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Evaluation of compost stability and maturity of floriculture solid waste in a Windrow System

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Applied Microbiology

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Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university and that all sources of materials used for the thesis have been correctly acknowledged.

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List of Symbols and abbreviations

AAS:	**Atomic Absorption Spectrophotometry**
DTPA:	**Diethylenetriaminepentaaceticacid**
EC:	**Electrical Conductivity**
EHPEA:	**Ethiopia Horticulture Producer Exporter Association**
EIA:	**Environmental Impact Assessment**
EM:	**Effective Microorganism**
EPA:	**Environmental Protection Agency**
EPLAUA:	**Environmental Protection, Land Administration and Use Authority**
ESAT:	**Ethiopian Society for Appropriate Technology**
ETHF:	**Ethio-highland Farm**
FAO:	**Food and Agricultural Organization**
SOM:	**Soil organic matter**
USDA:	**United States Department of Agriculture**

ABSTRACT

In Ethiopia, huge amount of flower residues are generated in each flower farm and damped into the environment leading to various problems. This initiated this work to utilize the wastes for soil amelioration and protection of the environment by composting via mixing the flower cuts with cow dungs (Pile1) and Effective Microorganisms (EM) plus molasses (Pile2) using Windrow method of compostingseparately in Ethio-highland and ZK farms. Samples were regularly taken from three locations of each pile for pyhsico-chemical and microbiological analysis over the 98 days of composting. The data showed three phases of temperature shifts, increase in macronutrients and TN as well as GI but reduction in C: N and NH_4-N: NO_3-N ratios and elimination of *Agrobacterium* spp. in both farms, in pile 1 and pile 2. In composting better in cow dung amended than EM plusMolasses added. The final compost products were found to be good quality in terms of plant nutrient, heavy metal and microbial composition. The composting activity of the flower cut should be encouraged and continued using cow dung in different flower farms to overcome environmental problems and use as fertilizer to improve agricultural productivity.

Key words/phrases*:* Cow dung, Effective Microorganisms, ETH Flower, Frequent Turning, ZK flowers

1. Introduction

Floriculture is one of the priority agro-industrial sectors of the country that makes substantial contributions to generate foreign exchange, employment for workers, increase incomes and reduce rural-urban migration (Abiy Shale and Potting, 2012). Consequently, a lot of flower farms have been established around many urban centers for the last few years.

According to the Ethiopian Horticulture Production and Export Association (EHPEA) annual report, (2014), more than 2000ha of land has been leased to 263 foreign and domestic investors and the sector employed over 70,000 work force and the sector exported more than 1.7billion flower stem and earned 160million USD in ten months in 2012 .These flower farms also generate huge amount of solid and liquid wastes; generating about10 tons of solid wastes every day as a result of pruning, clearing of unutilized and or under grade or diseased stems and leaves. These wastes also containresidual agrochemicals such as fertilizers and pesticides which are not easily degradable and persistent in the different food web and chain in the soil and aquatic ecosystems when they are dumped into them without treatment(Abiy Shale and Potting, 2012; Karr *et al.,* 1986).

The ever-increasing solid and liquid wastes in the country necessitate the need to intervene through different treatment systems with a dual purpose of protecting the environment and changing them into useful products. Composting is one of the methods that convert solid organic wastes into useful bio-fertilizer mediated by a variety of microorganisms (Epstein, 1997). In so doing, it can protect the environment from pollution and serve as additional inputs for growing plants.

Compost is the product resulting from the controlled biological decomposition of organic material that has been sanitized through the generation of heat and stabilized to the point that it is beneficial to plant growth (Lasaridi and Steniford , 1998). It is an organic matter resource that has the unique ability to improve the chemical, physical, and biological characteristics of soils or growing media. Elements such as nitrogen (N) and sulfur (S) are released through the process and can be available to plants. Compost products also enhance the porosity, water- and nutrient-holding capacity, conductivity, pH, and other properties of the soil.

Several studies showed the benefits of compost from agricultural residues for floriculture and foliage crops Fitzpatrick (1986). It is reported that two foliage plant species (dwarf schefflera and 'MaunaLoa' spathyphyllum) grew faster on bio-solids compost used as a growing medium, as compared to plants grown in a control medium. Although there was little information regarding composting of flower solid wastes, a recent study on coffee husk compost in Ethiopia showed that sorghum and mustard meal (Lulu and Insam, 2000) and coffee husk amended with cow dung and fruit/vegetable wastes could serve as good source of bio fertilizer (Fekadu *et al*. 2014).

Information of the nutrient content of compost is important because the nutrient content of compost can differ widely and also because it allows facility operators to determine an appropriate end use for the compost. The agricultural market also demands compost of high nutrient content, whereas compost low in nutrients is well suited for the landscaping sector and for use as mulch (Zethner *et al.,* 2000). In general, nutrients are organically bound within

compost and are slowly released over a period of time as a result of microbial activity. This ensures a continuous supply of nutrients to the plant (US Composting Council, 2003).

The Canadian Council of Ministers of the Environment defines compost as: "A solid mature product resulting from composting, which is a managed process of bio-oxidation of a solid heterogeneous organic substrate including a thermophilic stage" (Landscape Nova Scotia Horticultural Trades Association, 2003).Different countries set standards to compost quality that would help for evaluation. These include Austria, Germany, Canada, United Kingdom, US, Belgium, the Netherlands, and Luxembourg (Hogg *et al.,* 2002). Compost quality can be described in terms of age, maturity, nutrient content, and other physical, biological and chemical properties (Mathur *et al.,* 1993).

Recently, Adey Feleke *et al.* (2014) have reported that some microbial consortia from tannery waste water have the potential to effectively degrade polycyclic aromatic hydrocarbons which are similar to the insecticides and herbicides used in agriculture. There are also evidences where effective microorganisms (EM) could facilitate the mineralization of solid waste by bio-augmentation.

In addition to this, floriculture waste may contain agrobacteria and other pathogens that are common in most soils (Pitzscke & Hirt, 2010). The suppressive activity of certain types of compost towards plant pathogens is now well documented. To this effect, the most predictable and successful pathogen suppression has been reported in container production systems of flowers in the United States (Hoitink and Stone, 1997).

In Ethiopia, there is still dearth of information about the use of floricultural wastes in relation to composting.Therefore, it is so significant to utilize composting technology in the country to mitigate the environment from pollution and to supplement flower production with organic fertilizers (composts) (reduce cost of production).

2. Objectives

2.1. General objective

To evaluate and monitor the composting process and determine compost maturity of floricultural wastes from two flower farms (Ethio-hghland and ZK farms)

2.2. Specific objective

1. To monitor the different physical, chemical and microbiological processesduring composting
2. Toevaluatethe effect of Effective Microorganisms (EM) on the composting process and compost maturity and stability.
3. To detect and observe *Agrobacterium*spp.on different phases of composting process.

3. LITERATURE REVIEW

3.1. Composting

Any biogenic material originated from plant, animal or microbes can be composted if it has the optimum physical and chemical properties (Insam and de Bertoldi, 2007). Generally, plant materials contain various proportions of water-soluble organic compounds, proteins, lipids, structural or storage polysaccharides (cellulose, hemicelluloses, chitin, glycogen, etc.); and, lignin (Martin, 1991).

Animal manure is also good source of carbon and nitrogen in compost mixes (Mathur, 1989). Slaughterhouse wastes, meat leftovers, small bones, blood and seafood processing waste matters can be composted by the use of special care and practices (Dalzell *et al.,* 1987). According to Pudelski (1987),town and home refuses, culling, weeds, fallen leaves and yard trimmings are major sources of compostable materials. Vegetable materials left over from extraction of juices, oils, fibers, pulps, tea and coffee residues are valuable as compost materials.

3.2. Types of Composting Methods

Different substrate mixtures or feed stock can be composted in a number of different methods, including Static pile, aerated static pile, windrows systems, in-vessel system and the pit method (Christian *et al.,* 1997).

3.2.1. Static Pile

This is the oldest and most common form and yet, it is the least effective composting method. The static pile, as the name indicates, is simply a pile of raw materials, where the conditions affecting the composting process are not controlled. In this method piles that do not exceed six feet high (1.86 m) and twelve feet wide (3.7 m), are recommended in order to allow air to move through the pile (Rynk, 1992). This method of composting is slow and increases the chance of odors, and yields an inferior product.

3.2.2. Aerated Static Pile

In this method piles are five to eight feet high (1.6 to 2.5 m) and seventy to ninety feet long (21.7 to 27.9 m) (Rynk, 1992). Air is forced through the compost pile by a blower. In this technique the pile is formed over a bed of wood chips or chopped straw which contains the perforated aeration pipe where air is forced through the compost pile by a blower. The pile need to be covered with fresh composted manure to maintain moisture, reduce heat loss, and to minimize flies and odors, while also filtering out some ammonia (Martin,1991).

3.2.3. Windrow System

This is a relatively simple process that involves placing a mixture of manure and bulk in materials into windrows or piles. Windrow composting consists of placing the mixture of raw materials in long narrow piles called Wind-rows that are agitated or turned on a regular basis (Martin, 1991). Typically, the Wind-rows are 0.9 m high for dense materials such as manures

and 3.60 m high for light, voluminous materials such as leaves (FAO, 2003).Windrows are aerated primarily by natural or passive air movement (convection and gaseous diffusion). The rate of air exchange of a Win-drow depends on the porosity of the windrow.

A Wind-row of leaves can be much larger than wet Wind-row containing manure. When the Wind-row is too large, anaerobic zones occur near its center that release odors when the Wind-row is turned. On the other hand, small Wind-rows lose heat quickly and may not achieve temperatures high enough to evaporate moisture and kill pathogens and weed seeds (FAO, 2003). For small- to moderate-scale operations, turning can be accomplished with a front-end loader or a bucket loader on a tractor or manually using forks.

The frequency of turning depends on the rate of decomposition, the moisture content and porosity of the materials, and the desired composting time. The decomposition rate is greatest at the start of the process for the frequency of turning decreases as the Windrow ages. Turning release strapped gases, water vapor, and excessive heat that may exist in the compost mixture (FAO, 2003). In this method, the active composting stage generally lasts three to nine weeks depending upon the nature of the materials and the frequency of turning (Rynk, 1992**)**

3.2.4. In-vessel System

These systems include bin composting, quadrilateral agitated bins, and silos. In-vessel composting system was first developed by Becari and modified by Verdier and Bordas, which

was later, developed through time (Gotas, 1956). The main advantage of this system is process rapidity, low land requirement, complete process control and consistency of end-product.

The main feature of in-vessel composting systems is that the compost materials are mechanicallymixed and automatically aerated. In-vessel methods limit the compost mixture to buildings, containers or vessels, and tend to rely on numerous forced aeration and mechanical turning methods which accelerates the composting process (Rynk, 1992). In-vessel composting is both very sophisticated and expensive, and relatively uncommon despite its good results. They are costly to install and operate, and need intensive and skillful management.

3.2.5. The pit method

Composting can be carried out in a circular or rectangular pit. Crop residue, animal manure, aquatic weeds or green manure crops are used and often silt from riverbeds is mixed with the crop residues. The pits are filled layer by layer, usually, the first layer is of a green manure crop the second layer is a straw mixture and the third layer is of animal dung (FAO, 2003). These layers are alternated until the pit is full, when a top layer of mud is added; a water layer of about 4 cm depth is maintained on the surface to create anaerobic conditions which help to reduce losses of nitrogen. Three turnings are required, the first after a month of piling, the second after another month and thirdly after two weeks of turning (FAO, 2003).

3.3. Factors Affecting Composting Process

3.3.1. Particle Size of Feed stocks

The particle size of the feedstock affects the composting process (Christian *et al.,* 1997) .The recommended size of the substrate to be composted is 2-4mm. In general, the smaller the size of composting feedstock, the higher the composting rate. Smaller feedstock materials have greater surface areas in comparison to their volumes. This means that more of the particle surface is exposed to direct microbial action and decomposition at the initial stages of composting. Smaller particles within the composting pile also result in a more homogeneous mixture and improve insulation (Gray *et al.,*197l). Increased insulation capacity helps maintain optimum temperatures in the composting pile. At the same time, however, the particles should not be so small as to compact too much, to exclude oxygen from the void spaces.

3.3.2. Heap size

A minimum height of 1.5m and width of 2.5m is necessary to retain enough heat in a composting mass to the desirable thermophilic activity (Briddlestone*et al.,* 1987), although (Mathur,1985) showed that a height of 1m was sufficient when the medium of composting is peat and mixture of green manures with animal manure that have higher thermal -insulation capacities. The length of the heap and its total size will also depend on the aeration and agitation system used. In any case, it is important to consider that large heaps tend to allow pockets of anaerobic conditions due to compression by the overlaying burden.

3.3.3. Carbon to Nitrogen Ratio

For composting to continue efficiently, microorganisms require specific nutrients in an available form, in a suitable concentration, and in an appropriate ratio. The essential macronutrients required by microorganisms in relatively large amounts include carbon (C), nitrogen (N), phosphorus (P), and potassium (K). Microorganisms require C as an energy source.

In a composting system, either C or N is usually the limiting factor for efficient decomposition. High C: N ratios (i.e., high C and low N levels) inhibit the growth of microorganisms that degrade compost feedstock (Richard, 1992). Low C: N ratios (i.e., low C and high N levels) initially accelerate microbial growth and decomposition. With this acceleration, however, available oxygen is rapidly depleted and anaerobic, foul-smelling conditions result extreme amounts of N in a composting mass can form enough ammonia to be toxic to the microbial population, and inhibit the composting process (Haug, 1980). Excess N can also be lost in leachate, in either nitrate, gaseous ammonia, or organic forms (Richard, 1992). An ideal C: N ratio is considered to be in range of 25:1 to 30:1 (Epstein, 1997).

3.3.4. Temperature

Composting is a bio-oxidative and exothermic microbial degradation process that produces a relatively large quantity of energy. Only 40–50% of this energy can be utilized by microorganisms to synthesize ATP; the remaining energy is lost as heat in the mass. This large amount of heat causes an increase of temperature in the mass and can reach temperatures of the order of 70–90°C. Finstein calls this process “microbial suicide” (Finstein *et al.,* 1987) that inhibit microbial growth and slow biodegradation of organic matter.

Only few species of thermophilic bacteria show metabolic activity above 70°C. To have a high rate of biodegradation and a maximum microbial diversity, the temperature must range between 30 and 45°C (de Bertoldi *et al.,* 1983; Finstein *et al*., 1983).

During the composting processa feedback temperature control can be operated with a set point between 30 and 45°C in order to minimize the retention time. However, in a composting process, the thermophilic phase should not be totally eliminated because it is the most important phase in reducing pathogenic agents. Furthermore, the thermophilic phase must be maintained at the starting of the process, when the availability of readily degradable molecules allows temperatures to reach 70°C. In forced-aeration systems, the dominant heat-removal mechanismis evaporative cooling (vaporization of water), which accounts for perhaps 80–90% of the heat removal.

3.3.5. Hydrogen Ion concentration (pH)

During composting, organic matter with a wide range of pH (from 3 to 11) can be composted (de Bertoldi, 1985). However, the optimum range is between 5.5 and 8.0, for bacteria and fungi favor nearly neutral pH and acidic environment, respectively. In practice, the pH level in a composting mass cannot be changed easily. Generally, the pH begins to drop at the beginning of the process (down to 5.0) as a consequence of the activity of acid-forming bacteria that break down complex carbonaceous material to organic acids as intermediate products. When this acidification phase is over and the intermediate metabolites are completely mineralized, the pH tends to increase and at the end of the process is around 8.0–8.5.

High pH values in the starting material in association with high temperature can cause a loss of nitrogen through the volatilization of ammonia. In anaerobic digestion, the critical pH level generally covers a fairly narrow range (6.5–7.5), However the range in composting is so broad that difficulties due to an excessively high or low pH level are rarely encountered, except composting of fruit wastes where the pH can drop to 4.5 that requires buffering the composting mass by adding lime (calcium hydroxide). Although some loss of ammonia almost always occurs in aerobic composting, the loss is aggravated by the presence of lime. However, the lime does improve the physical condition of the composting wastes, perhaps partly by serving as moisture absorbent.

3.3.6. Oxygen

The source of oxygen for the microorganisms is the layer of air that essentially surrounds each particle. The oxygen that is removed from the air is replaced by CO_2released by the microbial cells. Eventually, the supply of oxygen in the air surrounding the particle is exhausted, and unless it is replaced by a layer of “fresh” air, anaerobic conditions soon prevail. Consequently, the primary objective in the design of aeration equipment is the renewal of the gaseous environment at a rate such that a sufficient supply of oxygen is always available to the microorganisms.

The renewal can be accomplished by: (1) physically moving the particles into a new position and consequently exposing them to supplies of fresh air, or (2) displacing the gaseous envelope while the particles remain stationary (Diaz, 1993).Composting can occur under aerobic or anaerobic conditions, but aerobic composting is much faster (10 to 20 times faster) than anaerobic composting (EPA, 1994).Anaerobic composting also tends to generate more odorous substances because gases such as hydrogen sulfide and amines are produced. Methane also is produced in

the absence of oxygen. To support aerobic microbial activity, void spaces must be present in the composting material. These voids need to be filled with air. Oxygen can be provided by mixing or turning the pile, or by using forced aeration systems. The amount of oxygen that needs to be supplied during composting depends on the stages of the process and the type, particle size and moisture content of the feedstock (Lorrine, 2003).

3.3.7. Moisture Content

Water is the key ingredient that transports substances within the composting mass and makes the nutrients physically and chemically accessible to the microbes. If moisture levels are too low microbial activity will decrease. On the other hand, too much moisture can lead to a lack of aeration and leaching of nutrients.The moisture content of a composting pile is interconnected with many other composting parameters, including the feedstock, microbial activity within the pile, oxygen levels, and temperature. Microorganisms require moisture to assimilate nutrients, metabolize new cells, and reproduce. Microbial activities also produce water as part of the decomposition process. If water is accumulated faster than it is eliminated via either aeration or evaporation (driven by high temperatures), then oxygen flow is impeded and anaerobic conditions result (Gray *et al.,* 1971).

According to Christian *et al.,* (1997) the acceptable moisture content throughout the composting process is 45-65 percent, with optimum range of 50-60 percent. If the moisture level drops below about 40 to 45percent, the nutrients are no longer in an aqueous medium and are not easily available to the microorganisms. Under the circumstances, the microbial activity decreases and the composting process slowdown. Below 20 percent moisture, very little microbial activity

occurs (Haug, 1980). It is not recommended that high moisture levels be maintained throughout the composting process (Richard *et al.,* 2002).

3.4. Microbial dynamics during composting

3.4.1. Microbial succession during the composting process

The microbial succession during the composting process can be separated into different phases, as guided by the temperature regime. During the first mesophilic phase, temperatures increase rapidly to 40–60°C, when sugars and other easily biodegradable substances are utilized (Hoitink and Boehm, 1999). During the second thermophilic phase, temperatures of 40–70°C prevail and cellulosic and other less well biodegradable substances are broken down. In the third phase,this is considered as curing or maturation phase, temperatures decline from 40°C to that of the ambient temperature (Hoitink and Boehm, 1999).

When temperatures drop, the total bacterial numbers decrease, but their taxonomic and metabolic diversities increase. Compost may contain pathogens like bacteria, viruses, fungi, and parasites, but numerically they are negligible fraction of the total microbial population (de Bertoldi *et al.,* 1983). So, the relatively large number of native saprophytic microorganisms plays an important role in pathogen control during composting through microbial competition and antagonism for nutrition.

The microbiology of composting is extremely complex, being characterized by the succession of microbial communities selected by a continuing change of environmental conditions determined by previous activity (Miller, 1996). Bacteria, actinomycetes, and fungi have been specifically identified during the composting process, but what is more important in terms of soil biological

fertility is that microbial communities in compost belong to the physiologic groups of cellulolytic, pectinolytic, proteolytic, nitrifiers, and so on which contribute, as a whole, to the cycling of soil nutrients. Moreover, saprophytic microorganisms in compost represent a supply of organic carbon and nitrogen that can be easily mineralized by soil microbial biomass(Hoitink and Boehm, 1999).

3.4.1.1. Bacteria

The importance of bacteria during the composting process was long neglected, probably because of the better visibility of fungi and actinobacteria. In some composting processes, e.g., the composting of sewage sludge, bacteria are more important than fungi from the beginning. If temperatures are kept under 60°C, more than 40% of the solids are degraded within the first 7 days, almost entirely through bacterial activity (Strom, 1985). The temperature range from 50 to 65°C is of selective advantage for some bacteria, and in particular for the genus *Bacillus*. When temperatures exceeded 65°C, *B. stearothermophilus*often is dominant, almost like in a pure culture.

3.4.1.2. Archaea

Many archaea are known to be thermophilic or even hyper thermophilic. They have primarily been isolated from hypothermal vents. Only in a few cases, archaea have been isolated from composts (Stackebrandt et *al.,* 1997), but since considerable methanogenesis in compost piles has recently been reported (Cabanas-Vargas and Stentiford, 2006), it is likely that methanogenic archaea may be found if specifically searched for. The reason for the relatively low abundance of archaea probably is that they are usually oligotrophic, and their generation times are much higher than those of bacteria, which make them unsuited to rapidly changing conditions.

3.4.1.3. Fungi

During the starting phase, fungi compete with bacteria for the easily available substrates. Since the maximum specific growth rates of bacteria exceed that of fungi by one order of magnitude (Griffin, 1985), fungi are very soon out-competed. A good supply of oxygen is more important for fungi than for bacteria, and even in force-aerated systems, temporary anoxic conditions may occur. For these reasons, but also because of the lower thermo tolerance, fungi play a negligible role during the thermophilic phase. One exception is the composting of substrates that are particularly rich in cellulose and in lignin where fungi remain most important throughout the entire process. In the later phases of composting, the water potential decreases, which is an advantage for fungi.

3.4.1.4. Actinobacteria

Actinobacteria prefer neutral or slightly alkaline pH and are able to degrade relatively complex substrates. Several are thermo tolerant, or even thermophilic, with a temperature range from 50 to 60°C. Most actinobacteriagrow best when the substrate is moist and the oxygen supply is good. These conditions are usually given when the most easily degradable substrates have already been consumed by bacteria, and when the temperatures rise beyond 45°C.

Members of the *Thermus/Deinococcus*group grow on organic substrates at temperatures from 40 to 80°C, with optimum growth between 65 and 75°C. The numbers in bio waste composts were as high as 10^7–10^{10} g−1 dry weight of compost (Biffa*et al.,* 1996).Thus, it seems that *Thermus*species, previously known only from geothermal sites, have probably adapted to the hot-compost system and play a major role in the peak heating phase. A number of autotrophic

bacteria were also isolated from composts. These non-sporing bacteria grew at 60–80°C, with optima of 70–

75°C, and closely resembled *Hydrogenobacter*strains that previously were known only from geothermal sites. They obtain their energy by oxidizing sulfur or hydrogen, and synthesize their organic matter from CO_2(Beffa*et al.,* 1996).

3.5. Evaluating Compost Quality in Relation to Physical and Chemical Attributes

Compost is the product resulting from the controlled biological decomposition of organic material that has been sanitized through the generation of heat and stabilized to the point that it is beneficial to plant growth (Lasaridi and Steniford*,* 1998). It is an organic matter resource that has the unique ability to improve the chemical, physical, and biological characteristics of soils or growing media. The Canadian Council of Ministers of the Environment defines compost as: "A solid mature product resulting from composting, which is a managed process of bio-oxidation of a solid heterogeneous organic substrate including a thermophilic stage" (Landscape Nova Scotia Horticultural Trades Association, 2003).

Different countries set standards to compost quality that would help for evaluation. These include Austria, Germany, Canada, United Kingdom, US, Belgium, the Netherlands, and Luxembourg (Hogg *et al.,* 2002). Compost quality can be described in terms of age, maturity, nutrient content, and other physical, biological and chemical properties (Mathur *et al.,* 1993). Parameters, which are a significant influence on compost quality, are the following.

3.5.1. pH

The application of compost to soil may alter the soil pH value and therefore have an effect on the availability of nutrients to plants. Bordna Mona (2003) recommends a range of pH from 6.9-8.3. The acceptable pH values of compost quality standards in European countries range from 6.5-8.5. If the pH of compost exceeds this range, there will be an effort need to adjust the pH. Adjusting the pH when it exceeds 8.5 can reduce ammonia volatilization and reduce odour (Woods End Research Laboratory, 1998).

3.5.2. Organic Matter

Organic matter content in compost is a vital component in all soils and has a key role to play in keeping soil structure, texture, nutrient availability and water holding capacity. There is no absolute value of organic matter, which is ideal for compost. It may range from 30-70% (US Composting Council, 2003).Under the EPA waste-licensing system of USA compostshould contain at least 30% organic matter on a dry weight basis while the European countries quality set standards on compost containing greater than 20% OM on dry weight basis. The organic carbon can be calculated from organic matter using the conversion factor 1.724 assuming that organic matter is composed of 58% organic carbon (Sahlemedhin and Taye, 2000).

3.5.3. Moisture Content

Moisture content is a measure of the amount of moisture present in a compost sample and is expressed as a percentage of fresh weight. Compost with low moisture content (<35%) may be too dry and dusty and irritating when handled. Compost with too high moisture content (>65%) can become too clumpy and difficult to transport which will limit its chances of being advertised

as a quality product (US Composting Council, 2003). Biotreat (2003) and US Composting Council (2003) recommend a moisture range of 45-65% fresh weight and the European countries and Composting Council of Canada recommend moisture content of finished compost less than or equal to 40 % water on dry weight basis.

3.5.4. Electrical Conductivity

Electrical conductivity (EC) is a numerical expression of the ability of an aqueous solution to carry an electrical current. It is generally related to the total solute concentration and can be used as a quantitative expression of dissolved salt concentration. The salt content of compost is due to the presence of sodium, chloride, potassium, nitrate, sulphate and ammonium salts (Brinton, 2003).

Some soluble salts may be detrimental to plants whereas, other plant nutrients supplied to plants exist in salt form and are essential for plant growth. Though excessive amounts of soluble salts in compost used in growing media or applied to the land may inhibit crop growth and affect crop yield (Barker, 1997).Bordna Mona (2003) reports that the recommended range for electrical conductivity in compost is between 2-6 mS/cm. High salinity levels (when suspended solids concentrations are greater than 10-15) can be toxic to plants (Travis *et al.,*2003).

3.5.5. C: N Ratio

The C: N ratio is an indicator of compost stability and N availability. It is the ratio of total carbon to total nitrogen in the sample. The ratio of these two can be used to provide an indication of the rate of decomposition of the feedstock and to determine when maturity has been reached (Anon, 1998). Composts with a high C: N ratio (>25) will tie up the available nitrogen, making it

unavailable, and composts with a low C: N ratio (<20) will release organic N making it available to the plant (Travis*et al.,* 2003).Therefore, C: N ratios should be used in combination with some other relevant parameter for testing compost maturity (Wood End Research Laboratory, 1998). The C: N ratio of mature compost should ideally be about 10 but this is hardly ever achievable due to the presence of recalcitrant organic compounds, or materials which resist decomposition due to their physical or chemical properties. C: N ratios of 5-15 in mature composts are acceptable as long as their further decomposition is slow and does not require additional N from the soil (Martin, 1991). The U.S. EPA (1994) specifies C: N of <25 within a waste license.

3.5.6. Nutrient Content of Compost

Compost contains macro and micronutrients, which is vital for plant growth and development (Zethner *et al.,* 2000). Nitrogen, phosphorous and potassium are the nutrients, which are consumed, in large amounts by plants. Information of the nutrient content of compost is important because the nutrient content of compost can differ widely and also because it allows facility operators to determine an appropriate end use for the compost. The agricultural market demands compost of high nutrient content, whereas compost low in nutrients is well suited for the landscaping sector and for use as mulch (Zethner *et al.,* 2000). In general, nutrients are organically bound within compost and are slowly released over a period of time as a result of microbial activity. This ensures a continuous supply of nutrients to the plant (US Composting Council, 2003). Total nutrient content is usually expressed as a percentage on a dry weight basis.

3.5.6.1. Total Nitrogen,Phosphorous and available Potassium

Nitrogen is a macronutrient for the growth and development of plants. The availability of nitrogen in compost is very important factor to be evaluated when considering its nutritional

value for soil. Knowledge of the concentration of nitrogen in compost is also important due to concern of groundwater pollution from excess NO_3- N (Iglesias-Jiménez, 2001). Typically more than 90% of nitrogen in compost is organically bound and the most available form to plants is when nitrogen is converted into an inorganic form and exists as NO_3-N (Fricke and Vogtmann, 1994).

The amount of total nitrogen and plant available nitrogen depends on the composition of the waste material and the composting process. Körner and Stegmann (2003) reported that certain parameters such as pH, temperature and moisture significantly influence the rate of nitrogen turnover from proteins in bio waste to inorganic and organic forms. They found that the highest concentration of ammonia could be measured during thermophilic stage while mature compost contains more nitrogen in organic nitrogen form and as NO_3-N. Hence, by regulating the composting process, compost with more predictable nitrate content can be produced. Total N is the sum of inorganic + organic N or it includes N in all its forms which include ammonium, nitrate and organic N.

In finished compost, most of the N should be in the organic form and total N ranges from 0.5-2.5% dry weight basis (Travis, *et al,* 2003). In stable, finished compost, Organic N is not immediately available to plants (about 15% the first year); however, this depends on other factors such as temperature, soil moisture and the C: N ratio. In order to determine compost as having fertilizing capabilities for agriculture, the TN content must be over 1%, dry weight (Barker, 1997). If compost contains TN of less than 1%, supplemental nitrogen fertilizer will be required if the compost is to be used as a soil improver or in potting media. If the TN in compost is approximately 0.6% or less there is a chance that nitrogen immobilization will occur, thus, compost with low TN levels is better used as mulch (Barker, 1997).

Phosphorous is also a macronutrient for plant growth and development. It plays a very important role for cell reproduction and metabolic reaction. Total phosphorous (TP) is usually expressed in terms of percentage weight per dry weight. The total phosphorus is usually expressed as P_2O_5 in percent on dry weight basis while available phosphorus is usually expressed as P_2O_5 in mg/L on a fresh weight basis (Bordna Mona, 2003). According to Bordna Mona (2003) and Travis *et al.,* (2003) the range of TP is usually between 0.4 - 1.1%, dry weight for bio waste and green waste compost.

Potassium is one of the macronutrients that are required by plants in large amount for growth and development. Potassium in its available form in compost exists as K_2O. The available/ exchangeable potassium is the portion of potassium electrostatically bound on an outer sphere of complex to the surface of humic substances. The amount of potassium in compost depends on the feedstock but also on the composting process (Barker, 1997). Compost usually does not contain a great concentration of potassium because of its high water solubility, and can be easily leached from the feedstock during the composting process. This may occur especially in uncovered windrows (Fricke and Vogtmann, 1994). Bordna Mona (2003) states that the typical range of total potassium in bio waste and green waste compost is between 0.6-1.7% on dry weight basis.

3.5.7. Maturity

Immature composts with high C:N ratios can also cause damage to plants when used in horticulture by tying up available nutrients in the soil (Biey *et al.,* 2000) and by depriving plants of oxygen in the root zone (Brinton, 2001). Low C: N ratio can cause phytotoxins to be released which can burn plant roots and thus inhibit plant growth. It is also significant to allow compost to

mature due to the fact that, as compost matures over time, the solubility of heavy metals decreases with a subsequent decrease in bioavailability in the environment. The metals become bound to humic compounds, metal oxides and phosphates in the compost when mixed with soil (Chancy, 1991).

Maturity, generally, cannot be described by one single property; instead maturity is described by examining two or more compost characteristics (US Composting Council, 2003). In addition to the value of C: N ratio the maturity of compost can be tested using germination of seeds, oxygen uptake rate, self-heating test and physical characteristics like color and odour (Haug,1993; Brinton *et al.*,1992).

2.5.7.1. Heat Evolution

A very simple and rapid means to evaluate compost maturity is to determine its temperature. In general, in moderate climates, if the temperature of the compost is more than 8°C higher than the ambient air, the compost is still fairly unstable. The self-heating test in Dewar flasks is the most frequently used test (Niese, 1963). The principle is the self-heating potential of biodegrading organic material through (micro) biological activity. A slow or no rise in temperature indicates a high degree of maturation.

In the test, a 2-L Dewar flask is filled with compost and a thermometer or a temperature sensor is placed in the upper third of the container. The maximum temperature is registered during a period of up to 10 days, and the result is transformed into decomposition classes. The Dewar flask self-heating test is considered a very robust test and in a comparative study, it was the most sensitive indicator of compost maturity. This test showed changes throughout the 57-day bio solids composting period evaluated.

3.5.7.2. Germination

The germination test is an indicator of compost maturity. Immature compost has phytotoxic compounds (toxic to plants) which inhibit seed germination, especially with highly sensitive cress and bean seeds.If these seeds have poor germination in compost being tested, the compost is not suitable for mulchuses. The phytotoxicity of the samples was determined following the method of Zucconi and de Bertoldi (1987).

Bean germination test is undertaken in several 4 inch pots with compost after planting 3 to 4 seeds per pot. Bean seeds should germinate in 5 to 7 days (Martin, 1991). Compost containing phytotoxic compounds will inhibit germination numbers and speed. Seedlings growing in immature compost will be less healthy. In 10 days to two weeks after germination, beans should have large, "bean-colored" leaves and an extensive, healthy root system. If the plants are not healthy, the compost is not mature and needs to continue composting or curing (Lorrine, 2003).

3.6. Microbiological Indicators of Compost Maturity.

The microbial activities like; the respiratory activities, nitrification potential, ATP content, enzyme activities, and microbial counts and biomass are key indicators of compost maturity (Tiquia, 2002).Composting results in an increase in microbial activities (O_2 consumption rate, ATP content, dehydrogenase activities and microbial biomass). Towards the end of composting, no further decomposition is taking place as C and N become stabilized. Consequently, no more heat is released as a result of microbial activities; the O_2 consumption rate, ATP content, dehydrogenase activities and microbial biomass dropped and stabilized to low levels (Tiquia *et al.,* 2005).

Dehydrogenase activity is thought to reflect the total range of oxidative activity of soil micro flora, and consequently may be a good indicator of microbiological activity (Tabatabai, 1994). Tiquia *et al.* (1996) indicate the oxygen uptake and dehydrogenase activity are closely related. Therefore dehydrogenase provides information on the active portion of the compost microbial community. Here, it can be seen that dehydrogenase activity can be used to monitor the composting process and as a valid marker of compost maturity. The decrease in dehydrogenase activity to low levels towards the end of composting indicates that there was no more active decomposition going on, and that the pig manure compost reached maturity. Compared with respiration rate, ATP content and microbial biomass procedures, dehydrogenase activity is the simplest, quickest, and cheapest method that can be used to monitor the stability and maturity of composts. (Tiquia *etal.,* 2002).

3.7. Maturity of Compost based on Enzymes activities

The enzymes released by the microorganisms during composting breakdown several organic compounds characterized by a complex structure, finally leading to the solubilization of simple water soluble compounds (Benitez *et al.,* 1999). The degradation of the labile substrates contained in organic materials can also be followed by studying specific hydrolases, which are relatively easy to determine, and specific to the substrate (Ayuso*etal.,* 1996). Various hydrolytic enzymes are believed to control the rate at which various substrates are degraded. Important enzymes involved in the composting process include: cellulases, which depolymerize cellulose, B-glucosidases which hydrolyseglucosidases and urease involved in N-mineralization, phosphatases and arylsulphatase that remove phosphate and sulphate groups from organic compounds (Mondini*et al.,* 2004).

In general, characterizing and quantifying enzymatic activities during composting can reflect the dynamics of the composting process in terms of the decomposition of organic matter and nitrogen transformations, and may provide information about the maturity of composted products (Tiquia, 2002). Moreover, enzymatic activity determination, in contrast to most of the analytical techniques used for compost stability evaluation, is easy, fast and relatively in expensive (Mondini et *al.,* 2004).

3.7.1. Microbial enzyme activities

3.7.1.1. Amylase,Phosphatase, ProteaseandCellulase activities

Amylases catalyze the hydrolysis of alpha-1, 4-glycosidic linkages of polysaccharides to yield dextrin, oligosaccharides, maltose and D-glucose. Raut*et al*. (2007) reported a maximum degradation of starch within 9 days due to increased activity of amylase during this period. High content of degradable organic compounds such as starch in the initial mixture may have stimulated microbial growth and enzyme synthesis, (Castaldi*et al.,* 2007).

Phosphatase has agronomic value because it hydrolyses compounds of organic phosphorus and transforms them into different forms of inorganic phosphorus, which are assimilable by plants. The phosphatase activity is due to the presence of phosphorylated compounds, which act as a substrate for the microorganisms to synthesize phosphatase and is considered as a general indicator of microbial activity(Ayuso*et al.,* 1996). Generally, alkaline phosphatase activity increases in the beginning of the composting process, reaching maximum activity by the end of the composting period (Ros*et al.,* 2006).The high initial activity could be related to the amount of organic phosphate compounds present in the composting mixture. Similar observations were also made by Garcia *et al.* (1994) in the degradation process of sewage sludge.

Protease activity is closely linked to the N cycle and catalyzes the hydrolysis of proteins to ammonia, acting on the short-chain poly peptide substrates. The activity of protease and degradation of protein is followed by removal of ammonia through aeration. Otherwise, ammonia can act as an inhibitor since it is the product of the hydrolytic reactions catalyzed by urease and proteases (Ros*et al.,* 2006).

Cellulases are involved in the degradation of cellulose. Cellulose decomposition limits the rapid production of compost more than any other substrates (Poincelot and Day, 1973). Cellulase activity is dependent on the types of cellulolytic microorganisms that develop on the organic waste (Goyal*et al.,* 2005). Mostly, fungi are involved in the decomposition of cellulose, hemicellulose and lignin present in the organic matter.

3.8. Benefits of compost

Compost increase the organic content of the soil and can improve its texture, nutrient content and its water retention and aeration capacities (Chuck, 2005). The application of compost includes: agriculture, nurseries, high way landscaping, home gardening, horticulture and other land reclamation and land fill cover.

The quality of compost dictates its application. It has been indicated that nurseries require high quality product, whereas, a lesser quality is suitable for landscaping or landfill cover ((Hogg *et al.,* 2002). Compost addition to soil have the potential to improve soil physical conditions increasing resistance to erosion, improving soil water infiltration and water holding properties. It provides nutrients to plants in a stable organic form in to the soil so as to make soil more porous,

allowing air and plant roots to penetrate more readily. It improves soil fertility; increase soil biodiversity and sequester carbon in to the soil (Chuck, 2005).

In recent years, consumer demand for organically grown produce has increased and stimulated the use of compost and other biological control measures for plant health improvement (Touart, 2000). During the late 1960's, nursery men in the United States began using composted tree bark as a substitute for peat to reduce the cost of growing media.The suppressive activity of certain types of compost towards plant pathogens is now well documented. The most successful pathogen suppression has been reported in container production systems in the United States (Hoitink and Stone, 1997).

4. Material and Methods

4.1. Study areas

Field experiment was conducted on two farms, Sebeta (Ethio-highland) and Bishoftu (ZK) representing the high land and low land areas, respectively.

4.2. Experimental set up

Flower residues were collected and sorted out in to non-degradable and degradable materials from the two experimental areas for composting. Organic additives such as animal dung and garden soils were included in the experimental set up to modulate carbon to nitrogen ratio of the feed stocks. Thereafter, different combinations of compost were made, and 1m X 3m width and length, 1m height piles of mixtures were arranged in Turned windrows methods (Diaz and Savage, 2007). The moisture content was adjusted to approximately 60%, and the process was regularly turned once in a week to maintain the aerobic environment.

Two different treatments(pile one and pile two) were undertaken: mixing flower wastes with cow dung in 1: 3 ratio , andmixing flower waste witheffective microorganisms (EM) plus molasses in 1:0.001:0.002 ratio. In order to protect the cross contamination of the piles, three sided boxes of 3m long, 1.5m high and 1.5m wide were made before putting the mixtures for composting.

4.2. Viability test for quality control of inoculum

Enumeration of viable bacteria from the concentrated packages of EM WOLJEEJII was $2.48X10^8$cfu/ml; and fungal/yeast count was found to be $3.37X10^7$cfu/ml. comparatively, the counts of bacteria and yeasts in the diluted packages was reduced in number, $1.23X10^7$cfu/ml bacteria and $5.73X10^6$cfu/ml yeasts. This number of organisms in the diluted form was used in the composting experiment.

4.3. Sampling techniques

Compost samples were collected once in two weeks starting from the beginning until the end of composting (three months). Approximately 1000g of samples from different locations of the piles were composited and collected into sterile plastic sheets, and preserved at 4 °C for microbiological analysis while the remaining were stored at room temperature for the chemical analysis.

4.4. Physico-chemical analysis

The temperature of compost was measured every week from the beginning until the end of composting from three different locations (top, middle and bottom) by using a digital thermometer, and the average was taken as the temperature of the composting at specific time.

Before the start of composting, moisture in the piles was determined according to the recommended permissible range(45-65percent)(Trautman and Richard, 2001). The changes in

moisture content (MC%, w/w) was determined after oven drying of compost samples (10±2g) at 105°C to a constant weight for approximately 24 h. The pH values of the compost were determined every two weeks electrometrically from filtered aqueous suspensions of fresh samples (1:10 w/v). Suspensions were shaken at 160 rpm, for 2 h, and then filtered and measured by using pH meter (HD8602, Italy).

Total Organic Carbon (TOC) was estimated from the organic matter (OM) value using the conventional 'Van Bemmelem factor of 1.724. This factor is based on the assumption that the soil O.M. contains 58% C (Allison, 1965). First, compost samples were oven dried for 24 h at 105°c followed ignition by using a furnace at 550°c for 3h. the organic matter (OM) was calculated from the difference of ash weight to oven dry weight and expressed as percentage.Total nitrogen content (TN) was determined by Kjeldahl digestion analysis through three successive steps (Keeney and Nelson, 1982): digestion of the compost material (to convert organic N into mineral N form, NH_4^+), distillation of the released ammonium into an absorbing surface or medium, and volumetric analysis or titration of NH_3 formed during digestion process.

Ammonium nitrogen (NH^+_4-N) was determined from the extracts of 10g of freshly sampled compost, shaken in 2M KCl extraction and filtered through 42-whatman filter paper and steam distillated by 0.2g of ignited and cool MgO and titrated with 0.02 N NaOH, then the result was calculated according to the equation suggested by the manufacturer (Warman and Termeer, 1996).

$$NH_4^+\text{-N (mg Kg}^{-1}) = \frac{(B-A)*N*14*mcf*100}{S*Z*1000}$$

Where, B: Volume in ml of NaOH solution required for blank titration

A: Volume in ml of NaOH solution required for sample titration

N: Normality of NaOH

S: weight of sample in gram

Z: Aliquot volume

Nitrate nitrogen (NO^-_3-N) was determined by Devard's distillation method through three steps digestion, distillation and titration, and then calculated the measurement according to the following equation:

$$NO_3^-N = \frac{(B-A)*N*14*mcf*100}{S*Z*1000}$$

B: Volume of NaOH solution required for blank solution

A: Volume of NaOH solution required for sample titration

N: Normality of NaOH

S: weight of the sample in gram

Z: Aliquot of volume.

Available Phosphorus was analyzed using the method of Olsen *et al.* (1954), including $NaHCO_3$ extraction of compost samples, and determining the changes by the colorimetric method as a molybdovandate phosphoric acid. The intensity of blue color formed was measured by the absorption of light at 882nm on UV-spectroscopy. Available potassium was quantified by flame

photometry after equilibrium of sample with exchanging cation made of neutral normal NH_4OAc, (Thomas, 1982).

Micronutrients such as Fe, Mn, Cu and Zn in compost samples were determined by using the method of Warman *et al*. (1995), by atomic absorption spectrophotometry (AAS) at 248.3nm, 279.5nm, 324.7nm, and 213.9nm, respectively after extracting with a chelating agent (DTPA).

All chemical analysis was carried out in triplicates. Total Organic Carbon (TOC), Total nitrogen content (TN), Ammonium nitrogen (NH^+_4-N), Nitrate nitrogen (NO^-_3-N), Available Phosphorus, Available potassium and Micronutrients such as Fe, Mn, Cu and Zn were analyzed by JIJE LABOGLASS PVT.LIMITED COMPANY.

4.5. Phytotoxicity

The phytotoxicity of the compost samples was determined following the method of Zucconi and de Bertoldi (1987). Compost samples from the different sampling time were dissolved in distilled water (10:50, w/v) shaken for 1 h and centrifuged for 15 min at 10,000 rpm (Centurion Scientific, Model, 2020). The supernatant was then collected and filtered through a 0.45 µm membrane filter. Ten seeds of garden cress (*Lepidium sativum* L.)were evenly distributed on a filter paper in a Petri dish and watered with 1 mL of the supernatant. A control treatment consisting of the same number of seeds watered with 1 mL of distilled water was also included. All Petri dishes were incubated for 24 h at 22° C in the dark and then the germination was stopped with 1 mL of ethanol. The number of seeds germinated up to at least 1 mm, was counted and the length of the germination root was also measured to calculate the Germination Index (GI) percentage.

4.6. Microbial count

The total counts of aerobic heterotrophs, actinobacteria and fungi in the compost sample were determined by direct plating on appropriate media (Tiquia *et al*., 2001). Accordingly, total aerobic heterotroph count was made in plate count agar (PCA. Oxoid, England). The microbial counts for actinobacteria and fungi were made using Starch casein agar (SCA) and Potato Dextrose Agar (PDA) supplemented with cyclohexamide, respectively.

In all cases, compost samples were ground to 0.25mm, serially diluted, in distill sterile water and each agar plate was divided into eight sections and about 1 ml of the compost suspension was dropped on to their respective media using the plate frequency technique (Tiquia *et al*. 1996). Plates were incubated using (DHP-9052 heating incubator) for three days at ($30\pm2^{o}C$) for the growth of bacteria and fungi and between five and seven days for Actinobacteria. After incubation any visible growth observed in any of the eight sections was scored positive. The total number of sections with positive growth at each dilution was counted, and the population of microorganisms in the sample was estimated using the Most Probable Number (MPN) method (Tiquia *et al*., 2002)

4.6.1. Detection of *Agrobacterium* spp.

Agrobacterium spp. were isolated from the compost at various stages (day 0, 63 and 98) using dilution-plate technique where by 0.1 ml of a 1g: 1000 ml of compost: distilled sterile water were pipetted on to selective medium (Kado and Heskett, 1970) containing per liter of distilled water: 15g mannitol, 5g $NaNO_3$, 6g LiCl, 20 mg Ca $(NaNO_3)_2.4H_2O$, 2g K_2HPO_4, 0.2g $MgSO_4.7H_2O$, 0.1g bromothymol blue, and 15g agar. The pH of the medium was adjusted to 7.2 and it appeared blue. Inoculated plates were incubated at 27 ^oC for a week.

4.7. Data Analysis

The data analyseswere carried out using SPSS 16.0 program. A normality test was madeusing Ks for all parameters prior to analyzing the variance. Chemical and microbiological data was subjected to a repeated measures of analysis (ANOVA) in which the piles represented the subjects and the composition of the parent material was fixed as the between-subject factor and the composting time (0,7,21,35,63,91,98) was fixed as the within subject factor. All the variables which did not meet sphercity condition (Mauchly's test) were corrected with Greenhouse-Geiser (G-G) procedure(Potvin*et al*. 1990). Significant differences in the main effect were further analyzed by paired comparison with the Bonferroni test

5. RESULTS AND DISCUSSION

5.1. Physico-chemical analyses

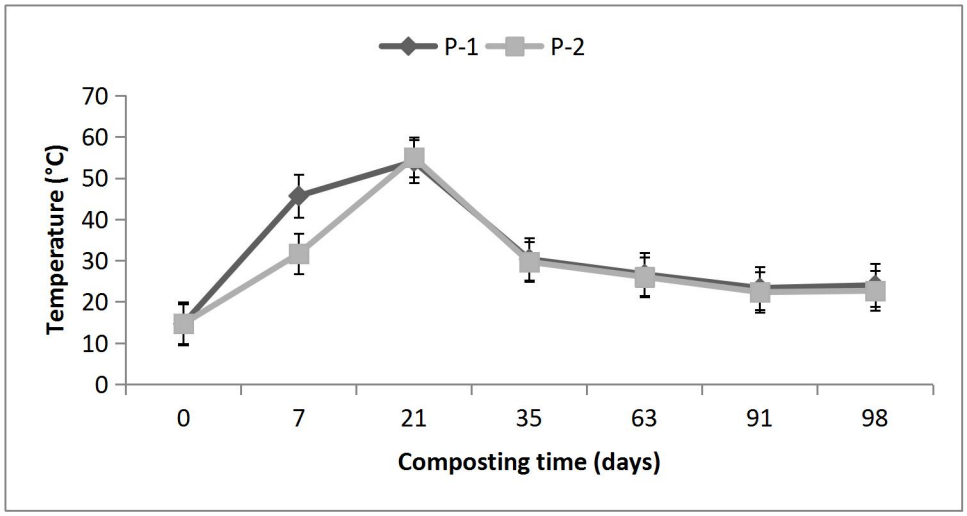
5.1.1. Temperature, Moisture and pH analysis

Temperature changes in compost piles made in the two farms (Eth-highland and ZK farms) are shown in Fig 1a and b. At the start of composting, the temperature of the piles of both sites was around 15°C. As composting was progressed, the temperature of cow amended compost (pile1)at the site of Eth-highland increased faster to 45°C in 7 days and reached 54°C (thermophilic stage) in 21 days. Unlike pile 1, the EM- treated (pile 2) reached to 30ºC within day 7, and attained temperature of >55ºC in 21 days (Fig1a).Both of them retained the thermophilic temperature (>45°C) until the 21st day indicating that (pile1) sustained thermophilic stage longer than pile 2. After day 28, both piles gradually declined to second mesophilic phase (<35ºC). Several workers have showed that such a decline in temperature is due to the faster exhaustion of easily degradable substrates(Ryckeboer *et al*. 2003).

In contrast, the two piles in ZK site did not show significant difference in temperature changes between them in the dates of reaching the thermophilic stage (7 days) compared to the process at the Eth-Highland (Fig 1b). At the start, temperature of both piles was around 17°C. However, pile 1 and pile 2 reached to the highest temperatures of 55°C and 52°C, respectively faster than the piles at ETH-highland within 7 days and maintained the thermophilic phase for the next 15 days prior to declining to the second mesophilic stage at 28 day. The temperatures started to decline after 21 days and reached to the second mesophilic stage on the 35th day and lasted up to the end of the composting time indicating the cooling of compost piles of Eth-Highland site was

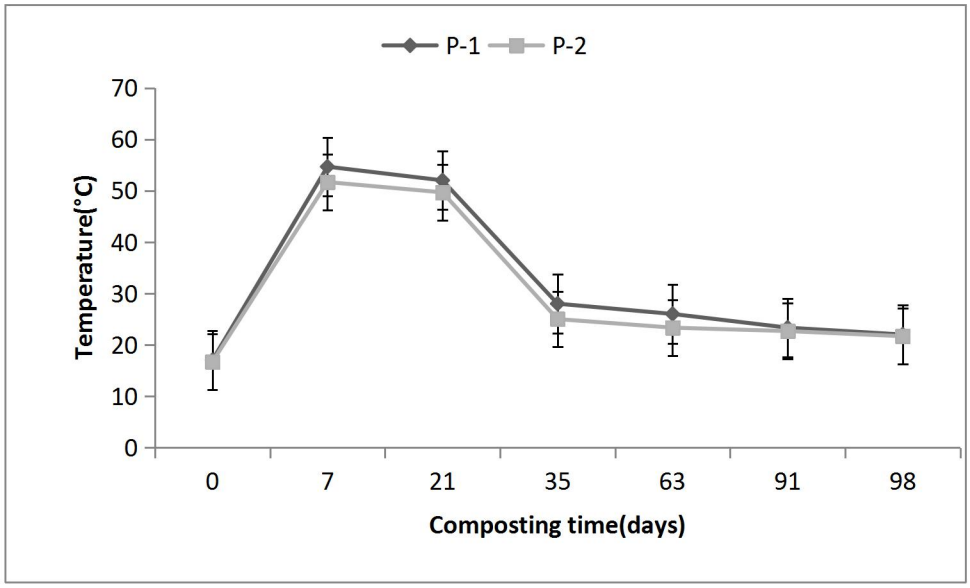
faster (28 days) than in ZK farm. In general, both piles maintain their thermophilic phase in 28daysand there was a decrease in temperature after 35 days which could be attributed to the depletion of easily degradable organic materials (Ryckeboer *et al*. 2003).The maximum temperatures attained in this study was lower than the maximum composting temperatures of treatment in Windrows to be within the optimum temperature ranges 48-71°C (Pincelot, 1975)

Fig1a. Change of temperature in compost piles at ETHF



P-1 = Pile one P-2 = Pile two

Fig1b.Change of temperature in compost piles at ZKF



P-1 =Pile one P-2 = Pile two

The moisture content of the compost piles of the two sites (Ethio-highland and ZK farms) is shown in table (1). At the beginning of composting, moisture content of the treatments of the two sitesat EHF and ZK Flowers was 67.9-74.3 irrespective of the treatments (Pile 1 and pile 2) and considerably higher than the suggested range at the initial stage ofcomposting of agricultural residues (Haug, 1993 and Miller, 1996). After day 21, the moisture contents of pile 1 and pile 2 of both composting sites was drastically reduced by30%compared to the other times, It has been also showed a drastic decrease in moisture content due to evaporation of water as a result of intense microbial activities and generation of energy at the earlier period of composting (heating) (Rebollido*et al.*, 2008; Fekadu *et al*.,2014). The final moisture contents of the matured composts were between 35.5%-43.7% with relatively lower values for pile 2 than pile 1. However, pile 1 of both sites did not show significant difference in their final moisture content.

The pH of all composting sites was slightly acidic (pH 6.4 and pH 6.8) at the initial phase of the process which was later increased into slightly basic pH (7.6) and lowered to near neutral (pH 7.1) atthe end of composting (Table.1). The increase in pH values over time can be attributed to the removal of carbon dioxide and increase in nitrogen content through the mineralization of protein products (Gómez-Brandón *et al*., 2008).

Table.1. Effect of moisture content and pH value of the two composting sites

Composting Time	ETH-Highland				ZK Flowers			
	Pile 1		Pile 2		Pile 1		Pile 2	
	MC	pH	MC	pH	MC	pH	MC	pH
0	74.3 (1.54) [a]	6.7 (0.25) [c]	71.9 (1.67) [a]	6.5 (0.25) [d]	68.6 (3.52) [a]	6.8 (0.02) [c]	67.9 (3.11) [a]	6.4 (0.05) [d]
7	61.4 (2.31) [b]	7.1 (0.11) [b]	57.1 (2.02) [b]	7.2 (0.05) [b]	57.2 (2.12) [b]	7.1 (0.02) [b]	53.2 (0.25) [b]	7.1 (0.03) [b]
21	56.3 (1.42) [c]	7.2 (0.25) [b]	54.7 (1.24) [c]	7.1 (0.05) [c]	51.6 (1.65) [c]	7.4 (0.05) [a]	51.2 (1.01) [c]	7.3 (0.05) [a]
35	55.6 (2.52) [c]	7.4 (0.35) [b]	50.1 (2.42) [d]	7.2 (0.06) [b]	41.2 (0.55) [d]	7.5 (0.05) [a]	42.6 (0.53) [d]	7.0 (0.05) [c]
63	49.7 (1.32) [d]	7.7 (0.23) [a]	45.3 (3.02) [e]	7.1 (0.06) [c]	41.1 (1.013) [d]	7.6 (0.13) [a]	42.8 (1.02) [d]	7.1 (0.02) [b]
91	45.8 (1.25) [e]	7.6 (0.25) [a]	36.1 (2.51) [f]	7.5 (0.12) [a]	42.5 (1.11) [d]	7.4 (0.12) [a]	41.5 (1.05) [d]	7.1 (0.03) [b]
98	43.2 (2.14) [f]	7.1 (0.34) [b]	35.5 (1.35) [f]	7.6 (0.27) [a]	43.7 (0.52) [d]	7.2 (0.12) [b]	39.2 (0.35) [e]	7.1 (0.05) [b]

Values are means±standard error (n=3). Values within the same column followed by the same letter are not significantly different according to Bonferroni test (P=0.005)
MC=Mositure Content

5.1.2. Organic carbon and Total Nitrogen

The pattern of organic carbon(OC) and Total nitrogen(TN) contents of the compost piles of the two farms (Ethio-highland and ZK farms) indicated in table (2).

At the beginning of composting organic carbon in pile one and pile two atEthio-highland and ZK was found in the range 45.7 to 45.9 %, 42.2 and 42.3%respectively.The cow dung mix compost in ETHF was reduced 56% and that of EM mix was 37% of their OC content. In ZKF, however, the OC content of cow dung and EM reduced by approximately 60% and 41% respectively.The organic carbon content decreased in all treatment windrows that may be because of the evolution of carbon dioxide (Hernandez-Apaolaze *et al.,*2000).Both farms in Ethio-highland and ZK during composting period, percentage of organic matter in pile one and pile two decreased drastically.

At the beginning of composting total nitrogen content in Pile one and Pile two at Ethio-highland and ZK was found in the range 1.5 to 1.1 %, 1.35 to 1.043 respectively. The data showed a decrease of 37-60% of OC, and an increase of20-26% ofTN, in manure amended (pile 1) modulating their C: N ratio at the minimum acceptable limit of around 30.5(ETH) and 31.2 (ZK) compared to the pile 2 of both sites (>41%) (Table. 2).At the end of composting the total nitrogen content of the two finished composts wassignificantly higher (1.3-1.9%) than TN of (1.3.-1.5%) reported by Travis*et al*. (2003)

Table.2: The fate of Organic carbon (%) and total nitrogen (%) of the composting material during the composting processes at the two composting sites.

Time	ETH-highland						ZK Flowers					
	Pile 1			Pile 2			Pile 1			Pile 2		
	OC	TN	C:N	OC	TN	C:N	OC	TN	C:N	OC	TN	C:N
0	45.7 (1.1)[a]	1.50 (0.1)[f]	30.5 (1.2)[a]	45.9 (1.2)[a]	1.1 (0.1)[e]	42.5 (0.5)[a]	42.2 (1.5)[a]	1.35 (0.1)[a]	31.2 (1.3)[a]	42.3 (1.3)[a]	1.04 (0.1)[d]	40.6 (1.6)[a]
7	40.9 (2.1)[b]	1.55 (0.2)[e]	26.4 (0.5)[b]	39.2 (1.2)[b]	1.1 (0.1)[e]	35.6 (0.6)[b]	35.1 (1.1)[b]	1.40 (0.1)[a]	25.1 (0.6)[b]	37.3 (1.2)[b]	1.06 (0.1)[c]	35.2 (1.2)[b]
21	36.2 (0.5)[c]	1.65 (0.1)[d]	21.9 (0.4)[c]	31.9 (0.5)[c]	1.2 (0.1)[d]	26.6 (1.2)[c]	30.7 (1.4)[c]	1.41 (0.2)[a]	21.8 (1.2)[c]	35.2 (1.2)[c]	1.06 (0.1)[c]	33.1 (1.4)[c]
63	30.6 (1.6)[d]	1.75 (0.1)[c]	17.4 (0.5)[d]	30.7 (0.6)[d]	1.3 (0.2)[c]	23.6 (1.1)[d]	22.3 (0.4)[d]	1.55 (0.1)[a]	14.4 (1.1)[d]	27.1 (1.3)[d]	1.1 (0.1)[b]	24.5 (0.5)[d]
91	25.5 (1.0)[e]	1.86 (0.1)[b]	14.1 (0.2)[e]	29.8 (1.2)[e]	1.4 (0.1)[b]	21.3 (1.1)[e]	21.7 (0.2)[e]	1.61 (0.2)[a]	13.5 (1.1)[d]	25.7 (1.1)[e]	1.29 (0.2)[a]	21.4 (0.5)[e]
98	20.0 (1.2)[f]	1.91 (0.1)[a]	11.0 (0.2)[f]	28.6 (1.2)[e]	1.5 (0.1)[a]	19.4 (0.5)[f]	16.6 (1.2)[f]	1.7 (0.1)[a]	11.5 (1.1)[e]	24.7 (1.2)[e]	1.3 (0.1)[a]	19.5 (1.1)[f]

Values are means±standard error (n=3). Values within the same column followed by the same letter are not significantly different according to Bonferroni test (P=0.005)

Fikadu*et al.*, (2014) also reported a decrease in organic carbon (35-37%) in vegetable amended coffee husk composting after 90 days of treatment.Bernal *et al* (1998) also showed similar decreasing pattern of organic carbon mineralization (51%) in compost mixture of city refuse and sweet sorghum bagasses and (25%) in poultry manure + cotton waste + olive mill waste water. At the end of composting both manure- amended piles in the two composting sites achieved C: Nratio of <15 after 91 days of composting; whereas the two EM-amended composts achieved C:

N ratio of almost 20 after 98 days of composting. Similarly, the C: N ratio of final composts in this study was comparable with the C: N ratios of 11.07, 12.73, and 18.11 reported from cow amended and vegetable mixed coffee husk composting (Fekadu *et al.*, 2014).Finally, the mature composts C: N ratio of Pile 1 was within the recommended range 5-15 (US EPA, 1994).

5.1.3. Ammonia-Nitrogen, Nitrate-Nitrogen and Ammo-N: Nitr-N

The analysis of the different intermediates of nitrogen catabolism (NH_4-N, NO_3-N, and the ratio ofNH_4-N:NO_3-N) during the various stage of composting is shown in Table3 and 4. In all cases there was an increase in NH_4at all composting sites. Accordingly, composts at Ethio-Highland farm showed the highest NH_4contents of 1619-2887mg/kg at P1 and 1048-2190 mg/kg compost at P2.during the first phases of composting likewise the NO_3-N contents increased at the latter stage with 1215-2297 mg/kg at P1 and 1029-2156mg/kg at P2. The composts at ZK farms showed similar pattern up to 2188-2386.7NH_4 (mg/kg) and NO_3 of 1550-1940, mg/kg and $NH_4$of 1624-1890 mg/kg and NO_3 of 1236-1944 mg/kg at P1 and P2, respectively.

The ratio of Ammonia-N and Nitrate-N is another simple chemical indicator of maturity. Consequently, a ratio of 0.06 and 0.19,and respectively ratio of with NH_4-N: NO_3-N ratio of 0.01 and 0.11, were recorded from ETH and ZK flowers at P1 and P2 composting, respectively.

In general, there was an inverse relationship between NH_4-N and NO_3-N as afunction of composting age in favor of the oxidized form of NO_3. The ratio is more evident at P1 than P2 (Table 3 and4).

Ammonia-N is often highest in the early stages of composting, declining as compost stability increases. The lower respiration rates that occur in mature compost are more favorable for nitrate production via nitrification and less favorable for nitrateloss via denitrification. The low nitrate during the first phase (thermophilic stage) is due to the fact that nitrification is strongly inhibited at temperatures above 40°C. The loss of ammonia and the increase in nitrate may be due to the conversion of the former to nitrate by oxidation process during the maturation stage which was similar to the work of Tiquia, (2001).Generally, the highest concentration of ammonia during initial and processing stage is the result of organic N is first mineralized as ammonia during the active phase of degradation, followed by nitrification during the maturation stage composting process (Francou*et al.,* 2005).

Table 3.Variation of Ammonia-N (mg Kg^{-1}), Nitrate-N (mg Kg^{-1}) and Ammo-N: Nitr-N (mg kg^{-1}) in flower Cut Composting with time in Ethio-Highland farm. The results are expressed as means plus standard error of three replicates

Time	Ammonia-N		Nitrate-N		Ammonia-N: Nitrate-N	
Time	Pile 1	Pile 2	Pile 1	Pile 2	Pile 1	Pile2
7	1619.93 ±4.58^{c}	1048.49±4.58^{c}	17.02±2.11^{e}	21.10±2.11^{d}	95±2.17^{a}	50±2.17^{b}
21	2197.76±6.01^{b}	1517.82±6.01^{b}	23.06±1.41^{d}	17.92±1.41^{e}	95±4.26^{a}	84±4.26^{a}
63	2887.56±9.36^{a}	2190.4±6.18^{a}	2297.82±4.53^{a}	1510.38±1.87^{b}	1.3±2.2^{b}	1.5±3.3^{c}
91	312.82±6.18^{d}	178.33±9.36^{e}	1215.36±4.53^{c}	2156.36±4.5^{a}	0.25±1.4^{c}	0.08±2.08^{c}
98	111.07±0.2^{e}	196.62±0.82^{d}	1754.96±19^{b}	1029.63±19.4^{c}	0.06±0.01^{d}	0.19±0.04^{d}

Values are means±standard error (n=3). Values within the same column followed by the same letter are not significantly different according to Bonferroni test (P=0.005)

Table 4.Variation of Ammonia-N (mg Kg^{-1}), Nitrate-N (mg Kg^{-1}) and Ammo-N: Nitr-N (mg kg^{-1}) in flower Cut Composting with time in ZKfarm. The results are expressed as means plus standard error of three replicates

	Ammonia-N		Nitrate-N		Ammonia-N: Nitrate-N	
Time	Pile 1	Pile 2	Pile 1	Pile 2	Pile 1	Pile2
7	2188.43 ±71.2 [b]	1821.06±71.2 [a]	25.57±5.21 [d]	13.600±5.21 [d]	85.5±13.7 [a]	133.9±13.7 [b]
21	2386.71±1.33 [a]	1624.90±1.33 [b]	24.49±1.02 [d]	6.880±1.02 [e]	97±1.3 [b]	236.2±1.3 [a]
63	1930.76±1.2 [c]	1890.427±1.3 [a]	1944.86±4.8 [a]	1188.33±4.7 [c]	0.99± 0.3 [c]	1.59±0.27 [c]
91	96.223±5.9 [d]	170.100±5.9 [d]	1236.84±2.8 [b]	1250.98±2.8 [a]	0.07± 2.1 [c]	0.14± 2.1 [c]
98	14.68±.43 [e]	145.00±4.34 [e]	1142.46±5.6 [c]	1215.28±5.6 [b]	0.01±0.07 [d]	0.11±0.77 [d]

Values are means±standard error (n=3). Values within the same column followed by the same letter are not significantly different according to Bonferroni test (P=0.005)

5.1.4. Total Phosphorusand Potassium

The total phosphorus and potassium contents of the compost piles at Ethio-highland and ZK farmsduring the different composting age are shown in (Table6). In both cases, the nutrients increased in P (515-7921) and K (1101-4521mg/kg) of composts. The increase in both nutrients was more on the dung-amended compost (P1) than the EM-treated composts(P2).

In general the total percentage of phosphorus content of piles one and pile two of both sites had shown an increasing trend during the composting period which wassimilar to the work of Tiquia, (2001). Alexander (1987) showed that decomposing microorganisms consume only small

quantities of phosphorus for the synthesis of protoplasm and release the remaining soluble phosphates to be stored (sorbed) in the compost. The differences of the phosphorus contents of piles may be associated with the difference rate of mineralization which may be associated with the OC and TN contents at the initial phase that may have influenced the activity of the microbes to release phosphorus.

Table6. Available phosphorus (mg Kg^{-1}) and available potassium (cmol(+)/Kg) contents of the different composttreatments (piles) of the two composting sites at Ethiopian Highland Flower and ZK Flower farms

Age	ETH				ZK			
	P1		P2		P1		P2	
	TP	TK	TP	TK	TP	TK	TP	TK
7	515 (7.912)^{e}	1125 (11.43)^{e}	200 (6.514)^{e}	1101 (7.851)^{a}	315 (4.231)^{e}	1451 (5.25)^{e}	253 (3.25)^{e}	1211 (4.252)^{e}
21	732 (6.114)^{d}	1543 (6.251)^{d}	895 (4.635)^{d}	1751 (5.732)^{d}	645 (6.223)^{d}	1517 (9.25)^{d}	435 (4.11)^{d}	2356 (4.232)^{d}
63	1615 (6.424)^{c}	5560 (11.64)^{c}	1115 (19.60)^{c}	5981 (6.713)^{a}	2500 (4.215)^{c}	6912 (6.51)^{b}	1500 (11.2)^{c}	4100 (9.42)^{b}
91	3651 (7.423)^{b}	6211 (14.25)^{a}	4132 (11.52)^{b}	4922 (4.142)^{b}	3942 (9.215)^{b}	7122 (6.52)^{a}	2500 (13.25)^{b}	4980 (7.523)^{a}
98	7921 (4.122)^{a}	5611 (17.92)^{b}	5211 (6.124)^{a}	4211 (6.752)^{c}	6715 (6.225)^{a}	6100 (1.2)^{c}	4521 (11.23)^{a}	3921 (6.253)^{c}

Values are expressed as means of three triplicates. Numbers followed by different letters along the column are significantly different (Tukey HSD, p=0.05)

TP = Total phosphorous TK = Total potassium

The exchangeable potassium contents of the different piles at both farms progressively increased as a function of time. Its contentwas higher than phosphorus and more on pile 1 than pile 2 during composting. However, unlike phosphorus, potassium content slightly decreased at the end of composting. This may be due to the fact that it is highly soluble in water and excess water soluble potassium may be easily lost through leachate since water was frequently showered over the windrows during composting (Frike and Vogtmann, 1994).

Table 7.Summary Matured Composts

		ET-Highland		ZK Flowers		
No	Parameter	P1	P2	P1	P2	Standard
1	pH	7.1	7.6	7.2	7.1	6.5-8.5de Bertoldi,(1985)
2	MC (%)	43.2	35.5	43.7	39.2	<40% European countries and
3	TN (%)	1.9	1.5	1.7	1.7	0.5-2.5%Travis,*et al*,2003
4	C: N (%)	11.00	19.4	11.5	19.5	5-15%Martin (1991)
5	Ammonia (%)	0.011	0.02	0.001	0.014	0.04 % Zucconi and de Bortldi,1987
6	Ammonia: nitrate ratio (%)	0.06	0.19	0.01	0.11	0.16% Bernal *etal*,1998
7	TP (%)	0.79	0.52	0.67	0.45	0.4-1.1% Bord na Mona(2003)and Travis,*et al*,2003
8	TK (%)	0.60	0.421	0.61	0.40	0.6-1.7% Bord na and Mona(2003)
9	GI (%)	81.11	71.67	72.8	71.5	50% Pytotoxin free and 80% Mature Zucconi *etal*,1981a and b.

MC = MoistureContent GI =Germination Index

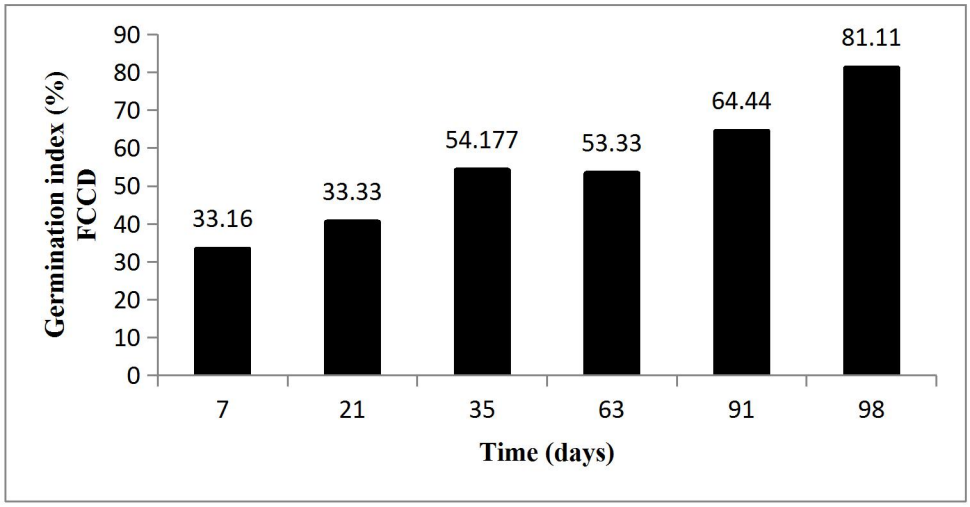
5.2. Maturity Test

The maturity of the compost was tested through observation of physical parameters such as color and odor. The finished composts did not show foul smell; but a pleasant earthy odor and the color of the compost was dark brown which was an indicator of maturity and stability (Martin,

1991, Haug, 1993).The C: N ratio is also a good indicator of how well the compost is finished and cured (Bernal *et al.,* 1998).

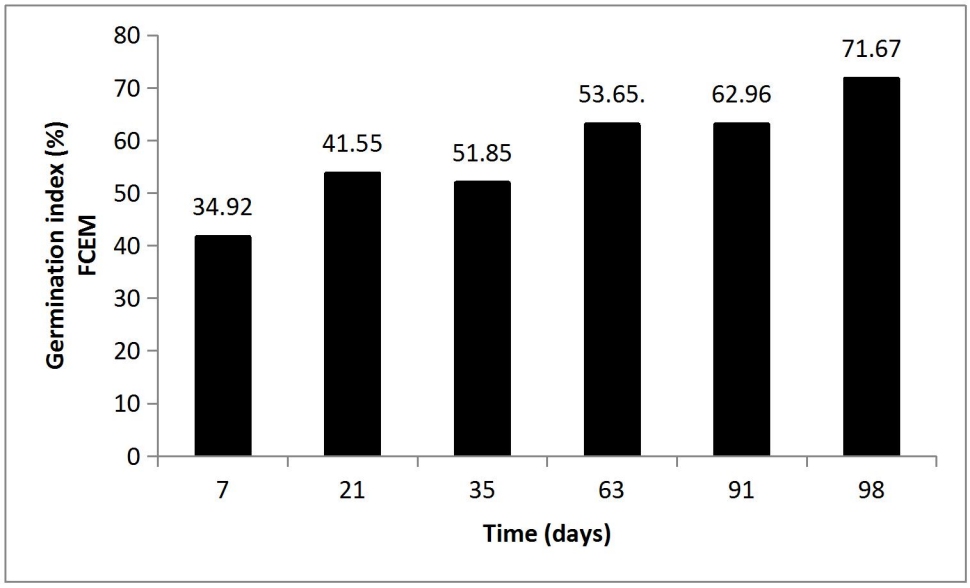
At the beginning of the composting, germination index (GI) of all piles at both Ethio-highland and ZK Flowersites,was below 50% (Fig 2a, 2band3a,3b).But the percentage of germination indices in pile one at Ethio-highland and ZK sites was above 50 after 35 and 63 days of composting, respectively. At 90th days of composting, the percentage of germination indices ofPile 1 and Pile 2 was 81.11 and 72.8 respectively at Ethio-highland farm, whereas the germination indices of the different piles was 72.2 and 71.5 indicating that the piles would have required more time to reach to the minimum GI of >81% to mature. According to Zuuconi *et al*.(1981) germination index of composts above 60% on tests of *Lepidium sativum*is considered as free from phytotoxic substances, but composts with GI above 80% areonly considered as a measure maturity benchmark of safety.

Fig 2aChanges in germination index of compost material collected at different times of the process from Flower Cuts-Cow Dung at EHF.



FCCD = Flower Cuts plus Cow Dung

Fig2bChanges in germination index of compost material collected at different times of the process from Flower-Cuts plusEMplusmolasses at EHF.



FCEM = Flower-Cuts plus EM plus molasses

Fig 3a:Changes in germination index of compost material collected at different times of the process from Flower Cuts plus Cow Dung at ZK farms.

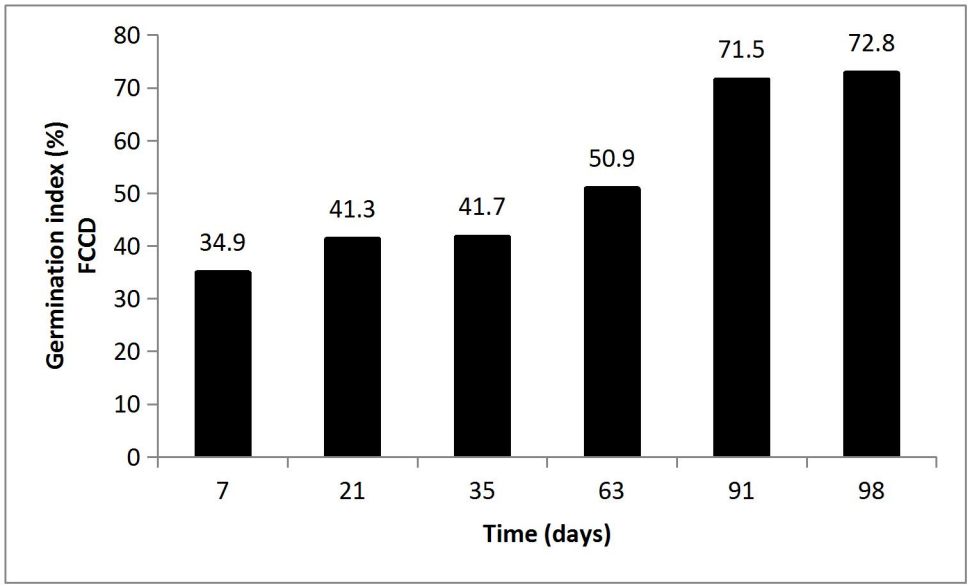
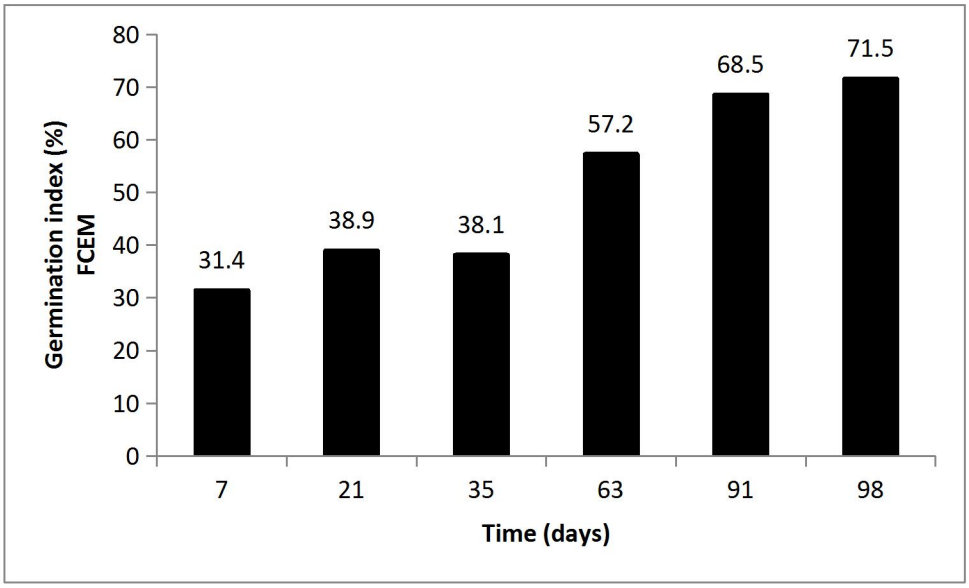


Fig 3b:Changes in germination index of compost material collected at different times of the process from Flower Cuts plus EM plus molasses at ZK farms.



5.3Micronutrient

The micronutrient contents of Fe, Mn, Cu and Zn of the different compost piles at the two experimental sites at the end of composting is shownon table (8).Availability of all micro nutrients (trace metals) in both pileswas not significantly different.

Heavy (Trace) metal concentration of the matured composts**:** The trace metalconcentrations at the two farms and in both piles were within the acceptablelimitsof the proposed standards by the World Bankfor MSW composts in developing countries(Hoornweg*et al.,* 2000):Cu (8-10mg Kg^{-1}), Zn (20-25mg Kg^{-1}) and Fe and Mn (50-300mg Kg^{-1})

Table7. Micronutrient contents of the different compost piles at the two experimental sites in mg Kg^{-1}after 90 days of composting.

	ETH		ZK	
Micronutrients	P1 Mean ± SE	P2 Mean ± SE	P1 Mean ± SE	P2 Mean ± SE
Mn	197.62(7.23)	195.203(7.06)	146.5(1.2)	145.2(5.2)
Zn	25.197(2.96)	23.505 (2.96)	21.5(0.2)	21.4(0.1)
Fe	96.825 (1.43)	94.38 (1.43)	149.1(0.3)	146.2(1.0)
Cu	9.85(.400)	8.826(4.182)	9.3(0.04)	8.2 (0.3)

5.4. Total aerobic bacteria, actinobacteriaandfungi analysis

Total counts of aerobic bacteria (TBA), actinobacteria and fungi from the two different compost piles indicated significant variations in relation to temperature changes during the composting process (Table 9).The data showed that the microbial counts of Total aerobic bacteria (TAB) of the different piles (at both experimental sites was high (log 6.32-7.46 MPN g-1 dw) at the initial stage and further increased up to7- 21 days of composting, and drastically reduced by two units (4.9-5.8 MPN g-1 dw) and stabilized at the cooling stage (91-98 days).The TAB showed the same count pattern across the piles with slightly higher count in P1 than P2, irrespective of the sampling site(Table 9).

The microbial counts of the actinomycestes was much lower than the TAB count at the beginning of composting (4.26-4.85MPN g-1 dw) within the piles and steadily increased by 2-3 units irrespective of the composting stage and treatments (piles 1 Piles 2) (both active and cooling stage).

The fungi showed the lowest lower number of counts (2.2-5.5 MPN g-1 dw) than both the bacteria and the actinomycetes with population fluctuations in the middle of composting (21-63 days), and eventually stabilized at the maturation (end of composting) stage (91-98 days).

The decrease infungal numbers is associated with temperaturesabove 50^0Cwhere most fungi are unable to thrive at temperatures above50^0C (Ryckeboer*et al*., 2003). They increased later when temperatures dropped. The return of fungal communities at the end of composting may be as a result not only of the reduced temperatures, but also the availability of cellulose, hemicelluloseand lignin in the remaining piles (Hassen*et al*., 2001). Similarly, the highest number of actinobacteria at the end of composting atboth ETH and ZK farms in all pilesmay be due to their r strategy, and their capacity to utilize polymers such as hemicellulose, lignin and cellulose left in mature composts (De Bertholdet *al*., 1983).

Table 9:the distribution of Total Aerobic bacteria, actinomycetes, and fungi on the different piles of the two experimental sites

Compost age	ETH						ZK flowers					
	P1			P2			P1			P2		
	TAB	Act	Fun	TAB	Act	Fun	TAB	Act	Fun	TAB	Act	Fun
0	7.46	4.40	4.50	6.81	5.04	3.18	6.81	4.26	4.60	6.32	4.85	4.21
7	7.85	5.18	4.30	6.90	4.11	3.45	6.53	4.52	4.80	6.95	4.43	4.13
21	7.92	5.34	3.15	7.15	5.18	2.29	5.98	4.30	3.15	4.70	4.30	2.20
35	5.15	6.31	4.51	5.60	5.92	2.51	4.48	5.43	3.51	4.21	5.19	3.11
63	4.32	5.98	5.11	5.11	6.31	3.91	4.91	5.98	4.91	5.41	5.40	4.56
91	5.11	6.48	5.25	4.91	6.32	4.57	4.51	6.01	5.12	4.95	6.01	5.53
98	5.31	7.15	5.55	5.81	6.40	4.92	5.11	6.57	4.85	5.23	5.82	5.19

5.5. Detection of *Agrobacterium* spp.

Agrobacterium spp. appeared and produced convex, circular, translucent, pale blue-green colonies that were readily distinguished from other bacteria that produced a yellow (acid) reaction in the medium as described by Spiers(1979) at the initial phases (0 days) of composting. But, on day 63, their colony number was found to be highly reduced and became nil on the 98thday. This disappearance of *Agrobacterium* spp. shows good quality of the compost since they are phyto-pathogens and it could be due the progressive effect of antagonist bacteria present in the compost as reported by Kerkeni *et al*. (2014).

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Composting cow dung and cut flower produces valuable organic fertilizer compost with large amount of major plant nutrients such as nitrogen, phosphorus and potassium than composting using effective microorganism (EM)plus molasses. It was also found to be better in C: N ratio, NH_4-N: NO_3-N ratio as well as germination index that is related to compost maturity.

This composting system is technically simple, economically workable and easily adaptable to construct anywhere at floriculture industries in the country to improve crop productivity.

6.2 Recommendations

- Windrow composting method should be used by flower industries since it is technically simple, economically workable and easily adaptable to construct.
- To perform rapid composting of cut flower and cow dung using windrow system, water showering and turning of piles every seven days interval should be done to complete the process within three month.

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APPINDICES

Annex I. Pictures Taken During the Composting Period

Fig.1. Waste dumping area in ETHF at Sebeta

Fig.2. Showing shredding offlower waste before composting at ETHF

Fig.3.Treatment windrows and shed preparation at the beginning of compostinginZK

Fig.4. Turning of pile in ETHF at Sebeta

Fig.5. Picture of Sampling

Fig.6. Pictures of finished compost