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EVALUATION OF HYT BIOFERTILIZERS AND BIOCHAR ON THE GROWTH CHARACTERS AND YIELD OF HOT PEPPER

BY

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DECLARATION

This is to certify that this thesis is the result of research undertaken by Appah George Buernortey towards the award of the Masters of Philosophy Crop Science (Agronomy) in the Department of Crop Science, College of Agriculture and Consumer Sciences, University of Ghana.

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ABSTRACT

The research was conducted to investigate the effects of High Yield Technology (HYT) biofertilizers, biochar and inorganic fertilizer on the growth and yield of pepper. The studies were conducted at the University of Ghana Forest and Horticultural Crops Research Centre (FOHCREC), Kade from May 2011 to April 2012. The experiment consisted of three factors namely, HYT, Biochar and inorganic fertilizer at three levels each (HYT: 100%, 50% and 0%); Biochar: 7t/ha, 3.5t/ha and 0t/ha; inorganic fertilizer: 100%, 50% and 0% of recommended rate). There were twenty seven treatments with three replications arranged in a randomized complete block design (RCBD). Data were collected on plant height, plant diameter and leaf number, fruit number per plant and yield (t/ha) as well as soil chemical and microbial properties. Analysis of variance (ANOVA) was used to analyze the data. The results indicated that application of HYT biofertilizers and biochar significantly affected plant height, stem girth, number of leaves and fruit yield and plant nutrients. The results revealed that 3.5t/ha to 7t/ha biochar + 50-100% HYT biofertilizer combination increased the yield of hot pepper. Microbial count before and after planting also showed significant increased with the application of biofertilizers.

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DEDICATION

I dedicate this work to my dear wife and children for their sacrifice towards my education and this work.

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ABBREVIATIONS

ADP	Adenosine Diphosphate
ATP	Adenosine Triphosphate
BNF	Biological Nitrogen fixation
CEC	Cation Exchange Capacity
CN ratio	Carbon Nitrogen Ratio
DAS	Days After sowing
DAT	Days After Transplanting
EC	Electrical Conductance
FYM	Farm Yard Manure
HYT	High Yield Technology
NPK	Nitrogen Phosphorus Potassium
Ppm	Parts per million
RDF	Recommended Dose of Fertilizer
VAM	Vesicular Arbuscular Mycorrhizae

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CHAPTER ONE

INTRODUCTION

1.1 Background

Hot pepper (*Capsicum* spp) is reputed to be an important vegetable crop worldwide. It belongs to the Solanaceae family of which tomato, potato, tobacco, and petunia are members (Bosland and Votava, 2000; Seleshi, 2011). *Capsicum* was domesticated at least five times by prehistoric people in different parts of South and Middle America. The genus *Capsicum* consists of approximately 22 wild species and five domesticated species. The five domesticated species include *C. annuum* L, *C. frutescens* L, *C. chinenses, C. baccatum* L, and *C. pubescens* R (Bosland and Votava, 2000; Seleshi, 2011). On the other hand, *Capsicum* species can be divided into several groups based on fruit/pod characteristic ranging in pungency, colour, shape, intended use, flavor and size. Despite their vast trait differences most cultivars of peppers commercially cultivated in the world belong to the species *C. annuum* L (Smith *et al.*, 1987; Bosland, 1992; Seleshi, 2011).

According to Bosland and Votava (2000); and Seleshi, (2011) sweet pepper and hot pepper, like tomato and eggplant are rich in Vitamins A and C and a good source of B_2, potassium, phosphorus and calcium. *Capsicum* fruits are consumed as fresh, dried or processed, as table vegetables and as spices or condiments (Geleta, 1998; Seleshi, 2011). The nutritional value of hot pepper needs special attention, since it is a rich source of vitamin A, C and E (Poulos, 1993; Seleshi, 2011). Both hot and sweet peppers contain more vitamin C than any other vegetable crops (Poulos, 1993; Seleshi, 2011). Hot pepper pungency is a desirable attribute in many foods

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(Hoffman *et al*., 1983; Seleshi, 2011). Pungency is produced by the *capsaicinoids*, alkaloid compounds ($C_{18}H_{27}NO_3$) that are found only in the plant genus, *Capsicum* (Hoffman *et al*., 1983; Seleshi, 2011).

According to Sonago, (2003) and Nkansah *et al.*, (2011) pepper fruits may be used as a vegetable, spice and colouring as well as for medicinal purposes. A survey of the Mayan pharmacopoeia revealed that the tissue of *Capsicum* species is included in a number of herbal remedies for different kinds of ailments of probable microbial origin (I-San Lin, 1994). According to Bosland and Votava (2000), pepper is the most recommended tropical medication for arthritis. The pharmaceutical industry uses capsaicin as balm (cream), for external application of sore muscles (Thakur, 1993).

In Ghana, pepper is one of the leading vegetable crops noted for export (Nkansah *et al.*, 2011). Its production is a good source of income for small producers or out growers and is significantly one of the foreign exchange earning vegetable crops (Bonsu *et al.*, 2003; Nkansah *et al.*, 2011). It is used daily in most homes and makes positive impact at the local and export markets (Nkansah *et al.*, 2011)

Capsicum has been in existence since the beginning of civilization in the Western Hemisphere. It has been a part of the human diet since 7500 BC (Mac Neish, 1964; Seleshi, 2011). Hot pepper is produced in all the continents except for Antarctica, and historically it has been associated with the voyage of Columbus (Heiser, 1976; Seleshi, 2011). Columbus is given credit for introducing hot pepper to Europe, and subsequently to Africa and Asia. On his first voyage, he encountered a

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plant whose fruits mimicked the pungency of the black pepper; *Piper nigrum* L. Columbus called them red pepper because the pods were red, later, it was classified as *Capsicum*. It has since been commercially grown in the United States (DeWitt and Gerlach, 1990; Seleshi, 2011). However, it is also believed chilli and sweet pepper (*Capsicum annuum)* are from Mexico while aromatic hot pepper (*Capsicum chinense*) is from the Amazonian region and bird pepper (*Capsicum frutescence*), the coastal regions of the southern part of tropical South America (Purseglove *et al*., 1981; Grubben *et al*., 2004; Nkansah *et al*., 2011)

The long viability of the seeds and the ease with which they can be transported assisted in its rapid spread in the tropics and subtropics throughout the world after 1492 (Purseglove, 1988) *Capsicum frutescens* is cultivated mainly in the tropics and in the warmer regions of the USA (Kochhar, 1981). *Capsicum annuum* is grown as sole crop in Nigeria where it is used for export, however, *Capsicum frutescens* which is used locally, may be intercropped (Irvine, 1979). Both *Capsicum annuum* and *Capsicum frutescens* are cultivated in Ghana and usually treated as annuals, although when grown near houses they may be grown as perennials (Irvine, 1979). Pepper is produced in every region in Ghana, but especially in the Greater Accra, Volta, Eastern, Ashanti and Brong Ahafo regions (MoFA, 2011). The two main varieties of pepper in West Africa are *Capsicum annuum* and *Capsicum frutescens*, called commercially Capsicum and Chilli. *Capsicum annuum* has many varieties and its fruits are larger than those of *Capsicum frutescens*. Fruits of both species vary greatly in size and shape and are usually bright red although they may be white, pale yellow, orange, or purple. (Irvine, 1979)

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Farmers in Ghana largely depend on the use of chemical fertilizers and other agro-chemicals such as herbicides and insecticides. The use of such agro-chemicals indiscriminately, results in polluting water bodies and also degrading the environment impacting negatively on how attractive agro-inputs remain. Thus many farmers are resorting to adopting alternative practices such as the use of organic agro-inputs. The demand for organic crops for consumption including even organic spice crops on the international market has been showing an upward trend, with consumers willing to pay a premium price for organic products against conventional products. (Owusu and Owusu 2013)

Generally, excessive amounts of inorganic fertilizers are applied to vegetables to achieve higher yields (Stewart *et al.,* 2005 and Deore *et al.,* 2010) and maximum value of growth (Badr and Fekry, 1998; Arisha and Bradisi, 1999; Dauda *et al.*, 2008; Deore *et al.*, 2010). The use of inorganic fertilizer alone, however, may cause problems for human health and environment (Arisha and Bradisi, 1999; Deore *et al*., 2010). Studies on various crops have shown that the balanced use of NPK fertilizer alone, could not maintain the higher yields over a long time due to emergence of secondary and micronutrients and deterioration of soil physical properties (Deore *et al.,* 2010). However, the use of only organic manures can also not satisfy the crop nutrients requirement (Kondapa *et al*., 2009; Deore *et al.,* 2010). Bokhtiar *et al*., 2008; and Deore *et al.,* 2010), reported that when organic manures are applied with chemical fertilizers, it results in better yield than when applied individually. Consumers these days are demanding higher quality and safer food and are therefore highly interested in organic products (Deore *et al.,* 2010).

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According to Abd El-Hakeem (2003), farmers try to increase yields of vegetable crops by means of heavy nutrition. He went on to say that the use of chemical nitrogen and phosphorus fertilizers at high levels had an adverse effect on the accumulation of NH_4+, NO_3^- and PO_4^- in fruit tissues, therefore, clean agriculture now depends on using organic and biofertilizers in order to produce high yields with the best fruit quality without contamination and less accumulation with heavy metals.

Biofertilizers are substances that contain living microorganisms, when they are applied to seeds or plants, they colonize the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to host plant (Revllas *et al.,* 2000, Vessey, 2003 and Shanmuga *et al.*, 2013). The use of artificial fertilizers leads to environmental pollution and causes depletion of important nutrients (Shanmuga, *et al.,* 2013). Biofertilizers contain symbiotic or nonsymbiotic microorganisms stimulate the growth plant. Cultivation of plants with biofertilizers could result in resistance to diseases, the production of phyto hormones and water soluble vitamins (Kumar, *et al.,* 2001 and Shanmuga, *et al.,* 2013). Biochar is an organic charred material produced from thermal decomposition of biomass by the process called pyrolysis or high temperature burning of agricultural biomass without the presence of oxygen. The limitation of oxygen in the system prevents the complete burning, and produces the charcoal that captures much more of the natural carbon from the biomaterial. Such a form of carbon will not only be able to capture additional carbon, but also store carbon dioxide in sinks and out of the atmosphere for thousands of years. Biochar has been found to be biochemically recalcitrant compared to un-charred organic matter and possesses considerable potential to enhance long-term soil carbon pool (Lehmann *et al.*, 2006; Tshewang *et al*., 2010). Biochar has been shown to

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improve soil structure and water retention, enhance nutrient availability and retention, ameliorate acidity, and reduce aluminium toxicity to plant roots and soil microbes (Glasser *et al.,* 2002; Tshewang *et al*., 2010).

HYT is an organic product which helps to improve the fertility of the soil (Agrinos, 2011). The product comes in three forms, that is, HYT^a HYT^b and HYT^c (Agrinos, 2011). There are no nutrients in HYT^a, but the product helps in Nitrogen fixation, and this optimizes the uptake of Nitrogen from other sources (Agrinos, 2011). When the microbes colonize the soil they also break up bindings in the soil in the process, and through that also loosen the soil (Agrinos, 2011). This ensures a break through the soil pan opening up new sources of nutrients in deeper soil layers (Agrinos, 2011). Permeable soils with a lot of microbial activity also prevent water run-off and with that additional loss of nutrients. Permeable soil is also better capable of storing moisture which is exceptionally important for plant growth, especially in areas that on regular bases are hampered by drought (Agrinos, 2011). The microbial ecosystem after some time is reported to collapse and die. The dead bodies of the microbes upon decomposition help to improve organic matter content of soil (Agrinos, 2011).

1.2 Objective

The main objective of the project was to evaluate the effect of biochar, and organic substrate (HYT) on the growth and yield of pepper.

1.3 Specific Objective

The specific objectives of the study were also to:

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1. Determine the effects of biochar and biofertilizer (HYT) on vegetative growth of hot pepper.
2. Evaluate the effect of biochar and biofertilizer (HYT) on fruiting and yield of hot pepper
3. Identify possible combinations of inorganic and organic fertilizers for profitable and effective cultivation of hot pepper in Ghana.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Biochar application to soil.

According to McElligot (2011), biochar, a byproduct of pyrolysis, is a biomass-derived black carbon intended for use as a soil amendment. It is similar to charcoal manufactured through traditional or modern pyrolysis methods, and to black carbon found naturally in fired ecosystems. Biochar from pyrolysis and charcoal produced through natural burning have similar characteristics such as long residence time in the soils and a soil conditioning effect (Glasser *et al.,* 2002). Lehmann and Joseph (2009) reported that biochar is used as a soil amendment to improve soil nutrient status, carbon storage and /or filtration of percolating soil water. It has been shown through research that application of biochar to soil may be more desirable as it increases soil organic carbon, improves the supply of nutrients to plants and therefore enhance plants growth and soil physical, chemical and biological properties (Glasser *et al.,* 2002; Lehmann *et al*., 2003; Rondon *et al.,* 2007). Not considering its commercial market value, biochar presents an opportunity to return site nutrients lost from biomes removal projects, which may overshadow other potential uses (McElligot,2011).

2.2.1 Biochar composition.

Biochar is produced from biomass and is mainly composed of recalcitrant organic carbon with contents of plant micro and macro nutrients retained from the start. It is known, from research on wild fire occurrences and the development of Anthrosols up Terra Preta soils, in the Amazon, that charcoal can remain in the soil for hundreds to thousands of years (Agee, 1996; Lehmann and Rondon, 2006). Biochar can therefore rapidly increase the recalcitrant soil carbon fraction of

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soil. The carbon in biochar, which is held in aromatic form, is resistant to decomposition when added as a soil amendment (Amonette and Joseph, 2009). Biochar ash consists of calcium (Ca), iron (Fe), magnesium (Mg), sodium (Na), potassium (K), phosphorus (P), silica (Si) and aluminium (Al) (Amonette and Joseph, 2009). Long-term positive effects of biochar applications were observed in a few studies which were monitored over several years (Steiner *et al.*, 2008; Blackwell *et al.*, 2009; Major *et al*., 2010). Composition varies by feedstock type and conditions of pyrolysis (Downie *et al.*, 2009). The actual carbon contents can range between 172g kg^{-1} and 905g kg^{-1}. Nitrogen content ranges from 1.8g kg^{-1} to 56.4g kg^{-1}, total phosphorus from 2.7g kg^{-1} to total potassium from 1.0g kg^{-1} to 58g kg^{-1} (Lehmann *et al.*, 2003; Lima and Marshall, 2005; Chan *et al.*, 2007). Biochar also contains varying concentrations of other elements such as oxygen, hydrogen, nitrogen, sulphur, phosphorus base cations and heavy metals (Preston and Schmudt, 2006). According to Lehmann *et al.*, 2005 and Cohen-Ofri *et al.*, 2007, freshly produced biochar consists of crystalline phase with grapheme layers and an amorphous phase of aromatic structures. It is noted that the outer surfaces contain oxygen and hydrogen functional groups and the grapheme sheets may contain O groups and free radicals (Bourke *et al.*, 2007). Biochar has also been produced with a range of pH values between 4 and 12, and this depends on the starting feedstock and operating conditions (Lehmann, 2007). Generally, low pyrolysis temperatures ($<400^0$C) yield acidic biochar, while increasing pyrolysis temperatures produce alkaline biochar. When it is incorporated to the soil, the surface oxidation occurs due to reactions of water, oxygen and various soil agents (Cheng *et al.*, 2006; Lehmann, 2007). The cation exchange capacity (CEC) of fresh biochar is actually very low, but increases with time as the biochar stays longer in the presence of oxygen and water (Cheng *et al.*, 2006; Liang *et al.*, 2006; Cheng *et al.*, 2008).

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2.2.2 Impacts of biochar on soil

Biochar has a lot of potential soil improvement due to its unique physical, chemical and biological properties and their interactions with soil and plant communities (McElligott, 2011). If biochar is used as soil amendment, it could help reduce the possible negative impacts of forest biomass removal operations (McElligott, 2011)

The physical properties of biochar give several benefits to the soil. The porous nature of biochar results from retaining the cell wall structure of the biomass feedstock. The wide range of pore sizes within the biochar results in a large surface area and a low bulk density. The application of biochar to the soil could alter soil physical properties such as structure, pore size distribution and density, with implications for aeration, water holding capacity, plant growth and soil workability (Downie *et al.,* 2009). Research has suggested that biochar application into soil may increase the overall net soil surface area (Chan *et al.,* 2007) and may also improve soil water nutrient retention (Downie *et al.,* 2009) and soil aeration especially in fine-textured soil (Kolb, *et al*., 2007). Biochar has a bulk density much lower than that of mineral soils (-0.3m gm^{-3} for biochar compared to typical soil bulk density 1.3m gm^{-3}) the application of biochar can therefore, reduce the total bulk density of the soil which is generally desirable for most plant growth (Brady and Weil, 2004).

The increase in surface area, porosity and lower bulk density in mineral soil with biochar can change water retention, aggregation, and decrease soil erosion. Biochar has higher surface area and greater porosity compared to other types of organic matter, and can therefore improve soil texture and aggregation which improve water retention in soil (McElligot, 2011). Biochar can affect soil aggregation through interactions with some minerals and microorganisms; however,

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the surface charge characteristics and their development over time determine the long-term effect on soil aggregation (McElligot, 2011).

Biochar has the potential to increase nutrient availability for plants (Lehmann *et al.,* 2003). According to Liang *et al.*, (2006) and Lehmann, (2007) nutrient availability can be affected by increasing cation exchange capacity, (CEC) altering pH or direct nutrient contributions from biochar. Liang *et al.*, (2006) and Lehmann, (2007) continued that one potential mechanism for enhanced nutrient retention and supply following biochar amendment is increasing CEC by up to 50% as compared to unamended soil.

It is also known that biochar can serve as liming agent resulting in increased pH and nutrient availability for a number of different soil types (Glasser *et al.,* 2002; Lehmann and Rondon, 2006). The concentration of biochar facilitates liming in soil and raises soil pH of neutral or acidic soils (VanZweiten *et al.,* 2007). Tyron (1948) reported a greater increase in pH in sandy and loamy soils than in clayey soils.

Fresh biochar can have net positive or net negative surface charge, but typically have initially low cation exchange capacities (CEC) compared to soil organic matter on a mass basis (Lehmann, 2007, Chan and Xu, 2009).

Biochar application can also change soil bulk density (Major *et al.*, 2010); with possible effects on soil water relations rooting patterns and soil fauna. This occurs both because the density of biochar is lower than that of some minerals, and also because biochar contains macro-and micro pores (Downie *et al.*, 2009), which can hold air or water greatly reducing the bulk density of the entire biochar particles. According to Chan *et al.*, (2007) there is evidence which claims that biochar application into soil may increase the surface area of soil, this may at the end improve

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the retention of water and nutrient (Downie *et al.,* 2009). According to Kolb *et al.*, (2007) the application of biochar improves soil aeration especially in soils which are fine-textured.

According to Chan *et al.*, (2007) some biochar feedstocks produce better carbonate concentrations due to pyrolysis conditions, and this makes some of the biochar better liming agents than others. Depending on the various concentrations, carbonates could have concentrations between 0.5% and 33%. Alkaline biochar could increase the pH of acidic soils and also help to improve microbial activity. This helps to promote the decomposition of organic matter in the soil (McElligott, 2011).

2.2.3 Biochar-aggregate analogy

Biochar properties such as total surface area and pore size distribution are known to vary with feedstock properties and pyrolysis temperatures (Downie *et al.,* 2009). In addition, surface area and pore volume may change upon contact with soil by pore clogging from sorbed organic and mineral material (Pignatello *et al.,* 2006; Joseph *et al.,* 2010).

2.2.4 Influence of nutrient and carbon availability on microbial abundance

Nutrient additions by fertilizers reduced the enhancing effect of biochar on microbial reproduction rates (Steiner *et al.,* 2008). Similarly Blackwell *et al., (*2010), found significant increases in the proportion of root colonization of wheat with AM in biochar-amended soils at no or low fertilizer additions but no significant increases when large amounts of nutrients were applied. This effect depends on the type of fertilizer applied and the particular microorganism

2.2.5 Biochar and plant roots

Biochar type materials have been reported to stimulate root growth for some time. The very different properties of biochar in comparison to surrounding soil in most known cases improved

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root growth. According to Matsubara *et al.*, (2002) the number of storage roots of asparagus increased with coconut biochar additions to a tropical soil.

2.3 Biofertilizers

Basically, biofertilizer is a substance which contains microorganisms that colonize the rhizosphere or the zone that surrounds the roots of the plants (Ahmad, 2009). These microorganisms have the ability to convert nutritionally important elements such as nitrogen (N), phosphorus (P) and potassium (K) from unavailable to available form through biological processes. There is evidence that proves that beneficial microbes had been used in agricultural practices over sixty years and now these beneficial microbial populations can be resistant to adverse environmental stress (Ahmad, 2009)

HYT[a] comes as a liquid concentrate and is diluted with 100 litres of ground water per litre product. It is 100% organic and a safe blend of naturally occurring non-pathogenic, microbial complex based in the soil, the enzymes which restore and increase the activity of microbes in the soil. The microbes fix atmospheric nitrogen and increase fertilizer efficiency (Agrinos, 2011) HYT[a] contains twenty one different strains of microbes with *Clostridium pasteurianum* and *Azobactervinelandii* as the primary species (Agrinos, 2011). Through the activities of the microbes, they break through the soil pan resulting in opening the soil nutrient and these results in better root formation (Agrinos, 2011).

HYT[b] is an organic free L-amino acids and mineral nutrient source which is plant and microbial bio-stimulant and stress relief (Agrinos, 2011). It is constituted of 12% L-amino acids of L-triptophan, L-aspartic acid, L-serine, L-histodine, L-glycine, L-thereonine, L-alanine, L-proline, L-tryosine, L-arginine, L-valine, L-metionine, L-isleucine, L-phenylalamine.6% ultra-soluble

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minerals i.e. Ca and Mg, and 82% transport (Agrinos, 2011). Jain and Patriquin, (1985) found that bacteria of the genera *Azotobacter* and *Azospirillum* could produce more than 30 mg of indole acetic acid (IAA), solution of enzymatic complex, lactic acid, polysaccharides, polypeptides and carbohydrates (Agrinos, 2011). It increases stress resistance, and also increases and supports photosynthesis, pollination and fruit set, stimulates vitamin formation and increases sugar content (Agrinos, 2011; Adu, 2012).

HYT^{c} is chitin- the super polymer. This is derived from shrimp exoskeleton. Chitin stimulates certain plant sensors strengthening immune system (Agrinos, 2011).

2.3.1 Effect of biofertilizers on growth, yield and quality parameters of hot pepper

Monib *et al.,* (1990), Abd El-Hakeem, (2003), found that when tomato plant seeds were inoculated with *Azosperillum brasilense* and *Azotobacter choococcum*, it resulted in a significant increase in plant height as compared to the control. It is possible inoculation of winter legumes with *Azospirillum* could increase nodulation, nitrogen fixation and crop yield (Sarig *et al*., 1986). Amirthalingam (1988), Siddesh (2006) observed that when soil inoculation was done with *Azospirillum* along with 50 per cent recommended dose of nitrogen, there was increase in plant height and number branches in chilli. Paramguru and Natarajan (1993), Siddesh, (2006) noticed significant difference in growth parameters in chilli when *Azospirillum* (10 kg/ha) with nitrogen (56 kg/ha) was applied compared to the control. Deka *et al.,* (1996), Siddesh, (2006) reported that application of *Azospirillum* to chilli plants with 70 kg N per ha produced the higher plant height (101.1 cm) and branches (11.2/plant) as compared to 70 kg N per ha applied singly, with plant height and number of branches (92.2 cm and 8.3 respectively). Jeevansab (2000), Siddesh, (2006) reported that *Azospirillum* + RDF (150:75:50) took more number of days to 50 per cent flowering as compared to RDF alone in *Capsicum*.

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2.3.2 Effect of Farm Yard Manure (FYM) on growth parameters

Damke *et al.*, (1988) and Siddesh, (2006) observed greater plant height (60.3cm) and yield in chilli (1.52t/ha) with application of farm yard manure (FYM) 9t/ha along with 50:50:50kg of N, P_2O_5 and K_2O per hectar. Siddesh, (2006), reported greater plant height (58.6 cm) and number of branches of capsicum (4.2) with the application of farmyard manure at 20 t/ha along with 100:80:100 kg N, P_2O_5 and K_2O per ha. Natarajan, (1990) and Siddesh, (2006), reported maximum plant height (65.5 cm) and number of branches per plant (10.1) in chilli when FYM was applied at 25t/ha along with 75:35:35 kg/ha NPK compared to inorganic fertilizers alone (56.7 cm and 8.93). Integrated application of recommended dose of NPK+FYM improved the growth parameters as well as yield and yield components in chilli (Mallanagouda *et al*., 1995; Siddesh, 2006). Application of FYM (15 t/ha) + 150:100:50 kg NPK per ha recorded significantly higher plant height (73.21 cm) and number of branches (62.01/plant) as compared to different fertilizer levels in tomato.(Sendurkumaran *et al*., 1998, Siddesh, 2006)

It is well known that N application in mineral and organic fertilizer plays an important role on plant vegetative growth, C/N ratio in plant leaves, flowering and fruit setting as well as early and total fruit yield. (Martinez *et al.*, 1994; Abd-El Hakeem, 2003) found that soil inoculation with *Azotobacter chroococum* increased the number of flowers per plant in tomatoes and reduced flower drop which resulted in earlier flowering.

Many investigators mentioned a positive response to fruit yields of solanaceous crops by inoculating soil or seeds with nitrogen free living bacteria. This increment in fruit yield depended on the genus and species of used bacteria; *Azotobacter* sp, *Azospirillum* sp, and *Kelebsilla* sp and it varied also due to the crops itself, the growing season and the inoculation method as well as soil conditions (Abd El-Hakeem, 2003). Chindo and Khan (1986) and Abd El-Hakeem, (2003)

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and observed that, tomato plant growth was increased with increased level of poultry manure application up to 8 tons/ha. Shashidhara (2000) noticed that Azospirillum + phosphobacteria recorded higher 1000-seed weight (5.93) which was significantly superior over 50% RDF (5.40) in chilli.

Chandrashekar (2003) and Jagadeesha (2008) observed that the plant growth parameters *viz*., shoot and root length and number of leaves per plant in green gram plants at 45 DAS were significantly increased due to inoculation of P-solubilizing of fungal strains along with rock phosphate application as compared to rock phosphate alone (control). Vasanthakumar (2003) Jagadeesha (2008) reported that combined inoculation of Azospirillum (AZUS10) and (PSB7) produced synergistic effect, resulting in increased root length, shoot length, stem girth, number of leaves and number of branches in solanaceous crop plants. Labeena (2001); Jagadeesha (2008); reported that the plant height, fruit weight per plant and diameter of the fruits were higher in mycorrhizae inoculated plants of tomato compared to uninoculated control plants.

Jeevansab (2000) and Jagadeesha (2008) recorded significantly higher number of seeds (194.8) per fruit, seed weight (1.44g) and 100-seed weight (0.75g) with the application of *Azospirillum* + RDF as compared to 50% RDF (175.8, 1.32g and 0.72g, respectively) in capsicum.

Narasappa *et al.*, 1985 and Siddesh, 2006 reported that the application of 150 kg N and 10t FYM per ha increased the green chilli by 60.42 % over the control. In Abd El-Hakeem (2003) field experiment carried out on sweet pepper where results showed that the most favorable treatment was that inoculated with Nitrobin + Phosphorin and fertilized with 75% of the required N and P level; 60 kg N + 48kg P_2O_5 + 96 kg K_2O gave the highest growth, yield and fruit quality of sweet pepper in both seasons.

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Rafi *et al.*, (2002) and Babli (2007) reported that application of 50% recommended dose of fertilizer and FYM (12.5t/ha) with reduced level of recommended dose of fertilizer (50% RDF) helps in higher vegetative growth and yield in tomato. Naidu *et al.*, (1999) and Babli (2007) reported that application of NPK (80:60:50 kg/ha) + FYM (20 t/ha) helped in obtaining higher plant height, number of leaves per plant, intermodal length and number of nodes per plant in okra.

Prabhu *et al.*, (2002) and Babli (2007) reported that, application of biofertilizers and FYM with reduced dose of inorganic fertilizers increased yields and yield attributes in okra. The treatment combination of FYM (10 t/ha) + 2/3 RDF + *Azospirillum* + VAM resulted in higher yield, suggesting possibility of reducing about 1/3 RDF without any detrimental effect on yield. Chindo and Khan, (1986) and Abd-El Hakeem, (2003) observed that, tomato plant growth was increased with increased level of poultry manure application up to 8 tons/ha.

Jeevansab (2000) reported that *Azosperillum* + RDF (150:75:50) took more number of days to 50% flowering to RDF alone in capsicum. This was attributed to improvement in plant vegetative growth at the expense of the development of the plants and their reproductive growth. A lot of studies realized increased yield by application of biofertilizers as compared to the control, (Shasidhara 2000; Nanthakumar and Veeraraghavathatham, 2001; Naik and Hosamani, 2003; Wange and Kale, 2004). According to Norman *et al.*, (2011), the observed results could be allocated to the cumulative plants vegetative growth such as plant height, number of leaves and branches due to the supply of balanced nutrition to the plants which led to effective photosynthesis and the efficient distribution of photo assimilates which increase in yield.

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2.3.3 Effect of FYM on fruit yield

Narasappa *et al.,* (1985) and Siddesh (2006) reported that the application of 150 kg N + 10t FYM per ha increased green chilli by 60.42% over the control. Higher fruit yield of chilli (1.83 t/ha) when FYM 25 tonnes per ha applied as basal dose along with 75:35:35 kg NPK per hectare has also been reported by Natarajan (1990).

2.4 Effect of inorganic application

2.4.1 Nitrogen, phosphorus and potassium

According to Siddesh (2006) major nutrients like nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) play an important role in vegetative and reproductive phase of crop growth. He went on to say to say that nitrogen is a component of protoplasm, protein, nucleic acid, chlorophyll and plays a vital role in both vegetative and reproductive phase of crop growth.

Phosphorus is a constituent of nucleoproteins, and it is involved in energy transfer of compounds like ADP, ATP. It also plays an important role in the transfer of energy in the metabolic processes (Siddesh, 2006). It is believed that phosphorus results in a better yield and more red coloured fruits (Matta and Cotter, 1994)

Potassium is responsible for regulation and maintenance of electrochemical equilibrium in cells and other parts involved in enzyme activities. In addition, it takes part in protein synthesis, carbohydrate metabolism, regulation of activities of the essential elements, and control in plants (Siddesh, 2006).

The amount of fertilizer to be applied depends on soil fertility, fertilizer recovery rate and organic matter, soil mineralization of nitrogen, and soil leaching of nitrogen (Berke *et al.*, 2005 and Seleshi, 2011). According to Seleshi, (2011) peppers require adequate amount of major and

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minor nutrients. However, they appear to be less responsive to fertilizer, compared with onion, lettuce and crops Cole crops (Cotter, 1986; Seleshi, 2011).

2.4.2 Effect of nitrogen, phosphorus and potassium on growth parameters

Nathulal and Pundnik (1971) observed the highest plant height (63.62cm) when 100kgN, 70kg P_2O_5 and 50kg K_2O per ha on the trial of NPK on chilli at different levels of N at 0, 60, 80, and 100kg per ha; P at 0, 70 and 90kg per ha and K at 0 and 50kg per ha. Shukla *et al.*, (1986); Kiran (2006) observed maximum plant height with maximum nitrogen (180kg/ha) level, while the response to P application was non-significant. It was observed by Hanchinamani (1980) that increased levels of nitrogen, phosphorus and potassium at 200:150:100 kg per ha, increased the plant height in Brinjal (Kiran, 2006).

According to Prabhakar *et al*., (1987), Kiran, (2006) maximum plant height was noticed with the highest N (90 kg/ha) level, while P application showed non-significant response in respect of plant height in chilli cultivar G-3 (Sharma, 1995). Kiran, (2006) in the study for the determination of optimum doses of nitrogen, phosphorus and potassium fertilization in tomato revealed that increase in the levels of nitrogen application showed increase in plant height and number of branches per plant. In the application of 150:75:75 kg NPK per ha compared to 100:50:50 and 125:62.5:62.5 kg NPK per ha in two chilli varieties Balaraj (1999), Kiran (2006) recorded significantly higher plant height and number of branches per plant.

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2.5 Effect of integration of biofertilizer, inorganic fertilizer and biochar on:

2.5.1 Plant vegetative growth

In trials on *Capsicum* grown in a clay loam soil under semi-arid conditions, Paramaguru and Natarajan (1993), Abd El-Hakeem (2003), when *Azosperillum* was applied as seed inoculation and soil application combined with 56 kg N per ha, there was an increase in plant height than the control treatment when no bacterial treatment was added. Considering the number of branches and weight of shoots as affected by N-biofertilizers, Paramaguru and Natarajan (1993), Abd El-Hakeem (2003), mentioned that, when Capsicum seeds and soil were treated with *Azosperillum* combined with 56 kg N per ha, there was an increase in plant growth as expressed as number and weight of branches as compared to the control without bacterial treatment.

Studies on the effect of inoculation of two commercial tomato varieties; Castle rock and UC 97-3 with *Azosperillum brasilense* (N-fixing bacteria) and *Bacillus polymaxa* (P-dissolving bacteria)' there was an increase in plant height, fresh and dry weight of plants inoculated with Bacillus polymaxa than plants treated *Azosperillum brasilense* and uninoculated control. (Moustafa and Omar, 1990; Abd El-Hakeem, 2003).

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CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was carried out at the Forest and Horticultural Crops Research Centre (FOHCREC) Kade, in the forest zone. FOHCREC is 114m above sea level on latitude $6^0.1573^/$ N and longitude $0^0.9153^/$ W (Nkansah *et al*., 2011). The centre is located in the semi-deciduous forest agro-ecological zone of Ghana in the Kwaebibrim district of the Eastern Region, 175km NE of Accra (Nkansah *et al*., 2011).

3.2 Soil characterization

The soil moisture regime is udic and soil temperature regime is isohyperthermic (Van Wambeke, 1992; Owusu-Benoah *et al*., 2000). The dominant soil is Haplic Acrisol (FAO/UNESCO, 1990; Nkansah *et al*., 2007; Nkansah *et al*., 2011).

3.3 Climate

The climate of the area is humid tropical, with temperature of between 25-38^0C (Ofosu-Budu, 2003; Nkansah *et al*., 2011). The annual rainfall ranges between 1300mm-1700mm and the distribution is bi-modal two peaks around June-July and September-October (Ofosu-Budu, 2003; Nkansah *et al*., 2011). The rainfall regime during the experimental period is shown in Figure 1.

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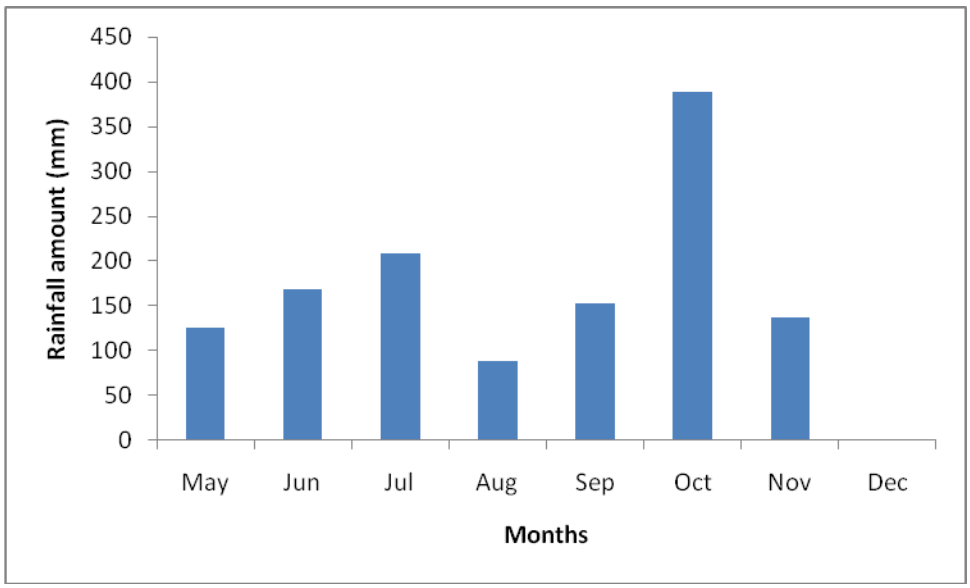

Figure 1: Rainfall distribution at the experimental site during the experimental period from May – Dec. 2011

3.4 Experimental Material

Pepper variety "Scotch Bonnet" was used for the experiment. It was purchased from Agriseed limited in Accra. HYT biofertilizers were provided by Agrinos while inorganic fertilizers used were acquired from Forest and Horticultural Crops Research Centre. Biochar was prepared at the centre by pyrolising rice husk.

3.5 Experimental details

Two field experiments (major and minor planting seasons) were conducted. The major planting season started in April and ended in July and the minor season commenced in August and ended in November.

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3.6 Experiment I: Field experiment (major and minor planting seasons)

3.6.1 Previous Crop Thriving of Site

The experimental site used for the major planting season was an abandoned citrus plantation. The plantation was destroyed and the site was prepared for the experiment. The experimental site used for the minor season was previously used to cultivate maize and was left to fallow for two years. The predominant plant species in the area were *Panicum maximum, Digitaria horizontalis, Commelina erecta, Mimosa pudica, Tridax procumbens, Cassia obtusifolia* and *Crotolaria retusa.*

3.6.2 Experimental layout

The experiments were laid out in a randomized complete block design (RCBD) with four replications. The experiment consisted of 27 different treatments each replicated four times. The treatments were biochar (carbonated rice husk), HYT^a and HYT^b biofertilizers and inorganic fertilizers, in the combinations as per the tree diagram.

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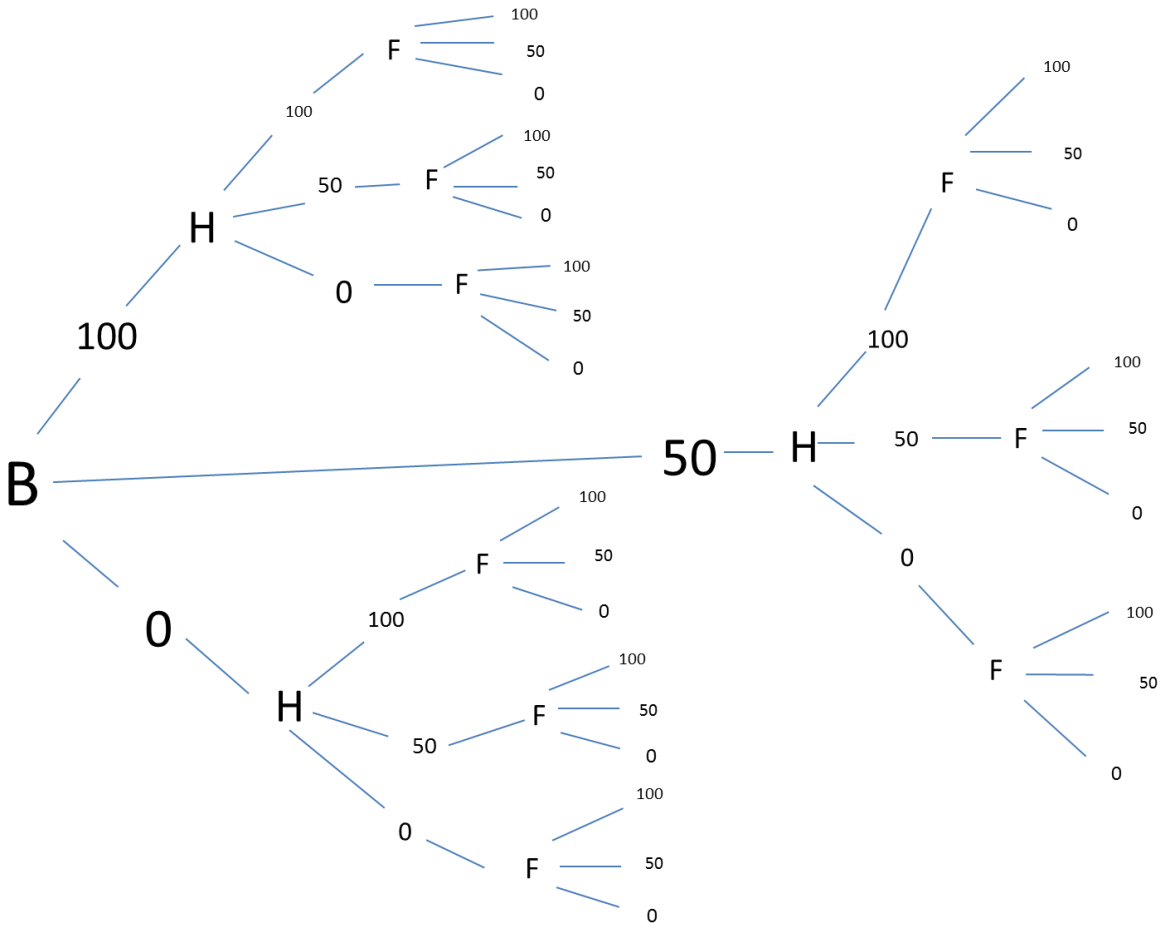

Figure 2: Diagram showing treatment combinations.

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Table 1: Treatment combinations

Treatment	Treatment explanation
T1:F0B0H0	Control
T2:F0B50H0	3.3t biochar
T3:F0B100H0	7t biochar
T4:F50B100H0	50% fertilizer +7t biochar
T5:F50B50H0	50%fertilizer + 3.5t biochar
T6:F50B0H0	50% fertilizer
T7:F100B100H0	100% fertilizer+ 7t biochar
T8:F100B50H0	100% fertilizer + 3.5t biochar
T9:F100B0H0	100% fertilizer
T10:F100B100H100	100% fertilizer+ 7t biochar+ 100% HYT
T11:F50B50H50	50% fertilizer +3.5t biochar+50% HYT
T12:F100B0H100	100% fertilizer+ 100% HYT
T13:F100B0H50	100% fertilizer + 50% HYT
T14:F50B0H100	50% fertilizer + 100% HYT
T15:F50B0H50	50% fertilizer + 50% HYT
T16:F100B100H50	100% fertilizer+7t biochar+ 100% HYT
T17:F100B50H100	100% fertilizer+3.5t biochar + 100% HYT
T18:F100B50H50	100% fertilizer+3.5t biochar +50% HYT
T19:F50B100H100	50% fertilizer+ 7t biochar +50%HYT
T20:F50B100H50	50%fertilizer+7t biochar+ 50%HYT
T21:F50B50H100	50% fertilizer+ 3.5t biochar+100%HYT
T22:F0B100H100	7t biochar +100% HYT
T23:F0B0H50	50% HYT
T24:F0B0H100	100% HYT
T25:F0B100H50	7t biochar +50% HYT
T26:F0B50H100	3.5t biochar +100% HYT
T27:F0B50H50	3.5t biochar +50% HYT

3.6.3 Plot Size and planting Distance

Each experimental plot was $8m^2$ (8m x 1m) in both seasons with 0.3m between plots and 0.6m pathway. The planting distance adopted at both sites was 70cm ×60cm, and the plant population per plot was 28.

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3.7 Cultural practices

3.7.1 Germination test

Prior to sowing of seeds, a germination test was carried out on the seeds to ascertain the viability and number of seeds needed to be nursed. Fifty seeds were placed in a petri dish containing a moist filter paper and covered and kept in a dark room. The process was repeated four times and the mean germination percentage determined by the formula below

$$Mean\ germination\ \% = \frac{\text{number of germinated seeds}}{\text{total munber of seeds}} * 100$$

3.7.2 Nursery preparation

Seedlings were raised using carbonated rice husk (biochar) as growing medium on 14 May 2011 and 16 August 2011 for the major and minor seasons respectively. A starter solution of 5g/L of N.P.K. 15-15-15 was applied two weeks after emergence at 10ml per plant. A nutrient solution of the same concentration and volume was also applied one week after the initial application. Fungicides Mancozeb 80 WP (Mancozeb dithiocarbamate) and Top Cop (Sulphur and Tribasic copper sulphate) were applied alternatively to prevent damping off at 10g/litre and 14ml/litre respectively. Cyperdicot (dimethoate 250g/L + cypermethrin 30g/litre) at 7.5ml/litre was applied fortnightly to control the activities of grasshoppers (*Zonocerus variegatus*), aphids (*Aphis gossypii*) and white flies (*Bemisia tabaci*)

3.7.3 Biochar preparation

A metal drum was cut at both ends and perforated at several places on the cylinder. Firewood was burnt inside the drum and when enough heat was generated, dried rice husk was heaped around the metal drum. It was left to pyrolyse. After pyrolising it was watered to cool down and

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put off the presence of any glowing material. It was then air dried and weighed into sacks ready for application on the field. Biochar was applied to their respective plots.

3.7.4 Land preparation and Biochar application

The land was deep ploughed and then harrowed twice to give fine tilth, on 11 May 2011 and 12 August 2011 in the major and minor seasons respectively. The plots were prepared according to the specifications and biochar was applied on 22 May 2011 and 23 August 2011 at 7.0t/ha (100%), 3.0t/ha (50%) and 0t/ha (0%) for major and minor seasons respectively. The application was done by incorporating biochar to the top 5cm of the soil with the aid of a hoe.

HYT biofertilizers were activated into their respective concentrations on 27 May 2011 in the major season and 29 August 2011 in the minor season then applied to the various experimental plots three days later using a knapsack sprayer. The solution of the mixture (0.9litre) was measured and applied on each treatment plot ($8m^2$). All cultural practices were followed using instructions as per package.

3.8 HYT preparation and application

In preparing the HYT, 4 liters (100%) and 2 liters (50%) of HYT^b was added each to 100 liters of water and stirred for thorough mixing. The mixture was then allowed to stand for 15 minutes before the same quantity of HYT^a was added and stirred thoroughly to activate the enzymes and microbes. It was covered and stored away from rain and excessive heat. After seventy two (72) hours, the colour and smell of activated solution altered becoming less pungent in odour, with a light film forming on the surface of the solution with foam also appearing. These signs showed the successful activation of the product (Agrinos, 2011). The same volume of HYT^b (4 liters and

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2 liters for 100% and 50% respectively) was then added and agitated to reactivate the enzymes in accordance to the Agrinos (2011) Protocol. The solution was used for soil application at 900ml per $8m^2$ close to the root zone of the plants. The process was repeated fortnightly for three months.

HYT^b was added to 100 liters of water and applied at 450ml per $8m^2$ as foliar application. The process was also repeated every fortnight for three months.

Table 2: Application regime (of HYT)

Time/WAT	1	2	3	4	5	6	7	8	9	10	11
Application	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil

WAT: weeks after transplanting.

3.8.1 Thinning

At 7 days after transplanting (DAT) weak crop seedlings were thinned out retaining only one plant per stand.

3.8.2 Fertilizer application

NPK 15-15-15 at 250 kg/ha (100%) and 125kg/ha were applied at 14 DAT. Sulphate of ammonia was applied at flowering at 150kg/ha (100%) and 75kg/ha (50%). Ring placement method was used for the application of the various fertilizer treatments. The application rate per plant was calculated using the area of a hectare and the planting distance as follows:

$$\text{Plant population per hectare} = \frac{\text{Area of a hectare}}{\text{Planting distance}}$$

$$\text{Amount of fertilizer applied per plant} = \frac{\text{Application rate of fertilizer}}{\text{Plant population per hectare}}$$

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3.8.3 Cultural practices

The experimental plots were kept free from weeds by regular hand hoeing. Supplementary irrigation was given as and when necessary. Necessary plant protection measures were taken to control the pests and diseases as and when necessary. Cymethoate at a rate of 7.5ml/l of water was sprayed on the field to prevent termites and cricket attack, Pyrinex 48EC at 3ml/l (Chlorpyrifos 480g/l an organophosphorus compound) was also applied four weeks after transplanting to control aphids (*Aphis spp*) and white flies (*Bemisia tabaci*). Cyperdicot (dimethoate 250gm/l + cypermethrin 30gm/L) at 7.5ml/l was applied to control the activities of leaf miners (*Liriomyza spp*), grasshoppers (*Zonocerus variegatus*), aphids (*Aphis gossypii*) and white flies (*Bemisia tabaci*). Broad spectrum fungicides Mancozeb 80 WP and Top Cop (Sulphur and Tribasic copper sulphate) were applied to prevent fungal attack.

3.8.4 Harvesting

Harvesting of the fruits was done at maturity. The harvested crops were weighed using the electronic scale.

3.8.5 Experimental data collection

Five plants from each treatment in each replication were randomly selected and tagged for record taking on growth, yield and yield components as well as fruit quality parameters.

The following data were collected:

3.8.5.1 Vegetative growth – related characters

1. **Plant height**

It was recorded in centimeters from the base of plant to the terminal growing point of tagged plants at 15, 30 and 45 DAT using a meter rule. Mean plant length was computed as;

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$$\text{Mean plant length (cm)} = \frac{\sum \text{Length of selected plants}}{\text{Number of plants selected}}$$

2. **Stem diameter**

The diameters were measured using vernier caliper and the averages worked out. The diameter was measured from about 5cm from the soil surface around the base of the plants at 15, 30 and 45 DAT.

$$\text{Mean plant diameter (cm)} = \frac{\sum \text{Diameters of selected plants}}{\text{Number of plants selected}}$$

3. **Number of leaves per plant**

The numbers of leaves per plant were counted at 15, 30 and 45 DAT.

4. **Plant canopy size**

Plant canopy size was determined using a meter rule. Canopy was measured in the north – south and east – west directions at 50% flowering stage.

5. **Phenology parameters**

Days to Flowering

The number of days taken for 50% of plants to flower was recorded in each treatment.

3.8.5.2 Fruit number and yield parameters

1. **Number of fruits per plant**

The mean fruit number per plant was worked out from the total number of fruits harvested over the entire harvest period of two months.

$$\text{Number of fruits per plant} = \frac{\sum \text{Number of fruits from tagged plants per treatment}}{\text{Number of tagged plants per treatment}}$$

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2. **Fruit yield per plant**

The mean fruit weight per plant was calculated from the fruits harvested over all the pickings.

$$\text{Fruit yield per plant (g)} = \frac{\text{Fruit yield per treatment (tagged)}}{\text{Number of tagged plants per treatment}}$$

3. **Fruit yield per plot**

The total fruit weight from the tagged plants was recorded from the fruits harvested from all the harvested fruits and fruit yield per plot computed as

Fruit yield per plot = Average fruit yield per plant * number of plants per plot.

4. **Fruit yield per hectare**

The total fruit weight per hectare was computed based on the fruit weight per net plot.

$$\text{Fruit yield per hectare (t)} = \frac{\text{Area of a hectare}}{\text{Area of net plot}} * \text{Yield per net plot}$$

3.8.5.3 Fruit quality parameters

1. Number of lobes per fruit

The number of lobes found in the fruits were counted and recorded

2. Fruit Pericarp thickness

Five fruits from each treatment and replication were dissected transversally and the thickness of the pericarp measured with a vernier caliper at the four cardinal points and averaged using the formula below:

$$\text{Mean Pericarp thickness(cm)} = \frac{\sum \text{thickness of pericarp}}{\text{Number of fruits selected}}$$

3. Number of seeds/fruit

The number of seeds in harvested fruits were counted and recorded.

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4. Weight of 100 seeds

100 seeds from fruits selected from the tagged plants were weighed.

3.9 Harvesting

Fruits were harvested at the red ripe stage.

3.10 Soil, biochar and plant nutrient analyses

Soil and biochar samples were air dried and were sieved using a 2mm mesh and stored before the laboratory analyses. Plant samples were oven dried at 70^0C for 72 hours, milled and sieved for the analyses of chemical properties.

3.10.1 Soil and biochar chemical properties analyses

Core soil samples were collected randomly from the 0-15cm depth on the site using a soil auger. Soil was then mixed thoroughly and the bulk sample was taken to the laboratory, air-dried and sieved to pass through a 2mm screen for chemical analysis. The soil pH (1:1 soil/water) and biochar pH (1: 2.5 biochar/water) were determined using a glass calomel electrode system (Crockford and Nowell, 1956). The soil N was determined by the microkjedahl method (AOAC, 1994) while available soil P was extracted by the Bray P1 extractant, measured by the Murphy blue colouration and determined on a spectronic 20 at 882 Um (Murphy and Riley, 1962). Soil K, Ca, and Mg were extracted with a 1M NH_4OAC (Ammonium acetate), pH 7 solution, then K analyzed with a flame photometer while Mg and Ca were determined with an atomic absorption spectrophotometer (Jackson, 1973).

Total nitrogen in sample was calculated as shown:

$$\%N = \frac{\text{molar mass of N} * \text{titre value} * \text{volume of extract} * 100}{\text{weight of sample} * 1000 * \text{volume of aliquot}}$$

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Available P in samples was calculated as shown

$$\text{P (ppm)} = \frac{\text{meter reading} * \text{volume of extract}}{\text{weight of sample} * \text{volume of aliquot}}$$

The concentration of potassium in the soil or biochar sample expressed in percentage was calculated as follows:

$$\text{K}\left(\frac{\text{me}}{100\text{g}}\right) = \frac{\text{meter reading}}{\text{atomic weight of K}}$$

The concentration of calcium and magnesium in the soil or biochar sample expressed in percentage was calculated as follows:

$$\text{Ca and Mg}\left(\frac{\text{me}}{100\text{g}}\right) = \frac{\text{AAS meter reading}}{\text{atomic weight of Cation}}$$

Soil particle size determination was done using the Bouyoucos Hydrometer Method (Bouyocous, 1962). The particle size distribution was determined using the formula:

$$(\text{clay} + \text{silt})\% = \frac{\text{5 minutes hydrometer reading}}{\text{mass of soil(g)}} * 100 \rightarrow \quad (\alpha)$$

$$(\text{clay})\% = \frac{\text{5 hours hydrometer reading}}{\text{mass of soil(g)}} * 100 \rightarrow \quad (\beta)$$

$$(\text{sand})\% = \frac{\text{oven dry mass(g) of particles retained on 45}\mu\text{m sieve}}{\text{mass of soil}} * 100$$

$$(\text{silt})\% = (\alpha) - (\beta)$$

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3.10.2 Soil microbial analysis

A screw cap bottle of about 250 ml volume was washed and covered with aluminum foil and sterilized in an autoclave at 121^{o}C for 15 minutes. A long rope was tied around the neck of the bottle. The cap of the bottle was opened aseptically and lowered down into the well to a depth of about 1 m making no air escaped. The bottle was raised out of the well and carefully replaced. The bottle was labeled, placed in an ice chest loaded with ice packs and immediately transported to the laboratory for incubation. 9ml of ¼ strength phosphate saline buffer were added to 1ml of well water sample for 1 in 10 dilutions.

The pour plate method was used in which 1ml aliquot of the well water sample was transferred aseptically with a micro pipette into a sterile petri dish. 10 ml of the sterile plate count agar (PCA) was added when palm hot (45^{o}C), mixed and allowed to set. It was then incubated at 35^{o}C for 18-24 hours. The microbial growth on the media was counted using the Start Scientific Colony Counter.

3.10.3 Plant analyses

The Kjeldahl digestion procedure as described by Okalebo *et al.*, (2002) was used in determination of N, P, K, Mg and Ca in the plants. A 0.1 g of milled and sieved plant samples were weighed into cleaned dry 125ml Pyrex conical flask. Five milliliters H_2SO_4 was added and left to stand for about 1 hour. The flask and its content were heated on a hot plate in a fume chamber and few drops of H_2O_2, adding 3 – 4 drops at a time to avoid vigorous reaction of the content until the solution turned colourless. The solution was cooled and transferred into 100ml volumetric flask. The content was topped to the mark using distilled water and used to determine N, P, K, Ca and Mg. Total nitrogen in plant samples was determined using the microkjedal method of distillation and titration as described for soil and biochar above. Available P was

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determined following colour development using the Bray P1 extractant, measured by the Murphy blue colouration (Murphy and Riley, 1962) and determined on a Spectrophotometer (model Perkin Elmer Lamda 45). Exchangeable K in samples was read by aspirating directly into Jenway flame photometer (PFP7). Calcium and Mg in the extract was determined using the Atomic Absorption Spectrometer (AAS). All parameters determined were expressed in percentages using the equations above.

3.11 Statistical Analysis

The data collected were analyzed using analysis of variance (ANOVA) at p=0.05 (GenStat, version 11). Significant differences among treatment means were separated using least significant difference (LSD) at p=0.05.

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CHAPTER FOUR

RESULTS

4.1 Vegetative growth parameters of hot pepper in the major and minor seasons

The study revealed that significant differences with the application of HYT biofertilizers and biochar on growth characters and yield of hot pepper at the vegetative stage in both the major and minor seasons.

4.1.1 The effect of HYT biofertilizer and biochar on the Plant height of hot pepper at major and minor season

Results in Table 3 show the effect of HYT biofertilizer and Biochar on plant height in the different seasons. It was observed that there were significant differences in both seasons at the various Days After Transplanting. AT 45 DAT there was significant increase in the plant height among the treatments and between the major and minor season. In the major season, the highest plant height at 45 DAT was identified to be 39.56 cm for treatment 50% fertilizer and the corresponding highest plant height at 45 DAT for minor season was 35.32 cm for treatment 100% fertilizer +3.5t biochar +50% HYT. Generally there was a significant increase in plant height in the major season than the minor season for the hot pepper among the various DAT.

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Table 3: The effect of HYT biofertilizer and Biochar on plant height of hot pepper in at 15, 30 and 45DAT in the major and minor seasons

Treatments	Major Season plant height (cm)			Minor Season Plant height (cm)		
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
Control	18.25	23.40	28.43	14.75	22.81	27.65
3.5t biochar	18.50	23.85	26.80	16.35	23.32	26.68
7t biochar	20.75	25.52	28.88	17.56	23.41	26.18
50% fertilizer+7t biochar	23.35	26.25	28.90	18.36	22.96	26.27
50%fertilizer+ 3.5t biochar	25.50	31.83	35.10	21.59	26.35	30.38
50% fertilizer	30.75	35.85	39.56	28.77	31.25	34.16
100% fertilizer+ 7t biochar	22.25	25.25	28.05	18.24	24.35	26.27
100%fertilizer + 3.5t biochar	19.50	24.47	28.05	16.18	23.68	26.83
100% fertilizer	22.25	26.20	29.53	21.12	29.85	33.10
100% fertilizer+ 7t biochar+ 100% HYT	20.75	24.60	28.16	20.33	23.32	24.74
50% fertilizer +3.5t biochar+50% HYT	24.00	30.10	34.25	24.13	30.71	33.66
100%fertilize+ 100% HYT	22.75	28.07	31.31	25.26	31.31	34.22
100% fertilizer + 50% HYT	24.50	31.32	36.23	20.86	25.89	28.22
50% fertilizer + 100% HYT	18.75	22.73	26.96	17.73	23.69	26.34
50% fertilizer + 50% HYT	25.00	32.15	35.38	16.26	23.61	26.76
100%fertilizer+7t biochar+ 100%HYT	24.00	29.90	33.48	22.09	25.55	27.56
100%fertilizer+3.5t biochar + 100% HYT	29.00	35.50	38.20	21.19	27.51	30.45
100%fertilizer+3.5t biochar +50% HYT	23.00	33.35	38.27	21.60	31.58	35.32
50%fertilizer+ 7t biochar +50%HYT	22.75	27.70	33.86	22.32	26.62	29.25
50%fertilizer+7t biochar+ 50%HYT	23.50	28.75	30.95	21.56	26.34	28.60
50%fertilizer+ 3.5t biochar+100%HYT	24.75	33.02	36.05	21.41	29.49	32.82
7t biochar +100% HYT	22.75	27.92	33.35	22.76	27.31	31.42
50% HYT	25.00	29.58	31.85	22.37	27.43	29.51
100% HYT	24.00	31.37	34.43	22.39	29.50	32.51
7t biochar +50%HYT	21.50	26.70	33.57	17.12	23.34	25.41
3.5t biochar +100% HYT	22.25	27.40	30.62	18.57	23.52	26.31
3.5t biochar +50% HYT	28.75	33.02	37.28	27.11	31.64	33.63
LSD (P=5%)	4.483	4.095	4.006	0.1888	1.1714	0.1741

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4.1.2 The effect of HYT biofertilizer and biochar on the stem diameter of pepper at major and minor season

Plant diameter is also one of the vegetative growth parameters that were used to identify the effect that HYT biofertilizer and Biochar had on hot pepper for the major and minor seasons. From Table 4 it was found out that there were significant differences among all the seasons at the various DAT, which are 15, 30 and 45 DAT. For the major season at 15 DAT the highest plant diameter observed was for the 50% fertilizer with a diameter of 0.51 cm as seen in Table 4. The lowest in plant diameter was found to be with fertilizer combinations of 100 fertilizer and 50% HYT. The biofertilizers were noticed to have narrow plant diameter in the major season. At 30 DAT, the widest plant diameter was for the 50% fertilizer only and this proved the minimum effect of the HYT fertilizer and the biochar. In the minor season there were appreciable significant differences observed in the plant diameter from 15 DAT to 45 DAT. The widest in plant diameter observed in fertilizer combinations 100% fertilizer was the value of 0.92 cm. It was also observed that the fertilizer combination between 100% fertilizer +7t biochar +100% HYT gave the lowest plant diameter as 0.47 cm from Table 4.

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Table 4: The effect of HYT biofertilizer and Biochar on plant diameter of hot pepper in different seasons

Treatment	Major season Stem diameter(cm)			Minor season Stem diameter (cm)		
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
Control	0.40	0.51	0.66	0.34	0.41	0.63
3.5t biochar	0.33	0.45	0.63	0.36	0.51	0.68
7t biochar	0.31	0.49	0.62	0.36	0.53	0.68
50% fertilizer+7t biochar	0.40	0.51	0.64	0.38	0.57	0.74
50%fertilizer+ 3.5t biochar	0.45	0.57	0.78	0.46	0.65	0.83
50% fertilizer	0.51	0.69	0.88	0.47	0.60	0.70
100% fertilizer+ 7t biochar	0.39	0.48	0.64	0.38	0.54	0.72
100%fertilizer + 3.5t biochar	0.41	0.59	0.78	0.39	0.55	0.82
100% fertilizer	0.44	0.63	0.84	0.41	0.64	0.92
100% fertilizer+ 7t biochar+ 100% HYT	0.34	0.53	0.64	0.32	0.39	0.47
50% fertilizer +3.5t biochar+50% HYT	0.34	0.47	0.69	0.25	0.37	0.55
100%fertilize+ 100% HYT	0.33	0.41	0.52	0.32	0.41	0.52
100% fertilizer + 50% HYT	0.28	0.48	0.60	0.42	0.35	0.56
50% fertilizer + 100% HYT	0.32	0.64	0.87	0.30	0.49	0.86
50% fertilizer + 50% HYT	0.38	0.49	0.67	0.30	0.38	0.52
100%fertilizer+7t biochar+ 100%HYT	0.41	0.54	0.67	0.39	0.48	0.57
100%fertilizer+3.5t biochar + 100% HYT	0.51	0.62	0.55	0.55	0.66	0.91
100%fertilizer+3.5t biochar +50% HYT	0.43	0.52	0.71	0.38	0.43	0.62
50%fertilizer+ 7t biochar +50%HYT	0.34	0.51	0.63	0.36	0.45	0.55
50%fertilizer+7t biochar+ 50%HYT	0.35	0.45	0.54	0.35	0.41	0.50
50%fertilizer+ 3.5t biochar+100%HYT	0.35	0.47	0.67	0.34	0.42	0.64
7t biochar +100% HYT	0.51	0.63	0.77	0.37	0.56	0.72
50% HYT	0.44	0.53	0.64	0.46	0.53	0.67
100% HYT	0.51	0.64	0.76	0.43	0.53	0.69
7t biochar +50%HYT	0.31	0.45	0.63	0.35	0.44	0.62
3.5t biochar +100% HYT	0.41	0.50	0.66	0.49	0.59	0.74
3.5t biochar +50% HYT	0.33	0.49	0.68	0.32	0.45	0.65
LSD (P=5%)	0.07737	0.07431	0.0711	0.05233	0.02466	0.00786

4.1.3 The effect of HYT biofertilizer and biochar on the number of leaves of hot pepper at major and minor season

In the major and minor season experiments, number of leaves was one of the vegetative growth parameters used to determine the effect of HYT biofertilizer and biochar on pepper. Table 5

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shows the effect of HYT biofertilizer and Biochar on the number of leaves for major and minor seasons, there were no significant differences for the 15 DAT at the major season but there were significant differences among the 30 and 45 DAT for both major and minor seasons among the various treatments. However the lowest number of leaves was recorded for the control for the major season at 15 DAT with a number of 23. The lowest reading for 30 DAT was 59, still under the control whilst that of 45 DAT was 101. The highest number of leaves for major season was 260 for the combination of 50% fertilizer + 50%HYT at 45 DAT and the highest for the minor season was observed for the 50% fertilizer +7t Biochar with the number of 183 at 45 DAT. The highest number of leaves for 30 DAT was 120 leaves for the minor and this was recorded by the 100% fertilizer.

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Table 5: The effect of HYT biofertilizer and Biochar on number of leaves of hot pepper at different seasons

Treatment	Major No. of Leaves			Minor No. of Leaves		
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
Control	23	59	101	29	53	128
3.5t biochar	63	103	137	51	92	124
7t biochar	73	115	151	52	83	110
50% fertilizer+7t biochar	73	132	207	66	114	183
50%fertilizer+ 3.5t biochar	69	103	148	59	94	138
50% fertilizer	78	158	263	59	100	139
100% fertilizer+ 7t biochar	68	124	196	64	102	168
100%fertilizer + 3.5t biochar	68	143	229	59	97	129
100% fertilizer	61	144	221	77	120	155
100% fertilizer+ 7t biochar+ 100% HYT	71	83	170	46	55	141
50% fertilizer +3.5t biochar+50% HYT	47	73	106	62	84	113
100%fertilize+ 100% HYT	94	126	191	49	80	140
100% fertilizer + 50% HYT	54	116	260	29	55	123
50% fertilizer + 100% HYT	36	88	139	44	62	119
50% fertilizer + 50% HYT	72	118	160	56	94	134
100%fertilizer+7t biochar+ 100%HYT	44	89	128	45	65	120
100%fertilizer+3.5t biochar + 100% HYT	83	119	146	68	105	131
100%fertilizer+3.5t biochar +50% HYT	88	131	173	62	103	145
50%fertilizer+ 7t biochar +50%HYT	53	109	200	28	73	151
50%fertilizer+7t biochar+ 50%HYT	86	116	162	67	83	127
50%fertilizer+ 3.5t biochar+100%HYT	65	110	231	53	99	133
7t biochar +100% HYT	40	85	143	25	64	129
50% HYT	83	123	173	57	97	147
100% HYT	73	114	156	49	86	127
7t biochar +50%HYT	55	121	197	31	65	127
3.5t biochar +100% HYT	69	105	235	52	91	132
3.5t biochar +50% HYT	63	100	195	46	73	121
LSD (P=5%)	96.25	18.33	50.65	0.56	1.32	1.15

4.1.4 The effect of HYT biofertilizer and biochar on canopy size of hot pepper for major and minor seasons

Canopy size is one of the growth parameters that show the area covered by the branches and leaves of the plant. It was noticed that there were significant differences in the major and minor

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seasons for the various fertilizer combinations and control plots respectively (Table 6). The minor season had the least canopy size of 0.041 m^2 for 50% fertilizer whilst the fertilizer combinations 50% fertilizer and 100% HYT had the least (0.121 m^2) for the major season. It was also observed that the canopy size was very wide for fertilizer combination for 100% fertilizer + 3.5t biochar + 100% HYT in the minor season with a value of 1.610 m^2. Although the differences in the canopy size were not that wide there were statistically significant differences in the canopy size in pepper for both major and minor season (Table 6).

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Table 6: The effect of HYT biofertilizer and Biochar on canopy size of pepper for major and minor seasons

Treatment	CANOPY SIZE (m^2)	
	Major	Minor
Control	0.167	0.140
3.5t biochar	0.267	0.272
7t biochar	0.241	0.230
50% fertilizer+7t biochar	0.393	0.371
50%fertilizer+ 3.5t biochar	0.427	0.389
50% fertilizer	0.416	0.041
100% fertilizer+ 7t biochar	0.321	0.301
100%fertilizer + 3.5t biochar	0.440	0.365
100% fertilizer	0.274	0.313
100% fertilizer+ 7t biochar+ 100% HYT	0.154	0.156
50% fertilizer +3.5t biochar+50% HYT	0.207	0.205
100%fertilize+ 100% HYT	0.127	0.133
100% fertilizer + 50% HYT	0.170	0.200
50% fertilizer + 100% HYT	0.121	0.122
50% fertilizer + 50% HYT	0.477	0.386
100%fertilizer+7t biochar+ 100%HYT	0.131	0.131
100%fertilizer+3.5t biochar + 100% HYT	0.146	1.610
100%fertilizer+3.5t biochar +50% HYT	0.427	0.428
50%fertilizer+ 7t biochar +50%HYT	0.235	0.201
50%fertilizer+7t biochar+ 50%HYT	0.266	0.268
50%fertilizer+ 3.5t biochar+100%HYT	0.372	0.370
7t biochar +100% HYT	0.465	0.352
50% HYT	0.386	0.393
100% HYT	0.311	0.311
7t biochar +50%HYT	0.358	0.352
3.5t biochar +100% HYT	0.351	0.303
3.5t biochar +50% HYT	0.276	0.277
LSD (P=5%)	0.08	0.09

4.2 Flowering of hot pepper plant

The reproduction of pepper for the seasons was calculated using days to 50% flowering as the main parameter. The observations made showed that there were no significant differences in the days to 50% flowering despite the changes that were identified in the various fertilizer

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combinations and the control plot. The longest days to flowering was observed in the control plants (65 days) while the least days to flowering was 53, observed in plants grown with the fertilizer combinations of 50% fertilizer + 7t biochar + 50% HYT, 100% fertilizer + 100% fertilizer + 50% HYT, 100% fertilizer + 3.5t biochar + 100% HYT, 50% fertilizer + 3.5t biochar + 100% HYT (Table 7).

Table 7: The effect of HYT biofertilizer and biochar on days to 50% flowering of pepper

Treatment	Days of 50% flowering
Control	**65**
3.5t biochar	**55**
7t biochar	**57**
50% fertilizer+7t biochar	**62**
50%fertilizer+ 3.5t biochar	**55**
50% fertilizer	**60**
100% fertilizer+ 7t biochar	**57**
100%fertilizer + 3.5t biochar	**57**
100% fertilizer	**53**
100% fertilizer+ 7t biochar+ 100% HYT	**55**
50% fertilizer +3.5t biochar+50% HYT	**57**
100%fertilize+ 100% HYT	**57**
100% fertilizer + 50% HYT	**53**
50% fertilizer + 100% HYT	**56**
50% fertilizer + 50% HYT	**54**
100%fertilizer+7t biochar+ 100%HYT	**56**
100%fertilizer+3.5t biochar + 100% HYT	**53**
100%fertilizer+3.5t biochar +50% HYT	**56**
50%fertilizer+ 7t biochar +50%HYT	**55**
50%fertilizer+7t biochar+ 50%HYT	**53**
50%fertilizer+ 3.5t biochar+100%HYT	**53**
7t biochar +100% HYT	**59**
50% HYT	**55**
100% HYT	**56**
7t biochar +50%HYT	**56**
3.5t biochar +100% HYT	**55**
3.5t biochar +50% HYT	**56**
LSD (P=5%)	**0.075**

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4.3 Yield and fruit quality parameters of pepper

The use of biochar, HYT biofertilizer and inorganic fertilizer were used with some yield parameter such as yield per plot and fruit quality parameter for instance shape of lobes, number of seeds, pericarp thickness, and 100 seeds weights were used to identify the effect of the fertilizers on the yield of pepper in both seasons.

4.3.1 The effect of HYT biofertilizer and biochar on number of lobes, number of seeds per fruit, pericarp thickness and 100 seed weight of pepper

The effects of HYT biofertilizers and biochar in association with the inorganic fertilizers on the fruit quality of pepper were found to be significantly different at a probability of 0.05. Despite the similarities observed in the number of lobes it was detected that the highest number of lobes was 4 and the lowest was 3. This was mainly recorded for the fertilizer combinations of HYT biofertilizer and inorganic fertilizers respectively. For the number of seeds per fruit of pepper, the lowest number of seeds per fruit of pepper was 25 and this was observed for the fertilizer combination of 50% fertilizer + 7t biochar + 50% HYT (Table 8). The control, however had more number of seeds per fruit than the other treatments with an average of 31 seeds/fruit. The pericarp thickness of pepper ranged from 1.30 cm to 2.60 cm for the various fertilizer combinations and the control (Table 8). The lowest size pericarp for the treatment combinations were observed for the control (1.30 cm). The treatment combination with HYT biofertilizer and the biochar resulted in appreciable increase in pericarp thickness with values ranging between 1.60 cm and 2.22cm. The highest seed weight was observed in the treatment combination of 50 % fertilizer + 50% HYT (0.86 g). The HYT biofertilizer combinations were identified to have increased the weight of 100 seeds.

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Table 8: The effect of HYT biofertilizer and Biochar on yield parameters and fruit quality of hot pepper

Treatment	Number of lobes	No. of seeds/fruit	Pericarp thickness (cm)	100 seeds weight
Control	3	31	1.30	0.58
3.5t biochar	3	35	1.55	0.56
7t biochar	3	35	1.60	0.61
50% fertilizer+7t biochar	3	32	1.50	0.55
50%fertilizer+ 3.5t biochar	4	35	1.99	0.66
50% fertilizer	4	30	2.26	0.71
100% fertilizer+ 7t biochar	3	28	1.48	0.53
100%fertilizer + 3.5t biochar	3	36	1.39	0.47
100% fertilizer	4	40	2.10	0.61
100% fertilizer+ 7t biochar+ 100% HYT	3	35	1.31	0.72
50% fertilizer +3.5t biochar+50% HYT	4	46	2.19	0.74
100%fertilize+ 100% HYT	4	39	1.71	0.59
100% fertilizer + 50% HYT	4	30	2.22	0.67
50% fertilizer + 100% HYT	3	37	2.15	0.68
50% fertilizer + 50% HYT	4	50	2.00	0.86
100%fertilizer+7t biochar+ 100%HYT	4	48	2.10	0.71
100%fertilizer+3.5t biochar + 100% HYT	4	33	2.23	0.66
100%fertilizer+3.5t biochar +50% HYT	4	37	2.06	0.65
50%fertilizer+ 7t biochar +50%HYT	3	31	1.34	0.60
50%fertilizer+7t biochar+ 50%HYT	4	25	2.12	0.83
50%fertilizer+ 3.5t biochar+100%HYT	4	56	2.28	0.81
7t biochar +100% HYT	3	40	2.06	0.66
50% HYT	4	34	2.18	0.68
100% HYT	4	35	2.18	0.68
7t biochar +50%HYT	3	39	2.35	0.58
3.5t biochar +100% HYT	4	36	2.10	0.66
3.5t biochar +50% HYT	4	52	2.30	0.58
LSD (P=5%)	0.59	9.1	0.19	0.07

4.3.2 The effect of HYT biofertilizer and biochar on yield of hot pepper

Results in Table indicate a yield range of 3.23kg/plot of 8.1m^2 (3.99t/ha) to 17.3kg/plot (21.9t/ha) in the major season. The minor season yield ranged from 3.38kg/plot (4.17t/ha) to 17.33kg/plot (21.4t/ha). The control recorded the least yield of 3.99t/ha while 100% fertilizer+

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3.5t biochar + 100% HYT and 50% fertilizer + 50% HYT had the highest yield of 21.89t/ha in the major season (Table 9). In the minor season, the control again had the least yield (4.17t/ha) and the highest yield was recorded by 50% fertilizer +50% HYT.

Table 9: The effect of HYT biofertilizer and Biochar on yield of hot pepper for major and minor seasons

Treatment	Major Season		Minor season	
	Yield (kg/plot)	Yield (t/ha)	Yield (kg/plot)	Yield (t/ha)
CONTROL	3.23	3.99	3.38	4.17
100% HYT	6.1	7.53	6.9	8.52
50% HYT	8.45	10.43	8.5	10.49
7t biochar	4.63	5.72	8.68	10.72
7t biochar + 50% HYT	6.23	7.69	7.23	8.93
3.5t biochar	5.1	6.30	5.48	6.77
3.5t biochar + 100% HYT	5.2	6.42	5.6	6.91
3.5t biochar + 50% HYT	5.13	6.33	5.93	7.32
100% fertilizer	8.88	10.96	9.18	11.33
100% fertilizer + 100% HYT	8.38	10.35	8.43	10.41
7t biochar + 100% HYT	8.45	10.43	8.48	10.47
100% fertilizer + 7t biochar	6.38	7.88	6.45	7.96
100% fertilizer + 7t biochar +100% HYT	7.68	9.48	6.93	8.56
100% fertilizer + 7t biochar + 50% HYT	8.75	10.80	10.13	12.51
100% Fertilizer + 3.5t biochar	8.73	10.78	8.45	10.43
100% fertilizer + 50% HYT	8.5	10.49	7.75	9.57
100 fertilizer+3.5t biochar + 100% HYT	17.73	21.89	11.28	13.93
100% fertilizer + 3.5t biochar + 50%HYT	12.05	14.88	11.73	14.48
50% fertilizer	7.2	8.89	7.1	8.77
50% fertilizer+ 100% HYT	10.48	12.94	10	12.35
50% fertilizer + 50% HYT	17.73	21.89	17.33	21.40
50% fertilizer + 7t biochar	5.4	6.67	5.25	6.48
50% fertilizer + 7t biochar + 100% HYT	10.75	13.27	8.98	11.09
50% fertilizer + 7tbiochar+ 50% HYT	8.15	10.06	8.5	10.49
50% fertilizer + 3.5t biochar	6.38	7.88	6.53	8.06
50% fertilizer + 3.5t biochar + 100% HYT	9.45	11.67	9.85	12.16
50% fertilizer + 3.5t biochar + 50% HYT	8.18	10.10	8.08	9.98
LSD (P=5%)	**0.58**	**3.85**	**0.69**	**2.12**

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4.4 Soil and plant nutrients parameters

The plant and soil nutrients determined included calcium, potassium, magnesium, nitrogen and phosphorus.

4.4.1. The effect of HYT biofertilizer and biochar on plant nutrients

The effect of HYT biofertilizer and biochar on the plant nutrients were identified to differed among the various treatments. It was observed that there were significant differences for the various plant nutrients. Calcium had a range of contents from 2.12 ppm to 12.72 ppm for fertilizer combinations of 100% fertilizer +7t biochar + 100% HYT and 3.5t biochar + 100% HYT, respectively as seen in Table 10. Potassium on the other hand ranged from 14.68 ppm to 41. 20 ppm for fertilizer combinations of 50% fertilizer + 7t biochar + 50% HYT and 7t biochar + 100% HYT respectively. Magnesium was observed to show larger range of nutrient content from 2.78 ppm to 9.18 ppm for fertilizer combinations of 50% fertilizer + 3.5t biochar and 100% fertilizer + 3.5t biochar + 100% HYT respectively. The nitrogen content in the plants was observed to have minimal differences. However the differences were significant. They ranged from 0.99 ppm to 2.12 ppm for fertilizer combinations of 7t biochar and 50% fertilizer + 7t biochar+ 50% HYT respectively. The last nutrient content that was observed from the hot pepper was phosphorus; it also ranged from 2.83 ppm to 7.43 ppm for the fertilizer combinations of 7t biochar +50% HYT and 100% fertilizer +100% HYT respectively.

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Table 10: The effect of HYT biofertilizer and Biochar the amount of hot pepper plant nutrients

Treatment	Plant Nitrogen	Plant Phosphorus	Plant Potassium	Plant Calcium	Plant Magnesium
	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Control	1.26	4.60	25.26	9.64	7.35
3.5t biochar	1.34	3.55	18.68	2.78	5.69
7t biochar	0.99	3.68	16.25	12.12	6.54
50% fertilizer+7t biochar	1.13	3.69	17.48	9.99	4.98
50%fertilizer+ 3.5t biochar	1.23	2.85	26.30	3.16	2.78
50% fertilizer	1.57	5.38	35.10	7.16	5.28
100% fertilizer+ 7t biochar	1.05	3.69	27.68	7.14	6.44
100%fertilizer + 3.5t biochar	1.32	4.07	30.30	10.23	5.97
100% fertilizer	1.44	3.52	40.45	4.42	4.93
100% fertilizer+ 7t biochar+ 100% HYT	1.24	3.49	36.00	7.69	7.21
50% fertilizer +3.5t biochar+50% HYT	1.08	2.88	27.50	8.56	5.24
100%fertilizer+ 100% HYT	1.73	7.43	22.83	8.66	7.09
100% fertilizer + 50% HYT	1.64	3.33	35.30	6.99	6.86
50% fertilizer + 100% HYT	1.68	2.86	30.60	8.48	5.22
50% fertilizer + 50% HYT	1.96	3.69	37.50	10.55	8.60
100%fertilizer+7t biochar+ 100%HYT	1.01	4.02	22.83	2.12	7.66
100%fertilizer+3.5t biochar + 100% HYT	1.25	4.05	35.30	11.33	9.18
100%fertilizer+3.5t biochar +50% HYT	1.71	4.41	30.60	4.22	4.99
50%fertilizer+ 7t biochar +50%HYT	1.19	3.69	14.68	9.56	6.03
50%fertilizer+7t biochar+ 50%HYT	2.12	4.14	34.60	8.34	6.59
50%fertilizer+ 3.5t biochar+100%HYT	1.98	4.47	37.70	4.32	6.86
7t biochar +100% HYT	1.50	4.22	41.20	5.27	8.53
50% HYT	1.13	4.75	31.43	3.14	4.19
100% HYT	1.33	4.96	34.40	10.25	7.24
7t biochar +50%HYT	1.14	2.83	19.14	10.87	7.12
3.5t biochar +100% HYT	1.31	2.94	17.73	12.72	5.85
3.5t biochar +50% HYT	1.05	3.75	35.20	5.59	5.85
LSD (P=5%)	0.07913	0.06993	1.3631	0.1694	0.7077

4.4.2 The effect of HYT biofertilizer and biochar on soil nutrients

The effect of HYT biofertilizers and biochar on the soil nutrients was observed to be different. From Table 11, there were significant differences for the various soil nutrients. Generally, there were high amounts of the various nutrients in the soil as compared to the plants. Calcium content

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in soil ranged from 10.55 ppm to 67.61 ppm for fertilizer combinations of 50% fertilizer+7t biochar and 3.5t biochar +50% HYT respectively (Table 11). Potassium on the other hand ranged from 9.08 ppm to 36.30 ppm for the different fertilizer combinations. Magnesium constituted a large range of nutrient contents ranging from 18.17 ppm to 37.51 ppm for the fertilizer combinations. Nitrogen content of the soil was not however much different despite the fact that the differences were with contents ranging from 0.67 ppm to 2.13 ppm. Phosphorus ranged from 0.25 ppm to 18.24 ppm for the fertilizer combinations of 7t biochar and 100% fertilizer + 7t biochar + 100% HYT respectively. The HYT bio fertilizers had a considerable effect on the nutrient content in the soil as seen in Table 11.

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Table 11: The effect of HYT biofertilizer and Biochar on the amount of soil nutrients

Treatment	Soil Nitrogen N (ppm)	Soil Phosphorus P (ppm)	Soil Potassium K (ppm)	Soil Calcium Ca (ppm)	Soil Magnesium Mg (ppm)
Control	0.67	9.29	17.55	44.47	34.03
3.5t biochar	1.56	0.37	9.08	41.50	32.58
7t biochar	1.44	0.25	15.60	13.35	28.56
50% fertilizer+7t biochar	1.30	3.06	11.53	10.55	24.21
50%fertilizer+ 3.5t biochar	1.61	7.38	20.35	12.22	37.51
50% fertilizer	1.39	8.48	32.50	59.19	21.60
100% fertilizer+ 7t biochar	1.33	2.50	11.33	47.35	37.32
100%fertilizer + 3.5t biochar	1.18	3.22	10.13	39.47	30.22
100% fertilizer	0.70	3.06	9.08	50.29	31.33
100% fertilizer+ 7t biochar+ 100% HYT	1.20	18.24	12.60	54.35	25.67
50% fertilizer +3.5t biochar+50% HYT	1.50	11.07	32.18	30.27	36.27
100%fertilize+ 100% HYT	0.85	6.67	32.23	29.08	36.28
100% fertilizer + 50% HYT	1.22	9.37	29.10	37.32	33.28
50% fertilizer + 100% HYT	1.70	15.99	39.15	33.28	21.47
50% fertilizer + 50% HYT	1.31	8.23	36.30	44.55	22.18
100%fertilizer+7t biochar+ 100%HYT	1.08	11.38	28.30	33.13	27.60
100%fertilizer+3.5t biochar + 100% HYT	1.15	11.30	35.28	29.11	26.14
100%fertilizer+3.5t biochar +50% HYT	1.30	7.42	24.23	13.69	33.41
50%fertilizer+ 7t biochar +50%HYT	2.13	8.28	24.83	40.73	30.46
50%fertilizer+7t biochar+ 50%HYT	1.62	9.35	33.38	54.06	19.60
50%fertilizer+ 3.5t biochar+100%HYT	1.31	7.10	30.35	20.23	19.14
7t biochar +100% HYT	1.33	8.78	24.58	10.75	33.23
50% HYT	1.26	17.39	36.24	45.70	24.62
100% HYT	1.33	15.32	42.55	47.84	25.39
7t biochar +50%HYT	1.10	3.31	25.85	30.23	25.89
3.5t biochar +100% HYT	1.44	15.46	35.43	35.47	18.17
3.5t biochar +50% HYT	1.69	9.22	33.58	67.61	22.73
LSD (P=5%)	0.2308	2.103	0.2724	0.4565	4.912

4.4.3 The effect of HYT biofertilizer and biochar on soil pH and EC

The amount of hydrogen and the soluble salts in the soil were identified and found to be significantly different for both of them. The HYT biofertilizer combinations had a considerable effect on the pH and the EC. Most of the fertilizer combinations were observed to make the soil

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very acidic with a pH ranging from 4.1 to 5.7 whilst the soluble salts were low ranging from 0.1 to 3.3 indicating the acidic nature of the soil.

Table 12: The effect of HYT biofertilizer and Biochar the amount of soil pH and EC

Treatment	SOIL pH	SOIL EC (ms/cm)
Control	5.4	0.4
3.5t biochar	4.3	0.8
7t biochar	4.2	0.5
50% fertilizer+7t biochar	4.1	0.2
50%fertilizer+ 3.5t biochar	5.5	0.1
50% fertilizer	5.5	0.1
100% fertilizer+ 7t biochar	4.1	0.1
100%fertilizer + 3.5t biochar	5.7	0.1
100% fertilizer	5.6	1.1
100% fertilizer+ 7t biochar+ 100% HYT	4.9	0.3
50% fertilizer +3.5t biochar+50% HYT	5.6	1.1
100%fertilize+ 100% HYT	5.2	1.8
100% fertilizer + 50% HYT	5.1	1.9
50% fertilizer + 100% HYT	4.9	0.2
50% fertilizer + 50% HYT	5.3	1.6
100%fertilizer+7t biochar+ 100%HYT	5.1	1.5
100%fertilizer+3.5t biochar + 100% HYT	4.8	3.3
100%fertilizer+3.5t biochar +50% HYT	4.5	0.4
50%fertilizer+ 7t biochar +50%HYT	5.7	1.5
50%fertilizer+7t biochar+ 50%HYT	5.1	2.0
50%fertilizer+ 3.5t biochar+100%HYT	4.9	0.1
7t biochar +100% HYT	5.3	1.1
50% HYT	4.7	0.2
100% HYT	5.4	1.5
7t biochar +50%HYT	4.8	1.0
3.5t biochar +100% HYT	4.6	1.3
3.5t biochar +50% HYT	4.9	2.0
LSD (P=5%)	0.1995	0.826

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4.4.4 The effect of HYT biofertilizer and biochar on microbial count

The population of microbes before and after planting was identified to be significantly different for the various periods of count. Before planting microbial count ranged from 2325 to 17750 whilst that of the counting after planting was determined to be from 1700 to 8400.

Table 13: The effect of HYT biofertilizer and Biochar on microbial count before and after planting

Treatment	Microbial Count INITIAL (BEFORE)	Microbial Count – FINAL (AFTER)
Control	5525	7225
3.5t biochar	4600	4525
7t biochar	4475	4300
50% fertilizer+7t biochar	6375	6325
50%fertilizer+ 3.5t biochar	6375	8400
50% fertilizer	8400	4650
100% fertilizer+ 7t biochar	5825	5650
100%fertilizer + 3.5t biochar	2550	3150
100% fertilizer	4575	4450
100% fertilizer+ 7t biochar+ 100% HYT	2400	1800
50% fertilizer +3.5t biochar+50% HYT	15500	5350
100%fertilize+ 100% HYT	3650	2150
100% fertilizer + 50% HYT	5350	8150
50% fertilizer + 100% HYT	4350	3825
50% fertilizer + 50% HYT	4900	2575
100%fertilizer+7t biochar+ 100%HYT	2750	2550
100%fertilizer+3.5t biochar + 100% HYT	16756	4575
100%fertilizer+3.5t biochar +50% HYT	17750	4200
50%fertilizer+ 7t biochar +50%HYT	4200	3800
50%fertilizer+7t biochar+ 50%HYT	17000	6550
50%fertilizer+ 3.5t biochar+100%HYT	11250	2625
7t biochar +100% HYT	5050	4650
50% HYT	6900	1600
100% HYT	4025	4275
7t biochar +50%HYT	7900	8400
3.5t biochar +100% HYT	5500	1700
3.5t biochar +50% HYT	2325	4650
LSD (P=5%)	805.9	156.5

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CHAPTER FIVE

DISCUSSION

5.1 HYT biofertilizer and biochar on vegetative parameters of hot pepper

The study of the evaluation of HYT biofertilizers and biochar on the vegetative parameters on hot pepper showed an appreciable variation in the various factors under study. The vegetative differences that were observed in the hot pepper for the application of the various fertilizer combinations were observed to be significantly different for the study in plant height, stem diameter and number of leaves (Tables 3,4 and5) at the various seasons (Major and minor). These differences were also observed in Kiran *et al.,* (2010). In the study, Kiran *et al*., (2010) observed that there were significant increases in these growth parameters by plant due to increase in the fertilizer levels. It could be attributed to the increased uptake of nutrient in the plants leading to enhanced chlorophyll content and carbohydrate synthesis. But in this present study the changes were due to the fertilizer combinations in the biofertilizers and biochar. This was also confirmed by Jagadeesha (2008) who also observed that there was a considerable change in the various vegetative parameters. The study continues to show that recommended dose of fertilizer alone recorded significantly higher values for growth parameters. It could be attributed to the quick and readily availability of major nutrients like N, P and K to plants at earlier stages of plant growth. While, organic manures recorded significantly lower values for growth parameters because of slower release of nutrients to the plants.

These results are supported by the report of Sharma (1995) in tomato, Wange and Kale (2004) in brinjal. Satesh Kumar and Sharma (2006) studied the effect of different methods of biofertilizer application in tomato seed production. They used four biofertilizers, namely *Azotobacter,*

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Azospirillum, *Pseudomonas* and vesicular arbuscular mycorrhiza (VAM), application of these biofertilizers were done with three methods i.e., nursery soil treatment, seedling treatment and field soil treatment, individually and in combinations. The study revealed that when *Azotobacter* was applied to nursery, there was a maximum increase in the number of fruits per plant (19.23), fruit yield per plant (1109 g) and per hectare (356.9 g), 1000 seed weight (3.63 g), seed yield per plant (4.58 g) and per hectare (152.70 kg).

Plant yield is the ultimate manifestation of morphological, physiological, biochemical processes and growth parameters and is considered to result from trapping and conversion of solar energy efficiently. Improvement in yield can be realized in two ways i.e. by adopting the existing varieties to grow better in their environment or be altering the relative proportion of different plant parts so as to increase the yield of economically important parts (Humphries, 1969).

5.2 HYT biofertilizer and biochar on the yield of hot pepper

In the present study, the results have indicated that all measured traits of yield and fruits quality of hot pepper were significantly affected by using the various fertilizer combinations of biofertilizer and biochar. Interactions were significant for all the parameters. Increase in fruit yield and its parameters can be attributed to the increase in the number of leaves which worked as an efficient photosynthesis structure and produced high amount of carbohydrates in the plant system. Similar findings were also reported by Nanthakumar and Veeraraghathatham (2001) and Anburani *et al.*, (2002) in brinjal. Increase in seed yield and its components may be ascribed to increase in seed weight per fruit, as a result of improvement in seed number to adequate mother plant nutrition. Further, it could be due to influence of other yield attributes such as number of

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branches per plant, number of fruits per plant, increase in fruit weight, fruit length, fruit diameter and fruit yield per plant.

The results are in agreement with the findings of Shashidhara (2000) in chilli. The increase in the fruit yield and its parameters may be due to more number of flowers per plant, which is one of the most vital attributes, was produced due to the combined application of inorganic fertilizers and biofertilizers. The significant differences in seed yield per plant were noticed in treatment and biofertilizers, where the interaction effect was also found to be significant (Table 8). Significantly higher seed yield per plant was noticed in biofertilizers application as compared to without biofertilizers application. The 100 seed weight, the number of lobes, number of seeds per fruits and pericarp thickness had a significant increase in the quality and quantity respectively. This was confirmed in the work done by Sharma, (2005).

5.3 Effect of HYT biofertilizer and biochar on the amount of plant and soil nutrients (N, P, K, Mg and Ca) on hot pepper

Nutrient efficiency is a measure of how much crop is produced per unit of nutrient supplied. The higher the efficiency, the more products is produced per unit of nutrient. The quality of soil affects nutrient use efficiency. Soil quality is measured or evaluated by a number of indicators. Data concerning the effect of mineral N, P, K, Mg and Ca levels on vegetative growth parameters of hot pepper plants that is the amount that is present in the soil and the plant (Table 10 and 11). The present result indicated that application of N, P, K, Mg and Ca levels significantly increased in both the soil and plant for the various fertilizer combinations especially for HYT biofertilizer and biochar. The necessity of N, P and K for growth has been demonstrated by several investigators, since nitrogen supply was desirable for vegetative growth, dry matter

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accumulation as well as nutrient uptake by potato plants (El- Ghamriny and Saeed, 2007a). The increase in plant growth may be attributed to the beneficial effects of nitrogen on stimulating the meristematic activity for producing more tissues and organs, since it plays major roles in the synthesis of structural proteins and other several macro molecules, in addition to its vital contribution in several biochemical processes that related to plant growth (Marschner, 1995).

Also, nitrogen may be contributed with the activation of cell division and cell elongation (Medani *et al.,* 2000). The promating effect of growth parameters could be attributed to phosphorus as structural part of high energy compounds (Sarg, 2004). It is also a constituent of the cell nucleus and is essential for cell division and the meristematic tissues development (Frank, 2002). The obtained results of growth parameters in this investigation are in good agreement with those obtained by El-Arquan *et al.,* (2002), El- Ghamriny and Saeed (2007a), Kamel *et al*., (2008), Rafla *et al*., (2009) on different crops.

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CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion and Recommendation

This work has indicted that the application of inorganic fertilizer, HYT biofertilizer and biochar on hot pepper resulted in significant difference in the vegetative growth, yield and nutrient quality for both the soil and the plant.

The study has shown marked differences in yield in the application of biochar and biofertilizers on yield of hot pepper. The results indicated a yield of 3.99t/ha for the control and 21.89t for 100% fertilizer + 3.5t biochar + 100% HYT and 50% fertilizer + 50% HYT in the major season. In the minor season, a combination of 50% fertilizer +50% HYT gave the highest yield (21.4t/ha) and the control the least yield (4.17t/ha).

The combination of inorganic, biochar and biofertilizers resulted in higher yields than pepper yields achieved in Ghana (8.0t/ha).

From the study it can be recommended that 50% -100% rate of NPK fertilizer, biochar and HYT biofertilizers be used by farmers due to its higher yields.

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APPENDICES

Appendix 1: ANOVA of plant diameter of major season at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.026063	0.008688	2.88	
Treatment	26	0.491407	0.0189	6.26	<.001
Residual	78	0.235637	0.003021		
Total	107	0.753107			

Appendix 2: ANOVA of number of major season at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	14723	4908	1.05	
Treatment	26	136040	5232	1.12	0.342
Residual	78	364725	4676		
Total	107	515489			

Appendix 3: ANOVA of plant height of major season at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	25.41	8.47	0.84	
Treatment	26	950.24	36.55	3.6	<.001
Residual	78	791.09	10.14		
Total	107	1766.74			

Appendix 4: ANOVA of plant diameter at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.009595	0.003198	2.31	
Treatment	26	0.470563	0.018099	13.1	<.001
Residual	78	0.107771	0.001382		
Total	107	0.587929			

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Appendix 5: ANOVA of no. of leaves at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	17.815	5.938	1.68	
Treatment	26	366.685	14.103	3.99	<.001
Residual	78	275.685	3.534		
Total	107	660.185			

Appendix 6: ANOVA of plant height at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.53879	0.1796	9.98	
Treatment	26	1174.33343	45.16667	2510.37	<.001
Residual	78	1.40338	0.01799		
Total	107	1176.2756			

Appendix 7: ANOVA of plant height of minor season at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.53879	0.1796	9.98	
Treatment	26	1174.33343	45.16667	2510.37	<.001
Residual	78	1.40338	0.01799		
Total	107	1176.2756			

Appendix 8: ANOVA of no. of leaves at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	3.3013	1.1004	6.86	
Treatment	26	19408.0436	746.4632	4655.9	<.001
R esidual	78	12.5055	0.1603		
Total	107	19423.8503			

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Appendix 9: ANOVA of stem diameter at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.016281	0.005427	1.83	
Treatment	26	0.267114	0.010274	3.47	<.001
Residual	78	0.230735	0.002958		
Total	107	0.514131			

Appendix 10: ANOVA of plant height at 15 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.2493	0.0831	3.18	
Treatment	26	212.33944	8.1669	312.61	<.001
Residual	78	2.03774	0.02612		
Total	107	214.62648			

Appendix 11: ANOVA of stem diameter of major at 30 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.011796	0.003932	1.41	
Treatment	26	0.515107	0.019812	7.11	<.001
Residual	78	0.217339	0.002786		
Total	107	0.744242			

Appendix 12: ANOVA of no. of leaves of major season at 30 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	2018	672.7	3.97	
Treatment	26	51729.2	1989.6	11.73	<.001
Residual	78	13227.5	169.6		
Total	107	66974.7			

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Appendix 13: ANOVA of plant height of major season at 30 dat

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	18.3	6.1	0.72	
Treatment	26	1440.701	55.412	6.55	<.001
Residual	78	659.888	8.46		
Total	107	2118.889			

Appendix 14: ANOVA of stem diameter at 30 DAT

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.0013842	0.000461	1.5	
Treatment	26	0.8339399	0.032075	104.61	<.001
Residual	78	0.0239164	0.000307		
Total	107	0.8592404			

Appendix 15: ANOVA on no. of leaves of minor season at 30 DAT

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	6.988	2.3293	2.64	
Treatment	26	36206.3776	1392.553	1578.88	<.001
Residual	78	68.7951	0.882		
Total	107	36282.1608			

Appendix 16: ANOVA on plant height of minor season at30 DAT

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	2.7844	0.9281	1.34	
Treatment	26	1018.5304	39.1742	56.58	<.001
Residual	78	54.0052	0.6924		
Total	107	1075.32			

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Appendix 18: ANOVA of no. of leaves at 30 DAT

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	21.519	7.173	1.75	
Treatment	26	691.074	26.58	6.47	<.001
Residual	78	320.481	4.109		
Total	107	1033.074			

Appendix 19: ANOVA on stem diameter at 30 DAT

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.22206	0.07402	0.88	
Treatment	26	2.12798	0.08185	0.98	0.507
Residual	78	6.53196	0.08374		
Total	107	8.882			

Appendix 20: ANOVA on plant height at 45 DAT

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	8853419	2951140	1	
Treatment	26	76759143	2952275	1	0.479
Residual	78	230304139	2952617		
Total	107	315916701			

Appendix 21: ANOVA on weight of 100 seeds

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.011529	0.003843	1.42	
Treatment	26	0.863585	0.033215	12.31	<.001
Residual	78	0.210496	0.002699		
Total	107	1.08561			

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Appendix 22: ANOVA on Ca

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.03154	0.01051	0.73	
Treatment	26	985.6781	37.9107	2617.94	<.001
Residual	78	1.12953	0.01448		
Total	107	986.83917			

Appendix 23: ANOVA on Ca 1 Ca

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	1.8421	0.614	5.84	
Treatment	26	24157.354	929.129	8834.39	<.001
Residual	78	8.2034	0.1052		
Total	107	24167.3996			

Appendix 24: ANOVA on EC

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	1.1927	0.3976	1.16	
Treatment	26	67.6923	2.6036	7.56	<.001
Residual	78	26.8454	0.3442		
Total	107	95.7303			

Appendix 25: ANOVA on K

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	3.1611	1.0537	1.12	
Treatment	26	7337.7085	282.2196	301.01	<.001
Residual	78	73.1311	0.9376		
Total	107	7414.0007			

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Appendix 26: ANOVA on K 1 K

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	4.18E+00	1.39E+00	37.17	
Treatment	26	1.10E+04	4.22E+02	11266.78	<.001
Residual	78	2.92E+00	3.74E-02		
Total	107	1.10E+04			

Appendix 27: ANOVA on Mg

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.4128	0.1376	0.54	
Treatment	26	206.0615	7.9254	31.36	<.001
Residual	78	19.7151	0.2528		
Total	107	226.1894			

Appendix 28: ANOVA on Mg 1 Mg

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	45.5	15.17	1.24	
Treatment	26	3655.79	140.61	11.54	<.001
Residual	78	950.41	12.18		
Total	107	4651.7			

Appendix 29: ANOVA on N

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.01313	0.004377	1.39	
Treatment	26	10.364417	0.398631	126.18	<.001
Residual	78	0.24642	0.003159		
Total	107	10.623967			

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Appendix 30: ANOVA on N 1 N

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	1.15311	0.38437	14.3	
Treatment	26	994.37656	38.24525	1423.22	<.001
Residual	78	2.09604	0.02687		
Total	107	997.62571			

Appendix 31: ANOVA on P

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.014119	0.004706	1.91	
Treatment	26	95.307741	3.665682	1485.46	<.001
Residual	78	0.192481	0.002468		
Total	107	95.514341			

Appendix 32: ANOVA on PH

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.64423	0.21474	10.7	
Treatment	26	24.41295	0.93896	46.77	<.001
Residual	78	1.56582	0.02007		
Total	107	26.623			

Appendix 33: ANOVA on pot exp

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.0018803	0.000627	0.85	
Treatment	26	0.0309989	0.001192	1.62	0.053
Residual	78	0.0572871	0.000734		
Total	107	0.0901663			

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Appendix 34: ANOVA on P 1 P

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	4.869	1.623	0.73	
Treatment	26	2570.398	98.861	44.29	<.001
Residual	78	174.117	2.232		
Total	107	2749.384			

Appendix 35: ANOVA on shape of fruit/ no. of lobes

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.7407	0.2469	1.4	
Treatment	26	14.1667	0.5449	3.09	<.001
Residual	78	13.7593	0.1764		
Total	107	28.6667			

Appendix 36: ANOVA on minor ex2

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.015729	0.005243	1.57	
Treatment	26	1.361038	0.052348	15.72	<.001
Residual	78	0.259777	0.00333		
Total	107	1.636544			

Appendix 37: ANOVA on minor ex2

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.027455	0.009152	2.08	
Treatment	26	1.05914	0.040736	9.25	<.001
Residual	78	0.343534	0.004404		
Total	107	1.430128			

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Appendix 38: ANOVA on no. of seeds /fruit

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	188.04	62.68	1.5	
Treatment	26	5627.5	216.44	5.18	<.001
Residual	78	3259.46	41.79		
Total	107	9075			

Appendix 39: ANOVA on pericarp thickness

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance	F pr.
Replication	3	0.021	0.007	0.37	
Treatment	26	12.89662	0.49602	26.15	<.001
Residual	78	1.47932	0.01897		
Total	107	14.39694			