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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON SOIL PHYSICOCHEMICAL PROPERTIES AND YIELD AND YIELD COMPONENTS OF MAIZE (Zea mays L.) and TEF (Eragrostis tef) AT YILMANA DESNSA DISTRICT, NORTHWESTERN ETHIOPIA

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BAHIR DAR UNIVERSITY

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GRADUATE PROGRAM

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M.Sc. Thesis

By

Tesfaye Bayu Zeleke

May, 2017

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A THESIS SUBMITTED TO COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES GRADUATE PROGRAM IN PARTIAL FULFILMENT TO THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (MSC.)

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THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defence examination, we have read and evaluated this thesis prepared by Tesfaye Bayu Zeleke entitled "**EFFECT OF INTEGRATED FERTILITY MANAGEMENT ON SOIL PHYSICO-CHEMICAL PROPERTIES AND YIELD AND YIELD COMPONENTS OF MAIZE (*Zea mays L.*)and TEF *(Eragrostis tef)* AT YILMANA DESNSA DISTRICT, NORTHWESTERN ETHIOPIA**". We hereby certify that, the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Land Resource Management.

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DECLARATION

This is to certify that this thesis entitled "**EFFECT OF INTEGRATED FERTILITY MANAGEMENT ON SOIL PHYSICO-CHEMICAL PROPERTIES AND YIELD AND YIELD COMPONENTS OF MAIZE (*Zea mays L.*)and TEF *(Eragrostis tef)* AT YILMANA DESNSA DISTRICT, NORTHWESTERN ETHIOPIA**" submitted in partial fulfilment of the requirements for the award of the degree of Master of Science in "Land Resource Management" to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by Mr. Tesfaye Bayu Zeleke (ID. No. BDU0805581PR) is an authentic work carried out by him under my guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

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Name of the Supervisor

1) Dr. Yihenew G.Selassie (Major Supervisor)

Signature & date____________________

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This thesis is dedicated to the remembrance of my charming grandfather, Agaje Endalew, and my grandmother, Yeshiareg Biru, who passed away before seeing my success.

LIST OF ABBREVIATIONS /ACRONMYS

AGDB	Above ground dry biomass
ANOVA	Analysis of Variance
BOARD	Bearu of agriculture and rural development
CEC	Cation exchange capacity
CIMMYT	International maize and wheat improvement canter
CSA	Central Statistical Agency
EL	Ear Length
ET	Effective tiller
FAO	Food and agriculture organization
GDP	Gross Domestic Product
GY	Grain yield
HI	Harvest index
IFM	Integrated fertility management
MRR	Marginal rate of return
OC	Organic carbon
PH	Plant height
PL	Panicle Length
RCBD	Randomized Complete Block Design
RDF	Recommended dose of mineral fertilizer
SAS	Statistical analysis system
SOM	Soil organic matter
SY	Stover Yield
TSW	Thousand seed weight
YDD OARD	Yilman Densa Distric Office Of Agriculture And Rural Development

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ABSTRACT

Low soil fertility status due to erosion, intensive farming and leaching are the major problems limiting current maize and tef yield. Field experiments were conducted at Yilmana Desnsa District, Northwestern Ethiopia in 2016/2017 with the objective of assessing nutrient status of the soil; evaluate the chemical quality of compost; quantify the effects of integrated fertility management on yield and yield components of maize and tef; and evaluate changes in soil physico-chemical properties due to integrated nutrient management in the study area. Maize variety named BH- 540 and tef variety called Kuncho were used as test crops. The treatments were factorial combinations of three compost rates (0, 5 and 10 t ha^{-1}) and three mineral fertilizer rates (0, ½ and full recommended NPSBZn plus urea).NPSBZn fertilizer was added at the beginning of sowing while urea was added in split application method half at planting and half at knee-height stage. The treatments were laid out in RCBD design with three replications. SAS (12.00 version) software was used for analysis of diverse parameters. Soil samples were taken and analyzed before planting and compared with critical levels from literature to determine nutrient requirement for study area. Compost samples from pit and heap piles were also collected and analyzed to evaluate their quality. Soil samples were also collected from the experimental fields after harvest (0-20cm depth) to evaluate the effect of compost and mineral fertilizers on some soil physico-chemical properties. Soils were moderately acidic in pH and low in OM, N, P, S, B and Zn. However, the soils had sufficient amount of K, Ca and Mg. The analysis of 18 compost samples collected from farmers' backyards indicated that the composts were suitable and well matured for application to the field. Results from the maize and tef field experiments revealed that combined application of compost and NPSBZn mineral fertilizers improved yield and yield components of maize and tef. The highest maize and tef grain yield was obtained from the application of 10 tons ha^{-1} compost and full recommended mineral fertilizer rate (150 kg ha^{-1} NPSBZn + 200 kg ha^{-1} urea). Similarly, application of 10 t ha^{-1} compost and full of the recommended mineral fertilizer rate (150 kg ha^{-1} NPSBZn and 200 kg ha^{-1} urea) was found to be economical feasible for maize and tef. Analysis of soil samples after harvest demonstrated that application of sole compost, sole mineral fertilizer as well as their combinations affected soil chemical properties. To get maximum economic benefit farmers should integrate 10 t ha^{-1} compost and full of the recommended mineral fertilizer.

Keywords: Compost, IFM, maize, mineral fertilizer, tef

Chapter 1. INTRODUCTION

1.1. Background and justification

Declining of soil fertility is a fundamental impediment to crops production and a major reason for slow growth in food production in Sub-Saharan Africa (SSA). In Ethiopia, soil degradation and nutrient depletion have gradually increased in area and magnitude and have become serious threats to agricultural productivity (Fasil Kebede and Charles, 2009).

Low soil fertility is exacerbated by soil fertility depletion through nutrient removal with harvest, tillage, weeding, and losses in runoff and soil erosion (Bai *et al*., 2008). Many farmers are unable to compensate for such losses, which resulted in negative nutrient balances (Cobo *et al.*, 2010). This situation is worsened by low input, continuous cultivation and overgrazing (Bai *et al.*, 2008). Researchers suggested that nutrient availability can be improved by nutrient application such as inorganic or organic fertilizer or their combination (Kaizzi *et al.*, 2007).

Soil fertility management for food and livelihood security is a major concern in the face of persistent poverty and rampant environmental degradation in the Sub Saharan Africa including Ethiopia. About 97% of agricultural land in SSA is under rain fed system (Bello *et al*., 2010), which remains dominant source of food production in the near future. Due to the widespread nutrient depletion in agricultural soils exacerbated by improper land use, yield and water productivity in the rain fed systems in many SSA countries is decreasing or stagnating (Bello *et al*., 2010). Mosisa Worku *et al*. (2012) suggested that, nutrient depletion is the chief biophysical factor limiting small-scale production in Africa.

Increasing the inputs of nutrients has played a major role in increasing the supply of food to a continually growing world population. However, over application of inorganic fertilizers causes inefficient use, large losses and imbalances of nutrients. It also leads to environmental contamination in a number of areas in developed world. On the other hand, insufficient application of nutrients and poor soil management, along with harsh climatic conditions and other factors, have contributed to the degradation of soils including soil fertility depletion in developing countries like Sub-Saharan Africa (Goulding *et al*., 2008).

To replenish the soil nutrient depletion, application of chemical fertilizers is essential. However, high cost of chemical fertilizers coupled with the low affordability of small holder farmers was the biggest obstacle for chemical fertilizer use. Moreover, the current energy crisis prevailing higher prices and lack of proper supply system of inorganic fertilizers calls for more efficient use of organic manure, green manure, compost, crop residues and other organic sources along with the inorganic fertilizers to sustain the yield levels (Sathish *et al*., 2011).

Various long term research results have shown that neither organic nor mineral fertilizers alone can achieve sustainability in crop production. Rather, integrated use of organic and mineral fertilizers has become more effective in maintaining higher productivity and stability through correction of deficiencies of primary, secondary and micronutrients (Milkha and Aulakh, 2010). Therefore, judicious use of integrated nutrient management is best alternative to supply nutrient to crop needs and improve soil conditions (Naresh *et al*., 2013).

IFM is the combined use of mineral fertilizers with organic resources such as cattle manures, crop residues, urban/rural wastes, composts, green manures and bio-fertilizers (Antil, 2012). Its basic concept is sustaining soil and crop productivity through optimization of all possible sources of plant nutrients in an integrated manner. In this system, all aspects of mineral and organic plant nutrient sources are integrated into the crop production system (FAO, 2006). IFM contributes in attaining agronomically feasible, economically viable, environmentally sound and sustainable high crop yields in cropping systems by enhancing nutrient use efficiency and soil fertility, increasing carbon sequestration, reducing nitrogen losses due to nitrate leaching and emission of greenhouse gases (Milkha and Aulakh, 2010)

Maize (*Zea mays L.*) has high genetic yield potential than other cereal crops. Hence it is called as ‘miracle crop’ and also as ‘queen of cereals’. Being a C4 plant, it is very efficient in converting solar energy in to dry matter. As heavy feeder of nutrients, maize productivity is largely dependent on nutrient management. Therefore, it needs fertile soil to express its yield potential. Ideal soils are rarely found in nature (Mahdi *et al*, 2010). Over 70% of maize in Africa is produced by resource poor small-scale farmers and the average maize yield in Africa stood at 1.3 t ha^{-1} compared to 3.0 t ha^{-1} elsewhere (FAO, 2013). This low grain yield can be attributed to a number of constraints which include both biotic stress (diseases, pests, and lack of suitable varieties) and abiotic stresses (low soil fertility and lack of capital to purchase farm inputs) (Bello *et al*., 2010: Veiga *et al*., 2012). In Ethiopia maize is a staple food and one of the main sources of calories in the major maize producing regions. It is cultivated on about 1.7 million ha of land. However, maize varieties mostly grown in the highlands altitude (1,700 to 2,400 m.a.s.l) of Ethiopia are local cultivars (Zelalem Bekeko,2014).

Tef (*Eragrostis tef*) is an Ethiopian cultivated crop which is mainly grown for its grain as a major staple food and market cereal crop. Most tef grains are made into *injera* (most popular food in the national diet), which is flat spongy and slightly sour bread that looks like a giant bubbly pancake (Gebreysus Berhania, 2015). Tef covers about 2.8 million hectares of land per year accounting 22.95% of the grain crop area, which is more than any other major cereals such as maize 16.91%, sorghum 14.85 % and wheat 13.33% (CSA, 2016). Despite of its these all importance and large area coverage, the productivity of teff is very low which is on average nationally 1.56 ton ha^{-1}, compared that of other major cereals like wheat, maize, sorghum and barley whose productivity is 2.5, 3.3, 2.3 and 1.9 ton ha^{-1} , respectively (CSA, 2016).

Lower tef grain yield is mainly attributed to low soil fertility, minimum use of mineral fertilizers, weeds, erratic rainfall distribution in lower altitudes, lack of high yielding cultivars, lodging, water-logging, low moisture and inappropriate tillage (Fasil Kebede and Charles, 2009).

Integrated Fertility Management (IFM) which implies combined application of organic and inorganic fertilizers helps to overcome the problems associated with independent application of organic or inorganic source to enhance crop production and improve soil fertility. The study was initiated to signify the effect of combined use of compost and mineral fertilizer on soil properties, yield and yield components of maize and tef at Yilmana Densa District.

1.2. Objectives

1.2.1 General objective

The general objective of the study was to assess compost quality, and evaluate the effect of integrated fertility management on soil physico-chemical properties and yield and yield components of maize and tef at Yilmana Densa District, Northwestern Ethiopia.

1.2.2 Specific objectives

Specific objectives of the study were:-

- To asses inherent soils nutrient status of the experimental plots;
- To evaluate the chemical quality of compost collected from farmers' backyards;
- To evaluate changes in soil physico-chemical properties due to integrated fertility management;
- To quantify the effects of integrated fertility management on yield and yield components of maize and tef;

1.3. Research questions

In line with the specific objectives the research is attempted to address the following significant questions:

- Do soils of the study area require nutrient amendment?
- What is the chemical quality of compost produced and used by farmers?
- What is the combined effect of compost and mineral fertilizer application on soil physical and chemical properties?
- What is the combined effect of compost and mineral fertilizer on yield and yield components of maize and tef?

Chapter 2. LITERATURE REVIEW

2.1. Soil fertility and nutrient requirement

2.1.1 Overview of Soil Fertility

Soil fertility can be defined as the capacity of soil to provide physical, chemical and biological needs for the growth of plants for productivity, reproduction and quality, relevant to plant and soil type, land use and climatic conditions (Abbott and Murphy, 2007).

Low soil fertility is recognized as a constraint to increased food production and farm incomes in many parts of Sub-Saharan African (Tittonell *et al*, 2008). Ethiopia is one of the Sub Saharan countries with highest rates of nutrient depletion due to lack of adequate synthetic fertilizer input, limited return of organic residues and manure, high biomass removal from farm lands, high soil erosion rate and leaching loss of nutrient elements. The annual nutrient deficit in the country is estimated at 41kg N, 6 kg P, and 26 kg K $ha^{-1}yr^{-1}$ (Cobo *et a.l*, 2010).

Soil fertility and plant nutrition are an important components of plant production. Productive capacity of soils requires the provision of adequate and balanced amounts of nutrients to ensure proper growth of the plants. The fact on the ground is that, soil nutrient status of most farming systems is widely constrained by the limited use of inorganic and organic fertilizers and by nutrient loss mainly due to erosion and leaching (Balesh Tulema *et al*., 2007).

2.1.2 Soil Fertility Status in Ethiopia

Agriculture in Ethiopia has long been a priority and focus of national policy such as Agricultural Development Led Industrialization (ADLI) and various large scale programs such as the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (Alemayehu Seyum, 2008).

However, the sector is characterized by low productivity and the prevalence of a fragmented smallholder/subsistence farmer population that is relegated to highly degraded/marginal land due to loss of soil fertility. Low productivity can be attributed to limited access by small farmers to agricultural inputs such as in organic fertilizer, poor attitude on organic fertilizer, financial services, improved production technologies, irrigation and agricultural output markets and, more importantly, to poor land management practices that have led to severe land degradation in some areas (MoARD, 2010).

Ethiopia faces a wider set of soil fertility issues beyond inorganic fertilizer use which has historically been the major focus for extension workers, researchers, policy makers and donors. These issues interact and include loss of soil organic matter, macronutrient (N, P and K) and micronutrient (Fe, Mn, Zn, Cu, B, Mo and Cl) depletion, topsoil erosion, acidity, salinity and deterioration of other physical soil properties (Zeleke Gete *et al*., 2010).

2.1.3 Soil Fertility determining factors

Several factors contribute to reducing the fertility status and quality of soil in Ethiopia. The major ones being land degradation because of massive deforestation, human and livestock population pressure, limited use of crop residue and animal dung and little or no use of modern technologies to restore soil fertility, high price of mineral fertilizer and low use of organic nutrient sources (Taye Belachew and Yifru Abera, 2010).

Physical and chemical properties of soil are the major determinant factors of soil fertility status. Different physical and chemical properties of the soil relate to one another and hence, the presence of one can indicate the status of the other (Brady and Weil, 2004).

2.3.1.1 Soil Physical Properties

The physical properties of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil physical properties also largely determine the soil's water and air supplying capacity to plants. Many soil physical properties change with changes in land use system and its management practices such as intensity of cultivation, the instrument used and the nature of the land under cultivation, rendering the soil less permeable and more susceptible to runoff and erosion losses (Sahrawat *et al*, 2010).

Measurement of soil bulk density (the mass of a unit volume of dry soil) is required for the determination of compactness, as a measure of soil structure, for calculating soil pore space and as indicator of aeration status and water content. Bulk density also provides information on the environment available to soil microorganisms.

White (1997) stated that values of bulk density ranges from < 1 g/cm^{3}for soils high in OM, 1.0 to 1.40 g/cm^3 for well- aggregated loamy soils and 1.4 to 1.8 g/cm^{3}for sands and compacted horizons in clay soils. Soils having low and high bulk density exhibit favourable and poor physical conditions respectively (Mitiku Haile *et al*, 2006).

Bulk density normally decreases as mineral soils become finer in texture. Bulk densities of soil horizons are inversely related to the amount of pore space and soil OM (Brady and Weil, 2002). Any factor that influences soil pore space will also affect the bulk density. For instance, intensive cultivation increases bulk density resulting in reduction of total porosity.

2.3.1.2 Soil chemical Properties

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil Wang *et al*. (2007).

Soil reaction (usually expressed as pH value) is the degree of soil acidity or alkalinity, which is caused by particular chemical, mineralogical and/or biological environment. Soil reaction affects nutrient availability and toxicity, microbial activity, and root growth. Thus, it is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond so markedly to their chemical environment (Troeh and Thompson, 1993).

Descriptive terms commonly associated with certain ranges in pH are extremely acidic (pH < 4.5), very strongly acidic (pH 4.5-5.0), strongly acidic (pH 5.1-5.5), moderately acidic (pH 5.6-6.0), slightly acid (pH 6.1-6.5), neutral (pH 6.6-7.3), slightly alkaline (pH 7.4-7.8), moderately alkaline (pH 7.9-8.4), strongly alkaline (pH 8.5-9.0) and very strongly alkaline (pH > 9.1) (Rowell, 2014).

Soil organic matter (SOM) is the organic fraction of soil derived from the decayed tissue of plants, animals and from animal excreta. SOM content in liquid digested slurry and slurry compost has a major influence on the physical and chemical properties of soils (Teklu Erkossa, 2005).

Soil organic matter helps to bind soil particles together that improve the physical properties of the soil making it easier for roots to penetrate. OM forms complexes with micro nutrients and prevents them from being lost through leaching . During anaerobic fermentation process, about 25 to 30 % of the OM from the manure is converted into biogas while the rest becomes available as residual manure (Chendu, 2006).

Nitrogen occurs in soils in both organic and inorganic compounds of which plants absorb N in its cationic form ($NH4^{+}$) and anionic form (NO_3^{-}) and obtain readily available N forms from different sources. The total N content of a soil is directly associated with its OC content and its amount on cultivated soils is between 0.03 % and 0.04 % by weight (Zibilske *et al.*, 2000).

The major sources include biological N fixation by soil microorganisms, mineralization of organic matter and industrial fixation of N gas and fixation as oxides of N by atmospheric electrical discharge. The availability of N through biological N fixation is influenced by soil pH and its mineral nutrient status, photosynthesis, climate and crop management. Similarly, mineralization of organic N to inorganic forms depends on temperature, level of soil moisture and supply of oxygen (Zibilske *et al.*, 2000).

Soils have little capacity to retain oxidized forms of N and ammonium accumulation in soils is small; consequently, most of the soil N is associated with SOM. Release of N from SOM is slow and unpredictable. If SOM is depleted, as occurs in cultivated soils, N for plant growth is limited (Brady and Weil, 2004). Nitrogen is the most limiting nutrient in plant growth. It is a constituent of chlorophyll, plant proteins, and nucleic acids and useful for vegetative development (Yihenew G/Selasie, 2007)

The N content is lower in continuously and intensively cultivated and highly weathered soils of the humid and sub humid tropics due to leaching and in highly saline and sodic soils of semi- arid and arid regions due to low SOM content. Because of their low soil organic matter content, most of the Vertisols in Ethiopian highlands have low total N content and there is a high crop response to N fertilizers in these areas. On account of rapid nitrification, most of the N added as fertilizer containing NH_4 or NH_2 is subject to leaching or de-nitrification soon after application (Desta Beyene, 1986).

Carbon (C) to nitrogen (N) ratio (C/N) is an indicator of net N mineralization and accumulation in soils. Organic matter rich in carbon provides a large source of energy to soil microorganisms. Consequently, it brings population expansion of microorganism and higher consumption of mineralized N. Dense populations of microorganisms inhibit the upper soil surface and have an access to the soil N sources. If the ratio of the substrate is high there will be no net mineralization and accumulation of N. They further noted that as decomposition proceeds, carbon is released as CO_2 and the C: N ratio of the substrate falls. Conversion of carbon in crop residue and other organic materials applied to the soil into humus requires nutrients (Lee, 2005).

Phosphorus (P) is known as the master key to agriculture because lack of available P in the soils limits the growth of both cultivated and uncultivated plants (Rowell, 2014). Phosphorus is among the most limiting nutrients for food production in the sub-humid and humid tropical highlands of East Africa (Sanchez *et al.*, 1997). Next to N, P is the most limiting nutrient in Vertisols agricultural (Nordt and Driese, 2010) and this holds true for Ethiopian soils and the problem in Ethiopia is further exacerbated by nutrient mining due to the prevailing low input agriculture and continuous cultivation.

Studies show that the total P status of some representative major soil types in Ethiopia is low (Piccolo and Huluka, 1985). Most of the Vertisols in the Ethiopian highlands, 70% of the cases, are reported low in available P content which is below 5 ppm or <5 mg kg^{-1} (Khitrov, 2016).

Next nitrogen, potassium is a mineral nutrient plants require in the largest amounts. Potassium (K) is involved in photosynthesis, sugar transport, water and nutrient movement, protein synthesis and starch formation. It also helps to improve disease resistance, tolerance to water stress, winter hardiness, tolerance to plant pests and uptake efficiency of other nutrients (Zublena, 1997).

The ability of a soil to retain cations such as potassium (K^+), ammonium (NH_4^+), hydrogen (H^+), calcium Ca^{2+}) and magnesium (Mg^{2+}) in a form that is available to plants is known as cation exchange capacity. The Cation exchange capacity (CEC) of soils also defined as the capacity of soils to adsorb and exchange cations (Brady and Weil, 2002). There is a fairly constant equilibrium between adsorbed cations and those moving freely in the soil moisture. When the equilibrium is disturbed, ion exchange between the solid and liquid soil phases occur, resulting in either adsorption or release of cations (Samuel Taye *et al*, 2000).

In general, CEC is crucial factor in the determination of soil fertility for two fundamental reasons. The first reason is that, the total quantities of nutrients available to plants as exchangeable cations depend on it. The second reason is that, it can influence the degree to which hydrogen and aluminium ions occupy the exchange complex and thus, affect the pH of soils (Sahlemedihn and Taye, 2000).

According to Landon (1991), the levels of exchangeable cations is of great importance because many effects, for example soil structure and nutrient uptake by crops, are influenced by the relative concentrations of cations as well as their absolute levels. However, Vertisols and high organic matter containing soils retain more basic cations, which are mainly dominated by exchangeable Ca and Mg.

The cations in productive agricultural soils are present in the order, $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$. Deviations from this order can create ion imbalance problems for plants. High Mg, for example, in soils formed from serpentine rocks inhibits Ca uptake by plants. High Na occurs in soils where drainage is poor and evaporation rates exceed rainfall. High Na creates problems of low water flow in soils and availability for plants (Bohn *et al*., 2001).

2.1.4. Nutrient requirement and critical levels

Several elements take part in the growth and development of plants, and those absorbed from the soil are generally known as plant nutrients. Besides these, the plant takes up carbon, oxygen and hydrogen, either from the air or from the water absorbed by roots. In all, 16 elements have been identified and are established to be essential for plant growth. There are carbon (C), hydrogen (H), Oxygen (O), nitrogen (N), phosphorus(P), potassium(K), calcium(Ca), magnesium (Mg), iron (Fe), sulfur(S), zinc (Zn), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), and chlorine(Cl)(EthioSIS, 2013).

These elements serve as raw materials for growth and development of plants, and formation of fruits and seeds. Most of the essential elements are found in liberal quantities in the mineral soils. In spite of the fact that these are available in plenty, these may not be available to the plants, as they are tied up in mineral and chemical compounds. The roots cannot absorb and deliver them to the growing plants for synthesis, and hence, the need for assessing the plant available amounts of nutrients in the soil and meeting deficiency by application of manures and fertilizers to such soils for optimum crop production (Taylor and Francis, 2006).

The proper rates of plant nutrients can be determined by knowledge about the nutrient requirement of the crop and supplying power of the soil. However, Ethiopian farmers used to apply only chemical fertilizers Di-ammonium phosphate (DAP) and urea to increase crop yields for about five decades and this did not consider soil fertility status and crop nutrient requirement (Tilahun, 2007).

Critical levels may vary with crop, soil type and climate and they are also specific to the soil test method used. Optimally critical values should be calibrated for each crop and for conditions that are as similar as possible to the conditions under which the fertilizer recommendations are applied (EthioSIS, 2013).

Generally critical nutrient level for different nutrients was given as follow as; Nitrogen (0.2%), Phosphorous (15 $mgkg^{-1}$), Potassium (190 $mgkg^{-1}$), Calcium (50 $mgkg^{-1}$), Magnesium (10 $mgkg^{-1}$), Sulphur (20 $mgkg^{-1}$), Zinc (1.5 $mgkg^{-1}$), Boron (0.8 $mgkg^{-1}$) EthioSIS (2014)

2.1.5 Soil Fertility Improvement methods in Ethiopia

Multiple interventions are needed to address these soil fertility issues including, but not limited to, chemical and organic nutrient sources. Positive steps have been made in many areas by MoARD and EIAR, and achievements in the scale-up of inorganic fertilizer use are especially noteworthy (Taye Belachew and Yifru Abera, 2010).

Organic nutrient source improves the physical, chemical and biological quality of soil besides providing both macro and micro nutrients to crops. The improvement in qualities include improvement in soil structure, water holding capacity, electrical conductivity, bulk density, lesser soil erosion, preventing the leaching of nutrients and provide nutrients to soil micro flora (Fentaw Ejigu, 2010).

Compost amendments influence various soil fertility parameters, such as nutrient content and availability, soil structure and microbiological activity. They impact plant growth and health directly and indirectly (Fuchs and Larbi, 2005). Compost is a stabilized and sanitized product of composting, which is the biodegradation process of a mixture of organic substrates carried out by a microbial community composed of various populations, both in aerobic conditions and solid state (Insam and de Bertoldi, 2007).

Organic fertilizers enhances soil fertility, soil structure and water storage capacity for two or more years, unlike inorganic fertilizer. Fentaw Ejigu (2010) noted that use of composts with mineral fertilizer increased yield and production of wheat, green beans, gram and rice for two consecutive years. Grain and straw yields of rice were significantly higher in amendments that received compost application with NPK than in no compost with NPK amendments, thereby highlighting the beneficial effects of compost to increase the crop yield.

Inorganic fertilizers are used in modern agricultural system to correct known plant nutrient deficiencies; to provide high levels of nutrition and to maintain optimum soil fertility conditions . The different types of inorganic fertilizers are usually classified according to the three principal elements namely N, P and K (Samuel Taye *et al*., 2000). In Ethiopia, farmers' uses only Urea and DAP. These two fertilizers were recommended since their nutrient content of Nitrogen and Phosphorus is high compared to other types of inorganic fertilizers (Takashi and Ayumi, 2010).

According to the report by Alemayehu Seyum (2008), about 10 % of the total land of Ethiopia is under crop cultivation but fertilizer is applied only on 40 % of the cultivated land and the rate of application is below the optimal dosage level (Eyasu Esayas, 2009). The blank recommendation for Ethiopia is 100kg of DAP and 50 kg urea ha^{-1} but farmers apply between 7 and 10 kg ha^{-1} annually (Eyasu Ealias, 2002).

Synthetic fertilizers can have a large yield impact, but only under the right soil conditions and with adequate soil and water management. Soil fertility amendments are also made by adding traditional fertilizer to the soil such as cow manure, organic compost, crop residues, bio slurry and inorganic fertilizer (Takashi and Yuma, 2010).

Application of inorganic fertilizers alone is not sufficient for crops growth (Dong and Li, 2010). According to the available nutrients contained in the organic fertilizer, it needs to be applied in bulks compared to inorganic fertilizers. On the other hand, there are improved varieties of crops which are responsive to high inputs and as such desired yield cannot be achieved unless recommended dose of plant nutrients are supplied in the form of mineral or organic fertilizers. Hence, there is a need to apply both organic and inorganic fertilizers in a balanced way to get expected output (Zebider Alemeneh, 2011).

Integrated fertility management implies the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity on one hand and to minimize nutrient losses to the environment on the other hand. It is achieved through efficient management of all nutrient sources. Nutrient sources to a plant growing on a soil include soil minerals and decomposing soil organic matter, organic and synthetic fertilizers, animal manures and composts, by-products and wastes, plant residue, and biological N-fixation (Singh. and Agarwal, 2001).

2.2. Chemical quality of compost produced by farmers

Quality of compost was measured based on the macro and micro nutrient content. Micro organism level in the compost and toxicity level are also considered as determining factor for compost quality. Compost quality was also different for different raw materials used. Compost made from parthinium either using vermi or conventional method (either pit or heap method) contains high level of major crop nutrient (NPK) as compared with conventional compost prepared without parthinium (Kasahun Kitila and Tesfaye Gemechu, 2014).

The quality of compost was sometimes determined by its organic matter content and pH value. Composts with high organic matter content are important with respect to the efficiency of the suppression and the regulation and maintenance of microbial communities in the soil. Similarly composts with optimum pH range play role in making nutrients available to crops (Hoitink and Boehm, 1999).

Compost quality was also determined by its maturity level. Compost must be mature for its use as an organic fertilizer and is defined as material in which biological activity has slowed down. The term mature can also refer to the degree of phytotoxicity of the compost, due to the presence of phenols and low molecular weight organic acids. If compost is applied too soon, the leaves of plants may burn, the growth can stop or sensitive plants can die. Immature compost is still hot, smells poorly, has a wide C:N ratio and high ammonium content, but continues to break down once it is incorporated into the soil. Mature compost is odorless, has a fine texture and dark color (Mohee, 2007).

Some researchers compare the nutrient content of compost produced with compost produced in other countries. Ayers (1997) report quality compost by measuring N, P, K, and C: N ratio, pH and concentration of heavy metal by comparing compost produced by other countries.

2.2.1 Pit method

Pit method is good anytime of the year where moisture is limiting, and is the best way to make compost after the rains have finished and during the dry season (Edwards and Hailu Araya, 2011). The decomposition of organic material is carried out by high temperature and micro organisms with the pit and contracted by preparing uniform size pits under the ground (Nancy *et al*., 2005).

One simple method for composting organic waste is to put it in pits and let it turn into compost over a period of six months or more. This process requires some space and time but the main benefit is that the waste is not visible as it is buried in the pit (Abebe *et al*., 2015).

This method involves making compost in pits that have been dug in the ground. The best depth for a pit varies according to local soil conditions and the depth of the water table. A typical pit would measure 1.5 to 2m wide, 50cm deep and any length. The pit can be lined with a thin layer of clay to reduce water loss. Often, several trenches are dug next to each other, to allow turning from one pit into the next (Madeleine *et al*., 2005).

2.2.2 Heap method

Heap is used in rainy season when there are plenty of green plants, such as weeds, getting water is easy or the materials are naturally wet, or where there is plenty of water available. Organic material decomposition in this method was conducted aerobically with the help of micro organisms and considering optimum temperature and moisture (Edwards and Hailu Araya, 2011).

In this method, the waste is put in piles on the ground and regularly turned to allow aeration. The size of the pile may vary depending on the amount of waste and available space, but generally, it should be 1 to 2 m on each side and not more than 1.5 m in height. Chicken wire or wooden planks can be used to keep the pile together (Bhushan and Dorothee, 2003).

Different organic materials are layered and arranged to establish the heap. The sequence of layers is repeated until the heap has reached a final height of 1.5 to 2 meters. In this way the heap is composed of many layers. Building the heap should be done quickly, preferably within a week (Madeleine *et al*., 2005).

2.3. Effect of fertilizer on soil and productivity

First step in maintaining soil fertility should be directed at maintaining the organic matter content of the soil. This can be done by using appropriate crop husbandry practices and by applying organic manure or compost together with mineral fertilizer. Chemical fertilisers can restore the soil fertility very quickly where as organic fertilizers will provide nutrients to the soil in slow way (Laura and Rienke, 2004).

It is generally known that the incorporation of fertilizers is increasing yield and agricultural productivity. The combination of both, organic and mineral fertilizers is crucial as they influence different soil properties. Mineral fertilizers are characterized by a high concentration of plant available nutrients. Several studies showed a significant increase of grain yield after mineral fertilizer treatment (Pinitpaitoon *et al*., 2011). At smallholder level organic material is applied in form of farmyard manure (FYM) as it is often the source of organic matter (Dunjana *et al*., 2012).

2.4. Effect of Integrated fertility Management on Soil Properties

2.4.1 Physical properties

Babhulkar *et al.* (2000) studied the effect of continuous application of fertilizers alone and in combination with graded levels of FYM for soybean based cropping system in a long term field experiment in swell-shrink soil at Nagpur. The results indicated that significant decrease in bulk density of soil and increase in soil porosity, water holding capacity and hydraulic conductivity was due to combined application of FYM and fertilizers as compared to other treatments without FYM. Selvi *et al*. (2005) noticed that continuous application of balanced fertilization (100% N, P and K + FYM @ 10 t ha^{-1}) did not show any deteriorating effect on physical properties of the soil; rather it significantly increased the water holding capacity and reduced bulk density of the soil in long run. Significant improvement in the physical properties of the soil was observed under the integrated application of organic and inorganic fertilizer.

Herencia *et al* (2011) observed a high correlation between organic carbon (OC) content and some physical soil properties. Bulk density (BD) was decreasing with long-term application of organic fertilizers. The aggregate stability (AS) showed an increase with time on plots fertilized with organic matter. Also Dunjana *et al*. (2012) recorded an increase of OC with increase of manure application and further an increase of aggregate stability

2.4.2 Chemical properties

Sihag *et al.* (2005) reported that application of chemical fertilizers alone or in combination with organic manures significantly increased all the forms of nitrogen except unidentified hydrolysable N over control or their initial status. Among the various N fractions, amino acid was the dominant N fraction. On an average, amino acid, amino sugar, ammoniacal N and unidentified hydrolysable N constituted about 33.2, 8.9, 29.0 and 29.8% of total hydrolysable N, respectively . Mann *et al*. (2006) reported that available phosphorus content increased from the initial value of 13.7 to 15.1, 18.4, 27.5 and 38.7 kg ha^{-1}in 50, 100, 150 per cent N and P and 100 per cent N, P and K + farmyard manure treatments, respectively.

Babu and Reddy (2000) recorded significant increase in the organic carbon content of sandy clay loam soil from 0.61 to 0.92 per cent due to the addition of FYM and inorganic nitrogen at 5 t $ha^{-1}$and 50 kg ha^{-1}, respectively. Studies conducted by Kimetu *et al*. (2008) in red clay loam soil revealed that the organic carbon content of the treatment that received either poultry manure or sheep/goat manure @ 10 t ha^{-1}along with 50 per cent recommended dose of mineral fertilizer significantly increased when compared to the treatment receiving only inorganic fertilizers.

Improvement in soil fertility through INM is also important to SOC sequestration (Lal, 2005) because concentrations of SOC and N are key indicators of soil quality and productivity through their favourable effects on physical, chemical, and biological processes, including nutrient cycling, water retention, root and shoot growth, and environmental quality. Increase in the SOC pool also enhances soil structure (Celik *et al*., 2004; Mikha *et al*., 2010). Soil aggregation is one of the important soil characteristics that mediates many soil chemical, physical, and biological properties and improves soil quality and sustainability (Moreno, 2009).

Application of organic manure in combination with chemical fertilizer has been reported to increase absorption of N, P and K in sugarcane leaf tissue in the plant and ratoon crop, compared to chemical fertilizer alone (Bokhtiar and Sakurai, 2005). Kaur *et al*. (2005) compared the change of chemical and biological properties in soils receiving FYM, poultry manure and sugarcane filter cake alone or in combination with chemical fertilizers and all treatments except chemical fertilizer application improved the soil OC, TN, P and K status.

It is widely researched that organic amendments contribute to higher OC values but the effects of mineral fertilizer on OC seem controversial. Hati *et al*. (2007) realized a decline in OC due to 29 years of intensive cropping in all treatments. Soils fertilized by manure +NPK showed the highest OC and OM value (Celik *et al*., 2010). Rasool *et al*. (2008) reported a higher increase of OC due to NPK application with FYM application.

2.5. Effect of IFM on yield and yield components of maize and tef

Combination of organic and inorganic sources of nitrogen significantly increased the plant height at maturity, numbers of cobs per plant, number of grains per cob, 1000-grain weight, and grain yield and harvest index. Combination of green manure with TSP at a rate of 50 kg ha^{-1}significantly increased maize yield from 24 to 508 % when compared to the control Mukuralinda *et al*. (2010).

Combination of organic (FYM) and inorganic sources of N gave higher yield than either of the sole application of urea and FYM. The maximum grain yield (6.13 t ha^{-1}) was noted with Urea + FYM and followed by urea (4.86 t ha^{-1}) alone. The better grain yield with combined application of urea and FYM was attributed to more number of grains per cob and 1000-grain weight (Syed *et al*. 2009).

The study by Mugwe *et al*. (2007) in Kenya showed that combining 30 kg $ha^{-1}yr^{-1}$ inorganic N fertilizer with legume plants (Tithonia, Calliandra and Leucaena) or cattle manure obtained a significantly higher yield of maize as compared with the application of legume plants, organic and inorganic fertilizer alone.

Fentaw Ejigu (2010) noted that use of composts with mineral fertilizer increased yield and production of wheat, green beans, gram and rice. Grain and straw yields of rice were significantly higher in amendments that received compost application with NPK than in no compost with NPK amendments, thereby highlighting the beneficial effects of compost to increase the crop yield.

Integrating organic and in organic nutrient source had significant effect on tef crop yield. Dejene Kassahun *et al*. (2010) noted an increase of 45% and 33% for grain and straw yields of tef, respectively due to integrated application of farm yard manure and inorganic fertilizer over control.

The application of organic and inorganic fertilizers had effect on the total biomass, grain and straw yields of tef. Application of 50% recommended NP rate and 50% manure and compost resulted in grain yield and total biomass increments of 122% and 113% compared to the control, and 33% and 31% compared to the farmers' treatment (23/10 kg NP ha^{-1}) according to Agegnehu *et al*. (2010).

Chapter 3. MATERIALS AND METHODS

3.1. Study area Description

3.1.1 Location

This study was conducted at Adet Zuria *kebele* (lowest administrative unit of Ethiopia) of Yelmana Densa District in the Amhara region (Figure 3.1). It is located about 40 kilometers south of Bahir Dar.

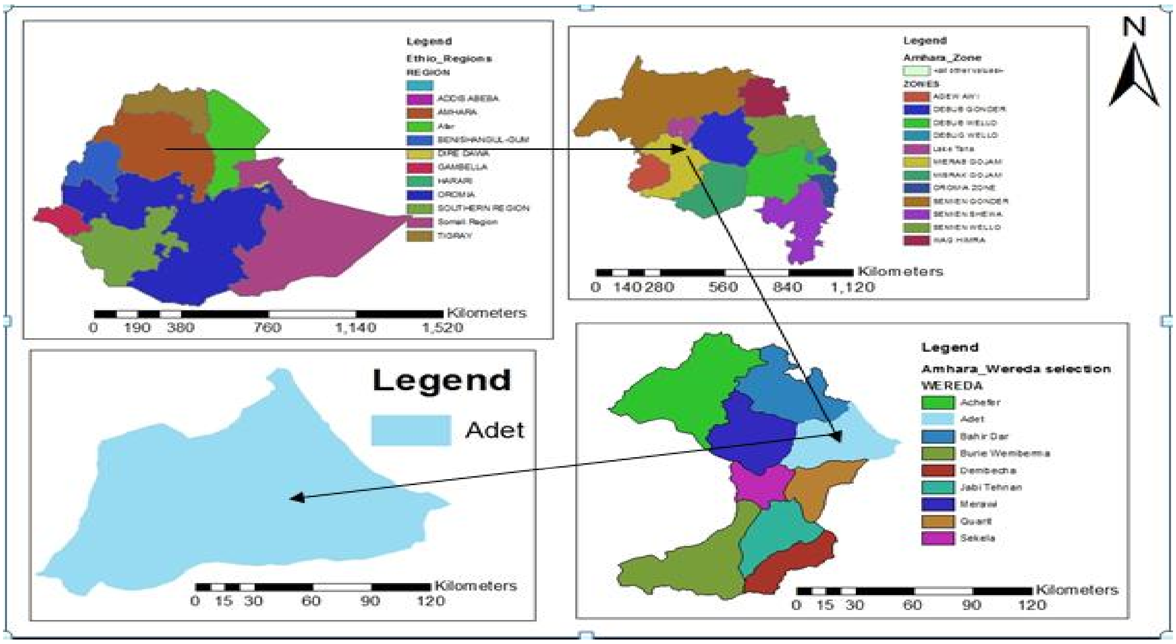

Figure 3. 1. Map of the study area

3.1.2 Topography, climate and soils

The altitudinal range of the District is from 1500 to 3500 meters above sea level. About 30 per cent of this area has Vertisols, 45 percent Nitisols soil and 25 percent Luvisols. According to office of the agriculture 57 percent of the *kebele* (lowest administrative unit of Ethiopia) is under crop cultivation, 2 per cent is covered by forest and bushes and 33 percent is grazing area and the rest is under different land use system. According to the National metrological station, annual rainfall in the District ranges from 1051.8 to 1488.2mm per year and is highly variable. Commonly mentioned environmental problems are soil erosion, land degradation, deforestation, increase rainfall variability and low soil fertility. The mean annual temperature ranges from 8.8-25.2°C (YDD-OARD, 2009).

3.1.3 Population

Adet is the district administrative town. The district has 33 rural and 3 town *kebeles* (lowest administrative unit of Ethiopia) and the total population of the district in 2007 was 214,852, of which 195,683 were living in rural and 19,169 in different towns (CSA, 2015).

3.1.4 Farming systems

Farming system of the study area is crop livestock mixed production system. Farmers in the study area rare animals and grow crops deliberatively. According to the District office of Agriculture, the main crops grown in the Kebele and Woreda are teff (*Eragrostis tef),* wheat *(Triticum aestivum* L)*,* maize *(Zea mays* L), barley *(Hordeum vulgare),* potato *(Solanum tuberosum),* field pea *(Pisum sativum),* faba bean *(Vicia faba),* finger millet (*Eleusine coracana)* and the like. Common agricultural practices according to the Agriculture office at the District were crop rotation, row planting, intercropping of maize and beans, livestock rearing and animal fattening which crop livestock is mixed production system (YDD-OARD, 2009).

3.2. Experimental Materials

3.2.1 Plant and fertilizer materials

A high yielding maize hybrid BH- 540, which is adapted to the agro-ecology of the area was used as one of the test crops. BH 540 is one of the most successful hybrid varieties released in 1995 by Bako Agricultural Research Centre through the National Maize Research Programme. (Mosisa Worku *et al*., 2001). For the other test crop, tef, *Kuncho* was used. It can be grown from sea level up to 2800 m a.s.l, under various rainfalls, temperature and soil regimes (Seyfu Ketema, 1997).

Nitrogen fertilizer in the form of urea (46% N) in the recommended rate (200 kg ha^{-1} N) was used for the study. NPSBZn fertilizers in the recommended rate of 150 kg ha^{-1} P_2O_5 was equally applied to concerned plots by banding at the time of planting. Both rates are based on ATA recommendation. For the N fertilizer application, urea was applied at the specified rates and timing during the growth of the plants by banding approximately 2-3 cm distances from the maize plant and immediately covered with soil. Compost was used in the rate of 5 t ha^{-1} and 10 t ha^{-1}. Compost was applied two weeks before planting for respective rates and each test crop and the compost prepared by farmers was used for the research.

3.3. Methods

3.3.1 Evaluation of inherent soils nutrient status of the experimental plots

Taking soil samples before planting

Composite soil samples (0-20 cm depths) were collected from each experimental field just before planting by vertical insertion of a shovel and mixed to get a composite sample. The composite soil samples from surface soil were properly labelled and placed both inside and outside the plastic bags and were transported to HORITCOOP (Horticultural) PLC laboratory located Debre Zeit.

Analyzing

In the laboratory, working samples obtained from each submitted samples, are dried with air, crushed and ground to pass through 2 mm sieves for available P, soil pH, exchangeable acidity, exchangeable bases, while 0.5mm for total N and organic carbon/organic matter in preparation for laboratory characterization of selected soil physical and chemical properties related to soil fertility.

Bulk density (Db) was determined from undisturbed soil samples using core samplers. Total Nitrogen analysis was done using the Kjeldahl method as explained in Sahelemedhin and Taye (2000). Available phosphorus was determined by Meliche-3 EthioSIS (2013). Potassium was determined Meliche-3 Meliche-3 as stated by EthioSIS (2013). Cation exchange capacity (CEC) was determined by Meliche-3 as stated by EthioSIS (2013). Organic Carbon was determined using Walklay and Black wet oxidation method as described by Jackson (1958). Zinc, boron and sulphur were analyzed by meliche-3 method. Meliche-3 method was also used to analyze K, Mg and Ca Meliche-3 as stated by EthioSIS (2013).

Comparing the values with critical levels

Different literatures were reviewed to get critical requirement for two test crops. Macro and micro nutrient requirement for Nitisols and Vertisols of the experimental sites was obtained from secondary data source. Soil laboratory result was used to compare with critical level to determine soil nutrient requirement for the study area.

The nutrient requirement of the soil for the following nutrients was done comparing laboratory result with critical level from literature. The nutrients used for compression are

Nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, boron and zinc. In addition to the OM, PH and CEC were compared and contrasted to determine the nutrient requirement of the soil.

3.3.2 Changes in soil physico-chemical properties due to INM

Soil sampling after planting

Similarly soil sample collection was done after treatment application from each individual plots within a block. Soil samples were collected by insertion of shovel to the soil within 0-20 cm depth for each treatment. Individual soil samples from each plot after treatment were properly labelled and placed both inside and outside the plastic bags and were transported to HORITCOOP (Horticultural) PLC laboratory located Debre Zeit.

Soil samples after treatment application were analysed in the laboratory for all parameters. In addition to above parameters Nitrate content was also analysed after application of treatments and after crop harvest.

Nutrient content changes after harvest

Soil property change was determined by comparison of laboratory result before and after treatment application. All soil parameters were compared before and after treatment application.

3.3.3 Evaluating chemical quality of compost

Taking compost samples

Just like soil sample compost samples which were collected for both heap and pit method from study area and were analyzed in the laboratory to characterize it. Available compost from the District was collected. Based on the compost preparation and application experience the three *Kebeles* (lowest administrative unit of Ethiopia) were chosen for compost collection. From these three *kebeles* (lowest administrative unit of Ethiopia) 18 available compost samples were collected and sent to laboratory for analysis.

Compost samples were labelled and send to libratory for analysis. In the laboratory, working samples obtained from each submitted samples, were air dried, crushed and ground to pass through 2 mm sieves for analysis.

Laboratory analysis was done for the following parameters. Compost pH was determined at 1:2.5 compost to water ratio using a glass electrode attached to pH digital meter. Total

Nitrogen analysis was done using the Kjeldahl method as explained in (Sahelemedhin and Taye 2000). Available phosphorus was determined by Meliche-3 as suggested by EthioSIS (2013). Potassium was analysed by as suggested by EthioSIS (2013). Cation exchange capacity (CEC) was analysed by Meliche-3 as suggested by EthioSIS (2013). Organic matter was determined by using Walklay and Black wet oxidation method as described by (Jackson 1958). Magnesium, Calcium, Iron, Copper, Zinc, Sulphur and molybdenum were measured by Meliche-3 as suggested by EthioSIS (2013).

The laboratory results of compost samples were compared and contrasted with the optimum from literature to evaluate the compost quality. Different literatures were reviewed for compost quality assessment.

3.3.4 Quantifying the effects of INM on yield and yield components of maize and tef

Different yield and yield related parameters were measured for the two test crops. The parameters that were measured for maize and tef were; date of 50% emergency, ear length, number of cobs per plant, plant height, thousand seed weight, Stover yield, effective tiller, panicle length, grain yield and harvest index.

3.4. Treatments and Experimental Design

This experiment was laid out as a randomized complete block design (RCBD) with three replications and 9 treatments for two test crops. Two treatments were organic where as two treatments was mineral fertilizer only and the reset treatments were combination of the two.

Treatments were:-

T1= F0C0, T2= F0C1, T3= F0C2, T4= F1C0, T5= F1C1, T6= F1C2, T7= F2C0, T8= F2C1, and T9= F2C2.

Note

- F0CO was the control without any input to the soil
- F0C1and F0C2, were plots with 5 t ha^{-1} and 10 t ha^{-1} respectively.
- F1C0 and F2C0 were plots with 75kg ha^{-1} NPSBZn and 100 kg ha^{-1}urea and 150 kg ha^{-1} NPSBZn and 200 kg ha^{-1} urea, respectively. Both rates are based on ATA recommendation.

In addition the above

- F0: treatment without mineral fertilizer
- F1: treatment with half of the recommended mineral fertilizer
- F2: treatments with full of mineral fertilizer recommendation
- C0: treatments without compost
- C1: treatments with 5 ton ha^{-1} compost
- C2: treatments with10 ton ha^{-1} compost

The field experiment was conducted for one main cropping seasons of 2016/2017 using rainfall. The tef experiment was conducted on Vertisols and maize was on Nitisols. The space between blocks for maize was 1.5 m. The space between each row for maize is 75 cm and planted seed is 40 cm (BOARD, 2010) and three rows were used as net plot size according to BOA. Net Plot size for maize is 2.25 m by 2.4 m (5.4 m^2). The total area used for this research using maize as test crop is 20.25 m by 10.2m (206.55m^2) (BOARD, 2010).

For tef the spacing between rows was 20cm and crop spacing was not allowed but spacing between plots was 50cm (BOARD, 2010). Totally five rows were used as net plot area. Additionally the blocks of tef experiment were separated each other by 1m spacing. Total plot size is 1m by 2m. The total research area for tef excrement is 18m by 7m which is 126cm^2(BOARD, 2010).

3.5. Experimental Procedure

3.5.1 Field preparation and layout

Two experimental sites were selected and prepared in proper manner in Yelmana Densa District at Mosobo kebele. Planting was carried out based on respecting plant population and experimental treatment for maize and tef.

3.5.2 Fertilizer application and field activities

Maize and tef seeds were sown in most favourable season (May and July, respectively). Weeds were managed by hand weeding after weed emergence. Late-emerging weeds were removed by hoeing to avoid interference with the maize plants for the N applied. Finally, maize and tef plants in the central net plot area were harvested (BOARD, 2010).

3.6. Data Collection

3.6.1 Morpho-phenological data

Days to emergence: recording Number of days from the date of sowing to the date when 50% of the plants in a plot emerge above the ground for maize crop.

Ear length (cm): It was recorded by measuring the point where the ear attaches to the stem to the tip of the ear for maize test crop.

Panicle length is the length of the panicle from the node to the tip of the panicle which was determined from an average of five selected tef plants per plot.

Number of effective tillers: for tef was determined by counting tillers from 0.25 m x 0.25 m area by throwing a quadrant into the middle portion of each plot.

Number of cobs: was measured by counting number of cobs from four randomly taken maize plants and the average value was used to each plot.

Plant height (PLH): was recorded by measuring height from the soil surface to the base of the tassel of four randomly taken maize and tef plants and the average value was used.

3.6.2. Yield and yield related parameters for both crops

Grain Yield: grain was measured using electronic balance and then adjusted to 12.5% moisture and converted to hectare basis.

Above Ground dry Biomass Yield (kg/ha): Plants from the net plot area was harvested at physiological maturity and weighed after sun drying.

Harvest Index: The harvest index (HI) was computed as the ratio of grain yield (GY) to the total above ground Dry-mass (DM) yield.

Stover yield: was determined by subtracting grain yield from above ground dry biomass.

1000-seed weight was determined by weighing 1000 randomly selected dry seeds of maize using a sensitive balance and the weight were adjusted to 12.5% seed moisture content.

Agronomic use efficiency (AE) = ratio of yield increase to the applied amount of nutrient.

3.7. Data analysis

Analysis of variance (ANOVA) was computed for all data collected using SAS (12.00 version) software. One way ANOVA was used to show the the difference among treatments. When ANOVA was found significant, the means were separated using LSD test at 5% probability level.

Economic Analysis: Mean grain yield of the selected treatment was used in marginal rate of return analysis. The field price of 1 kg of maize and tef that farmers receive from sale for the crop was taken as the market price of maize and tef at Adet near the experimental site, 40 km from Bahir Dar. Nitrogen was applied as urea and NPSZnB was used as P fertilizer. The price of mineral fertilizer was based on 2016 sal of fertilizer in Birr kg^{-1}. The Gross benefit was calculated as grain yield (kg/ha) multiplied by field price that farmers receive for the sale of the crop. Total variable cost is the sum of cost that was variable or specific to a treatment against the control. Net benefit was calculated by subtracting total variable cost from the gross benefit. Then marginal rate of return was calculated using the procedures described by CIMMYT (1988) as follows: MRR= (net income from superior dominant plot-net income from preceding inferior dominant plot)/ total variable cost from superior dominant plot-total variable cost of the preceding inferior dominant plot).

Chapter 4. RESULT AND DISCUSSION

4.1. Inherent Soils Nutrient Status of the Experimental Plots

The results from soil laboratory for soil samples before planting maize and tef are presented in Table 4.1.

4.1.1 pH value

According to the initial soil laboratory test results, the soil reactions were found to be moderately acidic for Vertisols and highly acidic for Nitisols with a pH ranging from 5.45 to 5.68 with a mean value of 5.57 for Vertisols and 5.09-5.14 with mean value 5.12 for Nitisols (Figure 4.1 and Table 4.1). According to EthioSIS (2013) pH was classified as < 4.5: strongly acidic, 4.5-5.5: highly acidic, 5.6-6.5: moderately acidic, 6.6-7.3: neutral, 7.4-8.4: moderately alkaline, >8.5: strongly alkaline.

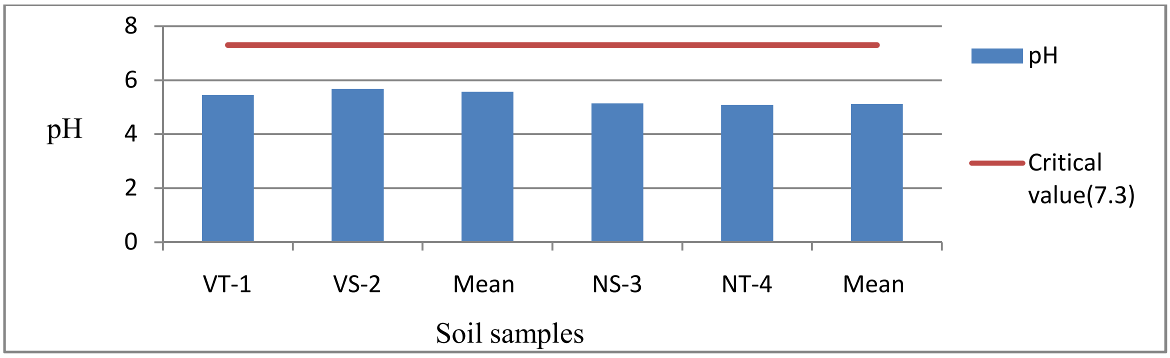

Figure 4.1 pH value after harvest

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

4.1.2 Bulk density

Bulk density ranges between 1.31-1.34 g/cm^3 for Nitisols and 1.29-1.3g/cm^3 for Vertisols (Figure 4.2 and Table 4.1). White (1997) stated that values of bulk density ranges from < 1 g/cm^{3}for soils high in OM, 1.0 to 1.4 g/ cm^3 for well- aggregated loamy soils and 1.4 to 1.8 g/cm^{3}for sands and compacted horizons in clay soils. Based on these soils of the study area were good for production with regarding to bulk density.

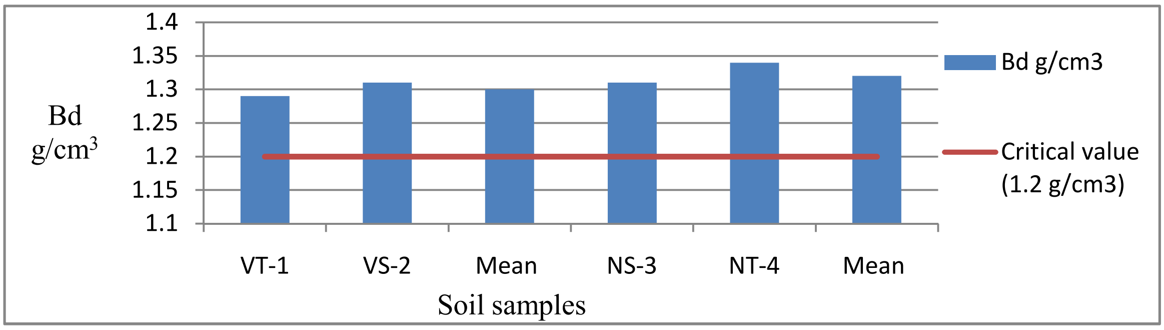

Figure 4.2 Change in bulk density after harvest

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

4.1.3 Organic carbon content

The OC content of the soil samples ranges from 1.21 to 1.41% with mean value of 1.31% for Vertisols and 1.7-1.8% with mean value of 1.75% for Nitisols (Figure 4.3 and Table 4.1). Hazelton and Murphy (2007) classified soil organic carbon percentages of < 0.60, 0.6 - 1.0, 1.0 - 1.80, 1.80 - 3.0, and >3 as very low, low, medium, high, and very high, respectively. This shows soils of the study area were medium in OC content.

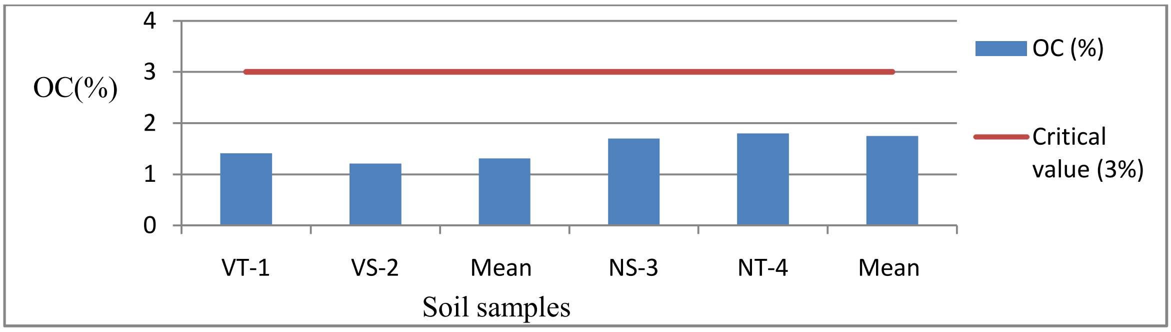

Figure 4.3 OC content of soil samples

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

4.1.4 CEC content

The laboratory result also shows that the CEC value of soil samples vary between 25.6 - 26.3 $cmol_c\ kg^{-1}$ with mean value of 25.95 $cmol_c\ kg^{-1}$ for Vertisols and 27.5-29.87 $cmol_c\ kg^{-1}$ with average value of 28.68 $cmol_c\ kg^{-1}$ for Nitisols (Figure 4.4 and Table 4.1). Soils having CEC of >40, 25-40, 15-25, 5-15,< 5 $cmol_c\ kg^{-1}$ categorized as very high, high, medium, low and very low, respectively (Landon *et al.*, 1991). Analysis result revealed that sols of the study area were high for Vertisols and Nitisols in CEC content.

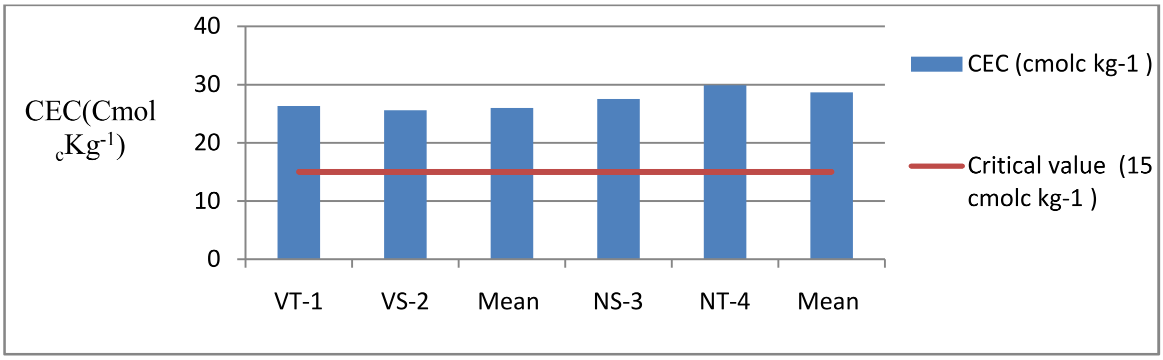

Figure 4.4 CEC value after harvest

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

Table 4.1 Soil physico-chemical status before improvement

Samples	Bd g/ cm^3	pH	TN %	AP mg kg^{-1}	OC%	CEC $cmol_c$ kg^{-1}	K mg kg^{-1}	Ca mg kg^{-1}	Mg mg kg^{-1}	B mg kg^{-1}	Zn mg kg^{-1}	S mg kg^{-1}
VT-1	1.29	5.45	0.09	9.71	1.41	26.30	480.61	1,788.42	304.07	0.045	1.1	7.96
VS-2	1.31	5.68	0.08	3.4	1.21	25.60	402.27	5,832.38	1,120.92	0.045	4.46	16.48
Mean	1.3	5.57	0.09	6.56	1.31	25.95	441.44	3,810.40	712.5	0.045	1.6	12.22
NS-3	1.31	5.14	0.15	5.94	1.7	27.50	384.84	4,377.85	1,039.10	0.045	1.35	14.65
NT-4	1.34	5.09	0.16	10.90	1.8	29.87	287.02	2,419.23	558.64	0.045	0.85	15.17
Mean	1.32	5.12	0.15	8.42	1.75	28.68	335.93	3,398.54	798.87	0.05	4.46	14.91

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two

4.1.5 Nitrogen content of soils of the study area

Total N content of soil samples ranges from 0.08 to 0.09% with mean value of 0.09% for Vertisols and 0.15-0.16% with mean value of 0.15% for Nitisols (Figure 4.5 and Table 4.1). According to EthioSIS (2014) TN content <0.1. 0.1-0.15, 0.15-0.3, 0.3-0.5, and >0.5 was very low, low, medium, high and very high, respectively. This shows soils of the study area were low in N content. The libratory result showed that the total nitrogen in the study area is very low for Vertisols and low for Nitisols. The result also indicates N is limiting factor for maize and tef crop growth. The optimum N level needed for crop production under most soils of Ethiopia is reported to be <0.2 % according to EthioSIS (2013). EthioSIS classified TN as <0.1% very low, 0.1-0.15% low, 0.15-0.3% optimum and > 0.3 high.

Thus, the soil of the experimental site has low nitrogen and requires nitrogen application as maize and some varieties of tef are highly exhaustive crops for nitrogen and the production potential of them was highly affected by N deficiency. This low deficiency in soils of the study area may be due to repeated cultivation and application of fertilizer below the recommendation. The result was in line with Tekalign Tadesse (1991) who classifies soils based on their N content. Masresha Mitiku (2014) also reported low amount of N content on soils which are cultivated repeatedly due to N leaching and N mining. Most Ethiopian black or dark grey soils are N-depleted and more than 50% of cultivated lands are N-responsive soils (Yihenew G/Selasie, 2002).

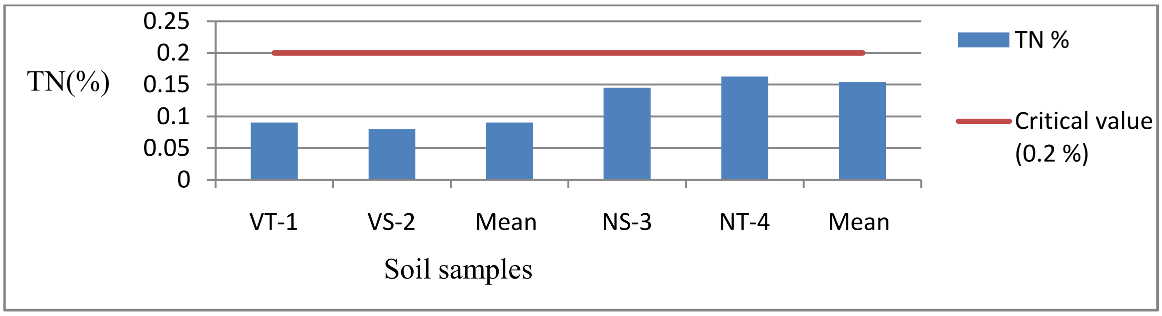

Figure 4.5 Nitrogen status of soil samples

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

4.1.6 Phosphorus status of the soil in the study area

The laboratory analysis result revealed that the available P ranges from 3.4 to 9.71% with mean value of 6.56 % for Vertisols and 5.94-10.9% with mean value of 8.42% for Nitisols (Figure 4.6 and Table 4.1). The phosphorous continent of soils of the study area was low. EthioSIS (2014) suggest optimum P content for most Ethiopian soil as 15 mg kg^{-1}. Based on this, the available phosphorous of the study area is very low and needs prosperous fertilizer. This very low phosphorous content is due to intensive mining of the farm fields and fixation by heavy metal cations. This shows that application of compost and mineral fertilizer with recommendation was important to improve its fertility status and crop production ability. In this regard, Foster (1973) reported that P response is likely in soils with less than 20 mg kg^{-1} soil available P. Masresha Mitiku (2014) also reported low amount of P content on soils which are cultivated repeatedly due to P fixation and P mining. Similarly, Habtamu Admas *et al*. (2015) reported that low contain of P was due to fixation problem.

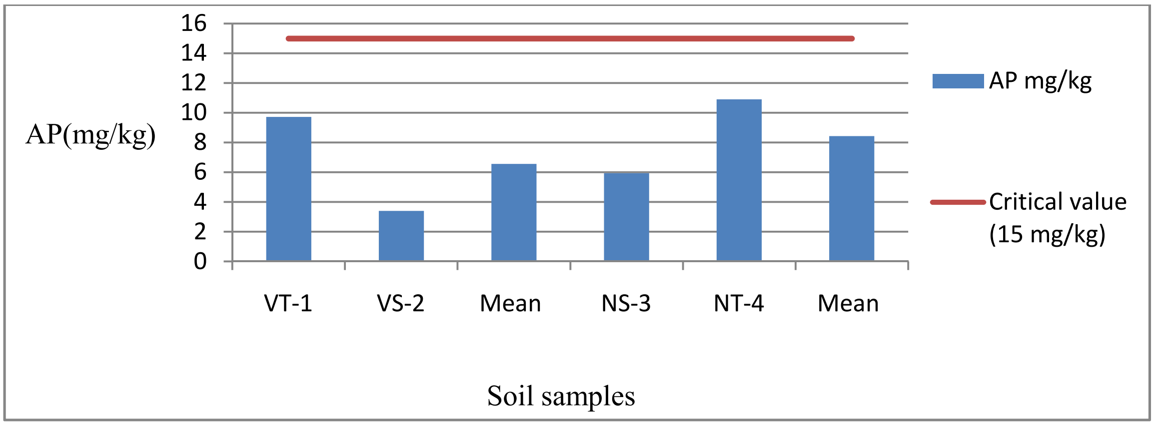

Figure 4.6 P status in the study area

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

4.1.7 Exchangeable Potassium status of the soil in the study area

Based on the soil laboratory result average value of Exchangeable K is 441.44 mg kg^{-1} (Figure 4.7 and Table 4.1). According to Ethiosis (2014), soil K value is classified as <90; very low, 90-190; low, 190-600; optimum and > 600 mg kg^{-1}; high. Therefore, K content of the study area was in optimum level. This shows there is no need of adding K fertilizer in the soil. The result was similar with Liu *et al.* (2011) who report soils in China had medium to high content of Exchangeable K. The result was also in agreement with

Teshome Yitbarec *et al.* (2016) who characterize soils of Abobo area that had high content of K.

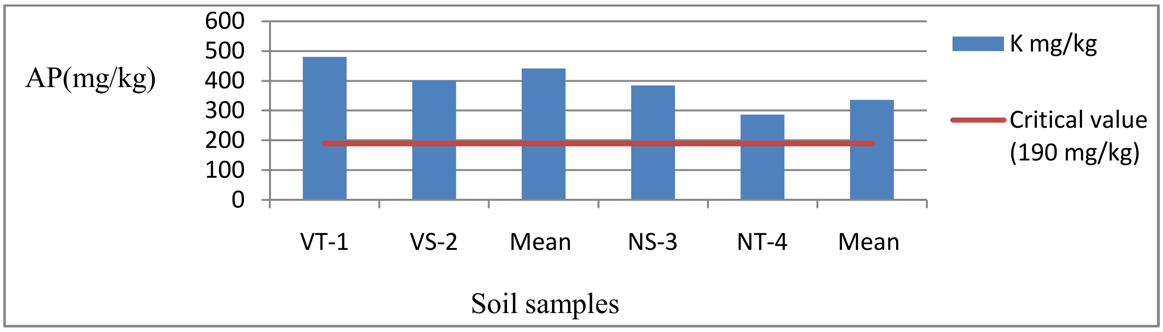

Figure 4.7 Soil K status of the study area

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

4.1.8 Exchangeable Calcium status of soils of the study area

According to the soil laboratory result the soil exchangeable Ca content is 3810.4 mg kg^{-1} on average (Table 4.2). According to EthioSIS, 2014) Ethiopian soils are classified as<30 very low, 30-50 low, 50-70 optimum and >70 mg kg^{-1} high. So the soil analysis shows there is no need of addition of Ca to the soil. This is in line with Gezahegn Wondimu (2011) who report that the soil of Ethiopia contains medium amount of Ca and Mg but high amount of K.

4.1.9 Exchangeable Magnesium status of soils of the study area

The soil analysis result revealed that the soil Mg content is 712.5 mg kg^{-1} on average (Table 4.2). The EthioSIS (2014) classify the soil Mg level as <8 very low, 8-10 low, 10-18 optimum and > 18 mg kg^{-1} high. Thus, the study area soil doesn't need magnesium fertilizer application. This is in line with the result of Gezahegn Wondimu (2011) who reported that the soil of Ethiopia contains medium amount of Ca and Mg but high amount of K. The result also agrees with Bello (2012) who found that soils of Tigray region were characterized by high concentration of Ca, Mg and K.

Table 4.2 Soil Exchangeable Ca and Mg status

Soil samples	Mg (mg kg^{-1})	Ca (mg kg^{-1})
VT-1	304.07	1,788.42
VS-2	1,120.92	5,832.38
Mean	712.5	3,810.40
NS-3	*1,039.10*	*4,377.85*
NT-4	*558.64*	*2,419.23*
Mean	798.87	3,398.54
Critical value	10	70

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

4.1.10 Soil Boron status

According to the result optioned from soil laboratory the mean B value of the soil is < 0.045 mg kg^{-1}(Figure 4.8 and Table 4.1). According to EthioSIS (2013), critical B value for most Ethiopian soils is 0.8 mg kg^{-1}. This shows that soils of the study area are deficit in B suggesting application of fertilizer which contains B. Intensive cultivation in the area was responsible for low B content of the soil. The result is in line with Hillette Hailu (2015) who found B deficiency in soil samples taken around Adiss Abeba.

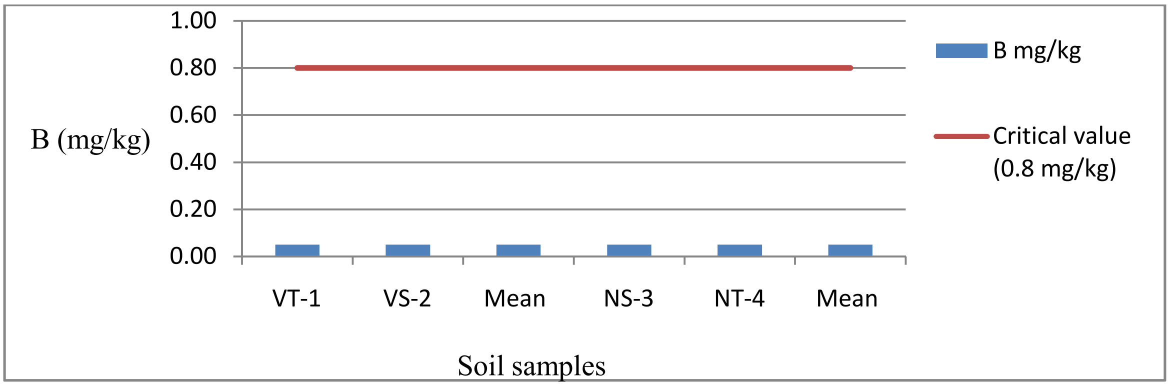

Figure 4.8 Soil B status in the study area

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

4.1.11 Zinc status of the soil of the study area

The soil analysis result shows that the Zn content of the study area ranges between 1.1-3.3 mg kg^{-1}(Figure 4.9 and Table 4.1). The Zn critical value for most Ethiopian soil was suggested by EthioSIS (2013) as 1.5 mg kg^{-1}. This shows that addition of fertilizer which contains Zn is necessary for Nitisols. This Zn deficiency may be related to excessive cultivation and continuous utilization of NPK fertilizer which doesn't provide Zn to soil.

Compared to Nitisols and Vertisols were high in Zn content due to high P content relatively. It was also due to low OM content of the soil. Jones (2003) found soils with deficiency in Zn content. The result also agrees with Asegelil *et al*. (2007) who reported Zn deficiency in 78.4 % of the soil samples collected from Vertisols and Nitisols of Ethiopia.

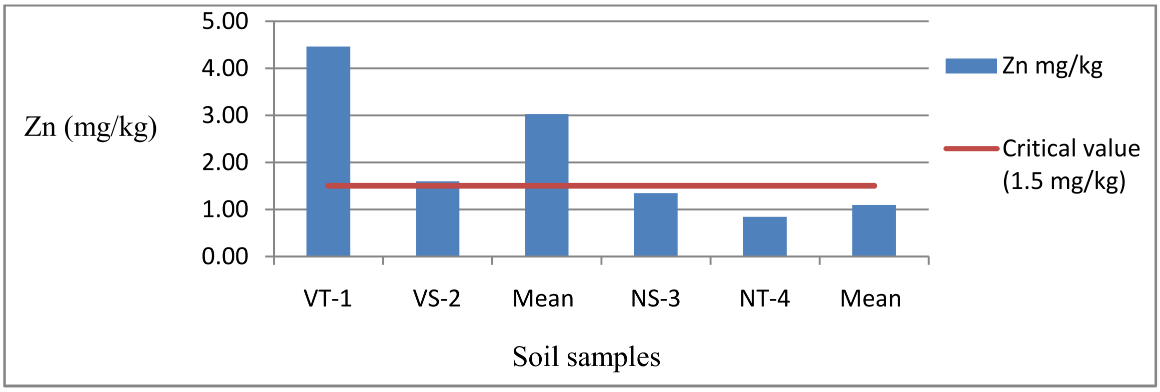

Figure 4.9 Soil Zinc status in the study area

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

4.1.12 Sulfur status of soils of the study area

The laboratory result revealed that the mean S value of the soil in the study area is 12.22 mg kg^{-1}(Figure 4.8 and Table 4.1). Based on EthioSIS (2014) soil classification for S values lies on low range. The classification is <9 very low, 10-20 low, 20-80 optimum, and > 80 mg kg^{-1} high. So addition of fertilizer which contains S is relevant. This low in sulfur content of the soil may be due to loss of OM and lacking of using S source mineral fertilizer. It was also related to continuous cultivation which result intensive mining of S from soil. This is similar with the report of Hillette Hailu (2015) who report soils around Adiss Abeba were deficient in sulphur content. Khalid *et al*. (2009) also report soils of Pakistan were deficient in S content.

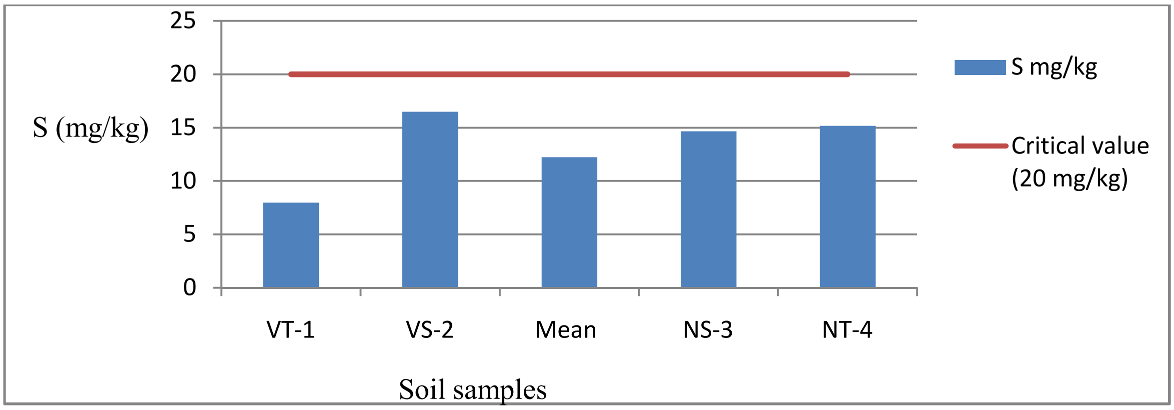

Figure 4.10 Soil S status in soil samples

VT-1, Vertisols samples from site one, VS-2, Vertisols samples from site two, NS-3 Nitisols samples from site one and NT-4, Nitisols samples from site two.

Generally soils of study area were low in OM, OC, N, P, S, Zn, B, content due to intensive and continuous cultivation that may aggravate OM oxidation, consequent leaching and erosion of macro and micro soil nutrients. Similarly, Saikh *et al.* (1998) and Negassa and Gebrekidan (2003) revealed that continuous cultivation of land results in the reduction of OC and total N. The soil in the study area was slightly acidic in its pH and sufficient in K, Ca, and Mg content. Habtamu Admas *et al*. (2015) also report that the soil OM, OC, CEC, N, P, S, Zn, and B content was very low for continuously cultivated farms. Eyob Kahsay (2007) reported that the soil with low amount of OM, OC, CEC, N, P, S, Zn, and B was unable to support crop growth and development.

4.2. Evaluation of the Chemical Quality of Compost

Compost is a source of various nutrients which could be resilient in the soil that might be due to the effects of nutrient rich raw materials that were used as sources for its preparation. The laboratory analysis result showed that compost samples were low but fair in OM (15.67%) total N (0.86%), but rich in available P (568.3 mg kg^{-1}) and S (862.6 mg kg^{-1}), CEC (39.3 $Cmol_c$ kg^{-1}), exchangeable Ca (8155.1 mg kg^{-1}), Mg (2037.65 mg kg^{-1}), and K (14492.42 mg kg^{-1}) and C: N ratio of 10.8 on average. This is due to microbial activities during its decomposition of raw organic source during preparation. This result was similar with Roland *et al*. (1997) reporting characteristics of different organic fertilizers according to their nutrient content. Therefore, using high rates of compost in agriculture might have potentials for developing an alternative fertilizer as it improves soil fertility status by supplying plant nutrients and improving physicochemical and biological properties of the soil.

4.2.1 PH value of compost samples

The laboratory result revealed that the mean pH value for heap compost samples were 7. 84 and 8.5 for pit (Figure 4.11) which whereas optimum pH value 7.5 as suggested by (Bunt, 1988). This optimum pH was due to optimum OM content. It may be also due to good composition of raw materials. This shows that the composts from the study area were slightly alkaline and used for soil fertility amendment and increase crop production. The result was in line with Sayed (2015) who reports optimum pH value for different compost types used to amend soil fertility and boost crop production. The result was also in line with Kassa Teka *et al*. (2014) who report pH of compost prepared by farmers was 8.27.

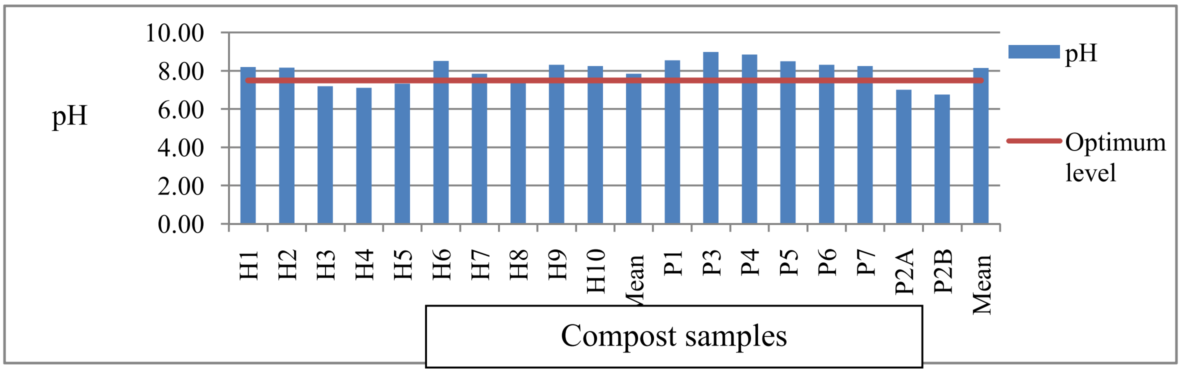

Figure 4.11 pH value of compost samples

From H1- H10 were samples from heap compost and P1-P2B were samples from pit compost

4.2.2 Organic matter content of compost

The laboratory result showed that the average OM content for heap compost samples was 17.14% and 15.58 for pit on average (Figure 4.12). According to Crohn (2016), the optimum OM content for soil amendment is 25%. This implies that using this organic fertilizer as soil amendment mechanism is good for the soil and crop performance but huge amount should be used. The high OM content may be due to decomposition of raw materials. The result was in line with Gezahegn Wondim (2011) who characterizes quality of FYM and found optimum OM content within it for soil fertility and crop production improvement. The result was also in line with Suge *et al*. (2011) who characterize FYM and found optimum OM content (17.25%).

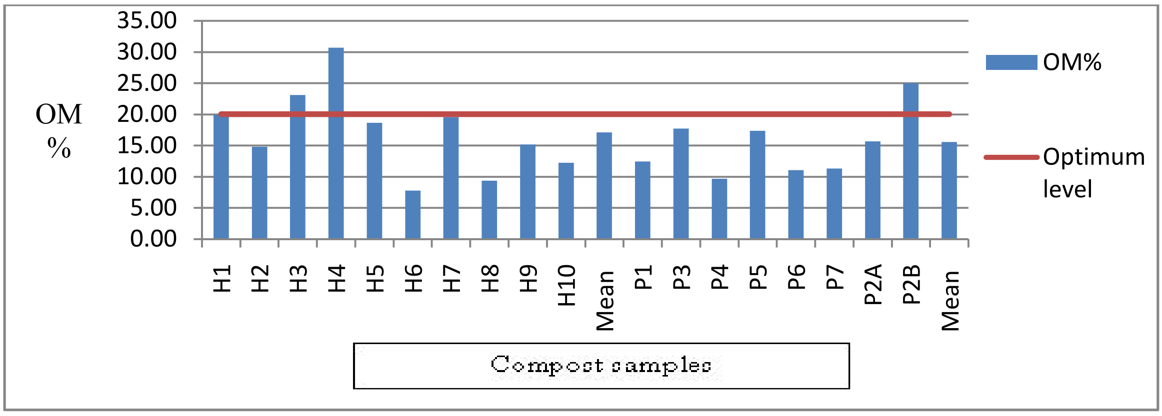

Figure 4.12 OM contain of compost samples

From H1- H10 were samples from heap compost and P1-P2B were samples from pit compost

4.2.3. Carbon to Nitrogen ratio of compost samples

The C: N ratio for compost samples collected from farmers backyard were 10.82 on average (figure 4.13). The optimum C: N ratio of compost that is used for soil amendment is <20:1 (Crohn, 2016). This shows that the compost samples was in optimum level for using it as organic fertilizer and facilitates crop growth and soil fertility. This was due to good maturity of compost which maintains the amount of carbon and nitrogen in optimum level. The result was also in line with Kebede Wolka and Bezashwork Melaku (2015) who reported C: N ratio of compost that was less than 20:1.

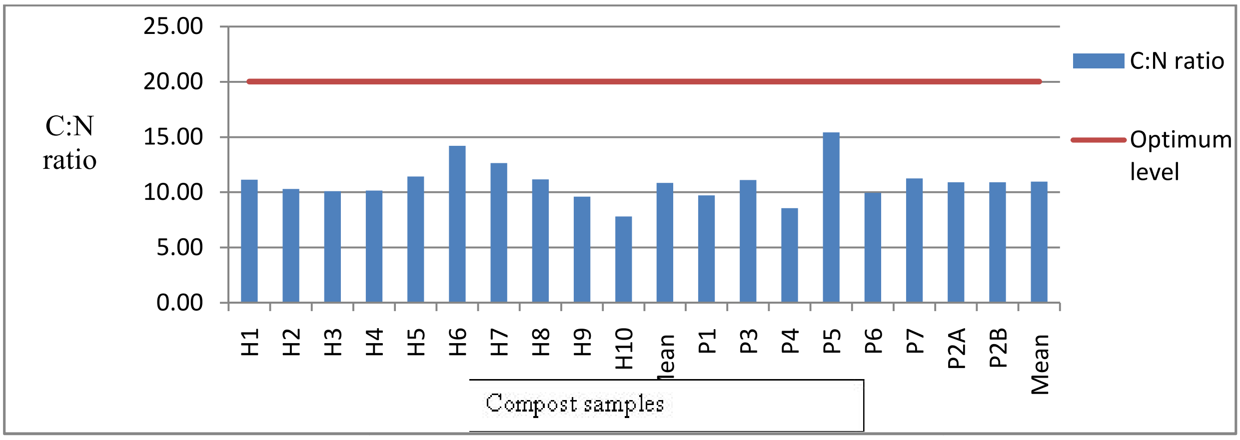

Figure 4.13 Compost pH and C: N ratio

From H1- H10 were samples from heap compost and P1-P2B were samples from pit compost

4.2.4 Nitrogen content of compost samples

As shown in figure **(**Figure 4. 14**)** the total nitrogen was 0.86% on average for compost samples. According to Alexander (2001) the optimum nitrogen content for compost was more than 1%. This was due to optimum content in OM and PH. Nitrogen was also available when organic source decompose by micro organisms over time. This shows that the compost produced in the study area provide less but fair amount of nitrogen. The result is in line with Jolien Van Haute (2014) who reported mean total nitrogen content of compost (1.89%) for use in soil fertility and crop yield improvement. This result was also similar with Ros *et al*. (2006) who reports mean value of compost total nitrogen contains 1.89% to be used for soil fertility and crop yield improvement. The result was also in agreement with Pedro *et al*. (2008) who characterize compost and obtained optimum N (0.99%) content.

Figure 4.14 Nitrogen content of compost samples

From H1- H10 were samples from heap compost and P1-P2B were samples from pit compost

4.2.5 Phosphorous content of compost samples

The laboratory result shows that available phosphorous was 532.68 mg kg^{-1} for heap and 541.3 mg kg^{-1} on average for compost samples (Figure 4.15). According to Alexander (2001), the optimum phosphorous content for compost was above 100 mg kg^{-1}. This shows that the compost produced in the study area provide sufficient amount of phosphorous for good crop performance and soil fertility improvement. This is due to high amount of Ash used in the preparation of compost. The optimum P content of compost samples was related to OM which serve as store house for P. P also available when OM was degraded by micro organism during composting. This result was in line with Sayed (2015) who reports mean value of compost samples for available phosphorous was 51 mg kg^{-1}. Masresha Mitiku (2014) also reported characteristics of compost and found of P (44 mg kg^{-1}) within compost samples. The result of this finding also agrees with John Gum (2012) who characterizes compost chemically and found optimum P content (120.8 mg kg^{-1}).

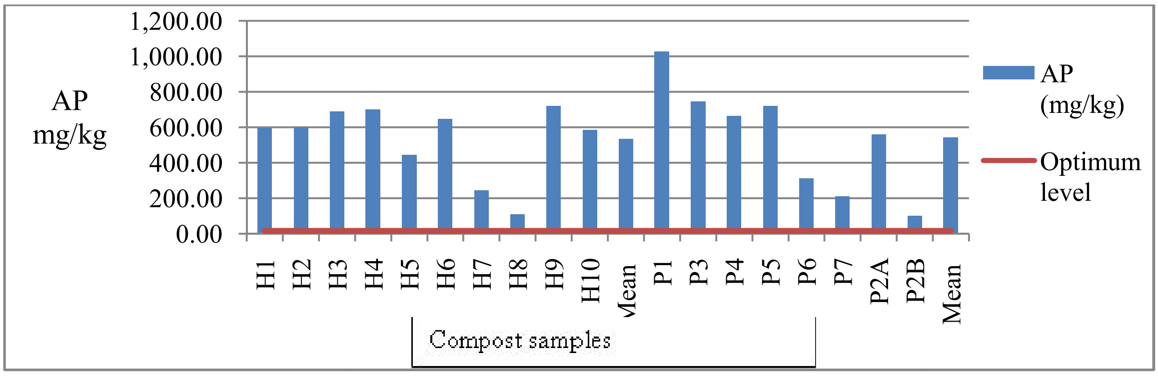

Figure 4.15 P content of compost samples

From H1- H10 were samples from heap compost and P1-P2B were samples from pit compost

4.2.6 Potassium content of compost samples

The potassium content of compost samples from laboratory analysis was found 11,437.26 mg kg^{-1} for heap and 17,163.03 mg kg^{-1} for pit on average (Table 4.3). The optimum K content of compost for soil fertility amendment and crop production improvement was suggested by Sayed (2015) was 65 mg kg^{-1}. This indicates that compost samples were ready to be used for soil and yield improvement. This is due to existence of Ash as raw material in compost preparation. The result was in line with Ros *et al.* (2006) that works on characterizing compost samples made from different raw material. The result was also in line with Jolien Van Haute (2014) who characterized compost samples made from different raw materials and found optimum amount of K (67 mg $kg^{-1)}$.

4.2.7 Calcium content of compost samples

Based on the laboratory result the mean Ca content was 8,013.65 mg kg^{-1} for heap and 7,888.40 for pit on average (Table 4.3). The optimum amount of Ca contain for compost added to improve soil fertility and boost crop production was suggested by Manohara and Belagali (2014) as 20.5 mg kg^{-1}. The same result was reported by Bueno *et al*. (2008) who characterize compost made from different organic sources and found optimum Ca (23.7 mg kg^{-1}).

4.2.8 Magnesium content of compost

The laboratory result revealed that mean Mg content of compost samples was 1,825.14 mg kg^{-1} for heap and 2,193.58 for pit with mean value of 2037.85 mg kg^{-1} (Table 4.3). The optimum Mg content of compost used to increase crop production and improve soil fertility was 30 mg kg^{-1}as suggested by Manohara and Belagali (2014). This shows that the compost samples had excess amount of Mg and were good to amend soil fertility and improve yield of crops. The result was in line with that of Khan and Ishaq (2011) who found difference between vermi-compost and pit compost on their Mg content.

Table 4.3 K, Ca and Mg content of compost samples

Compost samples	k (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
H1	434.83	2,810.41	600.11
H2	11,757.40	7,472.76	1,733.39
H3	15,623.70	6,729.94	1,745.04
H4	12,371.50	7,876.95	2,469.04
H5	13,904.10	10,586.30	2,331.51
H6	9,487.90	7,455.01	1,589.13
H7	18,332.50	14,282.90	2,441.25
H8	9,870.39	8,902.08	1,679.49
H9	7,413.55	5,075.69	1,359.62
H10	15,176.70	8,944.47	2,302.83
Mean	**11,437.26**	**8,013.65**	**1,825.14**
P1	15,468.50	5,921.51	1,801.78
P3	16,754.80	8,125.91	2,000.71
P4	23,581.20	9,241.90	2,686.62
P5	23,820.90	8,424.47	2,384.55
P6	19,080.50	10,959.90	3,096.44
P7	18,047.20	10,435.00	2,933.37
P2A	15,245.40	5,391.56	1,488.62
P2B	*5,305.76*	*4,606.96*	*1,156.51*
Mean	**17,163.03**	**7,888.40**	**2,193.58**
Optimum value	**65**	**20.5**	**30**

From H1- H10 were samples from heap compost and P1-P2B were samples from pit compost

4.2.9 Zinc content of compost samples

The laboratory result suggests that mean Zn value of compost samples with mean value of 16.58 mg kg^{-1} for heap and 56.33 mg kg^{-1} for pit ((Table 4.4)). The optimum Zn content of compost which is used for soil fertility and crop yield improvement was 280 mg kg^{-1}as suggested by Brinton (2000). Zinc was one part of heave metal which brings toxicity. But laboratory analysis result shows that compost produced in the study area was not toxic due to low content of Zn. The result is similar with William *et al*. (2012) who characterize compost samples in their quality and nutrient content and found low content of Zn.

4.2.10 Copper content of compost samples

The laboratory analysis result shows that mean cupper content of the compost samples mean value was 4.06 mg kg^{-1} for heap and 6.06 for pit (Table 4.4). The optimum Cu content of compost which is used as organic fertilizer was 100 mg kg^{-1} as suggested by (Brinton, 2000). This shows that compost produced in the study area was good in its potential for supplementing Cu for the soil and crops without causing toxicity. This work was analogous with William *et al*. (2012) who characterize compost samples in their quality and nutrient content and found the Cu content lower than the optimum limit for toxicity.

4.2.11 Molybdenum content of compost samples

The laboratory analysis result revealed that mean Mo content of compost samples was 0.97 mg kg^{-1} for heap and 0.98 for Pit (Table 4.4). The optimum Mo content in compost for use as soil fertility and yield improvement was 10 mg kg^{-1} (Brinton, 2000). The compost produced in the study is not toxic to crops based on its Mo content. Bolan *et al*. (2004) reported that the concentration of trace elements can vary considerably among animal manures.

4.2.12 Iron content of compost samples

The laboratory analysis result revealed that mean Fe content of compost samples was 295.88 mg kg^{-1} for heap and 290.02 for pit (Table 4.4). The optimum recommended Fe content of compost which was used for soil fertility and yield improvement was 6506 mg kg^{-1} on average (William *et al*., 2012). This shows that the Fe content of compost samples was in a good range to be used for soil fertility and crop yield improvement. The compost produced in the study was not toxic to crops based on its Fe content. Eneji *et al*. (2003) reported marked decrease in total Fe, Zn, Cu and Mn especially under anaerobic condition due to composting process. The result was also similar with Innocent (2014) who found the Fe content of FYM 250.36 mg kg^{-1}.

Table 4.4 B, Cu, Zn, Fe and Mo content of compost samples

Compost samples	Cu (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Mo (mg/kg)
H1	4.43	1.09	177.37	0.95
H2	2.77	16.22	398.12	0.91
H3	3.75	12.66	322.33	0.93
H4	2.40	17.99	195.69	0.95
H5	4.13	21.24	189.08	1.00
H6	6.26	26.80	323.87	0.94
H7	4.86	43.11	186.57	1.07
H8	4.34	11.96	364.04	1.03
H9	4.87	4.79	383.10	0.94
H10	2.78	9.91	418.68	0.98
Mean	**4.06**	**16.58**	**295.88**	**0.97**
P1	3.85	23.30	224.95	0.94
P3	4.04	23.44	322.78	0.96
P4	5.47	34.05	257.10	1.03
P5	4.80	32.17	222.02	1.03
P6	4.67	25.79	245.50	1.02
P7	4.91	12.31	262.25	1.02
P2A	2.72	19.61	356.94	0.93
P2B	*2.52*	280.00	*428.62*	*0.94*
Mean	**4.12**	**56.33**	**290.02**	**0.98**
Optimum level	**100**	**280**	**6506**	**10**

From H1- H10 were samples from heap compost and P1-P2 were samples from pit compost

4.3. Effect on IFM on soil physico-chemical properties

4.3.1 pH change of soils after harvest

This experiment indicated that pH was affected by integrated nutrient management which was increased with the application of high doses of compost and mineral fertilizer compared to the initial soil. The highest mean pH (7.45) for Vertisols was observed in plots treated with nil compost and full recommendation of chemical fertilizers that gave an increase (7.4%) from the initial soil (Figure 4.16). However, the lowest pH (6.9) for Vertisols was recorded from control plot. However, for Nitisols the maximum pH (6.1) was recorded from half recommended and 10 t ha^{-1} compost treated plots. This is due to dissociation of urea which release NH^+, so plants take NH^+ and release HCO_3^- which reacts with H^+ and form H_2CO_3 acid. This acid is weak acid and dissociate in to H_2O and CO_2. So CO_2 released to atmosphere water stays in the soil increasing pH by decreasing H^+ ion concentration in the soil solution. The increase in OM also increases pH since it can minimize the H+ from soil solution by forming organic complex. The minimum pH (5.7) was recorded from control.

Generally pH shows an increasing trend due to an increasing rate of compost and mineral fertilizer. But for Vertisols of the study area pH shows inconsistent trend as rate of organic and mineral fertilizer varies. These result was in line with that of Sarwar *et al.* (2010) who reported that compost has librated alkaline substances and cations such as Ca^{2+}, Mg^{2+} , K^{+} which increase CEC and pH level and counteract soil acidification. Achieng *et al.* (2010) also elucidated that retention of crop residues on land has the potential to increase soil pH. Similar results were reported by Negassa Wakene *et al.* (2005) who stated that addition of OM especially FYM into tropical soils increase soil pH.

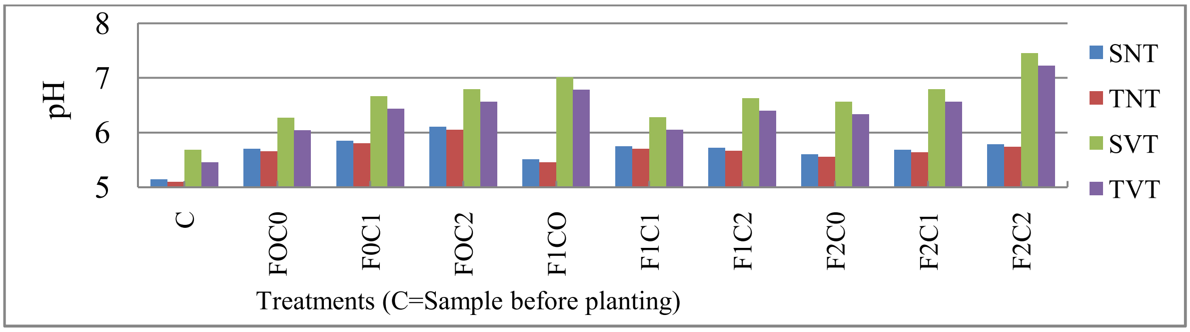

Figure 4.16 Soil pH value after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1}compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.3.2 Change in soil Bulk density after harvest

Application of compost and mineral fertilizer solely or in combination affected soil bulk density. In application of compost only bulk density was reduced from 1.29 to 1.26 g/cm^3 for Nitisols and 1.28 to 1.25 g/cm^3 for Vertisols, respectively (Figure 4.17). This was due to greater organic carbon content maintained as a result of applications of compost. The increase in OM content of the soil due to compost also decreases the level of compaction, decreasing bulk density to more favorable level. The result was in line with Gudadhe *et al.* (2015) who found decrease in soil bulk density as a result of continuous application of FYM. Bulk density was not affected in the application of mineral fertilizer only due to the decrease in OC and OM as result of decomposition over time. Wondimu Bayu *et al*. (2006)

also reported that application of inorganic fertilizers had no significant effect on bulk density of the soil.

In combined application of compost and mineral fertilizer the bulk density was reduced from1.24 to 1.21 g/cm^3 for Nitisols and from 1.22 to 1.2 g/cm^3 for Vertisols on average (Figure 4.17). This decrease in bulk density may be related to the increase in OC and OM which modify porosity and compactness of the soil. Modification in compactness and porosity would decrease bulk density. The result was similar with Muhammad *et al*. (2013) who found decrease in bulk density as a result of nutrient and crop management.

Generally bulk density decreases as the rate of compost and mineral fertilizer increases. The best bulk density was recorded on plots treated with 10 t ha^{-1} compost and full recommendation of mineral fertilizer. The result was in agreement with Shirani *et al*. (2002) reported significantly decreased in soil bulk density just after harvesting a maize field supplied with FYM.

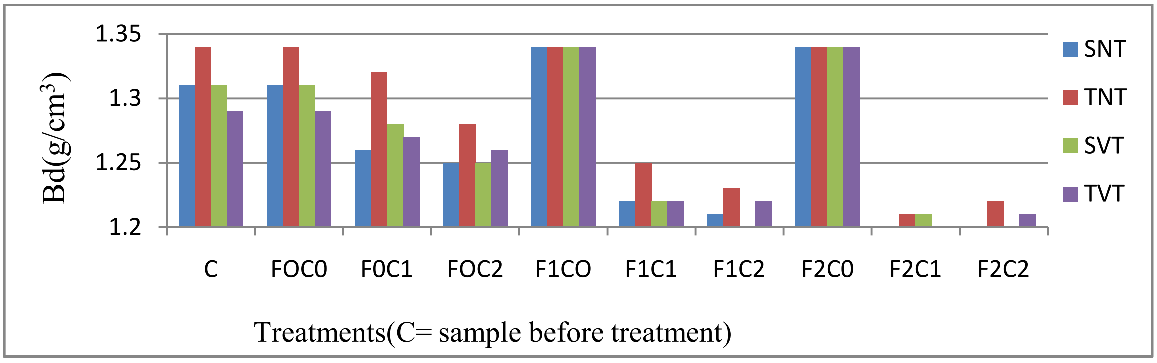

Figure 4.17 Change in bulk density of soil after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1} compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.3.3 Soil Organic Carbone content after harvest

Organic carbon in the soil was increased after harvesting with the application of organic and inorganic fertilizers (Figure 4.18). The highest OC content (2.38%) was recorded in plots treated with 10 t ha^{-1}compost and full recommendation of mineral fertilizer that indicated an increase of 55.04% from the initial soil analysis result. This increase might be due to the high application of compost with high OC contents and root residue decomposition of plants grown luxuriously by such high rate of compost and half recommended mineral fertilizers. The result was compatible with Shimeles *et al*. (2006) who reported high organic carbon in Nitisols of Ethiopia due to organic fertilizer application. Negassa Wakene and Heluf G/kidan (2001) also reported increase in OC of soil after harvest due to addition of higher biomass to soil. The finding was also similar with Antill *et al*. (2001) who found high OC after harvest due to application FYM and NP fertilizer. Sharma and Subehia (2003) also reported greater levels of soil organic carbon under integrated treatments of organic and inorganic fertilizer.

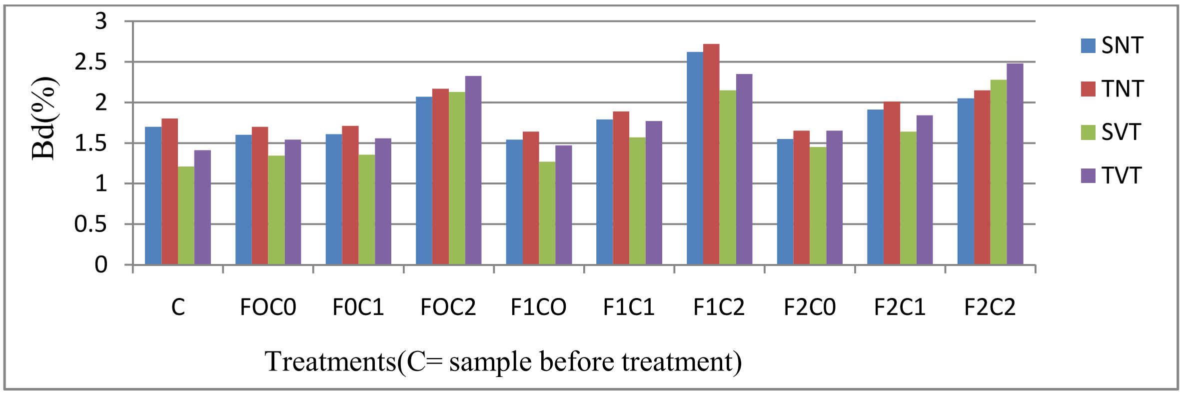

Figure 4.18 Change in OC content of soil after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1}compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.3.4 Nitrate content of soil after harvest

Nitrate concentration was higher at initial stage than after harvest due to low build up in Nitrate during growing of crops and direct uptake of NO_3^- by crops (Figure 4.19). The mean highest and lowest NO_3^{-1}content for plots treated with compost alone was 2.4 mg kg^{-1} and 2.1 mg kg^{-1} for Nitisols and similar 4.2 mg kg^{-1} for Vertisols. For plots treated with mineral fertilizer only the maximum and minimum mean value was similar 2.6 mg kg^{-1} for Nitisols and 4.2 mg kg^{-1} for Vertisols, respectively.

In the combined application of compost and mineral fertilizer maximum and minimum mean numerical value of NO_3^- was 2.54 mg kg^{-1} and 1.9 mg kg^{-1} for Nitisols and 5.2 mg kg^{-1} and 4.2 mg kg^{-1} for Vertisols, respectively (Figure 4.19). The increase in nitrate content in combined application of compost and mineral fertilizer may be due to increase in nitrification process as result high OM. The increase in nitrogen content in the soil due to combined application of compost and mineral fertilizer had also implication on increasing Nitrate content in soil of the study area. The result was in line with Burger and Jackson (2003). It was also comparable with Dubey *et al*. (2012) who reported that continuous use of nitrogenous fertilizers generally increased the available Nitrate status of the soil.

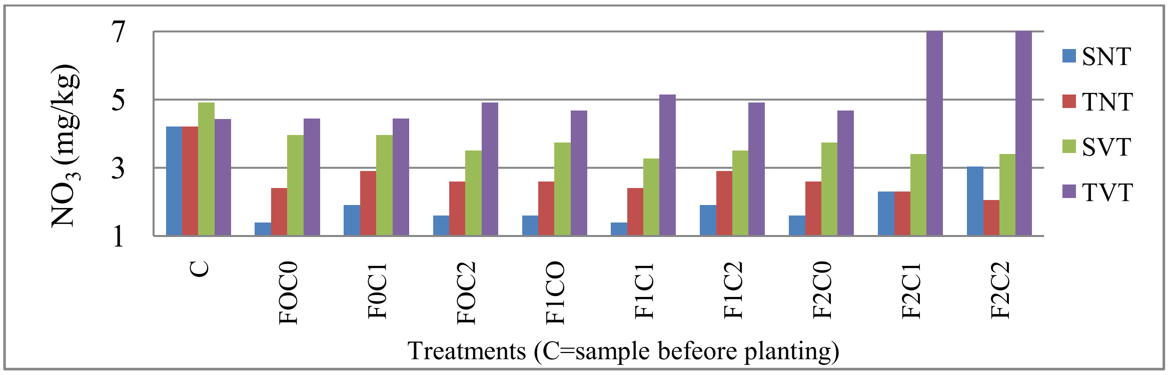

Figure 4.19 Nitrate content of soil after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1}compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.3.5 Total nitrogen content of soil after harvest

The mean value of total N was highest obtained (0.22 %) on plots treated with 10 t ha^{-1} of compost and half recommendation of mineral fertilizer for Vertisols and with 5 t ha^{-1} and full recommendation of mineral fertilizer for Nitisols, respectively. The lowest total N 0.11% for Vertisols and 0.14% for Nitisols was recorded the control plots. In the application of compost alone, the highest and lowest mean values of total N was 1.4% and 1.8% for Nitisols and o.14% and 0.21% % for Vertisols (Figure 4.20). In the application of mineral fertilizer, the highest and the lowest total N were 1.4 % and 0.18 % for Nitisols and 0.11% for Vertisols, respectively. Total nitrogen content decreases in mineral fertilizer treated plots due to increase pH which create probability of N- fixation. It was also decreased because of decline in organic matter content of the soil due to decomposition over time. Similar results have also been reported by Singh *et al*. (2001). It decreased under inorganic fertilizer alone because nutrients from this source were readily available and directly used by plants.

In the combined application of compost with inorganic fertilizers, the highest and the lowest values of total nitrogen content was 0.22 % and 0.16 % for Vertisols and 0.22% and 0.15% for Nitisols, respectively (Figure 4.20). Hence, it was clear that application compost with chemical fertilizers increased the total N, which may be attributed to mineralization of N from OM during decomposition of compost. Generally, across all the applied soil fertility amendments, the combined application of compost and mineral fertilizer at different rate affects total nitrogen in the study area.

The result was analogous with Fassil Kebede and Yamoah (2009) who report that total N contents of Vertisols of the Central highlands and Eastern lowlands of Ethiopia varied from 0.08 to 0.22 % when treated with different nutrient sources. The result was also similar with Tekalign Tadesse *et al*. (1988) who indicate that N was improved by application of inorganic fertilizers and OM

The study was in agreement with the findings of Muhammad *et al*. (2011) who reported that plots receiving crop residue and inorganic fertilizer have more total nitrogen content than control. Getachew Agegnehu and Taye Bekele (2005) also reported that the total N of soil was significantly improved due to the application of farmyard manure.

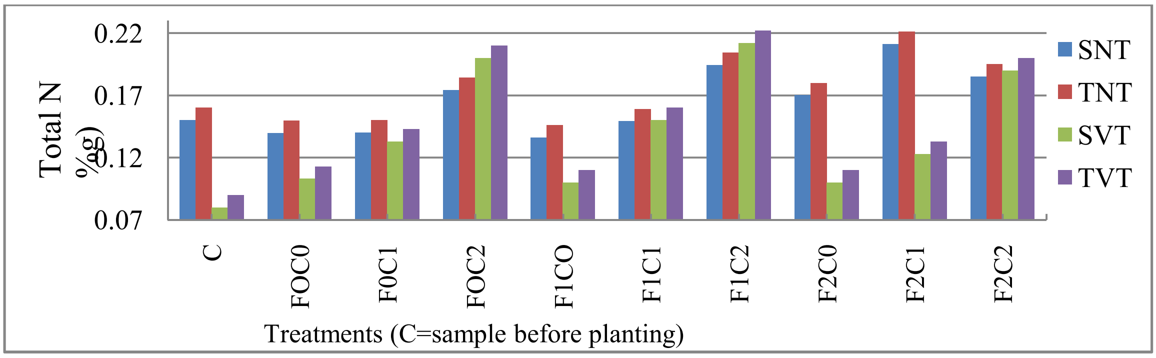

Figure 4.20 Change in total nitrogen after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1}compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.3.6 Available phosphorus content of soil after harvest

Phosphorus is a critical element in natural and agricultural ecosystems and its management need is second only to the need for the management of N for the production of healthy plants and profitable yields (Brady and Weil, 2002).

In solo application of compost as a soil fertility amendment option, the highest and the lowest content of available phosphorous were 14.70 mg kg^{-1} and 11.7 mg kg^{-1} that was observed under the application rate of 5 t ha^{-1} and 10 t ha^{-1} compost for Vertisols and 16.70

mg kg^{-1} and 13.4 mg kg^{-1} for Nitisols, respectively (Figure 4.21). This may be due to the added P and the pH was also suitable for the availability of phosphorous in the soil. The improvement in OM content also increases available P in the soil. The result was similar with (Ige *et al*., 2005).

With regarding to the solo application of inorganic fertilizer, the highest and the lowest available phosphorous were 25.07 mg $kg^{-1}$and 16.72 mg kg^{-1} for Nitisols and 19.6 mg kg^{-1} and 18.6 mg kg^{-1} for Vertisols. This is due to the direct addition of P from mineral fertilizer and increase in pH which minimize P-fixation.

In the combined application of compost along with inorganic fertilizers, the maximum and the minimum values of available phosphorous content was 52.7 mg kg^{-1} and 17.5 mg kg^{-1} for Vertisols and 44.8 mg kg^{-1} and 18.8 mg kg^{-1} for Nitisols, respectively (Figure 4.21). The incorporation of compost has been shown to increase the amount of soluble organic matter which were mainly organic acids that increase the rate of desorption of phosphate and thus improves the available Phosphorous content in the soil (Zsolnay and Gorlitz, 1994)

Generally, across all the applied soil fertility amendment options indicated in Figure 4.14, it can be concluded that application of compost and mineral fertilizer gave better in increasing P content than the other soil fertility amendment options. Combination of compost with chemical fertilizer helped in increasing the available P in the soil by mineralization or solubilising the native P reserves. These results are in confirmation with (Gawai, 2003).

Muhammad (2011) also reported that application of dry matter compost with mineral fertilizer resulted more phosphorous than other treatments because it supplied nutrients more quickly. Similar effects of fertilization on soil properties changes were shown by Sosulski *et al*. (2011), Mercik and Stępień (2012).

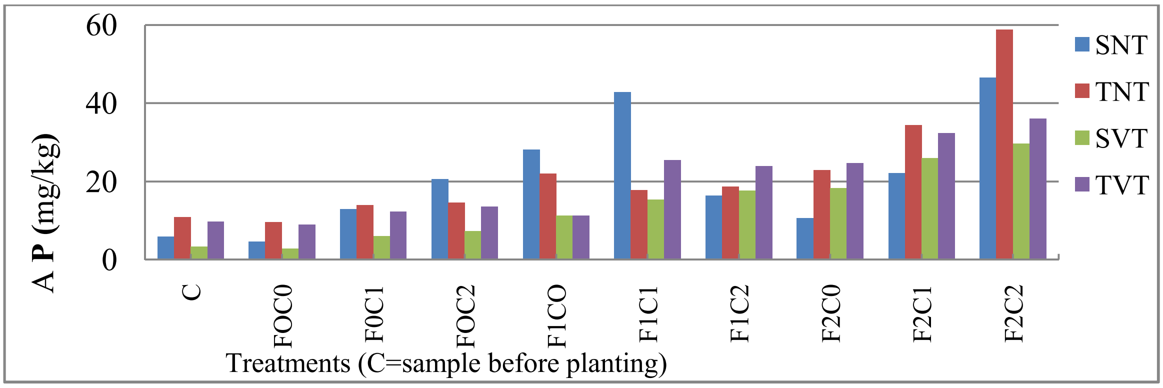

Figure 4.21 Available P change after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1} compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.3.7 Cation Exchange Capacity of soil after harvest

As indicated in Figure 4.15, in the sole application of compost the lowest CEC is (25.3) $Cmol_c\ kg^{-1}$ and the highest is 31.6 $Cmol_c\ kg^{-1}$ for Vertisols and 29.3 $Cmol_c\ kg^{-1}$ and 30.6 $Cmol_c\ kg^{-1}$ for Nitisols (Figure 4.22). This increase in CEC may be due to increase in OM and pH which facilitate the availability of exchangeable ions. In solo application of mineral fertilizer, the highest CEC was 28.56 $Cmol_c\ kg^{-1}$ and the lowest 28.4 $Cmol_c\ kg^{-1}$ for Nitisols and 29.8 $Cmol_c\ kg^{-1}$ and 29.1 $Cmol_c\ kg^{-1}$ for Vertisols, respectively. This may be due to pH increases, so do the number of negative charges on the clay or organic matter particles, and thus increase CEC.

In combined application of compost and mineral fertilizer, the highest and lowest CEC value was 32.9 $Cmol_c\ kg^{-1}$ and 31.5 $Cmol_c\ kg^{-1}$ for Nitisols and 34.7 $Cmol_c\ kg^{-1}$ and 31.1 $Cmol_c\ kg^{-1}$ for Vertisols (Figure 4.22). The change was due to addition of cations from mineral fertilizer and addition of OM due to compost. The increase in pH also had implication on increasing CEC value in soils of the study area. The result was in line with Lifeng *et al*. (2006) who found high CEC on plots treated with humic substance under different pH. The result was also in compliment with Fassil Kebede and Yamoah (2009) who found high CEC due to increase in OC. The rise of CEC can be also explained through retention by soil adsorptive complex of H^+ ions resulted after ammonium oxidation process. The result was similar with Agegnehu Getachew *et al*. (2014) who found increasing of CEC due to integrated nutrient management.

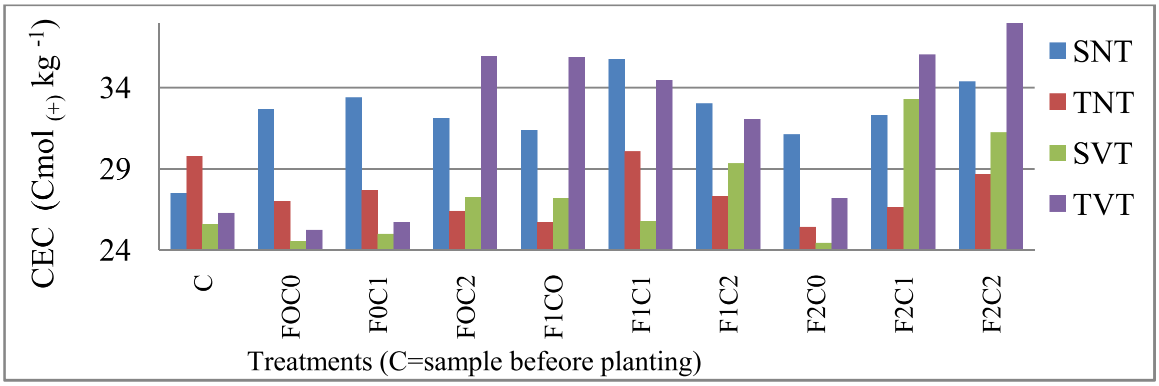

Figure 4.22 Change in CEC of soil after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1}compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.3.8 Change in Sulfur content of the soil after harvest

Sulfur content of the soil was affected by the application of compost and mineral fertilizer independently or in combination. The highest and smallest mean S content in the application of compost alone was 34.03 and 31.4 mg kg^{-1} for Vertisols and 22.09 and 18.01 mg $kg^{-1}$for Nitisols, for 5 t ha^{-1} and 10 t $ha^{-1}$of compost, respectively (Figure 4.23). The increase in sulfur content in these plots was due to the increase in organic matter which serve as source of S and increase pH which make sulfur more available. The use of organic fertilizer like compost in huge amounts satisfies other nutrient requirements and usually provides sufficient sulfur to soil. In plots receiving mineral fertilizer only the maximum and minimum S content was 18.01mg $kg^{-1}$and 17.45 mg $kg^{-1}$for Nitisols and 31.37 mg/kg and 30.53 mg $kg^{-1}$for Vertisols, respectively for half and full recommended mineral fertilizer (Figure 4.17). On plots treated with mineral fertilizer sulfur content was decreased due to decrease in OM and CEC.

In the combined application of compost and mineral fertilizer the highest and lowest mean S content was 22.18 and 17.67 mg $kg^{-1}$for Nitisols and 34.99 and 32.81 mg $kg^{-1}$for Vertisols, respectively (Figure 4.23). The change in Sulfur content was due to change in OM and CEC content of the soil samples in the study area. Organic fertilizers such as compost were also good to increase other micronutrients and sulfur. The result was in line with Skwierawska *et al*. (2008) who found increase in soil sulfur content after harvest when the soil was treated with sulfur fertilizer.

Generally as compared to the initial soil analysis result there was change in sulfur content in soils of the study area as the rate of compost and mineral fertilizer changes. The maximum S content was recorded from application of 10 t ha^{-1}compost and full recommendation of mineral fertilizer over the control. During the whole duration of the field trials, the effects were different for different rates of compost and mineral fertilizer on available sulfur content. This inconsistency may be corresponded with variability in OM content, CEC values and pH within the plots. The result of this finding was also similar with Singh *et al.* (2016) who reported that Available S increase in the soil after harvest due to sulphur fertilizer application.

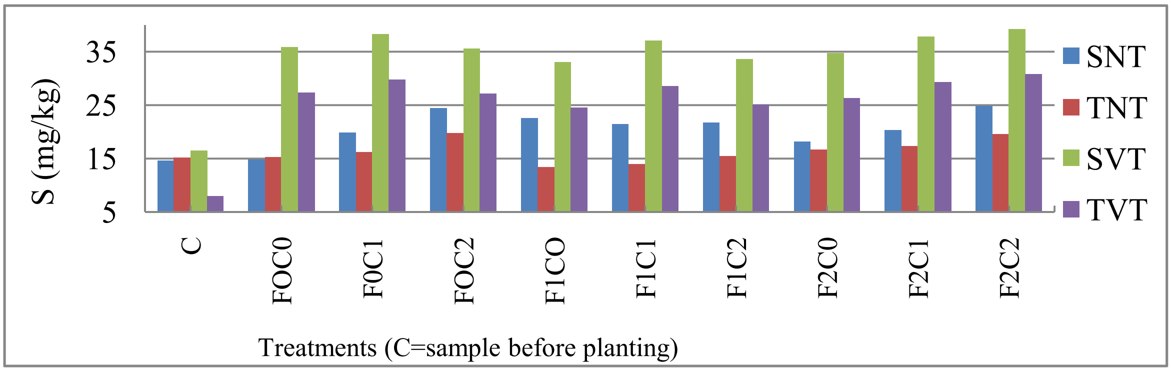

Figure 4.23 Sulphur content of soil after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1}compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.3.9 Change in zinc content of the soil

Zinc content of soil samples was affected by application of compost and mineral fertilizer as shown in (Figure 4.25), application of compost at different rate increase zinc content from 1.86 to 2.47 mg $kg^{-1}$for Nitisols and 1.92 to 2.05 mg $kg^{-1}$for Vertisols on average. This was strongly related to the improvement in OM content which plays a role for Zn increase in these plots. The application of mineral fertilizer with half and full recommendation rate decrease the Zn content from 14.56 to 12.19 mg $kg^{-1}$for Nitisols and increased from 4.04 to 6.18 mg $kg^{-1}$for Vertisols on average. This decrease in zinc content of the soil may be due to decrease in OM content of the soil.

Application of compost and mineral fertilizer increase Zn content from 10.04 to 17.64 mg $kg^{-1}$for Nitisols and 4.5 to 6.46 mg kg^{-1} for Vertisols, respective (Figure 4.25). Organic fertilizer like compost was served as direct source for zinc. Generally above critical value of zinc was recorded on those plots so care should be taken in using these soils for agriculture. Similar results were observed by Sienkiewicz *et al*. (2009). This may be due to the increase in organic matter content and increase in pH content which had tremendous effect on Zn availability within the soil. The result was also similar with Santos *et al.* (2010) who showed that Long-term application of organic matter to the soil increases Zn content of the soil. The result of this finding was also in agreement with Habtamu *et al.* (2014) who found significance difference in Zn due to interaction effect of land use and soil depth.

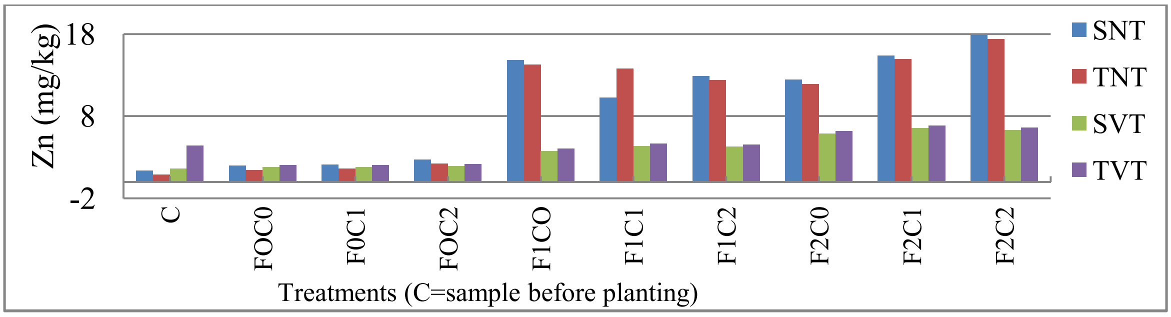

Figure 4.24 Zinc content of soil after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1} compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.3.10 Boron content change of the soil

Based on laboratory result the boron content of the soil was improved due to application of compost and mineral fertilizer. Application of compost alone increase B content from 0.29 to 0.36 mg kg^{-1}for Nitisols and from 0.64 to 0.71 mg kg^{-1} for Vertisols on average. This increase in B under organic fertilizer was related to increase OM as result of compost. Application of mineral fertilizer alone decreases B content from 0.79 to 0.68 mg kg^{-1} for Vertisols and but there was an increase from 0.47 to 0.64 mg kg^{-1} for Nitisols (Figure 4.26). This decrease in B was related to the decrease in OM in mineral fertilizer treated plots.

In combined application of compost and mineral fertilizer the B content of soil samples was increased from 0.48 to 0.72 mg kg^{-1} for Nitisols and from 0.85 to 0.95 mg kg^{-1} for Vertisols, respectively (Figure 4.26). This increase in boron content of soil samples may be related to the increase in OM and PH of soil samples in the study area. The increase in B also related to high Ca content of soil which needs high B for Ca-B ratio balance. The result was similar with (Reddy *et al*., 1997).

Generally boron content increase with increasing rate of compost and mineral fertilizer together as compared to the initial soil analysis result. The maximum boron content was recorded from plots treated with 10 t ha^{-1} compost and full recommendation of mineral fertilizer (Figure 4.15). The result was in line with Rahman *et al*. (2002) who reported increase in boron content after treating the soil with lime, fertilizer and micronutrients.

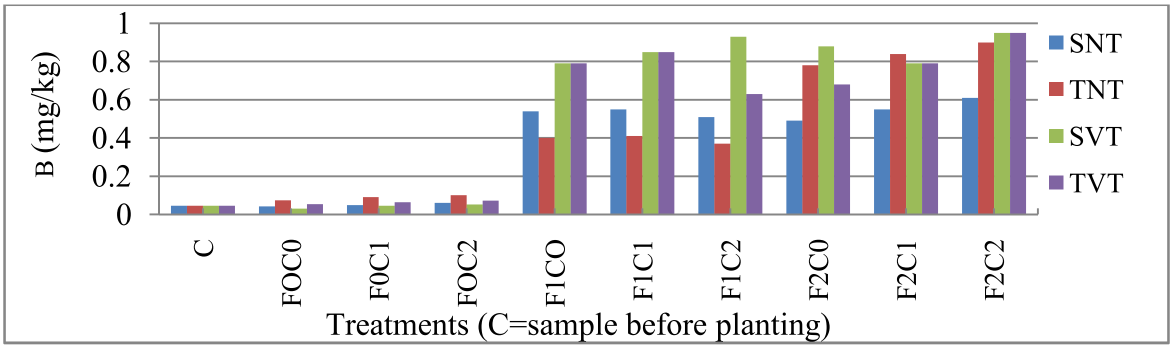

Figure 4.25 Boron content of soil after harvest

C= sample before improvement, F0C0, Sample from control, F0C1, F0C2, soil sample from 5 and 10 ton ha^{-1} compost treated plots, F1C0, F2C0, soil samples from half and full recommended mineral fertilizer treated plots, F1C1, F1C2, F2C1 and F2C2 soil samples from combined application of compost and mineral fertilizer; SNT, Nitisols samples from site one, TNT; Nitisols sample from site two, SVT; Vertisols samples from site one and TVT; Vertisols samples from site two.

4.4. Effect of IFM on yield and yield components of tef

4.4.1 Number of effective tiller

Crops with higher number of effective tillers could have higher grain yield, straw yield and biomass yield. The number of effective tillers counted at 0.0625 m^2 area was significantly ($p \leq 0.05$) affected by compost and mineral fertilizer application (Table 4. 5). The number of effective tillers was also influenced significantly ($P \leq 0.05$) by the interaction effect of the two factors (Table 4.6).

The number of effective tillers was significantly increased in response to increasing rate of compost and mineral fertilizer. The maximum number of effective tillers was recorded with application of 10 t ha^{-1} of compost and full recommendation of mineral fertilizer (10.50). The lowest number of effective tillers was obtained from the control plot (1.67). This indicated that the enhancement of effective tiller development of plants was because of increase in nutrient availability and improvement in soil fertility due to compost and mineral fertilizer (Figure 4.25). This result is in line with Haftom Gebretsadik *et al*. (2009) who reported higher number of tef tillers per plant with increasing fertilizer rate.

The synergic effect of compost and mineral fertilizer also bring high number of effective tiller due to increasing macro and micro nutrients and also bring improvement in the soil physical property. The current result is in agreement with that of Genene Gezu (2003) who reported higher tiller number and maximum survival percentage of tillers with increasing fertilizer application in bread wheat. Corroborating the results of this study, Botella *et al*. (1993) reported that stimulation of tillering with high application of nitrogen might be due to its positive effect on cytokinin synthesis.

Figure 4.26 Effective tiller from treated and untreated plots

4.4.2 Panicle length

Panicle length is one of the yield attributes of tef that contribute to grain yield. Crops with higher panicle length could have higher grain yield. Panicle length was significantly ($p \leq 0.05$) influenced by the main effects of compost and mineral fertilizer and significantly affected by the interaction effect (Table 4. 5; Table 4. 6; Figure 4.26). The highest panicle length was measured on plots treated with 10 t ha^{-1} of compost and full recommendation of urea and NPSZnB fertilizer (52.46 cm). Conversely, the smallest panicle length was recorded the control plot (11.50 cm). The highest panicle length in highest doses of organic and mineral fertilizer is due to availability of nutrients from the input to the crops specially nitrogen and phosphorous which facilitate crop growth and development.

This result was similar with that of Haftom Gebretsadik *et al*. (2009) who reported that tef panicle length increased in response to increasing rate compost and mineral fertilizer application, with the longest panicles being obtained at the 10 t ha^{-1} of compost and full recommendation of mineral fertilizer. The result was also coincided with Sate Sahle (2012) who found higher number of effective tillers by applying different rate of mineral fertilizer and seeding rate. The result was also in line with Rahma *et al*. (2002) who found higher panicle length of wheat under combined application of lime and micronutrient fertilizer.

Figure 4.27 Panicle length from treated and untreated plots

4.4.3 Plant height

The analysis of variance revealed that plant height was significantly ($p \leq 0.05$) affected by different compost and mineral fertilizer rates and significantly ($p \leq 0.05$) affected by interaction of the two factors. Plant height generally increased with the increase rate of compost and mineral fertilizer (Table 4.5).This agrees with Belay *et al*. (2001) who found that the application of organic fertilizers to the soil supply plant nutrients to increase plant height and more leaves in shallots.

The tallest plants were obtained from the plots receiving 10 t ha^{-1} compost and full recommendation of mineral fertilizer (130.38 cm). The shortest plants were observed from plots with no compost and mineral fertilizer (35.83 cm) closely followed by those plots supplied with 5 t ha^{-1} (46.42 cm) and 10 t ha^{-1} of compost (57.75 cm) (Table 4.5). This difference could be due to the fact that application of fertilizer provides nutrients to roots and enhanced plant growth (Abraha Arefaine, 2013).

A similar result was reported by Haftom Gebretsadik *et al*. (2009) showing that tef plants with higher plant height (92 cm) were found by applying a high amount of mineral fertilizer. Legesse Amsalu (2004) also reported that high N application resulted in tef plants with significantly taller plants due to direct effect of N on vegetative growth of crop.

The possible reason for maximum height in compost plus mineral fertilizer treatment may be due to mineral fertilizer sources fulfilled the N, P, S, Zn and B requirements at early growth stages while compost provided the crop with maximum nutrients in later stages. Thus, combination of compost and mineral fertilizer or INM might have nourished the crop in initial stages as well as in the later growth stages. In addition to this, increase in plant height in tef was due to increase in nitrogen content which initiates vegetative growth. The increase in nutrient content of the soil also increases plant growth due to facilitation hormones such as auxin.

The result of this experiment agreed with the finding of Amanuliah (2007) who reported that the use of increased rates of FYM and N increased plant height of wheat and the shortest plants were recorded from the control treatment. In agreement with this result, Ofosu and Leitch (2009) also reported that plant height of spring barley increased with organic manure application as compared to inorganic fertilizer alone. Similarly, Getachew (2009) reported that the use of organic manures in combination with mineral fertilizers maximized the plant height than the application of inorganic fertilizers alone.

Besides, this study was also in agreement with the on farm fertility management trial on tef carried out at Holetta agricultural research centre in year 2000 at Welmera (Lemlem *et al*., 2002). This study indicated a significant and consistent plant height increase with N and P increase.

However, the results of the present study contradict the study of Temesgen *et al*. (2001), who did not find significant increase in plant height of tef with increasing levels of N fertilizer application on Vertisols of Kobo, North Wollo. The lack of response was attributed to the variability of fertility levels; particularly, soil N. Tef varieties and erratic moisture condition of the area may be blamed.

Table 4.5 Number of effective tiller, panicle length and plant height of tef as influenced by the main effect of compost and mineral fertilizers

Main effect	Growth Parameters		
Compost	PH(cm)	PL(cm)	ET (m^2)
0 t ha^{-1}	78.28^c	29.15^c	4.56^c
5 t ha^{-1}	88.74^b	33.11 ^{b}	5.94^b
10 t ha^{-1}	100.89^a	38.69^a	7.44^a
LSD	2.21	0.83	0.38
SE±	1.44	0.51	0.29
CV	3.57	3.56	9.10
p	**	**	**
Mineral fertilizers(kg ha^{-1})			
0kg N and 0kg NPSZnB fertilizer	46.67^c	17.4^c	2.72^c
100kg N and 75kg NPSZnB fertilizer	97.84^b	34.78^b	6.67^b
200kg N and 150kg kg NPSZnB fertilizer	123.39^a	48.79^a	8.56^a
LSD	2.21	0.83	0.38
SE±	1.44	0.51	0.29
CV	3.57	3.56	9.10
p	**	**	**

PH= Plant height; PL=panicle length; ET= Number of effective tillers; LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at $p<0.05$. Means followed by the same letters in a column are not significantly different at $p<0.05$.

Table 4.6 Number of effective tiller, panicle length and plant height of tef as influenced by the interaction effect of compost and mineral fertilizers

Interaction effect	Growth parameters				
Compost	Mineral fertilizer rate	Treatments	PH(cm)	PL(cm)	ET(m^2)
C0	F0	T1	35.83^{f}	11.50^{g}	1.67^{f}
	F1	T2	83.38^{d}	30.54^{d}	5.50^{cd}
	F2	T3	115.63^{b}	45.42^{b}	6.50^{bc}
C1	F0	T4	46.42^{ef}	17.40^{f}	2.50^{ef}
	F1	T5	95.63^{c}	33.46^{d}	6.67^{bc}
	F2	T6	124.17^{ab}	48.50^{ab}	8.67^{ab}
C2	F0	T7	57.75^{e}	23.29^{e}	4.00^{de}
	F1	T8	114.54^{b}	40.33^{c}	7.83^{b}
	F2	T9	130.38^{a}	52.46^{a}	10.50^{a}
LSD			2.21	0.83	0.38
SE±			2.5	0.88	0.5
CV			3.57	3.56	9.10
p			**	**	**

PH= Plant height; PL=panicle length; ET= Number of effective tillers; LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at p<0.05. Means followed by the same letters in a column are not significantly different at p<0.05.

4.4.4 Above ground dry biomass of tef

Significant higher mean aboveground dry biomass yield (15.33 t ha^{-1}) was also recorded form 10 t ha^{-1}compost and full recommendation of mineral fertilizer application (Figure 4.27). Aboveground dry biomass was highly significantly ($p \leq 0.05$) affected by the individual effects of compost and mineral fertilizer application and highly significantly affected by the interaction effect of two factors (Table 4.7 and Table 4.8). The result is in line with that of Medhn Berhane (2013) who reported that application of fertilizer result increase in biomass production.

Biomass yield generally increased significantly with the increasing rate of compost and mineral fertilizers. The highest biomass yield (15.33 t ha^{-1}) was obtained under plants supplied with 10 t ha^{-1} of compost and full recommendation of mineral fertilizer, whereas the lowest biomass yield was obtained from plants grown in plots without any input (1.83 t ha^{-1}) (Figure 4.27). The increase in biomass is due to the increase in nutrient availability which increases plant growth and development. The availability of macro and micro nutrient facilitate photosynthesis and increase biomass. The result is also similar with that of Amanuel *et al*. (1991) who reported a significant increase in biomass yield of wheat as a result of increased rate of N application. In general, the biomass yield obtained from the fertilized plots exceeded the biomass yield from the unfertilized plot by about 88%.

These results concurred with the study of Temesgen *et al*. (2001) who observed a significant ($p<0.05$) biomass yield response to N application on Vertisols in the central highlands of Ethiopia. Similarly, WakeneTigre (2010) reported that efficient utilization of applied nutrients increased vegetative growth resulted in higher biomass yield of barley.

Figure 4.28 Above ground dry biomass fro treated and untreated plots

4.4. 5. Grain yield of tef

Application of compost and mineral fertilizer highly significantly ($p \leq 0.05$) increased grain yield of tef (Table 4.7). The highest grain yield of 3.22 t ha^{-1} was recorded at 10 t ha^{-1} of compost and full recommendation of mineral fertilizer while the smallest tef grain yield was recorded from control (0.43 t ha^{-1}). Tef grain yield was highly significantly affected by main effect of compost and mineral fertilizer and the interaction of two factors. This was due to the fact that yield could be improved if the crops obtain optimum nutrient requirement. This could be achieved by application of compost and mineral fertilizer. Mineral fertilizers could feed the crop immediately where as the compost could feed the crop and the soil slowly besides improving other soil physical, chemical and biological properties.

Earlier studies by Tekalign *et al*. (2002) and Mulegeta (2003) confirmed increase in tef grain yield with application of fertilizer. Application of compost increase grain yield by 57.84% over the control where as application of mineral fertilizer increase tef grain yield by 79.81%. But the combination of compost and mineral fertilizer increase grain tef yield by 86.65%.

According to farmers of the study area and Office of Agriculture and Rural Development (MOARD, 2006), farmers usually get an average grain yield of nearly 0.5 – 0.6 t ha^{-1}

during normal season regardless of compost application. So far, the national average for tef grain yield is around 0.89 t ha^{-1} (CSA, 1999). In view of this, the contribution of compost and mineral fertilizer to tef grain yield is appreciable. Nationwide as well as location-specific fertilizer trials on tef substantiate the findings of the present study. The result was also similar with Tekalign *et al*. (2002). The result was also supports that of Temesgen *et al*. (2001) where the response of tef to N significantly ($p<0.01$) increased grain yield.

4.4.6 Harvest index of tef

Significantly higher harvest index was observed from plots treated with 10 t ha^{-1} of compost and full recommendation of fertilizer. Harvest index is significantly affected ($p\leq0.05$) by the interaction of compost and mineral fertilizer and not affected by main effect (Table 4.8). This could be due to application of fertilizer had high amount of straw yield which contribute to grain yield which increases biomass production, whereas grain yield to biomass ratio was higher. The increase in harvest index was due to increases in AGDB which contribute yield increase in plots treated with compost and mineral fertilizer than control. The result was in line with Medhn Berhane (2013) who reported higher harvest index in plots treated with higher rate of N fertilizer.

Similarly, Osman *et al.* (2001) stated that increment in vegetative growth in turn increased grain yield by improving cumulative solar radiation intercepted on barley crop. Comparable reports stated by Evans (1993), showed that greater use of nitrogen fertilizers can delay leaf senescence and the need to mobilize N from leaves making more prolonged canopy photosynthesis and grain growth possible. Such shift in the balance between stages of the life cycle can increase HI and can have a substantial impact on yield potential.

Table 4.7 Above ground dry biomass, grain yield and harvest index of tef as influenced by the main effect of compost and mineral fertilizers

Main effect	Yield Parameters		
Compost	GY(t ha^{-1})	AGDB(t ha^{-1})	HI
0 ton ha^{-1}	1.30^{c}	6.53^{c}	0.2^{a}
5 ton ha^{-1}	1.72^{b}	8.17^{b}	0.21^{a}
10 ton ha^{-1}	2.12^{a}	9.97^{a}	0.21^{a}
LSD	0.03	0.22	0.09
SE±	0.01	0.14	0.01
CV	2.88	3.85	10.03
p	**	**	ns
Mineral fertilizers(kg ha^{-1})			
0 kg N and 0 kg NPSZnB fertilizer	0.73^{c}	3.44^{c}	0.21^{a}
100 kg N and 75 kg NPSZnB fertilizer	1.72^{b}	7.97^{b}	0.22^{a}
200 kg N and 150 kg NPSZnB fertilizer	2.72^{a}	13.25^{a}	0.21^{a}
LSD	0.03	0.22	0.09
SE±	0.01	0.14	0.01
CV	2.88	3.85	10.03
p	**	**	ns

PH= Plant height; PL=panicle length; ET= Number of effective tillers; LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at p<0.05. Means followed by the same letters in a column are not significantly different at p<0.05.

Table 4.8 Above ground dry biomass, grain yield and harvest index of tef as influenced by the interaction effect of compost and mineral fertilizers

Interaction effect	Yield parameters				
Compost	Mineral fertilizer rate	Treatments	GY(t ha^{-1})	AGDB(t ha^{-1})	HI
C0	F0	T1	0.43^{i}	1.83^{g}	0.04^{c}
	F1	T2	1.31^{f}	6.58^{d}	0.04^{c}
	F2	T3	2.42^{c}	11.17^{b}	0.05^{bc}
C1	F0	T4	0.73^{h}	3.25^{f}	0.04^{c}
	F1	T5	1.72^{e}	8.00^{d}	0.05^{bc}
	F2	T6	2.70^{b}	13.25^{ab}	0.06^{a}
C2	F0	T7	1.02^{g}	5.25^{e}	0.04^{c}
	F1	T8	2.13^{d}	9.33^{c}	0.05^{bc}
	F2	T9	3.22^{a}	15.33^{a}	0.06^{a}
LSD			0.03	0.83	0.09
SE±			0.02	0.88	0.01
CV			2.88	3.56	10.03
p			**	**	**

PH= Plant height; PL=panicle length; ET= Number of effective tillers; LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at p<0.05. Means followed by the same letters in a column are not significantly different at p<0.05.

4.5. Correlation of tef growth and yield components as influenced by compost and mineral fertilizer

A simple correlation analysis was done to assess the association of various agronomic characters of tef. Both positive and negative associations between the parameters have been observed. Grain yield of tef had significantly and positively correlated with panicle length ($r=0.976^{**}$), effective tillers per m^2 ($r=0.891^{**}$), above ground dry biomass yield ($r=0.987^{**}$) (Table 4.9). Similar findings were reported by Fufa Hundera *et al. (*2001) who stated that grain yield was positively and significantly correlated with panicle length, number of total tillers per m^2, number of effective tillers per m^2 and biomass yield per plot.

Biomass yield of tef showed significant and positive correlation with panicle length ($r=0.972^{**}$), number of effective tillers per m^2 ($r= 0.911^{**}$) and plant height ($r=0.952^{**}$). This is due to the fact that biomass yield was directly related to panicle length, grain yield and tillers numbers.

Table 4.9 Correlation among yield and yield components of tef

	ET	PL	PH	AGDB	GY
PL	$.906^{**}$				
PH	$.925^{**}$	$.978^{**}$			
AGDB	$.911^{**}$	$.972^{**}$	$.952^{**}$		
GY	$.891^{**}$	$.976^{**}$	$.960^{**}$	$.987^{**}$	
HI	$-.308^{*}$	$-.258^{*}$	$-.216^{ns}$	$-.280^{*}$	$-.163^{ns}$

**= Correlation is significant at the 0.01 level (1-tailed).
*= Correlation is significant at the 0.05 level (1-tailed).
PL= panicle length; PH= plant height; AGDB= above ground dry biomass; GY=grain yield; HI= harvest index

4.6. Effect of IFM on Yield and Yield Components of Maize

4.6.1 Days to 50% emergence

The main effects of compost and mineral fertilizer as well as their interaction had significant ($p \leq 0.05$) effect on days of 50% emergence (Table 4.10). Plots that received compost at a rate of 10 t ha^{-1} and full recommendation of mineral fertilizer emerged earlier (in 15.00 days) while plots with no compost and mineral fertilizer took the highest number of days (17.67) to emerge (Table 4. 10). This might be due to the fact that increasing nitrogen from compost and mineral fertilizer enhances days to emergence (Brady and

Weil, 2002). It is also known that availability of nitrogen in the soil due to compost and mineral fertilizer increase shoot growth and minimizes the number of days required to emerge.

In general, at each rate of mineral fertilizer and rate of compost increases, days to emergence was decreased. In line with the result of this study, Rosan *et al*. (1997) reported that application of N has hastened early germination in maize. The result is also similar with that of Masresha Mitiku (2014) who reported significant difference in days of 50% emergency with application of N fertilizer and compost. The result also agrees with that of Rahman *et al*. (2012) who reported maximum emergence by combining compost and mineral fertilizer.

4.6.2 Ear length

The main effect of compost and mineral fertilizer was significantly ($p \leq 0.05$) affected the ear length. Ear length was also highly significantly ($p \leq 0.05$) affected by interaction effect of compost with mineral fertilizer (Table 4.10). As the rates of compost increased from 0 to 10 t ha^{-1}, the ear length was increased from 17.24 cm to 21.60 cm (Table 4.10). The reason for the better ear length development was due to increase in photosynthesis activities of the plant on the account of adequate supply of nitrogen Jan *et al.* (2002). Nitrogen was also an essential requirement of ear growth so if the soil was nourished by compost and mineral fertilizer better ear length growth was achieved which had impact on yield. This result was in agreement with that of Rajeshwari *et al*. (2007) who reported a significant increase in ear length with increasing rates of nitrogen fertilizer application from different sources. The result is also similar with that of Masresha Mitiku (2014) who found significance in ear length with application of N fertilizer and compost.

Increase in ear length at higher nitrogen levels could be due to lower competition for nutrient that allows the plant to accumulate more biomass which facilitate photosynthesis resulting longer ear per plant. Ayman and Samier (2015) also reported that maximum ear length (21.25 cm) was recorded by application of 140 kg N ha^{-1}. Maral *et al*. (2012) also reported that with increasing nitrogen level from 50 to 200 kg ha^{-1} significantly increased the ear length of maize from 10.17 to 15.69 cm. Similarly, Imran *et al*. (2015) reported that ear length increases with increased in nitrogen level of 210 kg ha^{-1}.

4.6.3 Number of cobs per plant

The number of maize cobs per plant was significantly affected ($p \leq 0.05$) by the main effect of compost, mineral fertilizer and the interaction of two factors. When treated plots averaged across individual treatment and interaction of both, compost and mineral fertilizer produced the highest number of cobs (3.07), while the control has the least (0.37) which suggested that some plants did not bear any cob (Table 4.11). In other words, combined application of compost and mineral fertilizer increased number of cobs by 88% per unit area over the control plot.

Generally, the improvement of the soil conditions or enrichment with nutrients and organic matter due to soil-added materials might be responsible for better cob production under plots treated with compost and mineral fertilizer. This result is similar to the findings of Malaiya *et al*. (2004) who concluded that N fertilizer treatments in combination with FYM produced higher cobs and the minimum number of cobs per plant (1.020) was observed with sole FYM application. Similar result was also obtained by Raisi and Nejad (2012) and Shahid *et al*. (2016) who found high number of cops per plant from plots treated with combination of mineral fertilizer and organic fertilizer.

4.6.4 Plant height

The statistical analysis of the collected data revealed that there was significant ($p \leq 0.05$) difference in plant height among plots treated with sole compost, sole mineral fertilizer and the combined application of the two (Table 4.10 and Table 4.11). The tallest mean plant height (222.46 cm) was recorded in plots treated with combined rates of 10 t ha^{-1} compost and full recommendation of mineral fertilizers while, the shortest (110.04 cm) was observed under the control. These results were coincide with the findings of Adekayode and Ogunkoya (2010) who explained that there was very high significant difference in maize plant height in plots treated with high fertilizers compared with nil application

The high increase in plant height with increasing rate of compost and mineral fertilizer rate could be due to their synergistic effects compost and mineral fertilizer. This was also due to compost which acted as the store house of different plant nutrients, reduce P fixation, improve CEC, aeration, root penetration, water storage capacity of the soil (Rehman *et al.,* 2012).

Ogbonna *et al*. (2012) reported an influence of compost on plant growth. Similar results were reported by Ghafoor and Akhtar (1991) who stated that application of high N rates had significant effect on plant height of maize.

Table 4.10 Days to 50% emergence, ear length, number of cobs per plant and plant height of maize as influenced by the main effect of compost and mineral fertilizers

Main effect	Growth Parameters			
Compost	DE(day)	EL(cm)	NC(No.)	PH (cm)
0 ton ha^{-1}	16.89[c]	17.24[c]	1.30[c]	155.89[c]
5 ton ha^{-1}	16.55[b]	19.47[b]	1.63[b]	166.39[b]
10 ton ha^{-1}	16.00[a]	21.60[a]	1.99[a]	179.33[a]
LSD	0.198	1.72	0.04	2.40
SE±	1.65	0.23	0	2.064
CV	0.06	0.19	3.85	1.1
p	**	**	**	**
Mineral fertilizers(kg ha^{-1})				
0 kg N and 0 kg NPSZnB fertilizer	17.44[c]	14.89[c]	0.69[c]	119.57[c]
100 kg N and 75 kg NPSZnB fertilizer	16.33[b]	20.01[b]	1.59[b]	170.82[b]
200 kg N and 150 kg kg NPSZnB fertilizer	15.67[a]	23.40[a]	2.65[a]	211.22[a]
LSD	0.189	1.72	0.04	2.40
SE±	1.65	0.23	0	2.06
CV	0.06	0.19	3.85	1.1
p	**	**	**	**

PH= Plant height; PL=panicle length; ET= Number of effective tillers; LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at p<0.05. Means followed by the same letters in a column are not statically different at p<0.05.

Table 4.11 Days to 50% emergence, ear length, number of cobs per plant and plant height of maize as influenced by the interaction effect of compost and mineral fertilizers

Interaction effect			Growth parameters			
Compost	Mineral fertilizer rate	Treatments	DE(day)	EL(cm)	NC(No.)	PH(cm)
C0	F0	T1	17.67^{d}	12.88^{g}	0.37^{c}	110.04^{h}
	F1	T2	17.00^{cd}	17.92^{e}	1.32^{c}	157.46^{f}
	F2	T3	16.00c	20.92^{c}	2.23^{b}	200.17^{c}
C1	F0	T4	17.67^{d}	14.79^{e}	0.65^{c}	120.00^{g}
	F1	T5	16.00^{b}	20.21^{d}	1.60^{b}	168.13^{e}
	F2	T6	16.00^{b}	23.42^{b}	2.65^{a}	211.04^{b}
C2	F0	T7	17.00^{cd}	17.00^{e}	1.05^{c}	128.67^{g}
	F1	T8	16.00^{b}	21.92^{c}	1.87^{b}	186.88^{d}
	F2	T9	15.00^{a}	25.88^{a}	3.07^{a}	222.46^{a}
LSD			0.169	1.72	0.04	2.40
SE±			1.52	0.23	0	2.06
CV			0.10	0.33	3.85	1.89
p			**	**	**	**

PH= Plant height; PL=panicle length; ET= Number of effective tillers; LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at p<0.05. Means followed by the same letters in a column are not statically different at p<0.05.

4.6.5 Above ground dry biomass

Maize responds well to fertilizer application as a result of its well-developed root system which absorbs required nutrients for effective dry matter production. significant ($p \leq 0.05$) difference was also observed on total above ground dry biomass by sole application of compost and mineral fertilizers and the interaction of two factors (Table 4.12; Table 4 13; and Figure 4.28). The highest (14.9 t ha^{-1}) above ground dry biomass was recorded in plots treated with 10 t ha^{-1} compost and full recommendation of mineral fertilizer, while the lowest (2.16 t ha^{-1}) in the control with a difference of 12.74 t ha^{-1}.

This high difference in total above ground dry biomass might be also due to the synergistic effects of mineral fertilizer and compost as well as high doses of N and compost fertilizers which were well known to increase the vegetative growth of plants. Barker and Pilbeam (2007) reported that S and N fertilizers show strong interactions in their nutritional effects on crop vegetative growth due to their mutual occurrence in amino acid**s** and proteins. Kibunja *et al.* (2010) reported that total dry matter of maize was higher in treatment combinations of inorganic and organic fertilizers than chemical fertilizers alone. Fageria *et al*. (2011) stated that N availability delayed the vegetative and reproductive stages of phenological development and increase biomass production of maize.

Figure 4.29 Above ground dry biomass of maize from treated and untreated plots

4.6.6 Thousand Seeds weight

The grain yield is a function of combined effect of the individual yield components nourished under applied inputs and 1000-seed weight was important one of them. Combined application of compost and mineral fertilizers significantly ($p \leq 0.05$) affected thousand seed weight. The highest mean thousand seed weight (0.5 g) was recorded in plots treated with 10 t ha^{-1} compost and full recommended fertilizer rates while the lowest (0.3g) was in the control with an increase of 66% (Table 12). Such high increase in thousand seed weight was due to the synergistic effects of combined fertilizers for better growth and grain filling of maize crop. It was also due to the accelerated mobility of photosynthesis from the source to sink as influenced by the growth hormones synthesized due to application of organic and mineral fertilizer (Anuradha, 2003). Similar higher values of 1000 grain weight with higher doses of nitrogen were also reported by Onasanya *et al*. (2009).

This result was in accordance with the findings of (Garg and Bahla, 2008). There was also significant ($p \leq 0.05$) and strong positive correlations ($r = 0.905^{**}$ and 0.923^{**}) between thousand seed weight and grain yield, and total above ground dry biomass, respectively

(Table 4.14). The result was similar with Mentler *et al.* (2002) who showed that use of combination of chemical fertilizers and manure led to 1000-seeds weight increase in corn.

4.6.7 Harvest index of maize

The harvest index is a measure of productive efficiency that how efficiently a crop can use its physiological inheritance. The ANOVA table (Table 4.12) revealed that harvest index was significantly ($p \leq 0.05$) affected by the main effect compost, mineral fertilizer and interaction effect of two factors. For many crops the main sources of improved yield potential so far has been a rise in the proportion of biomass that is allocated to the harvested organ, i.e., in the harvest index increase in the biomass has in many cases, been slight, so the rise in HI must come from reduced investment in the non harvested organs, most notably the stem in recent years (Evans, 1993).

It might be due to the timely availability of N and improvement in soil condition. The result was also in line with Syed *et al*. (2009) who report that harvest index was significantly affected by the organic and inorganic source of N. This was contradicting with the findings of Wiqar *et al*. (2013) who also reported non-significant effect of integrated use of organic, inorganic and bio-fertilizers on harvest index of maize.

4.6.8 Stover yield of maize

The ANOVA table (Table 4.12) revealed that Stover yield was significantly ($p \leq 0.05$) affected by main effect of compost, mineral fertilizer and highly significantly affected by interaction of two factors. The highest Stover yield (8.54 t ha^{-1}) was observed when 10 t ha^{-1} compost was applied with combination of full recommended dose of mineral fertilizer. While the minimum Stover yields (0.97 t ha^{-1}) was recorded from control (Table 4.13).

The production of organic acids and growth promoting substances during decomposition of organic compost might have facilitated easy availability of macro as well as micronutrients. Adequate supply of nutrients to the crop helps in the synthesis of carbohydrates, which are required for the formation of protoplasm, thus resulting in higher cell division and cell elongation. Thus an increase in Stover yield might have been on account of overall improvement in the vegetative growth of the plant due to the application of compost in combination with inorganic fertilizer. Similar results were obtained by Makinde and Ayoola (2010) who reported that conjunctive application of organic and inorganic fertilizers is effective for the growth of maize and improving the yields.

4.6.9 Grain yield of maize

Interaction effects of compost and mineral fertilizers had shown significant ($p \leq 0.05$) difference on grain yield (Table 4.12) and grain yield of maize is highly significantly affected by main effect of compost, mineral fertilizer and interaction of two factors. The highest mean grain yield (6.37 t ha^{-1}) was recorded in plots treated with 10 t ha^{-1} compost and full recommendation of mineral fertilizers while lowest (1.32 t ha^{-1}) was recorded in the control with a difference of 5.18 t ha^{-1}. Grain yield of maize was increased by 81% due to the combined application of compost and mineral fertilizer over the control. The result was supported by the findings of N'Dayegamiye *et al*. (2010) who reported that application of compost with 120 kg N ha^{-1} led to high maize yields.

Wodndimu Bayu *et al*. (2006) and Makinde and Ayoola (2010) stated that high and sustainable crop yields were only possible with integrated use of mineral fertilizers with compost. Taffesse *et al*. (2011) also noted that applying FYM at 15 t ha^{-1} with 120 ha^{-1} kg N and 100 kg ha^{-1} P_2O_5 responded the maximum grain yield which increased by 123.0% compared to the control.

High doses of N and compost fertilizers increased grain yield as N is the main driving force to produce large yields of maize (Nivong *et al*., 2007) and compost is responsible in improving soil physical, chemical and microbial conditions.

The increase in yield of maize with combined application of P and compost probably could be due to the increase in P availability (Biswas, 2011). Mugwe *et al*. (2007) reported higher maize yields in treatments of compost either alone or in combination with mineral fertilizer were applied compared to the control. The result was also similar to the findings of Nagassa *et al*. (2005) who revealed that grain yield was significantly affected by N fertilizer in combination with FYM.

Table 4.12 Grain yield, above ground dry biomass, thousand seed weight, harvest index and Stover yield of maize as influenced by the main effect of compost and mineral fertilizers

Main effect	Yield Parameters				
Compost	GY(t ha^{-1})	AGDB(t ha^{-1})	SY (t ha^{-1})	TSW(g)	HI
0 ton ha^{-1}	3.65^{c}	8.42^{c}	4.81^{c}	0.37^{c}	0.37^{c}
5 ton ha^{-1}	3.99^{b}	9.43^{b}	5.45^{b}	0.40^{b}	0.39^{b}
10 ton ha^{-1}	4.25a	10.61^{a}	6.35^{a}	0.43^{a}	0.41^{a}
LSD	0.06	0.12	0.19	0	0.038
SE±	0.05	0.08	0.09	0	0.02
CV	5.37	1.79	4.85	0	12.15
p	**	**	**	**	**
0kg N and 0kg NPSZnB fertilizer	1.56^{c}	3.16^{c}	1.64^{c}	0.30	0.54^{c}
75kg N and 100kg NPSZnB fertilizer	4.36^{b}	11.86^{b}	7.51^{b}	0.43	0.37^{b}
150kg N and 200kg NPSZnB fertilizer	5.97^{a}	13.45^{a}	7.47^{a}	0.46	0.49^{a}
LSD	0.06	0.12	0.19	0	0.038
SE±	0.05	0.08	0.09	0	0.02
CV	5.37	1.79	4.85	0	12.15
p	**	**	**	**	**

PH= Plant height; PL=panicle length; ET= Number of effective tillers; LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at p<0.05. Means followed by the same letters in a column are not significantly different at p<0.05.

Table 4.13 Grain yield, above ground dry biomass, thousand seed weight, harvest index and Stover yield of maize as influenced by the interaction effect of compost and mineral fertilizers

Interaction effect			Yield parameters				
Compost	Mineral fertilizer rate	Treatments	GY(t ha^{-1})	AGDB(t ha^{-1})	SY (t ha^{-1})	TSW(g)	HI
C0	F0	T1	1.32^{e}	2.16^{h}	0.97^{f}	0.30^{c}	0.36^{c}
	F1	T2	4.25^{c}	11.11^{e}	6.85^{cd}	0.30^{c}	0.37^{c}
	F2	T3	5.39^{b}	12.00^{d}	6.62^{d}	0.30^{c}	0.40^{bc}
C1	F0	T4	1.54^{de}	3.06^{g}	1.52^{f}	0.40^{b}	0.43^{bc}
	F1	T5	4.26^{bc}	11.8^{d}	$7.56b^{c}$	0.40^{b}	0.45^{ab}
	F2	T6	6.16^{aa}	13.4^{b}	$7.26c^{d}$	0.50^{a}	0.46^{ab}
C2	F0	T7	1.84^{d}	4.26^{f}	2.42^{e}	0.40^{b}	0.50^{ab}
	F1	T8	4.56^{c}	12.66^{c}	8.10^{ab}	0.50^{a}	0.53^{ab}
	F2	T9	6.37^{a}	14.9^{a}	8.54^{a}	0.50^{a}	0.65^{a}
LSD			0.06	0.12	0.19	0	0.038
SE±			0.09	0.14	0.16	0	0.04
CV			5.37	1.79	4.85	0	12.15
p			**	**	**	**	**

PH= Plant height; PL=panicle length; ET= Number of effective tillers; LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at p<0.05. Means followed by the same letters in a column are not significantly different at p<0.05.

4.7. Correlation of Maize Growth and Yield Components As Influenced By Compost and Mineral Fertilizers

A simple correlation analysis was done to assess the association of various agronomic parameters of the maize crop. Both positive and negative associations between the parameters have been observed. Grain yield of maize had significantly and positively correlated with ear length ($r = 0.936^{**}$), number of cobs per plant ($r = 0.878^{**}$), plant height ($r = 0.971^{**}$), and highly significantly but negatively correlated with date of 50% emergency ($r = -0.869^{**}$) (Table 4.13). This indicates that grain yield was highly significantly increases with an increase of ear length, number of cobs per plant and plant height. Similar findings were reported by Yihenew G. Selassie (2015) and Habtamu Admas *et al*. (2015) that grain yield of maize were positively and significantly correlated with yield components.

Table 4.14 Correlation among yield and yield components of maize

Parameters	DE	EL	PH	NC	GY	AGDB	HI	SY
EL	-.922**							
PH	-.902**	.955**						
NC	-.867**	.908**	.913**					
GY	-.869**	.936**	.971**	.878**				
AGDB	-.876**	.916**	.945**	.818**	.965**			
HI	.397**	-.421**	-.449**	-.260*	-.409**	-.561**		
SY	-.849**	.869**	.893**	.748**	.906**	.985**	-.641**	
TSW	-.826**	.907**	.911**	.867**	.905**	.923**	-.428**	.899**

**. Correlation is significant at the 0.01 level (1-tailed).
*. Correlation is significant at the 0.05 level (1-tailed).

4.8. Economic Analysis

As shown in appendix Table 4.18, total variable costs which are responsible for yield increase in each treatment were listed. The economic analysis revealed that all the treatments had greater than 100% in MRR, and the highest marginal rate of return was obtained from plots treated with 10 t ha^{-1}compost and full recommendation of mineral fertilizer (37,429 Birr ha^{-1}) for maize and (40, 209 Birr ha^{-1}) for tef, respectively. The lowest nets benefit (8, 730Birr ha^{-1}) for maize and (11,050 Birr ha^{-1}) for tef at Adet district (Table 4.16) was recorded from plots treated with 5 t ha^{-1} compost only. The result was in line with Trinh *et al*. (2008) who obtained higher grain yield and higher net benefit from higher planting density with higher NPK rate of site specific nutrient management (SSNM)

Table 4.15 Dominances analysis

Treatments	TVC(birr/ha)		Net benefit (birr/ha)	
	Maize	Tef	Maize	Tef
1. F0C0	510	510	8730 **D**	11050 **D**
2. F0C1	1010	1010	9770	14290
3. F0C2	1510	1510	11370	17530
4. F1C0	2864	2864	26886	22976
5. F1C1	3364	3364	28556	27576
6. F1C2	3864	3864	30156	32346
7. F2C0	5191	5191	32539	35949
8. F2C1	5691	5691	37429	40209
9. F2C2	6191	6191	38399	45149

D *= Dominated treatment*

Treatment 1 (without compost and mineral fertilizer) is a dominated treatment. Hence, it is rejected from further consideration in marginal analysis. Based on this treatment one is rejected because it is dominated by other treatments.

Table 4.16 Marginal analysis

Treatments	TVC(birr/ha)		Net benefit (birr/ha)		MRR (%)	
	Maize	Tef	Maize	Tef	Maize	Tef
2. F0C1	510	510	8730	11050	-	-
3. F0C2	1010	1010	9770	14290	208	648
4. F1C0	1510	1510	11370	17530	320	648
5. F1C1	2864	2864	26886	22976	**1146**	402
6. F1C2	3364	3364	28556	27576	334	920
7. F2C0	3864	3864	30156	32346	320	**954**
8. F2C1	5191	5191	32539	35949	**180**	**272**
9. F2C2	5691	5691	37429	40209	978	852

4.9. Agronomic Use Efficiency

Agronomic use efficiency reflects the direct production impact of an applied fertilizer and relates directly to economic return. As shown from the Table 4.17, the NUE was good for those plots treated with mineral fertilizer and have the highest NUE which is 16.14% and 5.9% for maize and tef, respectively. This was due to the fact that mineral fertilizers were known in releasing nutrients immediately to the soil and crop which account in yield increase. Plots treated with mineral fertilize alone use 16.14% of nutrient from the added amount form maize, 5.9% for tef and the remaining might be lost through erosion, leaching, dinitrification and changed to organic stock.

This was similar with William and Gordon (1999) who reported low nitrogen use efficiency in cereal production due to dinitrifecation. Plots treated with compost alone or in combination with mineral fertilizer were low in their NUE. This is due to the fact that organic fertilizers are not providing nutrients to the soil and crops immediately. The smallest NUE was recorded from plots treated with compost (0.04% for maze 0.03% for tef) only. The result was in line with Paul *et al*. (2014) who report NUE for different regions of the world. William *et al.* (1999) also found the effect of N fertilizer rate on agronomic use efficiency.

Table 4.17 Agronomic use efficiency for maize and tef

Treatment	Compost(kg/ha)	N fertilizer(kg/ha	NPSZnB fertilizer(kg/ha)	total nutrient added	Grain yield of maize(kg/ha)	Grain yield of tef(kg/ha)	AUE for maize	AUE for tef
F0C0	-	-	-	-	1320	480	-	-
F0C1	5000	-	-	5000	1540	650	0.04	0.03
F0C2	10000			10000	1840	1120	0.05	0.06
F1C0		75	100	175	4250	1520	**16.14**	**5.90**
F1C1	5000	75	100	5175	4260	1820	0.57	0.26
F1C2	10000	75	100	10175	4560	2130	0.32	0.16
F2C0		150	200	350	5390	2420	11.63	5.5
F2C1	5000	150	200	5350	6160	2700	0.90	0.40
F2C2	10000	150	200	10350	6370	3020	0.50	0.25

CHAPTER 5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

From the result the study the following can be concluded. The soils of the experimental sites are deficient in N, P, S, Zn and B but are sufficient in K, Ca and Mg. The compost samples collected from farmers' backyards indicated that the composts are suitable and well matured for application to the field. Maize and tef field experiments revealed that individual as well as combined application of compost and NPSBZn improved crop yield and yield components of maize and tef.

The economic analysis result indicated that application of compost and mineral fertilizer was found to be economically feasible for maize but not for tef. Plots treated with mineral fertilizer are good in nutrient use efficiency. Similarly, analysis of soil samples after harvest demonstrated that application of sole compost, sole mineral fertilizer and their combinations affected soil physico-chemical properties and crop response.

5.2. Recommendations

To increase crop production and improve soil fertility at Yilman Densa district on a sustain way the following recommendations are suggested based on result of the study.

- Since soils of the study area were deficient in macro and micro nutrient, addition of appropriate fertilizer type should be done. That was NPSBZnB mineral fertilizer should be used instead of NPS fertilizer which was widely used by farmers in the study area.
- Organic fertilizers were good to improve the soil fertility and qualified organic fertilizers like compost should be used in combination with mineral fertilizer for crop production increment as well as soil fertility improvement.
- The best rate of combining compost and mineral fertilizer for yield increment, soil fertility improvement and to get maximum economic benefit was10 ton ha^{-1} compost with full recommendation of mineral fertilizer. So farmers should integrate and apply 10 ton ha^{-1} compost with full recommendation of mineral fertilizer to sustain agricultural production.
- Further study should be done to determine maximum rate of compost and mineral fertilizer integration.
- Further study should be done to investigate the residual effect of compost

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APPENDICES

Appendix Table 1. ANOVA table for number of effective tiller of tef

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	318.9259	159.463	538.19	<.0001
OF	2	75.14815	37.57407	126.81	<.0001
Rep	5	57.64815	11.52963	38.91	<.0001
MF*OF	4	6.074074	1.518519	5.12	0.0052
Rep*MF	10	3.740741	0.374074	1.26	0.314
Rep*OF	10	1.518519	0.151852	0.51	0.8615

Appendix Table 2. ANOVA table for panicle length of tef

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	8905.317	4452.658	3097.63	<.0001
OF	2	827.1777	413.5888	287.73	<.0001
Rep	5	48.21673	9.643345	6.71	0.0008
MF*OF	4	42.77199	10.693	7.44	0.0008
Rep*MF	10	130.2772	13.02772	9.06	<.0001
Rep*OF	10	1.832755	0.183275	0.13	0.999

Appendix Table 3. ANOVA table for plant length of tef

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	54948.75	27474.38	2710.05	<.0001
OF	2	4609.975	2304.987	227.36	<.0001
Rep	5	1269.075	253.8151	25.04	<.0001
MF*OF	4	448.2685	112.0671	11.05	<.0001
Rep*MF	10	177.8449	17.78449	1.75	0.1366
Rep*OF	10	37.24769	3.72477	0.37	0.9469

Appendix Table 4. ANOVA table for above ground dry biomass of tef

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	34.68111111	17.34055556	4335.14	<.0001
OF	2	4.27444444	2.13722222	534.31	<.0001
Rep	5	0.30444444	0.06088889	15.22	<.0001
MF*OF	4	0.13111111	0.03277778	8.19	0.0004
Rep*MF	10	0.12111111	0.01211111	3.03	0.0168
Rep*OF	10	0.10111111	0.01011111	2.53	0.0372

Appendix Table 5. ANOVA table for grain yield of tef

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	37.8337	18.91685	7511.1	<.0001
OF	2	4.858148	2.429074	964.49	<.0001
Rep	5	0.040926	0.008185	3.25	0.0262
MF*OF	4	0.138519	0.03463	13.75	<.0001
Rep*MF	10	0.030741	0.003074	1.22	0.3362
Rep*OF	10	0.01963	0.001963	0.78	0.6477

Appendix Table 6. ANOVA table for harvest index of tef

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	0.001022	0.000511	1.09	0.3561
OF	2	0.001055	0.000527	1.12	0.3449
Rep	5	0.007752	0.00155	3.3	0.0246
MF*OF	4	0.008524	0.002131	4.54	0.009
Rep*MF	10	0.004719	0.000472	1.01	0.4719
Rep*OF	10	0.006619	0.000662	1.41	0.2457

Appendix Table 7. ANOVA table for days to 50% of emergency of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	29.03704	14.51851852	196	<.0001
OF	2	7.259259	3.62962963	49	<.0001
Rep	5	0.148148	0.02962963	0.4	0.843
MF*OF	4	2.518519	0.62962963	8.5	0.0004
Rep*MF	10	0.296296	0.02962963	0.4	0.931
Rep*OF	10	0.740741	0.07407407	1	0.4755

Appendix Table 8. ANOVA table for ear length of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	661.419	330.7095	2927.59	<.0001
OF	2	171.2106	85.60532	757.82	<.0001
Rep	5	44.59259	8.918519	78.95	<.0001
MF*OF	4	2.018519	0.50463	4.47	0.0097
Rep*MF	10	2.428241	0.242824	2.15	0.0697
Rep*OF	10	2.094907	0.209491	1.85	0.1151

Appendix Table 9. ANOVA table for number of cobs per plant of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	40.25925926	20.12962963	572.11	<.0001
OF	2	16.03703704	8.01851852	227.89	<.0001
Rep	5	0.53703704	0.10740741	3.05	0.0331
MF*OF	4	8.18518519	2.0462963	58.16	<.0001
Rep*MF	10	0.85185185	0.08518519	2.42	0.0443
Rep*OF	10	0.40740741	0.04074074	1.16	0.372

Appendix Table 10. ANOVA table for plant height at harvest of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	75955.07	37977.54	3187.36	<.0001
OF	2	4964.704	2482.352	208.34	<.0001
Rep	5	110.3148	22.06296	1.85	0.1484
MF*OF	4	230.0463	57.51157	4.83	0.0069
Rep*MF	10	578.4977	57.84977	4.86	0.0013
Rep*OF	10	42.19907	4.21991	0.35	0.9527

Appendix Table 11. ANOVA table for above ground dry biomass of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	1104.613	552.3064	19124.8	<.0001
OF	2	42.91652	21.45826	743.04	<.0001
Rep	5	2.394681	0.478936	16.58	<.0001
MF*OF	4	2.800752	0.700188	24.25	<.0001
Rep*MF	10	2.762285	0.276229	9.57	<.0001
Rep*OF	10	0.448419	0.044842	1.55	0.1928

Appendix Table 12. ANOVA table for grain yield of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	179.211	89.60552	1974.7	<.0001
OF	2	3.258248	1.629124	35.9	<.0001
Rep	5	0.217032	0.043406	0.96	0.4672
MF*OF	4	1.106841	0.27671	6.1	0.0022
Rep*MF	10	0.497974	0.049797	1.1	0.4094
Rep*OF	10	0.494841	0.049484	1.09	0.4139

Appendix Table 13. ANOVA table for harvest index of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	0.266004	0.133002	44.5	<.0001
OF	2	0.069348	0.034674	11.6	0.0005
Rep	5	0.071765	0.014353	4.8	0.0048
MF*OF	4	0.073696	0.018424	6.16	0.0021
Rep*MF	10	0.159263	0.015926	5.33	0.0007
Rep*OF	10	0.043252	0.004325	1.45	0.2307

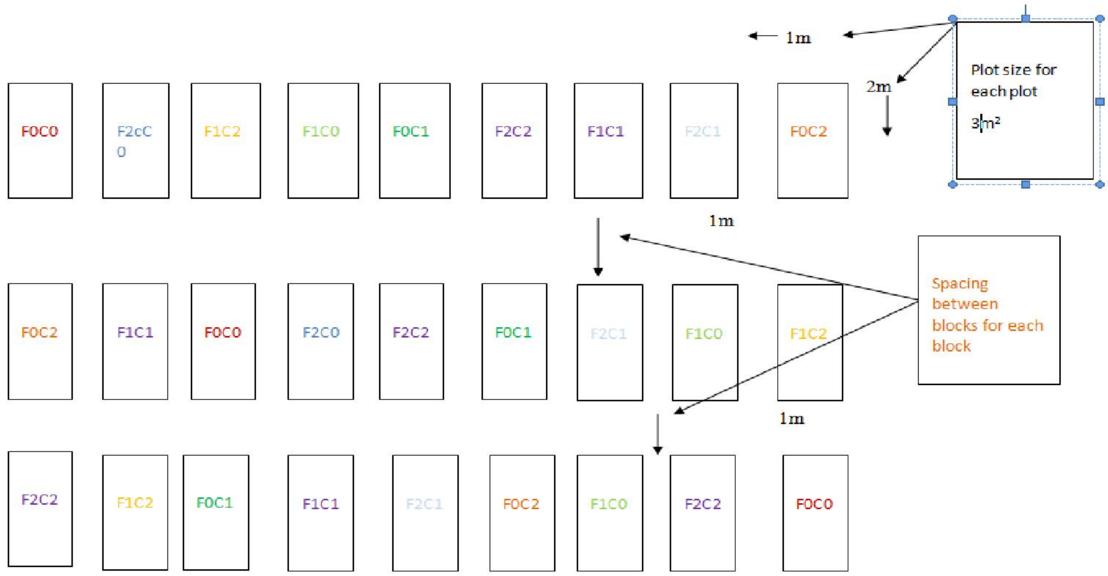
Appendix Table 14. ANOVA table for Stover yield of maze

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	411.1088	205.5544	2852.38	<.0001
OF	2	21.55951	10.77976	149.59	<.0001
Rep	5	1.321076	0.264215	3.67	0.0162
MF*OF	4	1.053141	0.263285	3.65	0.0217
Rep*MF	10	3.349996	0.335	4.65	0.0017
Rep*OF	10	0.887796	0.08878	1.23	0.3301

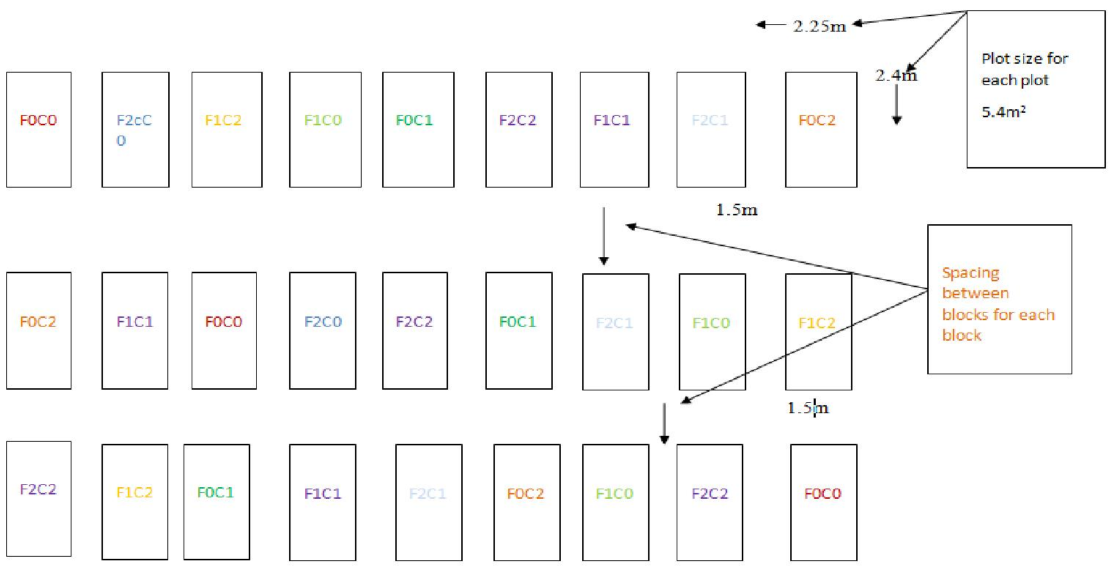
Appendix Table 15. ANOVA table for 1000 seed weight of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MF	2	0.9436	0.4718	Infty	<.0001
OF	2	0.1444	0.0722	Infty	<.0001
Rep	5	0	0	.	.
MF*OF	4	0.1444	0.0361	Infty	<.0001
Rep*MF	10	0	0	.	.
Rep*OF	10	0	0	.	.

Appendix Table 16. Experimental design for tef



Appendix Table 17. Experimental design for tef



Appendix Table 18. Partial budget analysis

Items	Treatments																	
	1		2		3		4		5		6		7		8		9	
	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T	M	T
GY (kg/ha)	1320	480	1540	900	1840	1120	4250	1520	4560	1920	4860	2130	5390	2420	6160	2700	6370	3020
FB (birr/ha)	9240	8160	10780	15300	12880	19040	29750	25840	31920	30940	34020	36210	37730	41140	43120	45900	44590	51340
Cost of compost	0	0	1000	1000	2000	2000	0	0	1000	1000	2000	2000	0	0	1000	1000	2000	2000
Cost of urea	0	0	0	0	0	0	900	900	900	900	900	900	1800	1800	1800	1800	1800	1800
Cost of NPSBZn	0	0	0	0	0	0	1400	1400	1400	1400	1400	1400	2800	2800	2800	2800	2800	2800
Cost of weeding	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Cost of top dressing	0	0	0	0	0	0	54	54	54	54	54	54	81	81	81	81	81	81
Cost of cultivation	324	324	324	324	324	324	324	324	324	324	324	324	324	324	324	324	324	324
Cost of harvesting	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170
TVC	510	510	1510	1510	2510	2510	2864	2864	3864	3864	4864	4864	5191	5191	6191	6191	7191	7191
NB (birr/ha)	8730	7650	9270	13790	10370	16530	26886	22976	28056	27076	29156	31346	32539	35949	36929	39709	37399	44149

BIOGRAPHICAL SKETCH

The author, Tesfaye Bayu, was born on 03 January 1980 E.C in Ankasha Guagusa District, Awi Administrative Zone, Amhara Regional State, Ethiopia. He attended elementary education (grade 1-8) at Dekuna Elementary School from 1989 - 1997 E. C. After completing elementary education, he was enrolled at Ankesha Senior Secondary and preparatory School at Gemjabet town from 1997 –2000 E. C (grade 9-12). He then joined Hawassa University Wondo Gent college of Forestry and Natural resource management in September 2001 E. C and graduated with Bachelor of Science degree on Natural Resource Management in July 2003 E. C.

Following his graduation, he was a Natural Resources Management Trainer at Burie Agricultural Technical Vocational Educational College from October (2004-2006 E.C) and then from 2007 E.C still now he is employed by Debre Markos University as assistant Instructor. Then after, in October 2008 E.C the author joined the school of graduate studies of Bahir Dar University, College of Agriculture and Environmental Sciences, Department of Natural Resources Management in regular program as a candidate for Master of Science degree in Land Resource Management.