THE EFFECT OF BIOCHAR AND POULTRY MANURE ON SOME SOIL PROPERTIES, AND ON THE GROWTH OF HOT PEPPER

Sairan Majeed M. Ali JAFF

Master Thesis

Department of Soil Science and Plant Nutrition

Supervisor: Assoc. prof. Dr. Abdulkadir SÜRÜCÜ

2017

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BINGOL UNIVERSITY
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This thesis was unanimously approved by the following jury on 16.01.2017

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PREFACE

My great thanks to God, for giving me faith and power to finish this study far from home and my children. My thanks and appreciation goes to my supervisor, Assist. Prof. Dr. Abdulkadir SÜRÜCÜ for his support and guidance. I am thankful for all of the presidency of Bingol University especially for funding my research project in project number BAP-ZF.2016.00.005. I am grateful to the faculty of Agriculture especially Prof. Dr. Alaaddin YUKSEL, and Assist. Prof. Dr. Ali Riza DEMIRKIRAN. I would like to express my special thanks to Assist. Prof. Dr. Veysel TURAN for his help in laboratory analysis and Kadriye ATEŞ for her help in the lab. Many thanks to the Directorate Agriculture Research Centre of Sulaymaniyah and Gaziosmanpasa University-Tokat for preparing biochar. I would like also to thank my friend Oral MOUSSA for his help and assistance; also, I would like to thanks my friend Ferhad Murasil for copy editing. Many thanks to my all my dear friends, especially Jwan Abdulla, Zainab Omer, and Narmin Hamid for their kindness and support during my master degree.

I dedicate this thesis to the soul of my father, and to my country. I also dedicate this work to my lovely mother Saadia Qader, and dear husband Soran Hussein for encouragement and supporting all the times, and to my lovely children Lara and Nali, and my sweet sisters and brothers for their continuous support, which led to successful completion of my work.

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LIST OF SYMBOLS

SYMBOL	: DESCRIPTION
B	: Biochar
PM	: Poultry manure
SOM	: Soil Organic Matter
OM	: Organic Matter
g	: grams
Kg	: Kilo grams
ppm	: Parts Per Million
%	: Percentage
l	: Liter
ml	: Milliliter
D.W	: Distilled Water
pH	: Potential of Hydrogen
EC	: Electrical Conductivity
CEC	: Cation Exchange Capacity
$CaCO_3$	: Calcium Carbonate
P_2O_5	: Penta Oxide of Phosphorus
EDTA	: Ethylene Diamine Tetra Acetic Acid

DTPA	: Diethylenediamine Penta Acetic Acid
N	: Nitrogen
K	: Potassium
P	: Phosphorus
Mn	: Manganese
Cu	: Copper
Fe	: Iron
Zn	: Zinc
H2SO4	: Sulfuric Acid
K2Cr2O7	: Potassium Dichromate

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ÖZET

Bu çalışmanın amacı, Biochar ve kanatlı gübresinin bazı toprak özellikleri, Acı biber (Capsicum annuum L.) bitkinin gelişimi ve onun bazı makro ve mikro bitki besin element konsantrasyonları üzerindeki olan etkinliğini belirlemektir. Uygulamalar; 0, 5, 10 ve 20 g / kg biochar, 0, 10, 20 ve 40 g / kg tavuk gübresi ve bunların kombinasyonu şeklindedir. Deney, 2016 yılı boyunca açık alanda saksıda yürütülmüştür. Hem biochar hem de tavuk gübresi uygulamaları, topraktaki kalsiyum karbonatı ($CaCO_3$) azaltmış, bitkideki P konsantrasyonunu artırmış, fakat bitkideki N ve Mn konsantrasyonları ile topraktaki ve bitkideki Cu konsantrasyonları üzerinde herhangi bir etki yapmamıştır. Biochar uygulaması, bitki gelişimi ve toprak EC, P ve Cu içeriği üzerine herhangi bir etkisi olmamış fakat toprağın pH, organik madde (OM), $CaCO_3$% , K, Mn ve Zn içeriğini azaltmışken, topraktaki demir içeriğini arttırmıştır. Biochar uygulaması, acı biberin yapraklarındaki N, K, Mn ve Cu konsantrasyonunu etkilemezken, P'u artırıp, Zn ve Fe'i azaltmıştır. Tavuk gübresi uygulaması, kök gelişimi hariç, bitki gelişimi üzerine önemli etkide bulunmuştur. Toprak pH, EC, OM ’si, topraktaki bitkiye elverişli P, K, Mn ve Zn ile bitkideki P, K ve Zn konsantrasyonunu artırmış fakat toprak kireç miktarını ve bitkideki demir konsantrasyonunu azaltmıştır. Ama topraktaki Fe ve Cu ile bitkideki N, Mn ve Cu konsantrasyonunu etkilememiştir.

Anahtar Kelimeler: Biochar, tavuk gübresi, besin elementi, acı biber.

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ABSTRACT

The objective of this study was to evaluate the effectiveness of Biochar and poultry manure on the plant growth, and soil pH, EC, Organic matter (OM), calcium carbonate ($CaCO_3$) ,P, K, Fe, Zn, Cu and Mn in the soil, also, N, P, K, Fe, Zn, Cu and Mn concentration of hot pepper (*Capsicum annuum L*.). The treatments were as follows: control, 0.5, 1 and 2% biochar (equivalent to 0, 5, 10 and 20 g/kg), control, 1, 2 and 4% poultry manure (equivalent to 0, 10, 20 and 40 g/kg), and their interaction. The experiment conducted in the pot in open field during 2016. Both biochar and poultry manure decreased the $CaCO_3$ in the soil and increased concentration P in the plant leaf, and there was no significant effect on the N, and Mn concentrations in the plant, and Cu concentrations in the plant and soil. Biochar application did not have any significant effect on the growth of hot pepper, biochar application decreased soil pH, OM, $CaCO_3$%, K, Mn and Zn in the soil and the soil EC was not affected, P and Cu, but biochar application increased Fe in the soil. Biochar application increased P and decreased Zn and Fe, but there was no effect on N, K, Mn and Cu concentration in the leaf of hot pepper. Poultry manure application significant effect on the growth of hot pepper except for the length of the root. Poultry manure application increased the soil pH, EC, OM and plant available, P, K, Mn and Zn in the soil, and decreased $CaCO_3$, but there was no effect on Fe and Cu in the soil. Poultry manure application increased P, K, and Zn, and decreased Fe, but not affected N, Mn and Cu concentration in the leaf of hot pepper. Their interaction (biochar and poultry manure) treatments for significant affect the soil pH, EC, OM, $CaCO_3$, P, K and Fe in the soil, but did not affect Mn and Cu in the soil while for plant nutrients only there was effected on Fe concentration in the plant.

Key words: Biochar, poultry manure, nutrient concentration, soil fertility, hot pepper plant.

1. INTRODUCTION

Biochar is the carbon rich materials created by pyrolysis (heating under limited or without oxygen) of biomass (e.g., agricultural crop residues, wood, waste, etc.), (Lehmann et al. 2006; Verheijen et al. 2010).

First biochar came familiar to the public from Amazon Basin (Wilson 2014). Where the Amazonian people added biochar with other organic wastes (food, animal, and human) over centuries to change the surface soil to high fertile soil called *Terra Preta* (Glaser et al. 2001; Lehmann et al. 2003; Krull 2009; Wilson 2014).

Terra preta, in the Amazon, contains high organic carbon in the form of char and the practice of (slash and char) by the people of the Amazon, and *Terra Preta* soils have up to 70 times more black carbon than the surrounding soils (Glaser et al. 2001). It contains higher concentrations of nutrients such as nitrogen, phosphorus, potassium and calcium, also contain large amounts of soil organic matter.

The fertility of *Terra preta* in the Amazon came from the higher level of soil organic matter, charcoal was responsible for high soil organic matter and soil fertility in *Terra preta* after adding charcoal to soil nutrient availability and higher nutrient retaining were found in the soil (Glaser et al. 2001, 2002). Improved holding capacity of nutrients like nitrogen, potassium, phosphorus and calcium, higher moisture and higher pH were noticed compared to the soil surround it (Glaser et al. 2001). Higher exchange capacity, surface area and direct nutrient adding were related (Glaser et al. 2002). Charcoal increased plant growth and nutrition (Lehmann et al. 2003).

In the *Terra preta* soil, charcoal can remain for long periods, hundreds to thousands of years (Lehmann and Rondon 2006).

There are two important factors effect on physical and chemical properties of the biochar feedstock (biomass) and pyrolysis conditions (especially temperature and residence time) (Downie et al. 2009; Kookana et al. 2011).

The structural formation and chemical of the feedstock effects on the formation of the produced biochar, therefore, its behavior, role, and fate in soils. For example, paralysis of wood feedstock created rough and resistant biochar with high contents (up to 80%) of carbon (Winsley 2007).

Pyrolysis is a process that made Biochar by heating biomass in the very low oxygen environment (Lehmann and Joseph 2009; Wilson 2014). During the pyrolysis process, components of polymeric (i.e. lignin, fats, cellulose and starches) are broken down thermally into three other fractions: bio-oil (condensed vapors), char (solid part) and non-condensable gasses (Mohan et al. 2006) depending on the heating rate and temperature.

However, from the same feedstock (biomass) can produce different biochars with the different specific surface area and microporosity, depending on the pyrolysis technique (Downie et al. 2009). The number of porosity mostly depends on the biomass matter, particle size and temperature treatment (Downie et al. 2009; Brewer et al. 2014).

The high specific surface area is one of the unique properties of the biochar. However, this property has the rule of many soil-biochar interactions, the specific surface area affected by the kind of the starting biomass and conditions of produce biochar (Downie et al. 2009). Together specific surface area and microporosity of biochar are increase with temperature (Kookana et al. 2011).

Biochar can be used as a soil amendment to improve the quality of agricultural soil (Lehmann et al. 2003) soil nutrient, carbon storage and filtration of soil water (Lehmann and Joseph 2009).

Glaser et al. (2002) reported that the use of biochar improved chemical, physical and biological properties of the soil, improved soil quality and also adding charcoal to soil, con increases seed germination, plant growth, and crop yields.
Rogovska et al. (2010) suggested that biochar might contain some phytotoxic combination that can affect plant germination or plant growth.

Biochar has the ability to increase the availability of nutrient to plant (Lehmann et al. 2003). Many researchers have shown that, biochar addition to soil may be more desirable as it can increase the soil organic carbon (SOC), improve water holding capacity and soil aeration, increases the cation exchange capacity (CEC), balances the pH of acidic soils, improves the soil microbial ecology (Sohi et al. 2010a).

Improved soil structure or soil aeration in fine textured soils (Kolb 2007) improve the nutrients supply to plants and increases plant growth and soil physical, chemical, and biological properties (Glaser et al. 2002; Lehmann et al. 2003; Rondon et al. 2007) and decreases nitrogen leaching (Singh et al. 2010). The large surface area and high capacity of biochar help to adsorb heavy metals and organic pollutants compounds (Zhang et al. 2013).

Biochar surfaces may provide the suitable place for microorganisms due to the greater concentration of adsorbed nutrients (Pietikainen et al. 2000). Biochar may also indirectly affect the soil environment for earthworms. Increasing pH of acid soils during the addition of charcoal can benefit earthworm population in the soil (Chan et al. 2008; Van Zwieten et al. 2010a). However, alkaline biochar if added at high rates can also affect the soil environmental conditions pH and EC adversely for earthworms (Liesch et al. 2010).

Biochar application also is increasing soil fertility and then agricultural productivity (Lehmann et al. 2006; Chan et al. 2008), improving nutrient and water use qualification (Glaser et al. 2002) and reduce the release of N_2O (Singh et al. 2010a).

Biochar is either naturally produced or manmade; probably it is the base of many humic materials located in soils (Hayes 2013). Biochar is described to be helpful in sorption of many naturals and anthropogenic organic combination (Lohmann et al. 2005; Yu et al. 2006; Sarmah et al. 2010). Interactions between biochar, microbes, soils and plant roots were happening during the short time after addition to the soil (Lehmann and Joseph 2009).

Biochars have the ability to a different range of pH values from a little acidic to alkaline (Chan and Xu 2009) although, (Jeffery et al. 2011; Kookana et al. 2011) reported that biochar has a high pH value and cation exchange capacity, and can increase soil productivity. Both feedstock and processing temperature are determining the ability to provide liming effects, increasing pyrolysis temperature mostly leads to high pH value of biochar (Singh et al. 2010b) and will increases the surface area of biochar, which eases higher sorption of chemicals such as pesticides (Tang et al. 2013). In addition, many studies have explained that biochar has a high capacity to adsorb pollutants in soils (Beesley et al. 2011; Yuan and Xu 2011).

Extension of biochar recently made attention to all, as an environmentally friendly technique, essentially as a climate change reductions strategy (Tang et al. 2013). Biochar is quietly recommended as a soil amendment because it cannot only reduce climate change by isolation of carbon C from atmosphere into soil (Marris 2006; Lehmann 2007a) but, can also improve soil properties, and increase soil fertility by improving moisture and nutrients retention (Lehmann et al. 2006), and microbial activity in the soil (Lehmann et al. 2011). Therefore, increasing crop productivity especially in soils with poor fertility, which is highly attractive given the fast growing in global population and decrease of the productive land area (Tang et al. 2013). Because biochar produced from many kinds of materials like (woodchips, animal manure, and crop residues), these increases recycle of agricultural and forestry wastes (Luo et al. 2011).

Soil improvement depends on the physical and chemical structure of the biochar, which themselves depends on biochar production conditions (Lehmann 2007b) and the amount of biochar applied to the soil (Chan et al. 2007; Chan et al. 2008; Van Zwieten et al. 2010b). Biochar has been reported to have many positive effects on soil quality in many ways, e.g., increasing soil organic matter content and pH, cation-exchange capacity (CEC), retaining soil moisture and nutrients, improving soil structure and activating microbial action, and thus raising plant growth (Lehmann et al. 2006; Sohi et al. 2010; Soinne et al. 2014).

Many researchers studied different soil amendments such as bio-solids, manure, poultry, biochar, crop residues etc., to increase soil phosphorus (P) desorption and availability in the soil.

Lehmann (2007b) reported that biochar, a carbon-rich material can sorbs phosphates, and recently results of decrease P leaching from biochar treated soils. Laird et al. (2010) found that biochar application reduced P leaching after manure addition.

Application of phosphorus in agricultural field is necessary to keep a high productivity. A large amount of P is being removed from the soil by the harvest of crop grains, and another amount of P is stored in the straws with low use efficiency (Zhai et al. 2015). For this reason, crop residues should be returned to the soil for sustainable P management (Tao et al. 2012). After charring, the concentration of P in biochar is mostly two to three times higher than the usual values in crop straws, and the volume substantially decreased. This makes biochar a promising alternative to the direct return of straw (Zhai et al. 2015).

Farmers in Iraq mostly depend on the use of chemical fertilizers and other agro-chemicals such as herbicides and insecticides. The use of such agro-chemicals randomly results in polluting water bodies and degrading the environment affecting negatively remain. Thus, many farmers are adopting other practices such as the use of organic inputs. Manure can be added to soil to increase P fertility by changing the soil pH. The total P content in manure is very changeable and nearly 70% of total P in manure is unstable (Shen et al. 2011).

Poultry manure is the richest of the animal manures and it is mostly a nitrogen and potassium fertilizer (Zhou 2002). It is usually available, easily accessible and a cheaper source of nutrient compared with inorganic fertilizers, which are rather expensive for the subsistence farmers and often hard to get. The large amounts of poultry manure produced can create environmental problems such as odor and leaching of nutrients to the environment. In addition to the original feed materials, poultry manure contains faecal matter, feather, dead bird and litter materials (Inal et al. 2015).

This study investigated the: effect of different doses of biochar, poultry manure and both together on nutrients availability in soil and investigate the optimal application rate of poultry manures and biochar in soil. Determine the effects of poultry manure and biochar application on vegetative growth of hot pepper plant. Investigate nutrient uptakes in hot pepper.

2. LITRETURE REVIEWS

Crop residues are valuable agricultural resources as they contain large amounts of nutrients. Restoration of these nutrients to the soil, with acceptable availability for crop uptake, is a challenge (Zhai et al. 2015). Burning of crop residues is a traditionally common practice to return the nutrients to soils in many countries including Iraq and particularly northern Iraq, Kurdistan despite the fact that this causes environmental problems such as air pollution, release of greenhouse gases, fine dust problems, and change of air circulation (Huang et al. 2012). To produce biochar from processing crop residues and applying biochar to soil is a better way of recycling of crop residues compared with the direct burning of residues in the field (Chun et al. 2004).

An old practice in many cultures was adding charcoal to soil to increase soil fertility, best exemplified by *Terra Preta* soils discovered in Brazilian Amazonia. However, recently the focus was on benefits this practice in both agronomic and environmental (Lehmann and Joseph 2009; Glaser et al. 2009; Sohi et al. 2010; Kookana et al. 2011). In the Amazon soil, it was found that CEC values were up to two times higher than in soils near it (Liang et al. 2006). Biochar has been produced from different organic materials, forestry, crop residues, paper-mill sludge, and poultry waste (Chan and Xu 2009).

Biochar has a higher sorption of organic and inorganic compounds, and the higher ability to retention nutrient compared to other forms of soil organic matter (Allen-King et al. 2002). Biochar application increase resistance of crop to disease which leads to increased crop production. Therefore, biochar can serve as a disease control factor in agriculture (Elad et al. 2010).

Gaskin et al. (2008) reported that increasing pyrolysis temperature is decreasing CEC of the biochar, although, Singh et al. (2010b) reported that CEC increases with increasing temperature. Biochars can probably increase the cation exchange capacity (CEC) of nutrient-poor sandy soils; however, this is dependent on the properties and aging of biochar application in the soil (Kookana et al. 2011).

Biochars are high carbon materials with unique properties such as microporosity, high specific surface area, and charge property. Still, the feedstock used and pyrolysis conditions are the key factors that are controlling biochars chemical and physical property (Downie et al. 2009). So, biochar has the possibility to change a quite range of chemical, physical, and biological properties of soil (Joseph et al. 2010), biochar can contain important nutrient (Chan and Xu 2009; Chan et al. 2008; Singh et al. 2010b; Van Zwieten et al. 2010a, b).

Plant growth improved when biochar was added to soil with compost. Schulz et al. (2013) studied it and tested different amounts of biochar in compost and different application rates of compost, in greenhouse pots planting oats, showed that plant growth increased with increasing application rates of compost and it was found that plant growth has increased as the amount of biochar in the compost increased.

Hass et al. (2012) discovered that S, K, and P are decreasing, and Cu and Zn availability are increasing in different rate of chicken manure biochar application, related to increasing in biochar production temperature. Biochar contains actual C range 172 g kg^{-1} to 905 g kg^{-1}. Nitrogen content from1.8 g kg^{-1} to 56.4 g kg^{-1}, total P from 2.7 g kg^{-1} to 480 g $kg^{-1}$and total potassium (K) from 1.0 g $kg^{-1}$to 58 g kg^{-1} (Lehmann et al. 2003; Chan et al. 2007). Biochar also contains other different elements concentration such as Oxygen (O), Hydrogen (H), Nitrogen (N), Sulfur, phosphorus (P), base cations, and heavy metals (Preston and Schmidt 2006). Biochar has a bulk density much lower than that of mineral soils (~0.3 Mg m^{-3} for biochar compared to typical soil bulk density of 1.3 Mg m^{-3}); therefore, utilization of biochar can decrease the total bulk density of the soil which plants like to grow on it (Brady and Weil 2004).

Increased some characteristics like the surface area, porosity and lower bulk density in mineral soil with biochar can change water retention, aggregation, and decrease soil erosion. Water retention of soil related to pores in the soil matrix, which generally affected by soil texture, aggregation, and content soil organic matter (Brady and Weil 2004). A higher surface area and major porosity of biochar relative to other types of soil organic matter improves soil texture and aggregation, which improves water retention in soil and improve water-holding capacity (Glaser et al. 2002; Gaskin et al. 2007). Kolb et al. (2007) reported that the application of biochar improves soil aeration, especially in fine-textured soil.

Biochar has the ability to increase available nutrient for plants (Lehmann et al. 2003), which is affected by increasing cation exchange capacity and changing soil pH. Biochar has the ability to adsorb and retain cations in an exchangeable form due to its large surface area, and negative surface charge (Liang et al. 2006). Increases in the availability of all major cations have been reported (Glaser et al. 2002; Lehmann et al. 2003). Biochar increase pH and nutrient availability for many different types of soil (Glaser et al. 2002; Lehmann and Rondon 2006).

Biochar ash is formed of calcium, magnesium, potassium, phosphorus, iron, silica, sodium and aluminum (Amonette and Joseph 2009). Nelson et al. (2011) reported that after biochar application a temporary increase in P availability in soil and inhibit of P sorption is noticed. Many researchers showed that possible effects of biochar addition on P availability are by changing the soil environment. Atkinson et al. (2010) noticed that adding biochar to changing the environment for microorganisms indirectly had affected to soil P availability and plant uptake of Phosphorus. Farrell et al. (2014) reported that biochar application effects on P availability in a calcareous soil.

Utilization of biochar to soil can effect on soil properties such as increase in soil pH, soil structure and availability of nutrients (Chan et al. 2007), adjust electrical conductivity (EC) and cation exchange capacity (CEC) (DeLuca et al. 2009) and nutrient retention (Singh et al. 2010a).

Several researchers studies have found that biochar addition to soil increases total C (Van Zwieten et al. 2010a), and add nutrients such as N, P and S (Atkinson et al. 2010; Sohi et al. 2010), reduce available Al in the soil (Chan et al. 2008; Van Zwieten et al. 2010b), increases in plant-available Ca, Mg and Zn (Major et al. 2010; Gartler et al. 2013), inorganic contaminants (Hua et al. 2009), and bioavailability of organic (Yu et al. 2009), organic matter decrease (Lehmann and Rondon 2006), indicates that biochar addition improves nutrient and water use efficiency and the soil pH value, and some macro-and micronutrient increasing in the soil after the application of biochar with compost (Liu et al. 2012).

Many researchers have confirmed that biochar addition increased N availability and retention when biochar applied with N fertilizer (Chan et al. 2007, 2008; Steiner et al. 2008; Van Zwieten et al. 2010b). Lehmann et al. (2003) noted that biochar applications increased plant growth resulted in high plant uptake of K, P, Ca, Zn and Cu.

Biochar decrease N leaching and helps retention of soil nutrients and water. (Novak et al. 2010; Deenik et al. 2010) reported that biochar could decrease nitrate leaching from the soil.

Biochar has been produced with a range of pH values between 4 and 12 (Lehmann 2007b). The pH and electrical conductivity EC of the biochar depend on the content and stricture of the mineral fraction (ash fraction), and this depends on the type of feedstock and biochar process conditions (Chan and Xu 2009; Singh et al. 2010b). The availability of nutrients in biochar related to the type of bonds of the element (De Luca et al. 2009).

Biochar formed from poultry manure have high pH and P content, sewage sludge can produce in biochar with high N and heavy metal concentrations, while fresh vegetation and wood may create biochar with balance pH and nutrient concentrations (Chan and Xu 2009). Gaskin et al. (2010) found that the application of peanut-shell biochar increases the pH and base cation concentrations in the soil when studded the comparison between biochar derived from peanut shells or wood chips, while wood-chip biochar had the little effect on these parameters.

Potassium is generally available to plants in biochar. Conversely, nitrogen availability from biochars depends on the final temperature of pyrolysis, heating rate, time of holding at final temperature, and type of feedstock (Amonette and Joseph 2009). Some researchers have found a low N availability (Gaskin et al. 2008).

Lehmann et al. (2003) found that application of biochar increased crop biomass and Hoshi (2001) found a 20% increase in volume and 40% increase in height of tea trees with biochar additions. In addition, yield increases are with biochar additions applied together with inorganic or organic fertilizer treatments (Glaser et al. 2002; Lehmann et al. 2002; Van Zwieten et al. 2007; Chan et al. 2007).

Biochar is seen to be useful in decreasing climate change, improving crop yield, reparation of polluted environment and recycling agricultural wastes according to most of the published literature. Profits of biochar are multiple, intertwined and contain both direct and indirect effects (Tang et al. 2013).

Biochar has both direct and indirect impact on soil nutrient availability, which can have effects on plant growth (Chan and Xu 2009). In the short term, biochar may provide a source of plant-available nutrients once applied to the soil (Gaskin et al. 2008; Sohi et al. 2010).

Major et al. (2010) reported that nutrient uptake by plants was increased in biochar addition to soil. Chan et al. (2007) noted that addition of poultry litter biochar increased N uptake by plants. Gaskin et al. (2010) also found that N in biochar produced from peanut hulls was not available for plant uptake.

Long-term positive effects of biochar additions were noticed in a few studies, watched over several years (Steiner et al. 2008; Blackwell et al. 2009; Major et al. 2010) which can increase the quality of the soil for thousands of years after a single application. Biochar is similar to the fertilizer that improves soil; it is doing this by minimizing nutrient leaching, improving water retention, and helping the development of microorganisms in the soil. In poor soils biochar can be applied, 100 g per square meter is enough to improve plant growth, while one to two kilograms per square meter are, recommended for more intensive uses such as vegetable growing (Brakels et al. 2010).

Biochar acts as a sponge holding water for plant growth and slowly allowing absorbing by the roots during several days between rainfalls or irrigation cycles (Ruehr 2007). Besides, biochar is much more environmentally friendly. Crops grow much better when the roots are in contact with biochar. Biochar has been reported to improve and stimulate root growth for some time. Matsubara et al. (2002) reported that the number of storage roots of asparagus increased with adding coconut biochar to a tropical soil.

Incorporation of biochar after application may not be seen immediately and may need natural mechanisms such as seasonal freeze-thaw events, moved by water, and earthworm activities (Topoliantz et al. 2005), or root uplift, which could delay biochar interactions with minerals and soil organic matter for years.

In the long study, using biochar product from wood, in the first year maize yields did not significantly increase but in the second year increased 28% and in the fourth year increased 140%, with an application rate of 20 ton per hectare (Major et al. 2010). The differences in plant response to biochar addition depend on the properties of the biochar (feedstock and pyrolysis temperature), the application rate, the soil type, and the plant variety being studied, feedstock can have negative effects on yield (Rajkovich 2010), animal waste biochar increases biomass while food waste biochar decreased biomass.

3. MATERIALS AND METHODS

3.1 Experimental Sites

The experiment was carried out at the Agricultural Research Centre of Sulaymaniyah in Bakrajo, Kurdistan Region-Iraq. The soil used in this study was collected from 0 to 30 cm depth of a fallow field on a farm in Zhalla district at the east south of Sulaymaniyah (542537.3 E; 3927490.5 N) in May 2016 (Figure 3.1).

3.2 Soil, Biochar, and Poultry Manure Materials

For soil after transporting, the soil was air-dried, and crashed, mixed thoroughly and sieved to 4 mm stainless steel sieve for using it in the pots. Some physical and chemical properties of the soil are given in Table 3.1.

The biochar that used in this study produced from maize which was prepared in Gaziosmanpasa University, Tokat, Turkey. The biochar sieved to pass 4 mm sieve for using it in the pots, some chemical properties of the biochar are given in Table 3.2.

The Poultry Manure was from the local factory (Shamal factory), crushed into and sieved to pass 4 mm sieve for using it in the pots, some chemical properties of the Poultry Manure are given in Table 3.3.

Table 3.1 Some chemical and physical properties of studied soil

Properties	Study soil
Sand%	11.69
Silt %	40.68
Clay%	47.63
Texture class	Silty Clay (S.C)
pH(1:1)	7.93
EC µs cm^{-1}	622
Organic Matter %	1.645
Carbonate Calcium$CaCO_3$%	23.26
Available Phosphorus(ppm)	7
Potassium (ppm)	352.67
Zn (ppm)	0.494
Mn (ppm)	48.500
Cu (ppm)	2.912
Fe (ppm)	7.022

Table 3.2. Some chemical properties of studied biochar

Properties	Study biochar
pH (1:5)	9.21
EC µs cm^{-1}	9.3
Nitrogen %	0.29
Available Phosphorus (ppm)	390
Potassium (ppm)	9530
Zn (ppm)	84.5
Mn (ppm)	41.1
Cu (ppm)	13.8
Fe (ppm)	321.4

Table 3.3. Some chemical properties of poultry manure

Properties	**Study Poultry Manure**
pH (1:5)	6.75
EC μs cm^{-1}	12.25
Organic Matter %	70.74
Nitrogen %	5.44
Available Phosphorus %	2.1
Potassium %	2.7
Zn (ppm)	291
Mn (ppm)	453
Cu (ppm)	310
Fe (ppm)	3365

3. 3 Experimental Design

The experiments were conducted as a factorial experiment with a completely randomized design CRD with three replicates for pot experiment to test the main and interaction effects of four doses of biochar, four doses of poultry manure and both together on the growth of hot pepper.

For the experiment, used plastic pots that hold 2 kg soil, the soil air-dried and 4 mm sieved weighed and mixed manually with treatments. Biochar doses: 0, 5, 10 and 20 g biochar/ kg soil (0, 0.5, 1 and 2% biochar). Poultry manure doses: 0, 10, 20 and 40 g poultry manure /kg soil (0, 1, 2 and 4% poultry manure)
Treatments were as follows:

B1P1 : Control
B1P2 : 1% Poultry Manure
B1P3 : 2% Poultry Manure
B1P4 : 4% Poultry Manure
B2P1 : 0.5% Biochar
B2P2 : 0.5% Biochar+1% Poultry Manure

B2P3 : 0.5% Biochar+2% Poultry Manure
B2P4 : 0.5% Biochar+4% Poultry Manure
B3P1 : 1% Biochar
B3P2 : 1% Biochar+1% Poultry Manure
B3P3 : 1% Biochar+2% Poultry Manure
B3P4 : 1% Biochar+4% Poultry Manure
B4P1 : 2% Biochar
B4P2 : 2% Biochar+1% Poultry Manure
B4P3 : 2% Biochar+2% Poultry Manure
B4P4 : 2% Biochar+4% Poultry Manure

3.4 Transplanting

Transplanting the seedling (30 days old) on 15 May 2016, one seedling of hot peppers (*Capsicum annuum* L.), planted in each pot, and then irrigated daily.

3. 5 Harvesting

The biomass was harvested 70 days after transplanting. Harvesting of hot pepper was accomplished, by cutting the biomass at the base of the plant approximately 2.5 cm above the soil.

3.6 Experimental Data Collection

Data collected at fruiting stage for each plant in each treatment. The following data collected:

3.6.1 Vegetative Growth Parameters

1. Days to 50% Flowering

The number of days to 50% flowering taken from the day planted to the date when 50%

of plants had at least one open flower. The average of the three replicated was taken to represent it.

2. Plant Height

Plant height was recorded in centimeters from the base of the plant to the apical point of plants using a meter rule in centimeters (cm). Mean plant length was computed.

3. Stem Diameter

The stem diameters measured three centimeters above the ground with vernier calipers immediately after cutting. For each plant, measurements were taken on the three replication plants and the mean calculated.

4. Number of Leaves

The total number of leaves per plant was count in each plant at harvest time for each replication and the average was taken.

5. Number of Main Branches

The number of main branches per plant was recorded by counting the number of main branches from each plant in replication and the mean was taken as the number of main branches per plant.

6. Fresh Weight of Shoot

The total of leaves and stem of the plant was separated collected and washed with normal water, then with distilled water and weighed at harvest time, measured grams (g) per plant.

7. Fresh Weight of Root

After harvesting and removal of shoots, the root of each plant was taken to washed with normal water to remove the soil, then with distilled water and dried by the paper after that weighted as fresh weight of root, measured grams (g) per plant.

8. Length of Root

Root length was recorded in centimeters from the bottom of the plant to the apical point of root using a meter rule in centimeters (cm). Mean root length was computed.

9. Dry Weight of Shoot

The total fresh leaves and stem separately, in each plant were taken then washed with normal water and then with distilled water and dried at 65^0C in an oven after that weighted as dry weighed of leave.

10. Dry Weight of Root

After being washed, the soil was removed from the root and dried at 65^0C in an oven, after that weighted as dry weight of root.

3.6. 2 Laboratory Analysis for Soil

After harvesting, soil samples were collected from each pot, and then mixed thoroughly and crushed gently the samples were taken to the laboratory to air-dried and sieved to pass through a 2 mm sieve for some chemical and physical analysis.

1. Soil pH and Electrical Conductivity (EC)

Soil pH and EC were determined according to methods mentioned by Richards (1954), added a 40 mL volume of distilled water (water ratio 1:1) and the mixture stirred with a spatula until soil became saturated. The soil saturation paste was left overnight, then pH measured by pH-meter by glass electrode, and by the conductance meter YSI model 34 measured EC.

2. Soil Organic Matter

It was determined by using the method of (Walkley and Black 1934) as described in (Jackson 1958).

Reagents

1. Weigh 49.04 g of Potassium dichromate $K_2Cr_2O_7$, (0.167 M, 1 N, dried at 105^oC) put it into 1 liter volumetric flask, and dissolved it in distilled water and mix well.

2. Concentrated of sulfuric acid H_2SO_4 (not less than 96%).

3. Indicator barium diphenylamine sulfonate ($C_{24}H_20BaN_2O_6S_2$) weigh 0.16 g of it was dissolved in 100 ml with distilled water as an indicator.

4. Weigh 140 g of ferrous sulfate hepta-hydrate ($FeSO_4.7H_2O$, 0.5 M) was dissolved with700 ml distilled water in l liter volumetric flask, 15 ml of concentrated sulfuric acid H_2SO_4 added and completed to 1 liter volume with distilled water.

Procedure

Added 1 g of air-dry soil sample (sieved to pass 0.5 mm) and 10 ml of 0.167 M potassium dichromate $K_2Cr_2O_7$ solution, into a 500 ml Erlenmeyer flask. The flask was gently swirled to accelerate the reaction. Then, 20 ml of concentrated sulfuric acid H_2SO_4 was added to the flask, mixed by gentle rotation carefully to avoid throwing soil up onto the sides of the flask. The mixture heated for one minute. Then, the flask was allowed to cool for 20 minutes, 200 ml of distilled water and15 drops of diphenylamine indicator were added to the flask.

At the final stage, the solution was titrated with 0.5 M ferrous sulfate $FeSO_4$. When the end- point approached, the color of the solution changed sharply from brown to dark green. The blank also treated in the same manner, but without soil to standardize potassium dichromate. The % of organic matter was calculated:

$$\% \, Organic \text{ Matter} = \frac{[A - (B \times NK)] \times 0.581}{\text{T}}$$

$$NK = \frac{10}{\text{V}}$$

A: Amount of Potassium Dichromate used (10ml)

B: Amount of Iron Sulphate used in Titration

T: weight of soil 1 g

Nk: actually used of Iron sulphate normality

V: used of Iron sulphate in titration in Blank

0.581: is equation number (constant equation)

3. Soil Calcium Carbonate $CaCO_3$ (Soil Total Lime)

First, 0.25 g of soil sample placed in a reaction jar-shaped bottle, to avoid immediate reaction between acid and soil. Next, 5 ml of diluted hydrochloric acid HCl was put in a small plastic vial in the jar-shaped. The monometer of the calcimeter adjusted to set zero, and the rubber cap at the end of the plastic tube, which was connected to the monometer, tightly fastened to the reaction bottle in a way that it formed a seal, and the system closed.

Then, the sample in the reaction bottle and acid in the vial mixed and shaken vigorously to allow the reaction between acid and soil particles. Shaking continued until the gas release had stopped until the last bubble was released.

Once the gas release ended, the volume of CO_2 gas released at calcimeter was recorded (V_t). After that, the atmospheric pressure and the temperature values of the laboratory measured by using barometer and thermometer, and these values recorded. The real gas volume (V_O, at 0°C and 760 mmHg) was calculated by using Boyle-Mariotto formula (Gülçur 1974; Goh et al.1993).

$$V_O = \frac{\mathrm{V_t} \times (\mathrm{b} - \mathrm{e}) \times 273}{760 \times (273 + \mathrm{T})}$$

$$\%\, CaCO_3 = \frac{\mathrm{V_o} \times 0.4464}{\mathrm{A}} \times 100$$

Where:

V_O = Gas volume converted at normal conditions (cm^3).

V_t = Gas volume read on Calcimeter (cm^3).

b = corrected Barometer pressure (mmHg).

e = Vapor pressure of water at t' ^oC (mmHg).

T = Temperature (^oC).

A = Weigh of soil sample (g).

4. Soil Texture

Soil particle size determined with Bouyoucos Hydrometer Method (Bouyocous, 1962).

Reagents

5% Calgon solution: Weight 50 g of Calgon and dissolve it in 1 liter of distilled water.

Procedure

Soil samples 50 g weighted and placed in a 250ml beaker, 20 ml of 5% Calgon solution and 200 ml of distilled water were added, stir it to mixed well and allowed to stand overnight. The samples mixed with Humbolt mixer, and mix for 5 minutes, then transfer to a graduated cylinder volume 1130ml and completed with distilled water at 1130 ml, and stir thoroughly 20 times, then record the hydrometer reading and temperature at 40 seconds also after 2 hours. The blank also treated in the same manner, but without soil. Samples of sand, silt, and clay calculated as percent after readings corrected for temperature.

40 Seconds reading

Silt % + Clay % = [(A-B) / wt of oven dry soil] × 100

Sand % = 100-(Silt + Clay) %

2 Hour reading

Clay % = [(A-B) / wt of oven dry soil] × 100

Silt % = 100-(Sand + Clay) %

A = Sample hydrometer reading + temperature correction

B = Blank hydrometer reading + temperature correction

5. Available Phosphorus in Soil

The concentration of phosphorus in organic soil was determined with Olsen method (Olsen et al. 1954). After extracting P with 0.5 M sodium bicarbonate $NaHCO_3$, phosphorous in the extract was determined with Ascorbic Acid Method using a spectrophotometer.

Reagents

I. Sodium Bicarbonate (0.5 M $NaHCO_3$)

Weigh 42.0 g sodium bicarbonate ($NaHCO_3$) and dissolve it in a 1 liter volumetric flask with distilled water and adjust the pH of this solution to 8.5 by using either 50% sodium hydroxide (NaOH) or 0.5 N hydrochloric acids (HCl).

II. Stock Solution A (Morphy- Rally)

1. Dissolve 12 g of ammonium hepta molybdate [$(NH_4)_6$ $Mo_7O_{24}.4H_2O$] in 250 ml volumetric flask with distilled water.

2. Dissolve 0.2908 g of Potassium antimony oxide [K (SbO). $C_4H_4O_6$. ½ H_2O] with 100 ml volumetric flask with distilled water.

3. In 2 liters flask mixing the two solutions and completed with nearly 1liter distilled water.

4. Add 138.9 ml of concentrated H_2SO_4 (d:1.84) gradually with stirring. Allow to cool and dilute to 2 liter with distilled water. The solutions stored in a dark bottle.

III. Solution B (Working Solution):

Solution B has to be prepared on a daily basis since it is stable only for 24 hours. Dissolve 0.53 g L-ascorbic acid in each 100 ml of solution A required, and stored in a dark bottle.

Procedure

2 g of air dry soil sample and 40 ml 0.5 M Sodium bicarbonate $NaHCO_3$ were added into a 100 ml Erlenmeyer flask, and the suspension was shaken on a mechanical shaker at a medium speed (RPM= 180) for 30 min and filtered through Whatman no.42 filter paper. Finally, 5 ml of filtrate and 5 ml of ascorbic acid solution were mixed in a 25 ml

volumetric flask and filled to volume with distilled water. The blank was also prepared in the same manner but without soil solution. The absorbance measured at 880 nm by using Specord 200 plus- spectrophotometer.

6. Plant Available K in Soil

Ammonium acetate 1 N NH_4OAc at pH 7.0, the method was used for extraction of plant available K, (Helmke and Sparks 1996). The plant available nutrients in the filtrate determined by flame photometer (BWB XP)

Reagents

Weigh 77.1 g of ammonium acetate put it in 1 liter volumetric flask, and add 900 ml of distilled water with continuously stirring to mixing the solution well, adjust the pH to 7.0 with using either 3 N acetic acid (CHCOOH) or 3 N ammonium hydroxide (NH_4OH).At the end, completed to a final volume of 1 liter with distilled water.

Procedure

First, weigh 3 g of air-dry soil sample into 100 ml plastic tube. Then, add 25 ml of the 1 N NH4OAc extraction solutions. Next, the plastic tube was shaken for 1 hour on a mechanical shaker at a medium speed (RPM = 180). After that, the content filtered through a funnel lined with Whatman No. 42 filter paper. Finally, the levels of extractable potassium K in the filtrate are determined by Flame Photometer (BWB XP).

7. Soil Micronutrients (Cu, Fe, Mn, and Zn)

The DTPA-TEA extraction method that was developed by (Lindsay and Norvell 1978) for extracting metal micronutrients in neutral used for measuring plant available Cu, Fe, Mn, and Zn. The extraction consists of 0.005 M DTPA (Diethylene Triamine Pentaacetic Acid $C_{14}H_{23}N_3O_{10}$), 0.1 M Triethanolamine (TEA), and 0.01 M $CaCl_2$, with a pH of 7.3.

Reagents

The DTPA {[(HOCOCH$_2$)$_2$NCH$_2$]2NCHCOOH}-TEA extraction solution consists of 0.005 M DTPA, 0.1 M TEA, 0.01 M $CaCl_2$, pH 7.3.

1. Weigh 14.92 g of reagent grade TEA into a beaker containing 200 ml distilled water and dissolve it.

2. Weigh 1.967 g of DTPA into a beaker and dissolve it in 200 ml distilled water, and wait for sufficient time until DTPA dissolved.

3. Weigh 1.47 g of calcium chloride $CaCl_2.2H_2O$ and dissolve it in 100 ml of distilled water.

4. In a 1 liter volumetric flask combine the three beakers and add enough distilled water to bring the volume to 950 ml.

5. Adjust the pH to 7.3 using hydrochloric acid 1.0 M HC1 with continuously stirring, and dilute to 1 liter with distilled water. This solution can be kept for several months.

Procedure

Weight 20 g of the air-dry soil sample into 100 ml Erlenmeyer flask, and 40 ml of the DTPA-TEA extraction solution, and let the flasks left overnight. Then, the content filtered through Whatman No. 42 filter paper. Finally, the amounts of Cu, Fe, Mn, and Zn can be determined by Atomic Absorption Perkin Elmer AAS800 (Figure 3.2).

3.6.3. Plant Analysis

The total fresh leaves only in each plant were taken as plant samples and prepared for the analyses by washing with normal water and then with distilled water and dried at 65^{o}C in an oven, ground in a Willey Mill. Then the ground samples kept in containers and closed to prevent adsorption of water from the humid environment.

Plant Digestion: 0.5 g of plant sample was weighed and put in a special plastic tube next added 10 ml of the concentration of HNO_3. Closed so tidily and cleaned well to remove any acid then covered by the metal cover, after that placed in a container of the machine that holds 40 tubes, starting digestion in the microwave machine Microdalga CEM model (MARS 6 240/50). After extraction cooling, in the hood it was opened carefully to pass the gas and put it to another tub that contained nearly 5 ml of distilled water slowly and completed to 25 ml with distilled water (Kaçar 1994). This solution was ready for using to determine elements.

1. Plant Phosphorus

The concentration of phosphorus in the plant was determined with Olsen Method (Olsen et al. 1954). Phosphorous was determined with the ascorbic acid method using a spectrophotometer (same method for phosphorus soil, described in Section 3.6, 5. Available phosphorus in Soil, page 21).

Procedure

0.5 ml of the digestion solution diluted to 25 ml with distilled water. From this diluted solution, taken 5ml and 5ml of ascorbic acid solution were mixed in a 25 ml volumetric flask and filled to volume with distilled water. The blank was also prepared. The absorbance measured at 880 nm by using Specord 200 plus- spectrophotometer.

2. Plant Potassium K Contents

To determine potassium in plant samples, the amounts of potassium can be determined directly from the digested solution by Atomic Absorption Perkin Elmer AAS800 in emission mode.

3. Plant Micronutrients (Cu, Fe, Mn, and Zn) Contents

For determine plant micronutrients used Atomic Absorption Perkin Elmer AAS800, for Cu and Fe were directly from the digesting solution were determined, but for Mn and Zn it was diluted 1:50.

4. Plant Total Nitrogen

Plant total nitrogen determined it with Dumas method, sieve plant sample with a 0.2 mm and weight approximately 0.05 g of sieved plant samples place in a thin Aluminum container and closed it. After that total nitrogen read by Dumatherm.

3.7 Statistical Analysis

A factorial experiment in a completely randomized design with three replications was used in this study.

Analysis of variance (ANOVA) to test the statistical significance and Tukey test to calculate the least significant difference (LSD) at 5% or 1% probability level was conducted using JMP software.

Figure 3.1. Hot pepper plant in pot after biochar and poultry manure applications

Figure 3.2. Analysis of micronutrients in the laboratory

4. RESULTS AND DISCUSSION

4.1. Results

The effect of the biochar doses, poultry manure doses, and their interactions on some vegetative growth of hot pepper, some soil properties and nutrient uptake by plants is going to be explained in this section.

4.1.1. Effect on Vegetative Growth

The results of analysis the application of biochar doses, poultry manure doses and their interactions to some vegetative growth of hot pepper, such as plant height, stem diameter, stem fresh and dry weight, number of leaves, leaves fresh and dry weight, root length, root fresh and dry weight, number of main branch and days of 50% flowering are given and explained in the tables below.

Results in Table 4.1 show that the effects of biochar, poultry manure and their interaction on vegetative growth of hot pepper plant (plant height, stem diameter, stem fresh and dry weight). It was observed that biochar doses did not have any significant effect. Application 1% poultry manure gave a significant result at $p<0.01$ for plant height, stem diameter, stem fresh and dry weight compared to the control that gave the lowest result, increasing in poultry manure doses more than 1% gave the opposite result.

Plant height, stem fresh weight, and stem dry weight gave a significant result at $p<0.01$, for their interaction (biochar and poultry manure) treatments.

The interaction application (biochar 0.5% + poultry manure 1%) recorded highest result in stem fresh and dry weight, but for plant height, the interaction application (biochar 0.5% + poultry manure 2%) recorded highest result.

However, biochar 0.5% + poultry manure 0% gave the lowest result for these parameters, and for stem diameter, their interaction not significantly affect.

Results in Table 4.2 show that the effect of biochar, poultry manure and their interaction on vegetative growth of hot pepper plant (number of leaves, leaves fresh and dry weight). It was observed that biochar doses did not have any significant effect. Application 2% poultry manure gave a significant result at $p<0.01$ for the number of leaves, leaves fresh and dry weight compared to the control that gave the lowest result.

Leaves fresh and dry weight gave a significant result at $p<0.01$, for their interaction (biochar and poultry manure) treatments and their interaction did not affect the number of leaves.

The interaction application (biochar 2% + poultry manure 2%) recorded the highest result in leaves fresh and dry weight, however; biochar 0.5% + poultry manure 0% gave the lowest result.

Results in Table 4.3 show that the effect of biochar, poultry manure and their interaction on vegetative growth of hot pepper plant (roots length, roots fresh and dry weight) It was observed that biochar doses did not have any significant effect. The treatments biochar doses, poultry manure doses, and their interactions did not significantly affect the length of the roots.

Application 2% poultry manure gave a significant result at $p<0.01$ for plant roots fresh and dry weight and application 4 % poultry manure gave the lowest result.

For their interaction (biochar and poultry manure), treatments did not significantly affect, root fresh and dry weight.

Results in Table 4.4 show that the effect of biochar, poultry manure and their interaction on vegetative growth of hot pepper plant (number of main branch and days of 50% flowering). It was observed that biochar doses did not have any significant effect

Application of 2% poultry manure gave a significant result at $p<0.01$ for the number of the main branch according to control that gave a lowest result and application of 4% poultry manure gave a significant result at $p<0.01$ for days of 50% flowering.

The interaction application (biochar 2% + poultry manure 4%) recorded highest result in days of 50% flowering however; biochar 0.5% + PM 1% gave the lowest result.

For their interaction (biochar and poultry manure), treatments did not significantly affect, the number of main branches.

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Table 4.1 Effects of biochar, poultry manure and their interaction on vegetative growth of hot pepper plant (plant height, stem diameter, stem fresh and dry weight)

Biochar %	**Poultry manure%**									
	Plant height (cm)					**Stem diameter (cm)**				
	0	**1**	**2**	**4**	**Means^{NS}**	**0**	**1**	**2**	**4**	**Means^{NS}**
0	20.67de	32.33abc	33abc	25bcde	27.75	0.46	0.6	0.58	0.52	0.54
0.5	**16.67e**	34.67ab	**36.67a**	30.67abcd	29.67	0.43	0.69	0.69	0.61	0.61
1	24.33bce	30.83abcd	26.33abcde	30.33abcd	27.96	0.54	0.56	0.52	0.61	0.56
2	30abcd	33.33abc	27abcde	23cde	28.33	0.5	0.61	0.61	0.55	0.57
PM Means	**22.92c**	**32.79a**	30.75ab	27.25b	**Means****	**0.48b**	**0.62a**	0.60a	0.57a	**Means****
LSD 1% 5%	**Biochar NS**		**PM 3.82****		**Interaction 10.45****	**Biochar NS**		**PM 0.08****		**Interaction NS**

Table 4.1 Effects of biochar, poultry manure and their interaction on vegetative growth of hot pepper plant (plant height, stem diameter, stem fresh and dry weight) (Continued)

Biochar %	**Poultry manure%**									
	Stem fresh weight (g)					**Stem dry weight (g)**				
	0	**1**	**2**	**4**	**Means^{NS}**	**0**	**1**	**2**	**4**	**Means^{NS}**
0	3.96de	14.74ab	13.85ab	8.90abcde	10.36	0.92ef	3.53ab	3.07abc	1.70cdef	2.30
0.5	**2.50e**	**15.88a**	15.24a	13.12abc	11.69	**0.57f**	**3.90a**	3.47ab	2.69abcd	2.66
1	6.02cde	10.92abcd	10.93abcd	14.11ab	10.49	1.38def	2.45abcd	2.10bcde	2.76abcd	2.17
2	7.40bcde	15.49a	12.40abc	7.08bcde	10.59	1.66cdef	3.39ab	2.90abc	1.36def	2.33
PM Means	**4.97c**	**14.26a**	13.11ab	10.80b	**Means****	**1.13c**	**3.32a**	2.89a	2.13b	**Means****
LSD 1% 5%	**Biochar NS**		**PM 2.81****		**Interaction 7.69****	**Biochar NS**		**PM 0.55****		**Interaction 1.5****

Table 4.2 Effects of biochar, poultry manure and their interaction on vegetative growth of hot pepper plant (number of leaves, leaves fresh and dry weight)

Biochar %	Poultry manure %														
	Number of leaves					Leaves fresh weight (g)					Leaves dry weight (g)				
	0	**1**	**2**	**4**	**Means^{NS}**	**0**	**1**	**2**	**4**	**Means^{NS}**	**0**	**1**	**2**	**4**	**Means^{NS}**
0	55.67	103.33	129	95.67	95.92	6.45 ef	19.25abc	22.51 ab	16.80 bcd	16.26	1.32e	3.94 abc	4.42 ab	2.72bcde	3.1
0.5	48.33	123.67	87.0	100.67	89.917	**4.43f**	21.85 ab	22.04 ab	21.37ab	17.42	**0.86e**	4.87a	4.3 ab	4.17abc	3.55
1	71.33	107	127	105	102.58	9.35def	16.43 bcd	19.12 abcd	24.36ab	17.32	1.91 de	3.3 abcd	3.43abcd	4.37 ab	3.25
2	79.33	97.67	104.33	79.67	90.25	11.31 cdef	23.49 ab	**26.79a**	15.02 bcde	19.15	2.31 c-e	4.68a	**5.02a**	2.67bcde	3.67
PM Means	**63.67b**	107.92a	**111.83a**	95.25a	**Means****	**7.89b**	20.26a	**22.61a**	19.39a	**Means****	**1.6c**	4.2a	**4.29a**	3.48b	**Means****
LSD 1% 5%	**Biochar NS**		**PM 27.7****		**Interaction NS**	**Biochar NS**		**PM 3.6****		**Interaction 9.85****	**Biochar NS**		**PM 0.69****		**Interaction 1.89****

Table 4.3 Effects of biochar, poultry manure and their interaction on vegetative growth of hot pepper plant (roots length, roots fresh and dry weight)

Biochar %	Poultry manure%														
	Length of roots					**roots fresh weight (g)**					**roots dry weight (g)**				
	0	**1**	**2**	**4**	**Means[NS]**	**0**	**1**	**2**	**4**	**Means[NS]**	**0**	**1**	**2**	**4**	**Means[NS]**
0	25.0	23.67	21.67	17.33	21.92	6.94	10.37	9.15	6.09	8.14	1.13	1.86	1.89	1.33	1.55
0.5	23.67	23.33	22.0	23.67	23.17	5.08	11.03	12.26	5.37	8.43	0.93	2.15	2.15	1.22	1.61
1	25.67	22.33	25.67	23.0	24.17	6.73	8.63	8.99	10.44	8.70	1.45	1.5	1.52	1.79	1.57
2	23.67	26.0	31.67	18.67	25.0	9.80	9.25	13.20	5.30	9.39	2.1	2.34	2.31	1.22	1.99
PM Means	24.5	23.83	25.25	20.67	**Means[NS]**	7.14b	9.82ab	**10.90a**	**6.80b**	**Means[**]**	1.40b	1.96a	**1.97a**	**1.39b**	Means**
LSD 1% 5%	**Biochar NS**		**PM NS**		**Interaction NS**	**Biochar NS**		**PM 3.24****		**Interaction NS**	**Biochar NS**		**PM 0.54****		**Interaction NS**

Table 4.4 Effects of biochar, poultry manure and their interaction on vegetative growth of hot pepper plant (number of main branches and days of 50% flowering)

Biochar %	**Poultry manure%**									
	Number of main branches					**Days of 50% flowering**				
	0	**1**	**2**	**4**	**Means^{NS}**	**0**	**1**	**2**	**4**	**Means^{NS}**
0	2.00	2.67	3.00	2.67	2.58	72a	57c	60bc	70ab	65
0.5	2.00	3.00	2.67	2.33	2.5	69ab	**57c**	61bc	68ab	64
1	2.00	2.33	3.33	2.67	2.58	66a-c	63a-c	69ab	68ab	67
2	2.33	2.67	3.33	2.33	2.67	68ab	63a-c	66a-c	**73a**	68
PM Means	**2.08b**	2.67ab	**3.08a**	2.5ab	**Means****	69a	**60c**	64b	**70a**	**Means****
LSD 1% 5%	**Biochar** NS		**PM** 0.71**		**Interaction** NS	**Biochar** NS		**PM** 3.69**		**Interaction** 10.11* (5%)

4.1.2. Effect on Some Soil Properties

The results of analysis the application of biochar doses, poultry manure doses and their interactions to some measured soil properties, such as pH, Electrical Conductivity (EC), calcium carbonate $CaCO_3$% and organic matter (OM) are given in Table 4.5. Macronutrient P and K were given in Table 4.6 and micronutrient Fe, Zn, Cu, and Mn are given in Table 4.7.

Results in Table 4.5 show that the effects of biochar, poultry manure and their interaction on soil pH, EC, $CaCO_3$, and OM in soil. It was observed that application of 0.5% biochar gave a significant result at $p<0.01$ for soil pH and OM and application 1% biochar gave the lowest result for soil pH, OM, and $CaCO_3$%. For $CaCO_3$ biochar affected significantly according to $p <0.01$, range from 17.90 to 23.49 application 1% Biochar and control respectively as seen. Biochar doses decrease $CaCO_3$ in the soil compared to the control. The biochar rates did not have any significant effect on EC.

For poultry manure application of 2%, poultry manure gave a significant result at $p<0.01$ for soil pH and OM, poultry manure doses increase pH and OM in the soil compared to the control. Poultry manure significantly affected EC according to $P<0.01$, ranges from 1022.75 to 1198.75 for application of 2% poultry manure and 4% poultry manure, respectively.

Poultry manure significantly affects $CaCO_3$ according to $P<0.05$, poultry manure doses decrease $CaCO_3$ in the soil compared to the control.

Soil pH and EC gave a significant result at $p<0.05$, for OM and $CaCO_3$ $p<0.01$, for their interaction treatments.

Results in Table 4.6 show that the effect of biochar, poultry manure and their interaction on macronutrients (P and K ppm) concentration in soil. It was observed that biochar for soil K gave a significant result at $p<0.01$, biochar doses decrease K in the soil compared to the control and control contained a higher concentration. The biochar doses did not have any significant effect on available P.

For poultry manure application of 4%, poultry manure gave a significant result at $p<0.01$ for P and K poultry manure increase P and K in the soil compared to the control.

Potassium K and P gave a significant result at $p<0.01$ for their interaction treatments, the interaction application (biochar 0% + poultry manure 4%) recorded the highest result in P and K.

Results in Table 4.7 show that the effect of biochar, poultry manure and their interaction on micronutrients (Zn, Mn, Fe and Cu ppm) concentration in soil. It was observed that biochar for soil Zn and Fe gave significant result at $p<0.01$ and for Mn at $p<0.05$, biochar doses decrease Zn and Mn in the soil compared to the control and control was containing a higher concentration of this nutrient, but for Fe, biochar doses increased Fe in the soil compared to the control, application of biochar 0.5% was a lower concentration of Fe, biochar with 1% was a lower concentration of Zn and Mn. The treatments by biochar doses did not significantly affect plant available Cu.

The application of 4%, poultry manure gave a significant result at $p<0.01$ for Zn and Mn. Poultry manure increase Zn and Mn in the soil compared to the control where control contained the lowest concentration of this nutrient, and the poultry manure doses did not have any significant effect on Fe and Cu.

Iron Fe gave a significant result at $p<0.01$ for their interaction treatments the interaction between the biochar and poultry manure did not affect Zn, Mn and Cu.

Table 4.5 Effect of biochar, poultry manure and their interaction on (soil pH, EC, $CaCO_3$ and OM) in soil

Biochar %	**Poultry manure %**									
	pH					**EC**				
	0	**1**	**2**	**4**	**Means****	**0**	**1**	**2**	**4**	**Means^{NS}**
0	8.01cde	8.18ab	8.15abc	8.17ab	8.13a	1098.33abcd	1035.33abcd	1067.00abcd	1216.0ab	1104.17
0.5	8.01cde	8.10bcde	**8.27a**	8.14abcd	**8.13a**	1135.67abcd	1023.0abcd	972.33cd	1139.67abcd	1067.67
1	8.0de	8.08bcde	8.09bcde	8.08bcde	**8.06b**	1112.33abcd	1004.67bcd	1118.67abcd	**1225.0a**	1115.17
2	**7.96e**	8.11bcd	8.14abcd	8.15abc	8.09ab	1086.0abcd	1180.67abc	**933.0d**	1214.33ab	1103.5
PM Means	**8.0b**	8.12a	**8.16a**	8.14a	**Means ****	1108.08b	1060.92bc	**1022.75c**	**1198.75a**	**Means ****
LSD	**Biochar**	**PM**		**Interaction**		**Biochar**		**PM**		**Interaction**
1%	**0.05****	**0.05****				**NS**		**78.57****		
5%				**0.15***						**215.06***

Table 4.5 Effect of biochar, poultry manure and their interaction on (soil pH, EC, $CaCO_3$ and OM) in soil (Continued)

Biochar %	Poultry manure %									
	OM %					$CaCO_3$ %				
	0	1	2	4	Means**	0	1	2	4	Means**
0	2.16a	1.59ab	1.94ab	**2.32a**	2.00a	**25.09a**	24.63a	23.26a	20.98a	**23.49a**
0.5	1.73ab	2.05a	2.24a	2.26a	**2.07a**	20.98a	18.24ab	17.33ab	18.70a	18.81b
1	1.62ab	**1.27b**	2.03ab	1.74ab	**1.66b**	23.26a	**10.03b**	17.33ab	20.98a	**17.90b**
2	2.24a	1.81ab	1.95ab	1.67ab	1.92ab	20.98a	22.35a	25.09a	22.35a	22.69a
PM Means	1.94ab	**1.68b**	**2.04a**	2.0a	**Means** **	**22.58a**	**18.81b**	20.75ab	20.75ab	**Means** *
LSD	**Biochar**		**PM**		**Interaction**	**Biochar**		**PM**		**Interaction**
1%	**0.28****		**0.28****		**0.76****	**3.06****				**8.37****
5%								**3.06***		

Table 4.6 Effect of Biochar, Poultry manure and their interaction on Macronutrients (P and K ppm) concentration in soil

Biochar %	**Poultry manure%**									
	P ppm					**K ppm**				
	0	**1**	**2**	**4**	**Means** ^{NS}	**0**	**1**	**2**	**4**	**Means****
0	5.67f	16.33ef	42.00de	**101.00a**	41.25	455.06efg	**378.26g**	510.42bcdef	**1839.69a**	**795.86a**
0.5	3.67f	20.67ef	30.00ef	83.67ab	34.50	470.00def	443.28fg	475.20cdef	580.53b	**492.25c**
1	**1.67f**	34.67def	45.33c-e	80.00abc	40.42	527.83bcde	518.11bcdef	517.34bcdef	554.27bc	529.39b
2	5.33f	49.00bcde	31.00ef	67.33abcd	38.17	518.89 bcdef	577.07b	540.28bcd	441.15fg	519.35bc
PM Means	**4.08c**	30.17b	37.08b	**83.00a**	**Means** **	492.94bc	**479.18c**	510.81b	**853.91a**	**Means** **
LSD 1% 5%	**Biochar NS**		**PM 13.19****		**Interaction 36.11****	**Biochar 29.07****		**PM 29.07****		**Interaction 79.58****

Table 4.7 Effect of Biochar, Poultry manure and their interaction on Micronutrients (Zn, Mn, Fe and Cu ppm) concentration in soil

Biochar %	Poultry manure%									
	Zn ppm					Mn ppm				
	0	**1**	**2**	**4**	**Means****	**0**	**1**	**2**	**4**	**Means***
0	1.08	2.36	2.90	4.94	**2.82a**	26.97	50.97	52.27	54.97	**46.29a**
0.5	0.92	2.04	2.29	3.87	2.28b	21.63	49.00	45.27	68.60	46.13ab
1	1.12	1.89	2.61	3.14	**2.19b**	26.50	35.47	35.67	42.77	**35.10b**
2	1.20	1.69	1.93	3.98	2.2b	25.90	41.33	50.33	55.17	43.18ab
PM Means	**1.08c**	1.99b	2.43b	**3.98a**	**Means ** **	**25.25c**	44.19b	45.88ab	**55.38a**	**Means ** **
LSD	**Biochar**		**PM**		**Interaction**	**Biochar**		**PM**		**Interaction**
1%	**0.53****		**0.53****		**NS**			**1.04****		**NS**
5%						**1.04***				

Table 4.7 Effect of Biochar, Poultry manure and their interaction on Micronutrients (Zn, Mn ,Fe and Cu ppm) concentration in soil (Continued)

Biochar %	**Poultry manure%**									
	Fe ppm					**Cu ppm**				
	0	**1**	**2**	**4**	**Means****	**0**	**1**	**2**	**4**	**Means^{NS}**
0	6.75a-c	6.41a-c	7.89a-c	7.85a-c	7.23ab	2.69	2.43	2.77	2.93	2.71
0.5	6.16bc	7.39a-c	**5.87c**	6.33bc	**6.44b**	2.71	2.65	2.52	2.65	2.63
1	6.83a-c	5.98c	7.16a-c	**9.16a**	7.28ab	2.58	2.33	2.69	2.21	2.45
2	7.56a-c	8.87ab	7.01a-c	7.98a-c	**7.86a**	2.51	2.50	2.30	2.82	2.53
PM Means	6.82	7.17	6.98	7.83	**Means ^{NS}**	2.62	2.48	2.57	2.65	**Means ^{NS}**
LSD 1% 5%	**Biochar 1.01****		**PM NS**		**Interaction 2.77****	**Biochar NS**		**PM NS**		**Interaction NS**

4.1.3. Effect on Leaf Nutrients Content

The results of analysis for the application of biochar doses, poultry manure doses and their interactions to some nutrients contain hot pepper leaf macronutrient N, P and K are given in Table 4.8 and micronutrient Fe, Zn, Cu, and Mn are given in Table 4.9.

Results in Table 4.8 show that the effect of biochar, poultry manure and their interaction on macronutrients (N, P, and K%) concentration in hot pepper leaf. It was observed that biochar is significantly effective according to $P<0.05$ phosphorus in the leaf range of contents from 0.21 to 0.29% for biochar application 0.5% biochar and 1% biochar, respectively. The biochar doses did not have any significant effect on N and K contents.

Poultry manure 4% gave a significant result at $p<0.01$ for P and K, poultry manure increase P and K in the leaves compared to the control, P, K concentration in leaf increase with the increase poultry manure doses, but there is the same effect between poultry manure doses. The poultry manure doses did not significantly affect N.

The interaction between the biochar and poultry manure did not affect N, P and K content of hot pepper leaves.

Results in Table 4.9 show that the effects of biochar, poultry manure and their interaction on micronutrients (Fe, Zn, Cu and Mn ppm) concentration in hot pepper leaf. It was observed that biochar is significantly effective according to $P<0.05$ for Zn and Fe, biochar doses decrease leaf Zn and Fe concentration compared to the control and control was contained a higher concentration of this nutrient. The biochar doses did not have any significant effect on Cu and Mn contents.

Poultry manure doses gave a significant result at $p<0.01$ for Fe, poultry manure doses decrease Fe in the leaf compared to the control and control was containing a higher concentration. Poultry manure 2% gave a significant result at $p<0.05$ for Zn, poultry manure increased Zn in the leaves compared to the control. The poultry manure doses did not have any significant effect on Cu and Mn contents.

Only Fe significantly affected according to P<0.01 by their interaction ranges from 105.48 to 234.30ppm for application 0.5% biochar + 2% poultry manure and 5% biochar + 0% poultry manure, respectively. The interaction between the biochar and poultry manure did not significantly affect Zn, Cu and Mn content of hot pepper leaves.

Table 4.8 Effect of Biochar, Poultry manure and their interaction on Macronutrients (N, P, and K %) concentration in hot pepper leaf

Biochar %	**Poultry manure%**														
	N%					**P%**					**K%**				
	0	**1**	**2**	**4**	**Means^{NS}**	**0**	**1**	**2**	**4**	**Means***	**0**	**1**	**2**	**4**	**Means^{NS}**
0	3.43	3.53	3.20	3.41	3.40	0.17	0.26	0.22	0.25	0.23ab	0.10	0.15	0.12	0.16	0.13
0.5	3.55	2.40	3.20	3.37	3.13	0.17	0.20	0.22	0.25	**0.21b**	0.11	0.13	0.14	0.15	0.13
1	3.63	3.54	3.73	4.15	3.76	0.13	0.28	0.37	0.39	**0.29a**	0.13	0.15	0.16	0.16	0.15
2	3.24	2.46	3.61	3.78	3.27	0.17	0.26	0.28	0.28	0.25ab	0.15	0.15	0.17	0.14	0.15
PM Means	3.46	2.98	3.43	3.68	**Means ^{NS}**	**0.16 b**	0.25 a	0.27 a	**0.29 a**	**Means****	**0.12b**	0.15ab	0.15ab	**0.16a**	**Means****
LSD	**Biochar**	**PM**		**Interaction**		**Biochar**	**PM**		**Interaction**		**Biochar**	**PM**		**Interaction**	
1%	**NS**	**NS**		**NS**				**0.07****	**NS**		**NS**		**0.03****	**NS**	
5%						**0.07***									

Table 4.9 Effect of Biochar, Poultry manure and their interaction on Micronutrients (Fe, Zn, Cu and Mn ppm) concentration in hot pepper leaf

Biochar %	**Poultry manure%**									
	Fe ppm					**Zn ppm**				
	0	**1**	**2**	**4**	**Means***	**0**	**1**	**2**	**4**	**Means***
0	199.57ab	178.67ab	172.13a-d	162.65b-d	**178.25a**	46.67	45.0	45.0	54.17	**47.71a**
0.5	**234.30a**	174.43a-c	**105.48d**	106.40cd	155.15a	16.67	29.17	37.50	50.83	33.54ab
1	178.25ab	144.80 b-d	147.13b-d	143.40 b-d	**153.40a**	13.33	20.83	54.17	28.33	**29.17b**
2	197.47ab	149.87 b-d	148.15 b-d	144.37 b-d	159.96a	37.50	38.33	46.67	35.00	39.38ab
PM Means	**202.40a**	161.94b	143.23b	**139.20b**	**Means ****	**28.54a**	33.33a	**45.83a**	42.08a	**Means***
LSD	**Biochar**	**PM**		**Interaction**		**Biochar**		**PM**		**Interaction**
1%		**25.06****		**68.60****						**NS**
5%	**25.06***					**17.65***		**17.65***		

Table 4.9 Effect of Biochar, Poultry manure and their interaction on Micronutrients (Fe, Zn,Cu and Mn ppm) concentration in hot pepper leaf (Continued)

Biochar %	Poultry manure%									
	Cu ppm					Mn ppm				
	0	1	2	4	Means ^{NS}	0	1	2	4	Means ^{NS}
0	4.73	5.67	4.43	7.58	5.60	719.17	725.00	902.5	868.33	803.75
0.5	6.05	7.13	7.78	6.32	6.82	1098.33	1012.50	895.83	754.17	940.21
1	5.20	5.45	6.60	7.95	6.30	668.33	944.17	846.67	1297.50	939.17
2	5.65	7.93	5.52	4.67	5.94	586.67	922.50	628.33	1197.50	833.75
PM Means	5.41	6.55	6.08	6.63	Means ^{NS}	768.13	901.04	818.33	1029.38	Means ^{NS}
LSD 1% 5%	**Biochar NS**	**PM NS**	**Interaction NS**			**Biochar NS**	**PM NS**	**Interaction NS**		

4.2. Discussion

4.2.1 Vegetative Growth

In the present study, the results have indicated that biochar application did not affect any of the vegetative growth of hot pepper. However, the size of the pots is limiting the growth of plants, but many researchers show that biochar application alone, type of biochar, biochar rates, type of studied plant and type of soil were affected on plant growth.

Asai et al. (2009) noted that applying biochar to the soil without any plant nutrients (fertilizers) especially nitrogen affects negatively on plant growth. However, when biochar applied with fertilizers, crop yields increased largely than when fertilizer applied alone without biochar. Decreased growth of plants reported with biochar application when biochar applied without fertilizer (Gundale and DeLuca 2007; Asai et al. 2009; Gaskin et al. 2010). The impacts of biochar on biomass and plant growth will depend upon soil properties and application rate (Gundale and DeLuca 2007; Asai et al. 2009; Van Zweiten et al. 2009).

Van Zwieten et al. (2009) recorded that biochar without fertilizer for specific plants and soil types, has no significant effects, while the highest result of biomass and plant growth recorded in the application of biochar with fertilizers.

Chan et al. (2007) found that plant yield of radish decreased at the minimum application rate of green waste biochar (10 ton ha^{-1}) but yields increased when the biochar applied with N fertilizer, yield generally increased as the biochar application rate increased.

Asai et al. (2009) noted that increase rates of biochar increase plant yield and nutrient concentrations on lower fertility place compared to higher fertility place, while Glaser et al. (2002) indicated that high rates of biochar did not generally lead to decrease in crop yields. Therefore, the optimal amount of adding biochar varies between soil and plant type, and biochar properties (Lehmann et al. 2002).

Recently, some researchers have noted that either biochar can have a positive or a negative priming effect, depending on the pyrolysis conditions and feedstock type used (Zimmerman et al. 2011).

Biochar did not increase plant production suggesting either that the amounts applied were too low or that one or several nutrients limiting plant growth were not available. Lentz and Ippolito (2012) noted that low nutrient recovery in plants grown in biochar addition to the soil could have contributed to a lack of yield response.

As we expected, the application of poultry manure affected all the vegetative growth of hot pepper, the results are similar to Sahin et al. (2014) who reported that poultry manure fertilization significantly improved pepper shoot growth and fruit yield. Manures increase plant growth by increasing soil organic matter and plant nutrients availability, and improve some soil physical properties (Azeez et al. 2010; Demir et al. 2010). Abd-El Hakeem (2003) reported that increase in poultry manure rate application up to 8 ton ha^{-1} increased tomato plant growth.

4.2.2. Soil Properties

The results have indicated that biochar application changes some chemical characteristics of soil. As mentioned previously, the addition of the biochar to soils increase Fe, but, decrease soil pH, OM, $CaCO_3$ and plant available K, Mn and Zn in the soil, and not affect soil EC, P, and Cu according to control. This finding is not in agreement with the finding of (Major et al. 2010; Chan et al. 2008).

Many researchers indicated many factors that affect the availability of nutrients in the soil, such as, soil pH, OM, $CaCO_3$, type of soil and plant (Ziadi et al. 2013). However, type of biochar and biochar pH will affect.

Soils of Iraq characterized by arid and semi-arid areas, with a high proportion of metal carbonate, particularly calcium carbonate up to 500 g kg -1 (FAO 1973) which affect some soil properties.

The results of this study indicated that application of biochar to alkaline soil is reduced Cu, Zn and Mn nutrition of hot pepper. The result in line with Gunes et al. (2014) who reported that application of biochar to alkaline soil reduced Fe, Cu, Zn and Mn nutrition of lettuce.

Biochar can indirectly affect nutrient availability by changing soil pH. The addition of biochar with high pH value 9.21 to the study soil 7.93, leads to high pH value 8.06-8.13 resulted a medium that nutrients not available.

The results showed decreased P may have resulted from the increase in soil pH, has been previously reported (Soinne et al. 2014), also, Uprety et al. (2009) reported decreasing soil pH leads to increasing concentrations of plant-available Cu, Mn, and Zn.

In another study, biochar feedstock greatly affects total N and phosphorus (P) contents because both are more in biochars produced from biomass of animal origin than those of plant origin (Chan and Xu 2009).

Zhai et al. (2015) in short-term study found a possibility of using maize straw biochar to improve soil P availability in low-P soils, application of 8% biochar (the higher biochar application rates) after 42 days affect significantly on soil P. Improvement of soil P availability by biochar is mainly due to high concentrations of P in the ash fraction.

The wide range of effects on nutrient function from biochar application to soil still poorly understood (Kookana et al. 2011).

Poultry manure application significant increase the soil pH, EC, OM and plant available, P, K, Mn and Zn in the soil, and decrease $CaCO_3$, as mentioned previously. The results are in line with Sahin et al. (2014) who reported that manures increase organic matter and plant nutrient availability, and improve some soil physical properties and therefore increase yield. In addition, many researchers reported that application of manure significantly increases available macronutrients, and this is a reason for the growth of plants when manure is applied (Demir et al. 2010; Gunes et al. 2014).

Many researchers reported increased nutrient concentrations in the soil after the application of manure and biochar (Glaser et al. 2002; Chan et al. 2007; Major et al. 2010; Gartler et al. 2013; Gunes et al. 2014).

4.2.3. Leaf Nutrient Content

As mentioned previously, the results have indicated that biochar application affected significantly most of the leaf nutrients this result was in agreement with the finding of (Lehmann et al. 2003).

The negative relationships between biochar application rate and plant nutrient concentrations can explain that plant growth can cause a small decrease in nutrient concentration (Rogovska et al. 2014).

However, the nutrients uptake of the plant was affected by some soil factors, like soil pH and $CaCO_3$%, contents are mostly responsible for the low availability of plant nutrient (Kaya et al.2009).

Decreased tissue Mn and Cu concentrations, can be explained by lower solubility and reduced plant availability due to an increase in pH following biochar application (Rogovska et al. 2014).

The biochar applications are not fully understood for N, it changes in N dynamics (Lehmann 2007b; Singh et al. 2010a).

Biochar may have a negative effect on soil N and decrease the availability of soil N (Lehman et al. 2002; Asai et al. 2009). While soil N was not measured in our study but we found a negative effect on plant N.

Biochar addition increased carbon-rich materials in the soil, it cause N immobilization and could potentially cause N lack in plants when applied to soil alone due to high C: N ratios (Lehmann et al. 2002; Chan and Xu 2009; Lehmann and Joseph 2009).

Chan et al., (2007) noted that addition of poultry litter biochar increased N uptake by plants, but not with the addition of green waste-derived biochar.

Lehmann et al. (2003) reported that biochar application increased uptake of P, K, Ca, Zn, and Cu by the plants with higher biochar application. Gunes et al. (2014) noted that biochar applications reduced Fe, Zn, Mn and Cu concentrations of the lettuce plants.

In another study, Chan et al. (2008) reported that addition of biochar formed from poultry waste increase radish yields and increased concentrations of N, P, S, Na, Ca, Mg, and K in plant biomass in a greenhouse experiment.

There are several possible explanations for the biochar effects on plant nutrient concentrations; biochar was effective at increasing soil pH. Solubility and hence bioavailability of P, Mn, Cu and Fe minimize with increasing pH (Alam et al. 1999).

In the present study, poultry manure application significant increase the leaf nutrients P, K, and Zn concentration (Reddy et al. 2000; Costa Araujo et al. 2006; Demir et al. 2010; Gunes et al. 2014).

Reddy et al. (2000) reported that the application of manure increased P uptakes and yields of wheat and soybean due to improved soil physical, chemical and biological properties.

Costa Araujo et al. (2006) reported that increase in poultry manure doses increased the concentration of potassium in the plant, which is an important mineral in fruit quality, and Gunes et al. (2014) biochar and poultry manure increased K concentration in lettuce plants.

Demir et al. (2010) noted that Poultry manure application increased P concentrations in both leaf and fruit of tomato and increase Zn and Cu concentration in tomato fruit.

Poultry manure application had no significant effect on N concentrations of lettuce leaves (Gunes et al. 2014) tomato plants (Demir et al. 2010) similar results, were observed in this study for the hot pepper.

Sahin et al. (2014) reported that Poultry manure fertilization on pepper had no significant effect on fruit K, Fe and Mg concentrations, however, poultry manure had no effect on leaf N, K, Fe and Mn concentrations but significantly increased leaf P concentrations and fruit Mn.

Myint et al. (2011) in two years study on the effect of organic manure application on the growth of rice found that poultry manure application provided the greater crop growth, dry matter accumulation, and grain yield. It might be due to the greater nutrient availability and high major nutrients contents (such as N, P, and K) of poultry manure.

The results for Zn and Mn are in line with Sahin et al. (2014) who report that applied poultry manure increased the concentrations of leaf Zn and Cu but unaffected Fe and Mn concentrations of pepper plants.

Inal et al. (2015) found that concentrations of micronutrient (Fe, Cu, Zn and Mn) in Bean plant increased by processed poultry manure and biochar applications. Processed poultry manure applications increased only the Zn and Mn concentrations of maize plants, but biochar increased Fe, Zn and Mn concentrations.

There are a few published works on micronutrient contents of plants as affected by biochar or poultry manure applications. Demir et al. (2010) and Gunes et al. (2014) reported the insignificant effect of poultry manure and biochar on Fe, Cu and Zn concentrations in tomato and lettuce plants.

Gunes et al. (2014) noted that Plant K concentrations, were increased in response to poultry manure and Park et al. (2011) reported biochar, increased availability of P and K.

5. CONCLUSION

This study was to investigate the effect of biochar, poultry manure and both together on vegetative growth of hot pepper, nutrient availability in soil and nutrient uptakes in hot pepper. Based on previously mentioned results, biochar application did not have any significant effect on any parameter of the vegetative growth of hot pepper. Biochar application decrease soil pH, organic matter (OM), $CaCO_3$% and plant available K, Mn and Zn in the soil, and not affect soil EC, P and Cu, but biochar application increase Fe in the soil. Biochar application increase P and decrease Zn and Fe, but not affected N, K, Mn and Cu concentration in the leaf of hot pepper.

Poultry manure application significant affect all parameter of the vegetative growth of hot pepper except length root. Poultry manure application significant increase the soil pH, EC, OM and plant available, P, K, Mn and Zn in the soil, and decrease $CaCO_3$, but not affect Fe and Cu in the soil. Poultry manure application increase P, K, and Zn, and decrease Fe, but not affected N, Mn and Cu concentration in the leaf of hot pepper. For their interaction (biochar and poultry manure) treatments for plant height, stem fresh weight, stem dry weight, leaves fresh weight, leaves dry weight and days of 50% flowering gave a significant result. Their interaction significant affect the soil pH, EC, OM, $CaCO_3$, P, K and Fe in the soil, but not affect Mn and Cu in the soil, but for plant nutrients only effect on Fe concentration, in the plant.

For our pot experiment biochar 1%, decreased $CaCO_3$% in the soil and increase P uptake in leaf plant. Poultry manure 2% affects most of the vegetation growth, but for soil and plant nutrients poultry manure 4% affect on most parameters. Results from the study must be validated through a field study to determine how realistic the results.

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