UNIVERSITY OF EDUCATION, WINNEBA

INFLUENCE OF COCOA POD HUSK BIOCHAR AND COMPOST ON SOIL PHYSICAL AND CHEMICAL PROPERTIES, SOME GROWTH PARAMETERS AND YIELD RESPONSE OF CARROTS

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MASTER OF EDUCATION (AGRICULTURE)

2022

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A THESIS IN THE DEPARTMENT OF

CROP AND SOIL SCIENCES EDUCATION, FACULTY OF AGRICULTURE EDUCATION

SUBMITTED TO

THE SCHOOL OF RESEARCH AND GRADUATE STUDIES,

UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF EDUCATION (M. Ed AGRICULTURE) IN THE UNIVERSITY OF EDUCATION, WINNEBA

JULY, 2022

..

DECLARATION

STUDENT'S DECLARATION

I, Michael Weittey declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

……………………………………….   ……………………………………

MICHAEL WEITTEY   Date

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this project work was supervised in accordance with the guidelines for supervision of dissertation as laid down by the University of Education, Winneba.

……………………………………….   ……………………………………

DR. BERNARD EFFAH   Date

ACKNOWLEDGEMENTS

I wish to express my deepest gratitude to the Almighty God for His guidance and protection throughout the period of study. I am also very grateful to Mr. Isaac Tete Mensah, a Senior Lecturer at the Department of Crop and Soil Sciences Education, University of Education, Winneba, for the support in conceptualizing the research topic. The resourceful and untiring supervision of this work by Dr. Bernard Effah, a Senior Lecturer at the Department of Crop and Soil Sciences Education, College of Agriculture Education of University of Education, Winneba, is extremely appreciated. The encouragements from Prof. Mrs. Margaret E. Essilfie Coordinator Graduate Studies, Faculty of Agriculture Education of University of Education, Winneba is also highly appreciated.

My Superiors at the College of Agriculture Education–Mr. Stephen K. Armah the Hall Manager of Amaniampong Hall and Mr. Augustus Kwaw Brew, the Campus Registrar who have been very motivational. I am also very appreciative of Mr. Kofi Amponsah and Alex Otabil-Assistant Registrars at the Department of Crop and Soil Sciences Education for their support. My course mates -Samuel Annim and Charles Osei have been wonderful. As special thanks go to Mr. Gabriel Weittey of Ofrico Company Limited for the encouragement and time sacrificed to help me finish when my initial supervisor got transferred to Winneba Campus. To my parents and siblings, I say thank you for your prayers and encouragements. To all my friends and classmates, I thank you for your support over the years. Finally, I thank my wife (Mrs. Matilda Weittey), my daughters (Weslyn Whitney Weittey, Winnie Wren Weittey, Quinn Lesley Weittey) and my son (Winston Michael Weittey) for standing by me and making the seemingly difficult journey a lively one.

DEDICATION

I dedicate this work to my mother (Mrs. Mary Weittey), my daughters (Weslyn Whitney Weittey, Winnie Wren Weittey, Quinn Lesley Weittey) and my son (Winston Michael Weittey).

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
CRI	Crops Research Institute
DAP	Days After Planting
DAS	Days after Sowing
FAO	Food and Agriculture Organization
GENSTAT	General statistics
HI	Harvest Index
K	Potassium
LAI	Leaf Area Index
MoFA	Ministry of Food and Agriculture
N	Nitrogen
OC	Organic Carbon
P	Phosphorus
RCBD	Randomized Complete Block Design
SDGs	Sustainable Development Goals
UNDP	United Nations Development Program
WAP	Weeks After Planting

ABSTRACT

Field experiment was conducted at the experimental field of the Department of Crop and Soil Sciences, Faculty of Agriculture, College of Agriculture Education to test the effects of cocoa pod husk biochar and cocoa pod compost on the physical properties of soil, growth and yield of carrots. The experiment was laid in Randomized Complete Block Design. There were four treatments with three replications. The four treatments included: 10 tons ha^{-1} cocoa pod husk biochar, 20 tons ha^{-1} compost from cocoa pod husk; a combination of 10 tons cocoa pod husk biochar and 20 tons compost from cocoa pod husk ha^{-1} and no amendment (control). Data were collected on the following soil physical properties: bulk density, total porosity, infiltration rate, volumetric and gravimetric water content; chemical properties included: Soil pH, Total Nitrogen, Organic Carbon and Organic Matter Content; growth parameters included: plant height, number of leaves per plant, chlorophyll content and canopy spread per plant whiles yield was measured in: root length, root diameter and fresh weight. The data collected were analyzed using GenStat Package and ANOVA. It was concluded that organic amendments when applied to the soil improved the physical and chemical properties of the soil which promoted growth and yield of carrots.

CHAPTER ONE

1.0 INTRODUCTION

The soil physical properties must be in good condition to enhance free flow of water and nutrients in the soil. Plants obtain their nutrition from organic matter and minerals found in soils. Soil health is the foundation of a vigorous and sustainable food system (UNEP, 2012). As the land is farmed, the agricultural process disturbs the natural soil systems including nutrient cycling and the release and uptake of nutrients which decline the soil fertility. As the natural stores of the most important nutrients for plant growth decline in the soil, growth rates of crops are inhibited. Modern agriculture is apropos to source the soil for nutrients and to reduce soil organic matter levels through repetitive harvesting of crops (Jatav *et al.*, 2017).

The most widespread solution to this depletion is the application of soil amendments in the form of biochar, compost, manure, fertilizers containing the three major nutrients: nitrogen, phosphorus, and potassium. In contemporary agriculture, soil must be resistant to various forms of degrading factors and soil properties must meet the requirement of sustainability and input saving crop cultivation technologies (Ferreira *et al.*, 2015).

It is therefore important to know the right amendment that may improve physical properties of the soil so as to improve growth and yield of crops in a short term. One of the ways of increasing the nutrient status is by boosting the soil nutrient content either with the use of organic materials such as biochar, poultry manure, other animal waste and use of compost with or without inorganic fertilizers (Tuffour *et al.*, 2014).

An organic amendment is relatively impervious to microbial degradation, essential for establishing and maintaining the optimum soil physical condition for plant growth. Organic amendment is also very cheap and effective as a good source of nitrogen for sustainable crop production (Tuffour *et al.*, 2014).

Composting is the biological decomposition and stabilization of organic materials into a final product sufficiently stable for application as soil amendment without adverse environmental effects. It is a very popular technique in the management of organic solid wastes and provides macro and micronutrients to plants when used as soil fertilizer Compost is primarily used as a soil conditioner because it improves soil characteristics such as aeration, water holding capacity, bulk density, aggregation, cation exchange capacity and activity of beneficial microflora. Additionally, compost provides a stabilized form of organic matter that imparts longer lasting residual effects to soil (Samaniego *et al.*, 2017).

In Ghana, agricultural waste materials including cocoa pod husks have been used to enhance soil productivity, increase the soil organic carbon content, enhance the activities of soil micro-organisms and improve soil crumb structure and the nutrient status of the soil as well as crop yield (Ofori-Frimpong *et al.*, 2010).

Carrot (*Daucus carota* L.) is a very important root vegetable mostly used in the diet of many Ghanaians. It is highly valued as food mostly because it is a rich source of Vitamin A. Carrot production can be a lucrative enterprise especially for most small scale, resource poor farmers in Ghana, since it is a short duration crop and higher yields can be obtained per unit area. In Ghana, it is one of the highly treasured exotic vegetables with great demand in urban centres and a potential export crop (MoFA, 2019). However, yields per unit area still fall below the estimated 8-12 t/ha for the tropics and the world average of 21 t/ha (Appiah *et al.*, 2017).

1.1 Statement of the Problem

In tropical Africa, agriculture encountered series of problems such as poor soil fertility, low nutrient content with low production input compared to develop countries. The productivity of soils under long-term carrot crop production in Ghana has been declining over the years, a challenge also experienced in most developing countries (Akom *et al.*, 2015).

Although high crop yields can be obtained with judicious use of inorganic fertilizers, agriculture with high chemical inputs has not been widely adopted in the humid and sub-humid tropical Africa. Various factors that have accounted for the low use of fertilizers include low-income levels of farmers and the increasing costs of fertilizers. Ways to remedy nutrient deficiency and declining soil productivity are to explore natural sources of fertilizers. Among the natural sources are farmyard manure, compost, biochar and green manures.

In Ghana, there is relative abundance of cocoa pod husk and compost in the rural and peri-urban areas, which use have some valuable potential source of Nitrogen and organic matter. However, vegetable crops such as carrot have not been widely tested with cocoa pod husk biochar and cocoa pod compost in general and in particular (Poku *et al.*, 2014).

1.2 Justification or Significance of the Study

There are large volumes of farm wastes being produced day in day out in rural areas, which are confronted by disposal problems, and research has shown that 80 % of these wastes are organic and can serve as resource to prepare compost to replenish the soil for high productivity (Lourdes *et al.*, 2017).

For sustainable crop production principles in line with the Sustainable Development Goals (SDGs) there is the need to use agricultural inputs that cause no threat to the environment. This study focused on carrot because it is the main crop grown by farmers in and around the Mampong Municipality. In this work, cocoa pod husk biochar and its compost are used as soil conditioner because of their documented positive significance on soil physical and chemical properties, plant growth and yield. It is based on this context that this study was carried out.

1.3 Objectives

1.3.1 Main Objectives

The main objective of this research was to evaluate the effects of Cocoa Pod Husk Biochar and Cocoa Pod Husk Compost on selected soil physical and chemical properties, some growth parameters and yield components of carrots.

1.3.2 Specific Objectives

The specific objectives sought to determine;

1 The effects of cocoa pod husk biochar and cocoa pod husk compost on some selected soil physical and chemical properties

2 The influence of cocoa pod husk biochar and cocoa pod husk compost on some carrots growth parameters.

3 The influence of cocoa pod husk biochar and cocoa pod husk compost on some yield components of carrots.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Carrot

The modern cultivar carrot has been derived from wild carrot (*Daucus carota* L.) found in Europe, Asia and Africa (Iorizzo *et al.*, 2013). The subspecies sativas has been cultivated from the early times in the Mediterranean region and it's now widely distributed in many tropical areas. It has been reported that carrots with purple roots were domesticated in Afghanistan and spread to the Eastern Mediterranean area under Arab influence in the 10th to 12th centuries and to Western Europe in the 14th and 15th centuries. At the beginning of the 17th centuries, in the Netherlands, repeated selections resulted in carrots with fleshy orange roots, and this carrot provided the basis for modern cultivars of sativus species. The crop was introduced by Europeans around 1930 into Ghana (Iorizzo *et al.*, 2013).

2.2 Botany of Carrot

Carrot is a dicotyledonous herbaceous crop grown for the enlarged tap root. The wild form is an annual but the cultivated crop which is believed to be derived from the wild type is biennial. The main or the tap root becomes thickened and swollen, and varies in shape and size. On the average, the size of a fully grown carrot can vary from 2 cm to 6 cm in diameter and from 6 cm to 9 cm in length (Sharma *et al.*, 2016).

The cross section of the root reveals two distinct zones, the outer zone where sugar and carotene are mainly stored, and a white woody inner central core which tastes less palatable. The leaves are alternate 2-3 pinnate, segmented divided with normally long petiole and often forms stealth at the base. The inflorescence is compound umbel 3-7 in diameter, and is borne on a much-branded stalk. The fruit is oblong to ovoid in shape 3-4 mm long and ridges with hooked spines (Abuzar *et al.*, 2013).

The flowers which are normally white or pink are small with 5 sepals and petals with hairy ovary. Carrot's flowers are protandrous and are therefore cross pollinated; however, the possibility of self-pollination always remains because of its extended flowering period. The stem is solid and condensed at the proximal part of the root (Abduallha, 2015).

2.3 Agronomic Practices in Carrot Cultivation

Carrots do well in raised beds and can also be grown in containers (Bajpai and Punia, 2015). Conventionally, carrots require sandy soils, sandy loam and silted loam. Heavy, clay soils or compacted soils may produce stunted roots. It is more appropriate to plant dwarf varieties of carrots in soils that grow dense below half an inch of depth. It is also recommended to amend clayey soils with loamy soil or organic material to create lighter, better-draining soil and amend the soil with minimal amount of nitrogen for positive effect on yield and quality of carrots (Kivuva *et al.*, 2014).

Carrots also grow best in a well-draining, loose, sandy soil which is free of large rocks and has a pH between 5.5 and 7.0. Water requirement is dependent on soil moisture level and climatic conditions (MoFA, 2019).

2.4 Growth Stages of Carrots

Taking a close look at the life cycle provides insight into what the plant needs in each step of its development. Two seasons of categorization in growth is identified: Season One which is the vegetative stage mostly involves germination of seeds, formation of taproot and appearance of the first true leaf, taproot begins lengthening and expanding, third true leaf formation and tuber expansion continues till the crop is ready for harvest; season two is the reproduction stage that involves the emergence of flowering stem, development of umbels and formation of seeds and senescence (Veitch *et al.*, 2014).

2.5 Nutrient Requirements of Carrot

According to the reports of Abdel (2015), the yield and quality of carrot are affected by the fertilizers and varieties. The potential quality of fruit is dependent on the cultivar type. Different cultivars are characterized by different quality parameters, making some more desirable to the producers and consumers. Further, the varieties may respond differently with different nutrient sources. Carrot is a heavy feeder of nutrients, and very sensitive to nutrient and soil moisture.

Similarly, Ahmed *et al.* (2014) also reported that major mineral nutrients like Nitrogen, Phosphorus and Potassium play an important role in vegetative and reproductive phase of carrot crop growth.

Mostly carrot growers use chemical fertilizers as the major supply of nutrients in order to achieve higher yields and growth. Even though an inorganic fertilization plays a vital role for the healthy plant growth and development, it does affect the soil health (Tuffour *et al.*, 2014).

2.6 Soil Properties

Soil physical properties seeks to define, measure, and predict the physical properties and behaviour of the soil, both in its natural state and under the influence of human activity.

Among soil physical properties, one distinguishes: soil colour, texture, bulk density, porosity, soil structure, soil consistency, moisture content, water retention, temperature, infiltration, saturated and unsaturated hydraulic conductivity, penetration resistance.

2.6.1 Soil Texture

Soil texture is the relative proportions of sand, silt and clay and also includes particles larger than sand in a soil. These proportions describe the classes of soil texture with a textural triangle. Soil texture can be determined by Robinson pipette method or by hydrometer method. It has a large influence on water holding capacity, water conducting ability, soil structure, chemical soil properties and the relative stabilization of soil organic matter. Moreover, the proportions of sand silt and clay can significantly correlate diversely with carrot crop yield (Ahad *et al.*, 2015).

2.6.2 Bulk Density

Bulk density is an indicator of the amount of pore space available within individual soil layers or horizons, as it is inversely proportional to pore space. A high bulk density above 1.5 indicates either compaction of the soil or high sand content which affects carrot tuber yield (Adekiya *et al.*, 2018).

Measurements can be done in-situ with the static hand penetrometer. Soil compaction can be induced by natural processes (as rain drops impact) and by field traffic of humans, animals and heavy machinery. Excessive soil compaction can impede carrot root growth and therefore limits the amount of soil explored by roots thus reducing the plant's ability to take up nutrients and water. Most researches indicate bulk density variously affects carrot growth and yield (Ferreira *et al.*, 2015).

2.6.3 Soil Structure

Soil structure is the way individual particles of sand, silt, and clay are assembled into larger units called aggregates. It is caused by the adhesion of those particles by various binding agents which influence soil structure development, amount and type of clay, as well as the exchangeable ions on the clay; amount and type of organic matter, presence of iron and aluminum oxides (Atakora *et al.*, 2014).

The addition of the raw organic matter that bacteria and fungi feed upon favours the formation of desirable soil structure. The destruction of soil structure during land preparation or soil faunal activity and decomposing Soil Organic Matter or both may improve the availability of nutrients to carrot crops (Lehmann *et al.,* 2011).

However, aggregation builds intra-aggregate and inter-aggregate pore space which control water, gases, solutes and pollutants movements in the soil. Thus, soil structure can affect aeration, soil compaction, water relations, soil temperature, resistance to erosion and plant root growth which influence carrot growth and yield (Atkinson *et al.*, 2010).

2.6.4 Temperature

Soil temperature is one of the most important growth factors of plants, along with water, oxygen or plant nutrients. Soil temperature is also a key factor controlling soil biological activity, the decomposition of soil organic matter and soil nutrient availability to carrot growth and production (Naikwade, 2013).

2.6.5 Soil Moisture and Water Retention

Soil water content or moisture content is the quantity of water contained in a soil material, which can range from 0 (completely dry) to the value of the materials' porosity at saturation.

They can be determined in laboratory with soil moisture equipment or in the field with Time Domain Reflectometry (TDR), hygrometer or a neutron probe (Evers, 1988). Soil water content is given on a volumetric or mass (gravimetric) basis. Soil moisture content can be improved by 1 to 10 g for every 1 g increase in soil organic matter (SOM) content (Fungo *et al.*, 2017).

The increase may be small, but it may suffice to help maintain crop growth between periods of rainfall of 5 to 10 days. Near or slightly wetter than field capacity moisture conditions are most favourable for both processes. Soil moisture can positively impact LAI and crop yield while it can negatively affected crop emergence (Shah *et al.*, 2017).

2.6.6 Soil Infiltration Rate

Infiltration rate can be determined on the field by the double ring or single ring method. Soil infiltration properties affects carrot growth and yield, this can be explained by the changes in soil texture, organic matter content, plant litter density, and root mass density (Brantley *et al.*, 2015).

Infiltration, the term applied to the process of water entering the soil, generally by downward flow through all or parts of the surface, is known to represent the main hydrological process. The rate of this process, relative to the rate of water supply, determines how much water will enter the root zone, and how much, if any will run off. Water infiltration is a driving force influencing carrot crop growth and yield, soil erosion and chemical leaching processes (Zhuang, 2017).

2.7 Cocoa Pod Husk Compost

In Ghana, agricultural waste materials including cocoa pod husks and animal manures especially poultry manure, abound and are increasing in quantity each year due to the growing number of cocoa and poultry farms. Cocoa pod husk is obtained after the removal of the beans and it represents about 70 % - 80 % in dry weight of the fruit. (FAOSTAT, 2014).

For cocoa, each ton of dry beans produced results in the production of 10 tons of Cocoa Pod Husk (Seehausen *et al.*, 2017), thereby, creating enormous quantities of cocoa wastes which host pests and disease-causing organisms and a serious challenge in waste management. An estimated 595,000 tons of dry Cocoa Pod Husk residues were generated in Ghana in 2008 (Ofori-Frimpong *et al.*, 2010).

When this Cocoa Pod Husk which might come from black pod disease infected and uninfected pods are left untreated in farms, they act as a source of inoculum for the *Phytophthora* spp which is the causal agent for the cocoa black pod disease. Cocoa pod husk is disinfected during composting due to the high temperatures produced (Ofori-Frimpong *et al.*, 2010), thus, reducing the inoculum levels of the pathogen.

There is a huge potential for the use of Cocoa Pod Husk and agricultural wastes in the production of good quality compost in Ghana. However, the quality of the Cocoa Pod Husk-based compost for use as growing media needs to be ascertained because the degree of maturity of compost has a great impact on its utilization (Poku *et al.*, 2014).

It is, therefore, important to assess the properties of the Cocoa Pod Husk-based compost that will affect plant growth potential, compost utilization and the soil.

2.8 Importance of Compost to Plant Growth and Yield

Compost serves as a source of carbon and nitrogen for microorganisms in the soil, enhances soil structure, reduces erosion and lowers the temperature at the soil surface and also helps in seed germination and increases water holding capacity of the soil (Brantley *et al.,* 2015).

When used in adequate quantities, compost has both an immediate and long-term positive effect on soil structure. In fine-textured (clay, clay loam) soils, addition of compost reduces bulk density, improves friability and porosity whilst improving soil aggregation and water holding capacity in coarse-textured (sandy) soil. In addition, it provides greater drought resistance and efficient water utilization ability. Compost is as 'slow-release fertilizer' whereas chemical fertilizer releases nutrients quickly in soil and soon get depleted (Seehausen *et al.*, 2017).

The nutrients in compost are available throughout the growing season. The addition of compost stimulates plant root growth and increases root system that makes a plant more drought resistant due to its ability to absorb more water from the soil. The increased root system also helps the plant to increase its nutrient uptake. The increased number of soil micro-organisms gives beneficial organisms a competitive edge over pathogens. A compost amendment has the ability to bind heavy metals and other contaminants in the soil, reducing their leachability and absorption by plants (Seehausen *et al.*, 2017).

2.9 The Influence of Cocoa Pod Husk Biochar on Plant Growth and Yield

Cocoa Pod Husk Biochar can be used as a soil amendment to improve crop quality and crop productivity in a variety of soils (Manu-Aduening *et al.*, 2020). Greenhouse and field studies have been conducted to look at the effect of biochar on crop yields and most studies revealed that biochar addition increased crop yields. For example, a plot trial where soil was amended with a green waste-derived biochar, showed benefits that included increase in plant growth, increased crop yield and improved soil quality (Carter *et al.*, 2013).

Field experiments have also reported substantial crop yield increase in response to soil biochar application (Manu-Aduening *et al.*, 2020) Other studies have attributed positive plant growth to positive changes in soil biogeochemistry as a result of biochar additions (Van Zwieten *et al.*, 2010).

Carter *et al.* (2013) in their study to verify the Impact of Biochar Application on Soil properties and plant Growth of Pot Grown Lettuce (*Lactuca sativa*) and Cabbage (Brassica chinensis) revealed that the biochar treatments were found to increase the final biomass, root biomass, plant height and number of leaves in all the cropping cycles in comparison to no biochar treatment.

An experiment conducted by Kumah (2012) at the University of Ghana Forest and Horticultural Research Centre to investigate the effect of type of initiation and growing media on growth and nutrient uptake of plantain at the nursery stage, the biochar induced the greatest pseudo stem height, pseudo stem girth, number of roots/corms, and root diameter and was significantly different from that of the sawdust and sawdust and carbonated rice husk.

Biochar has generally been shown to be beneficial for growing crops; additionally, biochar contains stable carbon (C) and after adding biochar to soil, this carbon remains sequestered for much longer periods than it would in the original biomass that biochar was made from. Soil microbial communities are responsive to biochar amendment because it increases microbial abundance and activities by providing an environment with ample aeration, water and nutrients (Ameloot *et al.*, 2013).

2.10 The Benefits of Biochar in Soil

Biochar is receiving a growing interest as a sustainable technology to improve soil fertility, nutrient use efficiency and plant growth (Zhuang, 2017). Biochar has lower bulk density than soil thus the addition of biochar to soil reduces the bulk density of the soil. The decrease of soil strength with application of biochar has been observed by Rutigliano *et al.* (2014). The increase in soil porosity as a result of soil aggregation with application of biochar has been observed for hard settling soil in Australia (Rutigliano *et al.*, 2014). This will in turn increase porosity and soil water retention which consequently leads to an increase in available soil water for plant uptake (Lehmann *et al.*, 2011).

Biochar alters the physical and chemical properties of soil by increasing aeration and water holding capacity of the soil, increasing soil pH and cation exchange capacity and a decrease in exchangeable aluminium and soluble ion. The increase in cation exchange capacity and soil pH with the addition of organic materials has been shown by Naikwade (2013). The addition of biochar also results in the addition of elemental plant nutrients such as phosphorus, potassium and calcium. Biochar has low to neutral pH thus making it useful in acidic soils hence used as a liming material. Consequently, biochar alleviates soil acidity which in turn improves nutrient uptake and growth of plants (Lehman *et al.*, 2015).

2.11 Biochar Application Rate

Biochar materials can differ widely in their characteristics, thus the nature of a specific biochar material (e.g., pH, ash content) influences application rate. In the published literature, several studies have reported positive effects of biochar application on crop yields with rates of 5-50 t/ha of biochar per hectare, with appropriate nutrient management. This is a large range, but often when several rates are used, the plots with the higher biochar application rate show better results (Fungo *et al.*, 2017). A 10 t/ha application of poultry manure biochar contains much less C (and more ash) than an equivalent application of wood waste biochar.

Most biochar materials are not substitutes for fertilizer, so adding biochar without necessary amounts of nitrogen (N) and other nutrients cannot be expected to provide improvements to crop yield. Instances of decreasing yield due to a high biochar application rate were reported when the equivalent of 165t of biochar was applied. The reasons for such a decrease remain to be fully explored and must be understood in order to determine which biochar material is best.

2.12 Effect of biochar and compost on Yield Components of Carrots

Individual root weight is one of the most important yield components that are directly dependent on fertilization rates, as confirmed by the results obtained by Veitch *et al.* (2014). The average yield of carrot is directly dependent on individual root weight and determined by the cultivar used, agro-environmental conditions, fertilization rates, and other factors. Measured yield parameters of carrots that affect yield and yield components include but not limited to root length, root diameter, fresh root weight, total dry matter accumulation, marketable weight and non-marketable weight (Veitch *et al.*, 2014).

Reports indicate that the quality of carrot roots is influenced by the type of fertilizer used, cultivar, agro conditions and irrigation regimes. This is in correspondence with the report of Ahmed *et al.* (2014) who stated that the root length and diameter of carrots was significantly affected as the application of biochar rate in combination with compost increases. These findings agreed with the finding of Abduallha (2015) who conducted the experiment to see the effect of cow dung, zinc and boron on carrot and found that the maximum root fresh weight and dry matter of root of carrots is affected.

The rate and source of biochar and compost may increase the shoot growth, weight and dry matter. In an experiment conducted to find out the effects of biochar on carrot yield, it was concluded that yield components such as marketable weights, non-marketable weights, and nutritional qualities have effects on the yield and crop performance potential of carrot (Manu-Aduening *et al.*, 2020).

Qasim *et al.* (2010) also stated that application of biochar-slurry manure increased yield of carrots by 23.5 % over the control. Increased response of root fresh weight might be due to the increasing level of fertility status of the soil. This is in line with the finding of Lehmann *et al.* (2011) who reported biochar is very best in improving soil fertility particularly for growing vegetable crops and affects the total gross yields.

Zidane *et al.* (2015) in their work on the impact of rice husk biochar and macronutrient fertilizer on fodder maize and soil properties discovered that the average maize height was increased with the addition of biochar as well as inorganic NPK fertilizers and that the highest plant height was obtained with the combined application of 25 % less than recommended rate of NPK and 10 t/ha-1 biochar. Consequently, this result depicted it relevance in the yield component of maize both in fresh weight and in dry matter.

Organic amendments are produced to supply nutrients found to be lacking in a particular soil and have the ability to make nitrogen, phosphorus and potassium immediately available to crop in required quantities. Ahmed *et al.* (2014) argued that while NPK 15-15-15 supplies adequate macronutrients, it lacks the ability to improve the soil physical properties. Akom *et al.* (2015) reported that 180 kg of P_2O_5 ha^{-1} gave higher yield effect, whiles Dawuda *et al.* (2011) also reported that, the application of 45 kg P_2O_5 ha^{-1} using single superphosphate resulted in a significant increase in both marketable and total yields of carrot.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

A Field experiment was conducted at the multi-purpose crop nursery research field of the College of Agriculture Education, Akenten Appiah - Menka University of Skills Training and Entrepreneurial Development, Mampong-Ashanti campus from March to September, 2021. Mampong Ashanti is located in the forest-savanna transition Agro- ecological zone of Ghana. The area has a bimodal rainfall pattern with the major rainy season occurring from March to July and the minor rainy season from mid-August to November. There is a harmattan (dry season) from December to February. The soils belong to the Bediase series of the savanna ochrosol, which are deep red sandy loam, well drained with pH of 5.5 – 6.5; and are classified as Chromic luvisol according to the FAO/UNESCO legend (Abuzar *et al.*, 2013; Atakora *et al.*, 2014).

3.2 Experimental Design and Treatments

A randomized complete block design with four treatments and three replications was used. The treatments were: 10 tons Biochar from Cocoa Pod Husk ha^{-1}, 20 tons compost from Cocoa Pod Husk ha^{-1}, a combination of 10 tons Biochar from Cocoa Pod Husk + 20 tons compost from Cocoa Pod Husk ha^{-1} and no amendment (control). The plot measured 9 m x 5 m. Twelve beds were raised in the plot and each bed measured 1 m × 1.5 m. There was a 0.5 m space between each bed. Field layout is indicated in Figure 3.1.

3.2.1 Treatments

The treatments for the experiments are as follows:

Treatments	Component	Details
T1	Compost	20 tons Compost
T2	Biochar	10 tons Biochar
T3	Biochar + Compost	10 tons Biochar + 20 tons Compost
T4	Control	No amendment

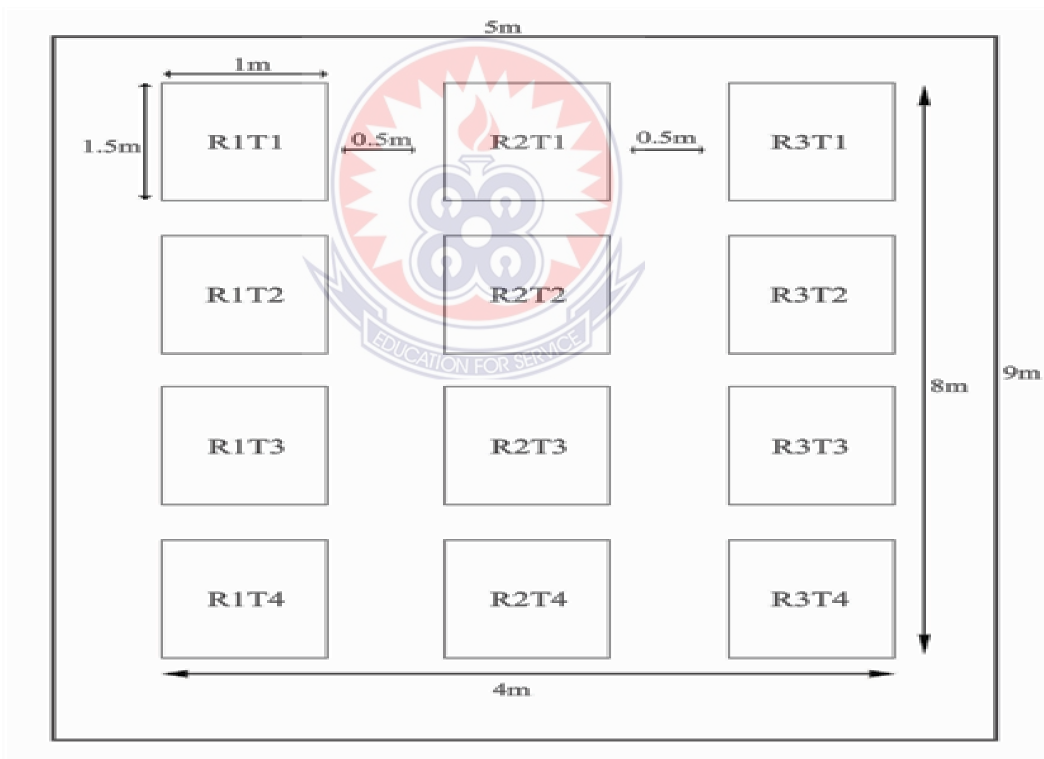


Figure 3.1: Field layout not drawn to scale

3.3 Cocoa Pod Husk Biochar Preparation and Application

Biochar was produced from cocoa pod husk (CPH) by using a charcoal production process at the College of Agriculture Education, Asante Mampong Campus solely for the purpose of the experiment as described by Obemah and Baowei (2014) and (Kung *et al.*, 2015) in which carbonization was done within a week at about 500 ºC in an anoxic pit reactor. The biochar produced after pyrolysis was cooled, collected, crushed, milled and sieved through a 2 mm sieve before being used. The powder biochar was then applied a week after preparation by mixing with soil at 10 cm deep to respective treatment and left for three weeks before planting.

3.4 Cocoa Pod Husk Compost Preparation and Application

Cocoa pod husk-based compost was prepared as described by Ofori-Frimpong *et al.* (2010). Four wooden stacks were driven into the ground on a flat land in an area of 1 m × 1 m to serve as the corner of the compost heap. Fresh cocoa pod husk (200 kg) and trash (30 kg) was chopped into pieces and the material spread on the ground as the first layer after which 400 kg top soil was added. This was repeated in succession until the height was 1 m. Water was sprinkled on each layer before the next layer was laid. The layers were turned at 4 and 8 weeks of composting to ensure adequate aeration and decomposition of the material. The heap was broken after 12 months and the composted materials were stored under cover.

3.5 Land Preparation

The site was cleared of all vegetation manually with cutlass and hoe. The debris was gathered into heaps outside the demarcated areas, to allow for ease of ploughing, harrowing, lining and pegging. Plot in the form of raised beds of size 8 m long by 4 m wide was prepared with a hoe to height of 0.20 m and level with a rake. There was a 0.5 m space between each bed. Twelve beds were raised in the plot and each bed measured 1 m × 1.5 m. Field layout is indicated in Figure 3.1 above

3.6 Crop Establishment

3.6.1 Planting

Seeds of an improved carrot variety (Kuroda) were sown by drilling to a depth of about 0.5 cm on each bed for the experiments. The beds were shaded with palm fronds to provide light shade and prevent the seeds from being washed away. The beds were watered. Germination was observed five to seven days after sowing. The shade was removed after 14 days after planting in a gradual procedure by removing the shade step by step in an order to allow hardening off. The seedlings were thinned 21 days after germination to intra-row spacing of 10 cm. After thinning weed control started. This was done by handpicking with the aid of a hand fork.

3.6.2 Cultural Practices

Watering was done once daily except when it rained. A fitted watering can of 15litres per bed was applied to allow each bed to receive the same quantity of water up to 21 days after sowing (DAS). This was done twice a day. Weeds were hand-picked. The spaces between the beds were weeded with cutlass and hoe four times during the experiment. Earthening-up of beds was done every two weeks after weeding to cover exposed roots. The inter-row spaces were stirred up with hand fork at two weekly intervals throughout the growing period to improve soil aeration and consequently enhance growth of the crop.

3.7 Soil Analysis

Soil samples were taken on the field from 0 cm to a depth of 15 cm with a soil augur two weeks after cocoa pod husk biochar and compost application. Soil physical properties such as bulk density, gravimetric/volumetric water content, total porosity, aeration porosity, infiltration rate and particle size distribution of % Sand, % Silt, % Clay and Texture were determined. Some soil chemical properties such as soil pH, total nitrogen in mg/g and in percentages, organic carbon and organic matter contents were also determined.

3.7.1 Soil Physical Properties

Bulk Density

The dry bulk density was determined from soil cores collected from the field with core sampler (Klute, 1987). The cylindrical metal sampler (core sampler) with a diameter of 5 cm and a height of 5 cm was driven into the soil vertically with the aid of wooden plank and a mallet to fill the sampler. The volume of the soil was taken to be the same as the volume of the cylinder. The cylinders were sent to the laboratory and oven dried at 105 ^{o}C to constant mass. The oven dried soil was weighed and the dry bulk densities calculated by dividing the oven dried mass (mass of solid component of the soil) by the volume of the soil that is the cylinder.

$$\text{Bulk Density} = \frac{\text{Mass of Oven Dried Soil}}{\text{Volume of Soil}} \quad \text{..........................}\textbf{Equation (1)}$$

ρb= Mi / Vi where Mi is Mass *of oven dry soil* and Vi is *Volume of Soi*l

Gravimetric and Volumetric water content

Gardner (1986) gravimetric method was used to determine the moisture content. This involved moist soil samples being taken from the field randomly from the various treatment beds with the core sampler and sent to the laboratory where they were weighed to find their initial masses. They were then oven-dried at a temperature of 105 ^{o}C to a constant mass. The loss of water upon drying constituted the mass of water contained in the sample.

The volumetric water content was determined from the formula;

$$Ov = \frac{\theta g.\rho b}{\rho w} \text{..............................} \textbf{Equation (2)}$$

Assuming ρw = 1, θg is gravimetric water content.

ρb is bulk density of the soil and ρw is the density of water assumed to be unity.

$$\theta g = \frac{M1-M2}{M2} \times 100 \text{ ....} \textbf{ Equation (3)}$$

where θg is the soil gravimetric moisture

M1 is the weight of soil before oven drying and M2 is the weight of soil after drying.

The Total Porosity

The Total Porosity (f) of various treatments were determined from the particle densities (PD) and the bulk density (BD) using the mathematical relationship by Zhuang (2017)

Total Porosity was also calculated by the formula;

$$f = 1- \frac{\rho b}{\rho s} \text{....................................} \textbf{Equation (4)}$$

where f is total porosity, **ρb** is bulk density and **ρs** is particle density= 2.65g/cm^3 (assumed). Air filled porosity was calculated by the formula, af = f - θv where af is air filled porosity, f is the total porosity and θv is volumetric water content.

Field infiltration

A study on the infiltration was conducted in the field using the single ring infiltrometer (Klute, 1987). Before the infiltration measurement was made, soil samples were taken to determine the moisture content of the soil at each spot. A cylindrical infiltrometer of 10 cm diameter and height of 30 cm was driven into the soil to a depth of 10 cm with the aid of a wooden plank and a mallet. The soil surface was mulched with plant debris (dry grass and leaves) to prevent the disturbance of the soil surface (dispersion and clogging of soil pores) and false measure of infiltration amount when the soil surface in the infiltrometer was instantaneously ponded with water. A constant water head of 5 cm from the soil surface was maintained in the cylinder with water from 1000 ml (1litre) glass measuring cylinder. The volume of water that was used as a representation of the amount that entered the soil at the stipulated time. The vertical infiltration was measured at 30 seconds period of 60 minutes for each spot. The initial infiltration was measured at 30 seconds interval for the first five minute when infiltration was very fast after which the interval was increased to 60, 180 and 300 seconds respectively as infiltration slow down over time towards the steady state.

The cumulative infiltration amounts (I) were plotted as a function of time for each spot on a linear scale. The slope of the cumulative infiltration amounts taken at different time scale represented the infiltration rates (i). The infiltration rates were plotted against time and the steady state infiltrability (Ko) was obtained at the point where the infiltration rate curve became almost parallel to the time axis.

Soil texture

The soil texture was determined by the hydrometer method. A 40 g of soil was weighed into 250 ml beaker and oven dried at 105 ºC overnight. The sample was removed from the oven and then placed in a desiccator to cool, after, which it was weighed and the oven dry weight taken. A 100 ml of dispersing agent commonly known as Calgon (Sodium Bicarbonate and Sodium Hexa -met phosphate) was measured and added to the soil. It was then placed on a hot plate and heated until the first sign of boiling was observed. The content in the beaker was washed completely into a shaking cup and then fitted to a shaking machine and shaken for 5 minutes. The sample was sieved through a 50 microns sieve mesh into 1.0l cylinder. The sand portion was separated by this method while the silt and clay went through the sieve into the cylinder. The sand portion was dried and further separated using graded sieves of varying sizes into coarse, medium and fine sand. These were weighed and their weights taken. The 1.0 litre cylinder containing the dispersed sample was placed on a vibration less bench in the night. The hydrometer method was used to determine the silt and the clay contents. The cylinder with its contents was agitated to allow the particles to be in suspension, it was then placed on the bench and hydrometer reading taken at 30 seconds, 4 minutes, for 4 hours and 24 hours intervals. At each hydrometer reading the temperature was also taken. Coarse silt, medium silt, fine silt and clay portion were then calculated graphically. The various portions were expressed in percentage and using the textural triangle the texture was determined

3.7.1.1 Soil chemical properties

Soil samples were randomly taken from five (5) different spots of the experimental area as initial data at a soil depth of 0-15 cm. Soil samples from same treatment bed and replication were bulked, air dried and sub-samples taken for analysis at the Soil Research Institute, Kumasi before planting. Soil plus biochar samples were then taken again at six weeks after soil amendment was applied for the assessment of soil available in solution. Soil pH, Organic carbon, total nitrogen, and organic matter content were analyzed in the laboratory.

Soil pH

Soil pH was determined by the use of the pH meter. The pH meter was calibrated using two buffer solutions. A 10.0 g of soil sample was placed in a 50-ml beaker and 20 ml of $CaCl_2$ solution was added. The soil was allowed to absorb the $CaCl_2$ solution without stirring. It was then stirred thoroughly for 10 seconds using glass rod. The suspension was stirred for 30 minutes. The pH was recorded on the calibrated pH meter (FAO, 1991).

Total Nitrogen

A 1 g of soil sample was weighed and placed in a Kjeldahl flask. A 0.7 g of copper sulphate and a 1.5 g of K_2SO_4 and 30 ml of H_2SO_4 were added. The set up was heated gently until frothing ceased. It was then boiled briskly until the solution was clear and digested for 30 minutes. The flask was removed from the heater and cooled; 50 ml of water was added and was transferred to a distilling flask. A 20 ml of standard acid (0.1M HCl) was placed in the receiving conical flask to get an excess of at least 5 ml of the acid. Three (3) drops of methyl red indicator solution was added and enough water was added to cover the end of the condenser outlet tubes. Tap water was run through the condenser before 30 ml of 35 percent NaOH in the distilling flask was added. The content was heated to distil the ammonia for about 30 minutes. The receiving flask was removed and the outlet tube was rinsed into the receiving flask with a small amount of distilled water. The excess acid was titrated in the distillate with 0.1M NaOH. The blank was determined on reagents by using the same quantity of standard acid in a receiving conical flask.

$$N\% = \frac{((25 - a)\ x\ 14)}{W(gr)\ x\ 100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{Equation (5)}$$

Where: 25 = ml of 0.1 N H_2SO_4 used in the beaker

a = ml of 0.1 NaOH used in the titration

W = weight of the soil in grams

14 = molecular weight of nitrogen

Organic Carbon

The Walkley-Black Method was used. A 1 g of soil was weighed and placed in a 250 ml Erlenmeyer flask. Under the hood, 5 ml of potassium dichromate and 10 ml of concentrated sulphuric acid was added. The solution was allowed to rest for 3 hours. Then 100 ml of deionized water, 2 drops of ferroin and titrate with Mohr's salt was added. At the same time a blank with 5 ml of dichromate and 10 ml of sulphuric acid was prepared. From the result, organic carbon or as organic matter was determine.

$$O.C\% = \frac{(b - a)\ x\ N\ x\ f\ x\ 0.39)}{W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{Equation (6)}$$

Where: b = ml of Mohr's salt used for the blank

a = ml of Mohr's salt used for the sample

N = normality of Mohr's salt

F = normality correction factor

W = weight of the sample

Organic Matter

Consequently, Organic matter was calculated from the relation as follows:

$O.M\% = O.C.X1.724$……………………………………………..**Equation (7)**

Growth and Yield Determination

Ten plants were randomly selected from the two middle rows and tagged for record taking. Plant height, number of leaves per plant and canopy spread were taken at 37, 51, 65, and 79 days after planting. Root length, root diameter at 2 cm from the top was measured after harvest. Yield of the roots from each plot was weighed with an electronic balance to get the fresh weight of roots as well as the gross yield per hectare.

3.8 Vegetative growth

Plant Height

Plant height was recorded from base of the root to the tip of the plant during growth at 37, 51, 65, and 79 Days after planting and at harvest and average plant height was taken in centimeter (cm).

Leaf Number

The leaf number was recorded for each of the tagged plants in each bed during growth at 37, 51, 65, and 79 Days after planting and at harvest and average leaf number was expressed in number.

Chlorophyll Content

Weekly chlorophyll content of Ten selected plants from each plot was taken with a chlorophyll content meter (Apogee instruments, model CCM-200 plus). The data was collected during the periods of four (4) weeks, eight (8) weeks and twelve (12) weeks after planting and at harvest.

3.8.1 Canopy Spread

Canopy Area and Leaf Area Index (LAI)

The canopy width was determined with a meter rule at 12 weeks after planting and used to derive the canopy area at maturity under the following assumptions; At 12 weeks after planting, carrots assume a generally and approximately cylindrical and overlapping canopy. The total area of leaves (leaf area) is approximately equal to canopy area. The leaf area index was determined using methods described in Wolf *et al.* (1970) and was calculated from the formula as follows (Landon, 1998) as cited by Vuolo *et al.* (2013).

$$LAI = \frac{(LA2 - LA1)}{2} \; X \, \frac{1}{GA} \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{Equation (8)}$$

Where LAI =Leaf Area Index at 12 WAP

LA2 =Maximum or Final Leaf Area at 12 WAP

LA1=Initial Leaf Area

GA=Ground Area

3.9 Yield and Yield Components

Yield and yield components were determined through the diameter of carrot root, length of root, harvest index, weight of marketable root, weight of non-marketable root, and the overall yield. Clean roots which showed no deformities such as cracked, nematode infected, forked, diseased, malformed shape and size or with spots and those weighing above 35 grams were selected from each plot and weighed as "Standard" or Grade 1 carrots as practiced by carrot farmers in Ghana. The Grade 1 carrots are also known as marketable yield. Roots which showed deformities such as cracked, forked, diseased, malformed shape and size, with spots and having weights below 35 g were selected from each plot and weighed. Broadly, this group of carrots are termed as non-marketable yield and classified by carrot growers in Ghana as "Social". The "social" group of carrots are also inclusive of a subgroup known as "broken" which is the least grade with the poorest price (Veitch *et al.*, 2014) as cited by Abdel (2015).

At harvest, thirty-six plants from the two middle rows of each plot were harvested and separated into root and vegetative parts and their separate weights taken for estimation of the harvest index as the ratio of the root yield to the total plant biomass yield as described by Agegnehu *et al.* (2016).

Root Length (cm)

The length of root was measured in ten randomly selected plants from each plot at harvest from the base of the root to the top of the root and average length was expressed in centimeter (cm).

Root Diameter

The diameter of ten roots selected randomly was measured by using caliper at basal portion and the average root diameter was expressed in centimeter (cm).

Fresh Weight of the Root

The weight of ten roots selected randomly at harvest was recorded with the help of beam balance and the average root weight was expressed in gram (g).

Dry Mass of the Root

The fresh mass of the root was chopped and dried by oven dry at 75 ^{o}C temperature for 48 hours at harvest and recorded with the help of beam balance and the average root weight was expressed in gram (g).

Gross Yield

The ten tagged plants that were harvested were weighted and converted to yield per ton.

3.10 Data Analysis

The data collected on the soil, some growth parameters and yield parameters were grouped through their means, coefficient of variation and the least significant difference. Subjected to analysis of variance using GenStat Software Package. The means were separated using Least Significant Difference (LSD) at 5 % probability level.

CHAPTER FOUR

4.0 RESULTS

4.1 Climatic Conditions

The annual total rainfall for the cropping season was 1529.7mm with the peak in June-July (Appendix K). The rainfall pattern showed a bimodal rainfall pattern with the main season occurring from March to July and the minor season from September to November. The experiment was conducted between March and September. The mean minimum monthly temperature between this period ranged between 22 ºC and 23 ºC while the maximum monthly temperature ranged from 28 ºC and 34 ºC, with the monthly greatest of 34 ºC in March. The mean monthly relative humidity of the area during the growing period ranged from 76 % to 98 % at 6:00 GMT and 36 % to 76 % at15:00 GMT (Appendix K).

4.2 Properties of Soil and Organic Amendments Used in the Experiment

The initial properties of the Soil, Cocoa Pod Husk Biochar and its Compost taken are presented in Table 4.1. The results indicated that the soil was moderately acidic (pH 5.2). The organic matter content level of the soil was moderate (1.55); the percentage N recorded was 0.08 which is less than 0.15 % and not considered optimum for the growth of carrot and other vegetables. The chemical properties regarding the total nitrogen, percentage organic carbon and organic matter of both the Cocoa Pod Husk biochar and compost were considered optimum for crops, however; the pH of the biochar was 7.6 which is alkaline in nature as compared to the compost which have neutral pH of 6.35 and was critically considered adequate for vegetables. The bulk density of the biochar was recorded to be 0.6 which indicates how small and porous the micro pores are distributed in the various spaces within the particles. In a sharp contrast, the bulk density of the soil recorded the highest value of 1.50.

Table 4.1: Physical and Chemical Properties of Soil, Cocoa Pod Husk Biochar and Compost used in the experiment

Soil Properties	**Biochar**	**Compost**	**Soil**
pH	7.60	6.35	5.20
Organic Carbon (%)	1.81	1.85	0.83
Total N (%)	0.50	0.52	0.08
Organic Matter (%)	3.10	3.20	1.55
Bulk Densities (g/cm^3)	0.60	1.20	1.50

4.3 Initial Soil Physical Properties

The percentage clay, sand and silt on the plots recorded were used to determine the soil texture. The plots show the same textural class as sandy loam. The mean bulk density was determined to be 1.5 g/cm^3. Mean values of soils from the experimental fields had low volumetric water content and poor porosity due to higher bulk density. This was compounded by low soil porosity and poor soil structure.

4.4 Soil Physical Properties after Biochar and Compost Application and Compost Mineralization

Table 4.2 shows the means for the various treatments, compost, biochar and their combinations, and the control for gravimetric moisture content, volumetric moisture content, bulk density, percentage solid space and soil porosity after the treatments have been applied. From Table 4.2, there are significant difference in gravimetric moisture content, volumetric moisture content, solid space and soil porosity between all the treatments and the control. The combinations treatment of compost plus biochar recorded the lowest bulk density and total porosity. For volumetric moisture content, bulk density, percentage solid space, and bulk density, there were significant interaction effects between treatments.

Table 4.3 shows the relative proportions of sand, silt and clay. These proportions describe the classes of soil texture with a textural triangle. There was an improvement in all the various proportions from the clay, sand and silt after the application of treatments except the control which remained the same. However, this did not change the texture.

Table 4.2: Changes in Soil Physical Properties after Treatment Application

Treatment	**Bulk Density (g/Cm^3)**	**Gravimetric Moisture Content (%)**	**Solid Space (%)**	**Volumetric Moisture Content (%)**	**Soil Porosity (%)**
Compost	1.34^b	22.60^c	48.90^b	27.50^c	51.10^c
Biochar	1.33^b	23.17^b	46.90^c	29.20^b	54.00^b
Compost + Biochar	1.30^b	25.80^a	43.60^d	31.20^a	56.40^a
Control	1.50^a	20.13^d	49.90^a	21.10^d	50.10^d
LSD	**0.09**	**0.31**	**0.20**	**0.09**	**0.20**
CV (%)	**3.66**	**0.69**	**1.06**	**0.18**	**0.95**

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

Table 4.3: Soil Texture after the application of treatments

Treatment	Clay (%)	Sand (%)	Silt (%)	Texture
Compost	12.5	77.50	22.5	Sandy loam
Biochar	9.00	81.00	20.5	
Compost + Biochar	8.00	82.00	18.0	
Control	7.80	80.80	10.20	

4.5 Effect of Treatments on Some Soil Chemical Properties

The chemical properties of the soil after the application of the various treatments are presented in Table 4.4. The pH was influenced by compost and biochar. Soils amended with biochar and compost had the same pH values recorded as 5.7. The control treatment had the most acidic pH of 5.20. The combination treatment of compost + biochar gave the least acidic pH and recorded 6.33 which indicates a neutral pH.

All the amended plots showed higher increase in all the nutrient levels than the control treatment (Table 4.4). The treated plots and their combinations recorded higher levels of organic carbon, percentage total nitrogen, and organic matter than the control. The amended treatments application influenced the soil pH on their various plots (Table 4.4). This study clearly indicates that soil acidity has been reduced.

In the present study, the combination of compost and biochar gave the highest organic matter content (3.01) followed by the sole compost (1.69) and the sole biochar treatment (1.65).

There were significant increases in the percentage total nitrogen for all the amended plots as compared to the control treatment.

Table 4.4: Changes in some Chemical Properties of Soil due to treatments application

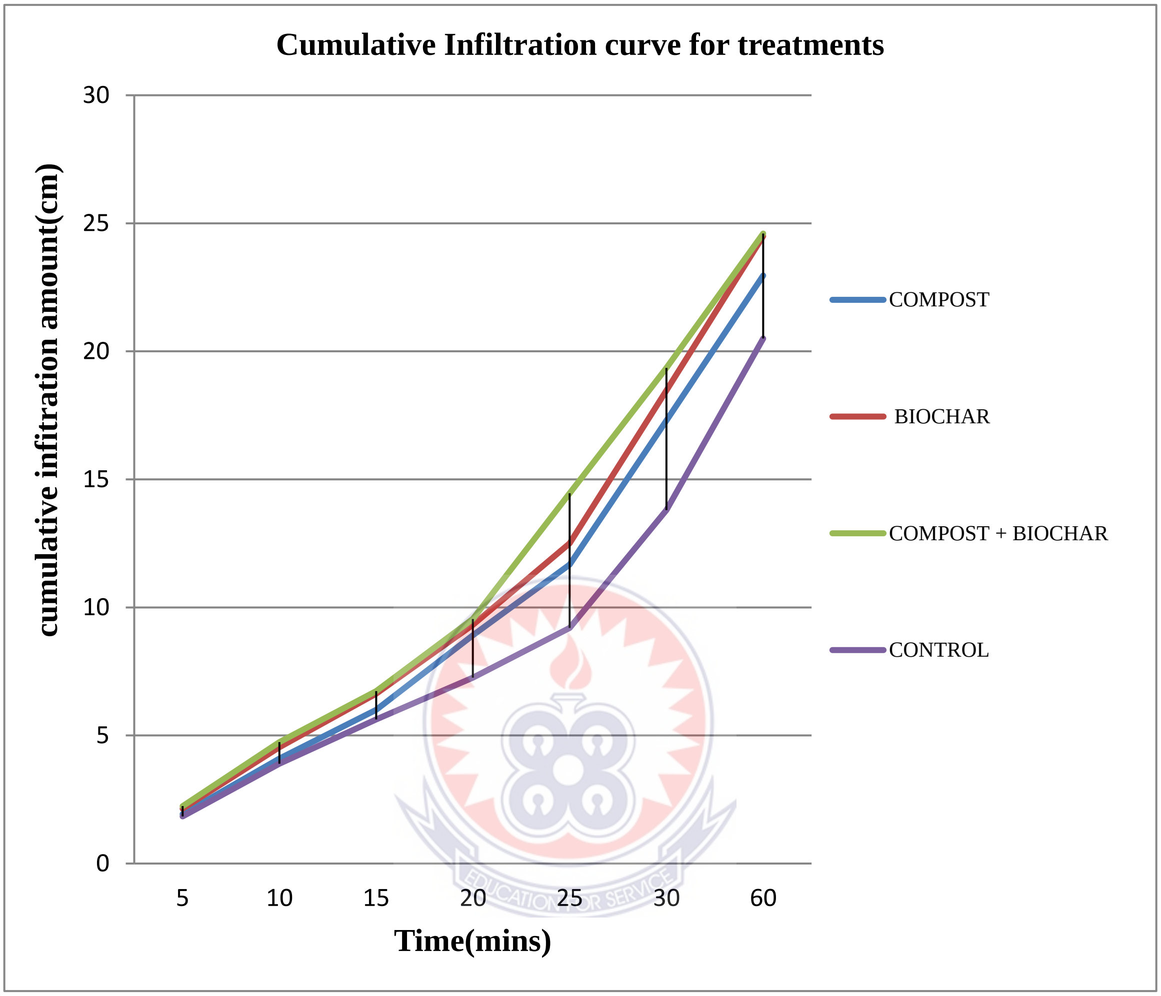
Treatment	**Soil pH**	**Organic Carbon (%)**	**Organic Matter (%)**	**Total Nitrogen (%)**
Compost	5.70^{b}	0.98^{b}	1.69^{b}	0.19^{b}
Biochar	5.70^{b}	0.96^{b}	1.65^{c}	0.18^{c}
Compost + Biochar	6.33^{a}	1.75^{a}	3.01^{a}	0.21^{a}
Control	5.20^{c}	0.83^{c}	1.55^{d}	0.08^{d}
LSD	0.49	0.06	0.02	9.98
CV (%)	4.30	2.62	0.39	3.03

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

4.6 Cumulative Infiltration as Influenced by Compost and Biochar

At the hour mark, the combination treatment of compost plus biochar plot recorded the highest cumulative infiltration amount of 24.60 cm, followed closely by the biochar treatment plot which recorded 24.50 cm and the compost treatment plot recording 22.96 cm with the control plot recording the least value of 20.50 cm (Figure 4.1). The cumulative infiltration amount curves are positively shewed towards all the amended plots at the hour mark but the magnitude of skewness is largely towards the control treatment. There was no error difference between the amended plots at the hour mark.

Figure 4.1 shows the curves for cumulative infiltration against time, generally there is an increasing order of the cumulative infiltration amount with time. The slope of the curves suggests an initial rapid change in the movement of water downward until at a point when the curves seem to slow down gradually and naturally become stable.

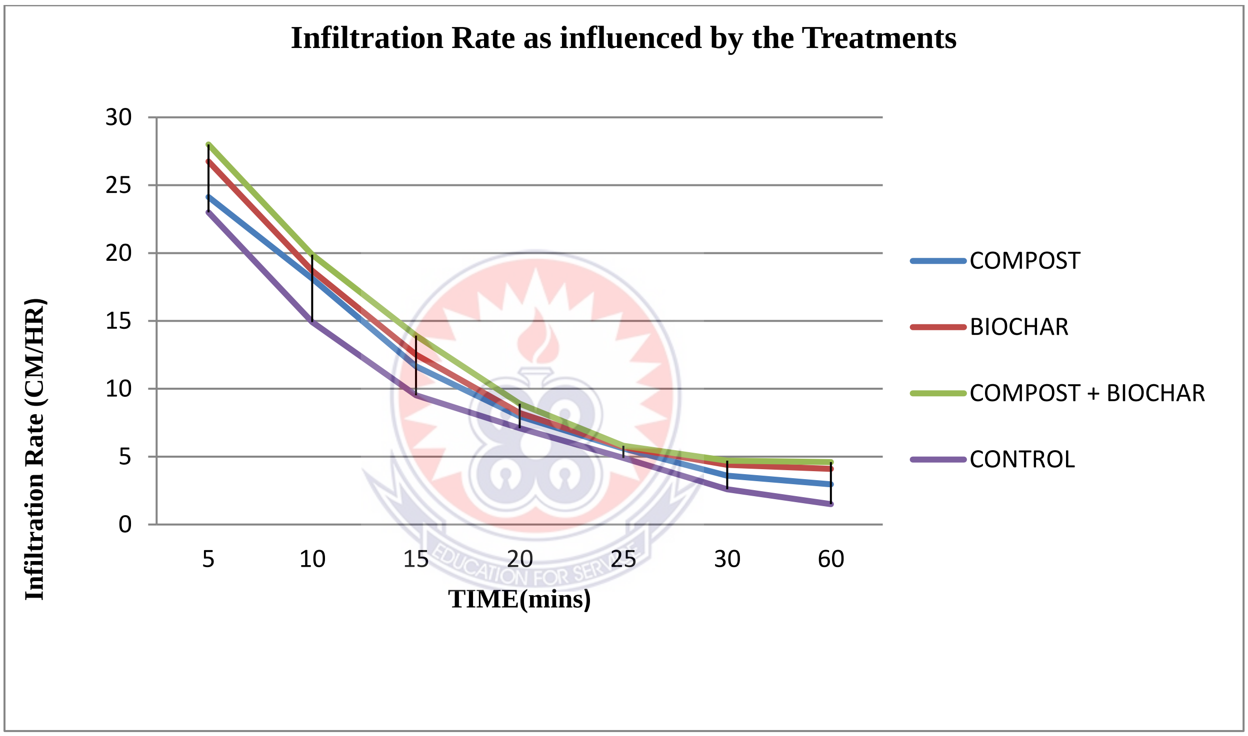


Vertical Bars represent Error bars

Figure 4.1: Cumulative infiltration curves for treatments

4.7 Infiltration Rates as Influence by Compost and Biochar

Figure 4.2 shows the curves for infiltration rate against time, generally there is a decreasing order of the infiltration rate as time increases. The slope of the curves suggests a consistent reduction in the movement of water downward to the soil until at a point when the curve seems to slow down gradually and naturally become stable. At the hour mark, the combination treatment of compost plus biochar plot recorded the highest infiltration rate followed closely by the biochar treatment plot and the compost treatment plot with the control plot recording the least value. The infiltration rate curves are positively shewed towards the amended plots. There was no significant difference between the amended plots, however there was statistical significance between the control treatment and the amended plots.



Vertical Bars represent error bars

Figure 4.2: Infiltration Rates as influenced by Treatments

4.8 Days to Emergence of Carrot Seeds as Influenced by Treatments

The mean germination percentage of carrot seeds on the 30th day after planting in the different treatment plots are reported in Figure 4.3. The highest germination percentage was recorded by the compost treatment and the lowest was recorded by the control treatment. At four (4) weeks after planting there was no significant difference in the germination percentage on the amended plots. The biochar treatment plot had 84% germination recorded as the least germination percent among the amended plots. However; there were significant differences between the amended plots and the control treatments. Combination treatment of compost plus biochar produced no significant result as compared to the biochar alone. The lowest days of emergence during the entire germination and growing season was recorded by the control treatment.

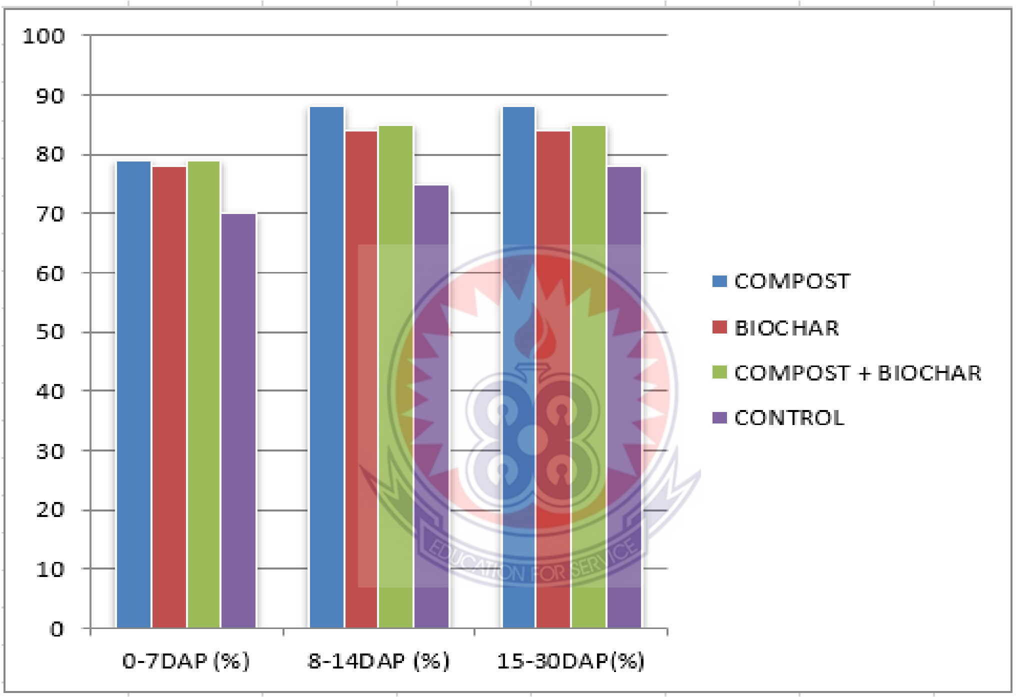


Figure 4.3: Germination Percentage of Carrot Seeds an Influenced by the Treatment

4.9 Plant Height as Influenced by the Application of Treatments

Data on mean plant height of carrot in the different treatments and their interactive effect are shown in Table 4.5. The plant heights recorded over the period for 65 DAP produced no significant effects among the amended treatments but there was significant difference between the amended treatments and the control treatment.

Aside this peculiar situation at 65 DAP, there were significant difference among all treatment for the 35 DAP, 51 DAP and 79 DAP for all treatments. However, the combination treatments of compost plus biochar produced plants with the maximum heights over the twelve-week period. The minimum plant height of 14.90 cm was recorded under the control treatment. All treatments increase their corresponding plant heights with time peaking at 65 DAP. The rate of growth was rapid during the vegetative phase of the carrot plant up to 65 DAP after which growth slowed down as the reproductive phase was initiated.

Table 4.5: Plant Height as influenced by the Application of Biochar and Compost

Treatment	**37 DAP**	**51 DAP**	**65 DAP**	**79 DAP**
Compost	17.80[ab]	37.50[b]	44.80[a]	46.37[b]
Biochar	17.00[b]	36.90[c]	44.10[a]	45.00[bc]
Compost + Biochar	18.20[a]	38.00[a]	45.00[a]	50.20[a]
Control	14.90[c]	34.00[d]	40.00[b]	42.50[c]
LSD	**0.88**	**0.40**	**2.64**	**2.57**
CV (%)	**2.69**	**0.55**	**3.04**	**2.80**

NOTE: DAP- Days After Planting

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

4.10 Number of Leaves as Influenced by the Application of Biochar and Compost

The number of leaves produced per plant for all amended treatments over the period generally was significant (Table 4.6). The control plot recorded the least number of leaves over the period. The combination treatment of compost plus biochar recorded the highest values for mean leaf number and was significantly different from all the other treatments.

This was followed by the sole biochar treatment and the compost treatment. The general trend was that the number of leaves during the period increase exponentially within the growing season with the control treatment recording the lowest values during the entire season. Statistical analysis shows that the organic soil amendments significantly affect the number of leaves.

Table 4.6: Number of leaves as influenced by the Application of Biochar and Compost

Treatment	**37 DAP**	**51 DAP**	**65 DAP**	**79 DAP**
Compost	4.40[a]	6.80b[c]	7.20[ab]	10.00[b]
Biochar	4.60[a]	6.90[ab]	7.40[ab]	9.67[b]
Compost + Biochar	4.80[a]	7.33[a]	8.50[a]	12.67[a]
Control	4.00[b]	6.40[c]	6.90[b]	8.03[b]
LSD	**0.43**	**0.49**	**1.46**	**2.64**
CV (%)	**4.55**	**3.60**	**9.77**	**13.11**

NOTE: DAP- Days After Planting

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

4.11 Canopy Spread as Influenced by Biochar and Compost

The mean canopy spread of leaves of carrot plants for all amended plots was higher than the control (Table. 4.7). The combination treatment of compost plus biochar had the highest canopy spread and this was followed by the compost and biochar treatment. Difference in the canopy spread with all amended treatments was significant. However; there was no significant difference between treated plots at 51 DAP. Statistical analysis shows that the organic soil amendments significantly affected the canopy spread of the carrot plant as compared to the control treatment.

Table 4.7: Canopy Spread as Influenced by Biochar and Compost

Treatment	37 DAP	51 DAP	65 DAP	79 DAP
Compost	5.80^{b}	22.68^{a}	41.75^{ab}	57.07^{b}
Biochar	5.90^{ab}	23.07^{a}	40.30^{b}	54.13^{b}
Compost + Biochar	6.10^{a}	24.23^{a}	43.00^{a}	60.60^{a}
Control	4.07^{c}	20.45^{b}	33.01^{c}	41.40^{c}
LSD	**0.24**	**1.70**	**2.07**	**3.07**
CV (%)	**2.18**	**3.77**	**2.63**	**2.88**

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

4.12 Mean Canopy Area and Leaf Area Index in Response to Treatments.

Table 4.8 shows the mean canopy and leaf area index in plant responses to treatments. During the growth season, the greatest canopy area was measured in the combination treatment of compost plus biochar to be 0.26 cm^3. This was followed by compost and the biochar which recorded 0.23 cm^3. The least canopy area was under the control plot 0.17 cm^3. For canopy area and leaf area index, interaction effects were significant between treatments. Amended plots produced the highest canopy area while the control plot produced the least. Results for leaf area index were similar to that of canopy area.

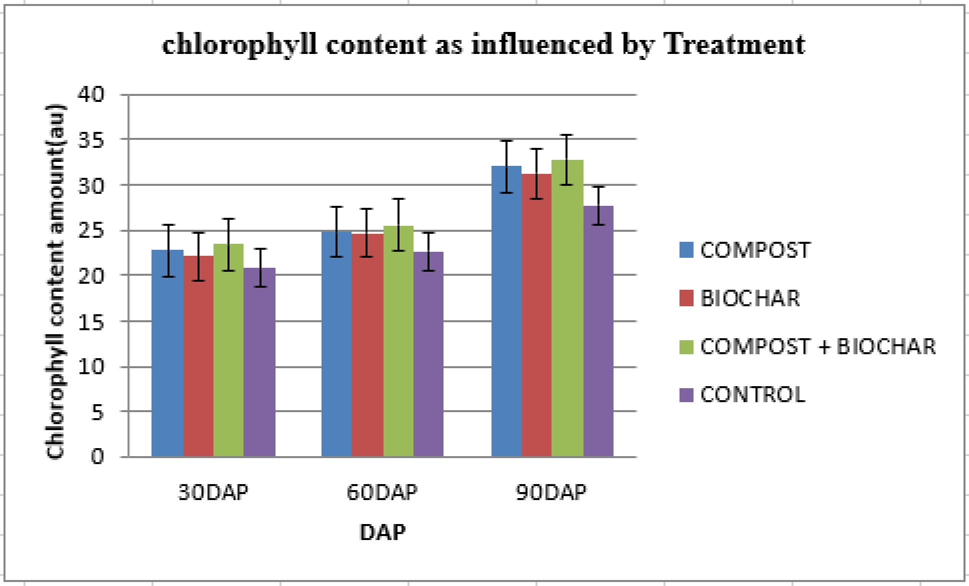
Table 4.8: Canopy Area and Leaf Area Index as Influenced by Treatments

Treatment	**Canopy Area (Cm^3)**	**Leaf Area Index**
Compost	0.23^b	0.23^c
Biochar	0.23^b	0.23^b
Compost + Biochar	0.26^a	0.26^a
Control	0.17^c	0.17^d
LSD	**5.99**	**5.99**
CV (%)	**1.35**	**1.35**

Treatment means having the same letters along the column are not significantly different from each other at 5 % level.

4.13 Chlorophyll Content of Fresh Carrot Leaves as Influenced by Treatments

Figure 4.4 shows the chlorophyll content of fresh carrot leaves as influenced by treatments. The results revealed that fields treated with organic amendments have plants with high chlorophyll content than the control plot during the growing season of the plants. The compost recorded relatively similar chlorophyll content values during the entire growing season as the biochar recorded. The control plot over the period recorded lower chlorophyll content values as compared to the other amended treatments. The combination treatment of compost plus biochar produced the highest values for chlorophyll content.



Vertical Bars represent LSD bars less than 5% significance

Figure 4.4: Chlorophyll Content of Fresh Carrot Leaves as Influenced by Treatment

4.14 Yield Data

Yield and yield components were determined through the diameter of carrot root, length of root, weight of marketable root, weight of non-marketable root and the overall yield.

4.14.1 Effect of Treatments on Root Length and Root Diameter

Table 4.9 show the differences in plant responses to treatments for carrot root length, root diameter, total plant fresh weight, fresh root weight and fresh leaves weight after harvesting. The measurements taken on root diameter produced significant effects among the treatments over the period. For root diameter, it's followed the same pattern, with the combination treatment recording the highest value of 4.40 cm followed by the Biochar which recorded 3.90 cm and closely followed by the compost 3.80 cm. The control treatment recorded the least root diameter (2.8 cm) as compared to the treated plots. There was no significant difference between the combination treatment and the biochar treatment plot but there was significance difference between the control and the amended plots.

Carrots grown on all the amended plots had significantly longer root length than carrots on the control plots. However; there were significant difference between these two and the control treatment. The combination treatments of compost plus biochar had the longest root length of 22 cm, followed by the sole compost 18 cm and the sole biochar 16 cm with the control plot recording the least value of 13 cm. All the amended plots also produced significantly longer roots than the control treatments.

4.14.2 Effect of Treatments on Total Plant Fresh Weight, Fresh Root and Leaf Weight

The weight of fresh roots was significantly affected by treatments and combined use of organic amendments as compared to the control treatment. Highest mean fresh root was produced by plants in the combination treatment of compost plus biochar (74.72 g) followed by compost (72.27 g), followed by the biochar (70.66 g), and the control (35.79 g) which recorded the least (Table 4.9).

The records taken on total plant fresh weight produced significant effects among the treatments over the period. It followed the same pattern, with the combination treatment recording the highest value of 133.72 g followed by compost 122.27 g, closely followed by the Biochar which recorded 120.66 g. The control treatment recorded the least total fresh plant weight 65.79 g as compared to the treated plots. There was significant difference between the combination treatment, compost, control and the biochar treatments.

4.14.3 Influence of Treatments on Dry Matter of Carrot Roots

Table 4.9 shows the mean effects of treatments on total dry matter accumulated, during the growth season. For total dry matter accumulated there was significant difference. Carrots grown on all the amended plots had significantly high dry matter accumulated than carrots on the control plots. The combination treatment of compost plus biochar plot had the highest mean dry matter accumulation of 67.23 g and was significant to all the amended plots and the control. Treatments effects were all significant on the dry matter accumulated during the period. The control plot recorded the least dry matter accumulated (31.35 g).

Table 4.9: Influence of Treatments on fresh weight of root, fresh leaves and Dry Matter of Carrot Roots

TREATMENT	Total Carrot Fresh Weight (g)	Fresh Carrot Root Weight (g)	Root Diameter/ Plant (cm)	Root Length/ Plant (cm)	Fresh Leaves Weight/ Plant(g)
Compost	122.27^{b}	72.27^{b}	3.80^{b}	18.00^{b}	50.00^{b}
Biochar	120.66^{c}	70.66^{c}	3.90^{b}	16.00^{c}	50.00^{b}
Compost + Biochar	133.72^{a}	74.72^{a}	4.40^{a}	22.00^{a}	59.00^{a}
Control	65.79^{d}	35.79^{d}	2.80^{c}	13.00^{d}	30.00^{c}
LSD	**0.68**	0.68	0.10	1.20	
CV (%)	**3.54**	3.54	1.34	5.80	

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

4.14.4 Mean Marketable, Non-Marketable and Total Yield as Influenced by Compost and Biochar

Table 4.10 shows the mean yield from treatments. Treatment effects on marketable, non-marketable and total carrot yield were significant for all treatments. For marketable yield, the combination treatment gave the highest marketable yield of 11.90 ton/ha followed by the compost which recorded 11.17 ton/ha and the biochar that recorded 8.50 ton/ha. The control plot recorded the least marketable yield of 6.67 ton/ha. In addition, non-marketable yield was highest for combination treatment (1.93) and lowest under the control treatment (1.07 ton/ha). On the whole, there was significant difference in the total yield for all treatments. Again, there were significant differences observed between all the treatments for marketable yield. All the amended plots recorded significant increases in their total yields than the control plot.

Table 4.10: Mean Marketable, Non-Marketable and Total Yield as Influenced by Compost and Biochar

TREATMENT	Marketable (ton/ha)	Non-Marketable (ton/ha)	Harvest index	Total Yield (ton/ha)
Compost	11.17^{b}	1.07^{b}	0.25	12.23^{b}
Biochar	8.83^{c}	1.67^{ab}	0.28	10.50^{c}
Compost + Biochar	11.90^{a}	1.93^{a}	0.55	13.60^{a}
Control	6.67^{d}	1.07^{b}	0.18	8.60^{d}
LSD	**0.68**	**0.61**		**1.09**
CV (%)	**3.54**	**19.08**		**4.88**

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

4.15 Correlation Analysis of Soil Properties, Growth, and Yield

In this experiment, it is noted From Table 4.11 that porosity, bulk density, gravimetric moisture content and infiltration rates which is positively and negatively correlated with pH, organic matter content and organic carbon as well as the total yield and harvest index. Additionally, it is obvious from the correlational matrix that the above-stated soil physical and chemical properties relationships also explain a lot of the agronomic observations from plant growth to harvest. This correlation analysis shows that both physical and chemical properties of soil affect the growth and yield of carrots. Though some indicators are showing inverse relationship others are perfectly and positively correlated irrespective of the magnitude of the values. This shows that management and anthropogenic changes in soil can be helpful or detrimental to carrot crop performance.

Table 4.11: Correlation Matrix of the Influence of Soil Parameters, Carrot Growth and Yield

	Bulk Density	Porosity	% Carbon	Moisture Content	% Organic Matter	pH	Infiltration Rate	Total Yield	Harvest Index
Bulk density	1								
Porosity	-1	1							
% Carbon	-0.12	0.12	1						
Moisture Content	-0.975	-0.957	0.975	1					
% Organic Matter	0.17	0.17	0.98	0.99	1				
pH	0.14	-0.14	-0.08	-0.11	0.11	1			
Infiltration Rate	-0.963	-0.956	0.974	0.993	0.983	0.998	1		
Total Yield	-0.23	0.23	-0.15	-0.13	-0.13	0.23	0.08	1	
Harvest Index	-0.03	0.03	-0.03	-0.33	0.29	-0.02	-0.31	0.19	1

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of compost and Biochar on Soil Physical Characteristics

Despite high variability both within and across the experimental sites, several notable trends were observed in examining the effect of organic amendments from cocoa pod husk biochar and its compost on soil physical properties. Soil of the site of the experiment was low in nutrient, sandy loam in texture and high in bulk density with low water holding capacity and low total soil porosity from Tables 4.1 and 4.2. These states of the soil are the characteristics of tropical soils (Du *et al.,* 2016). The high bulk density of the site was partly related to its low organic matter content. There was a reduced bulk density and increased porosity of the soil as a result of the application of organic amendments either alone or in combination as compared to the control treatment from Table 4.2.

This phenomenon was due to the relatively lower bulk density of biochar and the compost material relative to that of the soil (Lehmann *et al.,* 2011). Since all of the amendments tested are considerably less dense than soil, the reductions in bulk density may simply be the result of diluting the soil particles with a lighter material.

The results from the treatments showed that there was significant interaction effect between biochar and compost on bulk density. This means that one cannot say biochar alone or compost alone influences bulk density. Rather, bulk density is influenced by the application of organic amendments.

Further, the bulk density which is a measure of how compact the soil is, was assessed for the control, compost and biochar treated soils. One of the most important factors agriculturally in terms of bulk density is plant growth. It is also a measurement of the degree of compaction of the soil. The more compact the soil is the less suitable it becomes for crop production as compaction reduces the amount of disposable oxygen for microbial activities, retards root penetration, water infiltration and plant growth in general. For roots and tuber crops, higher bulk density is associated with reduced yield (Filiberto and Gaunt, 2013).

On the whole, the combination treatment of biochar plus compost gave the least bulk density of 1.3 compared to 1.5 for the control treatment. If the soil has a high bulk density (compaction), the growth of seed will be restricted in emergence and root growth will be affected. This will affect total plant growth and yield (Filiberto and Gaunt, 2013). The use of tractors will directly affect the soils bulk density causing extreme compaction especially if the soil is wet. Careful management on the land is required to create an ideal bulk density for optimum plant growth and healthy soil.

Biochar and compost amended soil and its combination recorded high porosity values (Table 4.2). Njoku *et al.* (2016) reported that the change in porosity with biochar treated soils was as a result of formation of macropores and rearrangement of soil particle. Laird *et al.* (2010) also reported similar finding and suggested that biochar is acting as a soil conditioner. The increase in porosity and decrease in bulk density as the level of organic amendment increased can be adduced to greater effects of organic amendments on porosity from each level of biochar application. This is in agreement with Katterer's *et al.* (2019) study in Kenya where biochar addition increased soil porosity and water holding capacity after continuous addition for 10 years compared with bared soil. A number of studies have suggested biochar, whether alone or in combination with other amendments, can improve aggregation (Du *et al.,* 2016); however, the effects are not always consistent and the mechanisms not entirely clear. These results are also in agreement with those of Njoku *et al.* (2016) where the applications of rice husk and sawdust biochar had a significant effect on soil moisture content, bulk density, porosity, and soil water-filled pore space.

Additionally, the percentage solid space and soil porosity which indicate how much solid particles and pore spaces are available respectively for air and water were assessed. The significant interaction effect of compost and biochar on the percentage solid space and soil porosity shows an improvement in soil compaction by increasing the carbon stock, expanding the surface area of microbial activity, and increasing the space occupied by air and water as predicted by soil porosity results (Table 4.2). These results are in agreement with most works on biochar amendments on soil (Satriawan and Handayanto, 2015).

The volumetric moisture content which determines the volume of water held in the pores of the soil provided similar results to the gravimetric moisture content signifying again that the soil treated with the combination treatment of biochar and compost held more water than other treatments. The implication is that the combination of 20 ton/ha compost plus 10ton/ha biochar use among farmers can reduce the cost of irrigation and increase profitability among farmers as more water is stored in the soil for plant use. The improved soil water content is attributed to the organic matter and improved moisture retention and water acceptance as a result of improved soil structure and macro-porosity and also it might be due to the colloidal and hydrophobic nature of the organic amendment (Schulz and Glaser, 2014). Poku *et al.* (2014) reported that addition of compost led to significant effects of physical properties of soil such as pore size distribution, aggregate stability and soil moisture retention.

A number of studies have suggested that organic amendments like biochar and compost can improve plant growth (Lehmann *et al.*, 2011), and this may occur through a variety of mechanisms, including changing nutrient and water dynamics, and biological activity in soils (Ma *et al.*, 2016).

The downward movement of water into the soil is known as infiltration. Results from Figures 4.1 and 4.2 indicated that organic amendment-applied plots increased infiltration rate compared with the control. The results also show that the combination treatment plot recorded the highest as compared to the control. This could be as a result of more pores created in the soil matrix as a result of biochar and compost application because these organic amendments are very porous. Ma *et al.* (2016) reported an increase in water infiltration after a 2-year experiment in which biochar was applied at a rate of 20 Mg ha^{-1} to a clay loam soil.

In this present study, the results show that the application of compost, biochar and its combination reduced bulk densities, increased soil moisture content, increased soil porosity, increased soil infiltration rate and improve on the texture and structure of the soil as compared to the control. This present result is in agreement with that of Katterer *et al.* (2019) where incorporating biochar into the soil significantly reduced soil bulk densities and improve the physical soil properties for growth and development after application of organic amendments compared with the control. It can therefore be said that organic amendments originating from cocoa pod husk biochar and its compost are good sources of organic amendment for improving soil physical properties of sandy soils.

5.2 Effect of Compost and Biochar on Soil Chemical Characteristics

Soil pH, total nitrogen, organic carbon and organic matter were very low for the soil at the experimental site from Table 4.4. According to the critical levels of nutrient, the soil of the experimental site of 1.55 % OM, 0.08 % N, indicated low nutrient level therefore poor soil fertility (FAOSTAT, 2014). It will, therefore, be unable to sustain crop yield without the addition of external input. The chemical composition of biochar and compost was relatively high in total Nitrogen and organic carbon at the level required for the growth of carrot (Table 4.1). Application of biochar and compost benefited the crop and soil.

With significant interaction effects of biochar and compost on pH, it can be inferred that the application of biochar, compost and their combination affect soil pH differently as compared to the control. In a work done by Schulz and Glaser (2014), it was reported that addition of biochar significantly increased soil pH in spite of the fact that pH value was generally lower during the second growth period (major season) probably due to leaching of base cations. It is implied that controlled use of biochar has a good potential for raising pH and reducing the incidence and cost of liming. The increase in pH with biochar was due to the fact that biochar contains ash. Compost as reported by Jatav *et al.* (2017) can help to absorb and bind organic matter, total soluble N, thereby increasing the nutrient retention capacity of the soil.

Soil chemical properties in the experiment such as organic carbon, total nitrogen were improved compared with the control; these results of soil chemical properties with organic amendment are in agreement with the work of Njoku *et al.* (2016) in which rice husk and sawdust biochar rates had a significant effect on all the chemical properties in the soil. This present result on soil chemical properties with biochar and compost is also in agreement with that of Zidane *et al.* (2015), where there was a significant increase in soil pH, base saturation, exchangeable Ca, Mg, K, and Na, and available P in biochar-applied soils compared to the adjacent soils.

On the percentage Organic carbon, there was a significant interaction effects from compost and biochar. Combined treatment of compost plus biochar showed a slight improvement in organic carbon content than compost applied alone. Amended-plot soil generally had higher organic carbon than treatments plots without amendments. This is attributable to the increased carbon content of cocoa pod husk used in the treatment. In spite of the dominant processes governing the balance of soil organic carbon stocks, carbon inputs from biochar, compost and other plant remains plus carbon emissions from decomposition and losses as particulate or dissolved carbon can be significantly altered if soil ecosystems are managed with biochar amendment (Agegnehu *et al.*, 2016).

The observation for % organic matter is similar to that of the % organic carbon as reported by (Abuzar *et al.*, 2013). The results showed that biochar and compost amended soils gave higher organic matter content (Tables 4.7). This is largely attributable to the increased carbon input from biochar and compost (Güereña *et al.*, 2015).

With total nitrogen there was an overall increase in the amended plots as compared to the control plot. Compost and their biochar combinations had significant different nitrogen contents with the combination treatment having the highest value. This is in contrast with findings that the control (without biochar or fertilizer or compost) had the highest nitrogen content in some studies. Veitch *et al.* (2014) in a dissimilar study reported that the reason for not seeing the effect of nitrogen among treatment plots but instead in the control could be due to the high base fertility of the soil environment under consideration. In this current study, total nitrogen was increased in all treated plots. It is obvious from Table 4.4 that for treatment without biochar would experience decreased availability of Nitrogen. This study is in tandem with Lehmann and Rondon (2015) who reported that biochar can adsorb both NH_{4+} and NH_{3}- from the soil solution and other nutrients such as phosphate, and other ionic solutes.

Compost can serve as a slow-release fertilizer and the nutrient value is dependent on its components. In comparison with the control, the nitrogen is in a more stable form and not susceptible to loss as NH_3 gas Dennis and Kelvin (2013). The quantity and quality of the compost materials can be regarded in a waste management strategy for soil enhancement. Compost constituents should be in proportions that decompose to give a stable product (Dennis and Kelvin, 2013).

5.3 Effect of Compost and Biochar on Carrot Growth

The days to emergence of carrot seeds was affected by the treatments applied. The plants applied with compost, biochar and its combination recorded significant changes in the germination percentage within the first 7 days compared to the control which germinated late. This may be due to the release of nutrients into the soil by the compost (Agegnehu *et al.*, 2016). This as well means that application of organic amendment affects the germination as well as the growth of plants. This might be due to the high rate and richness of the soil in soil organic matter and nutrients needed for the germination and growth of the seeds (Zhuang, 2017).

Again, the chlorophyll content measured showed significant differences among the treatments for most of the recorded monthly measurements. Chlorophyll content is the green colouring matter of the leaves of plants. The colour is mostly displayed because of nitrogen nutrients absorbed by the plant. It is further established that the photosynthetic machinery consists of various mechanisms, including gaseous exchange systems, photosynthetic pigments, photosystems, electron transport systems, carbon reduction pathways, and enzyme systems which affects the photosynthetic activity of the crop, their growth, their biomass production and nutrient composition (Grimm, 2018). The differences could be due to the nitrogen released by the treatments applied into the soil. The results revealed that fields treated with organic amendment have plants with high chlorophyll content. The control plot has over the period recorded lower chlorophyll content values as compared to the other treatments. This is because the control plot where no treatment was applied could not have a supply of nitrogen nutrients over the period to record high chlorophyll content as explained by Grimm (2018).

In this study, the amended plots produced plants with significantly higher number of leaves and higher plant height than the control. The significant increase in the number of leaves of carrots on the combination treatment plots and the other amended treatments plots as compared to the control might be due to the high nitrogen and presence of exchangeable cations in the organic amendments. According to Veitch *et al.* (2014), adequate amounts of nitrogen may be obtained from reasonable amounts of organic matter applied to the soil and it is directly responsible for the vegetative growth of plants. The number of leaves per plant is relevant to canopy development and closure, which is significant for the interception of solar radiation, dry matter accumulation and partitioning. This is similar to studies done by Qasim *et al.* (2010) that the higher rates of application of organic amendments produce more leaves. Statistical analysis in this study shows that the organic soil amendments significantly affect the number of leaves produced by the carrot plants on amended plots as compared to the control plots. The number of leaves produced is directly linked with the plant's ability to absorb essential nutrients for vegetative growth and development and might also be related to plant density in response to competition for available space. This agrees with the findings of Vuolo *et al.* (2013) that for most crops, plant density has a major influence on biomass.

The amended plots also produced taller plants than plants from the control plots with the combination treatment plot producing the highest (Table 4.5). This might be due to the higher nitrogen, carbon and increase in the organic matter contents that were involved in plant growth, respiration and energy storage and rapid shoot growth. This agrees with Alshankiti and Gill (2016) who reported that the application of organic fertilizers to the soil supply plant nutrients for increased plant height and more leaves in shallots. The general trend was that the rate of growth was rapid during the vegetative phase of the carrot plant up to 65DAP after which growth slowed down as the reproductive phase was initiated. This trend follows the normal growth curve of the carrot plant. This is largely due to the adequacy of precipitation received among treatments causing each treatment to perform fairly well in growth as reported by Muñoz-rojas *et al.* (2016).

On canopy spread, amended treatments effect was significant (Table 4.7) on canopy spread at harvest, canopy area and leaf area index. Consequently, the combination treatment produced the highest (60.60 cm) canopy spread as a result of the improved carrot productivity resulting from improved soil nutrient available to plants and assimilate translocation to carrot leaf tissues (Altieri *et al.*, 2017). Canopy area and Leaf Area Index, root length and root diameter were also significant during the growing season. With increased leaf area index following organic amendment application, there is a resultant increased interception of light, increased accumulation of assimilate and hence increased yield. In the work done by Altieri *et al.* (2017), it is argued that leaf area index is a function of days after planting, soil nutrient composition and stomatal conductance. In the case of carrots, the number of branches which is also taken as the number of leaves also informs the leaf area index. Consequently, organic amendment does not only increase the soil carbon stock, but by increasing the leaf area index, there is a concomitant increase in stomatal conductance which leads to increased carbon dioxide uptake and improved oxygen release into the atmosphere (Younis *et al.,* 2015).

At harvest, Carrots grown on all the amended plots had significantly longer root length and root diameter than carrots on the control plots. On the average the mean carrot root diameters on the amended plots were significantly higher than the control plots. The significant differences in carrot root length and girth (diameter) in amended plots compared to the control might be due to differences in soil structure and fertility. The increase in water holding capacity, improvement in soil organic matter, nitrogen, and presence of nutrients that provided some advantage (Poku *et al.,* 2014; Ofori-Frimpong *et al.,* 2010 and Ewulo *et al.,* 2008)

5.4 Effects of Treatments on Yield components of carrot

Findings revealed that Fresh carrot root weight was significantly similar for all the soil amendments and ranged from 70.66 - 74.22 g (Table 4.9). All the amended plots recorded significantly higher root yield, longer root length and diameter, than the control. Carrots grown on the combination treatment soils generally produced the highest yields and the control the lowest/ least yields among the amended plots. Harvest index for carrot roots did not differ among the soil amendments and ranged from 0.25 for compost, 0.28 for biochar and 0.55 for the combination treatment compared with 0.18 for the control. Harvest index (a dry matter partitioning coefficient or distribution index) indicates the level of efficiency that the dry matter produced by the crop is partitioned or distributed into the economically important parts of the crop (in this case the root) (Evers, 1988). The carrots grown on amended soils were therefore more efficient in distributing or partitioning dry matter into the economic root part than the control. The yield and other yield characteristics of carrot improved significantly with the application of the amendments (Tables 4.9), which followed the pattern of the changes in the nutrient levels in the soil after treatment application. Similar findings were obtained by Poku *et al.* (2014) that yield and yield characteristics of carrot improved in relation to rising levels of amendments and tend to be affected by increasing soil nutrients.

In terms of the weight of marketable roots, results showed that treatments combination plot with a mean of 11.90 tons has higher marketable roots compared to 11.17 tons of compost as to 8.83 tons of biochar as compared to carrot plant on the control plot which produced lower weight of marketable roots per ton with a mean of 6.67 tons (Table 4.10). Analysis of variance showed that the result was significant. This result implied that application of organic amendments had contributed to the production of marketable roots. Manu-Aduening *et al.* (2020) affirmed the findings of this study saying that growth, yield and healthiness of carrot plants are influenced by the soil properties and availability of water to proper timing. Ye *et al.* (2016) state that one factor to consider in carrot farming is the proper healthiness of the soil and irrigation schedule in order to maximize the crop yields.

The increase in yield recorded by the organic amendments and their combinations might have been due to the improvement of the physical structure of the soil and the nutrients supplied as stated by Dennis and Kuo (2014) and Ofori-Frimpong *et al.* (2010). The addition of organic amendments increased the total porosity which decreased the bulk density and thereby increasing root penetrability. This improves the nutrient exploration by plants for better growth and yield (Ameloot *et al.*, 2013).

5.5 Correlational Analysis on physiochemical soil properties growth and yield of carrots

High correlation was observed between porosity and gravimetric moisture content. This leads to a direct positive relationship between soil porosity and gravimetric moisture content and inverse relationship between soil porosity and either bulk density and %solids. This is in line with findings of Bhattarai *et al.* (2015). This is seen from the matrix showing pH, % organic carbon and % organic matter being strongly (highly and perfectly) correlated with moisture content of carrot. Carrot yield is also moderately correlated with soil organic matter and highly correlated with pH content. Evidently, much of plant growth, yield and nutrient quality is explained by the health of the soil in both physical and chemical terms. Consequently, application of organic amendments, as management practices have a huge potential not only for improving crop productivity and farmers income but also reducing deforestation and forest degradation stemming from soil fertility losses and economically impacts on the environment.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Results from the study showed that both cocoa pod husk compost and biochar affect soil physical and chemical properties. Chemical properties affected included pH, % organic carbon, total nitrogen, and % organic matter. Physical properties affected included bulk density, gravimetric and volumetric moisture content, infiltration rate, soil porosity, texture and structure of soil. Consequently, it is demonstrated that soil organic amendment affects soil chemical properties and render the soil environment either more or less conducive for crop growth which affect carrot growth parameters such as plant height, canopy spread, chlorophyll content, germination percentage, shoots and root growth.

Yield components such as root length, root diameter and total dry matter accumulated, harvest index, dry root weight, marketable and non-marketable yield and total yield differently were also influenced by the application of biochar and compost amendments. Positive and negative correlations among soil, some growth and yield parameters showed that management and anthropogenic changes in soil can be helpful or detrimental to crop performance.

It was discovered that, cocoa pod husk biochar and its compost when applied to a low fertility soil improved the physical and some chemical properties of soil for effective response to growth and yield of carrot.

6.2 Recommendations

a. It is recommended that 10 tons/ha cocoa pod husk biochar and 20ton/ha compost should be applied by farmers to sandy loam soils to help improve the properties of the soil and achieve high yielding results.

b. Based on the performance of the carrot seedlings at the experiment site, cocoa pod husk and/or compost is recommended for use to get high germination percentage.

c. Further research should be carried out to determine the influence of compost and biochar on rhizosphere biodiversity for a better understanding of the biological control systems arising from organic amendment and biochar application.

d. It is recommended that, farming areas with problems of limited water availability should start practicing the application of biochar in combination with compost as a strategy for conserving water and enhancing carrot crop productivity.

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APPENDICES

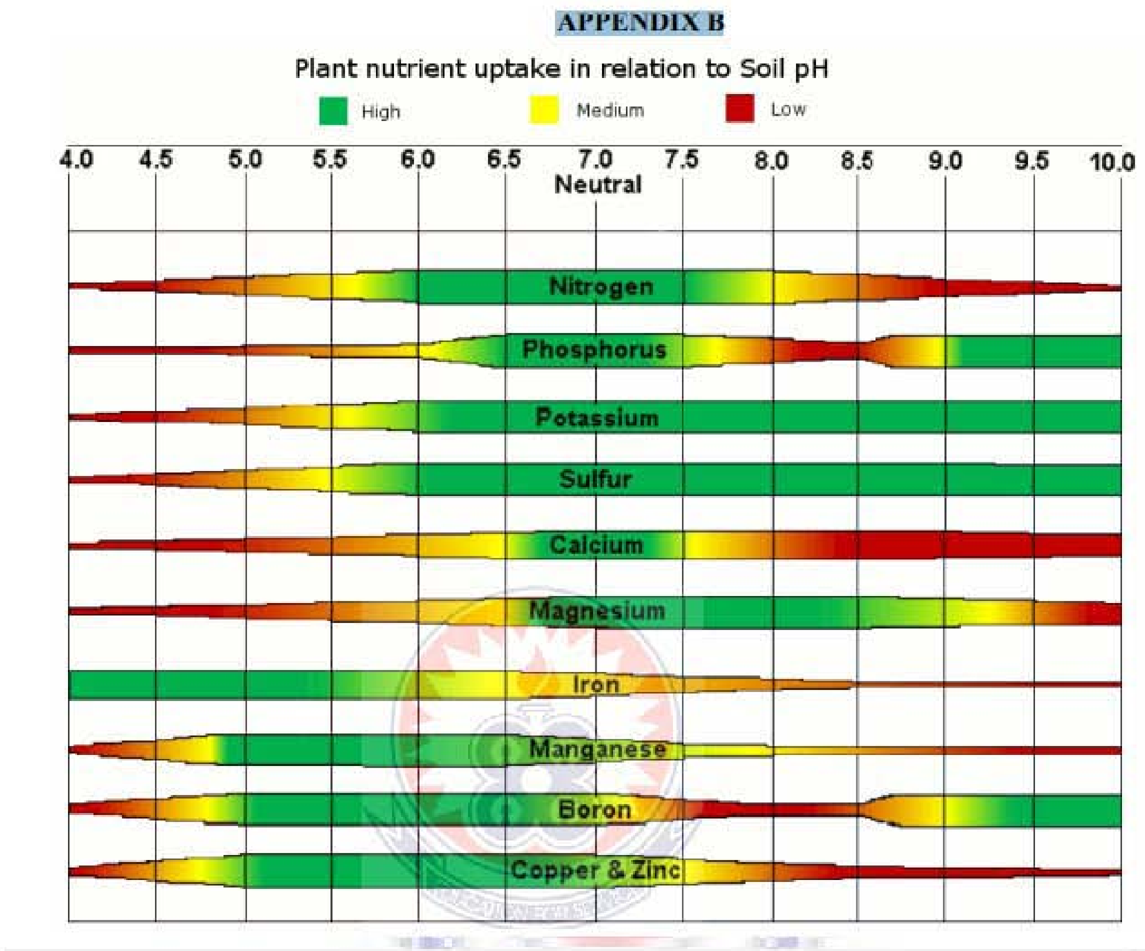
APPENDIX A

Guide to interpretation of soil analytical data in Ghana by soil research institute

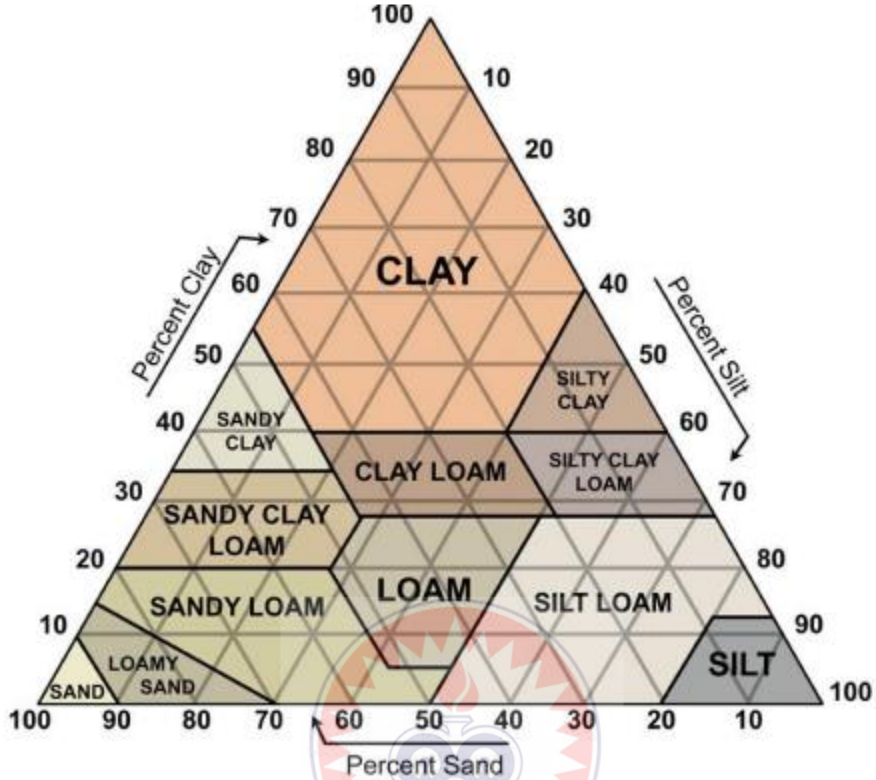
Nutrient	**Rank / Grade**
Soil pH (Distilled Water Method)	
>5.1	Very Acidic
5.1 – 5.5	Acidic
5.6 – 6.0	Moderately Acidic
6.0 – 6.5	Slightly Acidic
6.5 – 7.0	Neutral
7.0 – 7.5	Slightly Alkaline
7.6 – 8.5	Alkaline
<8.5	Very Alkaline
Organic Mater (%)	
<1.5	Low
1.6-3.0	Medium
>3.0	High
Nitrogen (%)	
<0.1	Low
0.1-0.2	Medium
>0.2	High
Carbon (%)	
<0.09	Low
0.15-1.8	Medium
>1.8	High

Council for Scientific and Industrial Research-Soil Research Institute (CSIR-CRI), Ghana, 2009.

APPENDIX B


APPENDIX B
Plant nutrient uptake in relation to Soil pH
High
Medium
Low
4.0
4.5
5.0
5.5
6.0
6.5
7.0
Neutral
7.5
8.0
8.5
9.0
9.5
10.0
Nitrogen
Phosphorus
Potassium
Sulfur
Calcium
Magnesium
Iron
Manganese
Boron
Copper & Zinc

APPENDIX C: Soil Texture Classification



Textural Triangle for Soil Aggregates

APPENDIX D: ANOVA Tables for Canopy Spread

Randomized Complete Block AOV Table for DAP37

Source	DF	SS	MS	F	P
BLOCK	2	9.9017	4.95083		
TREATMENT	3	7.9800	2.66000	187.76	0.0000
Error	6	0.0850	0.01417		
Total	11	17.9667			

Grand Mean 5.4667 CV 2.18

Randomized Complete Block AOV Table for DAP51

Source	DF	SS	MS	F	P
BLOCK	2	10.9044	5.45222		
TREATMENT	3	22.5194	7.50648	10.36	0.0087
Error	6	4.3489	0.72482		
Total	11	37.7728			

Grand Mean 22.608 CV 3.77

Randomized Complete Block AOV Table for DAP65

Source	DF	SS	MS	F	P
BLOCK	2	46.049	23.0243		
TREATMENT	3	180.215	60.0717	55.80	0.0001
Error	6	6.460	1.0766		
Total	11	232.724			

Grand Mean 39.515 CV 2.63

Randomized Complete Block AOV Table for DAP79

Source	DF	SS	MS	F	P
BLOCK	2	46.128	23.064		
TREATMENT	3	629.330	209.777	88.72	0.0000
Error	6	14.186	2.364		
Total	11	689.644			

APPENDIX E: ANOVA Tables for Chlorophyll Content

Randomized Complete Block AOV Table for DAP30

Source	DF	SS	MS	F	P
BLOCK	2	15.4400	7.72000		
TREATMENT	3	6.6667	2.22222	4.00	0.0701
Error	6	3.3333	0.55556		
Total	11	25.4400			

Grand Mean 22.400 CV 3.33

Randomized Complete Block AOV Table for DAP60

Source	DF	SS	MS	F	P
BLOCK	2	89.7267	44.8633		
TREATMENT	3	1.6667	0.5556	4.00	0.0701
Error	6	0.8333	0.1389		
Total	11	92.2267			

Grand Mean 24.567 CV 1.52

Randomized Complete Block AOV Table for DAP90

Source	DF	SS	MS	F	P
BLOCK	2	740.615	370.308		
TREATMENT	3	0.197	0.066	4.00	0.0701
Error	6	0.098	0.016		
Total	11	740.910			

Grand Mean 31.950 CV 0.40

APPENDIX F: ANOVA Table for Chemical Properties

Randomized Complete Block AOV Table for Total Nitrrogen

Source	DF	SS	MS	F	P
BLOCK	2	0.00005	0.00003		
TREATMENT	3	0.03030	0.01010	404.00	0.0000
Error	6	0.00015	0.00002		
Total	11	0.03050			

Randomized Complete Block AOV Table for Organic Carbon

Source	DF	SS	MS	F	P
BLOCK	2	0.00222	0.00111		
TREATMENT	3	1.58982	0.52994	605.65	0.0000
Error	6	0.00525	0.00088		
Total	11	1.59729			

Grand Mean 1.1308 CV 2.62

Randomized Complete Block AOV Table for Organic Matter

Source	DF	SS	MS	F	P
BLOCK	2	0.00012	0.00006		
TREATMENT	3	4.30762	1.43587	24615.0	0.0000
Error	6	0.00035	0.00006		
Total	11	4.30809			

Grand Mean 1.9758 CV 0.39

Randomized Complete Block AOV Table for soil pH

Source	DF	SS	MS	F	P
BLOCK	2	0.02167	0.01083		
TREATMENT	3	1.94000	0.64667	10.63	0.0082
Error	6	0.36500	0.06083		
Total	11	2.32667			

Grand Mean 5.7333 CV 4.30

APPENDIX G: ANOVA Tables for Physical Properties

Randomized Complete Block AOV Table for BULK DENSITY

Source	DF	SS	MS	F	P
BLOCK	2	0.00500	0.00250		
TREATMENT	3	0.07282	0.02427	9.71	0.0102
Error	6	0.01500	0.00250		
Total	11	0.09282			

Grand Mean 1.3675 CV 3.66

Randomized Complete Block AOV Table for GRAVIMETRIC MOISTURE CONTENT

Source	DF	SS	MS	F	P
BLOCK	2	0.0650	0.0325		
TREATMENT	3	48.6692	16.2231	656.21	0.0000
Error	6	0.1483	0.0247		
Total	11	48.8825			

Grand Mean 22.925 CV 0.69

Randomized Complete Block AOV Table for SOIL POROSITY

Source	DF	SS	MS	F	P
BLOCK	2	0.5000	0.2500		
TREATMENT	3	73.6200	24.5400	98.16	0.0000
Error	6	1.5000	0.2500		
Total	11	75.6200			

Randomized Complete Block AOV Table for % SOLID SPACE

Source	DF	SS	MS	F	P
BLOCK	2	0.5000	0.2500		
TREATMENT	3	73.6200	24.5400	98.16	0.0000
Error	6	1.5000	0.2500		
Total	11	75.6200			

Randomized Complete Block AOV Table for VOLUMETRIC MOISTURE CONTENT

Source	DF	SS	MS	F	P
BLOCK	2	0.0050	0.0025		
TREATMENT	3	81.4200	27.1400	10856.0	0.0000
Error	6	0.0150	0.0025		
Total	11	81.4400			

APPENDIX H: ANOVA Table for Plant Height

Randomized Complete Block AOV Table for DAP37

Source	DF	SS	MS	F	P
BLOCK	2	2.6450	1.32250		
TREATMENT	3	19.4625	6.48750	33.13	0.0004
Error	6	1.1750	0.19583		
Total	11	23.2825			

Randomized Complete Block AOV Table for DAP51

Source	DF	SS	MS	F	P
BLOCK	2	6.4800	3.24000		
TREATMENT	3	28.8600	9.62000	240.50	0.0000
Error	6	0.2400	0.04000		
Total	11	35.5800			

Grand Mean 36.600 CV 0.55

Randomized Complete Block AOV Table for DAP65

Source	DF	SS	MS	F	P
BLOCK	2	3.5000	1.7500		
TREATMENT	3	49.6425	16.5475	9.46	0.0108
Error	6	10.5000	1.7500		
Total	11	63.6425			

Grand Mean 43.475 CV 3.04

Randomized Complete Block AOV Table for DAP79

Source	DF	SS	MS	F	P
BLOCK	2	53.712	26.8558		
TREATMENT	3	93.070	31.0233	18.74	0.0019
Error	6	9.935	1.6558		
Total	11	156.717			

Grand Mean 46.017 CV 2.80

APPENDIX I: ANOVA Tables for Marketable, Non-Marketable and Total Yield

Randomized Complete Block AOV Table for MARKETABLE YIELD

Source	DF	SS	MS	F	P
BLOCK	2	6845000	3422500		
TREATMENT	3	4.610E+07	1.537E+07	683.00	0.0000
Error	6	135000	22500.0		
Total	11	5.308E+07			
Grand Mean	9825.0	CV 1.53			

Randomized Complete Block AOV Table for NON-MARKETABLE YIELD

Source	DF	SS	MS	F	P
BLOCK	2	3202117	1601058		
TREATMENT	3	1922800	640933	4.28	0.0616
Error	6	898350	149725		
Total	11	6023267			
Grand Mean	1843.3	CV 20.99			

Randomized Complete Block AOV Table for TOTAL YIELD

Source	DF	SS	MS	F	P
BLOCK	2	1.941E+07	9704058		
TREATMENT	3	4.115E+07	1.372E+07	79.42	0.0000
Error	6	1036350	172725		
Total	11	6.160E+07			
Grand Mean	11668	CV 3.56			

APPENDIX J: ANOVA Tables for Number of Leaves

Randomized Complete Block AOV Table for DAP37

Source	DF	SS	MS	F	P
BLOCK	2	3.92000	1.96000		
TREATMENT	3	1.05000	0.35000	7.50	0.0187
Error	6	0.28000	0.04667		
Total	11	5.25000			

Grand Mean 4.4500 CV 4.85

Randomized Complete Block AOV Table for DAP51

Source	DF	SS	MS	F	P
BLOCK	2	11.5217	5.76083		
TREATMENT	3	1.3225	0.44083	7.25	0.0203
Error	6	0.3650	0.06083		
Total	11	13.2092			

Grand Mean 6.8583 CV 3.60

Randomized Complete Block AOV Table for DAP65

Source	DF	SS	MS	F	P
BLOCK	2	7.2200	3.61000		
TREATMENT	3	4.3800	1.46000	2.72	0.1372
Error	6	3.2200	0.53667		
Total	11	14.8200			

Grand Mean 7.5000 CV 9.77

Randomized Complete Block AOV Table for DAP79

Source	DF	SS	MS	F	P
BLOCK	2	110.332	55.1658		
TREATMENT	3	33.169	11.0564	6.31	0.0276
Error	6	10.508	1.7514		
Total	11	154.009			

Grand Mean 10.092 CV 13.11

APPENDIX K:

Climatic Conditions During the 2021 Cropping Season

MONTH	Total Monthly Rainfall	Mean Monthly Relative Humidity % (Hours GMT)		Mean Monthly Temperature ºC		
		06:00	15:00	Min	Mean	Max
January	0.0	76	36	22	27.5	33
February	131.4	92	54	23	28.5	34
March	110.6	93	57	23	28.0	33
April	138.8	95	61	23	28.0	33
May	164.6	96	61	23	27.5	32
June	376.7	98	67	22	26.5	31
July	273.5	97	73	22	25.5	29
August	17.6	97	76	22	25.0	28
September	99.3	97	71	22	25.0	30
October	138.6	98	67	22	26.5	31
November	45.2	98	60	22	27.5	32
December	33.4	97	56	23	28.0	33

(Meteorological Services Department- Mampong Ashanti, 2021)