AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVLOPMENT (AAMUSTED)

MAMPONG-ASHANTI

EFFECTS OF DIFFERENT COMPOSTING METHODS AND APPLICATION RATES ON GROWTH AND YIELD OF CARROT (*Daucus carota* L.)

MICHAEL OKYERE

MASTER OF PHILOSOPHY IN CROP SCIENCE (AGRONOMY)

OCTOBER, 2025

AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

(AAMUSTED)

MAMPONG-ASHANTI

EFFECTS OF DIFFERENT COMPOSTING METHODS AND APPLICATION RATES ON GROWTH AND YIELD OF CARROT (*Daucus carota* L.)

MICHAEL OKYERE

(820197001)

A THESIS IN THE DEPARTMENT OF CROP AND SOIL SCIENCES EDUCATION, FACULTY OF AGRICULTURE EDUCATION, SUBMITED TO THE SCHOOL OF GRADUATE STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF PHILOSOPHER IN CROP SCIENCE

OCTOBER, 2025

DECLARATION

STUDENT'S DECLARATION

I declare that except for references to the works of other researches which have been duly cited and acknowledged, this research is the result of my own effort and that no part or whole has been presented for another degree elsewhere.

CANDIDATES NAME: OKYERE MICHAEL

Signature…………………..

Date………………………..

SUPERVISORS DECLARATION

I hereby declare that this work has been supervised according to the guidelines for the supervision of the postgraduate thesis as laid done by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

Prof. Kofi Agyarko (Main Supervisor)

Signature………………………

Date……………………………..

Rev. Kwame Nkrumah Hope (Co-Supervisor)

Signature……………………………..

Date……………………………….

ACKNOWLEDGMENT

I thank God Almighty for his protection throughout the period of my study. To him be the glory.

And Adorations. Again, I deem it unending joy to express my profound and heartfelt gratitude to my supervisors, Prof. Kofi Agyarko and Rev. Kwame Nkrumah Hope whose invaluable assistance in the form of advice, corrections, suggestions, encouragement, patience and directions made this work a successful one. God Almighty reward their precious time and energy sacrificed. My sincere thanks also goes to my lovely wife; Mrs. Grace Okyere for her encouragement towards this research. God richly bless you all.

DEDICATION

This thesis is dedicated to my lovely wife, Mrs. Grace Okyere and my lovely children; Nyametease Akua Konadu Okyere, Owusu Afriyie Adepa Okyere and Margaret Nyarko Okyere for their love and prayers throughout the period of my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The world population is expanding, cities are becoming more populated, living standards are growing, and technology is developing quickly. These factors have all led to an increase in the quantity and variety of solid wastes produced by industrial, residential, and other activities. The root crop yields have been increased through a number of efforts, but these efforts have raised questions about the use of inorganic fertilizers, which depletes soil fertility and soil health. Solid waste materials from industries and households were collected and used for the production of compost, an organic source of fertilizer which could be used to replace inorganic fertilizers. A field experiment was carried out from January to August 2022 at the research farm of Adanwomase Senior High School and the Teaching and Research field of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mamponteng Municipality, Ashanti Region, to determine the composting technique that offers most nutrients for crop growth and to evaluate the compost application rate needed to produce carrots at the maximum level possible.

The experiment was set up in a randomized complete block design with three replications. The treatments were composting technique (pit method, heap method and bucket method) and composting rates of (5t/ha, 10t/ha and 15t/ha). Agronomic parameters measured of the carrot crop were plant height, number of leaves of plant, root length, root width, number of harvested roots, and number of deformed roots, fresh root weight, and fresh leave weight. The results showed that the heap method of compost technique supplies adequate amount of macro and micro nutrients to plants for proper growth and that applying heap method of compost at an application rate of 15 tons/ha would give maximum performance and good yield of the crop than the other application rates of composting.

CHAPTER ONE: INTRODUCTION

1.1 Background

Land scarcity is one challenge that peri-urban smallholders farmers in various regions of West Africa are experiencing on an increasing basis (Brinkmann *et al.,* 2012). As a result, cropping intensifies and soil fertility falls (Becx *et al.,* 2012). The Green Revolution (GR) of the 1960s informed mid-20th century remedies to this issue and encouraged the use of inorganic fertilizers. Later soil fertility management (SFM) strategies, on the other hand, prioritized organic supplements like manures and composts and acknowledged the significance of sustainability (Ahmad, 2007). One such strategy was Low External Input Sustainable Agriculture (LEISA), which gained popularity in the tropics in the 1980s (Kessler and Moolhuijzen, 1994).

The current Integrated Soil Fertility Management (ISFM) model, which recognizes the significance of combining the application of inorganic and organic fertilizers, has kept this focus (Bationo, 2009). Farmers in the West African savanna have long used organic amendments, perhaps most notably in the densely populated Kano close settled zone in northern Nigeria (Mortimore, 1998; Smaling and Dixon, 2006). The world population is expanding, cities are becoming more populated, living standards are growing, and technology is developing quickly. These factors have all led to an increase in the quantity and variety of solid wastes produced by industrial, residential, and other activities. It is important to know what to do with the garbage produced by these advances in Ghana, where infrastructure, facilities, product creation, and service delivery are all developing quickly. In Ghana, household garbage includes glass, paper, plastic, metals (such as aluminum), and food waste. The amount of municipal solid waste (MSW), which is currently averaging 1.3 billion tonnes annually, is expected to increase to 2.2 billion tonnes annually by 2025, according to a report by the World Bank on the state of solid waste around the world, with a large portion of the increase coming from rapidly expanding cities in developing countries. With their populations predicted to reach 676 million by 2025, low-income nations are also anticipated to produce 213 million tonnes of solid trash daily. With a population of 2.08 billion, lower middle-income countries are also anticipated to produce 956 million tonnes of solid garbage each day. By 2025, countries with a projected population of 619 million in the upper middle-income bracket will produce 360 million tonnes of waste every day. By 2025, trash generation in high-income countries would be 686 million tons per day, while the population will be 912 million.

According to the analysis, municipal solid waste challenges will be substantial, if not even more so than the challenges posed by climate change (World Bank, 2012). Ordinarily, waste is disposed of without taking into account the effects on the environment and human health (Zerbock, 2003). In developing nations, managing solid waste is a huge challenge because of issues including population growth, poverty, and inadequate government investment (Jara- Samaniego *et al.*, 2017). Due to the lack of infrastructure for proper solid waste treatment and the indiscriminate disposal of waste in developing nations like Ghana, there has been a significant buildup of waste (Shekha, 2011). As the globe tries to keep up with its rapid generation, organic solid waste poses a severe threat to the ecosystem (Lim et al., 2016). Because of reluctance on the part of those in charge of garbage collection and disposal, the placement of the disposal facility at such a significant distance result in an overflow of municipal waste at the collecting point. Begum (2012) believes that although the municipal assembly's initiative is admirable, it is unclear whether it will have any impact on the prevalence of inappropriate solid waste disposal. The process of gathering, moving, processing, discarding, managing, and monitoring waste items is known as waste management. The process is typically carried out to lessen the impact of the materials on health, the environment, or aesthetics. According to Sharholy *et al.* (2008), MSW is typically dumped in low-lying regions, left to rot, and most of it is landfilled without any operational oversight or safety measures.

The organic waste from the vegetable market is creating a lot of trouble once it gets to the landfill due to its high biodegradability (Bouallagui *et al.*, 2004). However, burning of solid trash typically produces more harmful gases and other solid leftovers in the environment. According to Kulcu & Yaldix (2004), composting and biogas processes can be the best alternatives to landfilling as sustainable management for MSW. Pyrolysis and incineration may also be viable options for getting rid of this organic waste. The MWSR (2000) suggested composting as the best method for reducing waste problems in our community for stabilizing and digesting biodegradable trash. Therefore, proper management of these organic fractions is essential for protecting the environment and maximizing the value of any byproducts produced during the process. Organic waste that has been composted results in a final product that is stable, free of pathogens and phytotoxins, and that also has certain humic characteristics (Zucconi and de Bertoldi, 1987). In a developing nation like Ghana, almost 50% of a typical city's MSW stream may be easily composted.

The high animal and vegetable waste content of the waste stream, when paired with an established materials recovery system (mixed waste stream), is sufficiently biodegradable to produce high-quality compost at a small or medium scale in developing nations like Ghana. By simplifying the recovery of non-compostable and minimizing the introduction of new packaging into the waste stream (keeping in mind the substantial benefits of excellent packaging for public health), it is possible to achieve the goal of compostability (UNEP, 2014). Domestic waste is made up of all objects that people no longer need and either intend to dispose of or have already done so. Examples include plant peels, leftover vegetables, dried leaves (cowpea, etc.), and more. Poor waste management has been a serious issue for human life and health in both urban and rural regions. A healthy environment impacts good health, which in turn influences human productivity. Therefore, it can be claimed that all nations' wealth and economic standing are inevitably impacted by a decent and clean environment.

According to a study by Margaret (2013) on household knowledge, attitudes, and behaviors in solid waste segregation and recycling in urban Kampala, awareness and understanding of garbage disposal are influenced by a variety of factors. She said that the level of local recycling knowledge, household income, educational attainment, and gender all affected the participation in solid waste separation activities. Ayodeji (2013) also investigated the waste management methods and awareness of secondary school teachers in Ogun State, Nigeria, and found that despite having poor waste management procedures, instructors were knowledgeable and conscious of waste management. National and international guidelines on waste management are focused on preventing, minimizing, reusing, recycling, and recovering garbage (Topal, 2013). Composting as a method of waste management aids in enhancing the tilth and structure of the soil, enabling root development in deeper soil layers. In turn, this encourages plant development and raises yield. Although using organic fertilizers is one of the most traditional ways for farmers to produce crops, particularly in areas where these natural resources are abundant, it is important to keep in mind that using fresh manure is not advised due to its burning effects on plants, especially young seedlings (Oelhaf, 1978; Taiz & Zeiger, 1991; Lampkin, 2000; FSSA, 2003). Nitrogen is the ingredient that most restricts growth among the key nutrients required by crops.

Through the process of exchange capacity, compost increases the amount of humus in the soil, which has the capacity to hold both positively and negatively charged ions (cations and anions) and make them available to the plants. In times of drought, the humus that compost adds absorbs a lot of water and makes it available to plants. For sandy soils, which retain relatively little water and little nutrients, these characteristics are crucial as well as the ability to keep nutrients (Scholl and Nieuwenhuis, 2004). By adding organic matter to the soil, compost enhances the soil's structure or workability, making it easier to cultivate (sand and clay soils). Because clay soil has few macro-pores, it prevents water and oxygen from reaching plant roots, suffocating them and increasing their vulnerability to disease and pests. Composting hence aids clay soil architecture to open and enable air penetration to roots and water drainage, both requirements for optimum plant growth (Eimhoit *et al.*, 2005). Increased root growth and nutrient uptake from organic materials lead to increased yields. The high temperature in the compost heap used in composting processes kills illnesses, bugs, and weed seeds (Scholl and Nieuwenhuis, 2004). However, if organic fertilizers are used improperly, nitrates can build up in ground water and in crops if they are absorbed by plant roots (Oelhaf, 1978; Gontcharenko, 1994). Pathogens from plant or animal materials that are dangerous to people or plants may be present in improperly treated organic fertilizers. Municipal trash and sewage-derived compost may contain poisonous substances like lead, cadmium, and arsenic that contaminate food and lower quality.

1.2 Problem Statement and Justification

Root crop yields have increased through a number of efforts, but these efforts have raised concern about the use of artificial fertilizers, which depletes soil fertility and soil health. The use of inorganic fertilizers, according to Pahalvi et al. (2021), not only improves crop productivity but also changes the physicochemical and biological characteristics of the soil. However, continued use of these fertilizers causes a decline in soil organic matter (SOM) which translates to a decline in the agricultural soil's quality (Savci, 2012).

The structural and functional characteristics of microbial communities in the soil are said to be disrupted by the extended use of inorganic fertilizers, which has a negative effect on the microbial diversity of the soil *(Tripathi et al.,* 2020). The prolonged use of inorganic fertilizers by farmers leads to the buildup of heavy metals in the soil which causes soil pollution and thus, affects the productivity of crops in the field (Savci, 2012). Farmers typically let their agricultural byproducts go to waste instead of using them for compost. Agricultural byproducts and solid waste materials from households can be collected and used for the production of compost, an organic source of fertilizer which could be used to replace inorganic fertilizers (Hoornweg *et al.,* 2000). Unlike inorganic fertilizers, compost enriches the fertility of the soil without causing harmful effects to the physical, structural and biochemical properties of agricultural soils (De Corato, 2020). Composting allows for the decomposition and stabilization of organic waste into a product that can be utilized as an organic fertilizer or soil conditioner (Ahmad, 2007). It improves the soil's void ratio, organic matter content, water permeability in low-permeability soils, and eventually the soil's capacity to retain water. (Kurzemann *et al.*, 2020). Humus, a stable product of compost provides nitrogen retention, preventing nitrogen from blending into the groundwater in the soil (Martínez-Blanco *et al.*, 2013).

1.3 Objective the study

The main objective of the study was to evaluate compost application rates and methods that can be used to produce the maximum yield of carrot.

The specific objectives of the study were to:

1. determine the composting method that offers the most nutrients for crop production
2. assess the rates of compost on the growth and yield of carrot
3. evaluate the effects of the compost application rates on nutritional analysis of carrot.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and distribution of carrot

Carrot, one of the most widely cultivated vegetable is believed to have originated in central Asia, specifically in the hills of Punjab and Kashmir in India, with secondary distribution centers in Asia, Europe, and Northern Africa (Administrator, 2009). Since its introduction to the United States some 250 years ago, the carrot, *Daucus carota*, has proliferated across North America (Ohio Perennial and Biennial Weed Guide, 2009). The majority of these countries, as well as Central, East, and West Africa, South America, and the Caribbean cultivates the crop. The top ten countries that cultivates this crop are China, the USSR, the USA, Poland, the UK, France, Italy, Germany, and Canada (De Lannoy *et al.*, 2001).

According to research done by De Lannoy (2001), carrots have a hollow, upright, extremely short stem with quadrilateral leaves that can become as long as 30cm. In a cool region, where it is well adapted, carrot stalk can grow in the second year to a height of 1.8m or more, depending on the variety (Tweneboah, 1997). It has a single primary taproot system that develops into a tuberous structure with absorbent hairs but no secondary roots. Carrot roots have a diameter of 3–4 cm and are composed of an exterior section (cortex) that is soft and darker in color than the core and a center cylinder (core) that is more or less fibrous (De Lannoy, 2001). According to Langer *et al.* (1991), depending on the variety, carrot can develop and mature in 60 to 85 days.

2.2 Botany and Morphology of carrot

The carrot plant, *Daucus carota,* can grow to a height of 20 to 100 cm and is often produced as an annual crop. The main or tap root is swollen, irregular in size and shape, and it can be either orange or red in color. The stem is compact, sturdy, and short. The annual or biennial upright herb can reach a mature vegetative height of 50 cm and a blooming height of 150 cm. The taproot is straight, conical in shape, and is 2 to 5 cm in diameter at the top and 5 to 50 cm in length. At the base of the plant, the leaves form a rosetle. The majority of the blooms are bisexual, but there are also a few male flowers that are usually found in the middle of the umbel, which are dark purple and sterile (Kahangi *et al.*,2004). The segments-divided, 2-3 pinnate leaves alternate. Typically, the petiole is lengthy and covered at the base. The inflorescence is composed of compound umbels that range in size from 3 to 7cm and are carried on a stalk with several branches. The blooms typically have five sepals, five petals, and a hairy ovary. They are often white or pink in color. The fruits are 3–4 cm long, oblong-ovoid, and have hooked spines (Tindall, 1983).

Breeding efforts of *Daucus carota* have resulted in a plant with greater disease and insect resistance. The selection process was focused on altering length and diameter as well as reducing xylem size and enhancing phloem width and sweetness (Rachel, 2002). The first carrots were not orange; they were white, purple, red, yellow, or green. The species didn't change to orange until the 1500s, when Dutch settlers utilized mutant yellow North African carrot seed to create a carrot that resembled the color of the orange home (Rice *et al.*,1987). Carrots are an erect biennial that grow 20–100cm tall and are typically grown as annuals, according to Tindall (1988). The edible taproot swells up and takes on a variety of sizes and shapes. The root lower end may be blunt or pointed, with a globular or cylindrical shape. Carotene is present when fruit is orange or red in color (Rice *et al.*,1987). B-carotene, which in humans is converted into vitamin A, is what gives carrots their distinctive qualities and vibrant orange color. A high-carotenoid diet is linked to a lower risk of cardiac illnesses, according to research. Because of the advantages to health that are listed in Table 2.3, it is one of the exotic vegetables with high value in Ghana. Carrot is a potential crop for export and is in high demand in metropolitan areas (MoFA, 2002). According to Norman (1992), the nutrient-rich edible roots contain water, protein, ash, vitamins, and minerals. When put to layer feed, the carotene derived from the roots can be used to color margarine and enhance the color of egg yolks. Animal feed is made using the mature roots and leaves (Kahangi, 2004). Increased intake of carotenoids has been associated with 20% lower postmenopausal breast cancer rates.

Table 2.1: Nutritional value per 100g of carrot (Rice, 1987).

NUTRIENTS	% value per 100g
Carbohydate	9.00g
Fat	0.20g
Protein	1.00g
Thiamin (vitamin B1)	0.04mg
Riboflavin (vitamin B2)	0.05mg
Niacin (vitamin B3)	1.20mg
Viatimin B6	0.10mg
Vitamin C7	7.00g
Iron	0.66g
Calcium	33.0mg
Magnesium	18.0mg
Phosphorus	35.0mg
Potassium	240.0mg
Sodium	2.4mg.

In addition to providing the aforementioned elements, eating carrots fresh increases their nutritional value, according to research by Agusiobo (199). Consuming a raw carrot can help reduce stress and improve the body by enhancing immunity (particularly in older individuals), detoxifying the liver, combating bronchitis, combating anemia, improving eye health, improving the health of the muscles, flesh, and skin, and lowering the risk of cardiac disorders (ATTP).

2.3 Carrot production

The most popular crop in the *Apiaceae* family and a highly nutritious cool season crop is the carrot (*Daucus carota* L.). Despite being a biannual, the crop is produced as an annual. It is a member of the class of plants that are fairly resistant to winter cold and frost. The crop needs a deep, loamy soil with high levels of organic matter that is well-drained and has a pH between 5.5 and 6.5 (Yayock *et al.*,1988). It also thrives in cool environments, and their seed germinated pretty well, if slowly, in cool environments. According to Moncrief *et al.* (1991), greater temperatures cause crops to mature substantially more slowly.

An economically significant horticultural crop, it has grown in favor recently as people have become more aware of its nutritional benefits. Carotene (1890 mg/100 g fresh weight), a precursor to vitamin A and fiber, is found in abundance in carrot roots, which are consumed as vegetables (Chadha, 2003). It is a fragrant plant with diuretic and digestive characteristics, useful to stimulate the uterus with anti-cancer properties and it stimulates the flow of urine. It also helps to improve eyesight and skin health because of its rich source of beta-carotene (Ageless, 2009). The crop's root is used in salads, stews, curries, and pies. Grated roots are often used in pies. Pickles and halwa are made from tender roots (Kabir *et al.*,2000). The most common source of carotene and a coloring buffer in food preparation, carrot juice is also highly well-liked. When given to layer feed, carotene from the roots is used to color margarine and enhance the color of egg yolks (Kahangi, 2004). In several nations, the leaves (tops) are also utilized as a source for leaf protein extraction, as fodder, and for the creation of chicken feed (Kahangi, 2004). This vegetable crop is also said to have a number of therapeutic benefits, including a cooling effect on the body, a strengthening effect on the heart and brain, the ability to prevent constipation, and diuretic effects (Kifle *et al.,*2019). To make the 'Kanjal' beverage, which makes a great appetizer, purple and black carrots are utilized.

There is a great need to boost the production potential of carrots even though this root crop has many potentials and has been grown extensively for a long time (Allemann & Young, 2002). Rather than being utilized as food, carrot was widely employed by the ancients as a medicinal herb (Kifle *et al.,*2019). Carotene, a precursor to vitamin A, is abundant in it, and it also includes sizeable amounts of thiamin and riboflavin. The flesh of carrots is primarily consumed, either on its own, in combination with other vegetables, or in recipes with meat or fish. It can be roasted with meat or baked, boiled, steamed, or fried. Large quantities are also processed by canning, freezing, and dehydrating, either alone or in combinations with other vegetables (Warman, 2000). In Ghana, carrots are grown in a variety of agro-ecologies, from the lowlands to the mountains. They are one of the few alternative crops that may be produced in the highlands that are prone to frost since they are frost tolerant. They cannot grow in heavy clay or waterlogged soils, only in sandy loam and well-drained alluvial soils. However, some farmers cultivate carrots on up to 0.25 to 1 ha as a means of income (Simretkifle-Iyesus, 1994). Carrots are typically planted on tiny plots in the backyards of town and peri-urban people for family consumption. If rain and irrigation water are available, carrots can be cultivated all year long. However, other factors like as weeds, disease from the environment, and fertilizer application can affect the growth and development of carrot outputs. One of the most important and crucial issues in the production of this crop among those factors is fertilizer application. The need for fertilizer application primarily depends on the state of the soil. Farmers fail to produce excellent quality and yields of this crop since it is highly expensive to buy and utilize inorganic fertilizer. Farmers have been forced to explore for other solutions in order to maintain production due to the rising expense of fertilizers. The greatest option could be to apply compost, which is significantly more environmentally friendly. Compost is not frequently used in Ghana as a soil amendment. Nevertheless, to get a larger yield and better quality, organic and bio fertilizers like FYM, compost, chicken manure, and vermin-composting are becoming more and more important. Farmyard manure provides vital plant nutrients and organic matter, boosts soil microbial activity, and builds up surplus humus content. Both macro and micronutrients are abundant in compost (Fritz, 2007.

2.4 Climate and growth requirements of carrot.

The ideal temperature for carrots cultivation is between 16^{o}C and 24^{o}C. According to Tindall (1993) and Rice et al. (1987), the crop is extremely susceptible to high soil temperature, which causes limited germination, short roots, and pale color when the temperature is over 24^{o}C. Carrot seeds germinate between 7 and 30^{o}C, and excessive temperatures can burn carrot seedlings (Moncrief *et al.*,1991). Research conducted by Kononkov and Kiran (1998) established that carrots may germinate at temperatures between 4.4^{o}C and 26.7^{o}C and can successfully produce their maximum yield throughout the year. Depending on the desired tuber size and cultivar, the crop matures between 70 to 85 days (Rice *et al.*,1987). Carrots can be successfully grown in hot climates at elevations more than 500 meters, according to Parcey (1990). According to Tindall (1983) and Rice et al. (1987), carrot production requires an altitude of more than 500m. The amount of water a carrot needs depends on the environment and soil moisture content (Madgea *et al.*,2004). According to Madgea et al.., (2004), frequent watering is required in hot climates after sowing to minimize soil crusting, which hinders germination, and water stress should be avoided after germination to sustain rapid root growth. Although carrots can withstand a variety of rainfall, it shouldn't be so much that the roots' color changes (Madgea *et al.*,2004). The claim that the soil must be wet and not saturated for carrots is backed by Dupriez and Leener (1990).

According to Kononkov and Kiran (1988), the vegetative period is when carrots demand the most water. A sandy-loam soil that is deeply moist, well-drained, friable, and rich in organic matter is ideal for growing carrots. Dupriez and Leener's (1990) report that carrots can be grown well in deeply moist, fertile, well-loamy soil devoid of stones lends support to this. In sandy soils with lots of compost, carrots thrive. In thick soil, vegetables grow well, but carrots do not unless a lot of organic matter is supplied (Hodder and Stoughton, 1990). Carrot roots fracture in dry soils, yet when the soil is favorable, it has long roots (Tindall, 1983). The ideal soil pH for carrots, according to Tindall (1983) and Rice et al. (1987), is between 5.8 and 6.6. Sinnadurai (1992) similarly suggests that the ideal pH range for carrot growth and yield is between 5.8 and 7.0. According to Blumil et al.., (1999), the crop is thought to survive moderately acidic to alkaline soils. Raised beds are a good option for seed bed preparation because they remove plant waste from the soil's surface that would otherwise prevent seed germination and seedling emergence (Maadge *et al.*,2004).

2.5 Solid waste practice and management in Ghana

Municipal solid waste (MSW) in Ghana is the collective name for waste generated by people in their homes, on the streets, and in public spaces including stores, workplaces, marketplaces, and hospitals. It is frequently the responsibility of corporations or metropolitan local governments to manage this type of waste. Due to growing worries about environmental degradation and resource scarcity, waste management has become a crucial field of practice and research (Brewer, 2001). The majority of experts in solid waste management are aware that there isn't a single, straightforward solution to the issues with solid waste.

A rising number of situations, however, adopt an integrated strategy that combines components of various methodologies (Uif, 1998; Fromme, 1999). Garbage management involves gathering, moving, treating, recycling, and disposing of garbage to lessen its negative effects on amenities or human health. The kind of waste management methods that should be used for effective waste management rely on the makeup of the trash. Although all organic trash should be composted, recycling is a preferable option for managing wastes like plastic, metal, and glass. Waste is managed in a variety of ways, including anaerobic digestion, composting, pyrolysis and gasification, landfilling, and incineration (Adewale *et al.*,2011).

2.5.1 Landfilling

According to Daskalopoulos *et al.* (1998) and Adewale *et al.* (2011), landfilling is an efficient way to dispose of waste in poor nations. It entails dumping refuse into depressions, abandoned mine voids, excavated land, or borrowed pits. This is the practice of discarding waste materials uncovered in pits, excavated land, canals, sloping landscapes, or flat surfaces. Open landfills burn occasionally, causing air pollution. Other environmental disadvantages of landfills include the eyesore of the site, waste blown across the landscape, the presence of feces, the introduction of vermin like mice and rats, stink, and smoke, all of which have an adverse impact on human health (Adewale *et al.*,2011).

2.5.2 Open dump and its effect

An open dumping site is a place where solid trash is dumped without taking environmental protection measures, making it vulnerable to open burning and leaving it open to the elements, pests, and scavengers (Zerbock, 2003). The health risks associated with illegally dumping solid waste are substantial and genuine. Children who are susceptible to the physical (protruding nails or sharp items) and chemical (harmful fluids or dust) hazards posed by this garbage are able to quickly access areas for such dumping. These open dump sites draw rodents, insects, and other animals, posing a health danger. Tire waste dumps are the perfect place for mosquitoes to flourish because the warm, stagnant water inside the waste tire allows them to grow 100 times more quickly than in normal circumstances (EPA, 1998). Municipal solid waste (MSW) is frequently treated by burying it in landfills. Leachate and methane gas are produced by the biodegradation of organic materials buried in landfills (Worrell and Vesilind, 2012; Aziz and Mustafa, 2018). Typically, there is a lot of organic waste, which has a direct impact on the environment. Composting is one of the most significant solutions for organic wastes among the several treatment processes for MSW created. It can be used to recycle waste into usable products and to stop the growth of waste in landfills (Tchobanoglous, 2002). The issue is that countries and cities are producing significant volumes of biodegradable organic waste without having a good solution. As an illustration, regular grocery stores carry items like fruits, vegetables, bread, milk products, fish, and other frozen goods. Therefore, one of the popular solutions to treat organic wastes more cheaply is composting. In developing nations, managing solid waste is a huge challenge because of issues including population growth, poverty, and inadequate government investment (Jara-Samaniego *et al.*,2017). A considerable amount of waste accumulates due to the developing countries' rapid population growth, insufficient infrastructure for the correct disposal of solid waste, and indiscriminate waste disposal (Shekha, 2011). As the globe tries to keep up with its rapid generation, organic solid waste poses a severe threat to the ecosystem (Lim *et al.*,2016).

2.5.3 **Incineration**

According to the EPA (1995), incineration is the process of burning waste at a high temperature in a high-efficiency furnace to produce smoke and ash. The benefits of incineration include a significant decrease in waste volume as well as the generation of energy in the form of electricity and heat (Seo *et al.*, 2004). However, given the following—facility development and startup costs, which may be prohibitively expensive for impoverished nations (Rand *et al.*,2000; Adewale *et al.*, 2011)—the issues with garbage incineration cannot be overstated.

2.6 Composting

2.6.1 History of composting

Composting's origins are quite elusive, yet the history of urban garbage production and disposal dates back to the dawn of human civilization and urbanization. Making stone pits for the storage of organic waste to be utilized on agricultural fields began during the Neolithic era, when humans transitioned from hunting and gathering to farming. (Martin *et al.*,1992; Uhlig, 1976). However, the Knights Templar in the thirteenth century carried out the most precise and detailed descriptions of composting. During the Crusades, this military order was known as the Templars. A thousand years before Moses was born, the ancient Akkadian Empire in the Mesopotamian Valley recorded allusions to the use of manure in agriculture on clay tablets.

There is evidence that the Tribes of Israel, the Greeks, and the Romans were all aware of compost. Many New England farmers composted 10 parts of muck to 1 part of boneless fish (Martha *et al.*,2012). One development from the 20th century is the work done in India in 1933 by Sir Albert Howard. His work was among the earliest efforts to use compost in the management of organic farms that were ever documented (Howard and Wad, 1935; 1938). The "Indore Process" was created by Sir Howard and certain scientists. The "indore process" first just composted animal manure, but as time went on, it also used any other biodegradable materials that were readily available. There were only two ways used in the "indoor process": the heap and pit procedures. The "Bangalore Process" was created in 1939 by the Indian Council of Agricultural Research in Bangalore, with several modifications to the indoor process. This approach resolved the difficulties the indoor process was experiencing, such as bad weather, nutrient losses owing to strong winds and sun rays, frequent rotaten to achieve uniformity, fly nuisances, etc. (Howard and Wad, 1935; 1938). Even if the indoor process has improved, it was still challenging to produce insufficient quantities to meet market demand before the "Dano process" was created. A big, slowly rotating drum with internal baffles is used in this well-known in-vessel device to transport the contents during digestion (Banga, 2013). Composting is a biological process that turns mixed microbial populations of heterogeneous organic wastes into humus-like substances under tightly controlled ideal moisture, temperature, and aeration conditions. Microorganisms use composting to create soil humus out of organic wastes such manure, sludge, leaves, fruits, vegetables, and food scraps (Rynk, 1992; Reinikainen and Herranan, 1999). Composting allows organic waste to break down and stabilize into a product that can be utilized as an organic fertilizer or soil conditioner (Ahmad, 2007).

The inputs and outputs of the composting process are shown in Fig 2.1. Enzymes are created by bacteria so they can use complex carbohydrates as food by dissolving them into simpler ones. The composting process continues until the final microbes devour the last of the nutrients and the majority of the carbon is transformed into water and carbon dioxide (Rynk, 1992). The carcasses of deceased microorganisms and humus in the compost still contain the nutrients that become accessible during decomposition. First-degree disintegrates are bacteria, actinomycetes, and fungi that utilize waste as a first step in the breakdown of organic materials. The protozoa, rotifer mite, and numerous insects in the top level eat second-degree disintegrates. The populations of this degree are governed by third-degree disintegrates, which also feed on the creatures in the first two degrees. When organic matter is composted, microbes break it down into humus, carbon dioxide, water, and other extremely stable byproducts (Avcioglu *et al.*,2011). About half of the weight of the primary materials is lost during the process in CO_2 and water. Thus, as raw materials are converted into useful soil conditioners by composting, their volume and weight are reduced (Rynk, 1992; Uygun, 2012). When the right conditions are kept in place for the growth of microorganisms and when these parameters are kept in place, composting happens very quickly.

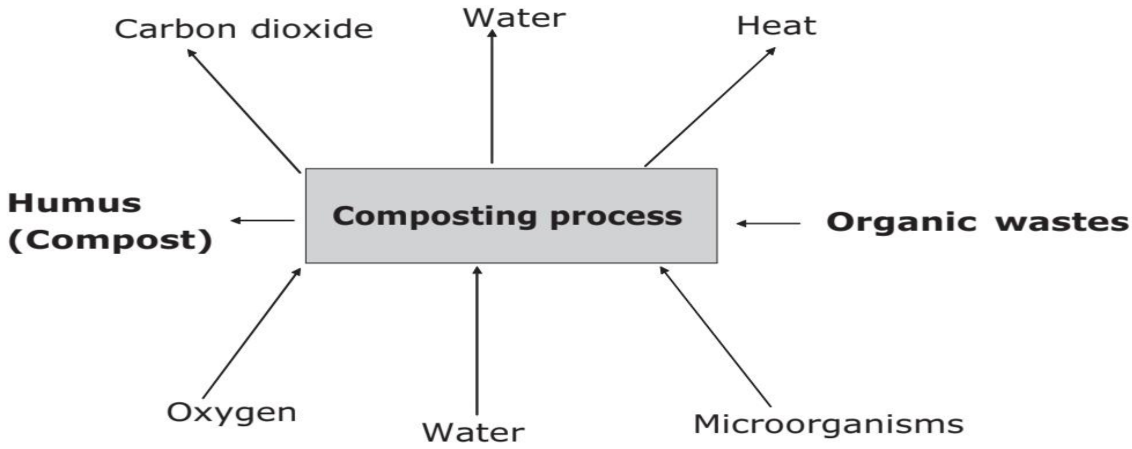

Figure 2.1 Inputs and outputs of composting process (Arikan, 2003)

In order for there to be strong microbial activity, there must be the following conditions: enough oxygen for aerobic microbes, enough moisture content to support biological activity without impeding ventilation, and suitable temperatures (Ozturk and Bildik, 2005). The primary goals of composting are to eliminate diseases, bug eggs, other undesired organisms, and weed seeds that may be present in solid wastes, as well as to transform separable organic material into biologically desired appropriate material to achieve the highest amount of nitrogen, phosphorous, and potassium that plants can use (Tosun, 2003) and to create a product that can be used for soil remediation. Composting allows for the decomposition and stabilization of organic waste into a product that can be utilized as an organic fertilizer or soil conditioner (Ahmad, 2007). Compost enhances the soil's organic matter content, water permeability in low-permeability soils, the void ratio between soil particles, and ultimately the soil's ability to hold water. By making root mobility easier, it promotes root development. The soil processing is made simpler as a result. Humus provides nitrogen retention, preventing nitrogen from blending into the groundwater. Compost also enhances soil structure and raises water permeability. In particular, rainwater reaching the soil surface is less likely to erode soil by being quickly absorbed into the ground as opposed to flowing into a surface stream (Avcioglu *et al.*,2011; Basturk, 1979).

When the right circumstances are kept in place for microbe growth and when these parameters are kept, composting proceeds most quickly. The right mix of organic materials to provide the nutrients needed for microbial activity and growth, including the right carbon to nitrogen (C:N) ratio, the right amount of oxygen for aerobic microorganisms, the right amount of moisture content to support biological activity without obstructing ventilation, and the right temperatures to support strong microbial activity are just a few of these conditions for composting (Ozturk and Bildik, 2005). Both aerobic and anaerobic conditions can be used for composting. Because anaerobic conditions require less energy per unit weight of organic matter to separate, are more likely to result in interim products that smell, take too long to form compost, and do not reach the necessary temperature levels, the majority of composting systems are operated aerobically. Typically, aerobic composting comes to mind when something is referred to as compost (Tanugur, 2009).

2.6.2 Raw Materials of Compost

To produce high-quality goods from organic wastes, the choice of the product quality to be composted is crucial (Varank, 2006). The utilization of uncontaminated organic wastes and other wastes that have been separated independently at the source is the first stage in getting compost material of a high caliber for compost manufacture. Rich and clean organic wastes from markets, parks and gardens, municipal solid waste collection systems, etc. should be used for this purpose and processed (Yildiz *et al.*,2009). Table-2.1 lists the densities, water contents, nitrogen percentages, and C/N ratios of the organic materials utilized in composting. The proper blending of various ingredients is a crucial phase in the composting process.

The mixture should be made as a composite of various materials, with the initial compost heap being C/N: 30/1, in order to be effective in the composting process and to obtain high product quality (CIWMB, 2007). Hygiene is another component of the compost basic material. Both in the compost heap and when using the product, hygiene is crucial. Diseased plant materials and animal waste from cats and dogs should not be added to the compost pile in order to prevent the spread of viruses and pathogens (Ozturk *et al.*,2015).

Table 2.2: Properties of some organic substances used in composting (NRAES,1999)

Organic Substances	%N (Dry weight)	C/N (weight/weight)	% Water content (Wet weight)	Density (kg/m³)
		Feces		
Chicken feces	1.6 – 3.9	13 – 30	22 – 46	470 – 640
cattle	1.5 – 4.2	11 – 30	67 – 87	820 – 1040
The dairy barn (tied bovine)	2.7	18	79	-
The dairy barn (free bovine)	3.7	13	83	-
Horse	1.4 – 2.3	22 – 50	59 – 79	760 – 1010
Racehorse	0.8 – 1.7	29 – 59	52 – 67	-
Egg hen	4 – 10	3 – 10	62 – 75	860 – 1010
Sheep	1.3 – 3.9	13 – 20	60 – 75	<1080
Swine	1.9 – 4.3	5 – 19	65 – 91	<1010
Turkey feces	2.6	16	26	485
		Stalk. dry grass. animal feed		
Corn	1.2 – 1.4	38 – 43	65 – 68	-
Dry Weed	0.7 – 3.6	15 – 32	8 – 10	-
flowering Herbs	1.8 – 3.6	15 – 19	-	-
seedless herbs	0.7 – 2.5	-	-	-
Stalk	0.3 – 1.1	48 – 150	4 – 27	36 – 240
Oat stalk	0.6 – 1.1	48 – 98	-	-
Wheat stalk	0.3 – 0.5	100 – 150	-	-
		Wood and paper		
Hardwood bark	0.1 – 0.41	116 – 436	-	-
Soft tree bark	0.04 – 0.39	131 – 1285	-	-
Corrugated cardboard	0.1	563	8	160
waste timber dough	0.13	170	-	-
Printed publication	0.06 – 0.14	398 – 852	3 – 8	120 – 150
Paper fibre sludge	-	250	66	710
Paper pulp sludge	0.56	54	81	-
Paper dough	0.59	90	82	870
Sawdust	0.06 – 0.8	100 – 750	19 – 65	220 – 280
Telephone directories	0.7	772	6	155
Wood crumb	-	40 – 100	-	276 - 385
Hardwood	0.06 – 0.11	451 – 819	-	-
Softwood	0.04 – 0.23	212 – 1313	-	-

2.7 Compost Phases

2.7.1 Lag Phase

Typically, composting is a chain of microbial populations that are almost always present in wastes. Setting up the proper conditions for composting starts the chain. Native or "resident" bacteria that can utilize the nutrients in the raw feces start to grow right away. Because of their work, the conditions in the composting mass are improved enough for other indigenous groups to flourish. Composting occurs in three stages: (1) an initial lag phase (the "lag phase"), (2) an exponential growth phase and accompanying intensification of activity (the "active phase"), (3) a final decline phase that gradually tapers off and lasts until ambient levels are reached (the "curing phase" or "maturation phase") (Luis *et al.*,2004). As soon as composting conditions are set, the lag phase starts. The waste-associated bacteria are going through a period of adaptation. By utilizing the raw waste's sugars, starches, simple celluloses, and amino acids, microbes start to multiply. Waste starts to decompose, releasing nutrients. The temperature of the bulk starts to increase as a result of the rapid activity (Luis *et al.*,2004).

2.7.2 Active Phase

An exponential rise in microbial population and a matching increase in microbial activity signal the change from the lag phase to the active phase. The composting mass's temperature rises sharply and continuously as a result of this process. The increase continues until there is a sufficient amount of easily decomposable waste to support microbial proliferation and vigorous activity. Up until the supply of conveniently accessible nutrients and decomposable materials starts to run low, the activity is at its peak (Luis *et al.*,2004).

2.7.3 Maturation or Curing Phase

Eventually, the material that can be broken down quickly runs out, and the maturation stage starts. The proportion of resistant material continuously increases while microbial proliferation decreases during the maturation phase. The temperature starts to fall inexorably and continues until ambient temperature is attained. According to Luis *et al.* (2004), the amount of time needed for maturation depends on the substrate, the environment, and the operational circumstances. It can take anywhere from a few weeks to a year or more.

2.8 The Microbiology of Composting

The biological process of composting is intricate and requires numerous different microbes working together. Regarding the temperatures at which they may grow, mesophiles and thermophiles are two kinds of microbe. Mesophilic organisms are those that thrive in the range of 20.0 to 35.0°C. Thermophiles are organisms that thrive in temperatures between 50.0 and 60.0°C. (Swatek, 1967; Lyles, 1969; Henis, 1987; Lester and Birkett, 1999) They can endure and survive at minimum temperatures of 30.0 to 40.0°C and maximum temperatures of 80.0 to 90.0°C. The three main microbial species involved in the breakdown of organic matter are bacteria, fungus, and actinomycetes (Stentiford, 1993; Eklind *et al.*,1997).

Mesophilic, thermophilic, cooling, and stabilizing microbial communities predominate at different stages of the composting process; each microbial community is adapted to a certain kind of organic material and environment (Gray *et al.*,1971a; Ryckeboer *et al.*,2003). Composting can be carried out in both aerobic and anaerobic conditions. Most of the composting systems are operated aerobically because less energy per unit weight of the organic matter separated by anaerobic conditions, the problem of odour due to interim products are exposed, the time required for compost formation is too long and the temperature of the composting organisms does not reach the required temperature values. In general, when it is called compost, aerobic composting first comes to mind (Tanugur, 2009).

2.8.1 General factors affecting composting process

The composting process is actively influenced by a number of elements. Individually, each of these elements; oxygen, temperature, particle size, pH, moisture content, carbon to nitrogen ratio, and microbial activity affects the composting process. A change in one of these variables could result in a change in the others because all of these variables are interdependent. Nutrient loss during composting may be kept to a minimum and composting time can be cut in half by optimizing operation conditions (Avcioglu *et al.*,2011). Compost enhances the soil's organic matter content, water permeability in low-permeability soils, the void ratio between soil particles, and ultimately the soil's ability to hold water. By encouraging root mobility, it also promotes root growth. The soil processing is made simpler as a result.

Humus provides nitrogen retention, preventing nitrogen from blending into the groundwater. Grown plants can be healthier and more resistant to illnesses and negative impacts thanks to humus-rich soils. As a result, there is less need for chemical and agricultural warfare. Compost also enhances soil structure and raises water permeability. In particular, the water hitting the soil surface with rain is less likely to erode the soil by being quickly absorbed into the ground as opposed to flowing into a surface stream (Avcioglu *et al.*,2011; Basturk, 1979).

2.8.2 Oxygen

According to Stofella and Kahn (2001), the composting process is an oxidation process in which oxygen is generally consumed while carbon dioxide is produced. Therefore, until the compost is generated, these two gases must be monitored as a trustworthy signal in the composting process. Compared to anaerobic settings, aerobic conditions result in higher temperatures and a greater elimination of pathogens. Additionally, composting under aerobic circumstances takes less time to finish and produces better-quality waste (Uygun, 2012). The oxygenation of the compost pile varies depending on a number of variables, including the moisture content, void ratio, and composting process. According to Ozturk *et al.* (2015), the compost stack's minimum oxygen levels should be as follows: • In the fast fermentation phase, > 10% oxygen; • At maturing stage, > 5% oxygen should be present.

2.8.3 Temperature

Heat is a byproduct of organic matter's biodegradation in compost. The temperature outside, the moisture content, the size of the stack, the amount of top cover, the C/N ratio, and the ventilation all affect how much heat is generated. A well-designed compost process needs three to five days to attain a planned temperature of 60 to 70^oC. The temperature throughout the composting process is kept below 70^oC. Ventilation and mixing are used to lower the high temperature if the stack temperature rises substantially (Topkaya, 2004). Low temperature causes biodegradation to proceed more slowly in the compost pile. If the temperature is high (> 70^oC), beneficial microorganisms decrease, leading to a decrease in microbial diversity (Ozturk *et al.*,2015). The critical temperature, which limits composting, has yet to be defined (Roger *et al.*,1991). However, Gaur (1997) suggested that a temperature of 55 to 60^oC should be maintained up to three days for efficient composting. In order to produce high-quality compost, temperature is a crucial aspect in the composting process. Composting processes that are finished at temperatures below those required can produce organisms that are harmful to the health of people, animals, and plants (Ozturk *et al.*,2015).

2.8.4 Porosity and particle size

A space between particles is called porosity. This void ratio is affected by particle size. The presence of free air is a crucial element in the compost pile's ability to circulate gases. The presence of pores ensures that bacteria have access to the oxygen they need as well as allowing carbon dioxide to escape from the stack of gases produced during biodegradation. The free air space must be protected from three key problems (Arikan, 2003; Ozturk *et al.*,2015).

a. Optimum particle size

Smaller particles are retained more quickly and may cause anaerobic conditions due to limited oxygen supply. Large particles speed up water loss, slow compression, and facilitate gas exchange. However, it is also challenging to manage the heat in big particles, and heat losses occur. The ideal particle sizes should therefore range from 6 to 75 mm (Ozturk *et al.*,2015; Bayer, 2008).

b. Particle size distribution

Compared to an organic material mass with uniform particle size, unequal, varied particle size offers superior porosity (Ozturk *et al.*,2015).

c. Regular mixing of compost stack

Due to biodegradation and the accumulation of particles in the pile over time, porosity gradually diminishes. To guarantee sufficient free air space and prevent stacking, the compost stack is mixed at regular intervals (Ozturk *et al.*,2015).

2.8.5 Microorganisms

In the complex process of composting, many kinds of microbes break down and eat organic wastes. Microorganisms including fungus, actinomycetes, and bacteria are actively involved in the composting process. Algae and protozoa may occasionally be encountered during this process. Composting affects the population of microorganisms (Uygun, 2012). Figure 2.2 shows these modifications, which apply to bulk composting with biological treatment sludge and wood chips.

.

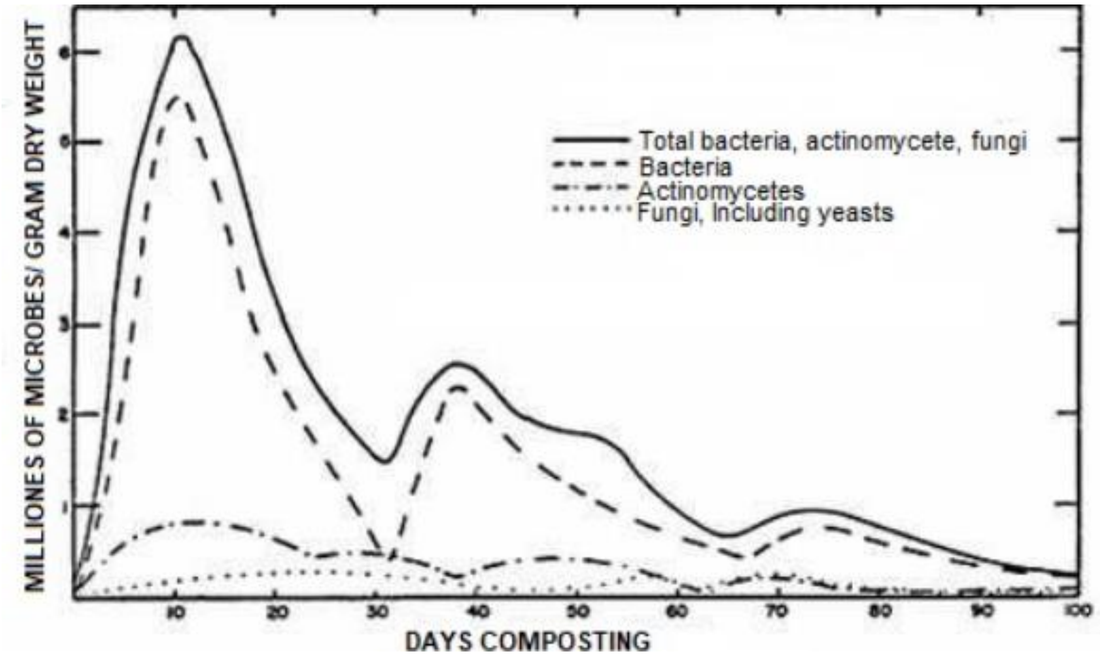

Figure 2.2 Variation in the composting process of the microbial population (Stofella & Kahn, 2001).

First-stage disintegrants include bacteria, actinomycetes, and fungi, which utilise organic waste as an intermediate. The protozoa, rotifer mite, and numerous insects in the upper level eat first stage disintegrants. Microorganisms break down organic material during composting to produce humus, a very stable byproduct that also contains carbon dioxide, water, and energy (Avcioglu *et al.*,2011).

2.8.6 Carbon (C), Nitrogen (N) and C/N ratio

There are six parts to the examination of the main parts of organisms. Carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur are the elements. These elements are present in all organic wastes and are necessary for biodegradation since they are found in all living things, including the bacteria that carry out the process. To establish the best procedure for composting, it's crucial to consider the C, N, and C/N ratio. Energy is produced by autotrophic microorganisms using carbon molecules. In the production of proteins, nitrogen molecules are employed as building blocks.

According to Ozturk *et al.* (2015), the C/N ratio for raw materials in a composting process should be between 20 and 35. A composting process with an initial C/N ratio of 30:1 result in a final C/N ratio of 10-15:1. The cause of this is because during the biodegradation of organic materials by microorganisms, 2/3 of the carbon is converted to carbon dioxide and taken outside. The remaining one-third of carbon is combined with nitrogen to create new microbial cells, which are then released upon cell death (Topkaya, 2004).

2.8.7 Moisture

Moisture plays numerous significant roles in the composting process, including the decomposing microbes. Moisture is crucial for managing temperature during the composting process as well (Erdener, 2010). For microbial stabilization to work as effectively as possible, there must be enough moisture in the solid waste (Dirksen and Dasberg, 1993; Iriarte and Ciria, 2001). Microbial activity both need water and produce it. The loss of water due to evaporation as the process moves forward is a significant component in composting (Stentiford, 1996). As a result of microbial heat generation, moisture also impacts porosity and gas diffusivity and is eliminated through vaporization (evaporative cooling) (Dean *et al.*,1987; Oppenheimer, 1997).

The structural characteristics, thermal characteristics, and rate of biodegradation of the materials are all impacted by the moisture content of the compost (Stentiford, 1996; Nakasaki *et al.*,2004, 2005). According to MacGregor and colleagues (1981), the temperature of compost is a result of the buildup of heat produced biologically and also influences metabolic activity. Heat and mass transport are important factors in the composting process, and several studies have examined them (Finger *et al.*,1976; Characklis and Gujer, 1979; Luong and Volesky, 1983; Incropera and DeWitt, 1985; Macky and Derrick, 1986; Kishimoto *et al.*,1987; Bach *et al.*,1987; Nakasaki and Akiyama, 1988; Richard and Walker, 1989; Keener *et al.*,2009. The range of 50 to 60% is the appropriate moisture level for composting. According to Topkaya (2004), decomposition slows down, anaerobic conditions develop, smells develop, and nutrients are separated by leaking water when moisture content is more than 65%. Punch testing is one of the practical methods for determining the level of moisture. In this test, the material is pressed into the hand's palm; if water escapes, the humidity level is 70% or more. Raw materials should be soaked in water if they have a very low moisture content. The material needs to be thoroughly blended and homogenous after the water has been added (Ozturk *et al.*,2015).

2.8.8 pH

The solubility of hazardous ions, the availability of nutrients, and microbial activity are all influenced by hydrogen ion concentration. The pH level of compost is considered to be a sign of the stabilization and decomposition processes. According to Miller (1993), Benito (2003), and Page (1982), the pH value changes during composting in a fairly predictable way: it initially dips somewhat before rising quickly to about 8.5 due to ammonification. As the compost reaches a state of stability, the pH value stabilizes at 7.5 to 8.0. In 4 composting combinations (a wide range of feedstock), pH values varied between 7.0 and 8.0 during the course of 20 weeks, according to Sanchez-Monedero (2001). However, pH is not a 100 percent accurate predictor of development and stability. According to Campell (1992), compost's pH value ceased increasing after six weeks at 6.7. The pH range of an isolated compost is typically 6.0 to 8.0 (Ozturk *et al.*,2015). The pH level also affects the availability of nutrients; at pH levels above 7.0, nitrogen volatilizes as ammonia.

2.8.9 Nature of materials

Conditions including adequate moisture, aeration, and temperature are directly impacted by the physical and chemical properties of the materials intended for composting. Particle size and moisture content are important physical features, and nutrient quality and the number of organic residues are important chemical attributes. Co-composting, which involves composting two or more materials simultaneously, can hasten the composting process and optimize the C:N ratio, moisture content, and particle size of the materials to produce high-quality soil conditioners and amendments

(Stratton and Rechcigl, 19 97). By combining nitrogen-poor and nitrogen-rich organic elements in the right proportions, the ideal amount of C:N ratio can be reached. Like, co-composting of woody plant materials and biosolids after mixing in proper ratio will result in a high-quality end product (Stratton *et al.*,1995; Haug, 1993; Barker, 1997).

2.8.10 Mineral additives

It is customarily advised to add mineral forms of nitrogen and phosphorus to composting material in order to reduce the C:N and C:P ratios as needed and to promote microbial activity. These inputs also significantly enrich the compost's nutrient content. The production of P-enriched compost by the inclusion of P sources including rock phosphate (RP), base slag, and bone meal, among others, has generated interest. Compost's humic acid content rises when RP is added to the composting material (Singh and Amberger, 1990). According to Tiwari et al. (1989), adding RP to wool waste caused the compost to have a C:N ratio of 20:1 after 10 weeks. By including 25% Mussoorie RP, Mishra (1992) created highly enriched compost from plant wastes. By adding 1% RP to paddy straw, a good quality compost (with a C:N ratio of 12.3) was created within 8 to 10 weeks (Gaur and Singh, 1995). Gowda et al. (1992) noted increased N and P content in the compost after adding RP. During composting, a sizeable amount of mineral N is lost through volatilization (Gaur and Singh, 1995). Pyrite minerals have been investigated as N conserving additions to solve this issue. Banger et al. (1989) created N and P enriched compost with much higher levels of total N and total P than normal using 1% urea N, 10 or 20% RP, and 10% pyrite as a conservative amount. Due to an increase in enzyme levels, it was discovered that adding NH_4NO_3 and NH_4Cl to the fermentation medium improved the macerating potentiality (Hamdy, 2005).

2.8.11 Plant growth regulators

Organic chemicals known as biologically active substances or plant growth regulators (PGRs) have demonstrated broad effects on plant growth even at low concentrations (Frankenberger and Arshad, 1995; Arshad and Frankenberger, 1998; Khalid *et al.*,2006). It's possible to turn organic waste into value-added organic fertilizer to boost crop yields by enriching composted material with nutrients and/or PGRs (kinetin, indole acetic acid, and giberellic acid). The growth and yield of wheat and maize were found to be improved by an organic fertilizer made by composting fruit and vegetable wastes and enhanced with N and PGRs at as little as 300kg/ha (Ahmad *et al.*,2007; Zahir *et al.*,2007).

2.8.12 Biological additives

It comprises the inclusion of earthworms or advantageous microbial inoculants. The decomposition process is known to be sped up by the compost inoculants. Microorganisms include *Trichuris spiralis, Paeciliomyces fusisporus, Trichoderma,* and *Aspergillus spp*. that are cellulolytic and lignolytic in nature. Inoculation with cellulolytic fungi speeds up the process' completion and raises the standard of the finished product (Gaur, 1982). After being inoculated with *Aspergillus niger* and *Penicillium spp.,* the nutritional quality of sorghum stalk and wheat straw compost was improved (Gaur and Sadasivam, 1993). It has also been documented that cellulolytic fungi have a positive impact on the composting of dairy farm wastes (Tiwari, 1989). Inoculating distinct waste types (mixed solid waste, municipal solid waste, and horticultural waste) with different microflora, including *Pleurotus sajor, Trichoderma harzianum, and Azotobacter chroococcum* in various combinations, was done by Singh and Sharma (2003). The garbage was digested for varying lengths of time before being composted for a set amount of time-one month. Regarding nutrient content, *P. sajor*, *T. harzianum*, and *A. chroococcum* provided the highest quality compost. When added at the rate of 300gt^{-1} material, cellulolytic fungal culture (*Trichuris spiralis, Paecilomyces fusisporus, Trichoderma viride,* and *Aspergillus spp*.) effectively reduced the bulk of organic wastes by 5–10% while increasing the overall N contents of the compost (Gaur and Singh, 1995). It has also been found that adding *Azotobacter chroococum* and P-solubilizing bacteria to compost improves its nutrient content (Sadasivam *et al.*,1981; Bhardwaj and Gaur, 1985).

The N content and manurial value of the compost are both increased by Azotobacter (Gowda *et al.*,1992; Yadav *et al.*,1992). The results of extensive studies by Gaur and Singh (1993) include the following: inoculation of compost with Azotobacter and P-solubilizing microorganisms and addition of Mussoorie RP showed an increased P content, which was further increased by inoculation with cellulolytic fungi; using chopped straw compost with 1.78% N and C:N ratio of 13.3 was produced with bioinoculant, as opposed to 1.30% N and C:N ratio of 20. Ahmad (2007) composted fruit and vegetable waste to create an organic fertilizer and added N to it. It was utilized to create a bio-fertilizer using the PGPR strain of *Pseudomonas fluorescens* biotype G (N3), which contains ACC-deaminase. It was discovered that this bio-organic fertilizer, used at a rate of 300kgha^{-1}, enhanced maize growth and nutrient uptake. *Pseudomonas fluorescens* strains have been shown in studies by Diby *et al.* (2005) to improve nutrient mobilization in the rhizosphere of black pepper, which led to increased plant vigor. Earthworms consume organic waste and only utilize 5–10% of the feedstock for growth, with the ability to consume more than their own body weight. They expel the undigested material that is mucus-coated as nutrient-rich worm casts (Bhawalker and Bhawalker, 1993). According to Kale *et al.* (1982) and Bhawalker (1991), these are also a rich source of vitamins, enzymes, antibiotics, growth hormones, and immobilized microorganisms. In compost piles, earthworms are frequently seen, with the exception of components that are harmful to their growth. In order to encourage microbial activity and enable aeration during composting, they operate as pulverizers of organic materials. They have attracted a lot of interest as composting inputs, and the process is called vermi-composting (Edwards *et al.*,1985).

The ability of earthworms to convert organic waste into compost has been demonstrated in a number of studies (Tomati *et al.*,1983; Haimi and Huhta, 1987; Kale and Bano, 1994). It is a suitable method for the disposal of organic solid and liquid wastes that are not harmful. It facilitates the low-energy, cost-effective recycling of industrial wastes, agricultural residues, and animal wastes (Jambhekar, 1992).

2.9 Compost maturity

Compost that is best suited for agricultural usage should be mature and well-cured. Recognizing variations in compost quality and age is key to determining application rates and timing. For a small-scale composting operation, there are both conventional tools and cutting-edge methodologies that can be used to assess the compost's maturity. According to Stratton et al.,(1995), maturity is defined as the following: (a) absence of toxins like acetic acid, phenols, and ammonia; (b) stabilization of nutrients like nitrate-N, phosphorus, iron, or other elements that could otherwise pollute ground or surface waters; (c) absence of harmful bacteria, fungi, and foul odors; and (d) a discernible decrease in heating upon rewetting. Texture, color, smell, and biological activity are a few distinguishing qualities that can be utilized to evaluate the age and quality of composts (Lekasi *et al.*,2003). When creating compost, coarse materials gradually get finer until a fine, loamy mixture is produced. Compost's ability to change color indicates both its quality and maturity. The less-decomposed substance has a mottled look and is made up of a heterogeneous collection of unprocessed organic components in various colors. Such material gets increasingly homogeneous as the decomposition process advances, maturing as a uniformly dark brown or black color.

The smell can help determine the stage of composting when using materials like animal manure, sewage sludge, and some industrial wastes. Ammonia and putrefaction are strongly odoriferous in fresh animal waste and manure in the early stages of decomposition.

Mature compost should only have a somewhat 'earthy' and unobtrusive odor. A further helpful sign of compost maturity is biological activity. The stage of compost maturation can be determined by looking for macrofauna, especially earthworms and grubs, in mature compost. Compost pile fauna and flora evolve with time, depending on the group of organisms, either increasing or reducing with age. Earthworm activity may peak and then fall as they approach maturity, although other soil fauna and fungus may reach their peak activity at different times. In mature compost piles, grubs (beetle larvae) are frequently found. The quality and maturity of compost can be predicted with some degree of accuracy by having a comprehensive grasp of changes in these several domains with respect to the composting process and phases (Lekasi *et al.*,2003) as indicated in Table 2.2. To assess compost maturity, a number of rapid bioassays have been devised. Plant tolerance testing is a simple technique (Silva *et al.*,2007). Others (Graetz, 1996; Ahmad, 2007) favor carbon dioxide release or oxygen uptake measurements.

Table 2.3: Physical and chemical characteristics of mature compost (Brewer, 2001).

Characteristics	Best range	Comments	References
Ph	6.5-7.5	If below 5 or above 8, then it may be injurious to plant	Anthronis (1994); Bary *et al.(*2017)
Color	Dark brown to black		Lekasi *et al.* (2003) Zia *et al.* (2003
Texture	Crumby	Large particle changes to fine ones	
Odour	Odorless	Mature compost (well decomposed) should be sight earthy smell.	Jara-Samaniego *et al.* (2017)
Moisture	15-25%	Low moisture materials may be dusty.	Anthonis (1994)
C:N ration	10-15:1	Compost with high C/N ratio will reduce N availability to plants	Bary *et al.* (2002)
Organic matter	40-60%	Low values indicates compost mixed soil. High values indicates fresh under-compost material.	
Electrical conductivity	0-4d ms^{-1}	Critical for greenhouse/ potting mixes; Less critical for farmland application.	
Nitrogen	1-3%		Anthonis (1994)
Phosphorus	0.5-1.0%		
Potassium	1-1.5%		

2.10 Some attributes influencing the non-acceptance of carrots

2.10.1 Cracks

According to Tindal (1988), dry soil conditions are more likely to lead to root breaking and seem to favor the growth of long roots. Insufficient moisture in the soil can cause fissures to form in the roots (Adusiobo, 1984). According to Rice et al. (1987), most vegetables benefit from well-rooted manure before planting, while large treatments may induce cracking in some root crops. The generation and transportation of carbohydrates from the leaves to the roots or bulb is what makes sweet potatoes, Irish potatoes, carrots, and onions grow. All year long, carrots require a plentiful supply of water. It was emphasized once more that moisture stress results in roots that are woody and have a weak flavor. The wrong irrigation of carrots results in growth fractures. Carrot root tubers may develop cracks if the soil is kept either too wet or too dry.

2.10.2 Fork

According to Clerk (1974), root-knot nematodes can occasionally induce forking, twisting, and cracking in addition to galling of roots and other root malformations. According to Sinnadurai (1992), plants grow low-quality (slender, fibrous, light-colored) roots when temperatures are high. Carrots may form many forks in rocky or hard soil. Being a tuber crop, transplanting seedlings is also not advised. Further information suggests that root-knot nematode, excessive watering, roots in touch with fertilizer pellets or fresh manure, hard soil or rocks, overcrowding, and hairy roots might result in carrots with forks or other irregular shapes.

CHAPTER THREE: MATERIALS AND METHOD

3.1 Description of the experimental sites

The experiment was carried out from January to August 2022 at the research farms of the Adanwomase Senior High School located in the Kwabre East-District and Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development located in the Mampong Municipality in Ashanti Region.

3.1.1 Mampong-Asanti

According to Obeng (2007), Mampong-Asanti is located in the Forest-Savanna Transitional agroecological Zone, which lies at 7 $^{o}4^{1}$ North, 1^{o} 24^{1} West. Mampong Municipal shares a boundaries with Sekyere Central to the east, Afigya Sekyere to the west, Ejura-Sekyeredumase to the south and Sekyere Afram Plains to the north as indicated in Figure 3.1. With an average annual rainfall of around 1300 mm, and the region features a bimodal rainfall pattern. While the minor season begins in September and ends in November, the major season begins in April and lasts until July. Between the two rainy seasons, August often experiences a brief dry period (MoFA, 2001).

Depending on the season, percentage relative humidity is typically high, ranging from 75 to 97% in the morning to between 73 and 32% in the afternoon. The daily temperature ranges from 24.4 to 28.6 degrees Celsius. The soil is savanna Ochrosol, which was produced from Voltian Sandstone, and it belongs to the Bediase Soil Series (Asiamah, 1998), and has been classified as Chromic Luvisol according to the FAO/UNESCO (1990) classification. The soil is deep, sandy-loam in texture, and reddish in color that is free of stones and pebbles, and it contains a sizeable number of organic materials (Adu, 1992).

Figure 3.1: District Map of Mampong Municipal; Source: Ghana Statistical Service, GIS (2016)

3.1.2 Adanwomase site

Adanwomase is located in the Kwabre East District of Ashanti. It is practically in the middle of the Ashanti area. It is located in the Forest-Savanna Transitional agroecological Zone, which lies at 6 ^{o4}4^{1} North, 1^{o} 33^{1} West. As illustrated in Fig. 3.2 above, Kwabre-East district shares common borders with Sekyere South District to the north; Kumasi Metropolis to the south; Ejisu Juaben District to the east; and Afigya Kwabre District to the west. The district is situated in the forest-agro-ecological zone with bimodal rainfall regime. The first rainy season runs from April to June, with June having the highest rainfall. Between September and December is the second rainy season. Beginning in December and lasting until March is the dry season. Annual total rainfall of 1259-17500mm is recorded each year, with relative humidity averaging between 75 and 80 percent during the rainy season and 70 to 72 percent during the dry. The lowest temperature is 26.10^{O}C, with the mean yearly temperature being around 300^{O}C (Obeng, 2007).

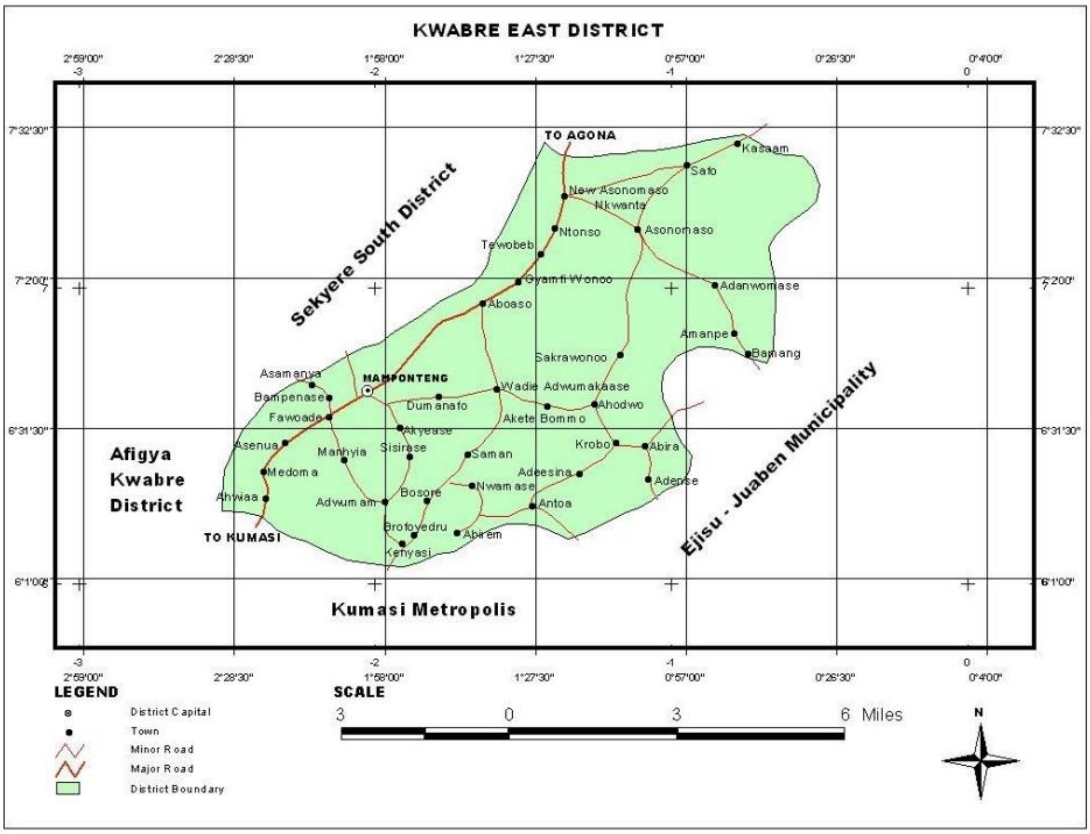

Figure 3.2: District Map of Kwabre- East (GIS, 2018)

3.2 Experimental Design and Treatments

A randomized complete block design (RCBD) was adopted, with three replications of each treatment. There were thirteen treatments consisting of a combination of three composting methods (bucket method, floor or pilling method, pit method and uncomposted – poultry manure) and three application rates (5t/ha, 10t/ha and 15 t/ha) plus a no fertilizer (control) as shown in Table 3. Each plot measured 2m by 1m (2×1). Blocks and plots were separated by 0.5m and 0.5m, respectively.

Table 3.1: Treatments and quantity of tonnage used.

Treatment	**Quantity (ton/ha)**
T1	CONTROL (No fertilizer)
T2	5t/ha PM
T3	5t/ha PMC
T4	5t/ha BMC
T5	5t/ha HMC
T6	10 t/ha PM
T7	10 t/ha PMC
T8	10 t/ha BMC
T9	10 t/ha HMC
T10	15t/ha PM
T11	15t/ha PMC
T12	15t/ha BMC
T13	15t/ha HMC

Key: PM = poultry manure**;** PMC = Pit method of composting**;** BMC = Bucket method of composting**;** HMC = Heaping

Seeds of carrot variety, 'Tokita Improved', were treated by dusting with Seed Plus (ai. Imidacloprid 5%, Metalaxyl 5%, and Carbendazin 10%) and sown on 1st May, 2022 and 14th May, 2022 for Mampong and Adanwomase respectively. The seeds were drilled at about 1-2 cm deep and at an inter row spacing of 20 cm. Shading of beds was done by placing palm fronds on the beds before watering. The seeds germinated seven days after sowing.

3.3 Composting

3.3.1 Gathering and preparation of materials

Composting materials were acquired from Mampong and its surroundings. Source-separated home trash from the market and other sources were gathered for the composting. As composting raw materials, a variety of readily available organic waste, including fruits and vegetables (market waste), ashes, and plant residues (garden waste), were utilised. Materials rich in C (plant residues) were added as bulking agents to produce the required C/N ratio necessary for efficient decomposition because the readily available domestic wastes (peels of crops, fruits, and vegetables) did not reach the desired C/N ratio.

The C/N ratio of 25 to 30 was taken into consideration when choosing the mixture for the composting process. In order to remove the non-biodegradable elements, sorting was done manually. The sorted materials were broken down into little bits and piled into the three composting techniques under consideration—the bucket method, the pit method, and the piles (floor) method—over the course of 13 weeks. After heaping the materials in each manner, the compost was adequately watered and stirred to maintain a moisture level of between 60 and 70%. Throughout the composting process, the moisture level of the feed was maintained at between 60 and 70 percent by liberally misting it with water.

3.3.2 Composting method considered in the experiment

The investigation looked at three (3) different composting techniques (Pit, Basket, and Heaping/pilling composting methods) to assess their nutrients release abilities. The components and amounts used in the composting process are shown in Table 3.1;

Table 3.2 Materials and quantities used in composting.

RAW MATERIALS	QUANTITY USED
Ashes	2.00kg
Peels (cassava, plantains, yam, fruits and vegetables)	50.00kg
Poultry manure obtained from university farm	18.00kg
Green materials (green vegetables, carrot leafs, mowed grasses etc)	20.00kg
Brown materials (dried grasses, cowpea husk, peanut husk)	10.00kg
Total	**100.00kg**

3.3.3 Pit composting method

Figure 3.3 shows Pit composting method. Using this technique, compost was created in pits dug into the ground. Three pits of size 1m deep by 2m wide as composting pits were dug as part of this procedure. The composting materials were placed in two of the pits, and the compost was turned in the third (Figure 3.3).

Figure 3.3: Pit composting method

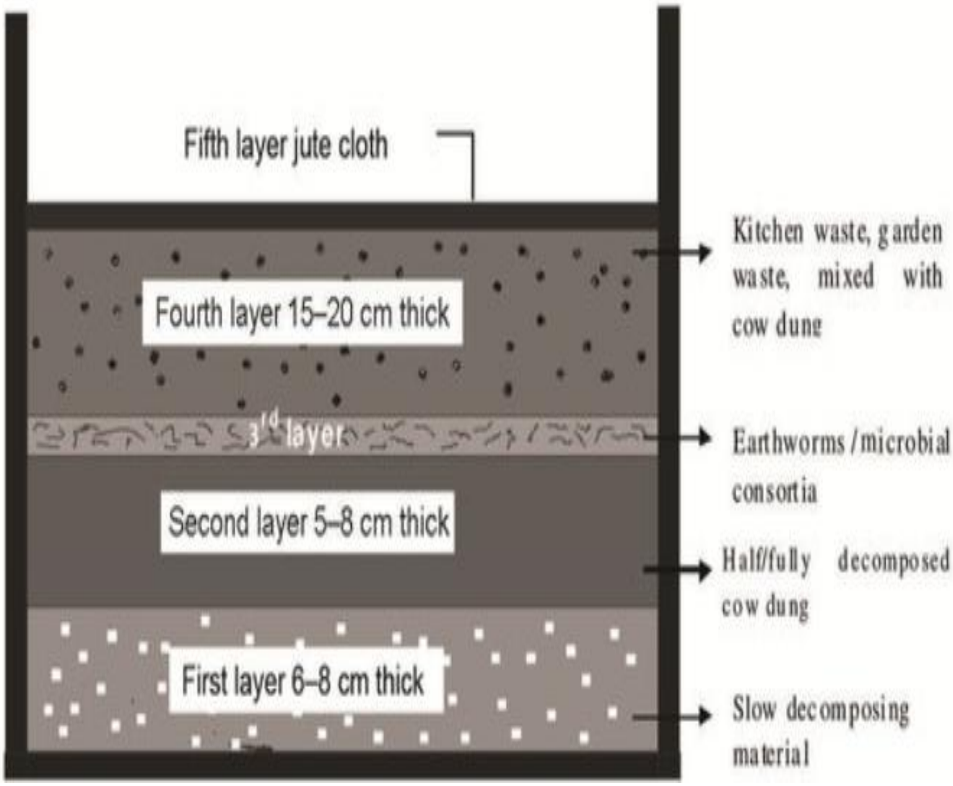

Figure 3.4: Diagrammatic representation of successive layers for the composting.

3.3.4 Basket composting method

Figure 3.3 represent the basket method of composting. This technique required the use of a basket or another container that was on hand. This technique involved preparing the compost in a Veronica basket. A 200-liter veronica basket was obtained from Mampong market, 10 circular holes with a diameter of 0.2cm were drilled, and the filling was carried out according to the configuration in (Figure 3.5). To get the microorganisms needed for the composting process, a thin layer of soil from the top of arable land was added; the layers were repeated until the heap reached a height of 1.5 m; enough water was applied to the heap to a moisture content of about 60-70%; the heap was then covered with polythene; and finally, the container's lid was placed on top to prevent water loss.

Figure 3.5: Basket composting method

3.3.5 Heaping/pilling composting method

Figure 3.6 shows how the Heaping/pilling composting method was prepared. Spreading the composting materials on the ground while paying close attention to layer layouts is how this method of composting is done. A tiny area of soil was cleared, and stalks were used to line the bottom because they are difficult to decompose. The materials for composting (both in the pit and the basket) were piled as before.

Figure 3.6: Heaping/pilling composting method

3.3.6 Compost management

***3.3.7.1* Turning over**

The mound was routinely flipped over while it decomposed to keep it well-aerated. Seven days after the heap's creation, it was first turned around. Shovel and a long fork were used for turning. The heap was messed up and turned inside out. The older heap's drier and outer, less-decomposed portion was placed in the middle of the new heap.

The multilayer structure's original form was lost. The second turnover happened 21 days after it had been established for the previous month. The materials were then allowed to reach maturity over a period of two weeks with no turning before the time of turning increased from two weeks to three weeks for the remainder of the duration. After using the active composting process, the composted material was given a minimum of one week of curing time to produce more stable compost.

3.3.7.2 Watering

The materials must be kept at their maximum moisture level in order to promote quicker decomposition of the components. Every two days, water was typically added in the morning or evening to meet the microorganisms' need for moisture. A compost pile's moisture content can be simply checked. If it feels clammy after five minutes, the moisture level is good. After five minutes, if it's still dry, the moisture content is too low.

3.4 Cultural and Management Practices

3.4.1 Land preparation and planting

Beginning in January 2022 and ending in August 2022 was the field preparation phase. The experimental fields (Mampong and Adanwomase) were fine-tilled by slashing, plowing, and harrowing. To level the field, the debris was scraped off, and then pegging and lining were also done.

3.4.2 Shading of beds

After drilling the seeds, palm fronds were placed over the beds to provide shade. After the seedlings emerged, the palm fronds were kept for 14 days before being removed.

3.4.3 Thinning out

To achieve a plant population of 98 plants per bed with a spacing of 0.2m between rows and between plants, the seedlings were thinned out 21 days after germination. Six plants were chosen from each plot's centre row after thinning, and they were tagged for data collection.

3.4.4 Weeding

Every two weeks, weeding was done using a hole and cutlass throughout the farm's boundaries and in the spaces between the blocks. Up until the crop was harvested, weeds on the beds and around the beds were controlled by hand pulling.

3.4.5 Earthing-up

After thinning out, earthing-up was done every two weeks to cover exposed roots with soil and stop green colouring at the root shoulders. Throughout the growing season, the interrow soils were mixed up with a hand fork once a week to optimize aeration and promote crop growth.

3.4.6 Forking of bed

The beds were forked to make a tiny trench next to each plant just after the third and fourth weeks since at this point the plant had begun to produce its tubers and shallow watering on the bed was unable to reach the tubers deep within the soil. To store or hold the water for the plant to use, these trenches were filled.

3.4.7 Watering

Except when it rained, the beds were irrigated twice a day with fresh water from water using 10 L watering cans.

3.5 Data Collected

Data were collected on number of leaves, plant height, canopy spread, root length, root weight and root diameter from six plants which were randomly selected. The leaves were counted whilst plant height was measured from soil level to the tip of the longest leaf. Canopy spread was recorded as the mean of the widest spreading leaves on opposite sides of the plant in two directions at right angles to each other with a meter rule. Root diameter was measured at about 1cm from the shoulder of the root with veneer calipers. Total yield and marketable yield were determined using all the harvest from the central bed of each plot. Roots which weighed at least 30 g and were without cracks, forks and galls on the main root, constituted the marketable yield. To prevent the border effect, the plants in the outside rows and the very ends of the center rows were not included in the random sampling.

3.5.1 Soil Analysis

Soil samples were randomly taken at a depth of about 0-20 cm on both field for analysis. All soil samples were analyzed at the CSIR- Soil Research Institute, Kwadaso-Kumasi. Parameters analyzed were: Soil pH, Soil Organic Carbon, Total Nitrogen, Phosphorus (P), Exchangeable Cations, Calcium (Ca), Magnesium (Mg), Exchangeable Potassium and Sodium, Exchangeable Acidity, and Effective Cation Exchange Capacity (ECEC).

3.5.2 Compost and Poultry Manure Analysis

Sample of the three (3) compost from each composting methods and poultry manure were subjected to laboratory analysis to determine the nutritional compositions of each compost method. Samples were delivered to the Kwadaso, Soil Research Institute at Kumasi for the analysis. Prior to analysis, the samples were dried in an oven at 70°C, grinded to obtain a fine texture then allowed to pass through a 0.1mm sieve before subjecting them to various methods or protocols in determining each nutrient. Both macro and micro nutrients were determined from the three compost methods considered and the poultry manure.

3.5.3 Vegetative Growth Parameters

3.5.3.1 Plant height

Six plants per plot were randomly selected from the middle rows and tagged for data collection at 28, 42, 56, 70, and 84 DAS. Following thinning out, measurements of plant height were made every two weeks using the centimeter rule. Values were recorded after measurements were made from the plant's base to the tip of the longest leaf.

3.5.3.2 Number of leaves per plant

At 28, 42, 56, 70, and 84 DAS, the number of leaves per plant of the six selected plants were counted. The plants' leaves were counted individually. The mean number of leaves per plant was counted, with only the smallest immature leaves at the plant's growth point being excluded.

3.5.4 Yield and Yield Components

The crop was harvested 93 days after the seeds were sown, on 17th August, 2022 for the Adanwomase field and 31st August, 2022 for the Mampong field. For best yield and quality, carrots should be picked 90 to 105 days after sowing, according to Rikabdar (2020). To protect the roots, watering was done before harvesting. The produce was meticulously hand-harvested plot by plot.

3.5.4.1 Root length

From the point where the leaves attach (proximal end) to the last point of the root (distal end), the average length of the root in each treatment combination was measured in cm using a meter scale.

3.5.4.2 Root width

With a vernier caliper, the width of each individual root was measured from the top to the tip, and the mean width was noted.

3.5.4.3 Root fresh mass

After cleaning the dirt and thin roots and detaching the subterranean modified roots from the leaves' connection, a triple beam balance measured the weight of the fresh material in grams (g).

3.5.4.4 Dry matter content of roots at harvest (%)

After harvesting the carrot, roots were carefully cleaned by being washed in water and then allowed to air dry. Then, a sample of 100g was collected from different roots, cut into little pieces, and sun-dried for three days before being dried in an oven for 72 hours at a temperature of 70°–80°C. Following oven drying, the samples were weighed using an electrical balance to determine the dry matter content;

- **%Dry matter of root =** $\frac{Constant\ dry\ weight\ of\ root\ (g)}{Fresh\ weight\ of\ root\ (g)} \times 100$

3.5.4.5 Dry matter content of leaves at harvest (%)

Chopped into little pieces were fresh leaves weighing l00g from the treatment sample. The samples were oven dried for 72 hours after being sun dried for three days. The samples were then weighed using an electronic balance, and the weight of the dry leaves was determined using the formula below;

- % Dry matter of leaves = $\frac{\text{Constant dry weight of leaves (g)}}{\text{Fresh weight of leaves (g)}} \times 10$

3.5.4.6 Percentage cracked root

From each plot, the cracked roots were sorted and counted. The following formula was used to determine the proportion of cracked;

- % Cracked = $\frac{total\ number\ of\ cracked\ roots}{\text{total number of harvested root}} \times 100$

3.5.4.7 Percentage forked

From each plot, the forked roots were sorted and counted and the following formula was used to determine the percentage forked;

- *% forked* $= \frac{total\ number\ of\ forked\ roots}{total\ number\ of\ harvested\ root} \times 100$

3.5.4.8 Rotten roots

At harvest, the number of rotten roots was counted, and the results were computed using the following formula on a percentage basis.

- Rotten roots (%) = $\frac{\text{Number of branched roots}}{\text{Number of total rootst}} \times 100$

3.5.4.9 Marketable Yield of Roots per Plot

Only high-quality roots, not branching, racked, or rotten roots, made up the commercial yield of roots per plot. Weighing and expressing the marketable roots in kilograms was done.

Marketable yield = Gross yield - Non marketable yield (cracked, branched and rotten roots).

3.6 Data Analysis

The data was analysed using GenStat Released 18.1 statistical software package using analysis of variance (ANOVA). For the microbial counts and nutritional analysis of the three compost techniques, the means were separated using the Least Significant Difference while for the growth and yield and yield components, the means were separated using Tukey's Honestly Significant Difference (HSD) at 5% level of probability.

CHAPTER FOUR: RESULTS

4.1 Initial Soil Analysis

Table 4.1 shows the initial soil analysis at both Mampong and Adanwomase. The pH at Mampong (4.81) and Adanwomase (4.39) are both classified as strongly acidic, with Adanwomase being more acidic. Mampong (15.55 mg/kg) and Adanwomase (12.65 mg/kg) show low to moderate phosphorus levels. Both sites exhibit low nitrogen content, with Mampong at 0.14% and Adanwomase at 0.12%. The organic carbon content is very low in both locations, 0.32% in Mampong and 0.31% in Adanwomase. Mampong (0.42%) has significantly lower organic matter compared to Adanwomase (1.60%). Both Mampong (0.16 cmol/kg) and Adanwomase (0.13 cmol/kg) have low potassium levels.

Calcium levels are low at both sites, with Mampong at 1.50 cmol/kg and Adanwomase at 1.11 cmol/kg. Mampong has adequate magnesium (1.04 cmol/kg), whereas Adanwomase shows a severe deficiency (0.04 cmol/kg). Sodium levels are very low at both sites. Adanwomase (0.43 cmol/kg) exhibits a higher level of aluminum toxicity risk compared to Mampong (0.33 cmol/kg). Both sites also contribute to total acidity with pH levels of 4.8 (Mampong) and 4.39 (Adanwomase). Both soils are classified as sandy loams, which are typically well-drained but poor in nutrient and moisture retention. Adanwomase has a slightly higher clay content, which may offer a marginal improvement in water and nutrient retention, although overall fertility remains limited.

Table 4.1 Soil Analysis

	Mampong	Adanwomase
pH	4.81	4.39
Avail. P (mg/kg)	15.55	12.65
Total nitrogen (%)	0.14	0.12
Org. Carbon (%)	0.32	0.31
Org. matter (%)	0.42	1.60
Exch.Bases(cmol/kg)		
K	0.16	0.13
Ca	1.50	1.11
Mg	1.04	0.04
Na	0.01	0.02
Exch.Acidity(cmol/kg)		
Al	0.33	0.43
H	0.23	0.25
Sand	87.40	85.47
Clay	6.96	8.80
Silt	5.64	5.64
Textural class	Sandy Loam	Sandy Loam

4.2 Composting Analysis

4.2.1 Microbial counts of compost method (technique)

There was a significant difference ($p < 0.05$) in microbial counts of salmonella found in the three compost techniques. The bucket method of compost technique had the highest salmonella count of 0.75x10 cfu/10ml which was significantly not different from the pit method of composting which had the second highest salmonella count of 0.63x10 cfu/10ml. The heap method of composting was observed to have significantly the lowest salmonella count of 0.17x10 cfu/10ml as shown in Table 4.2. No E Coli, was found in the three methods of composting.

Table 4.2 Results of microbial counts from the three compost techniques

Compost technique	Salmonella	Total Coliform (cfu/10 ml)	Mean
Bucket method	0.75 x 10a	0.20 x 10a	0.32
Pit method	0.63 x 10a	0.17 x 10a	0.09
Heap method	0.17 x 10b	0.29 x 10a	0.15
Mean	**0.52**	**0.22**	**0.25**
LSD (p <0.05)	**0.23**	**0.18**	
CV (%)	**13.7**	**26.7**	

4.2.2 Nutrients composition of compost

The heap method of compost technique had the highest percentage values of Nitrogen of 1.05%, Phosphorus of 0.29%, Potassium of 0.63%, Calcium of 0.85%, Magnesium of 0.81%, Sulfur of 13.64%, and Manganese of 247.25 mg/kg relative to the pit and bucket methods of composting (Table 4.3). Similarly, the bucket method of composting was observed to have the highest values of iron of 5267.8 mg/kg and copper of 32.95 mg/kg as compared to pit and heap methods of composting (Table 4.2). The pit compost method had the lowest values of Nitrogen of 0.54%, Phosphorus of 0.11%, Potassium of 0.12%, Calcium of 0.45% and Sulfur of 4.52% relative to the heap and bucket methods of compost techniques (Table 4.2).

Table 4.3 Nutritional analysis of the three compost techniques

Compost technique	**Nutrients composition**									
	%N	**%P**	**%K**	**%Ca**	**%Mg**	**%S**	**Fe (mg/kg)**	**Cu (mg/kg)**	**Zn (mg/kg)**	**Mn (mg/kg)**
Bucket method	0.69b	0.17a	0.24b	0.66ab	0.30b	4.68c	5055.6b	32.95a	22.85b	196.55c
Pit method	0.59b	0.16a	0.17b	0.50b	0.32b	5.57b	5267.8a	31.35b	25.35a	201.35b
Heap method	1.05a	0.29a	0.63a	0.85a	0.81a	13.64a	4935.4c	17.05c	22.85b	247.25a
Mean	**0.78**	**0.21**	**0.35**	**0.66**	**0.48**	**7.96**	**5086.27**	**27.12**	**23.68**	**215.05**
LSD (p <0.05)	**0.25**	**0.24**	**0.23**	**0.23**	**0.22**	**0.23**	**0.25**	**0.32**	**0.23**	**0.22**
CV (%)	**9.10**	**34.21**	**20.40**	**10.55**	**14.83**	**0.89**	**0.01**	**0.26**	**0.30**	**0.03**

4.3 Growth and yield and yield components of carrots

4.3.1 Plant height

Figures 4.1 and 4.2 show the results of the plant height of carrot as affected by composting (bucket, pit, and heap methods) at Adanwomase and Asante Mampong which was taken from 28 DAT to 84 DAT. The plant height increased throughout the entire period from 28 DAT to 84 DAP for both locations. At Adanwomase, the heap method of composting at a rate of 15 tons/ha (15 t/ha HMC) had the highest mean height of 9.83 cm, 18.38 cm, and 47.25 cm at 28, 42, and 70 DAP respectively (Figures 4.1 and 4.2). The bucket method of composting at a rate of 15 tons/ha (15 t/ha BMC) was observed to have the highest plant height of 41.56 cm at 56 DAP and the pit method of composting at a rate of 15 tons/ha (15 t/ha PMC) showed the highest plant height of 52.17 cm at 84 DAP.

At Mampong, poultry manure at a rate of 15 tons/ha (15 t/ha PM) had the greatest plant height of 10.15 cm at 28 DAP; the pit method of composting at a rate of 15 tons/ha (15 t/ha PMC) was observed to have the highest plant height of 20.93 cm at 42 DAP and 50.24 cm at 56 DAP (Figures 4.1 and 4.2). Furthermore, the heap method of composting at a rate of 15 tons/ha (15 t/ha HMC) had the highest plant height of 56.14 cm, and the bucket method of composting at a rate of 15 tons/ha (15 t/ha BMC) showed the highest plant height of 58.20 cm (Figures 4.1 and 4.2). Over the sampling period, the control (no fertilizer) had the least plant height.

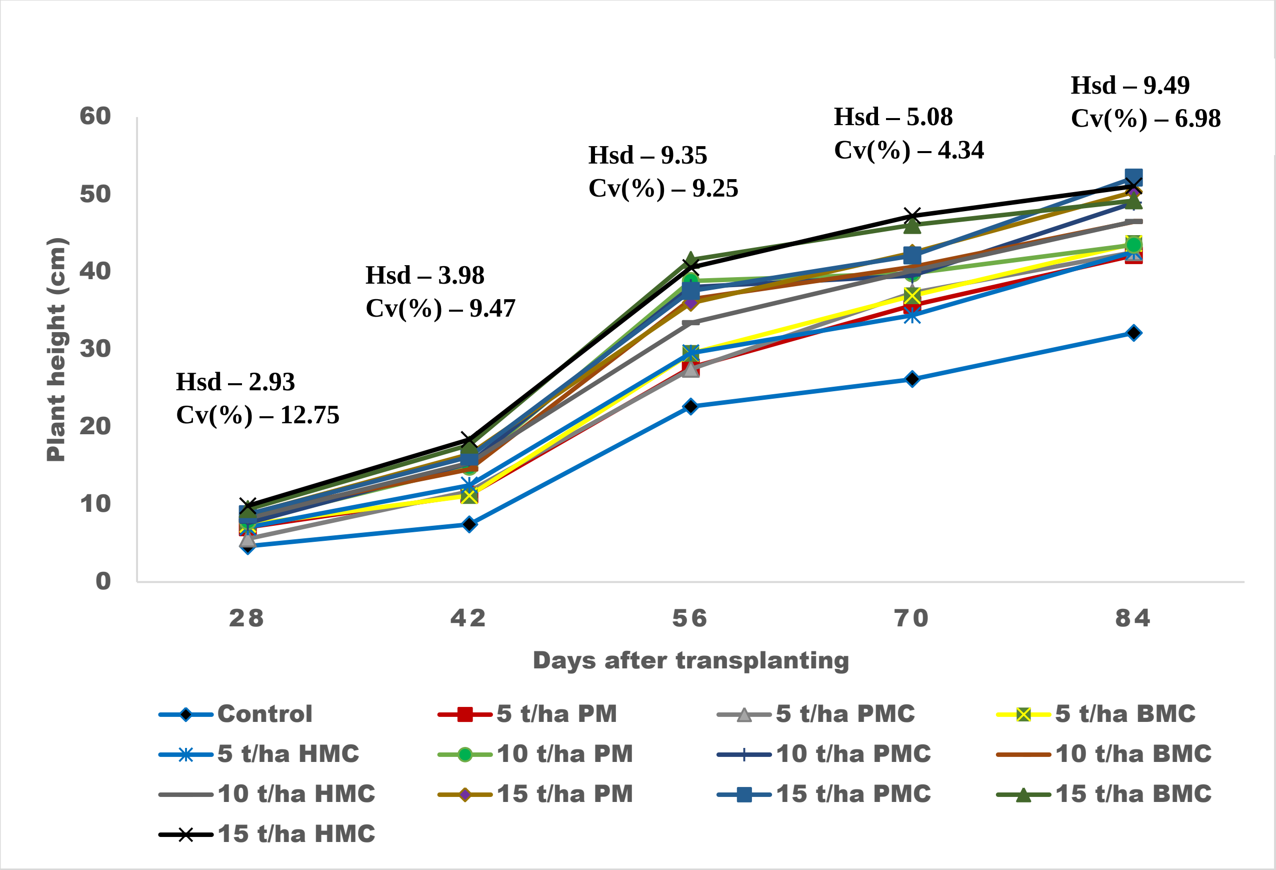

Figure 4.1: Plant height of carrot as affected by composting method and application rate   Adanwomase

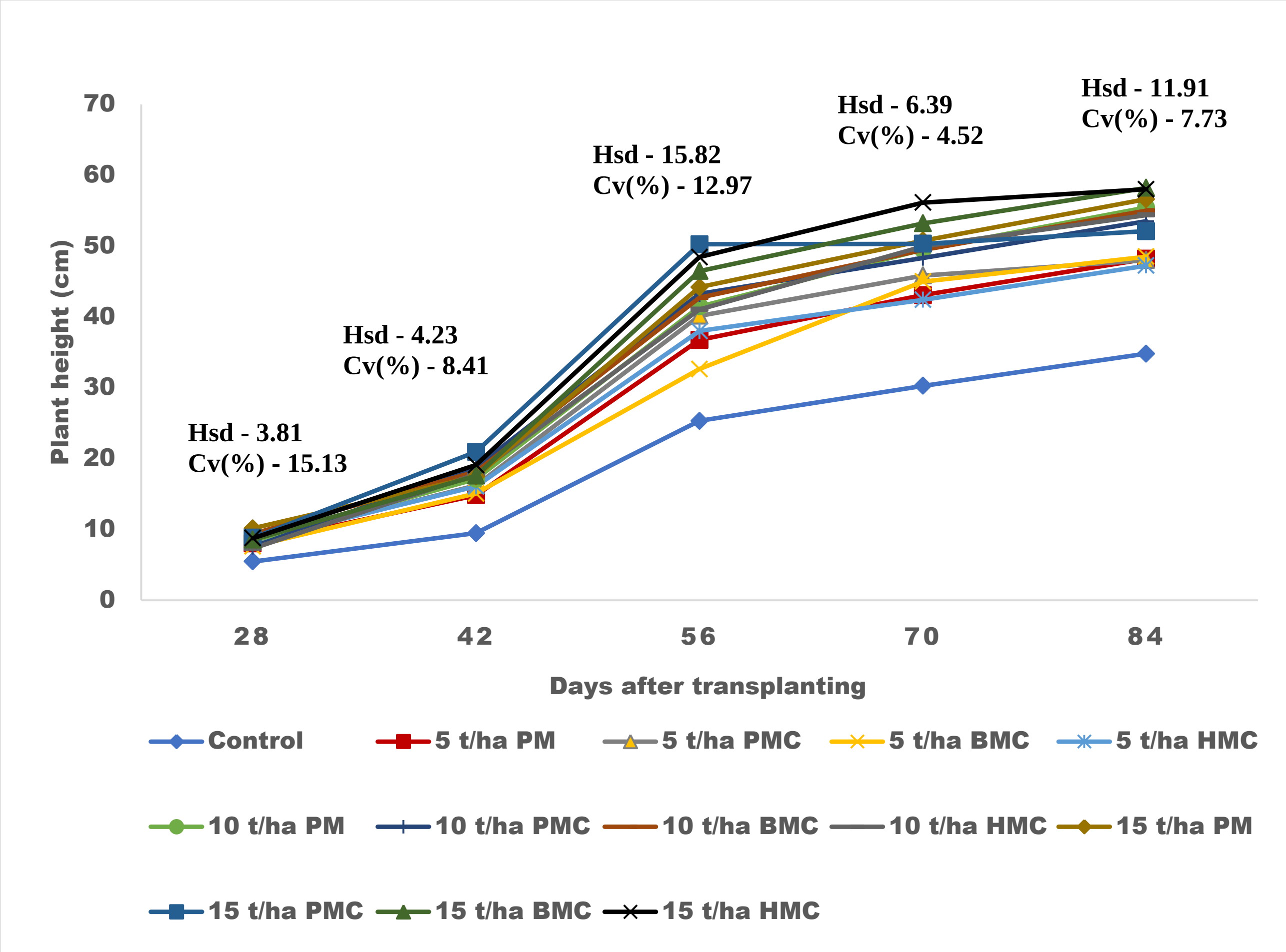

Figure 4.2: Plant height of carrot as affected by composting method and application rates at Mampong-Ashanti

4.3.2 Number of leaves per plant

The number of leaves per plant of carrot as affected by composting (bucket, pit, and heap methods) at Adanwomase and Asante Mampong which was taken from 28 DAT to 84 DAT is shown in Figure 4.3 and 4.4. The number of leaves per plant increased throughout the entire period from 28 DAT to 84 DAP for both locations. At Adanwomase, the poultry manure at a rate of 15 tons/ha (15 t/ha PM) showed the greatest number of leaves per plant of 2.74 cm at 28 DAP, and 4.66 cm at 56 DAP. In addition, the poultry manure at a rate of 10 tons/ha (10 t/ha PM) had the highest number of leaves per plant of 7.19 at 84 DAP (Figures 4.3 and 4.4). The bucket method of composting at a rate of 15 tons/ha (15 t/ha BMC) was observed to have the highest number of leaves per plant of 2.9 at 42 DAP; and the heap method of composting at a rate of 15 tons/ha (15 t/ha HMC) had the highest number of leaves per plant of 6.61 at 70 DAP (Figures 4.3 and 4.4). At Mampong, the poultry manure at a rate of 15 tons/ha (15 t/ha PM) had the highest number of leaves per plant of 3 cm at 28 DAP, and 3.4 at 42 DAP respectively. Moreover, the pit method of composting at a rate of 15 tons/ha (15 t/ha PMC) had the highest number of leaves per plant of 6.53 at 56 DAP, and 8.87 at 84 DAP (Figures 4.3 and 4.4). The heap method of composting at a rate of 15 tons/ha (15 t/ha HMC) had the highest number of leaves per plant of 8 cm at 70 DAP. On the average across all sampling dates the control (no fertilizer) had the least number of leaves per plant.

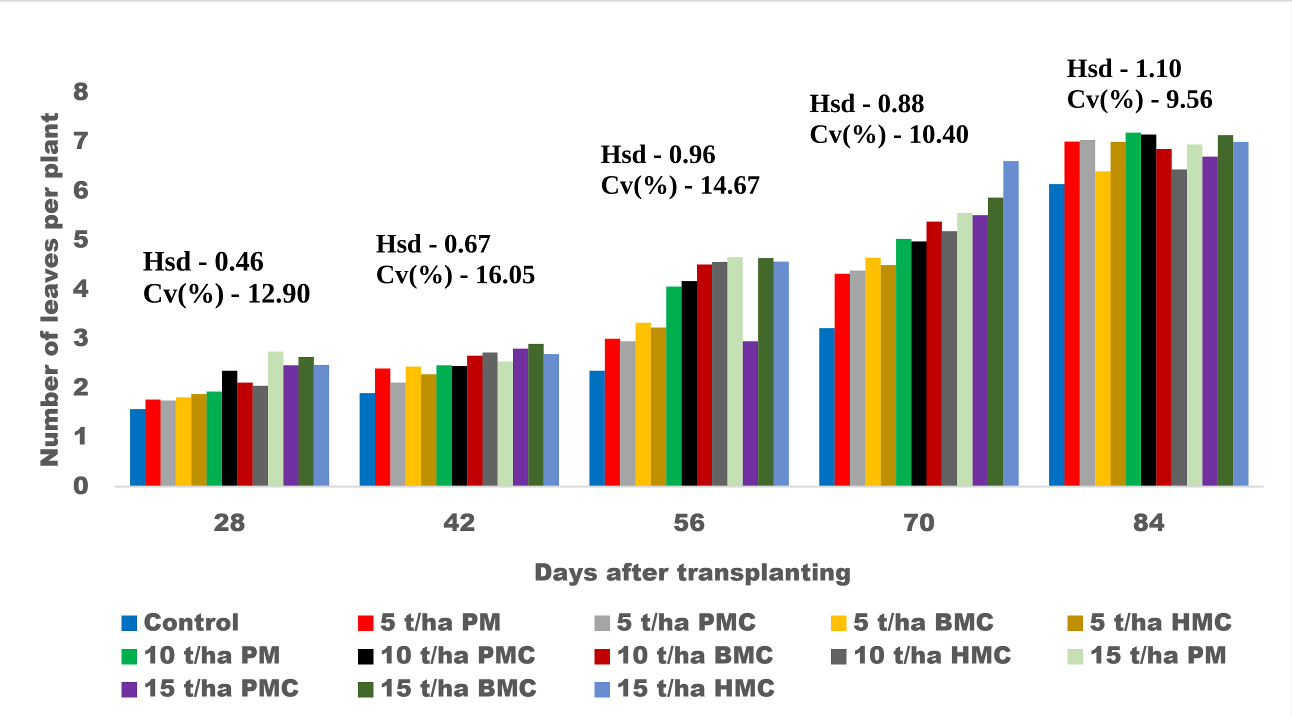

Figure 4.3: Number of leaves of per plant of carrot as affected by composting method and application rates at Adanwomase

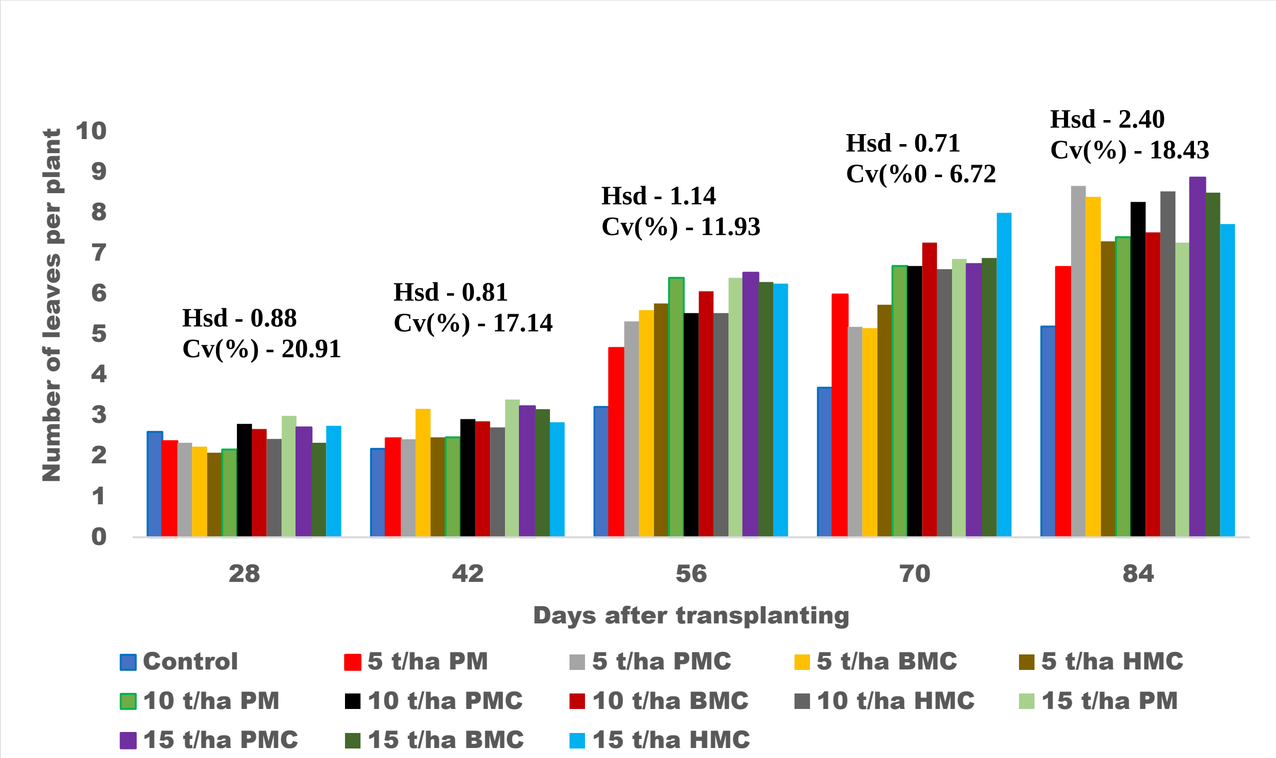

Figure 4.4: Number of leaves of per plant of carrot as affected by composting method and application rates at Mampong-Ashanti

4.3.3 Root length and root diameter

There were significant differences (P<0.05) in root length and root diameter for the yield components of carrot. At Adanwomase, poultry manure at a rate of 15 tons/ha (15 t/ha PM) showed the highest root length of 11.58 cm which did not differ significantly from 15 t/ha PMC, BMC and HMC. The heap method of composting at a rate of 15 tons/ha (15 t/ha HMC) was observed to have the highest root diameter of 3.75 (Table 4.4) which was also not significantly different from 15 t/ha PM, BMC and PMC. Similarly, at Mampong, the heap method of composting at a rate of 15 tons/ha (15 t/ha HMC) had the highest root length of 15.17 cm, and the bucket method of composting at a rate of 10 tons/ha (10 t/ha BMC) showed the highest root diameter of 3.54 (Table 4.3). There were significant (P<0.05) differences observed between the treatment means of location and treatment for the root length of carrot. For the treatment means of the root diameter of carrot, significant (P<0.05) difference was observed between the treatment and location x treatment interaction. The control (no fertilizer) had the least root diameter at both Adanwomase and Mampong (1.60 cm and 2.20 cm, respectively).

Table 4.4: Root length and Root width carrot as affected by composting method and application rates at both Adanwomase and Mampong

Treatment	Root length (cm)			Root diameter (cm)		
	Adanwomase	Mampong	Mean	Adanwomase	Mampong	Mean
Control	7.33g	10.59d	**8.96**	1.60e	2.20b	1.90
5 t/ha PM	8.25efg	10.78d	**9.51**	2.49cd	2.92ab	2.69
5 t/ha PMC	7.51fg	10.69d	**9.10**	2.31de	3.04ab	2.68
5 t/ha BMC	8.05efg	10.58d	**9.32**	2.40cd	2.72ab	2.56
5 t/ha HMC	8.19efg	10.06d	**9.13**	2.32de	2.78ab	2.55
10 t/ha PM	9.42bcde	11.42cd	**10.42**	3.35ab	3.14ab	3.25
10 t/ha PMC	9.12cdef	12.45bcd	**10.79**	2.98abcd	3.36a	3.17
10 t/ha BMC	8.85efg	10.92d	**9.89**	2.90bcd	3.54a	3.22
10 t/ha HMC	9.01defg	10.86d	**9.94**	3.19abc	3.33a	3.26
15 t/ha PM	11.58a	13.92abc	**12.75**	3.57ab	3.32a	3.45
15 t/ha PMC	10.66abcd	14.45ab	**12.56**	3.60ab	2.96ab	3.28
15 t/ha BMC	10.95ab	13.91abc	**12.43**	3.62ab	2.99ab	3.31
15 t/ha HMC	10.81abc	15.17a	**12.99**	3.75a	3.17ab	3.46
Mean	**9.21**	**11.98**	**10.60**	**2.93**	**3.04**	2.99
CV (%)	**6.36**	**7.54**	**6.95**	**9.09**	**11.80**	10.45
Location (HSD=0.05)	*0.44*	*(P<0.0001)*		*NS*		
Treatment (HSD=0.05)	*1.94*	*(P<0.0001)*		*0.64*		*(P<0.0001)*
*Location*Treatment (HSD=0.05)*	*NS*			*1.01*		*(P<0.0001)*

Means bearing the same letters within a column are not significantly different at 5% level of significance; CV = coefficient of variation; HSD = Highest significant difference at 5%; PM = poultry manure, PMC = Pit method of composting; BMC = Bucket method of composting; HMC= Heaping/ Pilling method of composting DAP = Days after planting.

4.3.4 Fresh root and leaf weight

There were significant differences (P<0.05) in fresh leaf weight and fresh root weight. At Adanwomase, the bucket method of composting at a rate of 15 tons/ha (15 t/ha BMC) showed the highest fresh leaf weight of 3.53 kg/plot, and fresh root weight of 4.22 kg/plot (Table 4.4). Moreover, at Mampong, poultry manure at a rate of 10 tons/ha (10 t/ha PM) had the highest fresh leaf weight of 3.77 kg/plot, and the bucket method of composting at a rate of 15 tons/ha (15 t/ha BMC) was observed to have the highest fresh root weight of 3.93 kg/plot (Table 4.5). Significantly (P<0.05), differences were observed among the treatments for the fresh leaf weight and the fresh root weight of carrot. However, between the location and location x treatment interaction, no significant (P≥0.05) difference was observed between the treatment means for the period of the experiment.

Table 4.5: Fresh root and leaf weight carrot as affected by composting method and application rates at both Adanwomase and Mampong

Treatment	Fresh leaf weight (kg/plot)			Fresh root weight (t/ha)		
	Adanwomase	Mampong	Mean	Adanwomase	Mampong	Mean
Control	1.87f	2.47bcd	2.17	5.951e	12.50c	9.23
5 t/ha PM	2.41cdef	2.37bcd	2.39	12.70cde	15.00abc	13.85
5 t/ha PMC	2.28def	2.60bcd	2.44	10.75de	12.50c	11.63
5 t/ha BMC	2.20ef	2.07d	2.14	12.65cde	12.50c	12.58
5 t/ha HMC	2.41cdef	2.13cd	2.27	13.45cde	14.50abc	13.98
10 t/ha PM	3.21ab	3.77a	3.49	19.05ab	17.00abc	18.03
10 t/ha PMC	2.89abcd	2.83bcd	2.86	16.05abcd	15.15abc	15.60
10 t/ha BMC	2.83bcde	2.73bcd	2.78	14.95bcde	17.35abc	16.15
10 t/ha HMC	2.50cdef	2.50bcd	2.50	16.10abcd	19.15ab	17.63
15 t/ha PM	2.83bcde	3.00ab	2.92	16.50abc	16.85abc	16.68
15 t/ha PMC	2.93abcd	2.87bc	2.90	16.75abc	19.50ab	18.13
15 t/ha BMC	3.53a	2.80bcd	3.17	21.10a	19.65a	20.38
15 t/ha HMC	3.04abc	2.83bcd	2.94	19.10ab	13.15bc	16.13
Mean	**2.69**	**2.69**	**2.69**	**3.06**	**3.15**	**3.11**
CV (%)	**15.35**	**17.36**	**16.36**	**21.08**	**24.20**	**22.64**
Location (HSD=0.05)		*NS*			*NS*	
Treatment (HSD=0.05)		*0.88*	*(P<0.0001)*		*1.41*	*(P<0.0001)*
*Location*Treatment (HSD=0.05)*		*NS*			*NS*	

Means bearing the same letters within a column are not significantly different at 5% level of significance; CV = coefficient of variation; HSD = Highest significant difference at 5%; PM = poultry manure, PMC = Pit method of composting; BMC = Bucket method of composting; HMC= Heaping/ Pilling method of composting DAP = Days after planting

4.3.5 Dry root and leaf weight

Table 4.5 shows results of dry root and leaf weight of carrot as affected by composting (bucket, pit, and heap methods) at both Adanwomase and Mampong. There was a significant ($P<0.05$) difference between the treatment means in dry leaf weight and dry root weight at both locations. At Adanwomase, the poultry manure at a rate of 15 tons/ha (15 t/ha PM) showed the highest dry leaf weight of 2.43 kg/plot, and dry root weight of 1.87 kg/plot (Table 4.6). Moreover, at Mampong, poultry manure at a rate of 15 tons/ha (15 t/ha PM) had the highest dry leaf weight of 2.63 kg, and a dry weight of 2.00 kg/plot (Table 4.5).

Generally, the poultry manure application at 15 tons/ha had the highest performance for both dry leaf weight as well as the dry root weight at both locations. Significantly ($P<0.05$), differences were observed among the treatments for the dry leaf weight and the dry root weight of carrot. However, between the location and location x treatment interaction, no significant ($P\geq0.05$) difference was observed between the treatment means for the period of the experiment.

Table 4.6: Dry root and leaf weight carrot as affected by composting method and application rates at both Adanwomase and Mampong

	Dry leaf weight (kg/plot)			Dry root weight (kg/plot)		
Treatment	Adanwomase	Mampong	Mean	Adanwomase	Mampong	Mean
Control	0.77c	0.87c	0.82	0.63b	0.70b	0.67
5 t/ha PM	1.03bc	1.10bc	1.07	1.00ab	1.13ab	1.07
5 t/ha PMC	0.93bc	1.06bc	1.00	0.63b	0.73b	0.63
5 t/ha BMC	0.77c	0.87c	0.82	0.77b	0.89b	0.83
5 t/ha HMC	0.83c	0.90c	0.87	0.73b	0.80b	0.77
10 t/ha PM	1.90ab	2.07ab	1.99	1.53ab	1.70ab	1.62
10 t/ha PMC	0.97bc	1.10bc	1.04	0.77b	0.86b	0.82
10 t/ha BMC	0.97bc	1.10bc	1.04	0.93ab	1.13ab	1.03
10 t/ha HMC	1.17bc	1.27bc	1.22	1.17ab	1.27ab	1.22
15 t/ha PM	2.43a	2.63a	2.53	1.87a	2.00a	1.94
15 t/ha PMC	1.17bc	1.27bc	1.22	0.93ab	1.10ab	1.02
15 t/ha BMC	1.00bc	1.10bc	1.05	0.93ab	1.13ab	1.03
15 t/ha HMC	0.97bc	1.10bc	1.04	0.83b	0.97ab	0.90
Mean	**1.15**	**1.26**	**1.21**	**0.98**	**1.11**	**1.05**
CV (%)	**29.20**	**27.68**	**28.44**	**34.31**	**31.93**	**31.38**
Location (HSD=0.05)	*NS*			*NS*		
Treatment (HSD=0.05)	*0.67*	*(P<0.0001)*		*0.68*	*(P<0.0001)*	
*Location*Treatment (HSD=0.05)*	*NS*			*NS*		

Means bearing the same letters within a column are not significantly different at 5% level of significance; CV = coefficient of variation; HSD = Highest significant difference at 5%; PM = poultry manure, PMC = Pit method of composting; BMC = Bucket method of composting; HMC= Heaping/ Pilling method of composting DAP = Days after planting

4.3.6 Number of cracked and forked roots

There were significant differences (P<0.05) in the number of cracked roots and the number of forked roots. At Adanwomase, the control was observed to have the highest number of cracked roots, and the highest number of forked roots (Table 4.7). Similarly, at Mampong, the control showed the highest number of cracked roots, and the highest number of forked roots (Table 4.6). Significantly (P≥0.05), no difference was observed between the treatment means of the number of cracked roots of carrot. For the number of forked roots of carrot, significant (P<0.05) difference was observed between the treatment means of location. However, between the location and location x treatment interaction, no significant (P≥0.05) difference was observed between the treatment means for the period of the experiment for the number of forked roots of carrot.

Table 4.7: Number of cracked roots and forked roots of carrot as affected by composting method and application rates at both Adanwomase and Mampong

Treatment	Number of cracked roots/plot			Number of forked roots/plot		
	Adanwomase	**Mampong**	**Mean**	**Adanwomase**	**Mampong**	**Mean**
Control	3.33a	5.33a	4.33	5.00a	5.00a	5.00
5 t/ha PM	1.00c	1.33b	1.17	1.67b	2.00ab	1.84
5 t/ha PMC	2.67ab	1.67b	2.17	1.67b	1.67b	1.67
5 t/ha BMC	1.33bc	2.33ab	1.83	2.33ab	2.33ab	2.33
5 t/ha HMC	1.00c	1.33b	1.17	2.00ab	2.67ab	2.34
10 t/ha PM	2.00abc	2.33ab	2.17	2.33ab	1.67b	2.00
10 t/ha PMC	1.00c	2.00b	1.50	1.67b	1.33b	1.50
10 t/ha BMC	1.33bc	1.67b	1.50	1.67b	2.33ab	2.00
10 t/ha HMC	1.67bc	2.00b	1.84	3.67ab	1.33b	2.5
15 t/ha PM	1.67bc	2.00b	1.84	2.33ab	3.00ab	2.67
15 t/ha PMC	2.00abc	3.33ab	2.67	3.33ab	2.67ab	3.00
15 t/ha BMC	1.33bc	2.00b	1.67	2.00ab	2.33ab	2.17
15 t/ha HMC	1.00c	1.67b	1.34	2.00ab	2.00ab	2.00
Mean	**1.44**	**2.23**	**1.84**	**2.44**	**2.33**	**2.39**
CV (%)	**33.45**	**47.34**	**40.40**	**41.40**	**46.75**	**44.08**
Location (HSD=0.05)	*NS*			*0.51*	*(P=0.0007)*	
Treatment (HSD=0.05)	*NS*			*NS*		
*Location*Treatment (HSD=0.05)*	*NS*			*NS*		

Means bearing the same letters within a column are not significantly different at 5% level of significance; CV = coefficient of variation; HSD = Highest significant difference at 5%; PM = poultry manure, PMC = Pit method of composting; BMC = Bucket method of composting; HMC = Heaping/ Pilling method of composting DAP = Days after planting

4.3.7 Number of harvested and deformed roots

There was a significant difference (P<0.05) in the number of deformed roots and the number of harvested roots. At Adanwomase, the control had the highest number of deformed roots, and the pit method of composting at a rate of 15 tons/ha (15 t/ha PMC) had the highest number of harvested roots of 40 (Table 4.7). Furthermore, at Mampong, the control was observed to have the highest number of deformed roots, and the pit method of composting at a rate of 15 tons/ha (15 t/ha PMC) showed the highest number of harvested roots at 40 (Table 4.8).

For the number of deformed roots of carrot, significant (P<0.05) difference was observed between the treatment means. However, between the location and location x treatment interaction, no significant (P≥0.05) difference was observed between the treatment means for the period of the experiment. Similarly, no significant (P≥0.05) difference was observed between the treatment means, location, and location x treatment interaction of the number of roots harvested for carrot.

Table 4.8: Number of harvested and deformed roots of carrot as affected by composting method and application rates at both Adanwomase and Mampong

Treatment	Number of deformed roots/plot			Number of harvested roots/plot		
	Adanwomase	**Mampong**	**Mean**	**Adanwomase**	**Mampong**	**Mean**
Control	4.67a	3.67a	4.17	22.67c	27.33b	25.00
5 t/ha PM	2.00b	2.33a	2.17	33.33abc	32.67ab	33.00
5 t/ha PMC	2.67ab	2.00a	2.34	36.67ab	35.67ab	36.17
5 t/ha BMC	1.00b	3.00a	2.00	34.67ab	39.67a	37.17
5 t/ha HMC	1.33b	2.00a	1.67	28.00bc	34.00ab	31.00
10 t/ha PM	1.67b	1.67a	1.67	30.67abc	36.33ab	33.50
10 t/ha PMC	1.00b	2.00a	1.50	36.33ab	34.67ab	35.5
10 t/ha BMC	1.67b	1.67a	1.67	33.67abc	37.67ab	35.67
10 t/ha HMC	1.33b	2.33a	1.83	35.67ab	36.33ab	36.00
15 t/ha PM	3.00ab	1.67a	2.34	38.67ab	37.00ab	37.84
15 t/ha PMC	1.67b	1.33a	1.50	40.00a	40.00a	40.00
15 t/ha BMC	1.33b	1.67a	1.50	36.00ab	36.00ab	36.00
15 t/ha HMC	2.33ab	2.33a	2.33	34.67ab	33.33ab	34.00
Mean	**1.97**	**2.13**	**2.05**	**33.92**	**35.44**	**34.68**
CV (%)	**43.23**	**43.82**	**43.53**	**11.69**	**10.13**	**10.91**
Location (HSD=0.05)	*NS*			*NS*		
Treatment (HSD=0.05)	*1.85*	*(P=0.0173)*		*NS*		
*Location*Treatment (HSD=0.05)*	*NS*			*NS*		

Means bearing the same letters within a column are not significantly different at 5% level of significance; CV = coefficient of variation; HSD = Highest significant difference at 5%; PM = poultry manure, PMC = Pit method of composting; BMC = Bucket method of composting; HMC= Heaping/ Pilling method of composting DAP = Days after planting.

4.4 Nutritional analysis of carrot at Mampong and Adanwomase

There were significant difference ($P<0.05$) in nutritional analysis in carrot after the compost application rates at Mampong. The bucket method of composting at an application rate of 15 tons/ha (15 BMC) had the highest ASH content of 12.16% in carrot followed by poultry manure (PM) at a rate of 15 tons/ha and heap method of composting (HMC) at a rate of 15 tons/ha which recorded significantly higher ASH contents of 11.65% and 11.57% in carrot respectively (Table 4.9).

In addition, poultry manure at a rate of 5 tons/ha (5PM) had the highest fibre and iron contents of 11.72% and 54.58 ppm in carrot as compared to pit method of composting at a rate of 15 tons/ha and bucket method of composting at 10 tons/ha which were observed to have lowest contents of fibre and iron in carrot (Table 4.9). Again, the control, where no soil amendment was done had the highest protein value content of 9.52% in carrot (Table 4.10). It was followed by pit method of composting at a rate of 15 tons/ha (15 PMC), pit method of composting at a rate of 5 tons/ha, and poultry manure at a rate of 5 tons/ha which were observed to have relatively higher protein values of 7.75%, 7.22%, and 7.05% in carrot respectively (Table 4.9). Furthermore, poultry manure at a rate of 15 tons/ha and bucket method of composting at a rate of 10 tons/ha had highest values of carbohydrates and calcium contents in carrot as compared to poultry manure at a rate of 5 tons/ha (Table 4.10).

There were also a significant difference ($P<0.05$) among the treatments in nutritional analysis in carrot after the compost application rates at Adanwomase. The treatments; bucket method of composting at a rate of 5 tons/ha (5BMC), bucket method of composting at a rate of 15 tons/ha (15 BMC), heap method of composting at a rate of 15 tons/ha (15 HMC), poultry manure at a rate of 15 tons/ha (15 PM), and pit method of composting at a rate of 15 tons/ha (15 PMC) had significantly highest ASH contents in carrot. Furthermore, poultry manure at a rate of 15 tons/ha was observed to have the highest calcium content and carbohydrate content in carrot relative to poultry manure at a rate of 5 tons/ha and 10 tons/ha respectively (Table 4.10). Poultry manure at a rate of 15 tons/ha was observed to have the highest carbohydrate content of 77.91% in carrot relative to poultry manure at a rate of 5 tons/ha and 10 tons/ha (Table 4.9). The control, where no soil amendment was done had the highest protein value content of 9.29% as compared to all other treatments that were applied to the crops on the field (Table 4.10).

Table 4.9a Results of compost method and application rates on nutritional analysis of carrot at Mampong

Treatment	Ash	Calcium	Carbohydrate	Fiber	Iron	Moisture	Protein
	Mg/kg						
Control	11.34abc	0.14d	69.42e	11.21ab	54.55a	91.03abcd	9.52a
5 t/ha PM	9.79de	0.18bc	69.42e	11.72a	54.58a	90.17bcd	7.05bcde
5 t/ha PMC	9.84cde	0.12e	75.10c	9.76bcd	30.29b	89.79cd	7.22bcd
5 t/ha BMC	10.55bcde	0.17c	75.13c	9.69cd	30.56b	89.79cd	6.21cdef
5 t/ha HMC	10.82abcd	0.14d	75.12c	9.95bcd	22.69d	90.29bcd	6.32bcdef
10 t/ha PM	9.52de	0.14d	75.10c	10.01bcd	22.28d	89.79cd	5.41f
10 t/ha PMC	9.57de	0.18bc	77.36ab	9.80bcd	20.31e	90.78abcd	5.40f
10 t/ha BMC	9.23e	0.24a	77.18ab	9.63cd	20.52e	89.64	5.68ef
10 t/ha HMC	9.55de	0.14d	76.69b	9.64cd	23.57d	90.23bcd	5.71def
15 t/ha PM	11.65ab	0.19b	78.62a	9.68cd	23.17d	91.12abc	7.72bc
15 t/ha PMC	11.42ab	0.14d	76.48bc	8.78d	29.17bc	90.24bcd	7.75b
15 t/ha BMC	12.16a	0.13de	73.21d	10.40abc	29.55bc	91.73a	6.65bcdef
15 t/ha HMC	11.57ab	0.14d	73.32d	10.29abc	28.26c	91.60ab	6.64bcdef
HSD (P≤0.05)	**1.53**	**0.02**	**1.53**	**1.47**	**1.53**	**1.41**	
CV (%)	**6.71**	**4.63**	**0.95**	**6.76**	**2.36**	**0.72**	**10.53**

PM = poultry manure; PMC = Pit method of composting; BMC = Bucket method of composting; HMC = Heaping/pilling method of composting; M = poultry manure; PMC = Pit method of composting; BMC = Bucket method of composting; HMC = Heaping/pilling method of composting; CV = coefficient of variation; LSD = Least Significant Difference.

Table 4.10 Results of compost application rates on nutritional analysis in carrot at Adanwomase

Treatment	Ash	Calcim	Carbohydrat	Fibre	Iron	Moistur	Protein
			mg/kg				
Control	8.72e	0.12bc	69.42e	11.28a	49.76a	89.53b	9.29a
5 t/ha PM	9.87de	0.16abc	69.42e	10.60ab	30.82b	89.98ab	7.05bcd
5 t/ha PMC	9.84de	0.11c	75.10b	10.39ab	30.29bcd	90.06ab	7.22bcd
5 t/ha BMC	11.92a	0.19ab	70.84de	10.11abc	30.56bc	89.97ab	6.07d
5 t/ha HMC	9.48de	0.14bc	71.91cd	6.95abc	26.81e	90.01ab	6.32cd
10 t/ha PM	10.39bcd	0.14bc	71.72cd	9.91abc	20.17h	90.28ab	7.06bcd
10 t/ha PMC	10.17cde	0.13bc	77.36a	9.62bc	21.04gh	90.56ab	6.41bcd
10 t/ha BMC	10.04de	0.16abc	77.18a	9.63bc	22.31fg	90.38ab	7.15bcd
10 t/ha HMC	10.12de	0.14bc	76.69a	9.64bc	23.17f	90.23ab	6.73bcd
15 t/ha PM	11.85ab	0.23a	77.91a	9.47bc	29.92bcd	91.39a	7.89ab
15 t/ha PMC	11.67abc	0.14bc	73.23c	8.78c	29.17cd	90.42ab	7.75bc
15 t/ha BMC	11.92a	0.14bc	73.21c	9.42bc	29.12cd	91.32a	7.82abc
15 t/ha HMC	11.71ab	0.14bc	73.01c	9.37bc	28.85d	91.29a	7.62bc
HSD ($P \leq 0.05$)	**1.53**	**0.07**	**1.53**	**1.53**	**1.52**	**1.53**	**1.53**
CV (%)	**6.75**	**23.59**	**0.96**	**7.17**	**2.47**	**0.78**	**9.74**

PM = poultry manure; PMC = Pit method of composting; BMC = Bucket method of composting; HMC = Heaping/pilling method of composting; M = poultry manure; PMC = Pit method of composting; BMC = Bucket method of composting; HMC = Heaping/pilling method of composting; CV = coefficient of variation; LSD = Least Significant Difference.

CHAPTER FIVE: DISCUSSION

5.1 Initial soil analysis

The initial soil analysis indicates that both Mampong and Adanwomase are characterized by strongly acidic soils, with pH values of 4.81 and 4.39 respectively. According to Nyadanu *et al.* (2021), optimal soil pH for most tropical crops lies between 5.5 and 7.0. Soils with pH values below 5.0, such as observed at Adanwomase, are often prone to aluminum and manganese toxicity, while also restricting the availability of essential nutrients like phosphorus, calcium, and magnesium. Similar findings were reported by Awoonor *et al.* (2024) in the Forest-Savannah Transition Zone of Ghana, where strongly acidic soils were found to limit nutrient uptake and reduce maize yields unless corrected by liming.

Available phosphorus levels at both sites, 15.55 mg/kg at Mampong and 12.65 mg/kg at Adanwomase fall within the low to moderate range. According to Yusuf et al. (2023), soils with available P below 20 mg/kg are considered deficient for most crops. In acidic environments, phosphorus becomes immobilized due to fixation with iron and aluminum oxides, rendering it unavailable for plant uptake (Singh *et al.*,2022). This phosphorus limitation could hinder root development and early crop establishment unless addressed with phosphorus fertilization or pH correction strategies.

The total nitrogen content of the soils is also low, 0.14% for Mampong and 0.12% for Adanwomase. These values align with findings by Dabessa *et al*. (2018), who noted that most cultivated soils in sub-Saharan Africa suffer from nitrogen deficiency due to continuous cropping, low organic inputs, and limited biological nitrogen fixation. Nitrogen deficiency is one of the most limiting factors in tropical agriculture, often leading to stunted growth and chlorosis. The organic carbon (OC) content is low at both sites (0.32% in Mampong and 0.31% in Adanwomase), while organic matter (OM) content is significantly higher in Adanwomase (1.60%) than Mampong (0.42%). This difference may reflect variations in land management practices, such as residue retention, previous organic amendments, or vegetation cover. According to Gurmu (2019), organic matter plays a critical role in enhancing soil structure, water retention, and microbial activity. The low OC and OM values in Mampong may result in reduced microbial biomass and nutrient cycling.

Exchangeable potassium (K) levels are low in both locations (0.16 cmol/kg in Mampong and 0.13 cmol/kg in Adanwomase). Potassium is crucial for osmotic regulation, enzyme activation, and stress resistance, and its deficiency can negatively affect crop resilience and productivity (Patel *et al.*,2022). Similarly, calcium (Ca) concentrations are below optimal thresholds (1.50 cmol/kg in Mampong and 1.11 cmol/kg in Adanwomase), suggesting limited supply for cell wall development and root elongation. The low cation exchange capacity (CEC) typically associated with sandy soils further exacerbates the leaching of such cations, as highlighted by Costa *et al*. (2020). Mampong has an adequate level of 1.04 cmol/kg, while Adanwomase shows a severe deficiency at 0.04 cmol/kg. Magnesium deficiency can severely impair chlorophyll formation and photosynthesis, and is particularly critical in acid soils where Mg tends to be leached rapidly. This supports the findings of Dodoo *et al.* (2023), who emphasized the need for site-specific Mg fertilization in Ghana's acidic agro-ecological zones.

Sodium (Na) levels are very low in both soils, which is favourable, as excess sodium can lead to soil dispersion, poor structure, and reduced permeability. Low sodium is commonly observed in well-drained, non-saline soils typical of humid regions (Chhabra, 2022). Exchangeable aluminum (Al), a key contributor to soil acidity and toxicity, is higher in Adanwomase (0.43 cmol/kg) than in Mampong (0.33 cmol/kg). According to Hue (2022), elevated exchangeable (Al) concentrations can inhibit root growth, reduce nutrient uptake, and impair crop productivity. The presence of high aluminum at Adanwomase, combined with a lower pH and severe magnesium deficiency, poses a serious constraint to crop production unless ameliorated through liming.

In terms of soil texture, both Mampong and Adanwomase are classified as sandy loams, with sand content above 85%. Such soils are well-drained but inherently low in nutrient and water retention capacity. Adanwomase has a slightly higher clay content (8.80% compared to 6.96% in Mampong), which may marginally enhance moisture and cation retention, although this is unlikely to offset the overall fertility constraints. The sandy nature of both soils makes them susceptible to nutrient leaching, particularly under high rainfall, as described by Abe *et al*. (2020) in studies across West African soils.

5.2 Microbial count of compost

The mean count of salmonella ranges from 0.17x10 cfu/10ml to 0.75x10 cfu/10ml among the three compost techniques. There was a considerable number of Salmonella found present in the compost. The bucket method of compost technique had the highest number of salmonella count of 0.75x10 cfu/10ml relative to pit and the heap methods of compost techniques. Bacteria (Salmonella) play important roles in the breaking down of organic waste materials into useful nutrients that are beneficial for living organisms (Insam & De Bertoldi, 2017). The higher the number of Salmonella populations present in compost, the greater the extent of decomposition, and the quicker the release of nutrients and energy. In the complex process of composting, the population of microorganisms determine the rate of the decomposition process. It is reported that different kinds of microbes such as fungus, actinomycetes, and bacteria break down and eat organic wastes that result in the production of nutrients and energy (Uygun, 2012).

The production of nutrients and energy from compost could be of great use to plants and other living things. According to Avcioglu *et al.* (2011), microorganisms break down organic material during composting to produce humus, a very stable byproduct that also contains carbon dioxide, water, and energy. Humus is rich in nutrient and its availability to plants could result in higher crop productivity. This is in agreement with a study performed by Zhu *et al.* (2019), which explains that the population of Salmonella in compost increases the availability of bioavailable organic nitrogen by converting high molecular weight bioavailable organic nitrogen into low molecular weight bioavailable organic nitrogen during the composting of various wastes.

Thus, the higher the number of bacterial populations present in the compost, the greater the extent of decomposition and the more availability of bioavailable organic nitrogen (Zhu *et al.*,2019). The lack of significant differences in *E. coli* and total coliform counts between the bucket, pit, and heap methods suggests that, *E. coli* may be more resilient to the specific conditions of each composting method or may be uniformly present across all treatments. Factors like temperature, aeration, and moisture content might not have varied enough between the methods to significantly impact the survival or growth of *E. coli*. Nitrogen (N) is a crucial nutrient for the development of microbes and plants. All organic and mineral N species that are easily accessible for microbial and plant uptake are included in bioavailable N in composts (Zhao *et al.*,2018). Bucket method of composting having the highest number of Salmonella count in the compost would have the fastest rate of decomposition as compared to pit and heap methods of composting. Thus, the availability of bioavailable organic nitrogen in compost needed for plant uptake and growth would be more in bucket method of composting as compared to pit and heap methods of composting.

5.3 Nutritional content of compost

Among the ten (10) mineral nutrients that were assessed in the compost during the laboratory analysis, the heap method of compost technique had the highest percentage values of Nitrogen of 1%, Phosphorus of 0.24%, and Potassium of 0.58% relative to pit and bucket methods of composting which were observed to have relatively lower percentages. The main nutrients that are highly required in compost for plant uptake are nitrogen, phosphorus and potassium (Sánchez *et al.*,2017). According to Anthonis (1994), a well prepared and matured compost has composition ranges of nitrogen (1-3%), phosphorus (0.5-1%) and potassium (1-1.5%). The nitrogen value of 1% in heap method of composting falls within the recommended range of nitrogen (1-3%) as described by Anthonis (Zhao *et al.*,2018). The phosphorus value of 0.24% and potassium value 0.58% fall below the recommended range of phosphorus (0.5-1%) and potassium (1-1.5%) respectively. Even though the heap method of composting had the greatest percentages of phosphorus and potassium relative to bucket and the pit methods of composting, their values were not significant as compared to the recommended range. This could be due to the fact that the compost was not properly enhanced during the preparation stages. Factors such as poor aeration, high moisture content, and insufficient nitrogen-rich materials could account for the low amount of phosphorus and potassium in the compost.

The primary goal of composting is to transform separable organic material into biologically desired appropriate material to achieve the highest amount of nitrogen, phosphorous, and potassium that plants can use, and to create a product that can be used for soil remediation (Tosun, 2003). This goal becomes difficult when there is high levels of moisture content, temperature, and improper aeration during the various phases of decomposition of the compost (Ozturk & Bildik, 2005). This compares well with a study conducted by Kuo *et.al* (2004), who noted that high moisture content, high temperatures, and improper aeration did not favor the activities of microorganisms which transform the organic mix into desired amount of nitrogen, phosphorus, and potassium.

Desirable proportionate of nitrogen, phosphorus, and potassium present in compost are the ones that can easily be utilized by plants for proper growth and development. According to a research study, adequate amount of nitrogen, phosphorus, and potassium in compost contributes to the enhancement of soil structure, and enables the mobilization of nutrients to the plants, which creates a more favorable soil equilibrium (Sánchez *et al.,*2017). Furthermore, the heap method of composting had the highest percentages of calcium (0.8%), magnesium (0.76%), sulfur (13.59%), and manganese (247.20 mg/kg) relative to bucket and pit methods of composting. Copper, zinc, iron and manganese are classified as micro nutrients. Unlike the nitrogen, phosphorus, and potassium, their usage are required in minute quantities. They are traces of elements that serve as supplement to the major nutrients required by the plants for other functional activities (Sukamto & Rahmat, 2023). The heap method of composting could provide more supplement of calcium, magnesium, sulfur, and manganese to the major nutrients required by carrot as compared to bucket and pit methods of composting. Fritz (2007) confirmed that compost provides vital plant nutrients and organic matter, boosts soil microbial activity, builds up surplus humus content, and has abundant of macro and micro nutrients required for plant growth.

5.4 Effects of different Composting methods and rates of Application on Agronomic Parameters of Carrot

There were significant differences ($P<0.05$) among the treatments in the fresh root weight, fresh leaf weight, plant height, number of leaves, root length, root width, number of harvested roots, number of cracked roots, number of deformed roots, and number of forked roots for the different rates of compost application to the carrot crop. The agronomic parameters that determine the growth, yield, and yield components of carrot crop include; plant height, fresh root weight, fresh leave weight, and number of leaves, root length, root width, and number of harvested roots of the crop. The pit method of composting at an application rate of 15 tons/ha (15 t/ha PMC) at Adanwomase had the highest plant height of 52.17 at 84 DAP; the poultry manure at an application rate of 10 tons/ha (10 t/ha PM) had the highest number of leaves per plant at 7.19 cm at 84 DAP; and the pit method of composting at an application rate of 15 tons/ha (15 t/ha PMC) showed the highest number of harvested roots at 40. This means that applying the pit method of compost at a rate of 15 tons/ha and poultry manure at a rate of 10 t/ha could help to give maximum performance of carrot crop in terms of plant height, number of leaves, and number of harvested roots. In addition, poultry manure at a rate of 15 t/ha showed the greatest root length of 11.58 cm; the heap method of composting at a rate of 15 t/ha was observed to have the highest root diameter of 3.75; the bucket method of composting at a rate of 15 t/ha had the highest fresh leaf weight of 3.53 kg, and fresh root weight of 4.22 kg. The bucket method of composting at a rate of 15tons/ha could be the best method of compost application technique to obtain a significant weight in fresh leaf and fresh root of carrot crop. The poultry manure at 15 t/ha and the heap method of composting at 15 t/ha could also be applied to carrots to increase root length and the root diameter for maximum production.

Similarly, at Mampong, the bucket method of composting at a rate of 15 t/ha had the highest plant height of 58.20 cm at 84 DAP; the pit method of composting at a rate of 15 t/ha was observed to have the highest number of leaves per plant of 8.87 at 84 DAP; and the pit method of composting at a rate of 15 t/ha showed the highest number of harvested roots of 40. Applying the pit method of compost at an application rate of 15 tons/ha, and the bucket method of composting at an application rate of 15 t/ha could help to increase the plant height, number of leaves, and number of harvested roots of the carrot crop. Furthermore, the heap method of composting at a rate of 15 t/ha had the highest value of root length of 15.17 cm; the bucket method of composting at a rate of 10 t/ha showed the highest root diameter of 3.54 cm; poultry manure at a rate of 10 t/ha had the greatest fresh leaf weight of 3.77 kg, and the bucket method of composting at a rate of 15 t/ha was observed to have the highest fresh root weight of 3.93 kg. The application of bucket method of composting at a rate of 15 t/ha and 10 t/ha could give the maximum root weight and increase the root diameter of carrots respectively. In addition, applying the heap method of composting at 15 t/ha and poultry manure at 10 t/ha could also help to increase the root length and maximize the weight of fresh leaf of carrot. At Adanwomase, the poultry manure at 5 t/ha, the heap method of composting at 5 t/ha, the pit method of composting at 10 t/ha, the heap method of composting at 15 t/ha the bucket method at 5 t/ha, and the pit method of composting at 10 t/ha were observed to have minimum number of cracked roots and number of deformed roots at 1 as compared to the rest of treatments application rates of compost. It is reported that higher number of deformed, cracked roots and forked roots are not acceptable in carrot production as they could contribute to the decline in yield of produce obtained from the field (Tindal, 1988).

The poultry manure at 5 t/ha, the heap method of composting at 5 t/ha, the pit method of composting at 10 t/ha, and the heap method of composting at 15 t/ha which had minimum number of cracked roots and number of deformed roots could imply that they provided sufficient moist conditions and favorable atmosphere which did not permit root breaking of carrots as well as cracking, twisting and forking of carrot roots. According to Tindal (1988), dry soil conditions are more likely to lead to root breaking of carrot. Insufficient moisture in the soil and uneven irrigation can cause fissures to form in the roots, leading to more deformed or broken roots of carrot (Adusiobo, 1984). This is in agreement with a study conducted by Clerk (1974) that suggested that roots that are in touch with fertilizer pellets or fresh manure, hard soil, overcrowding, and hairy roots might result in carrots with forks or other irregular shapes.

5.5 Compost Application rates and Composting methods on nutritional content of carrot

There were significant differences among the treatments in nutritional analysis in carrot after the compost application rates at Mampong. Moisture content, carbohydrate, protein, fiber, calcium, and Ash are major nutrients found in carrot that are important for human and animal dietary intake. Study shows the standard chemical constituents of carrot are moisture (86%), protein (0.9%), carbohydrate (10.6%), fiber (1.2%), total ash (1.1%), calcium (0.08%), and iron (22 ppm) (Sharma & Karki, 2012). These nutrients composition at the optimum level in carrot help to improve human and animal dietary intake as discussed by Sharma and Karki (2012). It was revealed in the study that the mean value of moisture content of carrots for all the different treatments application rates at both Mampong and Adanwomase ranged from 89.64 to 91.73% and 89.53 to 91.39, respectively.

This range values for moisture content in carrot for all the treatments application rates of compost including the control are greater than the recommended moisture content of 86%. According to Howard *et al.* (1962), the moisture content of carrot can vary from 86 to 89% depending on the variety. Though the mean range value of 89.64 to 91.73% and 89.53 to 91.39% moisture fall outside the recommended moisture value of 86 to 89%, all the application rates of compost for the treatments could be amended or improved to attain the maximum recommended moisture level content of the crop. At Mampong, crops that received heap method of composting at an application rate of 5 tons/ha, poultry manure at an application rate of 10 tons/ha, and poultry manure at an application rate of 15 tons/ha have favorable values of iron at 22.69 ppm, 22.28 ppm, and 23.17 ppm respectively, that revolves around the recommended value of (22 ppm) (Sharma & Karki, 2012) of iron in carrot. Similarly, at Adanwomase, the bucket method of composting at an application rate of 10 tons/ha, and heap method of composting at an application rate of 10 tons/ha also have favorable values of iron at 22.31 ppm and 23.17 ppm respectively that are around the recommended value of (22 ppm) of iron in carrot. According to Kahangi (2004), eating carrot provides adequate iron that is used to make hemoglobin in the red blood cells that carries oxygen from the lungs to all parts of the body. Furthermore, carrot is important for development of the human immune system. Thus, applying the heap method of composting at an application rate of 5 tons/ha, poultry manure at an application rate of 10 tons/ha, and poultry manure at an application rate of 15 tons/ha at Mampong; and the bucket method of composting at an application rate of 10 tons/ha, and heap method of composting at an application rate of 10 tons/ha at Adanwomase would maintain the optimum levels of iron content in carrot.

Crops that received different application rates of compost including the control at Mampong had mean values of protein of 5.40 to 9.52%, carbohydrate of 69.42 to 78.62%, calcium of 0.12 to 0.24%, fiber of 8.78 to 11.72%, and Ash of 9.23 to 12.16%. At Adanwomase, the crops after receiving the different compost application rates were observed to have mean values of protein of 6.07 to 9.29%, carbohydrates of 69.42 to 77.91%, calcium of 0.11 to 0.23%, fiber of 6.95 to 11.28%, and Ash of 8.72 to 11.92%. These set of range values are higher and are far from the standard chemical constituents of carrot of protein (0.9%), carbohydrate (10.6%), calcium of (0.08%), fiber (1.2%), and total ash (1.1%) (Sharma & Karki, 2012). This implies that carrots that received different application rates of compost at both Mampong and Adanwomase have more of protein, carbohydrate, fiber, calcium, and ash nutrient contents relative to the recommended compositions that are required for optimum carrot production. Excess nutrients could be harmful to human health. A study shows that excess nutrients found in carrot could lead to physical inactivity, chronic inflammatory diseases like obesity, and cardiovascular diseases, just as nutrient deficiencies in crops cause stunted growth, impaired immune function, and classic illnesses like scurvy, depression, and xeroptthalmia to the body system (Oz, 2017).

In general, the location of Asante Mampong and Adanwomase did not differ significantly among each other in terms of the compost treatments and may be due to several factors that could have been consistent across both locations, leading to similar outcomes. Asante Mampong and Adanwomase may have comparable climatic conditions, such as temperature, humidity, and rainfall, these factors could influence the composting process in similar ways. According to) Sharma & Karki (2012), temperature and moisture are critical for microbial activity in compost, and uniformity in these conditions across locations can result in similar microbial counts and compost performance. The composition of the soil, including factors like pH, organic matter, and nutrient levels, could be similar in both locations. Since the soil environment influences the composting process and microbial interactions, uniform soil characteristics can lead to comparable compost outcomes.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This research study revealed that the number of Salmonella populations present in the compost was higher in the bucket method of compost technique and that it will have the fastest rate of decomposition as compared to the pit and the heap methods of composting.

- The study revealed that heap method of compost had most of the macro and micro nutrients present in higher proportions and will be more readily available to supply adequate amount of macro and micro nutrients to plants for their functional activities as compared to the other composting method considered.
- However, applying the pit method of compost at a rate of 15 tons/ha gave maximum performance of the carrot crop in terms of plant height, number of leaves, and number of harvested roots at both locations (Adanwomase and Mampong). But applying the heap method of compost at 15 t/ha increased the root length, root diameter and the fresh weight of carrot.
- For the nutrient composition as affected by composting method and rates, it was revealed that applying 15 ton/ha of pit compost method was observed to have lower level of fibre compared to other compost method considered. For ash, calcium, carbohydrate and iron; pit compost method recorded the higher performance compared to other compost method considered at both locations.

6.2 Recommendations

1. The study recommends heap method of composting as the best alternative source of organic fertilizer for carrot production. This method of compost technique will supply adequate amount of macro and micro nutrients to crops for proper growth.
2. The study also recommends that smallholder farmers should apply heap method of composting at 15 t/ha and poultry manure at 10 t/ha to help increase the root length, maximize yield, and increase the weight of fresh leaf of carrot.
3. Furthermore, this research study should be repeated in other agro-ecological zones in Ghana to consolidate the findings of the study.

REFERENCES

Abe, S. S., Buri, M. M., Issaka, R. N., Kiepe, P., & Wakatsuki, T. (2020). Soil fertility potential for rice production in West African lowlands. *Japan Agricultural Research Quarterly: JARQ*, *44*(4), 343-355.

Adegbola RO, Ayodeji O, Awosusi OO, Atiri GI, Kumar PL. First report of banana bunchy top virus in banana and plantain (Musa spp.) in Nigeria. *Plant Disease.* 2013 (2):290-.

Adewale M.T.aiwo (2011). Composting as a sustainable waste management technique in developing countries, *Journal of Env. Sci & Tech.*, 4 (2):93-102.

Adeyemo, F.O. and Gboyesola, G.O. (2013) Knowledge, Attitude and Practices on Waste Management of People Living in the University Area of Ogbomso, Nigerian. *International Journal of Environment Ecology, Family and Urban Studies*, 3, 51-56.

Agegnehu, G., Amede, T., Erkossa, T., Yirga, C., Henry, C., Tyler, R., & Sileshi, G. W. (2021). Extent and management of acid soils for sustainable crop production system in the tropical agroecosystems: a review. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*, *71*(9), 852-869.

Ageless V.A., 2013. Growing carrots and other root vegetables in the garden. Technical Bull. Extension Horticulturist, Department of Horticultural Science. Southern Research and Outreach Center. University of Minnesota, USA.

Ahmad R. (2007). Use of recycled organic waste for sustainable maize (Zea mays L.) Production.

Alleman, L. and Young, B.W., (2002). An introduction to vegetable production. Nutrition, fertilizers, organic manures and compost making, 3rd end. Department of Agriculture & 9. Environmental Affairs, Pietermaritzburg, KwaZulu–Natal, South Africa.

Arikan O.A. (2003) Aerobic and anaerobic composting of different type organic solid wastes, Ph.D. Thesis, Institute of Science and Technology, Istanbul Technical University, Istanbul Turkey.

Arshad M., and Frankenberger Jr. W.T. (1998). Plant growth-regulating substances in the rhizosphere: Microbial production and functions. *Adv. Agron.*, 62: 145-151.

Avcioglu A, Turker U, Atasoy Z, and Kocturk D, (2011) Renewable Energies of Agricultural Origin, Biofuels. Nobel, Ankara Turkey. 493 p.

Awoonor, J. K., Amoakwah, E., Buri, M. M., Dogbey, B. F., & Gyamfi, J. K. (2024). Impact of Land use on soil quality: Insights from the forest-savannah transition zone of Ghana. *Heliyon*, *11*(1).

Ayodeji O.S ,Olufunlola Y.A, Atinuke A.T (2013); Evaluation of solid waste management practices in IKkotum market, Logos Nigeria. *International journal of Environmental Ecology.*

Bach, P. D., K. Nakasaki, M. Shoda, and H. Kubota (1987). Thermal balance in composting operations. *Journal of Fermentation Technology,* 65(3): 199-209.

Banga, M. (2013). Household Knowledge Attitudes and Practices in Solid Waste Segregation and Recycling: The Case of Urban Kampala. *Zambia Social Science Journal,* 27-39

Banga, M. (2013). Household Knowledge Attitudes and Practices in Solid Waste Segregation and Recycling: The Case of Urban Kampala. *Zambia Social Science Journal*, 27-39

Basturk A. (1979). A research model on solid wastes and applications for Istanbul., Istanbul Turkey.

Bationo, A. (2009). Constraints and new opportunities for achieving a green revolution in sub-saharan Africa through integrated soil fertility management. The proceedings of the international plant nutrition colloquium xvi, Department of plant sciences, UC Davis

Bayer Y, (2008). The effect of source separated on composting. M.Sc. thesis. Institute of Science, Yildiz Technical University, Istanbul Turkey.

Becx, G., G. Mol, J. Eenhoorn, J. van der Kamp and J. van Vliet, (2012). Perceptions on reducing constraints for smallholder entrepreneurship in Africa: The case of soil fertility in Northern Ghana. Current Opinion in Environmental Sustainability 4(5):

Begum, Z. (2012), Solid Waste Management, Dissemination Paper – 19. Centre of Excellence In Environmental Economics: Madras School of Economics, India.

Blumil, M.R.L., Williamson J.R L., Feuerherdt, C.N.I And Mory, D. R. 2 (1999): Land.

Bouallagui, H., Torrijos, M., Godon, J. J., Moletta, R., Cheikh, R. B., Touhami, Y., ... & Hamdi, M. (2004). Two-phases anaerobic digestion of fruit and vegetable wastes: bioreactors performance. *Biochemical Engineering Journal*, *21*(2), 193-197.

Brewer, L. J. (2001). Maturity and stability evaluation of composted yard debris. M.S. Thesis, Oregon State University, Corvallis, USA.

Brinkmann, K., J. Schumacher J., Dittrich A., Kadaore, I., and Buerkert, A. (2012). Analysis of landscape transformation processes in and around four West African cities over the last 50 years.

Campbell, J. E. (1992). Dielectric properties and influence of conductivity in soils at one to fifty megahertz. *Soil Science Society of America Journal,* 54: 332-341.

Chadha, K. L. (2003). Hand book of Horticulture, ICAR, New Delhi, pp. 1031.

Characklis, W. G., and W. Gujer (1979). Temperature dependency of microbial reactions. Prog. *Water Technol. Suppl.,* 1:111-130.

Chhabra, R. (2022). Nature and origin of salts, classification, area and distribution of salt-affected soils. In *Salt-affected soils and marginal waters: Global perspectives and sustainable management* (pp. 1-47). Cham: Springer International Publishing.

CIWMB (California Integrated Waste Management Board), (2007). Compost Use for Landscape and Environmental Enhancement, Sacramento, CA.

Clerk, G.C (1974): Crops and Their Diseases in Ghana. Ghana Publishing Corporation Pp.99-106 D.C.P ublishing Company. Pp 22-26, 631, 678 and 679.

Costa, A. C. S. D., Souza, I. G. D., Canton, L. C., Gil, L. G., & Figueiredo, R. (2020). Contribution of the chemical and mineralogical properties of sandy-loam tropical soils to the cation exchange capacity. *Revista Brasileira de Ciência do Solo*, *44*, e0200019.

Dabessa, A., Abebe, Z., & Bekele, S. (2018). Limitations and strategies to enhance biological nitrogen fixation in sub-humid tropics of Western Ethiopia. *Journal of Agricultural Biotechnology and Sustainable Development*, *10*(7), 122-131.

Daskalopopus, E.O., Badr and S.D. Probert, (1998). An Integrated approach to Municipal solid waste managent. Resour.Conserv. Recycling, 24 : 33-50.

De Beer, T., Hoornweg, G. P., Ariese, F., Velthorst, N. H., Brinkman, U. A. T., & Gooijer, C. (2000). On the potential of forward-scattering degenerate four-wave mixing detection in capillary electrophoresis. *Analytica chimica acta*, *416*(2), 151-155.

De Corato, U. (2020). Agricultural waste recycling in horticultural intensive farming systems by on-farm composting and compost-based tea application improves soil quality and plant health: A review under the perspective of a circular economy. *Science of the Total Environment*, *738*, 139840.

De Lannoy, G. (2001), Root and bulb vegetables. Geokint Graphics Nu-Belgium,Pp 480-485.

Dirksen, C. and S. Dasberg (1993). Improved calibration of time domain reflectometry soil water content measurements. *Soil Science Society of America Journal,* 57: 258-264.

Dodoo, D. N. A., Antwi-Agyei, P., Baidoo, E., Logah, V., Abubakari, A., & Adarkwa, B. O. (2023). Soil carbon stock and nutrient characteristics of forest–savanna transition: Estimates from four land use systems in Ghana. *Sustainable Environment*, *9*(1), 2262684.

Eimhoit, S., Schjonning, P. and Munkholm, L.J., (2005). Soil aggregation – a matter of proper management.

Ekinci, K. (2001). Theoretical and experimental studies on the effects of aeration strategies on the composting process. Ph.D. Dissertation, the Ohio State University, Columbus, USA. Facilities in Turkey. M.Sc. thesis. Institute of Science. Ankara University. Ankara Turkey.

Fritz, v.a., (2007). Growing carrots and other root vegetables in the garden. Communication & Educational Technology Service, University of Minnesota, U.S.A.

Ghana Institute of Engineers (2007). ICE Forum on “Accra Waste Management Strategy.

Ghana Statistical Services (2002) 2000 Population and Housing Census: Summary Report of Final Results. Ghana Statistical Services, Accra, Ghana, 62 pp

Goncharenko, Anatoliy V. "Generalizations of the Bruggeman equation and a concept of shape-distributed particle composites." *Physical review E* 68.4 (2003): 041108.

Gontcharenko, M. (1994). World Vegetables, Principles Production and Nutritive Values.

Gurmu, G. (2019). Soil organic matter and its role in soil health and crop productivity improvement. *Forest Ecology and Management*, *7*(7), 475-483.

Hamdy H.S. (2005). Purification and characterization of the pectin lyase produced by Rhizopus oryzae grown on orange peels. Ann. Microbiol., 55 (3): 205-211.

Herath E. and Lemma Dessalegn (eds) Horticultural Research and development in Ethiopia. Proceedings of the second national horticultural workshop of Ethiopia. 1-3 Dec. 1992. 105. Institute of Agricultural Research and Food and Agriculture Organization. Addis Ababa, Ethiopia.

Hoornweg, D. J., Hallmann, J. and Subbotin, S. A. (2000). Methods for extraction, processing and detection of plant and soil nematodes. In: Plant Parasitic Nematodes in Subtropical and Topical Agriculture, Luc M., Sikora, R. A. and Bridge, J. (eds) CABI Publishing. 53 – 86.

Hue, N. (2022). Soil acidity: Development, impacts, and management. In *Structure and functions of pedosphere* (pp. 103-131). Singapore: Springer Nature Singapore.

Insam, H., & De Bertoldi, M. (2007). Microbiology of the composting process. In *Waste management series* (Vol. 8, pp. 25-48). Elsevier.

Institute of Science and Technology, Istanbul Technical University. Istanbul Turkey.

Iriarte, M. L. and Ciria P. (2001). Performance characteristics of three aeration systems in the composting of sheep manure and straw. *Journal of Agricultural Engineering Research*, 79 (3): 317-330

Jara-Samiengo, H.,Idrovo, M.A., Gavilanes I. (2017). Composting as sustainable strategy for municipal solid waste management in Chimborazo Region. *Journal of Cleaner Production* 141,1349-1358,2017

Kahangi, E. (2004). Daucus carota L. In: Grubben, G.J.H. and Denton, O.A. (eds.) Plant Resources of Tropical Africa 2. Vegetables. PROTA Foundation, Wageningen, Netherlands. p 280– 285.

Kahangi, E. (2004). Daucus carota. In: Grubben, G.J.H. and Denton, O.A. Plant Resources of Tropical Africa 2. VegetablesPROTA Foundations. Wageningen, Netherlands, Backhuys Publishers, Netherlands/CTA. Pp.280-281.

Keener, H. M., Marugg C., Hansen R. C., and Hoitink H. A. J. (1992). Optimizing the efficiency of the composting process. In: Proceedings of the

International Composting Research Symposium, eds. H. A. J. Hoitink and H. Keener, Renaissance Publications, Columbus, USA, pp. 59-94.

Kessler, J. and Moolhuijzen M., 1994. Low external input sustainable agriculture: Expectations and realities. Wageningen Journal of life Sciences 42(3): 181-194.

Kishimoto, M., Preechaphan C., Yoshida T., and Taguchi H. (1987). Simulation of an aerobic composting of activated sludge using a statistical procedure. MIRCEN *Journal of Applied Microbiology and Biotechnology*, 3: 113-124.

Kononkov, P.F. and Kiran, V.C. (1988): Vegetable Growing in Home Gardens of Tropical And Sub-Tropical Areas. Mir Publishers, mosecow. Pp20-104.

Kulcu, R., and O. S. M. A. N. Yaldiz. "Determination of aeration rate and kinetics of composting some agricultural wastes." *Bioresource Technology* 93.1 (2004): 49-57.

Kurzemann, F. R., Plieger, U., Probst, M., Spiegel, H., Sandén, T., Ros, M., and Insam, H. (2020). Long-term fertilization affects soil microbiota, improves yield and benefits soil. *Agronomy*, *10*(11), 1664.

Lamb IV, J. C., Boffetta, P., Foster, W. G., Goodman, J. E., Hentz, K. L., Rhomberg, L. R., ... & Williams, A. L. (2014). Critical comments on the WHO-UNEP State of the Science of Endocrine Disrupting Chemicals–2012. *Regulatory Toxicology and Pharmacology*, *69*(1), 22-40.

Lampkin, Nicolas, Susanne Padel, and Carolyn Foster. "Organic farming." *CAP regimes and the European countryside: prospects for integration between agricultural, regional and environmental policies.*. Wallingford UK: CABI Publishing, 2000. 221-238.

Langer, R.H.M and Hill G.D (1991), Agricultural Plants, Cambridge University Press, New York. Pp.148-150.

Lim, S. M., R. T. Hatch, and T. M. Regan (2016). Aerobic microbial growth in semisolid matrices: heat and mass transfer limitation. Biotechnology and Bioengineering, 18: 1193-1218.

Luis F. Diaz *et al.*,(2004). Hand Book of solid waste management, pp-12.4-12.5.

Luong, J. H. T. and B. Volesky (1983). Heat evolution during microbial process - estimation, measurement, and applications. Advances in Biochemical Engineering/ Biotechnology, 28: 1-40.

Macky, B. M. and Derrick C. M. (1986). Elevation of the heat resistance of salmonella typhirmurium by sublethal heat shock. *Journal of Applied Bacteriology,* 66: 389-393.

Mampong Meteorological Station (2005). Annual report. Sekyere West District of Ashanti Region-Ghana.

Martínez-Blanco, J., Lazcano, C., Christensen, T. H., Muñoz, P., Rieradevall, J., Møller, J., ... and Boldrin, A. (2013). Compost benefits for agriculture evaluated by life cycle assessment. A review. *Agronomy for sustainable development*, *33*, 721-732.

Mehedi, T. A., Siddique M. A. and S. B. Shahid. (2012). Effects of urea and cow dung on growth and yield of carrot. *J. Bangladesh Agril. Univ*. 10(1): 9–13.

Miller, F. C. (1991). Biodegradation of solid wastes by composting. In: Biological Degradation of Wastes, ed. Martin, A. M., Elsevier Applied Science, London, UK, pp. 1- 31.

MoFA (2002). Food and Agriculture Sector Development Policy, MOFA, Accra, Ghana

MoFA (2005). Good Agricultural Practices and Crop Protection Recommendations for Selected Vegetables. 5. M. Kyofo-Boamah, E. Blay, M. Braun / A. Kuehn (eds.). PPRSD, MOFA, Accra, Ghana. 182.

Moncrief, J. F; S.L.Noll, and M.L Hamre, (1991).poultry manure analysis and utilization proceeding of the 7th poultry serve workshop. College of veterinary medicine, Assoc. of Avian veterinarians, and the minnesata extension service, St.paul .M N.

Mortimore, M.,(1998). Roots in the African dust: Sustaining the sub-saharan drylands. Cambridge University Press.

N'cropera, F. P., and DeWitt D. P. (1985). Fundamentals of heat and mass transfer. John Wiley and Sons, New York, USA.

Nakasaki, K. (1987). A new composting model and assessment of optimum operation for effective drying of composting material. *Journal of Fermentation Technology,* 65(4): 441- 447.

Nakasaki, K., and M. Shoda (1987). Oxygen diffusion and microbial activity in the composting of dehydrated sewage 345 International Journal of Current Research, Vol. 3, Issue, 12, pp.339-346, December, 2011 sludge cakes. *Journal of Fermentation Technology*,56(1):43-48.

Nakasaki, K., K. and Ariga O. (2004). Degradation of fats during thermophilic composting of organic waste. Waste Management & Research, 22(4): 276-282.

Nakasaki, K., K. Nag, and S. Karita (2004). Microbial succession associated with organic matter decomposition during thermophilic composting of organic waste. *Waste Management & Research*, 23 (1): 48-56.

Nakasaki, K., Nag K. and Ariga O.(2004). Degradation of fats during thermophilic composting of organic waste. *Waste Management & Research*, 22(4): 276-282.

Nieuwenhuis G. (1986). Soil Science. In: Introduction to Tropical Agriculture. A. Youdeowei, F.O.C. Ezedinma and O.C. Onazi (eds). Longman Group Limited, London, UK. pp 344.

Obeng, H.B. (2007). The soils of Ghana and their sustainability for increased and sustained agricultural production as well as other uses. Annual Lecture on sustainable agricultural production held on September 12, 2007 at College of Agric. UEW- Mampong Campus

Oelhaf, R.C., (1978). Organic agriculture: Economic and ecological comparisons with conventional methods. http://ideas.repec.org/a/eee/jfpoli/v6y1981i3p207-208.html (accessed February 2008).

Ohio Perennial and Biennial weed Guide (2009),Wild carrot.http:/ww.Oardc. Ohio-State.edu/weedguide.86. Rice, R.P. Rice, L.W. and Tindal H.D (1987):Fruit and vegetables production in Africa. Macmillan Publishers Limited, Pp.248-250.

Ozturk I., Demir I., Altinbas M., Arikan O.A., Ciftci T., Cakmak I., Ozturk L., Yildiz S., Kiris A., (2015) Compost Handbook (Technical Book Series - 1) (ISTAC – TUBITAK) Istanbul, Turkey.

Ozturk M, Bildik B, (2005). Compost production in animal farms. Ministry of Environment and Forestry, Ankara Turkey. 160 p.

Page, TO; Miller; DH and Keeney, Dr (Eds) (1982). Methods of Soil Analysis, Part 2, 2nd edn microbiological Chemical and properties. Agronomy Series 9 ROASTS SSSA, Madison, Wi., USA.

Pahalvi, H. N., Rafiya, L., Rashid, S., Nisar, B., & Kamili, A. N. (2021). Chemical fertilizers and their impact on soil health. *Microbiota and Biofertilizers, Vol 2: Ecofriendly Tools for Reclamation of Degraded Soil Environs*, 1-20.

Parcy, A. (1990): Gardening for Better Nutrition. Intermediate Technology Publication Limited. 1031105 South Ampton Road London Wclb 4hh. UK.Pp49.

Patel, M., Fatnani, D., & Parida, A. K. (2022). Potassium deficiency stress tolerance in peanut (Arachis hypogaea) through ion homeostasis, activation of antioxidant defense, and metabolic dynamics: Alleviatory role of silicon supplementation. *Plant Physiology and Biochemistry*, *182*, 55-75.

Prajapati, K., & Modi, H. A. (2012). The importance of potassium in plant growth–a review. *Indian Journal of Plant Sciences*, *1*(02-03), 177-186.

Rand, T., Hankohl J. and Marxen V. (2000). Municipal solid waste incineration, Decision maker guide. Work Bank Washington D.C.

Richard, T. L. and WalkeL. P.(1989). Temperature kinetics of aerobic solid-state biodegradation. Proceedings of the IBE, 1: A10-A30.

Roger S.W., Jokela E.J., Smith W.H. (1991). Recycling composted organic wastes on Florida forest lands. Dept. of Forest Resources and Conservation, Florida Cooperative Extension Services, University of Florida, USA.

Roux, B. L., Van der Laan, M., Vahrmeijer, T., Annandale, J. G., and Bristow, K. L. (2016). Estimating water footprints of vegetable crops: Influence of growing season, solar radiation data and functional unit. *Water*, *8*(10), 473.

Rynk R. (1992). On-farm Composting Handbook. Northeast Regional Agricultural Engineering Service, Coop. Ext., NRAES-54 Ithaca, USA.

Rynk, R. 1(992). On-farm composting handbook. Cooperative Extension Service, Northeast Regional Agricultural Engineering Services (NRAES), Ithaca NY, USA

Savci, Serpil. "An agricultural pollutant: chemical fertilizer." *International Journal of Environmental Science and Development* 3.1 (2012): 73.

Scholl, L.V. &Nieuwenhuis, R., (2004).Soil fertility management, 4thedn.Agromisa Foundation, Wageningen Publisher, Netherlands.

Seo, S.A., T. Aramaki, Y. Hwang and K. Hamaki (2004). Environmental Impact of solid waste treatment in Korea J. Environ. Eng., 130: 81-89.

Sharholy M., Kafeel A., Gauhar M., and Trivedi R. C (2008) - Municipal solid waste management in Indian cities–*A review of Waste Management 28, 459*-467.

Shekha A.C. (2011). Bulky organic manures and crop residues. In: Tandon H.L.S., (Ed.,) Fertilizers, Organic Manures, Recyclable Wastes and Biofertilizers, FDCO, New Delhi, India, pp. 37-51.

Simret K., (1994). Horticultural development in peasant agriculture. Pp. 29-36.

Singh, P., Bhatt, R., & Kaur, G. (2022). Phosphorus availability in soils and use efficiency for food and environmental sustainability. *Input Use Efficiency for Food and Environmental Security* (pp. 361-395). Singapore: Springer Nature Singapore.

Sinnadurai, S (1992). Vegetable Cultivation. Asempa Publishers, Ghana. Pp 127-130. Subtropical and tropical Agriculture. 2nd Edition. CABI Publishing, Wallingford, UK.

Smaling, E. and Dixon, J. (2006). Adding a soil fertility dimension to the global farming systems approach, with cases from Africa. Agriculture, Ecosystems and Environment 116(1-2): 15-26.

Stentiford, E. I. (1996). Composing control: principles and practice. In: The Science of Composting, eds. M. DeBertoldi, P. Sequi, B. Lemmes, and T. Papi, Blackie Academic and Professional, London, UK, pp. 49-59.

Stofella, P.J. and Kahn B.A. (2001). Compost Utilization in Horticultural Cropping Systems. CRC Press LLC. Vol.75, pp.78-91

Stratton M.L., Barker A.V., Rechcigl J.E. (1995). Compost. In: Rechcigl J.E., Ed., Soil Amendments and Environmental Quality, CRC Press, Boca Raton, Florida, pp. 249-309.

Stratton M.L., Rechcigl J.E. (1998). Agronomic Benefits of Agricultural, Municipal, and Industrial By-products and their Co-utilization: An Overview. United States Department of Agriculture, Beltsville, MD.

Tanugur I, (2009) Aerobic composting of broiler waste with different amendments.M.Sc. Thesis. Institute of Science and Technology, Istanbul Technical University. Istanbul Turkey.

Tindal H.D,(1988),Vegetable in the Tropics Macmillan Education Ltd. Hong Kong. Pp406-409.

Tindal, H.D. (1983). Fruit and Vegetable production in Africa. Macmillan publishers Ltd. London and Basingstoke.

Topal E.I. A, Topal M (2013) A review on compost standards, journals of Nevsehi Science and Technology, 2(2) 85-108, Turkey Nevesehir

Topkaya B, (2004) Compost lecture notes (unpublished). Akdeniz University, Antalya Turkey. 17 p.

Tosun I, (2003) Compostability of rose processing wastes with organic fractions of municipal solid wastes. Ph.D. Thesis. Institute of Science, Department of Environmental Engineering. Yildiz Technical University. Istanbul Turkey

Tweneboah, C.K. (2000), Vegetables and Spices in West Africa. Kodua Vile, North Dwowulu, Accra. Pp148-149.

UNEP (2014); Evaluating plastics pollution; how a voluntary contribution from industry will drive the circular plastic economy. *Frontiers in Marine Science* 6, 627,2014

UN-Habitat (2010), Solid Waste Management in the World's Cities: Water and Sanitation in the World's Cities 2010, Washington DC: Earthscan publications.

Uygun S., (2012) Evaluation of the Mechanization Applications in Some Compost Production

Uygun S., (2012) Evaluation of the Mechanization Applications in Some Compost Production Facilities in Turkey. M.Sc. thesis. Institute of Science. Ankara University. Ankara Turkey

VanderGheynst, J. S. (1997). Experimentation, modeling and analysis of a high-solids aerobic decomposition process. Ph.D. Dissertation, Cornell University, Ithaca, USA.

Varank G, (2006). Comparison aerobically stabilized solid wastes with compost product. M.Sc. thesis. Institute of Science, Yildiz Technical University. Istanbul Turkey.

W.H.O. (1993). Newsletter on Environmental Health, Geneva.

Warman, p. r., 2000.Plant growth and soil fertility comparisons of the long-term vegetable production experiment: conventional vs. compost-amended soils. In: P. R. Warman& B. R. Taylor (eds.). The Proceedings of the International Composting Symposium, CBA Press, Inc.,

World Bank (2012) What a Waste: A Global Review of Solid Waste Management. The World Bank Washington, DC, USA.

Yildiz S, Olmez E, Alparslan K, (2009) Compost Technologies and Applications in Istanbul. Composting Systems and Compost Application Areas Workshop. Istanbul Turkey.

Yusuf A. A, Ayse K, Ulas C, Namik K. (2017)- Composting as a Waste Management Method, Health Service Vocational School, Medical Services & Techniques Department, Igdir University, Igdir, Turkey. *J. Int. Environmental Application & Science*, Vol. 12(3): 244-255

Yusuf, Y. M., Madukwe, D. K., & Kebede, F. (2023). Establishing phosphorus critical values for tomato (Solanum lycopersicum) fertilization with phosphate fertilizers on the Sudan savanna soils using three soil phosphorus extraction methods and field experimentation in Kano State, Nigeria. *Frontiers in Agronomy*, *5*, 1181045.

Zerbock, O. (2003). Urban solid waste management, waste reduction in developing nations.Michigan: School of Forest Resources & Enviromental Science, Michigan Technology University

Zuccooni F., and De Bertoldi M., (1987). Composting organic residues; Bioenvironmental systems 3,95-141,1987