concentration is determined using atomic absorption spectrophotometer (AAS). The analytical results confirmed that the status of Fe and Zn fall in the deficient range in the majority of the samples. Generally, 96 and 98% of the samples were found to be deficient in Fe and Zn, respectively. Manganese deficiency is evident only in 11% of soil samples whereas, the status of Zn was in sufficient range in all soil samples, Therefore, future research should focus on assessing the availability of these and other micronutrients by collecting large number of soil and plant samples and conducting field trials in the area.

Keywords: Deficient, DTPA, Micronutrients, Vertisols.

INTRODUCTION

The drive for targeting higher agricultural production needs a balanced use of nutrients which otherwise create problems of soil fertility exhaustion and nutrient imbalances not only of major but also of secondary and micronutrients (Patel and Singh, 2009). Whenever either of the nutrients is deficient it resulted in abnormal growth, which sometimes cause complete crop failure. Most of micronutrients are associated with the enzymatic system of plants. Thus, micronutrient deficiency and toxicity can reduce plant yield (Tisdale et al., 1995). Besides, grain and flower formation does not take place in severe deficiency (Nazif et al., 2006). The availability of micro-nutrient to plant growth is particularly sensitive to change in soil environmental factors like organic matter, soil pH, lime content and soil texture (Nazif et al., 2006).

Katyal and Randhawal (1983) reported a wide spread micronutrient deficiencies when high analysis fertilizers like DAP and Urea continued to be the only one used in India. These fertilizers have been applied continuously and with increase rate particularly due to the release and adoption of new crop varieties that have high demand of these nutrients. When micro-nutrients are not applied to the soil in conjunction with common fertilizers, fertilizing soils with macronutrients are likely to promote imbalance between these nutrients group and individual nutrients. Furthermore, increased yield through intensive cropping and use of high yielding varieties, losses of micronutrients through leaching, and decreased farm yard manure application compared to chemical fertilizers contribute towards acceleration exhaustion of the supply of available micronutrients from the soil bank. It has been reported that, in spite of favorable development in the use of nitrogen and phosphorus fertilizers to increase crop production two to six-time more of the micro-nutrients are being removed annually through crop harvest from the soil, than are applied to it (Kayal and Randhawal,1983).

This could be significant particularly in Ethiopia, where there is no micronutrient application in the form of chemical fertilizers or organic elements (Asgelil et al., 2007). However, there is very little information available in Ethiopia about micronutrient levels in soils. Desta (1989) carried out study on the micronutrient status of Ethiopian soils. He collected limited samples from different areas of the country and reported that the contents of Fe and Mn were usually at an adequate level, while Mo and Zn contents were variable. Fisseha (1992) found that the micronutrient content of the soil is influenced by several factors among which soil organic matter content, soil reaction, and clay content are the major one. Haque (1987) indicates the role and importance of Mo in plants and to livestock nutrition.

Teklu et al. (2007) studied the status of micronutrients on Andisols of Rift Valley using different analytical methods. They reported that the status of Mn, Zn and B were in the sufficient range in all of the samples. Similarly, the status of Fe and Mo were in the sufficient ranges, except for 7.5% and 40% of the samples, respectively. In Vitric Andisols the status of Cu in all the samples were in the deficient ranges in traditional farms using DTPA-TEA method, while the samples were in sufficient ranges using AB-DTPA and Mehlich III methods in intensive farms.

Asgelil et al. (2007) also collected soil and plant samples from different parts of the country and indicated Fe and Mn are generally above critical limit and in some cases Mn toxicity was noted. On the other hand, Zn and Cu were deficient in most zones studied. Considering the soil orders, Zn deficiency was the largest in Vertisols and Cambisols (78%) but the lowest in Nitisols, whereas Cu deficiency was the highest in Fluvisols and Nitisols with the value of 75 and 69%, respectively. This indicates the need for systematic investigation of the status of micronutrients and each soil types should be treated differently.

In most of the nutrient studies related to Vertisols in Ethiopia, more emphasis a given to macronutrients, especially N and P. Studies related to the micronutrients status of Ethiopian Vertisols on the other hand are scarce, although the role micronutrients play in agriculture may be equally important. Therefore, the objective of the present study is to assess the status of micronutrients (Mn, Fe, Cu and Zn) in Vertisols of the central highlands.

MATERIAL AND METHODS

Description of the study area

The study was conducted in the five districts representing Vertisols of the Central highlands of Ethiopia, namely; Akaki, Gimbichu, Ada'a, Lume and Minjar-Shenkora.

Akaki district is geographically located between $8^0$33'-$8^0$57' N latitude and $38^0$43'-$38^0$50' E longitude. The average annual range of maximum temperature lies between 15 ^{0}C and 20 ^{0}C, whereas, low temperature lies between 10 ^{0}C and 15 ^{0}C. The average annual range of rainfall is from 800-1200 mm. The District lies between the altitudinal ranges of 1500 and 2300 m a.s.l. which fall in the two agroecological zones of Weyna-dega (mid-highlands) 98% and Dega (highlands) 2%. Vertisols covers almost the whole district (Damitew et al., 2012).

Gimbichu district is located at $08^0$57' N latitude and $39^0$06' E longitude, at about 40 km northeast from Addis Ababa. Most parts of the district are over 2300 m. Vertisols cover about 14.6% of the district. The area is characterized by mean annual rainfall of 900 mm and temperature of 17 ^{0}C (Teklu et al., 2006).

Minjar Shenkora is located within the Rift-Valley some 120 km south of Addis Ababa. The district is located in $8^0$45'to $8^0$55' N latitude and $39^0$15' to $39^0$45' E longitude. The mean annual maximum temperature varies from 27 to 29 ^{0}C and the mean minimum temperature varies from 10 to 13 ^{0}C (Befekadu, 2008).

Lume district is situated between 8°12' to 8°5' N latitude and 39°01' to 39°17' E longitude. It lies within an altitude ranging from 1500-2300 m a.s.l. The major soil type of the district is Vertisols (Addis et al., 2001).

Ada'a Woreda lies between 38°51' to 39°04' E longitudes and 8°46'to 8°59' N latitudes. The Woreda is characterized by sub-tropical climate and receives 860 mm rain per annum. In general the main rainy season occurs between mid-June and September, followed by a dry season that might be interrupted by the short rainy season in February and March. Mean annual temperature ranges from about 8-28°C. Vertisols is the dominant soil type, with good soil fertility but with water logging problems in those areas where the land slope is below 8% (Nigatu et al., 2010)

According to Tefera et al. (1996) the geology of Ada'a and Akaki consists of alkaline basalt and trachyte belonging to the Bishoftu formation of the Cenozoic volcanic eruptions. The geology of Gimbichu, Lume and Minjar-Shenkora consists of ignimbrites and rhyolitic flows belonging to Nazret series of the Cenozoic volcanic eruptions.

Soil sampling ad method of analysis

Fifty representative composite soil samples were collected from Vertisols of the five districts (Akaki, Gimbichu, Lume, Ada'a and Minjar-Shenkora) in Central highlands of Ethiopia. Each composite soil sample was taken using soil auger (made from stainless steel) from eight different spots. 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.

Soil pH in H_2O (1:2.5) was determined using digital pH meter with glass electrode. Extractable Mn, Fe, Cu and Zn were determined using DTPA as an extractant (Lindsay and Norvell, 1978). The amounts of these

Table 1. Soil pH of the study area

District	Range	Mean	SD
Gimbichu	6.1-7.1	6.6	0.4
Akaki	7.1-7.8	7.5	0.2
Minjar-Shenkora	6.5-7.0	6.7	0.18
Lume	6.9-7.9	7.6	0.26
Ada'a	6.8-7.7	7.1	0.26

nutrients in the extracts were determined by atomic absorption spectrophotometer (AAS).

For the purpose of micronutrient fertility ratings, the critical values developed by Lindsay and Norvell (1978) and used by Asgelil et al. (1978) in previous study were employed. Mean, range and standard deviation were computed and used for comparison.

RESULTS AND DISCUSSION

Soil pH

The soil reactions were found to range from slightly acidic to moderately alkaline with a pH ranging from 6.1 to 7.9 with a mean value of 7.1 (Table 1). The "ideal" soil pH is within a range from a slightly acidic pH of 6.5 to slightly alkaline pH of 7.5. It has been established that most plant nutrients are optimally available to plants within this pH range, plus this range of pH is generally very compatible to plant root growth (Tisdale et al., 2003).

Zinc

As shown in tables 2-6 available Zn in the surface soil samples ranged from 0.4 to 0.5 (mean = 0.4), 0.3 to 0.4 (mean= 0.4), 0.4 to 0.6 (mean = 0.5), 0.4-0.5 (mean = 0.5) and 0.5-1.02 (mean = 0.6) at Akaki, Gimbichu, Minjar, Lume and Ada'a, respectively. Zinc had been reported to be generally of low mobility in soils (Chesworth, 1991) and has a tendency of being adsorbed on clay sized particles (Alloway, 2008). In this study, 98% of the soil samples were found to be deficient in Zinc as the values were below the critical 1.0 mg kg^{-1} developed by Lindsay and Norvell (1978). In conformity with this study, Asgelil et al. (2007) also reported deficiency of Zn in 78.4% of the soil samples collected from Vertisols of Ethiopia. However, the mean value (0.5 mg kg^{-1}) obtained from this study is lower than the mean value (0.9 mg kg^{-1}) reported for Vertisols of Ethiopia by these authors.

Copper

The available Cu varied from 1.1 to 2.1 mg kg^{-1} (mean = 1.6 mg kg^{-1}), 1.1 to 2.2 mg kg^{-1} (mean = 1.5 mg kg^{-1}), 1.3 to 3.2 mg kg^{-1} (mean = 2.3 mg kg^{-1}), 1.0-2.0 (mean = 1.2 mg kg^{-1}) and 1.6-2.3 mg kg^{-1} (mean = 2.0) for Gimbichu, Akaki, Minjar-Shenkora, Lume and Ad'a Vertisols as shown in tables 2-6. All the mean values reported were lower than the mean value (2.8 mg kg^{-1}) reported for Ethiopian Vertisols (Asgelil et al., 2007). Based on the critical limit of 0.2 mg kg^{-1} (Lindsay and Norvell, 1978), all the soil samples found to have sufficient level of available copper, indicating that Cu deficiency is very unlikely for any crop production in this soil. This is however, in contrary to the findings of Asgelil et al. (2007), who used higher critical level (2 mg kg^{-1}) and reported that 51.6% of samples collected from Vertisols of Ethiopia were deficient in Cu. If this critical level is applied to the values obtained in this study, 40%, 80 %, 90 % and 100 % of the soil samples at Minjar-Shenkora and Ada, Gimbichu, Akaki and Lume falls in deficient range but this critical level is higher than reported in most literatures following DTPA extraction method.

Iron

The available Fe at Gimbichu district vary from 0.1 to 2.1 mg kg^{-1} with a mean of 0.6 mg kg^{-1}, at Akaki district from 0.1 to 0.4 mg kg^{-1} with a mean of 0.2 mg kg^{-1}, at Minjar-Shenkora from 0.1 to 5.4 mg kg^{-1} with a mean of 0.9 mg kg^{-1}, at Lume district from 0.1 to 0.7 mg kg^{-1} with mean values of 0.2 mg kg^{-1} and at Ad'a from 0.1 to 5.5 mg kg^{-1} with mean values of 1.2 mg kg^{-1} as shown in tables 2-6. The mean values reported here are by far lower than the mean value (22.7 mg kg^{-1}) reported by Asgelil et al. (2007) for Ethiopian Vertisols.

Although available Fe is generally high in the tropical soils, localized deficiencies of Fe are known to occur (Enwezor et al., 1990). In this study, considering 4.5 mg kg^{-1} DTPA-extractable Fe as the critical value (Lindsay and Norvell, 1978), all soil samples at Akaki, Lume and Gimbichu district and 90% of the soil samples at Minjar-Shenkora and Ada'a are deficient in available Fe. In the previous studies in Ethiopia Fe deficiency was not commonly reported, except in study by Teklu et al. (2007) who reported that 20 % of Vitric Andisols in the Rift Valley are deficient in Fe.

Table 2. Available micronutrients (mg kg^{-1}) in the soil samples of Akaki district

Micronutrient	Range	Mean	SD
Iron	0.1-0.4	0.2	0.1
Copper	1.1-2.2	1.5	0.3
Manganese	2.1-10.9	5.5	2.8
Zinc	0.4-0.5	0.4	0.0

Table 3. Available micronutrients (mg kg^{-1}) in the soil samples of Gimbichu district

Micronutrient	Range	Mean	SD
Iron	0.1-2.1	0.6	0.6
Copper	1.1-2.1	1.6	0.4
Manganese	0.1-30.4	6.1	10.5
Zinc	0.3-0.4	0.4	0.0

Table 4. Available micronutrients (mg kg^{-1}) in the soil samples of Minjar-Shenkora district

Micronutrient	Range	Mean	SD
Iron	0.1-5.4	0.9	1.59
Copper	1.3-3.2	2.3	0.53
Manganese	1.3-8.8	4.6	2.92
Zinc	0.4-0.6	0.5	0.05

Table 5. Available micronutrients (mg kg^{-1}) in the soil samples of Lume district

Micronutrient	Range	Mean	SD
Iron	0.1-0.7	0.2	0.21
Copper	1.0-2.0	1.2	0.27
Manganese	0.1-18.3	5.0	5.61
Zinc	0.4-0.5	0.5	0.02

Table 6. Available micronutrients (mg kg^{-1}) in the soil samples of Ada'a district

Micronutrient	Range	Mean	SD
Iron	0.1-5.5	1.2	1.49
Copper	1.6-2.3	2.0	0.20
Manganese	12.1-47.3	26.3	9.21
Zinc	0.5-5.0	0.6	0.16

Manganese

DTPA-extractable Mn in the studied soils varied from 0.1 to 30.4 mg kg^{-1} with mean value of 6.1 mg kg^{-1} for Gimbichu district, from 2.1 to 10.9 mg kg^{-1} with mean values of 5.5 mg kg^{-1} for Akaki district, from 1.3 to 8.8 mg kg^{-1} with mean value of 4.6 mg kg^{-1} for Minjar-Shenkora district, and from 0.1 to 18.3 mg kg^{-1} with mean value of 5.0 mg kg^{-1} for Lume and from 12.1 to 47.3 mg kg^{-1} with mean value of 26.3 mg kg^{-1} for Ada'a. The mean value (9.5 mg kg^{-1}) in the present study is lower than the mean value (35.2 mg kg^{-1}) reported by Asgelil et al. (2007) for Ethiopian Vertisols. Based on the critical limit (1 mg kg^{-1}) for Mn deficiency (Linsay and Norvell, 1978), 70% of the soil samples from Gimbichu and 40 % of the samples from Lume district were found to be deficient. Whereas, all samples collected from Akaki, Ada'a and Minjar-Shenkora were above the critical values. The highest content of Mn (47.2 mg kg^{-1}) was observed in the sample collected from Ada'a district.

CONCLUSIONS

It is apparent from this study that Fe and Zn appeared to be deficient in all districts. Copper is above the critical levels in all samples collected. On the other hand, Mn falls in sufficient range at Akaki, Ada'a and Minjar-Shenkora, but deficient in 40 and 70% of soil samples from Lume and Gimbichu districts. This calls for detailed studies on these and other micronutrients by taking large number of soil and plant samples and conducting field trials.

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