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Effects of poultry litter biochar on soil enzyme activities and tomato, pepper and lettuce plants growth

Muhittin Onur Akça, Ayten Namlı *

Ankara University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Ankara, Turkey

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Abstract

Biochar application to soils is being considered as a means to sequester carbon (C) while concurrently improving soil functions. A greenhouse experiment was carried out to determine the effects of biochar from the pyrolysis poultry litter (PL) on the soil enzyme activities, organic matter content and growth of tomato, pepper and lettuce plants. In the experiment, the combination of 15.15.15 composite fertilizer with 0, 200, 400 and 600kg/da doses of PL biochar were applied into the clay loam soil. Compared to the control and chemical fertilizer alone, the soil organic matter was significantly increased after biochar amendments. β-glucosidase, alkaline phosphatase, urease and arylsulphatase enzyme activities in soils were increased by the biochar applications significantly ($P<0.05$). Plant fresh and dry weight of tomato, pepper and lettuce plants were higher in 4kg/ha PL biochar treatment than in the other treatments. The results showed that PL biochar amendment to soils in the agricultural use increased yield of plants and enzyme activities with increasing soil organic matter content as well as improving soil properties.

Keywords: Biochar, soil, β-glucosidase, alkaline phosphatase, urease, arylsulphatase, organic matter, plants growth

Introduction

Many scientists showed interest in using biochar as soil amendment (Lehmann and Joseph, 2009; Sohi et al., 2010). Biochar has been described as a possible means to improve soil fertility as well as other ecosystem services and sequester carbon (C) to mitigate climate change (Lehmann et al., 2006; Lehmann, 2007; Laird, 2008; Sohi et al., 2010). Biochar is a highly stable compound created when biomass is heated to a temperature between 350 °C and 600 °C in the absence of oxygen. Biochar can increase concentration of soil organic matter, especially water-extractable organic carbon (Lin et al., 2012) and stimulate soil microbial biomass and their activities (Lehmann et al., 2011).

Enzymes are the catalysts organic matter decomposition in soil. Soil enzyme activities have been related to soil physico-chemical characteristics (Amador et al., 1997; Kussainova et al. 2013), microbial community structure (Waldrop et al., 2000; Kourtev et al., 2002), vegetation (Waldrop et al., 2000; Sinsabaugh et al., 2002), disturbance (Bolton et al., 1993; Eivazi and Bayan, 1996; Garci'a and Herna'ndez, 1997; Boerner et al., 2000), and succession (Tscherko et al., 2003). Soil enzyme datas have been the foundation for the development of conceptual models that provide a more comprehensive understanding of those key processes linking microbial populations and nutrient dynamics (Sinsabaugh and Moorhead, 1994; Schimel and Weintraub, 2003; Kızılkaya et al., 2012). Understanding the effect of biochar on the activity of these key

* Corresponding author.
Ankara University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, 06110 Dışkapı Ankara, Turkey
Tel.: +903125961758 E-mail address: aytenkrc@gmail.com
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enzymes has been identified as a research priority. What is discussed in more detail here is the possibility that changes in the microbial community composition or in enzyme activities are responsible for lower mineralization of soil C observed with biochar additions (Lehmann et al., 2011). The activity of two carbohydrate-mineralizing enzymes was shown to decrease after biochar additions to soil (Jin, 2010). Maximum velocity of both glucosidase and cellobiosidase decreased to very low levels with an application rate of 12 t biochar ha^{-1} or greater. Similar decreases in glucosidase activity were also observed with purified enzymes and fast-pyrolysis biochar produced from switchgrass (Bailey et al., 2010).

Biochar improves soil physical, chemical, and biological properties, including soil structure, nutrient availability, and water and nutrient retention and increases plant growth (Glaser et al. 2002; Lehmann and Rondon, 2005).The biochar treatments were found to increase the final biomass, root biomass, plant height and number of leaves in all the cropping cycles in comparison to no biochar treatments (Carter et al., 2013). Many of the short-term effects of biochar on plant growth and soil behavior reported from laboratory studies were not observed in the field emphasizing the need for long term field trials to help inform agronomic management decisions involving biochar (Jones et al., 2012). Poultry farming is a high volume enterprise in a number of areas throughout the Turkey. Poultry litter (PL) biochar is made from chicken manure and the bedding used in poultry operations: wood shavings, saw dust, straw or other organic materials (Draper and Tomlinson, 2012).

The objectives of this study were to evaluate the effect of PL biochar applications with and without composite 15.15.15 fertilizer into clay loam soil on β-glucosidase, alkaline phosphatase, urease, arylsulphatase enzyme activites and tomato, pepper, lettuce plants growth under greenhouse condition.

Material and Methods

In order to ease the usage of pelletized PL biochar as fertilizer, the experiment was carried out on the plants of lettuce, pepper and tomatoes in the greenhouse facilities of Agricultural Faculty in Ankara University, The biochar was produced poultry litter using gasification process. In the treatment, 4 kg of clay loam soil sieved from 4 mm opening sieze was weighed into the plastic pots as a dry weight base. The combinations of 15.15.15 ($N.P_2O_5.K_2O$) composite fertilizer with 0, 200, 400 and 600kg/da doses of PL biochar were applied into the soil before tomato, lettuce and pepper plants were grown for a period of 9 weeks. These treatments are A: control; B: 15.15.15 fertilizer; C: 200kg/da PL biochar; D: 200kg/da PL biochar + 15.15.15; E: 400kg/da biochar; F: 400kg/da PL biochar +15.15.15; G: 600kg/da PL biochar; H: 600kg/da PL biochar +15.15.15. Some properties of soil and PL biochar are given in Table 1.

Table 1. Some properties of the soil and PL biochar

Soil Properties		Unit	Soil	Biochar
Texture	Clay	%	39,7	-
	Silt	%	33,7	-
	Sand	%	26,6	-
	Class		Clay loam	-
pH $_{25^0C}$		1:2,5 (soil:water)	7,99	9,0
EC $_{25^0C}$		mS cm^{-1}	0,102	377
Organic matter		%	0,70	54,72
Total nitrogen		%	0,125	2,85

After harvesting of plants, the effects of the treatments on soil organic matter content and soil enzymatic activities and plant fresh and dry weights were determined.

Soil analysis

Soil samples taken from the pots were passed through a 2-mm sieve and stored at 4°C until analysis after harvesting. The samples were analyzed to determine a series of soil chemical (electrical conductivity, pH, total carbonates and organic matter content) physical (texture) and enzyme activities such as alkaline phosphatase, β-glucosidase and arylsulphatase. A pH-meter was used for soil reaction measurement in a 1:2.5 (w:v) of soil:water ratio. Soil texture was determined by the Bouyoucos hydrometer method

(Bouyoucus, 1951). Organic matter content was measured by Walkley-Black method (Jackson, 1962), total nitrogen by using Kjeldahl method (Bremner, 1965), and total carbonate content by using the Scheibler calcimeter (Jackson, 1962).

Soil enzymatic analyses

Soil samples were analysed for their β glucosidase activity (C cycle), alkaline phosphatase activity (P cycle) and arylsulphatase activity (S cycle) by the methods of Naseby and Lynch (1997), urease activity (N cycle) by the method of Hoffmann and Teicher (1961).

All determinations of enzymatic activities were performed in triplicate, and all values reported are averages of the three determinations expressed on an oven-dried soil basis (105 ^{0}C).

Statistical analysis

The results of the treatments were compared by ANOVA and least square difference test ($P<0.05$). All statistical analyses were conducted with SPSS package program.

Results and Discussion

Effect of PL biochar on soil organic matter content (OM)

The OM amounts of all the PL biochar treatment soils were found higher than soils in the treatments of A and B. It was determined that higher PL biochar application doses significantly increased OM amount in the soils at $P<0.05$ (Figure 1). According to Phoung-Thi et al (2013), compost and vermicompost had similar effects on soil carbon and nitrogen content, whereas the presence of biochar increased carbon and nitrogen sequestration. Singh and Cowie (2014) concluded that biochar stimulates native soil organic carbon (SOC) mineralization in the low-C clayey soil but that this effect decreases with time, possibly due to depletion of labile SOC from initial positive priming, and/or stabilization of SOC caused by biochar-induced organo-mineral interactions. Depending on the production parameters, more than 50% of the organic material's carbon may be sequestered in a stable form in the biochar. When the biochar is used as a soil amendment, a significant proportion of the recalcitrant biochar carbon can resist degradation for hundreds to even thousands of years, thus creating stable carbon pools (Draper and Tomlinson, 2012).

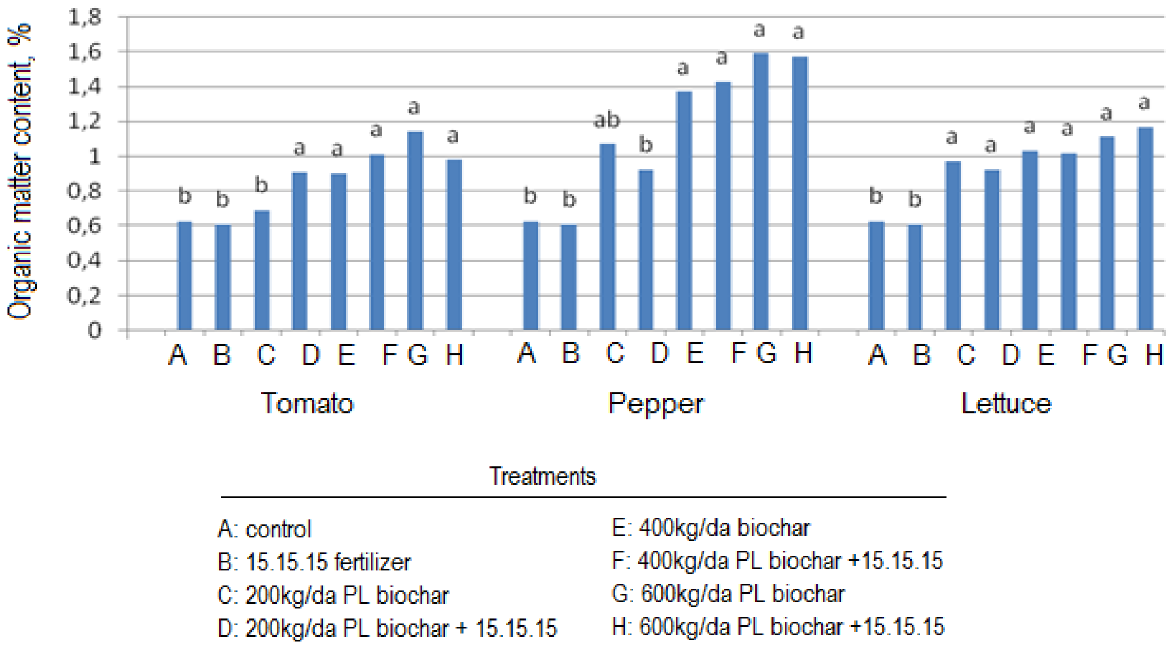

Figure 1. Effect of PL biochar on soil organic matter content

Effect of PL biochar on soil enzyme activities

Studies of enzyme activities provide information on the biochemical processes occuring in soil. There is growing evidence that soil biological parameters may be potential and sensitive indicators of soil ecological stress or restoration (Kızılkaya et al., 2004). Measurements of several enzymatic activities have been used to establish indices soil biological fertility (Kızılkaya and Hepşen 2004; 2007). In the present study, soil enzymes respentative of main nutrient cycles (C,N,P,S) were selected. Glucosidases are widely distributed in nature and their hydrolysis products as low molecular weight sugars are important source of energy for soil microorganisms. β-glucosidase catalyzes the hydrolysis of β-D-glucopyranoside and is one of the three or more enzymes involved in the saccharification of cellulose (Bandick and Dick, 1999; Turner et al. 2002). Urease is involved in the hydrolysis of urea to carbondioxide and ammonia, which can be assimilated by microbes and plants. It acts on carbon-nitrogen (C-N) bonds other than the peptide linkage (Bremner and Mulvaney, 1978; Karaca et al., 2002). Phosphatase is an enzyme of great agronomic value because it hydroles compounds of organic phosphorus and transforms them into different forms of inorganic phosphorus, which are assimilable by plants (Amador et al., 1997). Variations in phosphatase activity apart from indicating changes in the quantity and quality of a soil's phosphorated substrates, are also a good indicator of its biological state (Pascual et al., 1998, 2002). Arylsulphatase is the enzyme involved in the hydrolsis of arylsulphate esters by fission of the oxygen-sulphur (O-S) bond. This enzyme is believed to be involved in the mineralisation of ester sulphate in soils (Tabatabai, 1994). Also, it may be an indirect indicator of fungi as only fungi (not bacteria) contain ester sulphate, the substrate of arylsulphatase (Bandick and Dick, 1999; Kızılkaya and Bayraklı, 2005).

During the greenhouse experiment, alkaline phosphatase, β-glucosidase, urease and arylsulphatase enzyme activities of the soils were consistently higher in all doses of PL biochar treatments. Enzyme activities in all PL biochar applications were found to be higher than treatments of A and B. The higher enzyme activities were determined in the soils including PL biochar treatments combined with chemical fertilizer. The significant changes in enzyme activities at P<0,05 were given in Figures 2. All enzyme activities in successive application doses of biochar treatments (except treatment H) increased significantly when compared with the control and alone fertilizer treatment. The highest PL biochar doses (treatment H) was applied in combination with chemical fertilizer, a partial decrease in all enzyme activities were determined. Application of PL biochar stimulated enzyme activities in soil. Due to having a narrow C:N ratio, amended PL biochar might have quickly decomposed, resulting in high enzyme activities in all plants growth soil. In addition, increased content of organic matter may be caused increasing enzyme activities in the soil. Some authors reported that increasing organic matter increased enzyme activity in the soil (Leiros et al. 2000). Regarding results found at enzyme activities that increased due to increasing amount of biochar, results to the contrary have also been detected during other research studies regarding the biochar application that was added to the soil, Wu et al. (2013) detected a decrease in β-glucosidase enzyme activities and they stated that due to the fact that this carbon given in biochar form to the soil is solid in structure and therefore does not act as a stimulant to the enzyme activity in the soil.

Contrary to our results and also reported by other authors (Bailey et al. 2011), Paz Ferreiro et al. (2012) indicated that β-glucosidase enzyme activity diminished with the biochar amendment, phosphatase activity increased two fold while arylsulphatase activity exhibited no differences between with and without biochar applications. Researchers emphasized that S cycling in the used soil is unaltered by biochar application. Laboratory experiments and longer term field experiments indicate that soil arylsulphatase activity is rather insensitive to biochar amendment as neither inhibitory nor significant stimulatory effects are reported by Yoo and Kang (2012). In brief, effects of biochar on enzyme activities in soils are variable (Yoo and Kang 2012; Paz-Ferreiro et al. 2012; Wu et al. 2013) and biological effects of biochar could be crucial due to the potentially high quantity and persistence of biochar in soil.

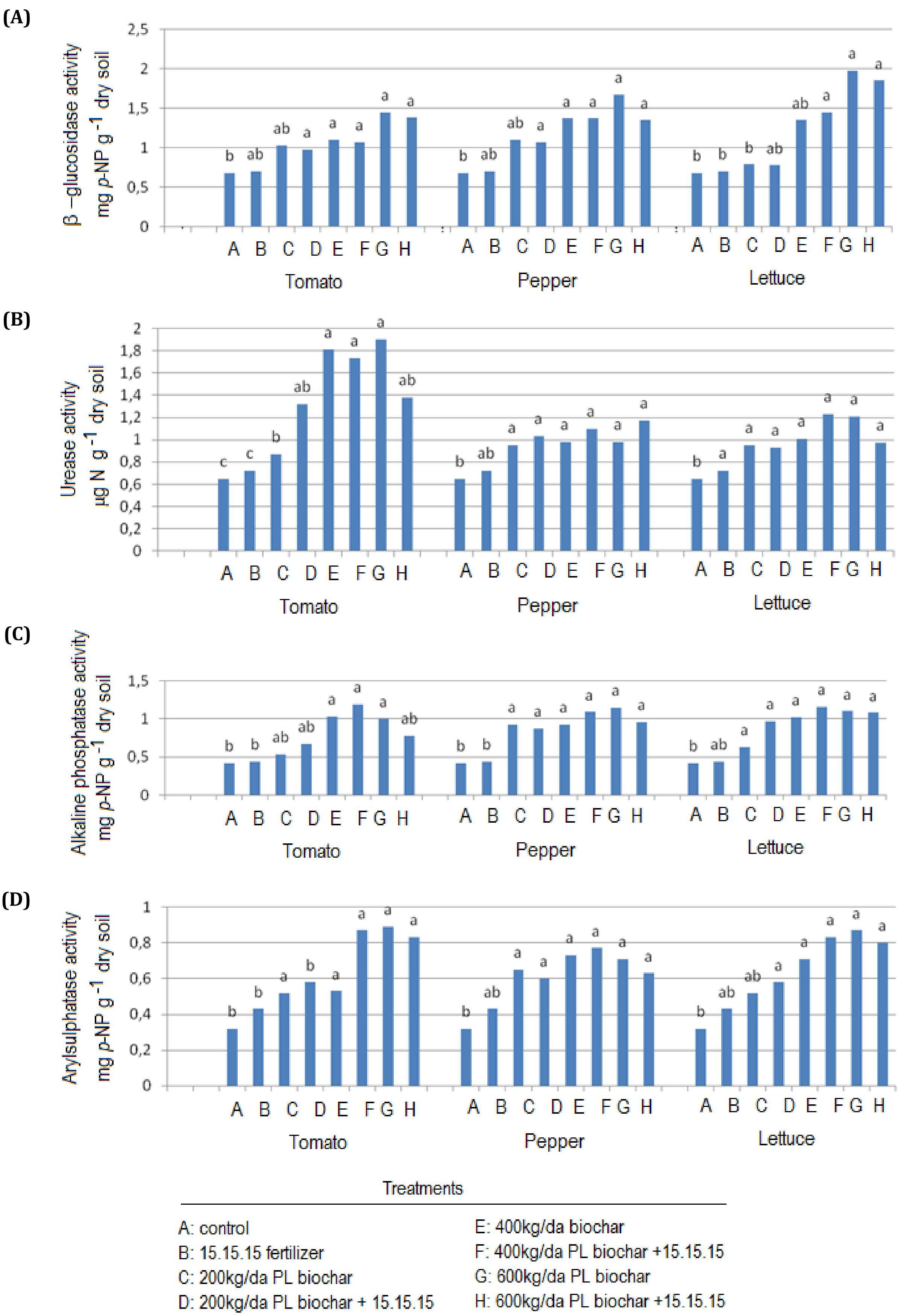

Figure 2. Effects of PL biochar on soil enzyme activities (A) β-glucosidase activity, (B) Urease activity, (C) Alkaline phosphatase activity, (D) Arylsulphatase activity

Effects of PL biochar on plant growth

The lowest and the highest values of fresh and dry tomato plant weights were determined in A and H treatments respectively (P<0,05). While the lowest fresh and dry pepper plant weights were determined in treatment A, higher fresh and dry weight values were found in treatments of D,F and G (P<0,05). However, fresh and dry plant weight values for lettuce did not show significant differences statistically (Figure 3). Application of PL biochar with 15.15.15 fertilizer greatly increased the development of tomato, pepper and lettuce plants. It can be said that using PL biochar reduces chemical fertilizer use in agricultural systems. In some studies corn yield was improved 140% (Major et al., 2010), cowpea by 100% (Glaser et al., 2002), while radishes grown with poultry litter biochar yielded a 96% increase (Chan et al., 2008). Hossain et al. (2010) applied wastewater sludge biochar at 10 tons/ha to cherry tomatoes resulting in increased production by 64% above the control soil conditions. Generally, improved crop yields have been attributed to soil improvements regarding critical conditions of soil pH, water content, and nutrient availability (Sun et al., 2014).

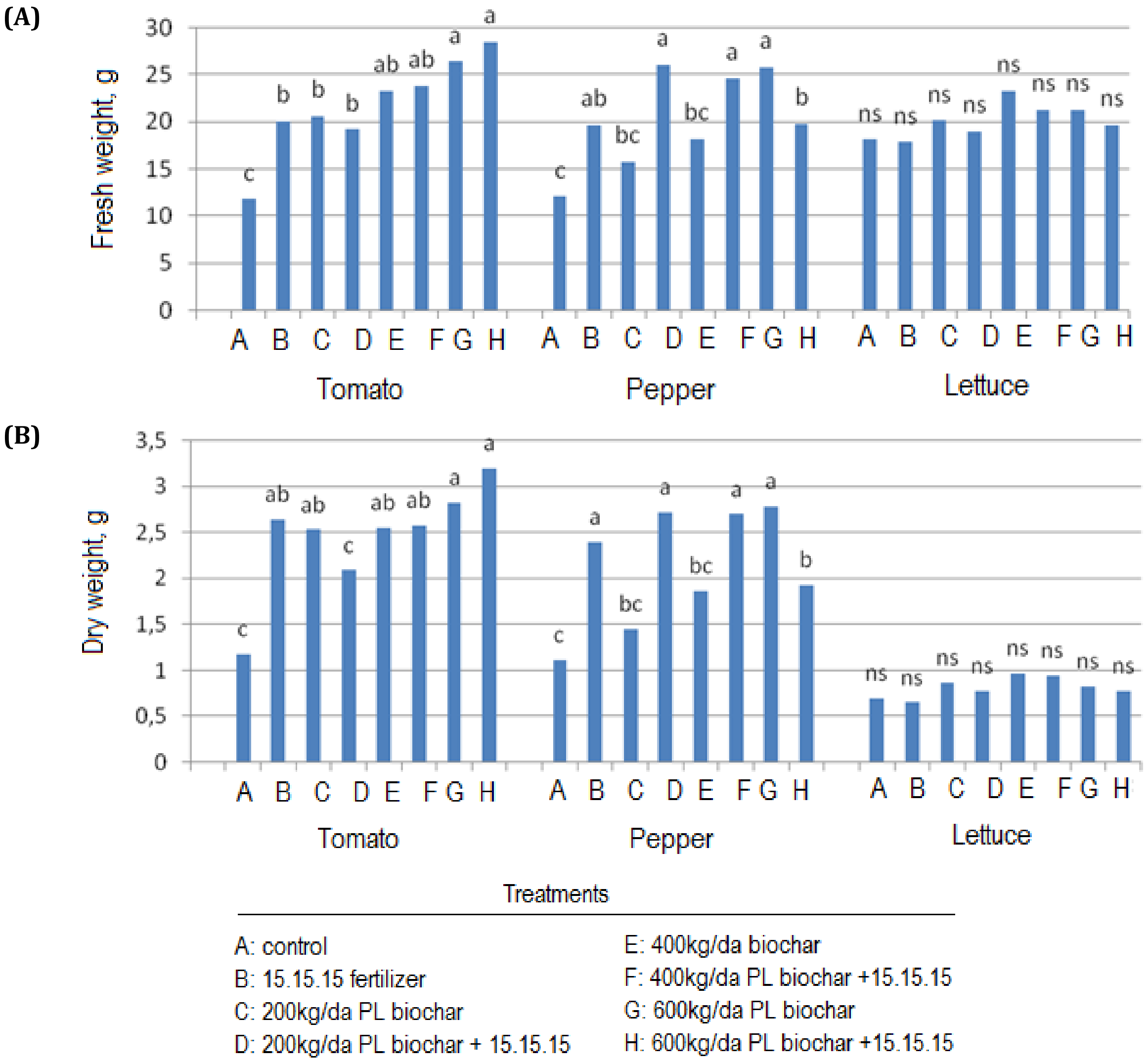

Figure 3. Effects of PL biochar on plants weight (A) Fresh weight, (B) dry weight

Conclusion

The results of this research indicated that poultry litter can be successfully decomposed. Decomposed biochar release much higher nutrients than the raw materials. In this greenhouse experiment, the nutrients released from PL biochar are available to plants. PL biochar amendment may be potential in improvement of soil properties to some extent to achieve the agricultural use. Biochar to be produced via gasification procedures by using poultry litter and other different agricultural waste material should be tested in different doses and field conditions. In Turkey, studies with biochar are not enough; we should much concentrate on this type of studies using biochar to achieve soil sustainability.

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