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THE EFFECT OF BIOCHAR FROM RICE HUSKS ON EVAPOTRANSPIRATION, VEGETATIVE GROWTH AND FRUIT YIELD OF GREENHOUSE TOMATO CULTIVAR ANNA F1 GROWN IN TWO SOIL TYPES

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ABSTRACT

Biochar made from crop residues has been shown to improve soil texture, soil porosity and soil structure. It can enhance fertilizer utilization, reduce leaching loses and hence improve nitrogen supply for plant growth. Utilization of biochar in preparation of potting substrates can enhance growth and yields of greenhouse tomato. A study was carried out to test the influence of rice husks biochar on substrate properties, growth and yield of greenhouse tomato. The experiment was carried as a factorial in completely randomized design with two factors: four biochar levels and two soil types, replicated three times. The biochar levels were volume ratios of 0 biochar: 1 soil (0Biochar), 0.25 biochar: 0.75 soil (0.25Biochar), 0.5 biochar: 0.5 soil (0.5Biochar) and 0.75 biochar: 0.25 soil (0.75Biochar). The two soil types used were the well drained deep red friable soil and imperfectly drained dark brown clay soil obtained from the University farm. Tomato Anna F1 was grown in four-liter plastic pots containing about 3 kg of soil-biochar mixture. Data were collected on the plant growth parameters of plant height, number of leaves per plant and plant dry weight upto the 8^{th} - 9^{th} week after transplanting, when fruit ripening began. The chlorophyll index of the leaves were measured using the SPAD meter. At harvesting, fresh weight and number of the fruits were determined. Incorporating biochar into potting substrate at 0.25-0.75 levels significantly increased evapotranspiration during early vegetative growth. This was indicative of biochar changing substrate properties mainly through significant reduction of bulk density and possibly increasing porosity. Biochar levels of 0.25-0.75 resulted in significant increases in vegetative growth and fruit yield of tomato. Adding biochar to the pot substrate increased tomato plant height, plant dry weight and fruit fresh weight by 21-34%, 50-64% and 49%-56%, respectively. The increase in vegetative growth and fruit yield at 0.25-0.75 biochar levels was attributed to the positive effect of biochar on substrate physical properties. Plant height and number of leaves per plant had a significant linear relationship whose slope, the rate of increase in plant height with increase in number of leaves was not influenced by biochar levels. Biochar enhanced growth without changing the ratio of plant height to number of leaves of tomato. It is concluded that incorporation of biochar made from rice husks at 0.25 level can enhance greenhouse production in both red and clay soils.

Key words: Bulk density, Dry weight, Fresh fruit weight, Number of leaves, Plant height

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INTRODUCTION

Biochar is a by-product of pyrolysis involving the thermal decomposition (exothermic) of biomass in an oxygen limited environment. Conversion of local bio-waste into biochar and its utilization as a soil amendment is of agronomic and environmental benefits [1]. Incorporation of biochar in soils and plant growth substrates has been shown to improve their physical and chemical properties. In Kenya, tomato as well as most vegetables grow optimally at pH range of 6-7.5 [2]. This often requires liming of acidic soils. Application of crop residue biochars has shown liming properties [3]. Applying biochar made from grain husk, paper fibre sludge and rice husk significantly increased pH of soil [4, 5]. However, there are cases where biochar application did not significantly change soil pH [6]. Applying biochar has been shown to significantly increase cation exchange capacity (CEC) and organic carbon of soils and plant growth substrates [5, 7]. These are often limiting to crop production in poor humid tropical soils.

Incorporating biochar in soils and growth substrates significantly reduces bulk density, increases porosity and water holding capacity [1, 3, 4, 5, 6, 8]. These effects suggest improved soil aeration and drainage and enhanced root growth, which ultimately may lead to better growth and yields of crops. This also implies that biochar is a potential material to be used in preparing pot growth substrates for vegetable crops as has already been shown for cucumber (*Cucumis sativus* L.) and cabbage (*Brassica oleracea* var. capitata) [9, 10].

Applying biochar has the potential to increase crop yields and this would likely be more pronounced on poor soils such as acidic humid and tropical soils. This is in line with the demonstrated positive effects of biochar on soil physical and chemical properties. Biochar from rice husks applied at 30 ton ha^{-1} was shown to significantly increase total dry matter of maize [11]. The positive effects of biochar application on rice (*Oryza sativa* L.) yield and yield attributes depend on the duration of biochar application [12]. Biochar made from tea leaves and co-inoculated with bacteria has been shown to enhance soil fertility, growth and yield of Mungbean (*Vigna mungo*) [13]. Blending urea with biochar made from urban green waste improved N-supply to maize, which was attributed to reduced leaching loses [14]. In tomatoes (*Lycopersicum esculentum* Mill.), it has been shown that applying timber waste biochar at 300 g/5 m^2 (0.6 t/ha) combined with 250 g/5 m^2 (0.5 t/ha) Trichoderma significantly increases plant height, number of leaves per plant, plant dry weight and fruit yield in terms of number and fresh weight per plant [15]. Similarly, another trial found that the growth rate of tomato in terms of plant height and stem diameter increased with increasing irrigation and biochar levels [16]. Yield was maximum at 25 ton ha^{-1} biochar level and it was concluded that application of biochar under full and severe deficit irrigation increased tomato yield [16]. There is limited data and information on incorporation of biochar in pot substrates for greenhouse tomato production. In this study, it is hypothesized that the incorporation of appropriate amounts of biochar in pot substrates will lead to improved growth and yield of tomato. The objective of this study therefore was to determine the effect of varying amounts of biochar in the pot substrates on the growth and yield of greenhouse tomato in selected soil types.

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MATERIALS AND METHODS

Experimental site

The experiment was conducted at Meru University of Science and Technology Demonstration/experimental Farm (latitude 0°08′08″N, longitude 37°42′24″E, 1420 m above sea level), in a plastic greenhouse between December 2019 and April 2020 and February-June 2020 for the first and second season, respectively. Growth temperatures ranged between 19.1°C to 19.8°C and 17.9°C to 20.6°C, for the first and second season, respectively.

Treatments and experimental design

The experiment was carried out as a factorial study in a completely randomized design with two factors: four biochar levels and two soil types. The biochar levels used were volume ratios of 0 biochar: 1 soil (0Biochar), 0.25 biochar: 0.75 soil (0.25Biochar), 0.5 biochar: 0.5 soil (0.5Biochar) and 0.75 biochar: 0.25 soil (0.75Biochar). The two soil types used were red soil and clay soil obtained from the university farm. The farm has two major soil types: the well- drained, extremely deep red friable soils and the imperfectly drained dark brown clay soils.

Biochar was made from rice husks (pyrolysis at 500°C was done at the Kenya Industrial Research and Development Institute, KIRDI Nairobi Kenya).

The soils were air dried to a constant moisture content, which was about 6.0 % and 9.0 % for red soil and clay soil, respectively. Potting substrate was prepared by mixing the soils and biochar according to the volume ratios and filled into 4- litre plastic pots to an average weight of about 3.0 kg. The exact weights were recorded and used to compute the gravimetric soil moisture contents. The experiment in each soil type had a set of five pots per biochar treatment replicated three times (60 pots per soil type), giving a total of 120 pots for the experiment.

Planting

Tomato (*Lycopersicum esculentum* Mill.) cultivar Anna F1 seedlings were raised on trays for four weeks in December 2019 and February 2020 for the first and second season, respectively. Transplanting was done in January and March 2020 for the first and second season, respectively. Watering was done by hand until the seedlings were well established in about one week.

Watering was done in the evening until saturated pots drained excess water from the bottom of the pots to leave soil at field capacity. The pots were weighed using a balance (model:Dahongying, Max 50 kg, Min 500 g, e=d=5 g) and each pot weight (P.W) was recorded as the 100 % pot capacity (PC) and 95 % PC was calculated as:

$$\mathrm{P.W\ 95\%\ PC} = \left((\mathrm{P.W\ 100\%PC} - \mathrm{P.W\ empty}) \times 0.95\right) + \mathrm{P.W\ empty}$$

Pots were weighed between 7.00 and 9.00 am each day and watering was done to maintain pot weighed at 95 % pot capacity. The difference in weights between two consecutive days was recorded as the evapotranspiration. Weighing of pots was stopped at the staking stage and water was delivered through drip irrigation to maintain moisture at about 95 % pot capacity. Soil moisture level was monitored periodically using soil moisture meter (model: DSMMS 500).

Triple super phosphate (46 % P_2O_5, TSP) was applied at planting at rate of 10 g per plant. This was mixed with soil media in the pots before planting. Calcium ammonium nitrate (CAN) was applied at rate of 30 g per plant. This was applied in five splits. In the first season, foliar feeds Easygro (NPK; 14:0:2+TE, 13 % Ca, 2.5 % Mg) and Quicelium (0.2 % B, 0.5 % Cu, 2 % Fe, 0.5 % Mn, 0.02 % Mo, 0.5 % Zn) were applied once every week. In the second season, these two were applied three times a week. The plants were pruned to one stem per pot. All suckers were removed immediately they formed. There were incidences of white flies, which were controlled with pesticides.

Data collection

Plant height, number of leaves, and chlorophyll index were determined weekly. Plant height was determined from base of the stem to the highest point using a meter rule. Plants were topped at the fruiting stage about 8 to 9 weeks after planting. Chlorophyll index was measured on the youngest leaf using the SPAD-502 meter. Plant dry weight was determined by the destructive harvesting of plants at crop establishment, during rapid vegetative growth and at the fruiting stage. Harvested plants were partitioned into roots, stems and leaves and dried at 70 °C for 48 hours in a hot air oven (Model: HAST70). Plant dry weight was measured using the Ohaus laboratory electronic balance (Model; CP 313, max 310 g, d=0.001 g).

Fruits were harvested at the turning stage and divided into marketable fruits and those with blossom end rot. The marketable fruits were counted and fresh weight was measured using the laboratory balance.

At the end of harvesting, the substrate physical and chemical properties were determined using standard laboratory procedures [17]. Bulk density was determined using the core method of undisturbed substrate from the pots. Empty cylinders of known volume and weight were used to take substrate samples from the pots. The substrate samples were dried to a constant mass in the hot air oven at 105 °C for 72 hours. The dry weight of substrate samples was determined using the electronic balance. Bulk density was calculated using the following formula:

$$\text{Bulk density (g/cm}^3\text{)}=\frac{\text{Substrate dry weight (g)}}{\text{Cylinder volume (cm}^3\text{)}}$$

where;

$$\text{Substrate dry weight (g)}=\text{Cylinder and substrate dry weight}-\text{empty cylinder weight}$$

pH was measured in a 2:5 media to water ratio using a pH meter. The CEC was determined using 1N-NH_4OAC at pH 7.

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Data analyses

Data on evapotranspiration, plant height, number of leaves per plant, chlorophyll index, dry weights and fruit yield were subjected to ANOVA using SAS. Mean separation was done using LSD at 5% significance level. Relationship between plant height and number of leaves was developed using linear regression in SAS.

RESULTS AND DISCUSSION

Evapotranspiration

There were no significant interaction effects between biochar levels and soil types on evapotranspiration. During December 2019-April 2020, evapotranspiration was significantly higher at 0.25-0.75 biochar levels between 18-20 days after transplanting (Fig. 1a). In February-June 2020, 0 and 0.25 biochar treatments had significantly lower evapotranspiration compared to the 0.5 and 0.75 biochar treatments between 1 to 11 days after transplanting (Fig. 1b). In 14 to 15 days after transplanting, 0.25-0.75 biochar treatments had significantly higher evapotranspiration than the 0 biochar treatment. In December 2019-April 2020, red soil had significantly higher evapotranspiration except at day 4, 5, 6 and 19 after transplanting, while in February-June 2020 red soil had higher evapotranspiration the whole period (Fig. 2a and b). Evapotranspiration at 0 biochar was between 67.0 %-78.0 % three weeks after transplanting in December 2019-April 2020 and 77.0 % to 80 % in February-June 2020 for the 0.25-0.75 biochar treatment. This finding suggests that application of biochar increases evapotranspiration, which can be attributed to the effect of biochar on soil physical properties. During the period, with increased evapotranspiration with biochar application, there were no significant differences in plant growth. Soils with biochar treatment had significantly lower bulk density and better aeration than soils without biochar. This means that biochar improves soil porosity, which has been shown to significantly increase with biochar application [18]. The red soil showed a higher evapotranspiration than the clay soil, which is the result of the significantly lower bulk density of the red soil.

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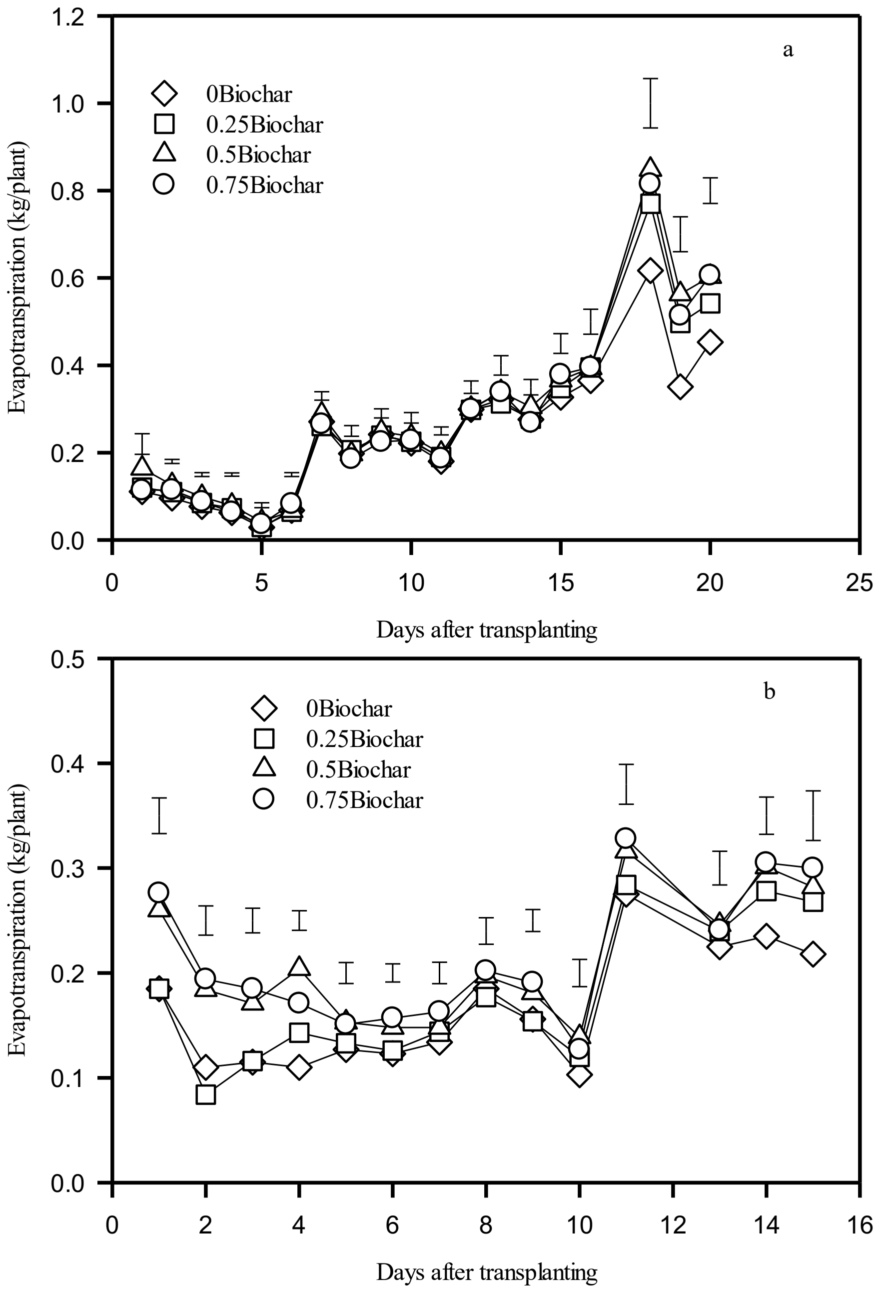

Figure 1: The evapotranspiration of greenhouse grown tomato as influenced by the biochar levels during December 2019-April 2020 (a) and February-June 2020 (b). Vertical bars show $LSD_{0.05}$.

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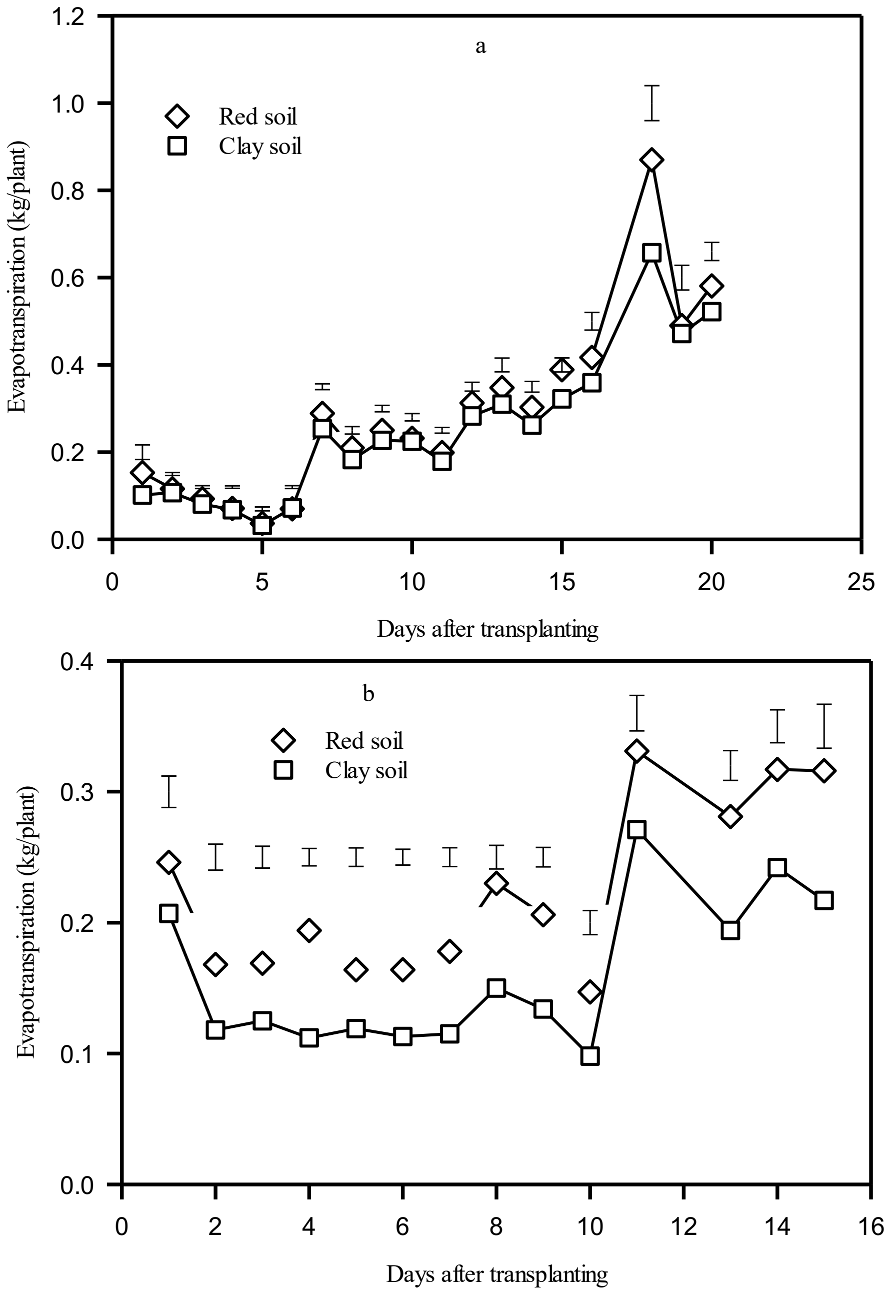

Figure 2: The evapotranspiration of greenhouse grown tomato as influenced by the soil types during December 2019-April 2020 (a) and February-June 2020 (b). Vertical bars show $LSD_{0.05}$.

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Substrate properties

There were no significant interactions between biochar levels and soil types. However, bulk density was significantly higher at 0 biochar treatment than the 0.25-0.75 biochar treatment in both seasons (Table 1). Similarly, the clay soil had significantly higher bulk density than red soil in both seasons (Table 1). Biochar treatments had no significant effect on unamended substrate pH in both seasons. However, substrate pH increased with increase in biochar level in December 2019-April 2020 but variable in February-June 2020 (Table 1). Red soil tended to be more acidic in December 2019-April 2020, although this was not significant. Clay soil exhibited significantly more acidic pH in February-June 2020 (Table 1). Biochar levels had no significant effect on CEC. This could be largely attributed to the soil types. Greater increases in CEC have been reported in loamy sandy soils ammended with biochar than clay soils [5]. However, the CEC tended to increase with biochar levels in both seasons (Table 1). Clay soils had higher CEC and this was significant in February-June 2020 (Table 1). The effect of biochar on substrate properties was more pronounced on bulk density. Addition of biochar to the substrate lowered soil bulk density. This is attributed to rice husk biochar having a significantly low bulk density of 0.16 g cm^{-3} compared to 0.96 and 1.05 g cm^{-3} for red soil and clay soil, respectively. Biochar made from a mixture of paper sludge and grain husks applied at 20 tha^{-1} was found to reduce bulk density by 12 % [18]. Use of commercial biochars made from different materials have been shown to reduce bulk density of growing substrates ranging from slight reduction to significant reduction [19, 20]. Biochar improved the soil water-holding properties through improved water infiltration. Substrates with 0 biochar treatment were observed to have transient flooding as an indicator of slow water infiltration. The effect of biochar on substrate pH and CEC was not conclusive. More studies are necessary to clarify this effect, considering that several studies have shown increase in both pH and CEC with biochar application [4, 5, 7].

Vegetative growth of Tomato

Plant height

In both seasons, plant height was not significantly affected by the interactions between biochar levels and soil types. Plants grown in the 0.25-0.75 biochar levels were significantly taller than those grown in soils without biochar (0 biochar level) between 5-8 and 5-9 weeks after transplanting, in December 2019-April 2020 and February-June 2020, respectively (Fig. 3a and b). In February-June 2020, plants in 0.5 and 0.75 biochar levels had significantly taller plants than those in 0.25 biochar, while plants in 0 biochar had the least height at 9 weeks after transplanting (Fig. 3b). Plants grown in red soil had significantly taller plants at 8 weeks after transplanting in December 2019-April 2020 (Fig. 3c). In February-June 2020, plants in red soil were significantly taller at 4-6 weeks after transplanting (Fig. 3d).

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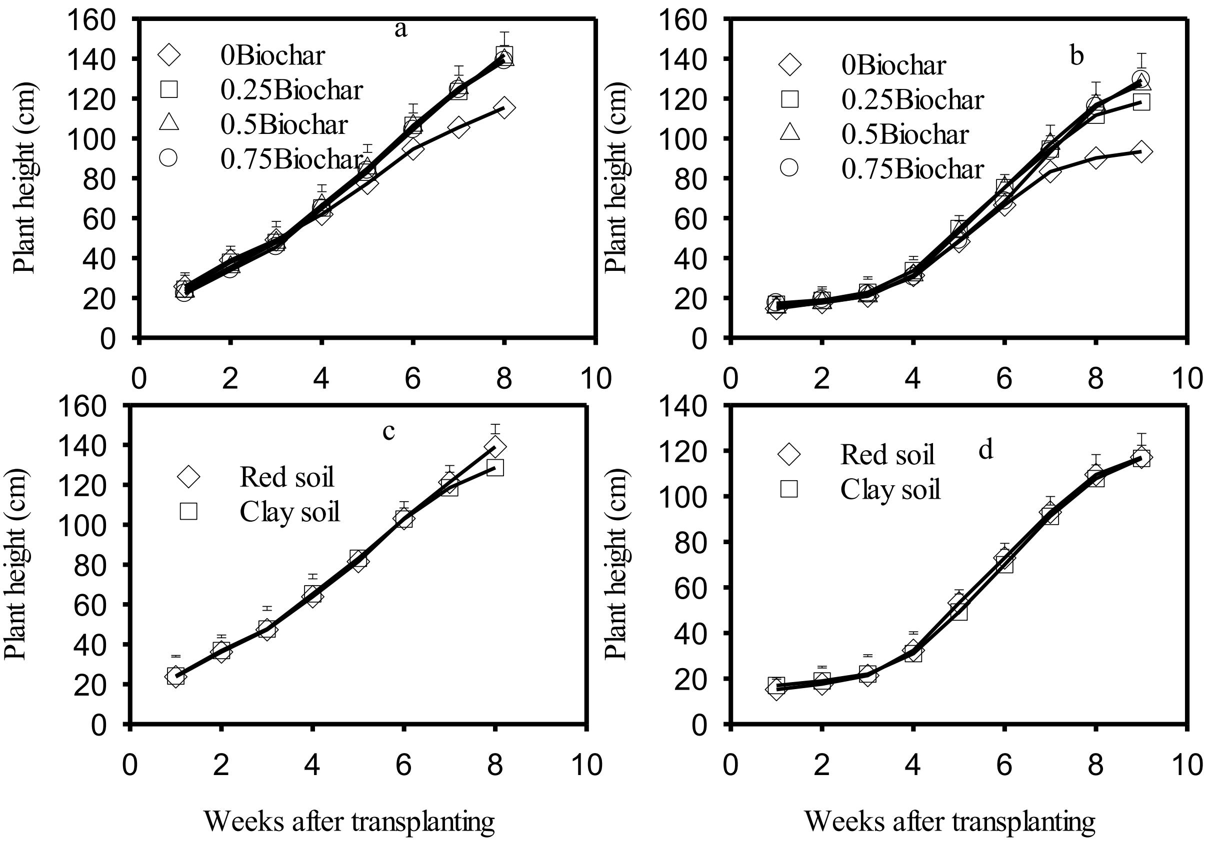

Figure 3: Plant height for tomato grown during December 2019-April 2020 (a, c) and February-June 2020 (b, d) as influenced by biochar levels and soil types. Vertical bars show $LSD_{0.05}$.

At 8 weeks after transplanting in December 2019-April 2020, 0.25-0.75 biochar levels resulted in increased plant height by about 21 % compared 0 biochar. This increase was about 34 % in February-June 2020. The increase in plant height with application of biochar can be attributed to the positive effect of biochar on the soil bulk density and aeration. Application of biochar has been shown to increase plant height of tomato and maize (*Zea mays* L.) [20, 21, 22, 23]. However, cases of no significant increase in plant height of tomato with application of biochar have been reported [24]. Soil types had significant effects on plant height at various periods during both seasons. However, the magnitude of the differences in plant height between red soil and clay soil were relatively low.

Number of leaves

There were no significant interactions of biochar levels and soil types on the number of leaves per plant. The effect of biochar levels on plant leaves was significant from 6 and 7 weeks after transplanting, in December 2019-April 2020 and February-June 2020, respectively. Plants grown in 0.25-0.75 biochar had significantly more leaves than the plants grown without bichar treatment, 0 biochar (Fig. 4a and b). Plants grown in red

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soil had significantly higher number of leaves than those in clay soil at 8 weeks after transplanting during December 2019-April 2020, and 3-6 weeks after transplanting during February-June 2020 (Fig. 4 c and d).

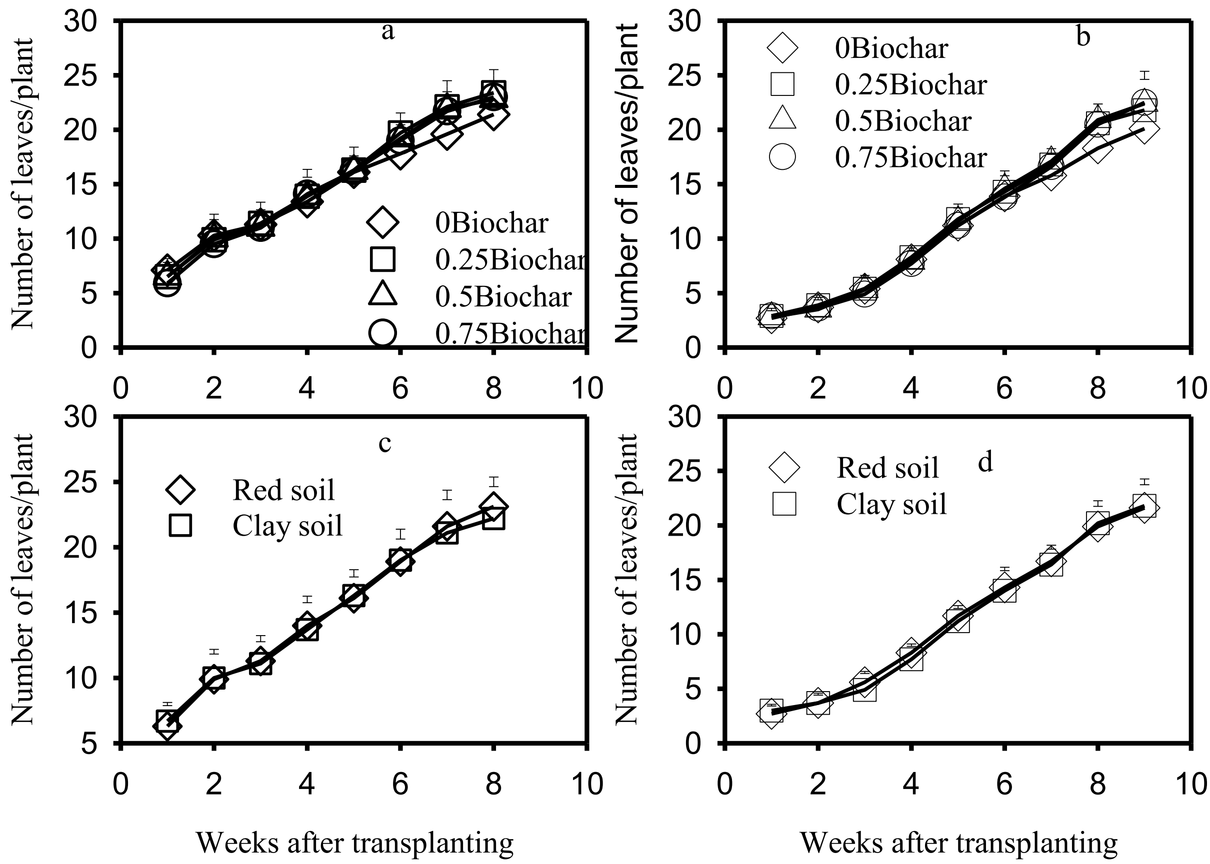

Figure 4: Number of leaves for tomato grown during December 2019-April 2020 (a, c) and February-June 2020 (b, d) as influenced by biochar levels and soil types. Vertical bars show $LSD_{0.05}$

Plants grown in substrates with 0.25-0.75 biochar had 2-3 more leaves than those grown in 0 biochar at 8-9 weeks after transplanting. Increase in number of leaves is indicative of better vegetative growth of tomato plants grown in substrates with 0.25-0.75 biochar. This can be attributed to lower bulk density and to some extent improved CEC. Increasing number of leaves in tomato with application of biochar has also been reported [23].

Relationship between height and number of leaves

Plant height and number of leaves had a significant linear relationship with a slope of 6.9 and 5.6, in December 2019-April 2020 and February-June, respectively (Fig. 5a and b, Table 2). Biochar levels had no significant effect on the slope, which refers to the rate of increase in plant height per unit increase in number of leaves.

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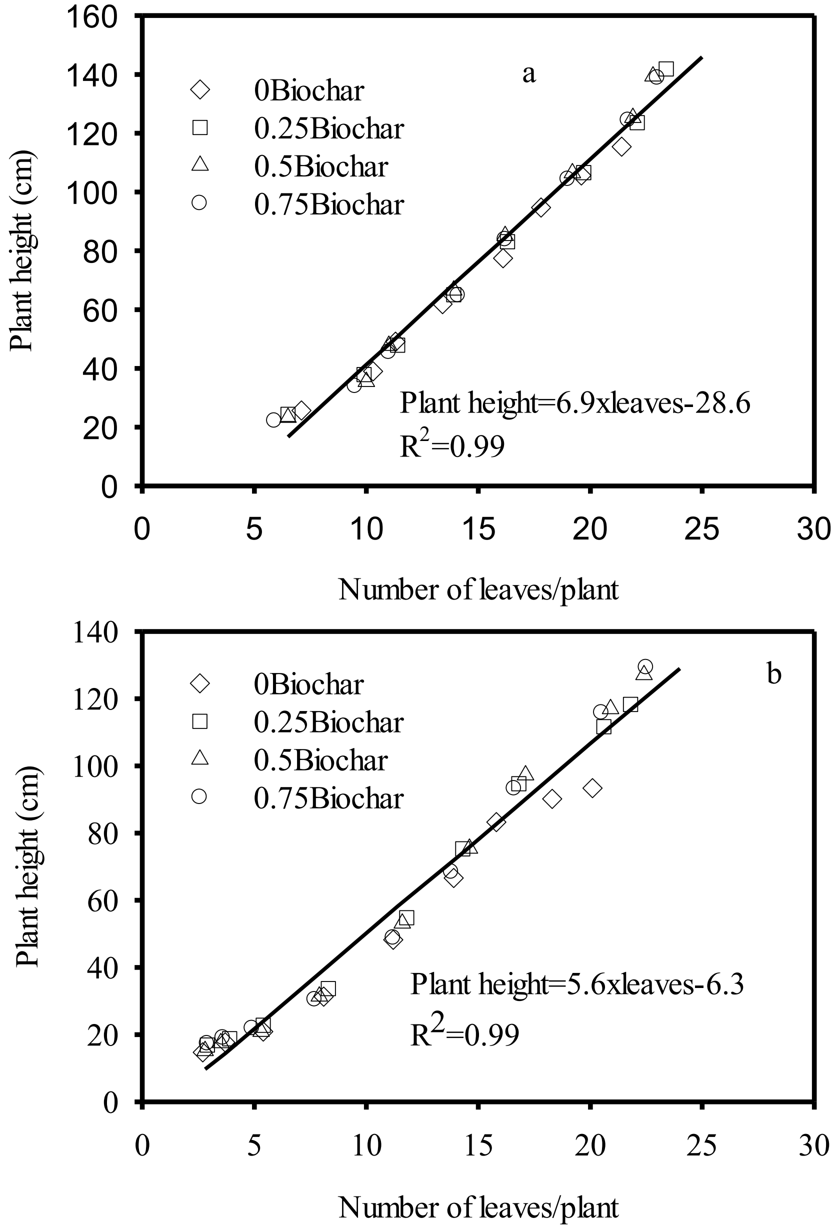

Figure 5: The relationship between plant height and number of leaves of tomato grown during December 2019-April 2020 (a) and February-June 2020 (b)

Applying biochar to the potted soil did not affect the relationship between plant height and number of leaves. This implies that while biochar significantly increased plant height and number of leaves per plant, it did not alter the ratio between plant height and number of leaves. Data reviewed from published manuscripts on biochar use has shown that biochar had no significant effect on above ground: below ground biomass ratio [25].

Dry weight
There was no significant interaction effect of biochar levels and soil types on dry weight in both seasons. In both seasons, there was no significant effect of biochar levels on dry weight between 1-5 weeks after transplanting. At 10 weeks after transplanting, plants grown in 0.25-0.75 biochar had significantly higher dry weight than those in 0 biochar (Table 3).

Soil types had significant effect on plant dry weight in December 2019-April 2020. During this period, plants in clay soil had significantly higher dry weight at 3 weeks after transplanting, than those in red soil which had significantly higher dry weight at 10 weeks after transplanting (Table 3).

Plants grown in substrates with 0 biochar had dry weight of 50-64 % of the dry weights of those in 0.25-0.75 biochar levels at 10 weeks after transplanting. The higher dry weight in plants grown in substrates with biochar indicates more growth, which can be attributed to improved substrate physical characterstics. The increase in dry weight with application of biochar observed in this study has also been reported by other researchers who used various crops such as maize (*Zea mays* L.), rice (*Oryza sativa* L., cv. Japonica), chilli (*Capsicum annuum* L.) and tomato [14, 20, 26, 27]. The biochar treatments significantly increased dry weight of tomato plants at ripening stage. Establishing the appropriate levels of biochar required for enhanced productivity of greenhouse tomato is important. Studies have shown that low levels of 0.5-1 % (w/w) of prepared biochar from broccoli crop residues gave shoot and root fresh and dry weights of tomato and bell pepper (*Capsicum annuum* L.) similar to that at 0 biochar [28]. On the other hand, higher levels of biochar reduced growth [28]. Tomato seedling growth was promoted by applying olive mill waste based biochar at 2.5 % and 5 % (w/w) after 10 weeks [29].

Chlorophyll index
There were no significant interaction effects of biochar levels and soil types on chlorophyll index (SPAD values). In December 2019-April 2020, the value was significantly higher in plants grown in 0 biochar at 2 weeks after transplanting. The chlorophyll index (SPAD value) ranged 36.4-59.5 (Fig. 6a). In February-June 2020, plants in 0 biochar had significantly higher values at 3 weeks after transplanting. However, plants grown in 0-25-0.75 biochar levels had significantly higher values at 8-9 weeks after transplanting (Fig. 6b). The chlorophyll index ranged from 23.9 to 55.0. Soil type had no significant effect on SPAD values in December 2019-April 2020 (Fig. 6c) while in February-June 2020, plants grown in red soil had significantly higher SPAD value at 2-3 weeks after transplanting (Fig. 6d).

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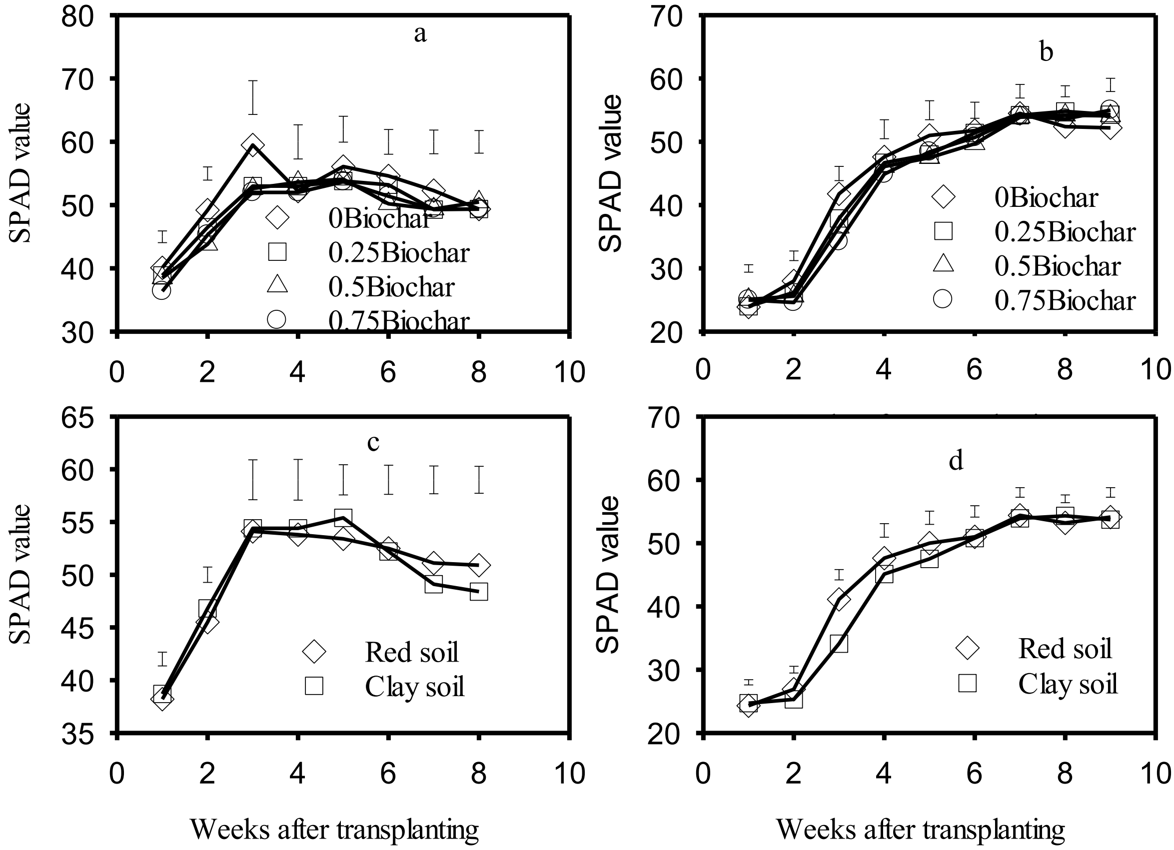

Figure 6: Chlorophyll index (SPAD value) for tomato grown during December 2019-April 2020 (a, c) and February-June 2020 (b, d) as influenced by biochar levels and soil types. Vertical bars show $LSD_{0.05}$

The effect of biochar levels and soil types on chlorophyll index (SPAD values) was not consistent, implying that biochar had minimal effect on chlorophyll content of the tomato leaves. Lack of significant effect of biochar on chlorophyll index has been reported in lettuce (*Lactuca sativa* L.) [30]. However, cases of biochar significantly affecting cholorophyll content have also been reported [28].

Fruit yield

There were no significant interaction effects of biochar levels and soil types on fruit fresh weight and number of fruits in both seasons although soil with biochar treatment had more fruit fresh weight than with soils without biochar. During the December 2019-April 2020 season, plants grown in 0.25-0.75 biochar had significantly higher fruit fresh weight than those grown in 0 biochar (Table 4). In that season, plants grown in the 0.25-0.75 biochar levels had higher fruit weights with blossom end rot than those grown in 0 biochar, but this was not significant and therefore only a trend of results. Plants grown in 0 biochar had significantly lower number of fruits than those in 0.25 and 0.75 biochar levels, but similar to those in 0.5 biochar (Table 4). In February-June 2020, plants grown in 0.25-0.75 biochar levels had significantly higher fresh fruit weight than those in 0 biochar (Table 4). Soil types had significant effect on number of fruits only in December 2019-April 2020. Plants grown in red soil had lower number of fruits (Table 4). This could be attributed to the lower CEC of red soil compared to clay soil.

Growing tomato plants in soils with 0.25-0.75 biochar increased fresh fruit weights by 56.0 % and 49.0 %, in December 2019-April 2020 and February-June 2020, respectively. Similarly, the number of marketable fruits increased by 37.0 % and 28.0 %, in December 2019-April 2020 and February-June 2020, respectively. The increased fruit yield in plants grown in soils treated with 0.25-0.75 biochar is a reflection of the higher vegetative growth due to better growing conditions. Repeated transient waterlogging observed in pots with 0 biochar possibly contributed to reduced vegetative growth and ultimately low fruit yields in plants. Similar increases in tomato and chilli fruit number and fresh fruit weight have been reported in several studies [20, 21, 27]. Other studies have reported no significant increase in tomato number of fruits per plant and fresh weight per plant with biochar application [22, 24].

CONCLUSION

It can be concluded from this study that incorporating biochar in soils at 0.25-0.75 on volume basis as a potting substrate for greenhouse tomato production significantly reduced the substrate bulk density. This level of biochar resulted in significantly increased vegetative growth and fruit yield of tomato. There was an indication that the biochar could also influence the substrate chemical properties. It is concluded that adding rice husk biochar to soil at 25.0 % upto 75% volume is beneficial to greenhouse tomato production irrespective of the soil type.

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Table 1: Selected physical and chemical properties of pot substrate for tomato grown during December 2019-April 2020 and February-June 2020 as influenced by biochar levels and soil types at end of experiment

	December 2019-April 2020			February-June 2020		
Biochar levels	**Bulk density (g/cm^3)**	**pH**	**CEC (cmol/kg)**	**Bulk density (g/cm^3)**	**pH**	**CEC (cmol/kg)**
0 Biochar	1.04a	5.57	21.50	1.05a	5.75	27.58
0.25 Biochar	0.89b	5.78	23.55	0.89b	5.60	55.65
0.5 Biochar	0.94b	5.91	26.30	0.90b	5.76	49.53
0.75 Biochar	0.85b	6.07	30.55	0.86b	5.77	46.00
LSD	0.09	-	-	0.09	-	-
P	0.0038	ns	Ns	0.0001	Ns	Ns
Soil types	**Bulk density (g/cm^3)**	**pH**	**CEC (cmol/kg)**	**Bulk density (g/cm^3)**	**pH**	**CEC (cmol/kg)**
Red	0.89b	5.43	17.80	0.89b	5.90a	35.62b
Clay	0.97a	6.23	33.15	0.96a	5.54b	53.77a
LSD	0.07	-	-	0.04	0.14	14.68
P	0.0419	ns	Ns	0.0027	0.0001	0.0185
CV	8	15	35	5	3	38

Means followed by the same letters down the column are not significantly different.

P=Probability, CV=Coefficient of variability.

Table 2: The slope and intercept for the linear relationship between plant height and number of leaves of tomato Anna F1

Season	**Slope**	**Intercept**	**R^2**
December 2019-April 2020	6.9 (6.2 to 7.6)*	-28.6 (-39.5 to 17.7)	99
February-June 2020	5.6 (5.0 to 6.3)	-6.3 (-14.5 to 1.9)	99

*The numbers in brackets show the 95% confidence limits for the slope and intercept

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Table 3: Plant dry weight for tomato grown during December 2019-April 2020 (a, b) and February-June 2020 (c, d) as influenced by biochar levels and soil types

Biochar level	December 2019-April 2020			February-June 2020		
	Weeks after transplanting			Weeks after transplanting		
	1	3	10	2	5	10
0Biochar	1.05	6.34	50.90b	2.07	8.47	27.90b
0.25Biochar	0.81	7.80	83.35a	3.11	12.99	50.68a
0.50Biochar	0.81	7.83	71.62a	2.60	10.24	58.50a
0.75Biochar	0.59	7.40	84.67a	2.71	8.17	54.98a
$LSD_{0.05}$	-	-	14.11	-	-	12.62
P	ns	ns	0.0004	ns	Ns	0.0004
Soil type						
Red	0.69	6.61b	77.65a	3.09	10.34	43.96
Clay	0.94	8.08a	67.62b	2.16	9.57	52.07
$LSD_{0.05}$	-	0.95	9.97	-	-	-
P	ns	0.0045	0.0485	ns	Ns	Ns
CV	20	15	16	30	32	21.5

Means followed by the same letters down the column are not significantly different.
P=Probability, CV=Coefficient of variability

Table 4: Fruit weight and number for tomato grown during December 2019-April 2020 (a, b) and February-June 2020 (c, d) as influenced by biochar levels and soil types

Biochar levels	December 2019-April 2020		February-June 2020	
	Fresh weight (g/plant)	Number of fruits/plant	Fresh weight (g/plant)	Number of fruits/plant
0 Biochar	705.2b	10.6b	888.3b	9.5c
0.25Biochar	1141.0a	15.2a	1244.7a	10.9bc
0.50 Biochar	975.3a	13.3ab	1317.4a	11.9ab
0.75 Biochar	1171.0a	15.1a	1408.2a	13.5a
$LSD_{0.05}$	210.2	3.1	185.0	2.1048
P	0.0001	0.0135	0.0007	0.0062
Soil type				
Red	971.4	11.8b	1218.2	11.7
Clay	1020.2	15.2a	1173.9	10.9
$LSD_{0.05}$	-	2.2	-	-
P	ns	0.0033	Ns	Ns
CV	31	34	17	14

Means followed by the same letters down the column are not significantly different.
P=Probability, CV=Coefficient of variability

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