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THE EFFECTS OF WALNUT SHELL AND THYME STALK BIOCHAR ON PEPPER: PLANT PARAMETERS

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Abstract

The aim of this study is to determine the effects of biochar that obtained from walnut shell and thyme stalk on yield and biomass development of pepper plant. Biochar obtained by self-constructed oxygen-free reactor at 400 °C. According to experimental design, 2 different biochar raw materials (walnut shell and thyme stalk) at 3 different doses (0, 0.1 and 0.2% w/w) were evaluated in either with or without sulphur application (0 and 0.1% w/w). Results revealed that the all parameters tested were greatly influenced from raw material, biochar dose as well as sulphur applications. Significant differences were determined between the raw materials in which the biochar was made. According to mean values the walnut shell biochar provide 38% more shoot dry weight than thyme stalk biochar. These findings clearly indicate that although biochar almost consisted of carbon, all of the biochar are not the same, and depends on the raw material; biochar even can reduce plant growth. The effect of sulfur application was also significant, especially in the pots where biochar and sulfur were applied together. The lowest yield value was determined at control as well as 0.1% thyme stalk biochar applied pots as 34.2 and 33.4 g pot^{-1}, respectively while the highest yield value was determined at 5 g walnut shell biochar and sulphur applied pot as 75.7 g pot^{-1}. It has been determined that dose and efficiency studies should be performed for each raw material to determine optimal biochar source and doses.

Keywords: Biochar, pepper, biomass development, yield

INTRODUCTION

The history of the biochar usage as a soil amendment goes back to 1878s (Chan *et al.*, 2010) which biochar recently been using to decrease global warming effects by reducing CO_2 concentration of the atmosphere (Sohi *et al.*, 2010; Prendergast-Miller *et al.*, 2011; Zavollini *et al.*, 2011). Biochar reduces nutrient leaching in tropical soils; however, limited information is available for temperate climate regions (Laird *et al.*, 2010). Although Luo *et al.* (2011) reported higher CO_2 formation as a result of higher biological activity of soil by biochar incorporation, emitted CO_2 to the atmosphere is rather lower compared the fixed carbon by biochar (Zavalloni *et al.*, 2011). N_2O formation is also influenced from biochar, as Castaldi *et al.* (2011) reported increment of N_2O formation at the first 3 month; but no differences between the treatments determined after 14 month. The discovery of biochar was in dark terrapreta soil of the Amazon forests that researchers have discovered that terrapreta soil contains as much as 2.7 times more organic carbon (Glaser *et al.*, 2002). Besides of the existing literature emphasized positive effects of biochar, a number of researchers reported that the biochar production parameters such as applied temperature (Song and Guo, 2012) are not yet fully understood. LeCroy *et al.* (2013) has taken this phenomenon one step forward and they reported that biochar application may not be effective on plant growth, or even affect negatively. It is also reported short term pH elevation (Castaldi *et al.*, 2011) due to the slight to very strong alkaline pH of the biochar (Fidel, 2012) which may lead nutrition disorders in the soil that have neutral or slightly alkaline pH. Sorrenti and Toselli (2016) reported that high dose of biochar inhibited iron uptake of the plant resulted chlorosis on the leaves.

Organic matter content of the soils in semiarid climate region is rather low due to the higher mineralization rate; therefore, the addition of organic matter to the soil should be done at regular intervals (Akbolat *et al.*, 2004, Coskan *et al.*, 2006). Instead, more stable substrates such as biochar may be effective in protecting soil fertility for a longer time. Due to its high stability, biochar cannot be easily decompose by soil microorganisms (Schmidt and Noack, 2000; Glaser *et al.*, 2002). Thus biochar can remain in the soil for hundreds of years (Brewer, 2012) and sustain soil productivity as organic matter does. Soil organic matter improves cation exchange capacity (Liang *et al.*, 2006); therefore, it has a potential to regulate excessive fertilizer usage as Atilgan *et al.* (2007) reported.

According to 2010 FAO data, 2 million 555 thousand Mg of walnuts are produced in 844 thousand hectares of land in the world. While China took the first place in world walnut production with 1 million 61 thousand Mg of production, followed by USA and Turkey with 457 and 178 thousan d Mg, respectively. Thyme is one of our important export products and Turkey holds about 70% of the world's thyme trade.

In this research the effects of walnut shell and thyme stalk biochar as well as their doses on yield and biomass development of the pepper plant were evaluated. To overcome pH elevation following biochar incorporation, sulphur application is tested.

MATERIAL AND METHODS

A pot experiment in the 2015 summer period was carried out at University of Suleyman Demirel, Isparta, Turkey according to randomized complete block design with 3 replicates. Factors were two biochar sources as walnut shell and tyme stalk, three biochar doses as 0, 5 and 10 g biochar pot^{-1} (0, 0.1 and 0.2% w/w) and elemental sulphur application as 0 or 5 g pot^{-1} (0 and 0.1% w/w). Biochar productions have done by self-constructed, oxygen-free; electrically powered reactor at 400 °C. Five kg of dry soil equivalent fresh soil was sieved from 4 mm and placed to pots where some soil properties presented in Table 1. The size of the pot used was 4 dm^3.

Table 1. Some properties of experimental soil

texture class	organic matter (%)	pH (1:2,5 H_2O)	$CaCO_3$ (%)	Salt (%)
SiC	1.08	8.24	27	0.018

Pots were fertilized by 200 mg kg^{-1} N, 150 mg kg^{-1} P_2O_5, 150 mg kg^{-1} K_2O. Marketable fruit weight was weighted as fresh, all other plant samples was dried at 65 °C, and their biomass weight and dry yield were determined by the methods described by Kacar and Inal (2010). Data obtained were statistically tested by MSTAT-C software (Crop and Soil Sciences Department, Michigan State University, Version 1.2) according to Three Factor Completely Randomized Design.

RESULTS AND DISCUSSION

The effect of walnut shell and thyme stalk biochar, their doses and sulphur applications on root and shoot dry weight, fruit number, marketable yield as well as total biomass development values are presented in Figure 1, 2, 3, 4, 5 and 6, respectively.

The root dry weight values of the pepper plant were markedly affected ($p<0.05$) from different biochar sources (Figure 1). Walnut shell biochar improved root development slightly compared to control application; however, root developments in thyme stalk incorporations were lower than both control and walnut shell. The mean root dry value in walnut shell biochar was 2.69 g pot^{-1} which statistically higher than the thyme stalk biochar which was 2.10 g pot^{-1}. Combined application of sulphur and biochar increased root dry weight, but the highest value was in control among the sulphur applied pots. Based on the mean values, sulphur application stimulated root growth ($p<0.05$) which associated the high pH of the test soil (Table 1).

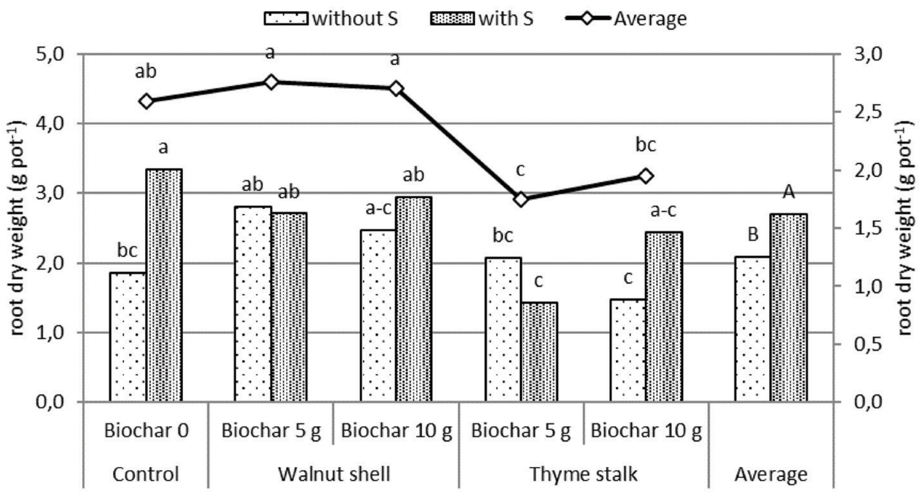

Figure 1. Root dry weight

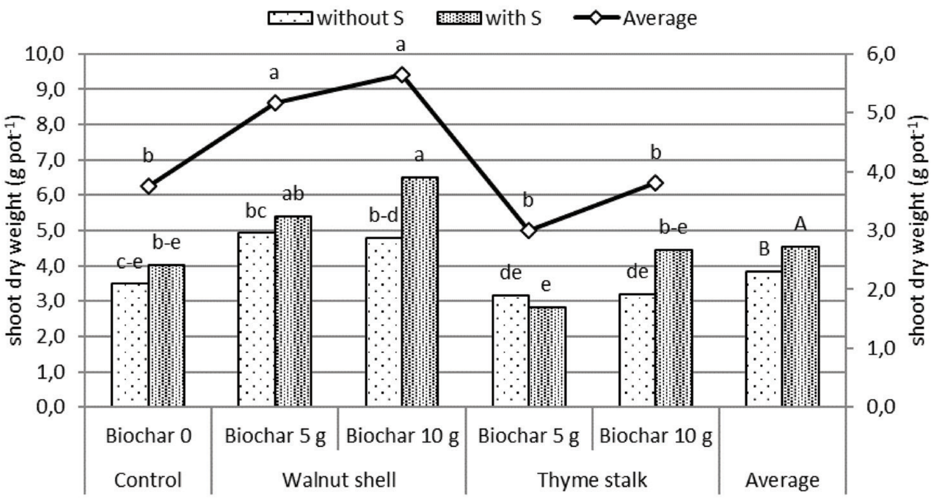

Figure 2. Shoot dry weight

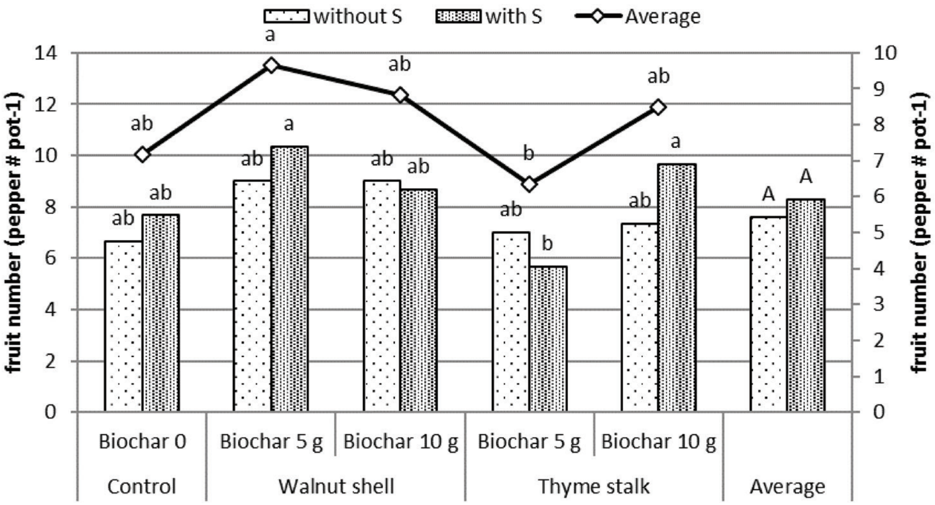

Figure 3. Fruit number

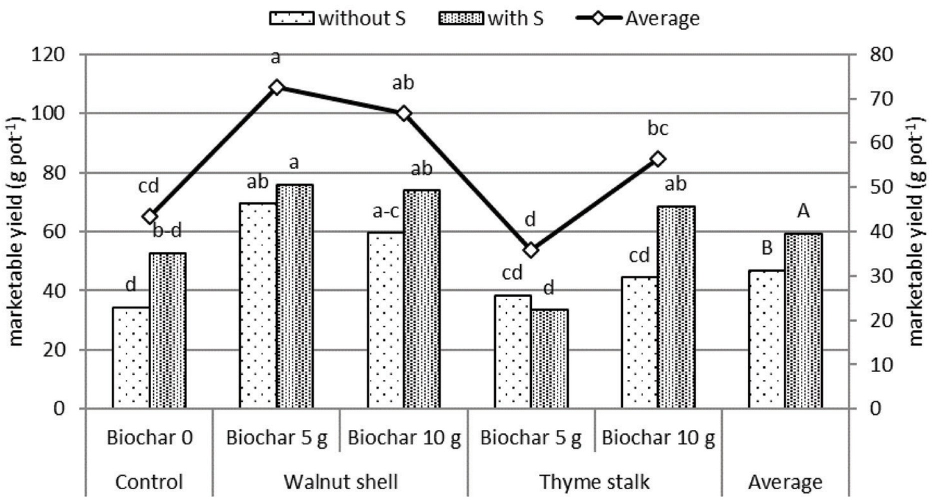

Figure 4. Marketable pepper yield

Shoot dry weight values were in accordance with root biomass weight whereas the higher positive influence was observed in walnut shell in both with or without sulphur addition (Figure 2). The highest value was in the highest walnut shell biochar applied pots along with sulphur applications. The average values of shoot dry weight were 4.86 and 3.52 g pot^{-1} for walnut shell and thyme stalk which walnut shell yielded 38% more shoot development. LeCroy *et al.* (2013) reported that biochar application may not always be beneficial, and may even cause adverse effects in some cases. Supporting this findings thyme stalk biochar has generally reduced the amount of dry matter of the plant in this experiment. Five g of thyme stalk biochar variant is an exception, sulphur applications increased shoot dry weight remarkably which reflected to the sulphur average values ($p<0.05$). Sulfur application is preferred to lower the pH in the areas which has high pH. The soil used in this experiment also has a high pH. Furthermore, Castaldi *et al.* (2011) have proposed that biochar application increases pH in the short term due to pH of the biochar is generally high (Fidel, 2012). Therefore the beneficial effect of sulfur application was related by increasing nutrient uptake as a result of decreasing pH.

Although the differences between the applications were statistically differing, the least influenced parameter was fruit number (Figure 3). The highest value in terms of mean values was determined in 5 g walnut shell biochar and sulfur applied pot, while the lowest value was determined in simultaneous application of 5 g thyme stalk biochar and sulphur. There was no difference between sulfur applications based on the averages ($p> 0.05$). Although the value obtained from the walnut shell biochar (8.6 fruit pot^{-1}) is greater than the value obtained from the thyme stalk biochar (7.3 fruit pot^{-1}), this difference is not statistically significant ($p>0.05$).

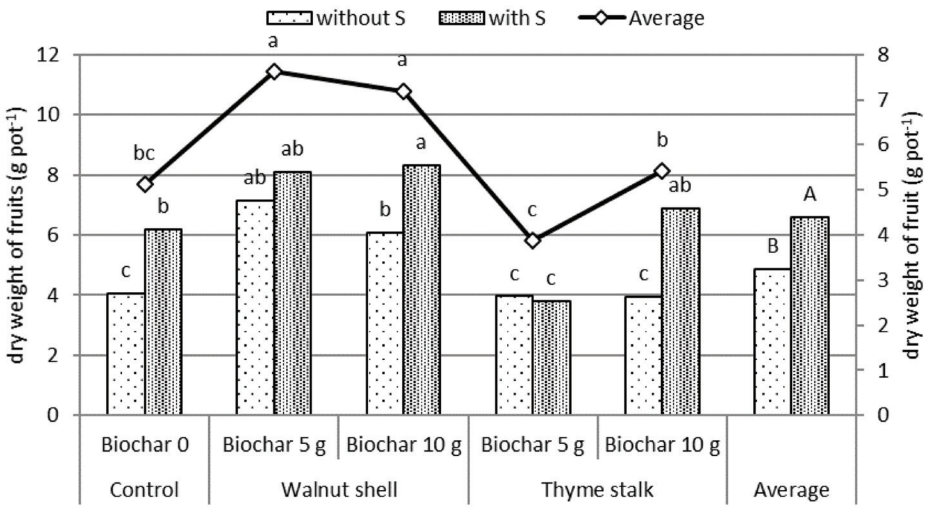

Figure 5. Fruit dry weight

During the growing period of the plant, two times fruits harvest were done and the total pepper yield value is presented in Figure 4. Probably the most major factor in farmer consideration is the yield which was the highest in combined applications of 5 g of walnut shell biochar and sulphur. Higher values have been determined once again at sulfur applied pots which sulfur application has a positive effect on yield. According to average values, 60.9 g of pepper per pot was harvested in walnut shell applied pots whereas this value was 45.2 in thyme stalk application. This difference between the biochar doses is statistically significant ($p < 0.05$). When the number of fruits and fruit weights were evaluated together, it was determined that applications were more effective on the fruit weights than the number of fruits.

After the determination of the fresh fruit weights, samples were dried out and dry weight values determined (Figure 5). This evaluation was done in order to demonstrate the fresh:dry weight ratio; however, no specific situation has been determined.

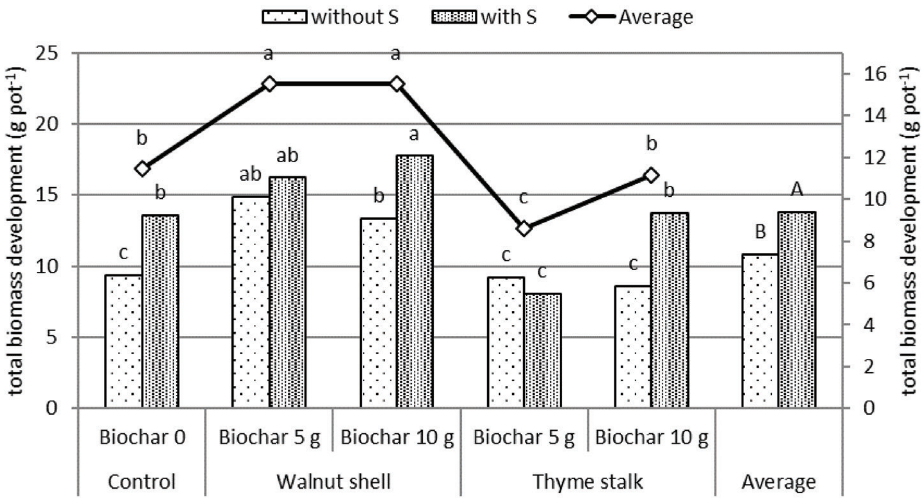

Figure 6. Total biomass development (dry total weight of root, shoot and fruits)

Total biomass formation is not important at the farmer level but it has a special importance because it shows the photosynthesis activity. The values in Figure 6 are the sum of dry weight of root, shoot and fruit of the plant and show the total biomass formation. Among these findings, the highest value was obtained from the pots that 10 g pot^{-1} walnut shell biochar and sulfur applied. The low dose of thyme stalk biochar application did not make any difference compared to the control. No doubt, sulfur has promoted biomass formation in terms of average values. As an average values, 14.2 g biomass was formed in the sulfur applied pots, whereas this value was 10.4 when the sulfur was not applied ($p < 0.05$).

CONCLUSSION

Results gathered strongly represent that the raw material leads great changes on the behavior of biochar; therefore, when referring to the biochar raw material must be mentioned. The effect of sulfur application on the determined parameters was found significant, and when applied together with biochar, this effect was found to be much more pronounced. It has also been determined that more studies required to determine optimum dose and raw material combination. According to the results of this study, it was determined that 0.1% walnut shell biochar and 0.1% sulfur should be recommended to farmers that cultivate pepper.

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