Investigating Iron and Zinc Status in Leaf of Potato Grown with Different Applied Fertilizers at Holeta, Ethiopia.

Fikerte Beyene Hunda

Addis Ababa University

Addis Ababa, Ethiopia

July 2013

Investigating Iron and Zinc Status in Leaf of Potato Grown with Different Applied Fertilizers at Holeta, Ethiopia

Fikerte Beyene Hunda

A Thesis Submitted to

The Department of Plant Biology and Biodiversity Management

Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science

(Plant Biology and Biodiversity Management)

Addis Ababa University

Addis Ababa, Ethiopia

July 2013

ADDIS ABABA UNIVERSITY
GRADUATE PROGRAMMES

This is to certify that the thesis prepared by Fikerte Beyene Hunde, entitled: *Investigating Fe and Zn Status in Leaf of Potato Tubers Grown With Different Applied Fertilizers at Holeta, Ethiopia* and submitted in partial fulfillment of the Requirements for the Degree of Master of Science (Plant Biology and Biodiversity Management) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by Examining Board:

Name	Signature	Date
1. Prof Legesse Negash (Examiner)		28/06/13
2. Prof Ensermu Kelbessa (Examiner)		28/06/2013
3. Prof Fisseha Itanna (Advisor)		28/06/2013
4. Prof Ensermu Kelbessa (Chairman)		28/06/2013

Investigating Fe and Zn Status in Leaf of Potato Grown with Different Applied Fertilizers at Holeta, Ethiopia.

Fikirte Beyene Hunda

MSc

Addis Ababa University, 2013

Abstract

The knowledge of micronutrients concentration in crop is one of particular interest due to their negative and positive effects on crops and on human. Iron and zinc deficiency in humans are very pressing global problem. Studying iron and zinc concentration in potato grown with different fertilizers is scarce in literature. Potato is leading vegetation crop grown at Holeta. Iron and zinc in potato varieties of Belte and Jalane were determined by growing them in combination with manure and inorganic fertilizer, compost and inorganic fertilizer, and inorganic fertilizer alone. Recently matured leaves were sampled and extracted with DTPA to determine iron and zinc. In both varieties grown with different fertilizers there were not significantly different concentrations of iron and zinc observed at ($P \geq 0.05$). In both varieties concentration of iron exceeded that of zinc. The soil under study area is acidic with sufficient concentration of iron, zinc and nitrogen. To have optimum range of iron and zinc in varieties Belte and Jalane grown on Humic Nitisols inorganic form of iron and zinc fertilizers are needed.

Key words: *Iron, Zinc, Potato, Manure, Compost, Inorganic Fertilizer*

CHAPTER TREE

CHAPTER FOUR

CHAPTER FIVE

List of Figures

List of Tables

List of Appendices

Acknowledgments

I am very grateful to my advisor Prof. Fisseha Itanna for his endless constructive comments, help in correcting, editing, criticizing and encouraging me to accomplish this work.

I would like to express my deepest gratitude to Oromia Trade and Market Development Bureau for allowing me to proceed with my education and providing sponsorship. My appreciation is also to Addis Ababa University for its provision of all necessary resources to accomplish my study from beginning to the end. I am also thankful to Holleta Agricultural Research Institute for their kind co-operation in facilitating conditions for my research work.

Finally, I am extremely grateful to my sister Genete Beyene, her husband Menyota Milke, my mother and my father for their understanding and help in using whatever resources they have and moral support. I should not forget also their care to me that brought me up to this success.

CHAPTER ONE

1. Introduction

Elements used plants in extremely largest amounts are carbon, hydrogen and oxygen. They are supplied by atmospheric air (CO_2) and water hence not considered as mineral elements (FAO, 2006). The other 13 mineral elements are available for plants as minerals from soil or must be added as fertilizers to soil. Essential elements have the following role in plans: Plans cannot complete their life cycle in absence of them, their functions are not replaced by other elements and they are directly involved in plant metabolism (Marschner, 1986). Essential elements are classified into macronutrients and micronutrients based on the amount required by plants. Macronutrients are required in larger amounts relative to micronutrients. Nitrogen, phosphors, potassium, calcium, magnesium, and sulfur are macronutrients. Micronutrients include boron, copper, iron, manganese, molybdenum, nickel, chlorine and zinc (White and Brown, 2010; Marschner, 1986).

Iron and zinc deficiency is most widely common is most widely common in developing nations. This is particularly due to the consumption of staple crops with inherently low tissue mineral concentrations. Inaddition to this, low fertility of soils where crops are grown, the poor uptake and translocation of such mineral elements to edible portions contribute to low mineral levels in several staple food crops (Sandstead, 1985, and Hercberg et al., 1987). Micronutrients are available for plants either from fertilizers or naturally from the soil. But their concentration in soil varies with different chemical and physical properties of soil, plant species, plant genotype, age and root distribution of the plant (House, 1999).

The concentration of elements in plants can also be affected by agronomic treatments (White, et al, 2009; cited in Etienne and Wang-Prusk, 2009) and cultivar (Randhawa et al., 1984). Organic fertilizers provide micronutrients and macronutrients to both soil and crops when they are utilized by combining with inorganic fertilizers. This is, because organic fertilizers are generally less concentrated source of nutrients than are conventional fertilizers, and low decomposition rate of nutrients than inorganic fertilizers. As result of this they do not alone satisfy the crops with for their growth and development especially at the year of application (Abebe Yadesa, 2001; Atsan et al., 2011; Triol-Padre et al., 2007; Tolasa and Friesen, 2001). The use and of farm-yard manure and other form of organic compost can also improve both the physical and biological characteristics of the soil. In many circumstances these changes improve soil physical structure and water holding capacity (Stevenson, 1991, 1994 cited in Welch, 2002).

Potato is a leading vegetation crop grown in most parts of Ethiopia and it serves as one of daily food diets. In addition to being a source of highly digestible carbohydrate and nutritionally complete protein, potato is also an excellent source of essential nutrients and vitamins. Potato skin contains 17% of total tuber zinc, 34% of calcium and 55% of iron. On a fresh weight basis, most minerals are higher in tuber flesh at the stem end than the bud end of tuber (Nithy et al., 2011). Potato tubers have high concentration of promoter substance such as ascerbate, b-carotene, and protein cytosine, various organic and amino acids that enhance the absorption of essential nutrients.

In addition to this, it has low concentrations of anti nutrients such as phytate (0.11- 0. 27%) and oxalates (0. 03%) as total dry matter, these factors improve the bio-availability of mineral nutrients in potato (Brian et al., 2004).

1.1 Statements of the problems

The knowledge of micronutrients concentration in crop is one of particular interest due to their negative and positive effects on crops and human. Information on status of micronutrients in both soil and crop are scarce in the literature. Farmers use permanently macronutrient fertilizers to grow crop. Using only micronutrient fertilizers to soil without giving attention to micronutrient fertilizers may affect availability and concentration of micronutrients in both soil and crop.

Potato is produced largely at Holeta area due to favorable climate and access of improved varieties from Holeta Research Center. Studying iron and zinc in potato by growing with inorganic and combination of organic and inorganic fertilizers is important to more targeted strategies to enhance desirable minerals through agronomy and to manage them. Such study is also necessary to assess the role of potato as source of essential micronutrients. Furthermore, the finding of this will provide adequate information on iron and zinc status of two potato varieties grown on Humic Nitosols at Holeta with combination of organic and in organic fertilizers, inorganic fertilizers alone.

1.2. Objectives of the Study

1.2.1. General Objective

To investigate iron and zinc status in two potato varieties by growing them with different fertilizers at Holeta

1.2.2. Specific Objectives

The specific objectives of this study were:

To characterize soil, manure and compost by their chemical and physical properties.

To compare status of Fe and Zn between potato varieties.

To determine correlation of Fe and Zn with other elements of the soil.

1.2.3. Research Questions

Some of the research questions the paper attempts to address include:

Which fertilizers are best for iron and zinc status of potato?

What are the ranges of iron and zinc in two potato varieties?

What are the ranges of iron and zinc in soil, manure and compost?

CHAPTER TWO

2. Literature Review

2. 1. A bout Potato

The name "potato" is thought to be originated from the Tainos Indian name, "batatas." The potato is one of about 2,300 species in the family Solanaceae. This family includes about 90 genera, the largest of which is the genus Solanum, including about 1,500 species. About 100 species of Solanum are tuber bearing, and thus commonly referred to as "potato". Being a dicotyledonous plant, the potato has the characteristics of all dicotyledons including stems with vascular bundles placed in a circular arrangement and containing definite layers of xylem (Harris, l992; Thompson and kelly, l972). It is native to South America (Eskin and Michsel, l989).

The potato is an extremely important food crop. It is grown in more countries than any other crop except maize. It is the world's fourth largest food crop and is a staple in many diets around the world. Its volume of production ranks fourth in the world after rice, wheat and maize (Munro and Lister, 2000). It is regarded as high-potential food security crop because of its ability to provide as high yield of high-quality product per unit area with a shorter period (mostly < l20 days) than major cereal crops like maize (CIP, l972). For many years in Ethiopia, potato production was limited to homesteads, as garden crop. World annual production of potato is about 330 million metric tons. In Africa the total production of potato is about l, 625, 680 tons with total area coverage of l, 765, 6l7 ha.

In Ethiopia, total production is around 572, 353 tons on area coverage of 69, 784 ha (Israel Zewide et al., 20l2). It is grown by approximately l million farmers (CIP, 1972). Recently, the price of cereals has strongly increased world-wide whereas; the price of tuber crops remained relatively low during the entire food crisis. This shows that there is room for added value in the chain of tuber crops. Potato is high in vitamin C and potassium, very high in protein and is nearly fat free. More potatoes are consumed by the world's population than any other vegetable (Bradshaw and Bonierb ale, 2010). Potato tuber is a subterranean swollen stem which evolved to survive from season to season as a dormant storage organ. The form of energy storage is almost entirely starch. As a staple food and as a vegetable, potatoes need to be cooked because of the indigestibility of their starch. Such cooking is frequently by baking, boiling, steaming, roasting, deep-oil frying (Bradshaw and Bonierbale, 2010).

They also provide significant amounts of vitamins C, B6 and B1, folate, the minerals potassium, phosphorus, calcium, magnesium, and micronutrients. The concentration of iron and zinc in potato is low compared with the concentration of these micronutrients in cereals and legumes. However, the bioavailability of iron in potato is greater than in cereals and legumes due to the presence of high levels of ascorbic acid (promoter of iron absorption) and low levels of phaytic acid (inhibitor of iron absorption) (Bradshaw, and Bonierbale, 2010).

Potato prefers cool to warm weather but will grow throughout the year provided they are not subjected to frost or drought. However, in summer, potatoes are lower yielding and have poor shape due to intensive disease at this season.

Well drained sandy loam soil is considered the most suitable for potato production. Black soil that has undesirable physical and chemical quality should be avoided (Lundaho et al., 2007). Consuming potatoes have the following benefits: Free of fat, all carbohydrate in potato is in the form of hydrated starch, contains little soluble sugar, high content of water about 75% dry weight less impact on blood glucose (Munro and Lister, 2000). In addition to this, potato is a source of water soluble vitamins and easily fermenting ability of potato fiber can contribute extra energy as short-chain fatty acids. Although, potatoes contain insufficient essential amino acid methionine they contain high quality of protein (Munro and Lister, 2000).

2.1.1. Potato Growth Stages

Potato has different growth stages. These are: Sprout development stage, Vegetative growth stage, and Tuber initiation stage, Tuber bulking stage and Tuber maturation stage. The time for this growth stage depends on different factors such as temperature, availability of moisture and selected cultivar (Tantowijoy and Fliert, 2006).

Sprout development stage: After tubers break dormancy they are able to grow and at early stage begins with several eyes sprouting when the tuber is in storage, continuous through planting and until shoot emergence from the surface of the soil. During this stage plants use nutrient reserves stored in the tuber (Munro and Lister, 2000).

Vegetative growth stage: This stage is a rapid stage of growth of leaves, stems, new shoots and roots. The plant still relies on food reserves stored in the seed tuber, but has already begun to take small quantities from the soil (Tantowijoy and Fliert, 2006).

Tuber initiation stages: Under suitable growth condition, the tips of stolons will hook and begin to swell resulting in initiation of new tubers. Plants require nutrients in large quantities during this stage (Bradshaw and Bonierbale, 2010).

Tuber bulking stages: This is the critical growth period for both tuber yield and quality. Under optimal growth conditions, tuber growth rates remain relatively constant during this period, which is often referred to as the linear tuber growth phase. At this stage the plant itself has already stopped growing and only the tubers become larger (Tantowijoy and Fliert, 2006).

2.1.2. Factors Affecting Tuber Bulking

Temperature: Potato vines and potato tubers are often competing with each other for limited nutrient resources, and excessive vine growth can result in reduced tuber growth. High soil temperature delay tuber growth (Eskin and Michsel, 1989).

Fertilization: Developing healthy plants necessary for maximum tuber growth requires that all essential nutrients be supplied at optimal rates. Both deficit and excess condition can reduce tuber bulking rates. Nutrient deficiency limit canopy growth and shorten canopy duration resulting in reduced carbohydrate production and tuber growth rates.

Seed physiological age: Aged seeds tend to produce potato plants with numerous stems that sprout and develop rapidly and die early. High stem numbers usually result in a high number of tubers per plant that reduce average tuber size by reducing the amount of carbohydrate available to reach tuber during bulking. In addition to this, early death shortens bulking time and limit overall productivity. Physiologically young potato seed begins to bulk later than those from aged seeds; this may shorten the linear tuber growth phase in areas with a short growing season (Bradshaw and Bonierbale, 2010).

Plant spacing: Closing plant spacing increases tuber density relative to canopy size, therefore limiting the photosynthetic capacity to bulk each tuber. Even though, the total yield may not reduce, bulking rates of individual tubers decrease. This results in smaller tubers and lower marketable yields. The wider than optimal spacing can lengthen the time it takes to reach canopy, which reduces carbohydrate supply to the tubers (Brian et al., 2004).

Planting date: Early planting can lead to seed piece disease and rot, slow emergence, and decreased plant vigor, which may slow tuber growth rates. But planting too late delays canopy development and reduce the time available for tuber bulking (Westermann, l993).

Irrigation: Soil moisture below critical levels reduces or stops canopy and tuber growth during the stress period. This effectively shortens the tuber bulking period and can also cause a variety of internal and external tuber defects. Excessive irrigation can also reduce tuber growth by restricting plant physiological activity and nutrient uptake and increasing disease susceptibility (Marschner, l986).

Tuber maturation stage: As potato vines die back several changes occur to the tuber such as yellowing leaves and drooping stem. At this stage tuber skins harden and do not peel off easily. This is due to increased starch content (Bradshaw and Bonierbale, 2010).

2.1.3. Water Management Practice for Potato

Water requirement will vary with soil type, climate, the crops to be irrigated and the growing system. Water has to be applied in the right amounts at the right time in order to achieve the desired crop result. At the same time, the application of water should avoid waste of a valuable resource and be in harmony with the environment as a whole. Water is very important for potato production due to its essentiality for maximum yield and quality of potato. Irrigation early in the growing season minimizes common scab, maximizes tuber number and encourages crop canopy growth. It allows tubers to grow at an optimum rate, and at the end of the season it can allow harvesting with minimal crop damage. The volume required at each application depends largely on the soil moisture deficit at the time of application, the water-holding capacity of the soil, and the evapo-transpiration rate of the crop (Haverkort, 1982).

Soil can serve as storage of water for plants. The amount of water being held in the soil depends on soil texture such as sand, silt, clay and structure (loose, compacted). Drainage due to gravity progressively removes water from the pores of the soil. But when more water is lost, the forces holding water along the soil particles increase until equilibrium is reached. This process is known as field capacity. As the crop grows, water is extracted from the soil, and lost by transpiration from the leaves and evaporation from the soil and leaf surfaces. The combined effect is known as evapo-transpiration. The accumulated amount of water lost from the soil is referred to as the soil moisture deficit (Nadia Gad et al., 2012). The amount of water stored at field capacity can be influenced by soil texture and structure.

Sandy soils hold little water due to their large pores. 0n their surface water freely drains down to soil profile. Even though, the quantity of water reserved not necessarily the same as the amount available for plants to utilize, as the soil becomes drier it is too difficult for crops to extract water from the soil (Nadia Gad et al., 2012).

2.2. Iron in Soils and Plants

The abundance of Fe in soils average 3.5% and is likely to be increased in heavy loamy soils and some organic soils. The color of soils is largely associated with amounts and forms of Fe compounds. The iron oxides and hydroxides in soil are responsible for its reddish and yellow color. Therefore, a content and profile distribution of Fe compounds has been used for the description of soil processes and for the soil classification (Atsan et al., 2011). The reactions of Fe in processes of weathering are dependent largely on the pH system of the soil and on oxidation stage of Fe compounds involved (Schulte, 2004). The soluble Fe level reaches a minimum in the alkaline pH range. As pH increases by one unit, activity of Fe^{+3} decreases by 100-fold due to the formation of insoluble Fe^{+3} hydroxide (Lindsay, 1979; cited in Abdul Rashid et a1., 2010). Acid soils are higher in soluble inorganic Fe than are neutral and calcareous soils. Thus, Fe^{2+} cations, when in acid anaerobic soils, may become toxic, but in alkaline well-aerated soils, the low concentration of soluble Fe species may not meet plant requirements for this metal (Schmidt, 1999). When soils are waterlogged, the reduction of Fe^{3+} to Fe^{2+} takes place and is reflected in an increase in Fe solubility. This process of Fe reduction can result in a high Fe^{2+} concentration in some submerged soils (Brady, 2002).

Iron is used by plants as Fe^{3+}, Fe^{2+} and Ferric iron (Fe^{+3}) has low solubility in the soil solution (Kabata-Pendias, 2011). Plant tissues react to iron more rapidily and intensely than animal tissues (Kabata-Pendias, 2011). Iron is indirectly responsible for much of green color of growing plants because of its role in growth chlorophyll. Iron stain occurs in chlorpalast, nuclie and in large mass scattered through the cytoplasm (Miller, 2005). Both Fe uptake and transport between plant organs are highly affected by soil pH, concentration of Ca and P. Generally, high degree of oxidation of Fe compounds, precipitation of iron on carbonate or on phosphate and, competition of other minor elements on same binding sites of chelating compounds are main factors responsible for low Fe uptake and disturbance in iron transport within plants. Mostly when iron is at higher deficiency level, plant roots play major role to extract iron from minerals and from chelating agents (Schulte, 2004).

Availability of iron for plants depends on different factor such as: soil aeration, reactions with organic matter, and plant adaptations. Aeration: poor soil aeration or reduced oxygen level is caused by flooding or compaction. It can increase or decrease iron availability depending on other soil conditions. Iron deficiencies occur most frequently on wet and cool soils early in the growing season, when microbial activity and root grown are limited. As soils warm, microbial activity and root proliferation increase allowing plants to absorb more iron. If microbial activity is sufficient to decrease the oxygen supply in acid soils, some ferric iron oxides and hydroxides will be transformed to more soluble ferrous forms (Schulte, 2004). On other hand in alkaline soil rapid microbial respiration may produce sufficient carbon dioxide to react with water to form bicarbonate ions. Plant absorbed bicarbonate ions immobilize iron within plants, resulting in deficiency (Kabata-Pendias, 2011).

Organic matter:-organic matter improves iron availability by combining with iron, therefore reducing chemical fixation or precipitation of iron as ferric hydroxide. This reduction in fixation and precipitation results in higher concentration of iron remaining in soil solution and make it available for root absorption (Schulte, 2004). Organic matter can also affect iron availability by acting as energy source for microorganisms that use up oxygen under waterlogged conditions. When micro organisms decompose organic matter, iron previously tied up in organic compounds is released in the form available for plant uptake. The amount of Fe in the leaves of a normal plant will generally average a few hundred parts per million. Iron is generally the most abundant of the micronutrients with dry mater content of 100 ppm ((FAO, 2006). According to Kabata-Pendias, (2011), iron transport between plant organs and taken by plant as the following method:

- Various Fe species may be absorbed, mainly as Fe^{2+}, but also Fe^{3+}, and Fe chelates.
- Plant roots may reduce Fe^{3+} to Fe^{2+}, which is fundamental in the Fe absorption by most plants.
- In xylem exudates, Fe occurs mainly in unchelated forms.
- The Fe transport is mediated largely by citrate chelates and by soluble ferritins (transference).

On soil rich in mobile Fe fractions, an excessive Fe uptake can produce toxic effects in plants. Plant injury due to Fe toxicity is most likely to occur on strongly acid soils (Ultisols, Oxisols), on acid sulfate soils, and on flooded soils. A high concentration of Fe in the soil solution is almost always related to Fe toxicity. This toxicity is also often associated with salinity and a low phosphorus or base status of soils.

Iron deficiency occurs frequently on calcareous soil but often it is found on acid soils also (Schulte, 2004). A deficiency of Fe first appears in the young leaves of plants thus reducing new growth. Young leaves develop an inter-venal chlorosis. In severe cases, leaves can turn completely white (Kabata-Pendias, 2011). Iron is not mobile in plants and symptoms appear on the new leaves first. Injured leaves or necrotic spots on leaves indicate an accumulation of Fe above 1000 $mgkg^{-1}$ (3–6 times as) high as the Fe content of healthy leaves.

Of all the micronutrients, iron is required by plants in the largest amount (Marschner, 1986; Kabata-Pendias, 2011). Iron is one of the most important and most problematic of all the micronutrients used by living organisms (Conte and Walker, 2011). The problematic nature of iron is due to two distinct chemical properties of iron. It is highly reactive and if over accumulated can cause cellular damage (Winterbourn, 1995 as cited in Conte and Walker, 2011). Fe is soluble in aqueous solution specially in well aerated enviroments where production of ferric hydroxides and other Fe salts limits Fe solubility (Marschner, 1995). The essentiality of iron for plants has been established by Gris in 1943 (FAO, 2006). It has a role as an essential cofactor for many cellular redox reactions involved in photosynthesis, respiration, and many other reactions (Conte and Sarah, 2011). Iron is also only sparingly soluble in aqueous solution, particularly in well-aerated environments where production of ferric hydroxides and other iron salts limit the solubility of iron (Marschner, 1995).

It is used for the synthesis of chlorophyll and is essential for the function of chloroplasts (Thomas et al., 1995). Without sufficient iron levels, plants show apical leaf chlorosis and slower root growth.

Despite the usually high abundance of iron in soils, the low solubility of iron bearing minerals limit the iron available for uptake by higher plants (Schmidt, 1999). Although abundant in soil, iron is one of the most common nutrients limiting plant growth in the world (Naihmatulah et al., 2002). Iron deficiency in potato occurs on younger leaves with yellow to nearly white but not necrotic. Leaf tips and edges remain green. The longest green veining occurs in leaves (Westremann, 1993).

2.3. Iron Reductase

Iron is prevalent in many types of soils in the form of Fe (III), which is unavailable to plants (Schmidt, 1999). To capture iron from the soil, plants use an enzyme called iron reductase, which converts Fe (III) to Fe (II). Botanically higher plants are divided into graminaceous (Strategy II) and non graminaceous (Strategy I) depend on the way they convert unavailable iron, Fe (III), into available iron, Fe (II) (Francoise-Jean, 2009; Marschner, 1986). Strategy I plants (non-graminaceous plants) convert Fe (III) into Fe (II) by proton extrusion through ATP and iron reduction by Fe (III) reductase located in the plasma membrane of root cells. The reduction of Fe (III) to Fe (II) by ferric chelate reductase (iron reductase) is thought to be an obligatory step in iron uptake for Strategy 1 plants (Naihmatulah et al., 2002).

Strategy 1 plants also use acidification/reduction methods that enhance Fe solubility prior to uptake. Plants secrete protons into the rhizosphere to lower the pH of the soil and thus increase the solubility of Fe (III) by root ferric chelate reductase using further enhances Fe solubility, since Fe (II) is more suluble than Fe (III). Reduction also prepares the Fe for uptake by iron regulated transporter 1 (RT1)-types ferrous transporters which move Fe (II) across the root epidermal plasma membrane (Conte and Walker, 2011; Lihua et al., 2004).

Strategy II plants (graminaceous plants) uptake Fe(II) by releasing high affinity chelat -es, called phytosiderophores, that form Fe (III) complexes and are absorbed into the roots (Volker, and Horst, l986). Strategy I and strategy II plants contain iron reductase in the plasma membrane of the root cells, but in strategy I plants, iron reductase activity is regulated by the availability of iron (Reduction of iron from ferric to ferrous on the root surface is a necessary process for iron uptake in strategy I plants (Lihua et al., 2004). Potato is a strategy I plant and likely regulates iron uptake by iron reductase. Plants have several responses to iron deficiency, including lowering the pH to make iron more available and increasing the root area to mine for iron and other micronutrients (Orozco-Mosqueda, 2012).

2.4. Irons in Human Physiology

Iron carries oxygen to the cells and is necessary for the production of energy, the synthesis of collagen, and the functioning of the immune system. Iron deficiency is common only among children and pre-menopausal women. Great care must be taken not to take too much iron, as excess amounts are stored in the body's tissues and adversely affect the body's immune function, cell growth and heart health (Tzonou, 1998; Halliday, 1998).

Iron deficiency may affect three billion people worldwide (Long *et al.*, 2004). In developing countries like Africa, iron deficiency is wide1y observed porob1em spread because of poor nutritional value feeding habits (Hercberg et al., l987). Iron is an important component in human diets because it regulates enzyme activity and plays a role in the immune system (Lynch, 2003). It is also an important component of human blood because iron is the central atom of hemoglobin (Long et al., 2004).

Humans require 10-15 milligrams of iron per day; if iron levels are not regulated, the deficiency can lead to mental and psychomotor impairment in children and an increase in both morbidity and mortality of mother and child at childbirth (Long et al., 2004).

Iron deficiency can also cause nutritional anemia problem during pregnancies, stunted growth, lower resistance to infections, long-term impairment in mental function, decreased productivity and food-energy conversion and impaired neural motor development (Welch, 2002 ;Conte and Sarah, 2011). Most adults' ages 20-50 years old require l4 μg iron/ kg of body weight for males and 22 μg/ kg of body weight for females (Herbert, l987). Anemia occurs when an individual does not absorb the necessary amount of iron from the blood stream. When the hemoglobin level of an individual falls below a cut-off point defined according to sex, age and other physiological considerations, the cause is usually anemia (Hercberg et al., l987).

Anemia affects over 80 million African children and over 60 million African men and women (Hercberg *et al.*, l987). Iron losses from the body occur from the shedding of cells internally and externally; most of which occur in the gastrointestinal tract (Hercberg *et al.*, l987). Men have a mean iron loss of l4 μg/ kg/day (Finch, l959). The average total iron losses in menstruating women are approximately l.4 mg/day (Hercberg *et al.*, l987). The amount of iron absorbed is impacted by three variables: the amount of iron ingested, its bioavailability, and the iron status of the individual (Hercberg *et al.*, l987). Iron in food is present in two forms: heme iron and non-heme iron; of the two, heme iron is easily absorbed into the body (Hercberg *et al.*, l987).

2.5. Zinc in Soil

The value of zinc in soil depends on the chemical composition of raw materials in soil. The amount of zinc on earth`s crust is approximately 80 mg/kg, and its value in soil is in the range between 10 to 300 mg/kg with an average of 50 mg/kg (Sayed, 2011). Zinc exists in different forms in the earth`s crust, such as sulfate, silica and carbonate minerals. But also zinc exists as water-soluble, exchangesb1e connected to organic matter and stabilized by secondary clay minerals in the soil (Alloy, 2008). Deficiency of zinc is related to soil pH and its value is very low in calcareous soils with high pH (Alloy, 2008). Zinc deficiencies also are found on soils leveled for irrigation where the subsoil is exposed on soils with very high levels of free lime, sandy soils. The mobility of zinc and its uptake from the soil depend on different factors such as soil acidity, zinc total value of soil, organic matter and soil type.

The most important factors affecting zinc availability can be noted as following (Chang et al., 2007; Sillanpaa, 1990 as cited in Mousavi, 2011).

- Zinc total value may be very low in high acidic soils due to the intense soil leaching.
- Availability of zinc decreases by increasing soil pH. This is due to mineral solubility reduce and zinc uptake increase by soil colloidal particles such as clay minerals, iron and aluminum oxides, organic matter and calcium carbonate.
- Zinc availability decreases by decreasing temperatures and light intensity due to limited root development.
- High level of soil phosphorus decreases availability of zinc.
- Zinc uptake by plants is inhibited by some metal cations such as Cu^{+2} and Fe^{+2} due to the same carriers for these elements in the plants roots.

2.6. Role of Zinc in Plant

The essentiality of zinc for plants has been established by Sommer, Lipman in 1931 (FAO, 2006). Zinc is needed in small but critical concentrations and if the amount available is not adequate, plants will suffer from physiological stress brought about by the dysfunction of several enzyme systems and other metabolic functions in which zinc plays a part. Zinc is involved in membrane integrity, enzyme activation, and gene expression (Debora and Cathy, 2012). Besides this, zinc has effect on carbohydrate metabolism through its effects on photosynthesis and sugar transformations. Zinc plays a role in the metabolism of starch, activity of sucrose synthetase. A numbers of starch grains are all depressed in zinc deficient plants. A deficiency of zinc can cause a reduction in net photosynthesis by 50 % -70 % depending on plant species and the severity of deficiency. The reduction of photosynthesis observed in zinc deficient plants can also be due to, a major decrease in chlorophyll content and the abnormal structure of chloroplasts (Alloway, 2008).

Zinc is taken up from soil solution in divalent cation form (Zn^{2+}) (Alloway, 2008; Marschner, 1986; FAO, 2006). In the xylem routes zinc is transmitted to divalent form or with organic acid bond. In the phloem sap zinc makes up complex with organic acids with low molecular weight, and increases its concentration (Tama and Mary, 1998). Zinc is not highly mobile in plants. Visual symptoms of zinc deficiency in plants are leaf moltting, inter venal chlorosis, and reduced plant growth. Sometimes Zn deficiency will lead to plants with shortened internodes, yellowish leaves, and bleached spots. Zinc deficiency occurs in younger leaves of potato with chlorotic, narrow and upward-cupped and develops tip burn. Other leaf symptoms are green veining, necrotic spotting, blotching and erect appearance (Westermann, 1993).

Zn toxicity can result in reduction in root growth and leaf expansion followed by chlorosis. It is generally associated with tissue concentration greater than 200 µg/g Zn (FAO, 2006). Healthy leaves contain about 25 to 150 ppm Zn. High levels of Zn can lead to toxicity where root growth is reduced and leaves are small and chlorotic. Zinc deficiency may occur in cold, wet soils or in soils with a very high pH where Zn is rendered unavailable to the plant. It is recognized that zinc deficiencies can be found on many types of soils in the different bio-climatic zones of the world (Kabata-Pendias, 2011).

There are relatively small numbers of widely occurring types of soil which are more frequently associated with zinc deficiency than any other. These are:

1. Calcareous soils
2. Organic soils
3. Sandy soils
4. Saline and Sodic (salt- affected) soils
5. Vertisols,
6. Gleysols (poorly drained/waterlogged soils).

2.7. Zinc in Human Physiology

Zinc is essential trace mineral, is required for the metabolic activity of 300 of the body`s enzymes, and is considered essential for cell division and the synthesis of DNA and protein. These enzymes are involved with the metabolism of protein, carbohydrate, fat. It is also critical to tissue growth; wound healing, taste acuity, connective tissue growth and maintenance, immune system function, and bone mineralization (Debjit et al., 2010).

Malnutrition is the most common cause of zinc deficiency (Sandstead and Harold, 1985). Over three billion people worldwide suffer from malnutrition (Welch et al., 2004). Health problems caused by zinc deficiency include anorexia, dwarfism, weak immune system skin legions, hypogonadism, and diarrhea (Debji et al., 2010). Zinc plays an important role in the immune system; it is necessary for lymphocyte development (Debji et al., 2010). Alcohol dehydrogenase, an enzyme that breaks down toxins in the human body, also depends on an adequate zinc supply to function properly. In Africa, it is estimated that 500-600 million people are at risk for low zinc intake (Harvest, 2007). Males, age's 15-74, need between 12-15 milligrams of zinc daily, while females, ages 12- 74, need between 6-8 milligrams of zinc daily (Sandstead and Harold, 1985). Zinc deficiency can cause growth retardation, delayed skeletal and sexual maturity, dermatitis, diarrhoea, alopecia and defects in immune function with resulting increase in susceptibility to infection (Welch, 2002).

2.8. Interaction of Zinc with Other Elements

Zinc deficiency leads to iron deficiency. This is because of prevention of transfers of Fe from root to shoot in zinc deficiency conditions (Rengel et al., 1998; Rengel and Romheld, 2000). The transfer of iron from root to shoot depends to zinc activity in the nutrient solution. Lower levels of Fe were transformed from the roots to shoot in plants that were grown in nutrient solution with zinc low activity. The zinc deficient plants had significantly higher iron concentration in shoots than the zinc sufficient plants (Imtiaz et al., 2003). Phosphorus is one of the important elements that interfere with zinc uptake.

High level of phosphorus decreases the availability of zinc in soil and reduces uptake of it by plants. This is due to the following reason:

Zinc transmission of plant roots to shoot is reduced by high concentrations of phosphorus, as result zinc accumulator in roots or its uptake decreases by roots. Zinc concentration in shoots of plants decreases by effect of induced growth response (dilution effect); means that the amount of zinc uptake in plant increases by increasing plant growth but its concentration decreases in plant tissues, in other words that element will be diluted in plant tissues. Metabolism defect in plant cells that is related to zinc and phosphorus imbalance, so by increasing the phosphorus concentration zinc tasks is impaired at specific positions in the cell (Cakmak et al., 1990; Alloway, 2008).

2.9. Major Nutrients Affecting Plant Growth

2.9.1 Nitrogen

The requirement of N nitrogen for plants is comprehensively reviewed by Tisadale et al., 1993. Nitrogen is important nutrient, and its supply is controlled by man (Adediran, 1995). In potato production it is a major yield determining factor and its availability in sufficient quantity throughout the growing season is essential for optimum growth of plant (Adediran, 1995).

In the soil, N found in decomposing organic matter may be converted into ammonium (N_4H^+) by soil microorganisms (bacteria and fungi) through mineralization (Pidwiny, 2002). Nitrogen in the form of (N_4H^+) in the form of NH_4^+ can then be adsorbed onto the surfaces of clay particles in the soil. The NH_4^+ ion that has a positive charge may be held by soil colloids because they have a negative charge (Pidwiny, 2002). NH4+ may be released from the colloids by way of cation exchange. When released, NH_4^+

may be chemically altered through bacteria action or processes resulting in the production of $NO3^-$ stays in the soil solution. If $NO3^-$ is not taken up by the roots, it can transport below the root zone and leached or denitrified.

As $NO3^-$ is soluble in water, it is easily leached from the root zone by excessive rainfall of irrigation (Simonne and Hochmuth, 2003). In plant nutrition, nitrogen is involved in the composition of all amino acids, proteins and many enzymes. Nitrogen is also part of puric and pyrimidic bases, and therefore is a constituent of nucleic acids (Mills and Jones, 1996). Typically, N content in plants ranges between 1 and 65 of the dry weight in leaf tissue. It is absorbed by plants in the form of nitrate and ammonium ions.

The supply of N is related to carbohydrate utilization. When N supply is insufficient, carbohydrates will be deposited in vegetative cells, which will cause them to thicken (Marti and Mills, 1979).When N supplies are adequate, and conditions are favorable for growth, proteins are formed from the manufactured carbohydrates, less carbohydrate is thus deposited in the vegetative cells and more protein formed, and because protoplasm is highly hydrated, a more succulent plant result. Excessive succulence in some crops may have a harmful effect. With grain crops, lodging may occur. When plants are deficient in N, they become stunted and yellow in appearance. This yellowing, or chlorosis, usually appears first on the lower leaves; the upper leaves remaining green as the lower leaves yellow or die is an indication of the mobility of N in the plant. When the roots are unable to absorb sufficient amounts of this element to meet the growing requirement, N compounds in the order plant will undergo lysis. This involves the conversion of protein N to a soluble form, which are translocated to the active meristematic regions and reused in the synthesis of new protoplasm (Marti and Mills, 1979).

2.9.2. Phosphorus (P)

Phosphorus-deficient plants therefore are stunted with a limited root system and thin stems. In many plants, seedlings look stunted and order leaves may turn purple because of the accumulation of purple pigments. Grain yield is often severely reduced (Jones et al., 2003). Plants concentrate phosphorus in the seed, which is usually harvested. The stem, leaves and roots of a mature crop tend to be lower in phosphorus and contribute only a small part of the next crop`s phosphorus requirements. Internally, most crops need 0.2 to 0.5% P in the dry matter for normal growth. Plants extract P exclusively from the soil solution in either $H_2PO_4^-$ or HPO_4^{-2} form (Holford, 1997).

2.9.3. Potassium (K)

Potassium is needed in large quantities by many crops. It is required for maintaining the osmotic potential of cells and turgidity of p1ants. K regulates osmotic potential of cells (the closing or opening conditions of stomata) hence it plays an important role in water relations in the plant. Potassium is involved in water uptake from the soil, water retention in the plant tissue, and long distance transport of water in the xyplem and of photosynthesis in the pho1em (Marschner, 1995). Potassium affects cell extension. With adequate K, Cell walls are thicker therefore improving plant resistance to lodging, pests and diseases (Bergmann, 1992). The most visual K deficiency symptom is firing along leaf tips and margins (Bergmann, 1992).

In soils, potassium is quite mobile as compared to phosphate. It exists as K^+ in soil solution and is absorbed by roots in that form.

Although K^+ can be retained to some extent by negative charges on clay surface, Ca^{+2} or Mg^{2+} can displace it into the soil solution, when gypsum or dolomite is added. Thus if K is not taken by plants, it may be lost by leaching (Bergmann, 1992). One way of reduce K leaching is add organic matter such as compost to the soil. Organic matter usually has large cation exchange capacity, which can retain K effectively (Bergmann, 1992).

2.9.4. Use of Organic Fertilizers

Organic fertilizers are valuable sources of nutrients and the yield increase effect of organic fertilizers are well established. Apart from the nutrients in organic fertilizers, their effect on improvement of soil organic matter, soil structure and the biological life of the soil are well recognized. There is also some evidence that they may contain other growth-promoting substance like natural hormones and B vitamins (Leonard, 1986). Many studies have demonstrated that application of organic fertilizers such as animal manure and compost produce crop yields equivalent to or superior to those obtained with chemical fertilizers (Motavalli et al., 1989). Crop quality has also been improved by manure and compost application (Pimpini et al., 1992).

When crop improvement with organic fertilizers were greater than those attained with commercial fertilizers, response was usually attributed to manure supplied nutrients or to improved soil conditions not provided by commercial fertilizer. Organic fertilizers improve the physical condition of the soil and increase P and biological activity (CAST, 1996).

The organic matter, total nitrogen and micronutrient content of the surface soil are increased as a result of organic fertilizers (compost and cattle manure) application. Organic fertilizers applications for most of the crops are high, ranging from 5 to 20 tons per hectare (Motavalli et al., 1989). Organic fertilizers, when applied, will be mineralized gradually and nutrients become available. However nutrient content of manures and compost varies because nutrients values are greatly affected by diet of animal, amount of bedding, storage and the original parent material of compost (Harris et al., 2001). Bationo and Mokwunye, 1992 noted that the addition of organic fertilizers either manure or compost has beneficial effects on the soil chemical and physical properties. It is also known that the use of organic fertilizers can reduce nutrient deficiency in soils. Koppen and Eich, 1993 noted that K and P deficiencies were reduced when organic fertilizers were applied. Compared to manure compost contains more stable form of nitrogen and not susceptible to loss as NH_3 gas (Leonard, 986). In the preparation of compost it is desirable to mix materials for composting in the proportion that give rapid, effective and complete decomposition to a stable product (Harris et al., 2001). Compost that has been made from a variety of materials is likely to provide the best spectrum of nutrients. Thus the range and supply of different materials may need to be considered in a waste management strategy for soil amelioration (Leonard, 986).

Table 1: Criteria for interpreting elements in soil test data.

Nutrients	Insufficient	Sufficient	Toxic
Zn (ppm)	< 0.5	1-30	> 30
Fe (ppm)	< 1.0	4-30	>30
N (%)	< 0.075	0.075 - 0.15	> 0.15
P (ppm)	< 18	18-27	> 27
OC (%)	0.50 - 1.50	1.50 - 3.0	> 3.00

Source (Chapman and Pratt, 1961).

Table 2: Range in nutrient concentrations for fourth petiole during tuber bulking stage of potato.

Nutrients	Deficiency	Sufficiency	Toxic
Fe (ppm)	< 20	20-50	> 50
Zn (ppm)	< 10	10-20	>20
N (%)	< 1	1- 1.5	> 2
P (ppm)	< 0.17	0.17- 0.22	> 0.22
OC (%)	< 7.0	7.0 - 8.0	> 8

Source (Bryan et al., 2004).

CHAPTER TREE

3. Materials and Methods

3.1. Location of the Study Site

The study was conducted at Holeta Agricultural Research Center. Holeta is located approximately 29 km West of Addis Ababa on the Central Plateau. The area ranges in elevation from 1,600 to 2, 800 m.a.sl.

3.2. Soils of the Study Area

Soil under the study area is characterized by: deep, well-drained, red soils this type of soil is called Humic Nitisols and shallow Chromatic Luvisols, clay loam in texture, occupy many of the steeper slopes. Lower, gentler slopes are often characterized by deeper clay Vertic Cambisols which are well drained and easy to work, but poor in organic matter and nitrogen. Deep, clay Eutric Vertisols occur in the lowlands. These are subject to water logging and are generally difficult to work (Fig 1).

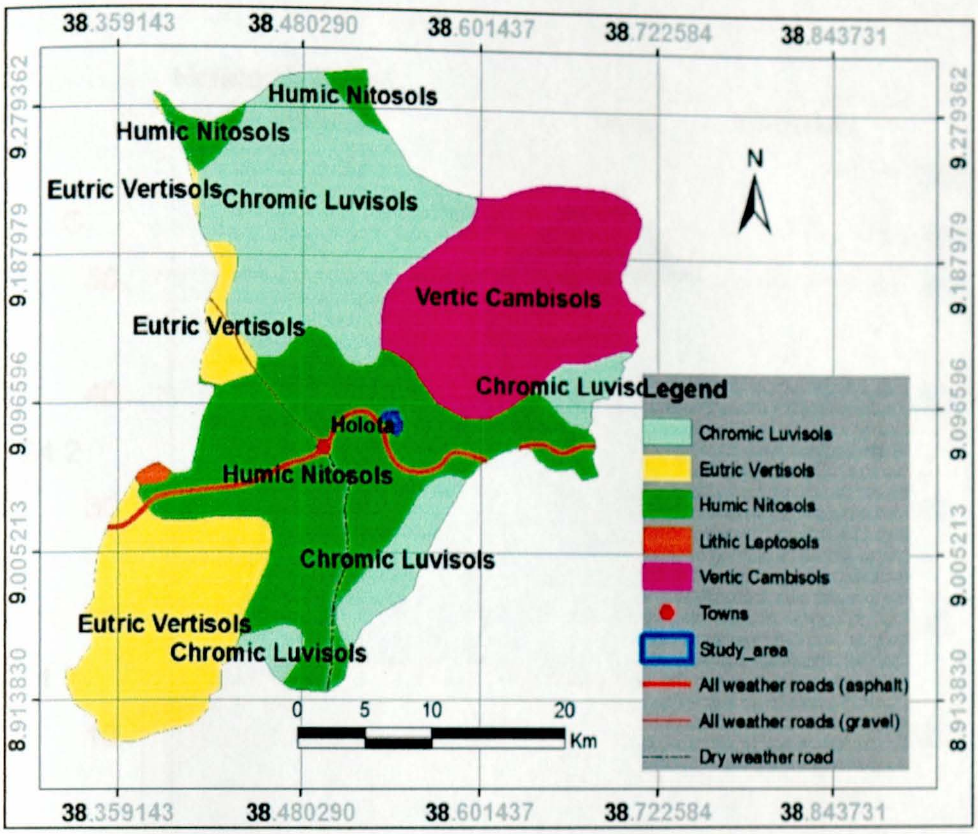


Figure 1: Map of soil types at Holeta

Source Borgal et al., 1980

3.3 Climate of the Study Area

Mean monthly temperatures range from 1.7 ° C in December to 24.2° C in March. Frost at night in the winter is common. Average annual rainfall was l, 035 mm. Most of this falls from June to September, with moderate rainfall (58.5-88.1 mm/month) from February to April, and little precipitation from October to December (Fig 2).

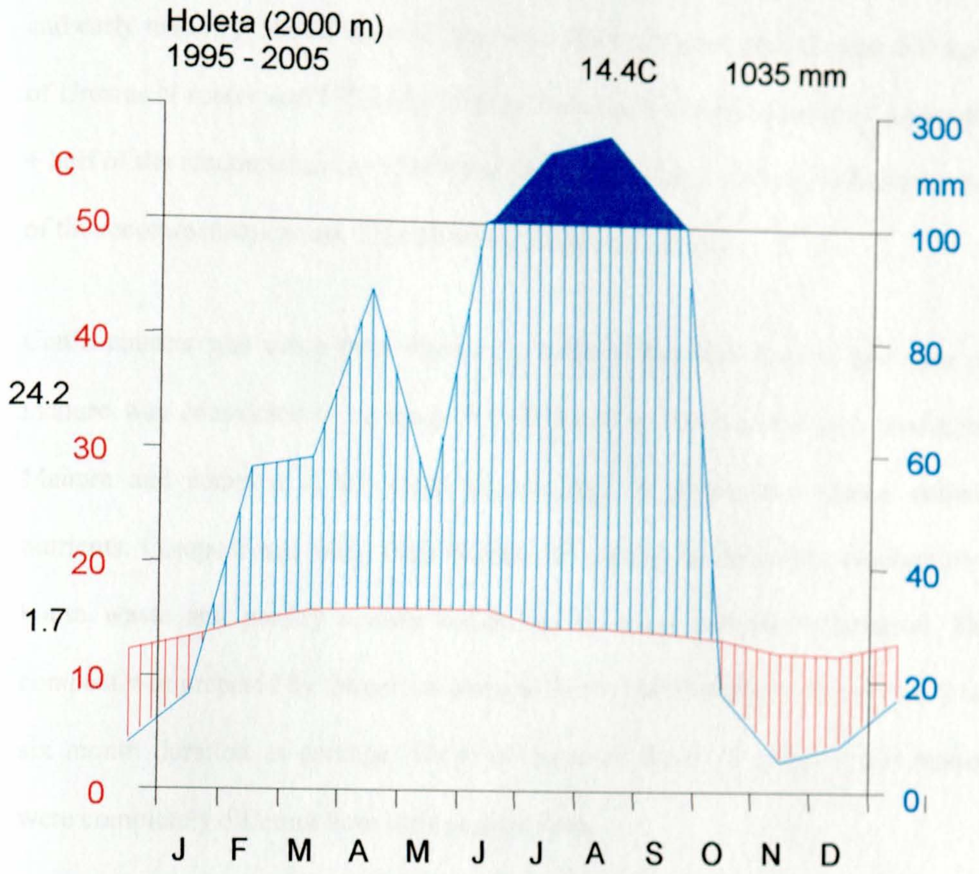


Figure 2: Annual temperature and rain fall at Holeta

Data Source: Ethiopian National Meteorological Station Agency (1995-2005).

3.4. Some Equipments and Materials Used

Materials that were used during this work were auger, clean plastic container with 1kg capacity spring balance, cutter, meter and so on.

3.5. Varieties and Fertilizer Treatments

Two potato varieties (`Jalane and Belte`) were taken from Holeta Agricultural Research Center. They were used as test crops to investigate the status of Fe and Zn in response to different fertilizers applications.

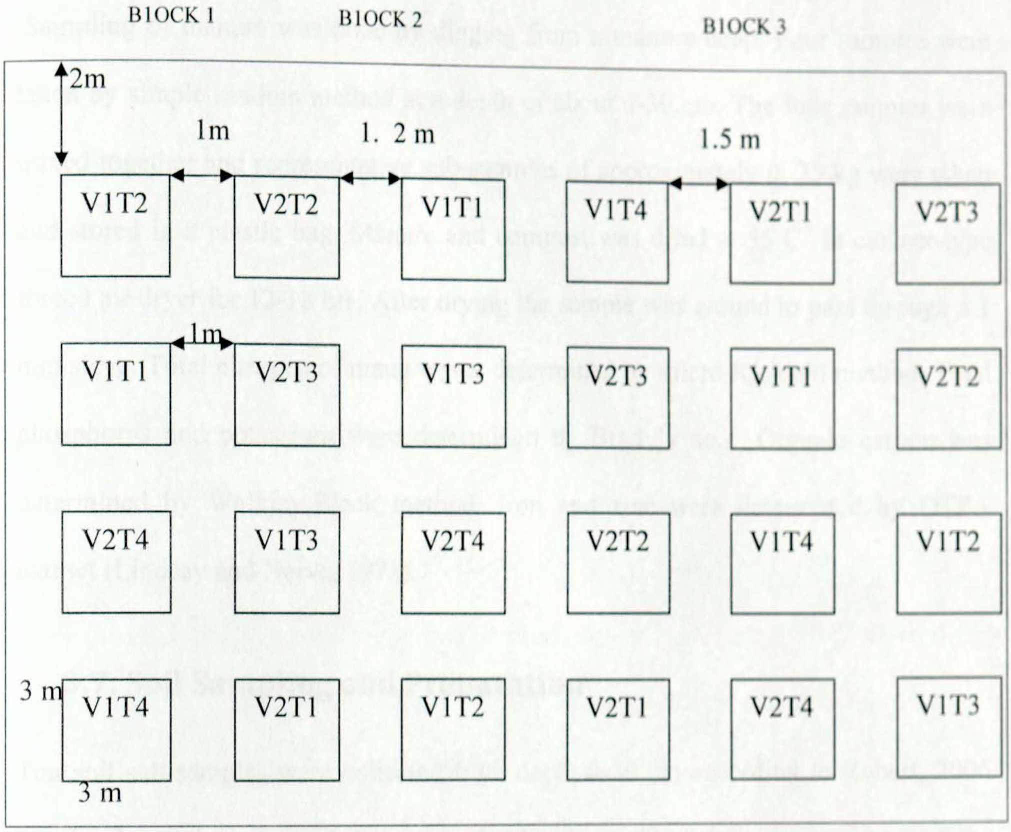
The cultivars were selected because of their high yield potential, disease resistance and early maturity (90-120 days of planting). The treatments applied were: 165 kg/ha of Urea as N source and 195 kg/ha DAP as P source, five tons of compost per hectare + half of the recommendation of N/P and five tons f animal manure per hectare + half of the recommendation rate of fertilizer (Wakene et al., 2002).

Cattle manure was taken from Holeta Agricultural Research Center. One year old manure was considered to be ready for utilization as fertilizer for crop production. Manure and compost at this stage were enough to mature and release essential nutrients. Compost was taken from farmers. It contains the following material: rural house waste and poultry manure but it had no paper and plastic material. This compost was prepared by farmers as garbage for the purpose of growing potato. It has six month duration as garbage. These decomposed forms of compost and manure were completely different from their original form.

The treatments were arranged in RCBD, with three replications. Each form of treatment was applied on plot size of 3 m × 3 m. The distance between block and plot was 1.5 m and 1m, respectively. Four rows, each having 10 plants, were used on 3 m × 3 m plot. Animal manure and compost were weighed (on dry weight basis) and applied to respective plot three weeks before planting date. At the planting date each plot of land was furrowed and small size of potato tubers were planted at a spacing of 75 cm between rows and 30 cm between plants. All cultural practices, such as weeding, earthing up, etc were carried out equally for all treatments. Fertilizers were applied by banding during planting the tubers about 2 inches to the sides and 2 inches below the seed piece to provide benefits of early growth.

Figure 3 Belte variety grown with manure and fertilizer

Figure 4 Jalane variety grown with manure and fertilizer



Where V1=Belte variety and V2=Jalane variety, T1= controlled, T2= Manure + fertilizer T3 = compost + fertilizer T4= fertilizer alone.

Figure 5: Layout of the field experiment

3.6. Manure, Compost Preparation and Sampling

Sampling of manure was done by digging from a manure heap. Four samples were taken by simple random method at a depth of about 0-30 cm. The four samples were mixed together and representative sub-samples of approximately 0. 25 kg were taken and stored in a plastic bag. Manure and compost was dried at 55 C^0 in cabinet-type forced air dryer for 12-18 hrs. After drying the sample was ground to pass through a 1 mm sieve. Total nitrogen of manure was determined by micro Kjeldahl method. Total phosphorus and potassium were determined by Brady's no.1. Organic carbon was determined by Walkley-Black method. Iron and zinc were determined by DTPA extract (Lindsay and Nerve, 1978).

3.7. Soil Sampling and Preparation

Ten soil sub-samples were collected from depth 0-30 cm according to Robert, 2006 by simple random method from the plot before potato tubers were planted. Sub-samples were then collected separately and properly labeled. Soil samples were air dried at room temperature and crushed by using a wooden mortar and pestle to pass a 2 mm mesh sieve.

3.8. Soil Chemical and Physical Analysis

3.8.1. Active Acidity (pH)

Soil pH was measured in a 1:1 soil-water ratio using a glass electrode (H19017 Microprocessor) pH meter. Approximately 25 g of soil was weighed into a 50 ml polythene beaker and 25 ml of distilled water was added to the soil. The soil-water solution was stirred thoroughly and allowed to stand for 30 minutes. After calibrating the pH meter with buffers of pH 4.01 and 7.00, the pH was read by immersing the electrode into the upper part of the soil solution and the pH value recorded.

3.8.2. Phosphors Available

Five gram of soil was weighed into 100 ml extraction bottle and 35 ml of extracting solution of Bray`s no.1 (0.03 M NH4 in 0.025 M HCl) was added. The bottle was placed in reciprocal shaker and shaken for 10 minutes after which the content was about 5 ml of the clear solution was kept into 25 ml of test tube and 10 ml of coloring reagent that is ammonium molybdate was added. The mixture was left for fifteen min utes to develop a blue colour. Available phosphorus was read from Spectrophotometer

3.8.3. Nitrogen Available

Total nitrogen was determined by the Kjeldahl Digestion method. Approximately five gram of soil was weighed into a Kjeldahl Digestion flask and 5 ml distilled water added. After 30 minutes 5 ml of concentrated H_2S0_4 was added to the soil and heated for 3 hours. The flask was removed and it was allowed to cool.

The digested material was distilled for four minutes and the distilled taken into a flask containing 2 ml of 4 % boric acid. The colour change was from pink to green after distillation with boric acid. Finally, percentage of nitrogen was calculated.

3.8.4. Organic Carbon

Soil organic carbon was determined by the Walkley-Black method. Five gram of soil sample was oven-dried at 105 °C and, was transferred into clean tarred porcelain crucibles. Finally, the organic matter was removed by combustion of the soil sample at 600 °C for three hours in a temperature regulated muffle furnace and the percent organic matter content was obtained by subtracting the percent mineral content from the total mass.

3.8.5 Determination of Available Potassium

Five gram of soil was weighed into 100 ml extraction bottle and 35 ml of extracting solution of Bray`s no.1 (0.03 M NH4 in 0.025 M HCl) was added. The bottle was placed in reciprocal shaker and shaken for 10 minutes after which the content was about five ml of the clear solution was kept into 25 ml of test tube. Available potassiu m extracted using the Bray's no.1 solution was determined directly using the Gallenka mp flame analyzer.

3.8.6. Fe and zinc in Soil

All samples were dried at 55 °C in a cabinet-type forced air dryer for 12-18 hrs. After drying the sample five gram was ground to pass through a 2 mm mesh sieve, grounded soil transferred into 150 ml of conical flask and 20 ml of DTPA extract was added. It was shaken for 2 hours and then filtered with filter paper. Total Fe and Zn were determined from filtrate by atomic absorption spectrophotometer.

3.8.7. Soil Texture

Soil texture was determined by the hydrometer method. Approximately five gram of soil was weighed into 250 ml beaker and oven dried at 105 ^{0}C for 24 hours. The sample was removed from the oven and then placed in a desiccator to cool, after which it was weighed and the oven dry weight taken. A 100 ml of dispersing agent was measured and added to the soil. It was then placed on a hot plate and heated until the first sign of boiling was observed.

The content in the beaker was washed completely into a shaking cup and shaken for five minutes. The sample was sieved through a 50 microns sieve mesh into a one litre cylinder to determine the sand portion. The cylinder with its content was shaken to allow particles to be in suspension; it was then placed on the bench and hydrometer reading of silt and clay portions were then calculated graphically.

3.9. Plant Sampling and Preparation for Analysis

Third to sixth leaf from top was sampled at flower initiation stage for Fe and Zn status. Thirty leaves were randomly collected from 20 different plants growing adjacent to each other per plot (Westermann et al., 1994). Physiologically active mature leaves were sampled according to Taber, (2009). This is the leaf that has turned from a light green juvenile color to a darker-green color and has reached full size. Leaves were shaken or wiped to remove dust. Leaf samples were quickly taken to the laboratory for analysis.

Separate leaf samples were placed in containers and then placed in forced-air oven and dried at 80 ^{0}C for twelve to twenty four hours. Leaf sampling was reduced (grounded) to 0.5 to 1.00 mm particle size by Willey Mills to ensure homogeneity and to facilitate organic matter decomposition.

The samples were thoroughly mixed and five gram was withdrawn for iron and zinc analysis. Dry ashing was conducted in muffle furnace at temperature of 500 to 550^{0}C for four to eight hours. At the end of the ashing period the vessel was removed from the muffle furnace, cooled and the ash was dissolved and diluted with HCl acid. Zinc and iron were extracted with DTPA and determined by Atomic Absorption Spectrophotometer.

3.9.1 Data Analyses

Treatments means were competed by using probability level of P = 0. 05 by using ANOVA according to Turkey test. To determine correlation of iron and zinc with other nutrients of soil SPSS version 20 is use.

CHAPTER FOUR

4. Results

4.1 Pre Plant Soil Analysis

4.1.2 Soil Texture

The percentage of the different soil separates were listed as the following: clay 42.25%, sand was 32.75% and silt 21.00%. The soil texture was dominated by clay followed by sand. The least particle size distribution was that of silt. This indicates that the soil has good drainage and aeration. Sandy soil has poor structure, high specific densities and it lacks coherence.

Table 3: Chemical properties of soil

Parameters	Statistics				
	Maximum	Minimum	Mean	SD	CV%
pH	6.05	5.2	5.54	0.28	5
K (ppm)	3.16	1.14	2.07	0.65	31
P (ppm)	33.75	19.23	26.67	0.82	21
N (%)	0.0191	0.0016	0.0165	0.60	76
OC (%)	0.0275	0.0015	0.0178	0.73	41
Fe (ppm)	38.72	17.38	23.62	0.74	31
Zn (ppm)	9.92	2.57	6.21	1.49	24

Table 3 shows chemical properties of Holeta soil. As indicted in the table, soil pH was slightly acidic with the range of 5.2 - 6.05 and a mean value of 5.5. This is satisfactory for most crops. The range of iron and zinc in soil are 17.38 - 38.72 ppm and 2.57- 9.92 ppm respectively with mean value of 23.62 ppm Fe and 6.21 ppm of Zn.

Table 4: Some chemical properties of compost

Parameters	Statistics				
	Maximum	Minimum	Mean	SD	CV%
pH	5.59	4.67	5.09	0.41	8
K (ppm)	3.72	1.20	2.12	0.63	29
P (ppm)	38.19	28.74	32.39	4.09	12
N (%)	0.0198	0.0116	0.0171	0.26	15
OC (%)	0.0438	0.0253	0.0351	0.81	23
Fe (ppm)	44.71	31.14	37.54	5.63	15
Zn (ppm)	9.41	7.23	8.81	1.13	12

On table 4 pH of compost ranges from 4.67 - 5.59 with a mean value of 5.09. This shows compost was acidic. Compost contains the greatest amount of organic carbon with a mean value of 0.0351% followed by nitrogen with a mean value of 0.0171 %. The range of iron in compost is 31.14 ppm - 44.71 ppm with a mean value of 37.55 ppm.

Table 5: Some chemical properties of manure

Parameters	Statistics				
	Maximum	Minimum	Mean	SD	CV%
pH	6.76	5.27	6.07	0.63	10
K (ppm)	3.08	1.69	2.37	0.57	21
P (ppm)	41.52	28.74	37.53	3.38	9
N (%)	0.0262	0.0158	0.200	0.45	22
OC (%)	0.0290	0.0196	0.0192	1.18	61
Fe (ppm)	80.16	69.36	74.9	4.54	6
Zn (ppm)	52.92	44.24	48.03	3.74	7

The chemical properties of manure are listed in table 5. pH of manure ranges from 5.27 - 6.76 with mean value 6.07. Hence manure is weakly acidic. Manure contains iron in the range of 69.36 ppm - 80.16 ppm with mean value of 74.9 ppm. Iron in manure was larger than that of compost and soil. Range of zinc in manure is 44.24 ppm - 52.92 ppm with a mean value of 48.03 ppm.

4.2. Plant Analysis

Table 6: Minimum, Maximum, Mean, standard devation and coefficient of variation of Fe and Zn in leaf of potato (Belte and Jalane varieties).

Varieties+ treatments	Statistics									
	Minimum(mg.kg^{-1})		Maximum(mg.kg^{-1})		Mean(mg.kg^{-1})		SD		CV%	
	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn
V1T1	4.09	0.35	8.54	0.85	5.6	0.59	2.54	0.25	45%	42%
V1T2	4.08	0.35	10.24	0.91	5.97	0.71	3.69	0.27	61%	37%
V1T3	3.76	0.40	5.03	0.82	5.37	0.64	0.68	0.23	12%	35%
V1T4	4.94	0.82	5.74	0.56	4.52	0.76	1.06	0.17	23%	23%
V2T1	3.81	0.56	9.91	0.89	8.66	0.76	1.11	0.15	12%	20%
V2T2	7.77	0.59	6.29	1.09	4.51	0.84	2.35	0.22	52%	26%
V2T3	1.84	0.67	3.69	1.26	4.68	0.93	0.99	0.31	21%	33%
V2T4	3.69	0.66	3.76	0.98	4.76	0.82	1.38	0.15	29%	17%

CV=coefficient of variation and T1= Controlled, T2=Manure+ fertilizer, T3= Compost+ Fertilizer, T4=fertilizer alone, V1= Belte variety V2= Jalane variety

From table 6, Belte variety grown on soil alone has the following ranges of 4.1 mg/kg - 8.5 mg/kg iron, 0.4 mg/kg - 0.9 mg/kg zinc with a mean value of 5.6 mg/kg and 0.59 mg/kg of iron and zinc respectively. Variety Belte grown on manure+ fertilizers has iron and zinc in, the range of 3.8 mg/kg - 10.2 mg/kg, 0.4 mg - 0.9 mg/kg respectively with mean value 5.97 mg/kg of iron and 0.71 mg/kg of zinc. The range of iron and zinc in variety Belte grown on compost + fertilizers are 4.9 mg/kg - 6.2 mg/kg and 0.8 mg/kg - 0.9 mg/kg respectively with a mean value of 5.37 mg/kg of iron and 0.64 mg/kg of zinc. Variety Belte grown on fertilizers alone has iron and zinc in range of 3.8 mg/kg - 5.7 mg/kg, 0.6 mg/kg - 5.0 mg/kg respectively with a mean value of 4.52 mg/kg iron and 0.76 mg/kg of zinc.

Iron concentration in variety Jalane grown on soil, manure + fertilizers, compost + fertilizers and fertilizers alone can be listed in the ranges of 7.8 mg/kg - 8.3 mg/kg, 1.8 mg/kg - 6.3 mg/kg, 3.7 mg/kg - 5.8 mg/kg and 3.8 mg/kg - 6.34 mg/kg respectively. The mean of iron in variety Jalane grown on soil, manure + fertilizers, compost + fertilizers and fertilizers alone can be listed in the following: 8.6 mg/kg, 6 mg/kg, 4.51 mg/kg, 4.68 mg/kg and 4.76 mg/kg respectively.

Zinc concentration in variety Jalane grown on soil, manure + fertilizers, compost + fertilizers and fertilizers alone can be listed in the ranges of 0.56 mg/kg - 0.89 mg, 0.59 mg/kg - 1.09 mg/kg, 0.67 mg/kg - 1.26 mg/kg, 0.66 mg/g - 0.98 mg/kg respectively. The mean value of zinc in variety Jalane grown on soil, manure + fertilizers, compost + fertilizes and fertilizers alone can be listed as the following: 0.76 mg/kg, 0.84 mg/kg, 0.93 mg/kg and 0.82 mg/g respectively. In all treatments Jalane variety has more iron concentration than concentration of zinc.

CHAPTER FIVE

5. Discussion, Conclusion and Recommendations

5.1 Discussion

Both iron and zinc in the soil are with sufficient range according to criteria listed on table 1. Soil contains high concentration of iron than zinc. The soil has high concentration of organic carbon with a mean value of 0.0178% followed by nitrogen with a mean value of 0.0165%. Soil contains potassium in lowest concentration followed by zinc and iron. Nitrogen and phosphorus in soil found as sufficient level according to criteria listed in table 1.

In Appendix 4, correlations of some elements of soil are listed. Correlation is used to relate what types of relation present between two variables. The value of correlation 1 shows as strong positive relation present. This means as one increase the other also increase the correlation of each elements within themselves show a value of 1.When we see correlation of Fe with that of pH it has a negative correlation value -0.114. This means as the pH increases the concentration of iron decreases. This is due to formation of in soluble iron phosphate salt in soil. This is significant ($P < 0.05$) at 95% confidence interval. Zinc and pH in soil have a correlation value of -0.373. This means as pH increases the concentration of zinc in soil decreases with a significance of 95% level of confidence interval. Correlation value of iron with zinc is -0.373 with significant difference ($P < 0.05$) at 95% confidence interval.

The relation of phosphorus with Zn and Fe is negative with correlation value of - 0.640 and -0.143 respectively, at significant of 95% confidence interval is observed. This is because phosphorus is one of the important elements that negatively interfere with zinc and iron in soil. The mean value of iron 37.54 ppm is greater than iron concentration of soil with a mean value of 23.62 ppm. Range of zinc in compost is 7.23 ppm - 9.41 ppm, with a mean value of 8.81 ppm. This is also greater than content of soil with a mean value 6.21 ppm. Iron concentration in compost is greater than zinc concentration of compost. Zinc content in manure is higher than both soil and compost. Manure contains higher phosphorus with a mean 37.53% followed by nitrogen with a mean value 2%. Iron concentration in manure is greater than zinc concentration.

From Appendices 7 and 8 concentrations of iron and zinc in Belte variety grown with inorganic fertilizer, soil alone, and combination of organic and inorganic fertilizer were not show a significant difference ($P \geq 0.05$). Similarly, from Appendices 9 and 10 concentrations of iron and zinc in Jalane variety grown with inorganic fertilizer, soil alone and combination of organic and inorganic fertilizer did show a significant different ($P \geq 0.05$). But variety Jalane grown on soil a lone and manure + fertilizers has a significant difference concentration of iron at ($P < 0.05$) (Appendix 10). Belte variety grown with all treatments has more iron concentration than zinc concent ration. Concentration of iron in Belte variety decreased in the following order V1T2 > V1T3 > V1T1 > V1T4. Concentration of zinc in Belte variety can also listed in the following decreasing order V1T4 > V1T2 > V1T3 > V1T1.

This study is agreement with the report of Tesfaye Abebe et al., (2012) where lower concentration of zinc in Belte variety was observed among 21 varieties which also include Jalane.

Concentration of iron in Jalane variety grown with soil alone has the largest iron followed by that grown with fertilizers alone. Concentration of iron in Jalane variety grown with manure + fertilizers has the least concentration of iron followed by variety Jalane grown with compost +fertilizers. Jalane variety grown on compost + fertilizer has the largest zinc concentration followed by that grown on manure +fertilizer.

The least zinc concentration in variety Jalane is recorded with that grown on soil alone followed by that grown on fertilizer alone. Concentration of iron and zinc in Belte variety grown on soil alone are less than Jalane variety grown on soil alone. Iron concentration in Belte variety grown with manure + fertilizer is more than that of Jalanr variety grown with manure + fertilizer. But zinc concentration in Belte variety grown with manure + fertilizer is less than that of Jalane variety grown with manure + fertilizer. Iron concentration in Belte variety grown with compost + fertilizer is more than that of Jalane variety grown with compost + fertilizer. But zinc concentration in Belte variety grown with compost + fertilizer is less than that of Jalane variety grown with compost + fertilizer. Iron concentration in Belte variety grown with fertilizer alone is approximately equal with Jalane variety grown with fertilizer alone. But zinc concentration in Belte variety grown with fertilizer alone is less than that of Jalane variety grown with fertilizer alone. In both varieties concentration of iron and zinc grown with different fertilizers are lower when compared with at tuber bulking stage of potato (Table 2).

In addition to this concentrations of iron and zinc in both Belte and Jalane varieties grown with different fertilizers in this study have lower concentration of iron and zinc when compared with the report of Tesfaye Abebe et al., (2012).

5.2 Conclusion and Recommendations

The soil under study area is acidic with sufficient concentration of iron, zinc and phosphorus while nitrogen in soil was in excess amount. Texture of soil was dominated with clay and sand. Status of iron and zinc in manure were larger when compared with soil and compost. Soil contains least concentration of iron and zinc than compost and manure.

Concentration of iron and zinc in Belte and Jalane varieties grown with inorganic fertilizer, soil alone and, combination of organic and inorganic fertilizer were not significant different ($P \geq 0.05$). But, variety Jalane grown on soil alone and manure+ fertilizers has a significant difference concentration of iron at ($P < 0.05$). Both Jalane and Belte grown on different fertilizers have higher concentration of iron than zinc. Iron and zinc have a negative correlation with phosphorus and pH this is significant at ($P < 0.05$). Iron and zinc have negative correlation significant at ($P < 0.05$) between each other. Iron and zinc has insignificant correlation at ($P \geq 0.05$) with nitrogen and potassium.

To have complete and general information further research should focus on iron and zinc status of different varieties of potato grown with different soil management practices, on different soil types and at different growth stages such as vegetative stage, flowering stage and tuber bulking stage.

Investigating iron and zinc status in potato at different growth stages and by growing with different fertilizers is recommended to manage these nutrients and solve deficiency of dietary problems caused by these elements.

Comparing iron and zinc status among potato varieties is important to select and consume varieties with optimum range of these nutrients.

To enhance uptake, translocation and to have optimum range of iron and zinc in Belte and Jalane varieties grown on Humic Nitisols inorganic form of iron and zinc fertilizers are needed.

References

Abebe Yadessa, Keyyalew Negisho, Friesen, D.K., Wakene Negassa, Ransom, J. (2001). Determination of optimum farm yard manure and NP fertilizers from maize on farmer field. 7th Eastern and Southern Africa Regional Maize Conference.

Abdul Rashid, Muhammad, I., Parvezkhan, M, Y., Aslam, M. (2010). The role of micronutrients in crop production and human health. *Pak. J. Bot.* **42(4):** 246 - 257.

Adedrian, J. A. (1995). Response of maize to N, P and K fertilization in savanna zone Nigeria, Commum. Soil Sci. Plant Anal 26: 593-606.

Alloy, B. J. (2002). Zinc the Vital Micronutrient for Health in High Value Crops, 2nd ed. International Zinc Association Paris, France.

Alloy, B. J. (2008). Zinc in Soils and Crops Nutrition, 2nd ed. International Zinc Association Paris, France.

Atsan, E., Ozturk, R., Polat, T., Kara, K. (2011). Variation in heavy metal concentration of potato (Solanum tubersom) Cultivas. *J. Anim. Plant Sci.* **21(2):** 235-239.

Bation, A. and Mokwunye, A. U. (1992). Role of manure and crop residue in alleviating soil fertility constraints to crop production. *Fertilizer Research.* **29:** 217-225.

Bergmann, W. (1992). Nutritional disorders of plants, 2nd ed. Gustav Fisher Verlag, Jena, German.

Bradshaw, J. E and Bonierbale, M. (2010). Root and Tuber Crops: Hand Book Plant Breeding New York, London.

Brady, N, C and Weil, R. (2002). Nature and Properties of Soils, 3rd ed. Prentice Hall, New Jersey.

Brian, Q. P., Mengshi, L., Barbara, R. (2004). Analysis of phayte in raw in raw and cooked potatoes. *J. Food. Com. Anal.* **17:** 217- 226.

Borgal, H. B., Arend, C. J., Kanyarukis, S., Kulazia, A., Lemaga, B. L., Mogeeka, W. (1980). Production, marketing and consumption of potato in the Ethiopia highland Center of Advanced training in agricultural development technology University of Berlin, Berli.

Burton, W. G. (1989). The potato, 3rd ed. Prentice Hall Inc. Englewood. N. J.

Bryan, H., Westermann, D., Stark, J. (2004). Nutrient Management Guidelines for Russet Burbank potatoes. Bulatein no 840.

Cakmak, L., Marshner, H., Oberle, H., Romheld, V. (1990). Growth enhancement by silicon in cucumber (Cucumissativus) plants depends on imbalance in phosphorus and zinc supply. *Plant soil* **124:** 211- 219.

Chapman, H. D and Pratt, T. (1961). Methods of analysis for soils, plant and water. University California, California.

Chen. Y. and Hadar, T. (1991). Iron nutrition and interaction in plants. Kluver, Netherlands.

CIP. (1972). The prospects for the potato in the developing world. (CIP) Co-publication International Potato Center) Lima, Peru.

Conte, S. and Walker, L. E. (2011). Transpoters contributing to iron trafficking in plants. *Molec. Plant*. **16:** 393- 406.

Debjit, B., Chiranjib. K.P., Sampath, K. (2010). A potential medicinal important of zinc in human health and chronic disease. *Int. J. Phar. Bio. Sci* **1(1):** 5-11.

Deborah. R. M and Cathy, W. L. (2012). Iron Channels and Zinc: Mechanism of Neurotoxic and Neuro degeneration. Florida State University Collsge of Medicine, Tallahasse.

Eskin, N. and Michel, A. (1989). Quality and Preservation of Vegetables. CRS Press, Inc. Boca Raton, Florida.

Etienne, L. and Wand-Prusk, G. (2009). Distribution of Elements in potato Tubers and Their relationship after cooking to darkening. *Hort. Science*. **44(7):** 1866 - 1873.

FAO. (2006). A guide for intergrated nutrient management of fertilizer and plant nutrition bullet FAO (Food and Agricultural production for united nation), Rome.

FAO. (2008). Potato World: Africa International Year of the Potato, 3rd ed. FAO (Food and Agricultural production for united nation), Rome.

Francoise-Jean, T. (2009). Mechanism of iron homeostatic in plants and the irregulation. *J. Food. Com. Anal.* **22(2):** 335- 339.

Finch, C. A. (1959). Body iron exchange in man. *J.Clin.Invest.* **38:** 392-396.

Grusk, M. A. and Della, P. D. (2010). The Nutrient Composition of plant to Enhance Human Nutrition and Health. *Ann Rev. Plant* **17:** 204 - 226.

Halliday, J, W. (1998). Hemochromatosis and iron needs. *Nutr. Rev*. **56:** 530-537.

Harris, P. M. (1992). The Potato Crop: The scientific base for improvement, 2nd ed. Chapman and Hall, London.

Harris, P. J., Allison, M., Smith, G., Kindness, H. M. and Kelly, J. (2001). Potential Uses of Waste Stream Production for Soil Amelioration in Agricultural Production Systems. In : Waste Composting for Urbana and Peri-urban Agriculture. Lima, Peru.

Haverkort, J, A. (1982). Water Management in Potato Production. Technical Information Bulletin Lima, Peru.

Herbert, V. (1987). Recommended dietary in takes (RDI) of iron in humans. *Amer. J. Clinical Nutr* **45:** 679 - 686.

Holford, I. C. R. (1997). Soil Phosphorus: its measurement, and its uptake by plants. *Aust. J. Soil Res.* **35:** 227-239.

House, A. W. (1999). Trace element bioavailability as exemplified by iron and zinc. *Field crop Research* **60:** 15-141.

Israel Zewide, Ali Mohammed and Solomon Tulu. (2012). Effect of different rate of nitrogen and phosphorus on yield and yield competent of potato (Solanum tubersom L.) *Inter. J. Soil Sci.* 7(14): 146-156.

Imtiaz, M., Alloway, B. J., Shah, K. H., Siddiqui, S. H., Memon, M. Y., Aslam, M., Khan, P. (2003). Zinc Nutrition of Wheat II: Interaction of Zinc with other Trace Elements. *Asian. J. Plant. Sci,***2: 156-160.**

Jones, D. I., Dennis, P. G., Owen, A. G .and Van Hee, P. W. (2003). Organic acid behaviour in soils misconceptions and knowledge gaps. *Plant. Soil.* **248**: 331- 341.

Kabata-Pendias, A. (2011). *Trace Elements in Soils and Plants,* 4th *ed.* London New York, CRC Press.

Koppen, D. and Eich, D. (1993). Influence froma 85 year different rated organic manuring and mineralfertilization on soil fertility in the static experiment at bad land chstadt. *Soil land Fertilizers.***56 (1):** 402- 432.

Lang, N. S., Stevens, R. G., Thomton, R. E., Pan W. L., and Victory, S. (1999). Potato nutrient management for Central Washington. Washington State University, Washington.

Leonard, D. (198). Soil, Crop, and Fertilizer Use: Field Manual FOR Development Workers. Under Contract with Peace Crops. 4th editin revised and expanded. United State Peace Crops. Information Collection and Exchange. Reprin R0008.

Lihua, L., Xudong, C. and Ling, H. (2004). Isolation and characterization of Fe (III) chelate re ductase gene in tomato. *Plant. Mol. Biol* **.54:** 125 - 136.

Lindsay, W. L., and Norvell, W. A. (1978). Development of a DTPA soil test for zinc, iron, m anganese and copper soil. *Sci. Soc. Am. J.* **42:** 421- 428.

Long, J. K., Marianne, B. and Margare, E . S. (2004). Analysis of grain iron and zinc density in southern African adapted maize inbreds. Crop Sci.44: 2019 - 2026.

Lungaho, C., Lemaga, B., Nyonges, M., Gildemache, P., Kinye, P., Demo, P., and Kabira, J. (2007). Comercisl seed potato production in Eastern and Central Africa. Kenya Agricltural Research Institete, Acopp.

Marschner, H. (1986). Mineral Nutrition of Higher Plants. Academic Press, New York.

Marschner, H. (1995). Mineral Nutrition of Higher Plants, 2nd ed. Academic Press, New York.

Marti, H. R. and Mills, H. A. (1991). Nutrien uptake and yield of sweet peppea affected by stage of development and N Form. *J. Plant Nutr.* **14(11):** 1165- 1175.

Maryam, R., Mohammad, G., Sayed, R. M. (2012). Interaction of zinc with other elements in plants. *Intl. J. Agri. Crop. Sci.* **4(24):** 1881- 1884.

Mousavi, R. M. (2011). Zinc in Crop Production and Interaction with Phosphorus. *J. Bas. Appl. Sci.* **5(9):**1503-1509.

Miller, C. E. (2005). Plant physilogy with reference to the green plant. 2nd ed. Academic Press, Delhi.

Mills, H. A., and Jones, J. B. (1996). Plant Nutrition and Analysis of Essential Macronutrients : In Plant Analysis Handbook. Macromocro, Athens, GA.

Munro, J. and Lister, C. E. (2000). Nutrition and health qualities of potatoes. Plant and Food Research Confidential Report No. 143. New Zealand.

Nadia, G., Rahim, I. S. and Abdal, E. M. (2012). Potato yield quantity and quality under different irrigation regimes in newly reclaimed soil. *Mid. E. J. Agri. Res.* **1(1):** 26-32.

Naihmatulah, B. Hirotak, Y., Naoko, K. N., Haromi, N., Satoshi, M. (2002). Cloning iron regulated metal transporter from rice. *J. Exp. Bot.* **53:** 1677 - 1682.

Nithya, K. S., Philip, J. W., Martin, R. B., and Gavin, R. (2011). The three dimensional distribution of minerals in potato tubers. *Annal. Bot.* **107:** 681- 691.

Orozco-Mosqueda, C., Santoyo, G., Faris Rodriguez, R., Macias Rodrigue, L. and Valencia Cantero, E. (2012). Identification and expression analysis of multiple FRO gene copies in Medicago Truncatula Morelia. Michoacan, Mexico.

Randhawa, K. S., Sandhu, R. D., Kaur, G., Singh, D. (1984). Studies of the evaluation of different genotypes of potato (Solanum tuberosum L.) for yield and mineral content. Qua *Plant. Foods. Hum. Nutr.* **34:** 239 - 242.

Reid, R. J., Brooks, J. D., Tester, M. A. and Smith F. A. (1995). The mechanism of zinc uptake in plants. Characterization of the low affinity system. *J. Plant.* **198:** 39-45.

Rengel, Z., Romheld. V., Marschner, H. (1998). Uptake of zinc and iron by wheat geno types fering. In: tolerance to zinc deficiency. *J. Plant. Physi.* **142:** 433- 438.

Rengel, Z., Romheld, V. (2000). Root exudation, iron uptake and transport in wheat genotypes differing in tolerance of Zn deficiency. *J. Plant. Soil.* **2 (22):** 25 - 34.

Sandstead, H. (1985). Requirement of zinc in human subjects. *J. Amer. Nutr.* **4:**73-82.

Schmidt, W. (1999).Mechanisms and regulation of reduction-based iron uptake in plants. *New Phytol.* **141:** 11- 26.

Schulte, E. (2004). Understanding plant nutrients: soil and applied iron. University of Wisconsin, Wisconsin.

Schulte, E. (2004). Understanding plant nutrients: soil and applied iron.University of Wisco nsin, Wisconsin.

Taber, G. H. (2009). Plant analysis sampling procedures and micronutrient characteristics with emphasis on vegetable crop. Lowa State of University, Science and Technology institute.

Taheri. N., Heidari, H., Yousefi, K., Mousavi, S. R. (2011). Effect of organic manure with phosphorus and zinc on yield of seed potato. *Aust. J. Bas. Appl. Sci.* **5(8):** 775-780.

Tama, C. F. and Mary, L. (1998). Molecular biology of cation transport in plants. *Annul. Rev. Plant Physiol. Mol.* Biol. **49:** 669 - 96.

Tantowijoyo, W. and Fliert, V. E. (2006). In Widagdo, H. and Ketelaar, W. J. (eds). All about Potatoes: An Ecological Guide to Potato Integrated Crop Management. Academic Press, London.

Tesfaye Abebe, Shermarl, W., Thunya, T., Oranuch, L. (2012). Variation of minerals concentration among different potato varieties grown at distinct location in Ethiopia. *Nat. Sci.* **46:** 837- 850.

Thompson, H. C. and Kelly, W. C. (1972). Vegetable Crops. Tata McGraw. Co. Ltd, New Delhi.

Thomas, L, W and John, N., 1995. Early iron deficiency stress response in leaves of sugar beet. *Plant. Phys.* **108:** 1487-1494.

Tisdale, S. L., Nelson, W. J. and Beaton, J. D. (1993). Soil Fertility and Fertilizers, 4th ed. Macmillan, New York.

Tolessa Debelle and Friesen, D. K. (2001). Effect of enrich farmyard manure with mineral fertilizer on grain yield of maize at Bako Western, Ethiopia. Seventh Eastern and South Africa Regional maize conference.

Tzonou, A., Lagio, P., Trichopoulou, A., Tsoutso, V. and Trichopoulos, D. (1998). Dietary iron and coronary heart disease risk: *Am. J. Epid.* **147:** 161-166.

Volker, R. and Horst, M. (1986). Evidence for a specific uptake system for iron roots of grasses. *Plant. Phys.* **80:** 175- 180.

Westermann, D. T. (1993). Fertility Management in Potato Health Management. Minneapolis, MN, APS Press.

Westermann, D, T., Bosma, S, M. and Kay, M. A. (1994). Nutrient concentration relationship between the fourth petiole and upper stem of potato plants. Amer. Pot. J. 71: 817- 828.

Welch, M, R. (2002). The impact of mineral nutrients in food crops on global human health. *Plant. Soil.* **247:** 83 - 90.

White, P. J., Bradshaw, J. E., Dale, F. B., Ramsey, G., Hammond, J. P., Broadley, M. R. (2009). Relationship between yield and mineral concentration in potato tubers. *Hort. sci.* **41:** 68-96.

White, P. J. and Brown P. H. (2010). Plant nutrition for sustainable development and global health. *Anna. Bot.* **105:** 1073-1080.

Appendices

Appendix 1: Chemical properties of soil

Sample no	Depth (0-30cm)	parameters						
		pH	Fe(ppm)	Zn(ppm)	OC(%)	N (%)	P(ppm)	K(ppm)
1		5.20	16.06	1.90	0.0161	0.0165	20.34	1.14
2		5.96	19.58	2.57	0.0275	0.0019	19.70	2.27
3		6.05	15.84	5.09	0.0105	0.0036	21.48	1.72
4		5.63	19.58	5.81	0.0160	0.0036	31.85	2.28
5		5.44	17.38	6.99	0.0205	0.0016	33.75	2.67
6		5.45	20.90	8.22	0.0223	0.0049	28.84	1.32
7		5.23	25.74	9.61	0.0242	0.0031	21.96	1.19
8		5.18	29.26	9.92	0.0196	0.0051	19.43	2.18
9		5.42	38.72	4.62	0.0142	0.0118	25.76	2.85
10		5.56	34.76	6.70	0.0218	0.0127	30.62	1.76

Appendix 2: Chemical properties of manure

Sample	depth	Parameters						
		pH	Fe(ppm)	Zn(ppm)	OC(%)	N (%)	P(ppm)	K(ppm)
Manure 1		6.32	73.76	46.25	0.0196	0.0175	36.36	1.69
2		5.27	80.16	44.24	0.0285	0.0158	33.57	2.24
3		6.76	69.36	52.92	0.0290	0.0205	38.68	2.48
4		5.91	76.38	48.74	0.0275	0.0262	41.52	3.08

Appendix 3: Chemical properties of compost

Sample	Depth	Parameters						
		pH	Fe(ppm)	Zn(ppm)	OC (%)	N (%)	P(ppm)	K(ppm)
Compost 1		5.59	44.71	9.41	0.0253	0.0158	38.19	2.43
2		4.67	31.14	9.80	0.0438	0.0152	32.02	1.13
3		5.24	38.27	7.23	3.0393	0.0116	28.74	1.20
4		4.84	36.06	8.81	0.0322	0.0181	30.62	3.72

Appendix 4: Correlations of elements in soil

		PH	Fe	Zn	OC	N	P	K
PH	Pearson Correlation	1	-.114(*)	-.373(*)	-.071	-.129	.126(*)	.244
	Sig. (2-tailed)		.024	.032	.826	.690	.016	.444
	N	12	12	12	12	12	12	12
Fe	Pearson Correlation	-.114(*)	1	-.483(*)	.057	.129	.143(*)	.284
	Sig. (2-tailed)	.024		.012	.860	.689	.028	.371
	N	12	12	12	12	12	12	12
Zn	Pearson Correlation	-.373(*)	-.483(*)	1	.180	-.224	-.198(*)	-.114
	Sig. (2-tailed)	.032	.012		.576	.485	.037	.724
	N	12	12	12	12	12	12	12
OC	Pearson Correlation	-.071	.057	.180	1	-.144	.118	.101
	Sig. (2-tailed)	.826	.860	.576		.655	.715	.755
	N	12	12	12	12	12	12	12
N	Pearson Correlation	-.129	.129	-.224	-.144	1	.241	.024
	Sig. (2-tailed)	.690	.689	.485	.655		.451	.940
	N	12	12	12	12	12	12	12
P	Pearson Correlation	.126(*)	.143(*)	.198(*)	.118	.241	1	.459
	Sig. (2-tailed)	.016	.028	.037	.715	.451		.133
	N	12	12	12	12	12	12	12
K	Pearson Correlation	.244	.284	-.114	.101	.024	.459	1
	Sig. (2-tailed)	.444	.371	.724	.755	.940	.133	
	N	12	12	12	12	12	12	12

* Correlation is significant at the 0.05 level (2-tailed).

Appendix 5: Fe and Zn concentrations in Belte leaves

Sample	V1T1	
	Fe mg/g	Zn mg/g
1	8.5394	0.3546
2	4.1806	0.5642
3	4.0852	0.852
	V1T2	
4	10.2408	0.4038
5	3.9236	0.818
6	3.7586	0.9062
	V1T3	
7	5.0286	0.8246
8	6.164	0.8974
9	4.935	0.818
	V1T4	
10	5.7446	0.5616
11	3.8098	5.003
12	4.0106	0.7256

Appendix 6: Fe and Zinc concentrations in Jalane leaves

Sample	V2T1	
	Fe mg/g	Zn mg/g
1	8.3028	0.5936
2	7.7684	0.7884
3	9.9026	0.8994
	V2T2	
4	1.8389	0.6742
5	5.3894	0.7506
6	6.299	1.0947
7	V2T3	
8	3.6982	0.6646
9	4.6712	0.853
	5.6704	1.2664
	V2T4	
10	4.1864	0.708
11	6.34	0.7652
12	3.7586	0.9842

Appendix 7: Variation of zinc concentration in Belte variety grown on different fertilizer

Dependent Variable: Zn

			Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
Tukey HSD	V1T1	V1T2	-.11907	.22992	.952	-.8554	.6172
		v1t3	-.04640	.22992	.997	-.7827	.6899
		V1T4	-.16740	.22992	.883	-.9037	.5689
	V1T2	V1T1	.11907	.22992	.952	-.6172	.8554
		v1t3	.07267	.22992	.988	-.6636	.8090
		V1T4	-.04833	.22992	.996	-.7846	.6880
	v1t3	V1T1	.04640	.22992	.997	-.6899	.7827
		V1T2	-.07267	.22992	.988	-.8090	.6636
		V1T4	-.12100	.22992	.950	-.8573	.6153
	V1T4	V1T1	.16740	.22992	.883	-.5689	.9037
		V1T2	.04833	.22992	.996	-.6880	.7846
		v1t3	.12100	.22992	.950	-.6153	.8573

Appendix 8: Variation of iron concentration in Belte variety grown on different fertilizer

Dependent Variable: Fe

			Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
Tukey HSD	V1T1	V1T2	-.37260	1.90321	.997	-6.4674	5.7222
		v1t3	.22587	1.90321	.999	-5.8689	6.3206
		V1T4	1.08007	1.90321	.939	-5.0147	7.1748
	V1T2	V1T1	.37260	1.90321	.997	-5.7222	6.4674
		v1t3	.59847	1.90321	.988	-5.4963	6.6932
		V1T4	1.45267	1.90321	.869	-4.6421	7.5474
	v1t3	V1T1	-.22587	1.90321	.999	-6.3206	5.8689
		V1T2	-.59847	1.90321	.988	-6.6932	5.4963
		V1T4	.85420	1.90321	.968	-5.2406	6.9490
	V1T4	V1T1	-1.08007	1.90321	.939	-7.1748	5.0147
		V1T2	-1.45267	1.90321	.869	-7.5474	4.6421
		v1t3	-.85420	1.90321	.968	-6.9490	5.2406

Appendix 9: Variation of zinc concentration in Jalane variety grown on different fertilizer

Dependent Variable: Zn

			Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
Tukey HSD	v2t1	v2t2	-.07937	.17802	.969	-.6495	.4907
		V2T3	-.16753	.17802	.785	-.7376	.4026
		v2T4	-.05867	.17802	.987	-.6288	.5114
	v2t2	v2t1	.07937	.17802	.969	-.4907	.6495
		V2T3	-.08817	.17802	.958	-.6583	.4819
		v2T4	.02070	.17802	.999	-.5494	.5908
	V2T3	v2t1	.16753	.17802	.785	-.4026	.7376
		v2t2	.08817	.17802	.958	-.4819	.6583
		v2T4	.10887	.17802	.926	-.4612	.6790
	v2T4	v2t1	.05867	.17802	.987	-.5114	.6288
		v2t2	-.02070	.17802	.999	-.5908	.5494
		V2T3	-.10887	.17802	.926	-.6790	.4612

Appendix 10: Variation of iron concentration in Jalane variety grown on different fertilizer

Dependent Variable: Fe

			Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
Tukey HSD	v2t1	v2t2	4.14883(*)	1.26979	.046	.0825	8.2151
		V2T3	3.97800	1.26979	.055	-.0883	8.0443
		v2T4	3.89627	1.26979	.060	-.1700	7.9626
	v2t2	v2t1	-4.14883(*)	1.26979	.046	-8.2151	-.0825
		V2T3	-.17083	1.26979	.999	-4.2371	3.8955
		v2T4	-.25257	1.26979	.997	-4.3189	3.8137
	V2T3	v2t1	-3.97800	1.26979	.055	-8.0443	.0883
		v2t2	.17083	1.26979	.999	-3.8955	4.2371
		v2T4	-.08173	1.26979	1.000	-4.1480	3.9846
	v2T4	v2t1	-3.89627	1.26979	.060	-7.9626	.1700
		v2t2	.25257	1.26979	.997	-3.8137	4.3189
		V2T3	.08173	1.26979	1.000	-3.9846	4.1480