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Evaluation of Micronutrient Status in Nitisol, Vertisol and Their Relations under Wheat and Teff Growing Area of West Shewa Zone, Oromia

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Abstract: Soil micronutrients are important elements for plant growth despite being required in small quantities and they have the same agronomic importance as macronutrients and play vital roles in crop production. Based the point of view, the study was conducted to evaluatemicronutrient status in soil and their relations under wheat and teff growing area of West Shewa Zone, Oromia. Accordingly, about 90 composite soil and plant tissue samples were collected for each crop from nitisol and vertisol. The extractable micronutrients were determined by atomic absorption spectrophotometer. The study shows that the mean values of extractable micronutrients indicates that Fe (201.06ppm) medium in range, Zn (76.8 ppm) sufficiently level was recorded innitisol. Also medium in Fe (80.29ppm), sufficiency level of Zn (39.56ppm) and very low level in Mn (2.44ppm) and Cu (ppm) in recorded in vertisol, respectively. The mean values were in the order of Fe>Zn>Mn> Cu from nitisol. Positive and negative associations were observed between micronutrients in soil and plant tissue from both crop and soil type. Based on the analysis, the extractable Fe, Mn and Zn values were high and above the critical levels almost in 100% in nitisol. Therefore, the study indicates that there was a significant correlation among the available micronutrients studied and the soils will not require additional application of Fe and Zn rich fertilizer since they are above critical limits in both soil type but a balancing supply of copper and manganese fertilizers were recommended to vertisol.

Key words: Soil Samples · Soil Fertility · Extractant · Micronutrient

INTRODUCTION

The evaluation of soil fertility is perhaps the most basic decision-making tool in order to impose appropriate nutrient management strategies. Soil fertility depletion occurs when conditions that support soil's health are not maintained andthe components which contribute to fertility are removed and notreplaced [1]. Increased in cropyields from application of micronutrient nutrient source occurred in many parts of the world [2]. They further stated that, there is growing awareness that micronutrient deficiencies may limit cropyields even though plants require exceedingly small amounts. In Ethiopia, micronutrients investigation has received little attention since it was considered that there was adequate level of micronutrient [3]. In the central highland of Ethiopia, soil fertility is low to very low and the effect of liming on zinc showed that there was an adequate indication to warrant a further investigation into the possible deficiency of Zn in soil [4, 5] found that the contents of Fe and Mn were usually at an adequate level while Mo and Zn contents were variable.

Different factor affects the soil–plant relationship. Thus, a combined use of soil and plant analysis is believed to evaluate the complex interaction, get an accurate image of limiting nutrients and design corrective actions [6]. Ideally, soil and tissue nutrient concentrations are expected to be positively correlated for most nutrients [7]. Nevertheless, factors such as soil nutrient level, soil conditions, genotype or climate influence the required nutrient concentrations in plants [8, 9]. In order to improve nutrient application and crop yield, knowledge on soil–plant relationship has great practical importance. However, wide surveys dealing with soil–plant nutrient relationship are insufficient. Thus, it is hypothesized that most of the intensively cultivated fields under low- to

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no-input systems in west Shewa area are likely to be deficient in micronutrients. The objective of this study was, therefore, to evaluate soil and plant nutrient status and investigate soil–plant nutrient relationships on different soil types.

MATERIALS AND METHODS

Description of the Study Area: The study was conducted in Welmera and Adaberga Districts of West Showa zone, Oromia regional state during 2017/18.

Welmera district is located between 09°00'3"N latitude and 38°0'20" E longitude and at an altitude of about 2400 meter above sea level (masl). The rainfall is bimodal with average annual rainfall of 1041.4 mm, about 85% of which is received from June to September and the rest from January to May. The average minimum and maximum air temperature is 6.7 and 21.7°C respectively with relative humidity of 58.7% [10]. The environments are seasonally humid and the major soil type of the area is Eutric Nitisols (FAO classification).

Ada berga district is situated at the latitude of 09° 03' N, longitude of 38°30' E and an altitude of 2450 m.a.s.l. the experimental site has a mean annual rainfall of 1044 mm, mean maximum temperature 23.2°C, mean minimum temperature 7.8°C and mean relative humidity 61.6%. The -main rainy season is from June to September and accounts for 70% of the annual. Eutricnitisols associated with humicnitisols are the most prevalent soils (FAO classification).

Dendi district, is situated at the latitude of 9° Nandlatitude 3' 30"E. The topography is flat land situated at an altitude of 2200 ma.s.l. The soil in the study area is predominantly Vertisol. The area has a bimodal rainfall pattern, with the main rain from June to September and short rain from February to April. The long term (30 years) average annual rainfall, maximum and minimum temperatures are 1094.95 mm and, 24.6°C and 8.4°C respectively (Weather data from Ginchi sub center),

Farming Systems of the Study Areas: The farming systems in the study area are mixed crop-livestock production and mainly based on continuous cultivation with infrequent fallow periods. In the areawheat and barley is the dominant crop. In addition, potato and teff are also some of the major crops growing at Welmera and Ada Berga districts. Whereas, at Dendi district, *tef* (Eragrostis *tef*) is one of the major crops complemented by other cereals such as maize and chickpea, grasspea and wheat are also some of the major crops growing

Soil and Plant Sampling and Analysis: A total of 90 samples randomly taken from each field of wheat and teff-growing fields were used for soil and plant sample collection. From each field, relevant information regarding topography, cropping history, soil fertility management practices and estimated yield was recorded using a short-structured questionnaire.

Soil Sampling and Analysis: Soil samples were taken from 0–20 cm depth. About 10 subsamples from each field were taken to form 1 kg composite sample. After soil processing (drying, grinding and sieving), soil chemical properties their micronutrient contents was analyzed. Micronutrients (Fe, Mn, Zn and Cu) were extracted from the soil samples with DTPA as described by Lindsay and Novell [11]. All micronutrients extracted with DTPA were measured by atomic absorption spectrophotometer.

Plant Sampling and Analysis: For the determination of mineral nutrients, leaves adjacent to the uppermost mature or flag leaves were considered. The uppermost mature or flag leaves are best indicators of mineral nutrients [12, 13] and about 30 to 40 leaves/field were collected from different plants. These samples were homogenized to make one representativesample for a field. Leaves were first washed with distilled water, oven dried at 70 °C for 48 hr to a constant weight. Thereafter, samples were ground and stored in airtight plastic bags. From the composite samples, subsamples were taken for analyzing micronutrients (Cu, Fe, Mn and Zn). The tissue analysis was carried out at HARCsoil and plant analysis Lab. in accordance with the procedures indicated in Sahlemedhin and Taye [14]. Plant digests using concentrated nitric acid (HNO_3) and 30% hydrogen peroxide (H_2O_2) were prepared to extract and analyze Cu, Fe, Mn and Zn using by atomic absorption of spectrophotometer.

Statistical Analysis: Descriptive statistics was carried out to reveal the soil - plant relationships. Correlation analysis was performed to assess the relationships between soil and plant nutrient contents and it was considered as a good measure for judging the reliability of the results.

RESULTS AND DISCUSSION

Wheat and Teff Production and Soil Characteristic: The survey result revealed that wheat and teff cultivation in the sampled fields was carried out on varied by soil types. Wheat and teff production is based on continuous cultivation with little fallow periods. The major crops that are commonly grown on Vertisols in Ethiopia are teff. However, cereal-dominated cropping systems, aimed at meeting farmers' subsistence requirements, coupled with low usage of chemical fertilizers have led to widespread depletion of soil nutrients in the major cereal crops growing regions of the country. Heavy rains during the early part of the main cropping season (June to August) also cause substantial soil nutrient losses due to intense leaching and erosion on Nitisols and denitrification on frequently water-logged Vertisols. For managing soil fertility, farmers have been using DAPand urea fertilizers up to recent date .Then after NPS and NPSB was replaced. NPS and NPSB fertilizer was applied at higher rates than urea. In the surveyed fields, NPS and NPSBapplication on the sampled wheat and teff fields varied. The wider range of fertilizer use implies soil fertility management differences among wheat and teff-growing farmers [15, 16].

Extractable Micronutrients in Nitisols and Vertisols: Brady and Weil [17] indicated that the solubility, availability and plant uptake of micronutrient cations (Cu, Fe, Mn and Zn) are more under acidic conditions. The soil micronutrient contents revealed variability among wheat growing fields (Fig. 1& 2). The mean values were in the order of Fe>Zn>Mn> Cu at both study sites. Based on classification of micronutrients Fe in soil at welmera (Fig. 1) and at Adaberga (Fig. 2) was found in range of medium soil fertility classes (201.06 ppm) and(191.19ppm). The result of Zn in soil was 76.8 ppm at welmera (Fig. 1) and 76.29 ppm at Adaberga (Fig. 2) was found sufficiently level categories (Fig. 1 & 2). The DTPA soil test for Zn provides some indication of sufficiency.The presence of Fe in high concentrations in soils could lead to its precipitation and accumulation and upon complex chemical reactions leading to the formation of phlintite (laterite). This upon alternate wetting and drying could irreversibly yield hard consolidated material which could restrict root penetration and drainage. This observation is similar to that of Ephraim [16].

Whereas, Mn (ppm) content of the study sites were found in deficient level. Accordingly, high level of Fe and Zn can reduce Mn and it will be enhanced by addition of acid causing NH_4^+ to soil and the availability of thus micronutrients increased due to leaching losses, increasedsolubility, and sorption anions. Iron is an essential micronutrient for almost all living organisms because of it plays critical role in metabolic processes such as DNA synthesis, respiration and photosynthesis [17, 18]. In overall, available iron status was high (Figure 2). There may have high possibility for stress of iron toxicity as well deficiency of antagonistic elements in plants. Therefore, nutrients like potassium; phosphorus etc. should be applied in adequate amount for reducing iron toxicity stress in plants. Available iron showed high variability (191.19%) among the soil samples. In general soils which are dominated by acidic soil (nitisol) areas, the deficiency of Zn and Fe ismostly not expected, whereas deficiency of Cu was found in oxisol areas (nitisol) [19, 20].

Similarly, significant variation was observed in Vertisols (Figure 3). The concentration of EDTA extractable micronutrients in vertisols were in order of Fe >Zn>Mn>Cu. As rated [21, 22] micronutrients content indicates that medium in Fe (80.29ppm), sufficiency level of Zn (39.56ppm) and very low level in Mn and Cu (Figure 3.) According to the fertility classes suggested the mean value of extractable Fe and Mn in the study area indicates that, there is no as such problem of soil fertility regarding available Fe and Mn. [23] observed that the total Zn, Mn and Fe contents of the at all sites of his study area were comparable Vertisols at all sites of his study area were comparable and, on most cases, higher than values reported for most Vertisols elsewhere. These results are supported by the findings [24, 25]. This finding is in contrast with the report [26, 27] the amount of extractable Mn is generally high in the tropical soils and Mn toxicity is even more common than deficiency.

Micronutrient Concentration in Plant Tissue of Wheat (Nitisols) Andteff (Vertisol): There existed variability among micronutrient concentrations of wheat leaves. The mean concentration of Fe (318.29ppm), Zn (6.73ppm), Mn (53.27pmm), Cu(2.3pmm) were recorded from wheat tissue (Figure 1). Similarly, the concentration of Fe (429.56ppm), Zn (14.12ppm), Mn (71.27pmm) and Cu (4.58 pmm) were recorded (Figure 2) High concentration of Fe (pmm) was recorded from both sites while sufficient micronutrient (Zn, Mn and Cu) concentration in the plant tissue noted as[28, 29]. Whereas, the mean concentration of Fe (789.11ppm), Zn (19.47ppm), Mn (137.62ppm) and Cu (6.4ppm) were recorded from plant tissue of teff (Figure 3). Excess concentration of Fe (789.11ppm) and high concentration of Mn (137.62ppm) were recorded from the study sites, whereas sufficient micronutrient (Zn and Cu) concentration in the plant tissue were recorded as indicated by [30, 31] . When the solution PH was increased, Mn absorption increased and that of Fe decreased (Figure 3). In their further attempt to compare cheated Fe source with Fe in ionic forms, [32] observed that plant uptake of Fe was favored by Fe2+ or cheated Fe source as compared to Fe3+ source.

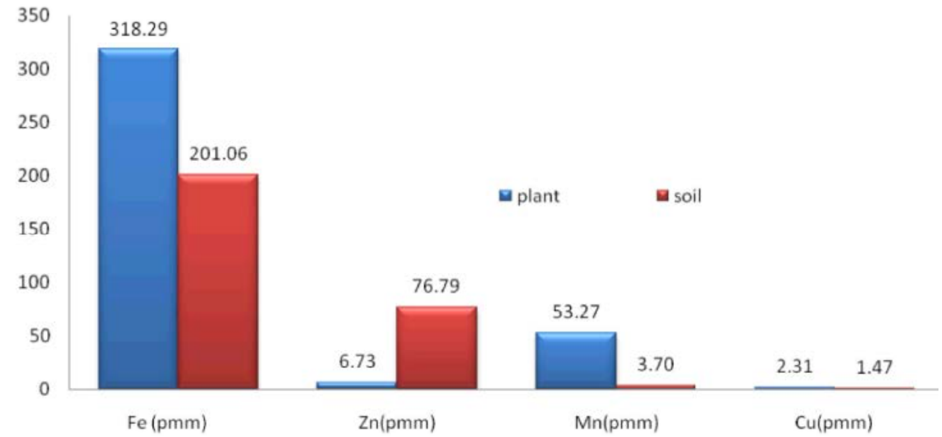

Fig. 1: Micronutrient concentration in plant and soil of wheat growing fields at Welmera districts

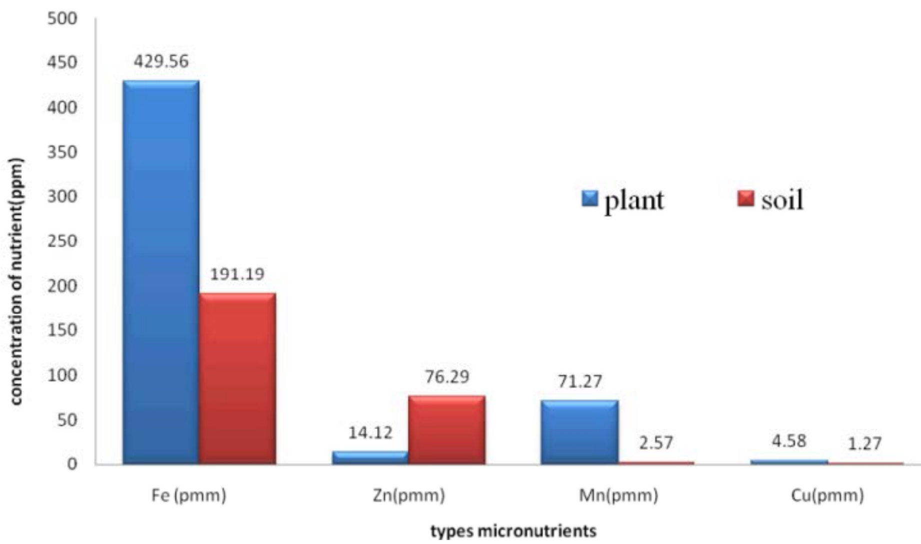

Fig. 2: Micronutrients concentration in plant and in soil of wheat growing fields at Adaberga districts

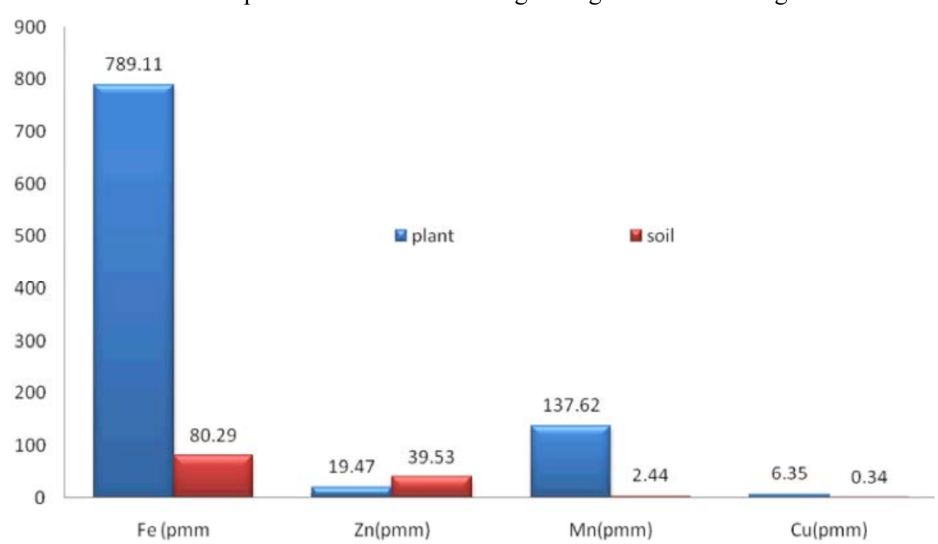

Fig. 3: Micronutrients concentration in plant and in soil of teff growing field at Dendi District

Table 1: The relationship between soil and plant tissues of wheat at Welmera District

	Plant				Soil			
	Fe	Zn	Mn	Cu	Fe	Zn	Mn	Cu
Fe in plant	1							
Zn in plant	0. 8**	1						
Mn in plant	0.589**	0.46*	1					
Cu in plant	0.89**	0.67**	0.68**	1				
Fe in soil	0.39*	-0.4*	-0.12	-0.23	1			
Zn in soil	0.39*	0.35*	0.03	-0.28	0.47	1		
Mn in soil	-0.4*	-0.43*	-0.13	-0.3*	0.57**	0.49**	1	
Cu in soil	0.27	-0.17	-0.2	-0.35	0.03*	0.48*	0.38*	1

* and ** significant at p≤ 0.01 and 0.001, respectively

Table 2: The relationship between soil and plant tissues of wheat at Adaberga District

	Plant				Soil			
	Fe	Zn	Mn	Cu	Fe	Zn	Mn	Cu
Fe in plant	1							
Zn in plant	0.3	1						
Mn in plant	0.64**	0.5**	1					
Cu in plant	-0.2	0.2	-0.1	1				
Fe in soil	0.46*	-0.09	-0.36	0.05	1			
Zn in soil	0.23	-0.09	0.06	0.22	0.09	1		
Mn in soil	-0.47	-0.04	0.28	0.06	0.89	0.21	1	
Cu in soil	0.34	-0.21	-0.28	0.17	0.73**	0.28	0.76	1

* and ** significant at p≤ 0.01 and 0.001, respectively.

Table 3: The relationship between soil and plant tissues of teff under vertisol at Dendi District

	Plant				Soil			
	Fe	Zn	Mn	Cu	Fe	Zn	Mn	Cu
Fe in plant	1							
Zn in plant	-0.25	1						
Mn in plant	0.03	-0.12	1					
Cu in plant	-0.11	-0.03	-0.15	1				
Fe in soil	0.22	0.20	-0.21	-0.3	1			
Zn in soil	0.51*	-0.07	0.18	0.2	-0.29	1		
Mn in soil	-0. 01	0.10	0.15	-0.15	0.56*	-0.02	1	
Cu in soil	0. 3	-0.04	-0.11	-0.1	0.53*	-0.06	0.39	1

* and ** significant at p≤ 0.01 and 0.001, respectively

Relation Between Soil Nutrients and Plant Nutrients: In order to evaluate whether a particular nutrient in the wheat plant tissue is generally in similar trends with soil nutrient status, a simple correlation analysis was performed (Table 1, 2 & 3). Positive and negative associations were also observed between micronutrients (Table 1, 2 & 3). Accordingly, Fe content was significant and positive correlation with Fe(r=0.39), Zn(r=0.39) and negative correlation with Mn (r=-0.4) of the soil (Table 1). Similarly, the Fe content in wheat tissue was significant and positive correlated with Fe (r=0.46) and negatively correlated with Mn (r=-0.4) of the soil (Table 2).

In vertisols of teff growing fields, Fecontent in plant tissue was significant and positively correlated with Zn(r=0.51), non-significant and positively correlated with Fe(r=0.22) and non-significant and positively correlated with Cu(r=0.3) in soil (Table 3). These results are supported by the findings of authors [33, 34].

CONCLUSION

In terms of soil fertility, one cannot talk about the complete fertility of soils in the absence of micronutrients. Though they are required in trace, they are as essential as the macronutrients. Unfortunately, there is no enough information on micronutrients of Ethiopian soils in general and the study area in particular. The nutrient deficiencies identified in this study could be due to either inherently low availability of these nutrients in the soils or as a consequence of continuous intensive cropping without applying fertilizer or manure containing these nutrients. This led to low levels of some micronutrients in the soil. This was partly reflected in the leaf or tissue test results. In addition, the influence of soil nutrient imbalances on the uptake of nutrients was observed. The overall result obtained is indicative of the existing situations. Furthermore, it also showed that soil test should be complemented with tissue analysis. Therefore, soil management practices and fertilizer application that would address observed nutrient limitations of micronutrients is recommended for realizing better yield. In addition, further studies considering other all cereal crop and soil type is suggested.

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REFERENCES

1. FAO (Food and Agriculture Organization), 2015. Soil fertility management in support of food security in Sub-Saharan Africa. Rome, Italy. 2001. ftp://fao. org/agl/agll/docs/foodsec.pdf. Accessed 20 Jan.
2. Asgelil, D., B. Tayeand A. Yesuf, 2007. The status of micro-nutrients in Nitisols, Vertisols, Cambisols and Fluvisols in major Maize, Wheat, Teff and Citrus growing areas of Ethiopia. In: Proceedings of Agricultural Research Fund, pp: 77-96.
3. Yifru, A. and K. Mesifne, 2013. Assessment on the Status of Some Micronutrients in Vertisols of the Central Highlands of Ethiopia international Research. J. Agric. Sci. Soil Sci., 3(5): 16.
4. EthioSIS (Ethiopia Soil Information System), 2015. Ethiopian Agricultural Transformation Agency.http://www.ata.gov.et/highlighted-deliverables/ethiopian-soil-information-system-ethiosis/.
5. Fanuel Laekemariam, Kibebew Kibret, Tekalign Mamo and Heluf Gebrekidan, 2016. Soil–Plant Nutrient Status and their Relations in Maize-Growing Fields of Wolaita Zone, Southern Ethiopia, Communications in Soil Science and Plant Analysis, 47(11): 1343-1356
6. Aref, F., 2011. Concentration of zinc and boron in corn leaf as affected by zinc sulfate and boric acid fertilizers in a deficient soil. Life Science Journal 8(1): 2-11.
7. Fageria, N. K., V.C. Baligar and C.A. Jones, 2011. Growth and mineral nutrition of field crops, 3rd ed. Boca Raton, FL USA: CRC Press.
8. Fanuel Laekemariam, 2015. Soil spatial variability analysis, fertility mapping and soil plant nutrient relations in Wolaita Zone, Southern Ethiopia. PhD dissertation. Graduate School, Haramaya University, Harar, Ethiopia.
9. Ethio SIS (Ethiopia Soil Information System), 2014. Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia. Addis Ababa, Ethiopia, July 2014
10. HARC (Holetta Agricultural Research Center), 2016/2017. Agrometeorological data annual progress Report, Holeta, Ethiopia
11. Lindsay, W.L. and W.A. Novell, 1978. Development of a DTPA soil test for zinc, iron, managancese, Litz, R.E. 2000.Botany, Production and CABI.UK. London, pp: 184-185.
12. Campbell, C.R. and C.O. Plank, 2000. Reference sufficiency ranges of corn. In Reference sufficiency ranges for plant analysis in the southern region of the United States C. Southern cooperative series bulletin #394, ed. R. Campbell. Raleigh, NC: North Carolina Department of Agriculture and Consumer Services Agronomic Division.
13. Ramulu, C. and G.B. Raj, 2012. Nutrient status and extent of their deficiencies in maize crop a survey in three districts of Andhra Pradesh. Journal of Research ANGRAU, 40(1): 16-20.
14. Girma Chala and Temesgen Desalegn, 2020. Optimization of Nitrogen and Phosphorus Fertilizer for Growth and Yield of Food Barley on Nitisols in the Central High Lands of Ethiopia. World Journal of Agricultural Sciences, 16(2): 74-81.
15. Sahlemedhin, S. and B. Taye, 2000. Procedures for soil and plant analysis. Technical paper 74, National soil research center, Ethiopian Agricultural Research Organization, Addis Abeba, Ethiopia.
16. Matias Dejene, Girma Chala, Zeleke Obsa and Mihretu Bedasa, 2021. Soil Test-Based Phosphorus Calibration Study for Chickpea (*Cicer arietinum*) on Vertisol of Dendi District Under Balanced Soil Fertilization in Central Ethiopia. World Journal of Agricultural Sciences, 17(2): 95-103, 2021. ISSN 1817-3047.

17. Rout, G.R. and S. Sahoo, 2015. Role of iron in plant growth and metabolism. Review of Agriculture Science, 3: 1-24.
18. Brady, N.C. andR.R. Weil, 2005. The Nature and properties of soil (Thirteenth Edition) Macmillan Publishing Co. New York
19. Ephraim, R.B., 2012. Status and distribution of available micronutrients along a toposequence at Gubi Bauchi North Eastern Nigeria. International Research Journal of Agricultural Science and Soil Science, 2(10): 436-439.
20. Baissa, T., 2004. Assessment of micronutrient status of Nitisols and Andisols in some selected areas of Ethiopia for maize production. PhD dissertation, Graduate School, Kasetsart University, Thailand.
21. Bellete, T., 2014. Fertility mapping of soils of Abay-Chomen District, Western Oromia, Ethiopia. MSc Thesis, Haramaya University, Harar, Ethiopia.
22. Jones, J.B., 2003. Agronomic Handbook: Management of crops, soils and their Fertility. Boca Raton: CRC Press LLC, pp: 482.
23. Hazelton, P. and B. Murphy, 2007. Interpreting soil test results: What do all the numbers mean? 2nd Edition.CSIRO Publishing, 152, 7.
24. Eyob, T., K. Kibebew, M. Tekalign and S. Hailu, 2015. Assessment and Mapping of Some Soil Micronutrients Status in Agricultural Land of Alicho-Woriro Woreda, Siltie Zone, Southern Ethiopia. Am. J. Plant Nutr. Fertil. Technol.. 5: 16-25.
25. Nandapure, S.P., B.A. Sonune, V.V. Gabhane, R.N. Katkar and R.T. Patil, 2011. Influence of long term fertilization on micronutrients availability, their uptake and productivity of sorghum-wheat sequence under semi-arid condition on a Vertisol. Crop Research (Hisar), 42(1/2/3): 35-39.
26. Matias Dejene, Girma Chala and Zeleke Obsa, 2021. Response of Bread wheat (*Triticum aestivum* L.) for Different Application Rates of Blended Fertilizer (NPSZnB) and Urea on Nitisols of Ejere District, Central Highlands of Ethiopia. World Journal of Agricultural Sciences, 17(1): 33-39, 2021 ISSN 1817-3047.
27. Haque, I., N.Z. Lupwayi and Tekalign Tadesse, 2000. Soil micronutrient contents and relation to other soil properties in Ethiopia. Communications in Soil Science and Plant Analysis, 31: 17 &18: 2751-2762
28. Beyene, D., 1982. Micronutrient status of some Ethiopian soils. Soil Science Bulletin No. 4, Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia, pp: 1-43.
29. Asgelil Debebe, Taye Bekele and Yesuf Assen, 2007. The status of Micro-nutrients in Nitisols, Vertisols, Cambisols and Fluvisols in major maize, wheat, teff and citrus growing areas of Ethiopia. In: Proceedings of Agricultural Research Fund Research Projects Completion Workshop held on 1-2 February 2007 at Ethiopian Institute of Agricultural Research, pp: 77-96.
30. Alemu Lelago, Tekalign Mamo, Wassie Haile and Hailu Shiferaw, 2016. Soil micronutrients status assessment, mapping and spatial distribution of Damboya, Kedida Gamela and Kecha Bira Districts, Kambata Tambaro zone, Southern Ethiopia. African Journal of Agricultural Research, 11(44): 4504-4516, 3.
31. Lemma, G. and G.N. Smit, 2008. Relationships between plant and soil nutrient status and position in the landscape on Pellic Vertisols of Ethiopia. Afr J. Plant Soil, 25: 119-26.
32. Schwab, G.J., C.D. Lee, R. Pearce and W.O. Thom, 2007. Sampling plant tissue for nutrient analysis. University of Kentucky Cooperative Extension. AGR-92 Loide V. 2004. About the effect of the contents and ratios of soil's available calcium, potassium and magnesium in liming of acid soils. Agronomy Research, 2(1): 71-82.
33. Neguse, A. and E. Kissi, 2012. Physicochemical characterization of Nitisol in Southwestern Ethiopia. Global Advanced Research Journal of Agricultural Science, 1(4): 066-073.
34. Denis, M.K.A., L.P. Parameshgouda, M.K. Augustine and H.S. Daniel, 2017. Assessment of soil fertility status using nutrient index approach. Acad. J. Agric. Res., 5(2): 028-038.