

## Level of zinc in maize seeds and maize growing soils of central Mecha, Amhara National Regional State of Ethiopia

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### ABSTRACT

Ethiopia is one of the world countries with reported zinc deficiency or high probability of zinc deficiency. Zinc deficiency is an important soil constraint to crop production, food quality and human health. The aim of this study was to evaluate the zinc concentration of different cultivars of maize seeds and soil samples in central Mecha area using a laboratory analysis to establish whether the roles and effects of zinc in crop productivity and quality in the area could be significant due to plant factors (e.g. cultivar) or changes in soil nutrient zinc concentration or both. Thirty representative soil samples from seven kebeles of the central Mecha and six genotypes of maize grains (Bako Hybrid-540, Bako Hybrid-543, Bako Hybrid-660, Pioneer Hybrid-3253, Melkassa Hybrid-2, and Melkassa Hybrid-4) available in the region for farmers archived by Ethiopian Seed Enterprise (ESE) were collected and analyzed in the laboratory. Zinc levels were determined by FAAS using wet digestion and dilute acid extraction methods. The mean pH (KCl) value of the soils indicated the samples studied are acidic (pH = 4.60). The means and ranges of concentrations of total zinc using strong acids wet digestion and available HCl-extractable zinc in soils (mg Kg<sup>-1</sup> DW) were 50.49 mg Kg<sup>-1</sup> (44.80 to 65.22 mg Kg<sup>-1</sup>) and 2.95 mg Kg<sup>-1</sup> (1.76 to 4.94 mg Kg<sup>-1</sup>), respectively. ANOVA analysis revealed significant differences (P < 0.05) between maize varieties in zinc levels. There was significant genetic variability in the level of zinc between the maize cultivars from 16.18 mg Kg<sup>-1</sup> for Bako Hybrid-540; 20.08 mg Kg<sup>-1</sup> for Bako Hybrid-660; 21.08 mg Kg<sup>-1</sup> for Pioneer Hybrid-3253; 23.26 mg Kg<sup>-1</sup> for Bako Hybrid-543; 29.38 mg Kg<sup>-1</sup> for Melkassa-2 to 32.52 mg kg<sup>-1</sup> for Melkassa-4. Chemical analysis of composite soil samples indicated that inherent zinc level was on the borderline sufficiency to support good crop growth for now, however; the variations in the level of zinc among the different maize cultivars should be significant in limiting high and quality yield for consumption. Adequate zinc in soils and high zinc concentrations in seeds ensure agronomic and nutritional benefits resulting in high yield and nutritional quality crops.

**Keywords:** Crops, Micronutrients, Zinc deficiency, Soil acidity, Ethiopia

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### INTRODUCTION

Zinc (Zn) is an essential micronutrient for plants, animals as well as for humans (Hotz and Brown, 2004). It is an essential trace element and a constituent of more than 300 metalloenzymes involved in major metabolic pathways in biological systems that support life. Thus, there is always an optimal concentration of this essential element required by organisms; above or below the optimal concentration, in which a toxic or deficiency state in the ecosystem is developed may compromise

health, quality and productivity. A typical dose-response curve for elements in crops is shown below (Figure 1) (Alloway *et al.*, 2004).

The soil is the primary source of zinc for plants, animals and humans. The zinc mineral that is supplied through the food chain from the soil overlying the surficial lithosphere could be sufficient, deficient or excessive resulting into effects on health, quality and productivity of plants, animals and humans; mostly with hidden symptoms and sometimes with clear subclinical and clinical symptoms. The underline zinc deficiency in soils and crops as-

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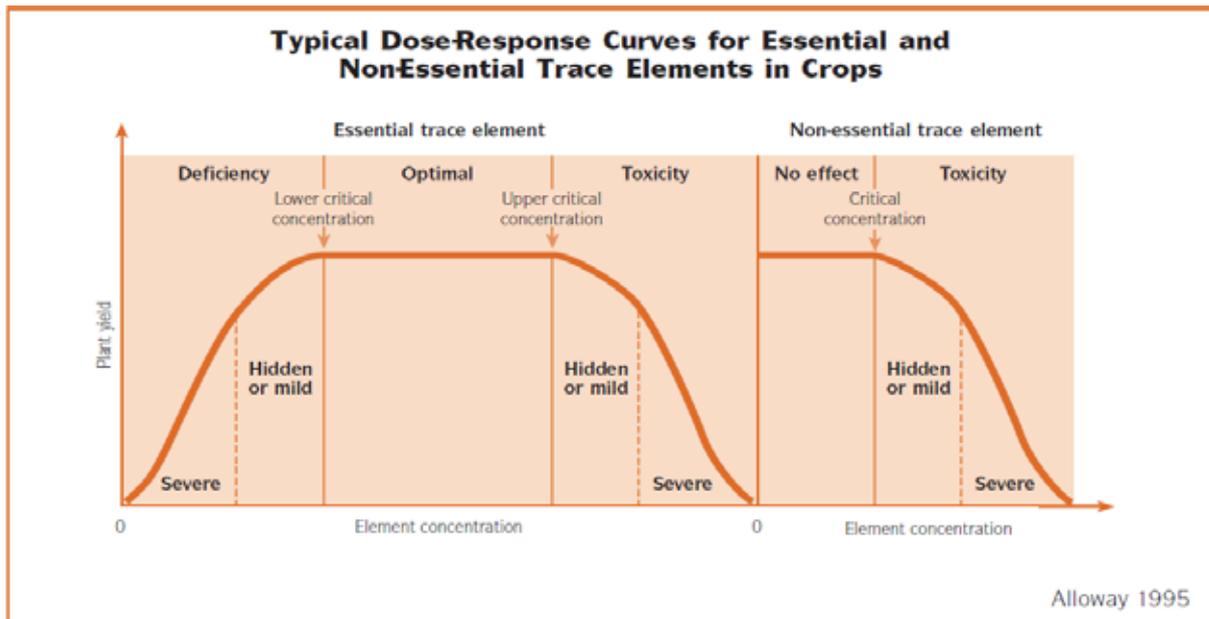


Figure 1. Typical dose-Response Curves for Essential and Non-Essential Trace Elements in crops.

sociated with soil infertility; yield loss, immaturity and chlorosis in plants is caused by several factors including low total zinc content in the soil, use of zinc inefficient crops, and high phosphate application among some others (Figure 2) (Cakmak, 2008).

Zinc deficiency in crop production is known in

many parts of the world with deficient soils in their underlying agricultural soil. Agricultural productivity in Ethiopia is below the region average because of soil fertility problems due to nutrient depletion or unavailability. An earlier global project (initiated in 1974 by FAO) aimed to determine the status of soil micronutrients in agricultural systems

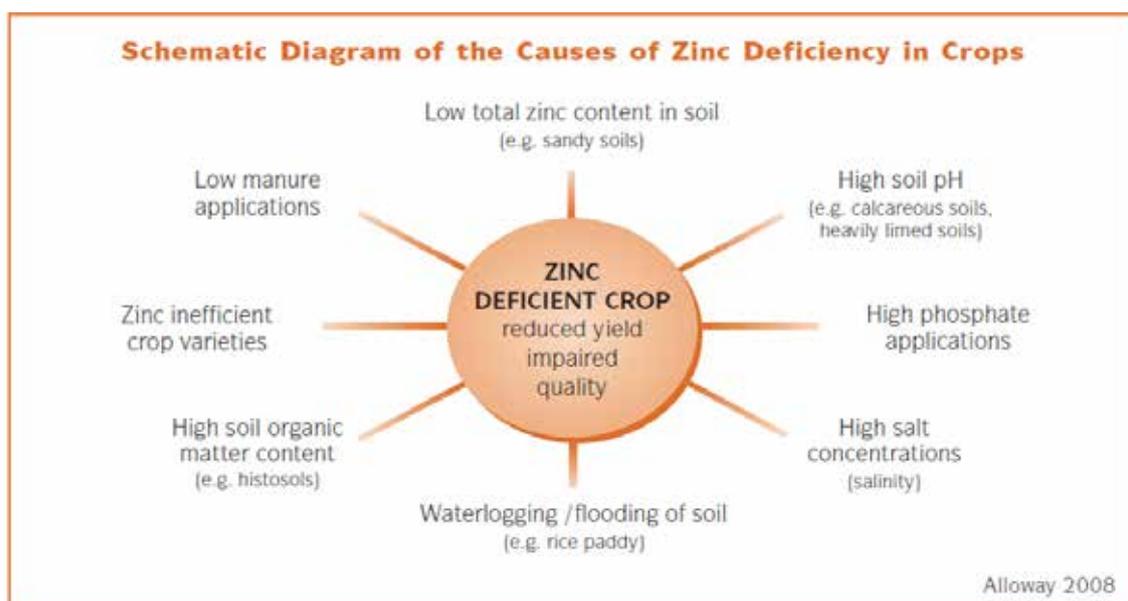


Figure 2. Schematic Diagram of the Causes of Zinc Deficiency in Crops.

has showed low concentration products for iron and zinc deficiencies (Sillanpaa, 1990). In recent researches to assess the status of micronutrients in central highlands of Ethiopia the available Zn in Nitosols, Luvisols and Cambisols soils in Bale area were low (Teklu Baissa *et al.*, 2005; Teklu Baissa *et al.*, 2007; Asgelil Dibabae *et al.*, 2007; Ashenafi Ali *et al.*, 2010; Mesfin Kebede and Yifru Abera, 2013; Tuma Ayele *et al.*, 2014).

According to a WHO report on the risk factors responsible for development of illnesses and diseases, Zn deficiency ranks 5th among the 10 most important factors in developing countries. Zinc deficiency in animals and human beings due to the lack of Zn in their diet or unavailability for absorption is associated with cessation of growth, psychomotor delay, hypogonadism and suppression of both primary and secondary sexual characteristics. There are estimates that some two billion people worldwide are afflicted by Zn deficiency, and up to half of the population in developing countries are at risk of Zn deficiency (WHO, 2002).

Ethiopia is one of the world countries with reported zinc deficiency or high probability of zinc deficiency (Welch *et al.*, 1991; Alloway *et al.*, 2004). Zinc deficiency is an important soil constraint to crop production, food quality and human health. A study carried out in Ethiopia on existence of zinc deficiency showed that high prevalence of parental zinc deficiency exists and that it is one of the major contributing factors for high stunting rates in infants and young children in Ethiopia (Jemal Haider *et al.*, 2005; Afework Kassu *et al.*, 2008; Samson Gebremedhin *et al.*, 2011). Zinc deficiencies are thus known in Ethiopian population particularly in rural and slum areas where people mainly depend on cereals as the main staple food and with little or no access to fruits and vegetables and animal products.

Generally, the distribution of zinc deficiency in

the world correlates with the availability of Zinc in the biological ecosystem (Welch *et al.*, 1991; Alloway *et al.*, 2004). The regions with Zn-deficient soils are most of the time the regions where Zn deficiency in human beings is widespread, for example in India, Pakistan, China, Iran and Turkey (Yang *et al.*, 2007). There are suggestions indicating that available Zn in the soils can be a limiting factor for crop production and zinc deficiency in the population who depend on Zn deficient soils. The main hazards that limit high yield crop production and access to quality food and micronutrients for human and livestock consumption in Ethiopia based their roots from soil fertility challenges including top soil erosion, organic matter, macro and micro nutrients depletion, acidity and an array of pests and diseases including African boll worm, grasshopper, maize stalk borer, aphids and root rot (Yihenew Gebreselassie, 2002; ATA, 2013). However, the empirical relationship between widespread Zn deficiency problem in Ethiopian population and soil concentrations and plant uptake has not been reported or diagnosed.

In this study availability of zinc in the soils of nitosols in central Mecha Kebeles in the south west maize livelihood area in Amhara and zinc accumulation in maize cultivar grains for seeds cropped in the area were diagnosed. The main objective of the study was to identify issues to improve the management of maize production in the study area with respect to yield and nutritional quality increment for human and livestock consumption in the region.

## MATERIALS AND METHODS

### Description of the study area

The South West Maize livelihood zone is one of the historically food secure areas in Amhara Region. It spreads across: West Gojam; Agew; and

East Gojam. It is predominantly located in woina dega agro-ecology with some parts kola. The study area, Mecha woreda is located in this maize livelihood zone in the southwest Amhara Regional State in Ethiopia (Figure 3). The study sites cover seven central Kebeles around Merawi town, about 35 Km south from Bahir Dar, the capital city of the Region. The seven Kebeles are Tagel Wodefit, Ambo Mesk, Inguti, Kudmi, Enamirt, Bachima and Enashenifalen. Together, they have a production area for maize (*Zea mays L.*) of more than 27,000 ha.

The region has a high crop production potential. However, agricultural productivity has not reached its potential so far and people living in the area who depend on staple foods from their agriculture have paradoxically witnessed micronutrient defi-

ciencies (a hidden hunger) due to the lack of nutrient dense quality foods (Melaku Umeta, 2003).

### Research Methodology and Data Analysis

Thirty representative soil samples from seven kebeles from central Mecha and six genotypes of maize grains ((three Bako Hybrids, BH-540, BH-543 and BH-660); (a Pioneer Hybrid, PH-3253) and (two Melkassa Hybrids, MH-2 and MH-4)) available in the region for farmers archived by Ethiopian Seed Enterprise (ESE) in Bahir Dar were collected and analysed for zinc levels during land preparation periods from February to June 2010. The randomly selected thirty half-hectare individual farm fields which were systematically chosen prior to the field visit using pre defined coordinates by a portable global positioning

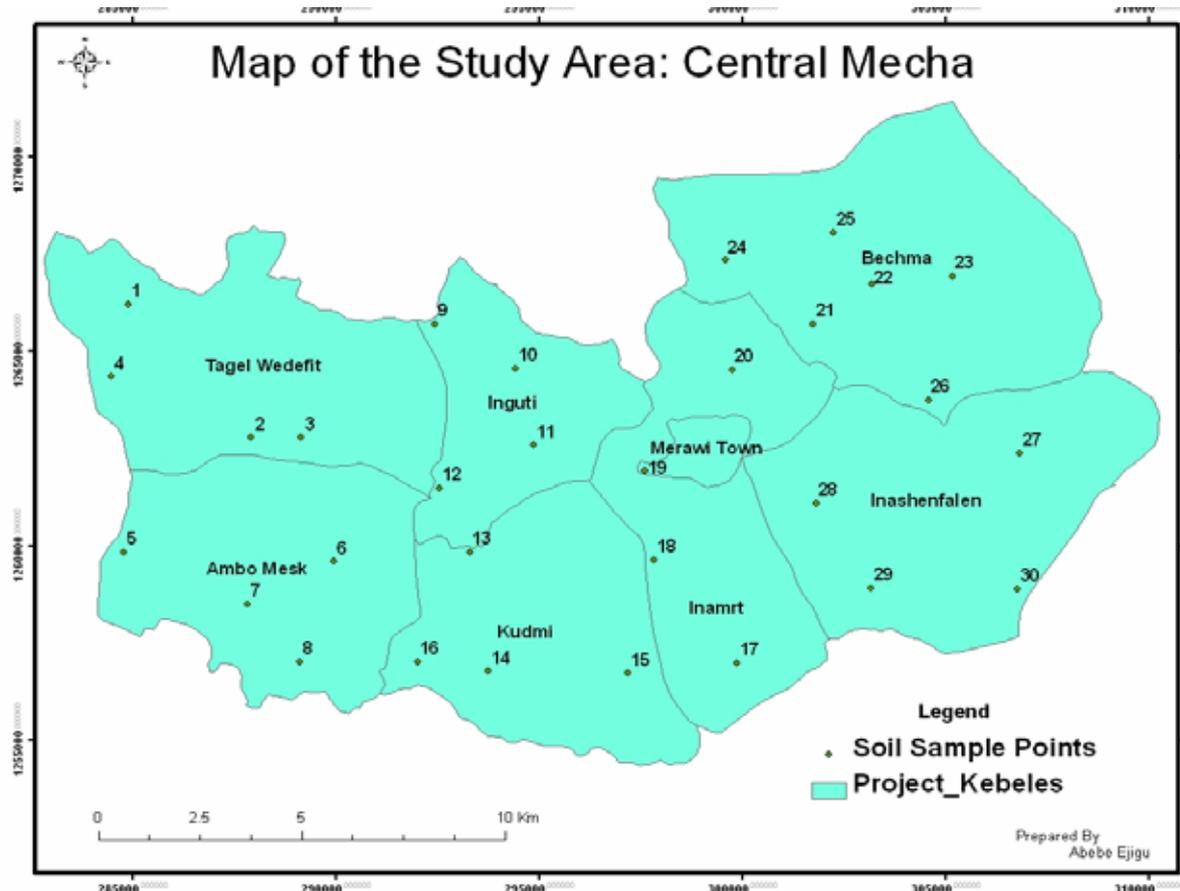


Figure 3. Map of the Central Mecha Kebeles and Farm Fields where thirty (1-30) Composite Soil Samples were collected.

system (etrex Vista HCX Garmin, USA) with positional accuracy of a few meters into the nearest farm field. From each of this farm fields, six soil point samples of 0 to 20 cm depth were dug at different points in a zig-zag pattern inside the fields and mixed into one composite sample per field. In this way, thirty composite soil samples were collected from Enguti (4 fields), Enamirt (4 fields), Enashenfalen (4 fields), Kudmi (4 fields), Ambo Mesk (4 fields), Tagelwodefit (4 fields), Bachima (6 fields). Approximately 1 kg of each of the composite soil samples were packed in polythene bags and transported into laboratory; air-dried and passed through a 2 mm sieve and archived for standard laboratory analyses. About 100 g of each of the archived different cultivars of maize grain samples from regional Ethiopian Seed Enterprise archive in Bahir Dar were packed in polyethylene bag, transported, and rinsed briefly with deionized water, dried at 80 °C, and ground into a powder with manual grinding in an agate pestle and mortar.

The soil pH was measured potentiometrically using a digital pH meter in a supernatant suspension of 1:2.5, soil: liquid ratio and the liquid were water and 1M of KCl using a method outlined by Van Reeuwijk (Van Reeuwijk, 1993). Oxidable organic carbon (OC) was measured using the method of Walkey and Black dichromate wet oxidation method (Walkey and Black, 1934). Approximately 10 g of composite soil samples from each field and grain samples from the ESE archive were further ground to <0.15mm in an agate ball mill.

The total zinc concentrations in the soil and grain samples were determined by a wet digestion method as described by Minaleshewa A (Minaleshewa *et al.*, 2010) after about 0.5 g of the samples were digested with ultra pure concentrated HCl (36-38%, Hopkins and Williams, UK), HNO<sub>3</sub>

(69-72%, Spectrosol, BDH, UK) and hydrogen peroxide solutions (35% v/v, Blulux, Laboratories (P) Ltd., India) in open vessels inside a fume hood. The extractable zinc concentrations from the soils were determined by approximately taking 0.5 g of composite soil samples from each field and extracting using 20 ml of 0.01M HCl extractant (soil: solution ratio 1:5) according to Shituu, Brennan, Srivastava, and or Mclean and Langille (Mclean and Langille, 1976; Brennan *et al.*, 1993; Srivastava *et al.*, 1996; Shituu, 2013; Tayie *et al.*, 2013). Distilled de-ionized water was used throughout the analysis.

Concentrations of Zn in the digests or extracts were determined by Flame Atomic Absorption Spectrometry (Buck Scientific Model 210 VGP, East Norwalk, USA) equipped with deuterium arc background correctors using air-acetylene flame (Lindsay and Norvell, 1978). All statistical analyses were performed by means of the software SPSS 11.5 (SPSS Inc. 2002) and Excel 2007 for Windows.

### **Quality Assurance and Quality Control Methods**

To check the efficiency of the procedure in determining the total and phytoavailable zinc in soil and grain samples using Flame atomic absorption spectrometry triplicate measurements of the samples and measurements after appropriate stock solutions of zinc spiked on them were performed. The results of the percentage of recoveries for studied materials were all between 90 to 105%. The detection limit of the instrument was determined to be as low as 0.5 µg g<sup>-1</sup>.

## **RESULTS AND DISCUSSION**

### **Properties of Studied Soils**

The soils in central Mecha woreda are largely developed on parent materials of volcanic origin

predominantly basalt. In terms of topography, the zone is predominantly plain with some hills between 1500 and 2500 meters altitude (Yihenew Gebreselassie, 2002). The interrelationships between many soil-forming factors in years have resulted in the formation of an agriculturally important reddish brown soils which were classified Nitosols according to the FAO soil classification system. The soils are mostly red and moderately fertile. The reddish brown clay soils have deep profile that allow easy root penetration and combine good moisture retention with free drainage. All sampled soils were characterized by a medium to high clay content (about 30% mean average that is ranging from 160 to 560 g kg<sup>-1</sup>). The soil OC content was generally low (<1%), ranging from 3.57 to 6.2 g kg<sup>-1</sup>, which is typical for soils in the region. The pH (CaCl<sub>2</sub>) (3.9 to 5.7) values of the soil samples studied in here indicated that about 4% of the soil samples were highly acidic (pH 3-4), 76% of them were moderately acidic (pH 4-5) and only 20% of the sampled soils were slightly acidic (pH 5-6). Low organic matter, high phosphorus fixing capacity and acidity of the soil in the area has been previously identified as limiting factors for agricultural quality and productivity in the area (Yihenew Gebreselassie, 2002; ATA, 2013). Total annual rainfall is comparatively very high between 1713 and 1881 in the rainy season (Kiremt) which lasts from May to June and with a long-term mean of 1366 mm per annum. Temperature in the area varies between the mean annual maximum of 26 °C and mean annual minimum of 10 °C.

### **Total and Available Zinc Concentrations in Soils**

The total zinc content of a soil is largely dependent upon the geochemical composition of the weathering rock parent material on which the soil has

developed (Kabata-Pendias and Pendias, 2001). However, in some cases, environmental pollution or the agricultural application of zinc-rich materials can mask the parent material's contribution. The average zinc content of rocks in the Earth's crust is 78 mg Zn kg<sup>-1</sup> and the average concentrations of zinc in the various types of rock which make up the Earth's crust show higher concentrations of zinc for the basic igneous rocks, such as basalts and for sedimentary rocks containing clay and shale basis. More silica-rich igneous rocks, such as granites, metamorphic rocks including gneiss, and sedimentary rocks including limestone and sandstone have much lower total zinc contents. These examples show a clear trend of low concentrations in sandy soils and higher zinc concentrations in soils with larger clay contents. Sandy soils all over the world are often found to have low, or deficient, zinc concentrations for crops. This is a consequence of both the higher zinc concentrations in clay and shale parent materials and also the greater ability of clay-rich soils to adsorb and retain zinc and other elements relative to soils with lower percentages of clay and higher percentages of sand (Alloway *et al.*, 2004).

However, it is important to stress that in many parts of the world, soils tend to be very heterogeneous in their distribution, especially in areas affected by soil formation processes with a wide range of soils developed on drift deposits. Thus, patches of sandy soil of low zinc and other nutrient element status can often be found amongst more clay-rich soils with adequate levels of available micronutrients. Zinc total value may be very low in highly acidic soils due to the intense soil leaching (Brennan *et al.*, 1993). N, P, K, S and Cu, Zn and Mo deficiencies are common in many coarse textured, acid soils of Ethiopia. Zinc deficiency is widespread in Ethiopia's human and cattle populations that depend on teff, maize and

straw, respectively, as major source of Zn. Cereals Zn concentration has been reported to be low in Ethiopia. This could be partly due to low soil Zn supply (Melaku Umeta *et al.*, 2003).

The means and ranges of concentrations of total zinc in the studied soil samples were found to be 50.49 mg Kg<sup>-1</sup> (44.80-65.22 mg Kg<sup>-1</sup> DW), respectively. A critical value of 20 mg Kg<sup>-1</sup>

has been suggested as a general value for the interpretation of soil analyses. Thus, the total soil micronutrient concentration averages in this study were all in ranges that are considered normal for soil background concentrations. Similar total soil micronutrient concentrations compared well with the respective values reported from other countries are documented (Kabata-Pendias and

Table 1. Ranges and Means (X±SD, n = 3) of Total Zinc Concentrations in Surface Soils (0-20 cm) from Central Mecha; 2010.

Study Kebeles	Number of Fields	Range (mg Zn Kg <sup>-1</sup> )	Mean of Zn (mg Kg <sup>-1</sup> )
Bachima	6	55.29-65.22	58.38 ± 0.16
Ambomesk	4	52.6-54.95	54.05 ± 0.01
Tagel Wodefit	4	51.16-51.95	51.68 ± 0.02
Inguti	4	50.17-50.47	50.37 ± 0.01
Enashenifalen	4	48.53-48.93	48.78 ± 0.02
Enamirt	4	46.22-47.95	47.27 ± 0.01
*Kudmi	4	44.78-46.72	45.55 ± 0.01
<b>Total</b>	<b>30</b>	<b>44.78-65.22</b>	<b>50.87</b>

\*Zinc total level may be very low in highly acidic soils due to the intense soil leaching.

Table 2. Means and ranges of soils in Central Mecha Vis-à-Vis other soils in Ethiopia and around the world.

Location	Soil type and Climate	Range (mg Zn Kg <sup>-1</sup> )	Mean of Zinc (mg Kg <sup>-1</sup> )	Reference
France	Clay soils	-	(98)	Alloway, B.J.
German	Clay soils	-	(76.4)	Alloway, B.J.
Poland	Loess soils	28-116	60	Kabata-Pendias <i>et al.</i>
USA	All types	-	56.5	Alloway, B. J.
India	Humid tropical soils	22-74	54	Alloway, B. J.
Australia	Old Soils	2-180	34	Alloway, B.J.
World	All types	10-300	50	Alloway, B.J.
Mecha	Nitosols	44.78-65.22	50.87	This study

Table 3. Ranges and Means ( $X \pm SD$ ,  $n = 3$ ) of available Zinc Concentrations in surface Soils (0-20 cm) from Central Mecha; 2010.

Study Kebeles	Number of Fields	Range (mg Zn Kg <sup>-1</sup> )	Mean of Zn (mg Kg <sup>-1</sup> )
*Bachima	6	1.94-3.01	2.51 ± 0.09
Tagel Wodefit	4	2.26-3.24	2.63 ± 0.06
Enashenifalen	4	1.79-3.19	2.74 ± 0.05
Ambomesk	4	2.61-3.84	3.06 ± 0.05
Inguti	4	2.66-4.45	3.18 ± 0.07
Enamirt	4	2.29-4.06	3.22 ± 0.04
Kudmi	4	2.37-4.94	3.39 ± 0.09
<b>Total</b>	<b>30</b>	<b>1.79-4.94</b>	<b>2.96</b>

\*Plant available Zinc level may be very low in soils with lower organic content and higher PH of the soil solution.

Pendias, 2001). Tables below (Table 1 and 2) show sufficient inherent total zinc concentrations in the soils of central Mecha.

The total Zn concentration are seldom used as a test for evaluating plant availability of soil Zn as the total Zn pool often incorporates Zn in unweathered minerals that is unavailable for plant growth. There has been a general trend towards the use of different soil test procedures which can be used for several micronutrients and also potentially toxic elements in one extraction to assess plant available micronutrients in soils. On a global scale, DTPA (Diethylene-triamine-penta-actetate), EDTA (Ethylene-diamine-tetra-acetate), hydrochloric acid, ammonium bicarbonate-DTPA and Mehlic test are relatively popular. The use of hydrochloric acid as extractant is used in here to determine plant available zinc concentrations in the soil samples as described by Brennan and others (Brennan *et al.*, 1993). The mean and ranges of concentrations of available HCl-extractable Zn in the studied soils were found to be 2.95 mg Kg<sup>-1</sup> (1.76 to 4.94 mg Kg<sup>-1</sup> DW) (Table 3).

The concentrations of 0.1M HCl-extractable zinc

used for interpreting soil analyses show levels of plant availability and zinc concentrations (mg Zn Kg<sup>-1</sup> dry soil). According to Brennan and Srivastava (Brennan *et al.*, 1993 and Srivastava *et al.*, 1996), the concentrations of 0.1M HCl-extractable Zn of 1.6 -3.0 mg kg<sup>-1</sup> are considered medium as it is in between the critical levels for normal crop growth. Available Zn in the studied surface soils varied from 1.76 to 4.94 mg kg<sup>-1</sup> with a mean value of 2.95 mg kg<sup>-1</sup>. Considering 0.8 mg kg<sup>-1</sup> as the lower critical limit of available Zn as suggested by Brennan and Srivastava (Brennan *et al.*, 1993 and Srivastava *et al.*, 1996), the entire representative soils were under sufficient categories. The 0.1M HCl extractable zinc concentrations of studied soil samples were medium it in all instances. HCl-extractable soil metal concentrations were generally medium, as is to be expected for nitosol soils from young basaltic rock origin.

The critical concentrations for the interpretation of soil tests are often highly specific to certain types of soil and crops. It is therefore important for local expert advice to be sought in the interpretation of soil test results and the most appropriate method of treatment, if this is required. Quite often soil pH,

clay and organic matter contents will also be taken into consideration. The advantage of soil tests over plant analysis is that they enable possible deficiencies to be predicted in advance of growing the crop so that appropriate fertilisation or other treatments can be made to prevent the yield and/or quality of the future crop being impaired by zinc deficiency. The phytoavailability of soil micronutrients de-

pends on soil properties such as total micronutrient concentrations, pH, calcium carbonate ( $\text{CaCO}_3$ ) content, organic matter (OM) content, soil moisture conditions, and available phosphorus (Mahin *et al.*, 2009). Available Zn showed significant correlation coefficient with pH, OC, available N, and available  $\text{P}_2\text{O}_5$ . Low solubility of Zn in soils rather than low total amount of Zn is the major reason for

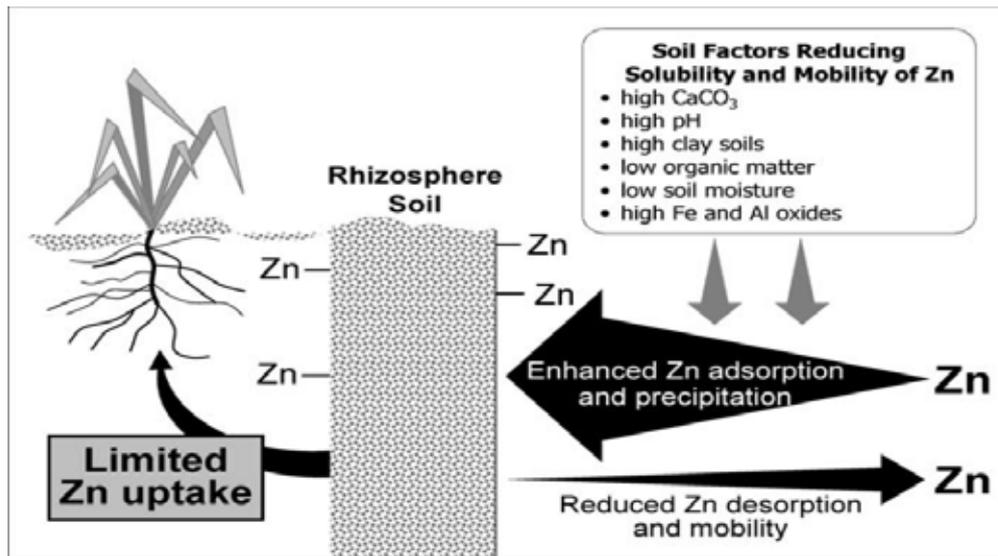


Figure 4. Major Soil Physical and Chemical Factors Affecting Availability of Zinc to Roots.

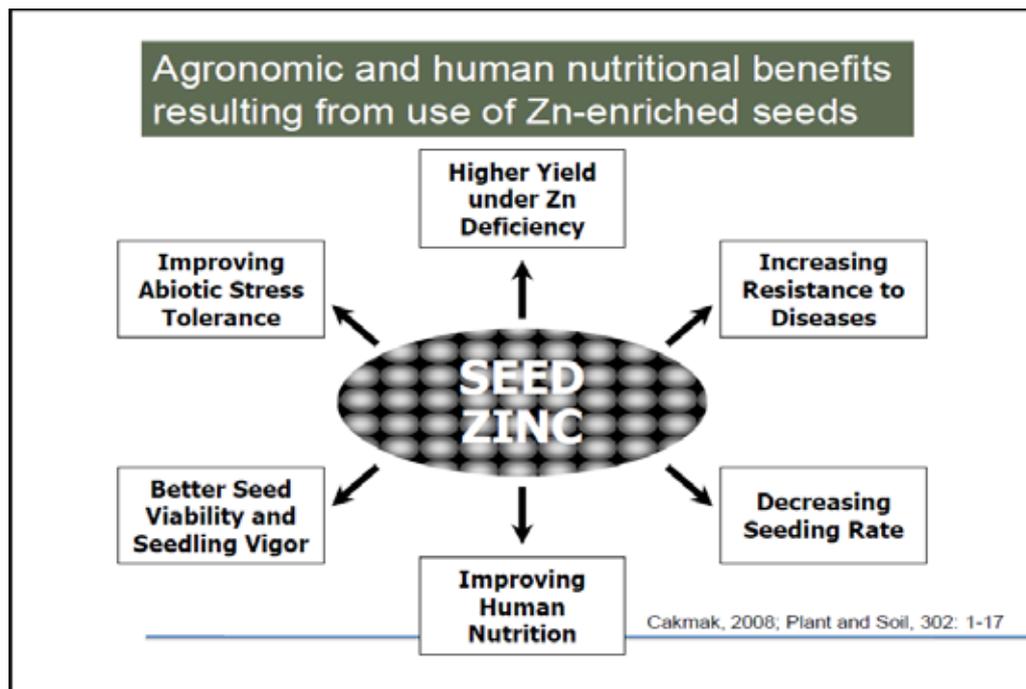


Figure 5. Agronomic and human nutritional Benefits from use of Zn-enriched seeds.

the widespread occurrence of Zn deficiency problem in crop plants (Figures 4).

### Zinc Concentrations in Seeds of Maize

The concentration of zinc in grain can also be used as a retrospective indication of the zinc status of the previous crop and in identifying areas where future grain crops could suffer from deficiency. A critical value of 15 mg Zn kg<sup>-1</sup> has been suggest-

ed as a general value for the interpretation of grain analyses (Mahin *et al.*, 2009; Ghulam *et al.*, 2011). ANOVA revealed significant differences ( $P < 0.05$ ) between maize varieties in their zinc levels. There was significant genetic variability in the level of zinc between the maize cultivars from 16.18 mg Kg<sup>-1</sup> for BH-540; 20.08 mg Kg<sup>-1</sup> for BH-660; 21.08 mg Kg<sup>-1</sup> for Phb-3253; 23.26 mg Kg<sup>-1</sup> for BH-543; 29.38 mg Kg<sup>-1</sup> for Melkassa-2 to 32.52 mg kg<sup>-1</sup> for Melkassa-4 (Table 4 and 5).

Table 4. Ranges and means ( $X \pm SD$ ,  $n = 3$ ) of levels of grain Zinc (mg Kg<sup>-1</sup>) in six different tropical maize genotypes in Central Mecha; 2012.

Genotypes	Source	Range (mg Zn Kg <sup>-1</sup> )	Mean of Zn (mg Kg <sup>-1</sup> )
BH-540	Bako NMR	16.01-16.35	16.18 ± 0.13
BH-660	Bako NMR	20.00-20.16	20.08 ± 0.08
PhB-3253	Pioneer	21.08-21.13	21.08 ± 0.05
BH-543	Bako NMR	22.46-24.06	23.26 ± 0.80
Melkassa-2	Melkassa	28.14-30.62	29.38 ± 1.24
Melkassa-4	Melkassa	32.1-32.94	32.52 ± 0.42

NMR= National Maize Research

Table 5. Range in concentrations of zinc (mg Kg<sup>-1</sup>) in maize and different crops.

Crop	Genotypes/Location	Range of Zinc (mg Kg <sup>-1</sup> )	Mean of Zn (mg Kg <sup>-1</sup> )	Reference
Wheat	Wheat grains in Turkey	23.25-41.76	27.23	Ali Riza D.
	Wheat grains in Ethiopia	5.93-9.88	7.905	Zelalem T.
Maize	Corn grain in Turkey	16.31-130.56	35.06	Ali Riza D.
	Corn grain in Mecha	16.01-32.52	23.7	This study
Teff	Red teff, Ethiopia	23.0 -67.0	47.9	Zelege K.
	White teff, Ethiopia	23.9-29.8	29.8	Zelege K.
Gibto	Gibito in Ethiopia	40.3-53.6	46.8	Shimelis E.
Lentils	Lentils in Ethiopia	86.2-100.3	87.9	Leshe S.

It has been indicated that micronutrient levels in maize grains were controlled to a large extent by environmental factors and interactions between the genotypes and the environment (Mahin *et al.*, 2009; Ghulam *et al.*, 2011). Based on a range of reports and this survey study, the average concentration of Zn in whole grain of Maize in various countries was between 16 to 35 mg kg<sup>-1</sup> (Rengel *et al.*, 1999; Cakmak *et al.*, 2004). The Zn concentrations in cereals reported so far and found in this study were too low to meet daily human requirement, especially for those consuming a high proportion of cereal-based diets.

Recommended dietary allowance for zinc in infants (6 months-1year); 3-5 mg/day, children (1-10 yr); 10 mg/day, adults; 15 mg/day, pregnant women; 20 mg/day, and lactating mother; 25 mg/day. Generally, recommended dietary allowance for Zn is around 15 mg per day (National Research Council, 1989). Fortification and supplementation are other strategies to combat zinc deficiency emergencies in risk populations. Zinc supplementation (*Lemelem* plus oral rehydration salt provision) during diarrhoea has lowered morbidity and mortality in children. Zinc deficient infants showed improvements in growth rate and a reduced incidence of acute lower respiratory infection after zinc supplementation. Chronic ingestion of zinc supplements exceeding 15 mg/day is not recommended without adequate medical supervision

For a measurable biological impact on human health, the concentration of Zn in whole maize grain needs to be increased at least by approximately 10 mg kg<sup>-1</sup>, assuming a 400 g per day intake for adult woman in the countries where whole grain flour is used for making food (Pfeiffer and McClafferty, 2007). Thus, there is increasing interest in the zinc concentration (density) in grains used for human consumption. The aim will be to increase the zinc concentration in grain to 40-60

mg Zn kg<sup>-1</sup> which is much higher than the concentration indicating possible yield losses due to zinc deficiency. This can be achieved by either genetic or agronomic biofortification. The use of improved varieties and or application of fertilizers blended with zinc compounds can be used for optimal results. However, it is also important to note that future experimental research on the amount of zinc required for alleviating zinc deficiency should consider severity of deficiency, soil types, nature of crops and cultivars. In majority of instances of Zinc deficiency in the soils can be best alleviated with the use of 5-11 kg Zn ha<sup>-1</sup> to wheat, rice and maize agricultural farms.

## CONCLUSIONS

The chemical analysis of composite soil samples in central Mecha Kebeles in the south west maize livelihood zone in Amhara region indicated that Zn in the soil is sufficient to support good crop growth for now, however; the variations in the level of zinc among the different maize cultivars should be significant in limiting high and quality yield for consumption than inherent zinc deficiency in the soils. The use of speciality fertilizers which contain zinc and use of zinc efficient crop varieties may give positive responses if other limiting factors such as low organic matter, high phosphorus fixing capacity and acidity of the soils are also concurrently managed. Generally future work in this area should focus on better understanding of the biogeochemical processes that control trace element cycling and comprehensive dataset on the abundance of trace elements in abiotic and biotic environmental compartments to better manage trace elements in the environment which is a prerequisite to sustain land use and, presumably, to increase product yield and quality in agriculture and diminish health risks due to deficiency or toxicity of micronutrients in the biosphere.

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