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Soil micronutrient status Assessment in sugarcane plantation of Ethiopia: Case of Fincha and Metahara

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Abstract

The present study was conducted to assess some micronutrient status in Fincha and Metahara soils of Ethiopian sugar plantation which has never been done before. Thirty random samples from each plantation were taken at a depth of 0-30cm. The result of analysis showed the Micronutrients status and could be used to refine the calculation of fertilizers applied for sugarcane crops. Fertilizers use for sugarcane crops in the two estates, has until now focused on nitrogen and phosphorus macronutrients. The micronutrients status for this study, were extracted by using Mehlich-III multi-nutrient extraction method and their concentrations were measured by using inductively Coupled Plasma Optical Emission Spectrometer. The extraction was done for soil status of boron (B), copper (Cu) iron (Fe), manganese (Mn), and Zinc (Zn). The extracted Bo ranged from 0.06 to 0.12 and 0.9 to 1.09 mg/kg, Cu ranged from 3.21 to 4.93 and 2.07 to 3.02 mg/kg for, the extracted Fe ranged from 101.34 to 190.34 and 51.73 to 56.00 mg/kg , the extracted Mn ranged from 94.20 to 130.95 and 277 to 336.12 mg/kg and the extracted Zn ranged from 1.37 to 1.46 and 2.10 to 2.56 mg/kg in Fincha and Metahara soils, respectively. In order to strengthen this result, plant sample analysis and calibration of micronutrients with plant response in green house experiment is recommended.

Keywords: Boron, Copper, Iron, Manganese, Mehlich-III, Micronutrient, Zinc

1. Introduction

The term micronutrients refer to number of essential nutrients or elements that are required by plants in very small quantities. According to (Foth and Ellis, 1997), micronutrient are the elements that are contained in plant tissues, in amounts less than 100 mg kg^{-1}. From these four elements exist as cations in soils unlike to boron and molybdenum are zinc (Zn), copper (Cu), and iron (Fe) and manganese (Mn). In plants, they are important for protein and auxin production (Zn), as constituent of cytochrome oxidase (Cu), photosynthesis (Fe), carbon assimilation and nitrogen metabolism (Mn) (Alemu *et al.*, 2016). They are all harmful when the available forms are present in the soil in large quantities and indiscriminate use of micronutrients is not advisable because of the small amounts needed and their interaction with other nutrients (Wondewosen and Sheleme, 2011). Maximizing agricultural production needs, among others, a balanced use of micronutrients (Patel and Singh, 2009). The deficiency or the excess presence of micronutrients such as Fe, Mn, Zn and Cu may produce synergetic and antagonistic effects in plants. As a result, either deficiency or excess (toxicity) of micronutrients results in abnormal growth, which sometimes cause complete crop failure. Thus, micronutrient deficiency and toxicity can reduce plant yield (Teklu *et al.*, 2003). However, there is very little information available in Ethiopia about micronutrient levels in soils. Desta (1983) 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. (Teklu *et al.,* 2003), 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. (Asgelli *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. The deficiencies of Mo, Cu, and Zn are mainly reported on Ethiopian Nitisols (Tisdale *et al.,* 1995). Also, Yadav and Meena, (2009) reported the deficiency of Fe and Zn in the majority of soil samples collected from the Vertisols of central Ethiopia. Use of nitrogenous and phosphatic fertilizers in the intensive cropping system may cause the quick depletion of micronutrients in soils (Kitila, 2013). This indicates the need for systematic investigation of the status of micronutrients for each sugar estates. Thus attention should be given to access to up-to-date data about status of micronutrients to ensure sustainable sugarcane productivity. However, in Fincha and Metahara soils of Ethiopian sugar estates, information on micronutrient status as fertilizer was needed. The objective of this study, therefore, was to assess status of Bo, Cu, Fe, Mn and Zn, in at three soil types of Fincha and three fertility classes' soils at Metahara sugar estates.

2. Materials and Methods

2.1. Description of Study Area

The soil samples were collected from Fincha and Metahara sugar estates which are under Ethiopian Sugar Corporation. Geographically Fincha and Metahara Sugar Estates located in western and eastern Ethiopia lying between of 9°30' to 10°00' of North of latitudes, and 37° 15' to 37°30' of East of longitude 8°21' to 8o 53' N latitude and 39°12' to 39o 52' E longitude respectively. At an altitude in the range of 1350-1600 and 950 masl and average annual precipitation of 1300 and 551 mm. Based on FAO-UNESCO classification system, the soils of Fincha belong to Luvisols, Vertisols and Fluvisol (Murphy and Waish, 1972) and the former two soils account for more than 95 % of the total area of land planted with sugarcane at Fincha and Most soils of the Metahara Sugar Estate are comparatively of recent alluvial origin and are classified as Cambisols (Booker, 2009). The soils have high clay content and show shiny ped faces and thus are Hypovertic and Haplic Cambisols according to the FAO, (2006) classification. The clay soils cover more than 90% of the estate and generally the soils of the estate are grouped into three fertility classes as class I, class II and class III (Booker, 2009).

2.2. Soil sampling and preparation

Random soil samples from representative management field for each soil type of Fincha and soil fertility class of Metahara sugarcane plantation farm were collected following standard procedure described by (Brook, 1983), in which surface soil (0-30cm) were taken using augur from thirty replicated points by waking in a zigzag manners. Then all the thirty samples collected from each soil type were transferred into clean plastic bucket and mixed thoroughly to make a composite sample. From the composite sample 1 kg of subsample from each soil were taken and brought to Fincha sugar estate soil laboratory. In the laboratory the samples were air dried, grounded to pass 2 mm sized sieve and preserved for analysis of physicochemical properties and micronutrient analysis.

2.3. Analytical procedures

The processed soil samples were analysed for selected physicochemical properties following procedures described by Jones (2001) in which texture was determined by Bouyoucous hydrometer method, pH was measured in 1:2.5 soil water solution by digital pH meter, organic carbon (OC) by wet digestion method (Anderson and Christensen, 1998). The micro nutrients of the soil were determined by extracting soil by Mehlich-III multi-nutrient extraction method and their concentrations were measured by using Inductively Coupled Plasma Optical Emission Spectrometer (Mehlich, 1984).

2.4. Statistical analysis

Data on soil properties, soil micronutrients status were subjected to Pearson correlation analysis using SAS software (SAS, 2000) to determine the relationship between soil properties and micronutrients as different soil properties affect availability of micronutrients. This correlation analysis is very important for showing soil properties and micronutrient status and level of significance was tested by 1% and 5%.

3. Results and Discussion

3.1. Results

The physicochemical properties of soil samples of Fincha and metahara sugar states are summarized in Table (1 and 2). Accordingly the soils from Fincha and Metahara were found to be textural classes of clay. The pH (in soil: water) of the soils of Finchaa and Metahara ranged between 6.60 to 7.3 and 8.5 –8.6 with mean value of 6.90 and 8.60 respectively. According to Oyinlola and Chude, (2010) are classified as neutral and moderately alkaline at Fincha and Metahara respectively. The organic matter content of soils from Metahara varied between 1.5- 1.6 % with mean value of 1.55 % that of Fincha was1.20 to 2.20. According to Jones (1990), soil with OC contents between 1-2 % are in low category and hence all soils of Metahara and Fincha were classified as low in their OC contents.

Table 1. Selected physicochemical properties and micronutrient status of Fincha sugar estate soils.

Soil type	Sand	Clay	Silt	Textural Class	pH	OM	B	Cu	Fe	Mn	Zn
		%							mg/kg		
Luvisol	34.00	52.80	13.20	Clay	6.80	1.60	0.12	3.21	101.34	130.95	1.37
Vertisol	22.00	61.00	17.00	Clay	6.60	2.20	0.07	4.93	190.62	94.20	1.37
Fluvisol	26.00	56.00	18.00	Clay	7.30	1.20	0.06	4.32	171.36	99.95	1.46
Mean	27.30	56.60	16.00	Clay	6.90	1.66	0.08	4.15	154.44	108.37	1.40

Table 2. Selected physicochemical properties and micronutrient status of Metahara sugar estate soils.

Soil type	Sand	Clay	Silt	Textural Class	pH	OM	B	Cu	Fe	Mn	Zn
		%							mg/kg		
Class I	17.20	48.60	34.00	Clay	8.60	2.80	1.07	2.26	56.00	336.12	2.53
Class II	22.20	49.40	28.40	Clay	8.50	1.60	1.09	3.02	51.73	306.80	2.10
Class III	23.40	46.80	27.80	Clay	8.60	1.02	0.90	2.07	52.05	277.00	2.10
Mean	20.90	48.20	30.10	Clay	8.60	1.80	1.02	2.45	53.30	316.64	2.24

3.2. Discussion

3.2.1. Boron status

Mehlich III extractable B varied from 0.06 to 0.122 mg/kg, 0.9 to 1.09 mg/kg in sugarcane growing soils of Fincha and Metahara respectively (Table 1 and 2).The mean B value was found to be 0.08 mg kg^{-1} for Fincha, and 1.02 mg kg^{-1} for Metahara. All the soils of Fincha were found to be very low. On the other hand, soils of Metahara showed Mehlich III extractable B status of optimum range. All agricultural soils of the Fincha areas were below critical level in B status and it is one of the crop yield limiting nutrient in the study areas. The result of this study is in line with that of (Vijaya *et al.*, 2013 and Eyob, 2015), who reported that B was deficient in some soils of western and southern Ethiopia. The possible reasons for B deficiency in the study area may be due to loss of B through leaching in acidic soil, low B absorbing capacity of soils, low OM, continuous cultivation of soils, low B containing parent materials, lower application rate of manure and use of non B containing fertilizer (Chesworth, 2007). Generally, this finding revealed that B is deficient and it may be one of yield limiting elements in all soils of Fincha since its deficiency affects the growing points of roots, shoots and young leaves and retard the uptake of calcium (Tandon, 1997).

Therefore, it is strongly recommended that B should be included in blended or compound fertilizer to boost the crop yield in the Finchaa area. But at Metahara, since Mehlich III extractable B status of optimum range, no need to included in blended or compound fertilizer.

3.2.2 Copper status

As shown in Table (1 and 2), extractable Cu ranged from 3.21 to 4.93 and 2.07 to 3.02 mg/kg in sugarcane growing soils of Fincha and Metahara, respectively. The mean Cu values were found to be 4.15 and 2.45 mg/kg for Fincha and Metahara, respectively. According to Cu critical levels, adopted by (EthioSIS, 2014), the soils of the Fincha and Metahara sugar estates were found to be optimum in Mehlich III extractable Cu status. According to (Hillett *et al.*, 2015), Soils derived from coarse-grained sediments (sands and sandstones) as well as acid igneous rocks are usually low in Cu but in this study soils were not acidic since soils the study areas have the same parent material. According to the same author, factors affecting the soils ability to provide Cu to plants include pH, humus content and proportion of sand to clay. The findings of this study showed clearly that all soils of Fincha and Metahara should not be supplemented with Cu containing fertilizers.

3.2.3 Iron status

The Mehlich III extractable Fe varied from 101.34 to 190.62 and 51.73 to 56 mg/kg in sugarcane growing soils of Fincha and Metahara, respectively. The mean Fe values were found to be 154.44 and 56 mg/kg for Fincha and Metahara, respectively. According to the critical level adopted by (EthioSIS, 2014), almost all of sugarcane growing soil of Fincha, were found to be optimum in Fe status. This finding is in agreement with the results of (Abayineh, 2005), (Foth, *et al.*, 1997) and (Hillett *et al.*, 2015) who reported that Fe was adequate in the soil samples collected from different regions of the country. The existence of adequate Fe content in these soils may be due to the parent material that contains minerals like Feldspar, Magnetite, Hematite and Limonite which together constitute the bulk of trap rock in these soils (Teklu *et al.*, 2007). In addition to these, soil reaction (pH) of the Fincha soils may contribute to the high amount of available Fe since the pH of the majority of soils in the study area is around 7 that can enhance the solubility of Fe. All the sugarcane growing soils of Metahara, according to the critical level adopted by (EthioSIS, 2014), were found to be in very low category. This go in line with (Teklu *et al.*, 2003) reported that 20 % of Vitric Andisols collected from Rift Valley of Ethiopia were deficient in Fe. Similarly, Yadav and Meena, (2009) reported Fe deficiency in 96% of soil samples collected from central highlands of Ethiopia. Also, EthioSIS fertility mapping project reported that Fe was deficient in some Tigray agricultural soils (EthioSIS, 2014).

3.2.4 Manganese status

As shown Table (1 and 2), the Mehlich III extractable Mn ranged from 94.20 to 130.95 and 277 to 336.12 mg/kg for sugarcane growing soils of Fincha and Metahara, respectively. The mean Mn values were found to be 108.4 and 316.64 mg/kg for Fincha and Metahara, respectively. The concentration of extractable Mn ranged from low to optimum in soils from Fincha and Its concentration optimum to high in soils of Metahara sugar estate. This finding is in contrary with the finding of Eyob, (2015) and Vijaya *et al.*, (2013) who reported that amount of extractable Mn are generally high in the tropical soils and Mn toxicity is even more common than deficiency.

3.2.5 Zinc status

Table (1 and 2), shows that the extractable Zn ranged from 1.37 to 1.46 and 2.10 to 2.53 mg/kg for sugarcane growing soils of Fincha and Metahara, respectively The mean Zn values were found to be 1.40 and 2.24 mg/kg for Fincha and Metahara, respectively. The concentration of extractable Zn level of Fincha soils (Table1), according to the critical level adopted by (EthioSIS, 2014), (Table 5), were in low range and that of Metahara soils were in Optimum range. This may be due to the parent materials of soil that are high in Zn content at Metahara. Certain soil conditions reduce the availability of Zn, notably high pH (Katyal and Randhawa, 1983).

3.3. Simple correlation between extractable micronutrients and some soil properties

The correlation between soil properties and micronutrients, as tested at 0.01 and 0.05 levels is shown in Table (3 and 4). Factors affecting the extractability of micronutrients are parent material, soil reaction, soil texture, and soil organic matter (Brady and Weil, 2002). The soil texture of sand was highly negatively correlated with Clay, Silt, Cu and Fe and Clay, Silt and OM at Fincha and soils respectively. Clay soil separate highly positively correlated with Cu at Fincha and not correlated with any of properties at Metahara. At Fincha, silt, was highly negatively correlated with pH and highly positively correlated with OM and Cu at Metahara. The pH not correlated with any soil properties at Fincha and correlated negatively with OM and positively with Fe and Zn. OM not correlated with soil properties at Fincha and correlated positively with B at Metahara. Concentration of Cu correlated positively with Fe and Zn at Fincha and not correlated at Metahara. Fe correlated positively with Cu, Mn and Zn and Zn at Fincha and Metahara respectively.

Table 3. Correlation between soil properties and micronutrients of Fincha soils

Soil Properties	Sand	Clay	Silt	pH	OM	BO	Cu	Fe	Mn	Zn
Sand	1.00									
Clay	-0.96**	1.00								
Silt	-0.63*	0.40	1.00							
Ph	0.09	0.10	-0.61*	1.00						
Om	0.28	-0.26	0.18	0.08	1.00					
Bo	0.20	-0.14	-0.32	0.42	0.06	1.00				
Cu	-0.53*	0.60*	0.04	0.12	-0.09	0.29	1.00			
Fe	-0.56*	0.62*	0.11	-0.008	-0.43	0.003	0.80**	1.00		
Mn	0.30	-0.26	-0.23	0.29	0.30	0.40	-0.40	-0.56	1.00	
Zn	0.13	-0.23	0.21	-0.02	0.09	0.55	-0.77*	-0.77*	0.56*	1.00

**Significant at P = 0.01 level; * significant at P = 0.05 level; OM = Organic Matter

Table 4. Correlation between soil properties and micronutrients of Metahara soils

Soil Properties	Sand	Clay	Silt	pH	OM	BO	Cu	Fe	Mn	Zn
Sand	1.00									
Clay	-0.9**	1.00								
Silt	-0.50*	0.21	1.00							
pH	0.44	-0.23	-0.39	1.00						
Om	-0.60*	0.40	0.55*	-0.53*	1.00					
Bo	-0.20	0.15	0.38	-0.38	0.50	1.00				
Cu	0.20	-0.047	-0.21	-0.01	-0.14	0.44	1.00			
Fe	-0.21	0.16	0.38	-0.8**	0.50	1.0**	0.44	1.00		
Mn	-0.21	0.013	0.58*	0.06	0.40	0.48	-0.12	0.48*	1.00	
Zn	0.20	-0.10	-0.12	0.76**	-0.35	-0.25	0.19	-0.25	0.14	1.00

**Significant at P = 0.01 level; * significant at P = 0.05 level; OM = Organic Matter

Conclusion

The assessment results of micronutrient status of both Fincha and Metahara soils showed that soils samples from Metahara sugar state showed all assessed micronutrients are at optimum range and soil samples from Fincha sugar estate had low B and Z status and optimum other amount of micronutrients.

Significance of the study

This study was conducted discover Micronutrient level that can be beneficial for sugarcane growth. In states, the micronutrient level, which has not been studied well before, can be very significant for nutrient management and for further scientific study.

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