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Evaluation of coconut biochar as a soil amendment for enhanced productivity of sweet peppers (*Capsicum annuum* L.) in Joanna, Black Bush Polder, Corentyne, Berbice, Guyana

Roshnie Singh [1], Gomathinayagam Subramanian [2,*] and Abdullah Ansari [3]

[1] *Division of Natural Science, University of Guyana Turkeyen Campus, Guyana.*
[2] *Division of Agriculture Science, University of Guyana Berbice Campus, Guyana.*
[3] *Faculty of Natural Science, University of Guyana Turkeyen Campus, Guyana,*

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Abstract

Agriculture plays a vital role in providing food globally including Guyana, however, the increase in the human population adversely decreases farm size, which results in nutrient depletion on existing farms due to extensive farming activities on the same land season after season. Biochar is commonly used as a non-conventional farming system to enhance the soil's quality and simultaneously to produce better yield of various staple food crops. Therefore, the purpose of this study was to evaluate the effectiveness of coconut biochar as a soil amendment and to quantify its impact on the growth performance of sweet peppers (*Capsicum annuum* L.) in Joanna, Black Bush Polder, Corentyne, Berbice, Guyana. A field trial was carried out using the randomized block experimental design with 15 g, 30 g, 45 g biochar; 2 g NPK; and control, each replicated on clayey loam soil. The physico-chemical characteristics of biochar were determined along with the soil-biochar mixture before and after cultivation. In addition, vegetative and reproductive parameters of the sweet peppers, nutrient content of the fruits and chlorophyll content of the leaves were examined. The results obtained from this study revealed that biochar played a minor role in enhancing the yield of the sweet peppers (31.44 g) and amending the soil characteristics when compared to the control. It was observed in this study that soil pH (8.4), organic carbon (1.9 %), carbohydrates concentration (1.25 %) of fruits and chlorophyll content (a:5.6097µM, b: 5.4833 µM, total: 11.093 µM) of the leaves increased with the application of biochar. Based on the obtained results, it can be inferred that biochar may potentially be recommended in the range of 30 g to 45 g as a soil amendment to enhance the growth performance of sweet peppers, however, further experiments with diverse crops and soils are still required to investigate the use of the exact quantity of biochar sourced from different materials.

Keywords: Biochar; Sweet peppers; Joanna; Black Bush Polder; Soil amendment; Coconut

1 Introduction

The world population growth rate is increasing day by day at an alarming rate (Elferink & Schierhorn, 2016). Global statistics reveal presently that approximately 7.7 billion people are living on earth (Cleland, 2013) and a significant enhancement in population is expected at a rate of approximately 1.05 % per year and will continue to escalate in the 21st century (Cleland, 2013). Thus, the massive increase in the human population may impacts arable lands tremendously, since more space is needed to build homes, and other important facilities such as farms space to produce food are required to accommodate the growing population (Ricker-Gilbert *et al*., 2014). Moreover, an utmost challenge for agriculture all over the world, demands production of approximately 70% more food crops for an extra 2.3 billion people expected by 2050 globally (Ricker-Gilbert *et al*., 2014). Since production is minimal, the demand for more food

* Corresponding author: Gomathinayagam Subramanian

is expected to increase as per population ratio, thereby, advancing pressure on the agricultural sector, more specifically on the farmers to expand the production of crops and maintaining a healthy environment (Elferink & Schierhorn, 2016).

Increasing human population and simultaneously reducing the land available for crop cultivation are two major threats for agriculture worldwide (Elferink & Schierhorn, 2016). The continuous planting of crops on the usable agriculture land season after season may decrease the soil's value. As such, plants are experiencing major challenges in order to obtain sufficient soil nutrients which are required for maintaining fundamental biological processes due to their stability (Morgan & Connolly, 2013). Therefore, nutrient inadequacy effects result in an overall decrease in plant productivity. A number of important symptoms may include underdeveloped plants, necrosis, poor seed germination, and chlorosis (Morgan & Connolly, 2013).

Some studies reveal that soil nutrient depletion is a major factor that is directly linked to food insecurity in most provinces as a result of the heightening of production activities with inadequate soil management (Henao & Baanante, 1999). Several strategies have been developed by many farmers in order to enhance crop productivity on existing agricultural lands, but recently the application of synthetic fertilizers seems to be a promising one. Synthetic fertilizers are manufactured products that supply plants with nutrients. These manufactured fertilizers are made to boost plant performances or enhance the nutrients needed for plant growth in the soils (Food and Agriculture Organization, 1979). Despite their beneficial effects, synthetic fertilizers pose long-term challenges that impact the environment negatively (Kumar & Prakash, 2019). It kills beneficial soil microbes that turn dead humus and plant remains into nutritious organic manure. Fertilizers containing nitrogen and phosphate filter into water and expand toxicity, thereby contaminating the water and degrades the soil's quality. Plants grown in soils with excess fertilizers are lacking fundamental nutrients such as iron, zinc, carotene, vitamin C, copper, and protein. Also, these fertilizers disrupt aquatic ecosystems (Kumar & Prakash, 2019). More so, synthetic fertilizers increase the soil's nitrate level. Plants grown under such an environment, upon digestion, are changed to lethal nitrites in the intestine. Nitrites are hazardous to humans and interact with the hemoglobin in the bloodstreams, resulting in methemoglobinaemia, which destroys the transport and respiratory systems (Gilani, 2020; Sabry, 2015). On the other hand, organic fertilizers are nature's by-products, such as plant residues, that offer a slow release of nutrients to the soil that may be used to enhance the productivity and fertility of soils with little to no environmental pollution. Thus, organic fertilizers can be used to cultivate crops with improved productivity to satisfy the need of the growing population (Singh, 2012).

Many countries worldwide, including Guyana, are focusing on establishing food security and sustainability, which is needed to feed the growing population and maintaining an eco-friendly environment (Pretty, 2008). In modern decades, agriculture production has increased tremendously, with major growth in food production worldwide. Food production has increased by 145%, since the beginning of the 1960s. In Africa, it rose by 140%, Latin America by almost 200%, and Asia by 280%. However, a massive increase by five-fold has occurred in China (FAO, 2005).

In the past few decades, global agricultural trade has increased significantly with contributions from Latin America and the Caribbean region. In Guyana, according to Winston Jordan in 2018, agriculture is one of the priority areas, who emphasized on food reliability, safety, fruitfulness, better infrastructure, new value chains, and advanced industries that magnify investment in agro-industry, and organization dimensions. Also, the finance minister highlighted that approximately 1,500 farmers will be furnished with comprehension and expertise in breeding and certified seed production (Department of Public Information, 2018). Hence, the agricultural section is anticipating growth by 2019 with approximately 3.9% (Department of Public Information, 2018). With this being done, more food is expected to be available and may qualify for exports.

A number of reports highlighted that the incorporation of biochar enhances crop productivity. A study in pot culture was carried out whereby green-waste biochar was used to alter the soil. The results obtained from this study have shown the positive effects on crop production and soil quality (Chan *et al*., 2007). Likewise, field trials resulted in remarkable increases in crops, especially when biochar was applied to the soil (Yamato, *et al*., 2006).

2 Material and methods

2.1 Site of Work

This project was conducted on a farm located in Joanna, Black Bush Polder, Corentyne, Berbice, Guyana. Analysis of soil samples was done at the University of Guyana, Berbice Campus, John's Science Centre, and at Nand Persaud Soil and Plant Testing Laboratory. Analysis of biochar, sweet peppers, and leaves was done at GUYSUCO, L.B.I. Laboratory.

2.2 Sampling Site

The agricultural field used was located in Joanna, Black Bush Polder. The land was measured and the experiment was set up on a 76 ft by 12 ft plot with five treatments, three replicates each.

2.3 Production of Biochar

2.3.1 Collection of Materials

One hundred coconuts were purchased from a farm located in Joanna, Black Bush Polder. The shells and husks were removed and used to make biochar through the pyrolysis process using an improvised version of the cone pit method.

2.3.2 Making Biochar

A longitudinal cut of approximately 374 mm in width was made on a 55-gallon barrel. Wood scraps were used to start up the fire within the barrel as shown as Figure 1. A few shells and husks were added and it was allowed to develop a lot of heat as shown as Figure 2. Shells and husks were continuously packed on top of the lighted/heated materials in the barrel and allowed to char as shown as Figure 3. The heated char was quenched with water and allowed to cool. Cooled char was removed from the barrel and ground to be used as shown as Figure 3 and 4. Ground char was charged and inoculated as shown as Figure 5.

Figure 1 Making Biochar

Figure 2 Making Biochar

Figure 3 Making Biochar

Figure 4 Biochar

Figure 5 Crushed Biochar

Figure 6 Charging Biochar

2.4 Vegetative Performance

Average Number of Leaves, Average Length of Leaves, Surface Area of Leaves (small, medium, large), Shoot Length, No. of Branches, Fresh weight of roots and shoots and Dried weight of roots and shoots were used standard methods.

2.5 Reproductive Performance

Number of Fruits, Weight of Fruits, Average Fruit Diameter, Average Fruit Length, Length/Diameter Ratio of the Fruit, Average Number of Seeds, Average Weight of Seeds, Number of Nodes, and Yield of Buds were used standard methods.

Laboratory Analyses of Soil + Biochar Mixture, Biochar, and Fruits the following bio-chemical analyses such as Protein (Jones, 1991), Lipid (Dittmer *et al*., 1969), Total Carbohydrates (Magwaza & Opara, 2015), Vitamin C (Abdullah, 2016) Measurement of reduced Vitamin C, Chlorophyll Content Analysis (Manolopoulou *et al*., 2016) were used standard methods.

Soil and Biochar Analyses of Bulk Density (Gerlach *et al*., 2002), Particle Density (Gerlach *et al*., 2002), Porosity (Gerlach *et al*., 2002), Hydrophobicity (Gerlach *et al*., 2002), Moisture Content (Lee & Latham, 1976), Electrical Conductivity (Motsara & Roy, 2008), pH (Motsara & Roy, 2008), Organic Carbon (Homer, 2003), Phosphorous (Homer, 2003), Nitrogen (Homer, 2003), and Potassium (Homer, 2003) were used standard methods. The above procedures were repeated for all the treatments.

2.6 Statistical Analysis

Statistix 10 Program - RCBD ANOVA was used for statistical analysis. Physicochemical characteristics were analyzed descriptively. Data analyzed were generated and displayed via tables and graphs using Statistix 10 Program and Microsoft Excel Program.

3 Results

The effectiveness of coconut biochar as a soil amendment on the growth variables of *Capsicum annuum* L. in Joanna, Black Bush Polder, Corentyne, Berbice, Guyana. Based on our observations, no major significant differences between the vegetative and reproductive parameters of the sweet pepper plants were found. The soil + biochar mixture before and after cultivation displayed a change in value for each characteristic analyzed. Also, the nutrient and chlorophyll contents of the peppers and leaves tested had no significant differences.

Table 1 Physico-chemical Parameters of Coconut Biochar

Parameters	**Values**
Moisture Content (%)	29.71 ±0.07
Bulk density (g/cm^3)	70.29 ±4.03
Particle Density (g/ml)	0.20 ± 0.00
Porosity (%)	74 ± 4.2
Hydrophobicity (seconds)	66
pH	9.99
Electrical Conductivity (µs)	803
Organic Carbon (OC) (%)	84.5
Nitrogen (N) (mg/kg)	7825
Phosphorous (P) (mg/kg)	152
Calcium (Ca) (meq/100g)	1.35
Copper (Cu) (mg/kg)	Nd
Iron (Fe) (mg/kg)	6.65
Manganese (Mn) (mg/kg)	11.9

Nd – not detected

The physico-chemical characteristics of coconut biochar are shown in Table 1. During the analysis of the biochar, there was no detection of copper. This occurs because the level of copper that was present in the biochar may have been extremely low, which was beyond detection using the Atomic Absorption Spectrophotometer.

3.1 Vegetative Parameters

The Figure 1 and 2 of clustered columns depicts the mean shoot fresh weight and dry weight per treatment, respectively. The findings of this study revealed that no significant differences ($p>0.05$) existed between the various treatment for the shoot fresh weight and shoot dry weight. The shoot fresh weight for treatment 3 had the greatest mass, while treatment 4 had the lowest mass. The dry shoot weight for treatment 2 had the most weight, while treatment 4 had the least weight.

3.1.1 Fresh and Dry Weight of Shoot, Fresh and Dry Weight of Root

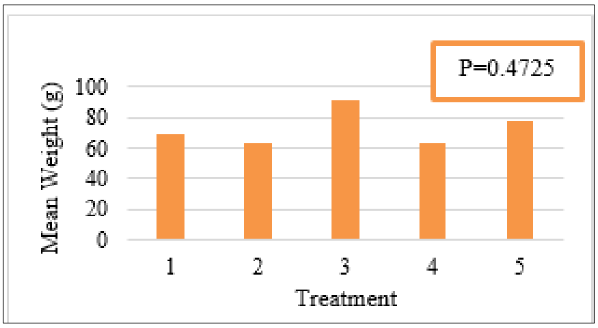


Figure 7 Mean Shoot Fresh Weight per Treatment

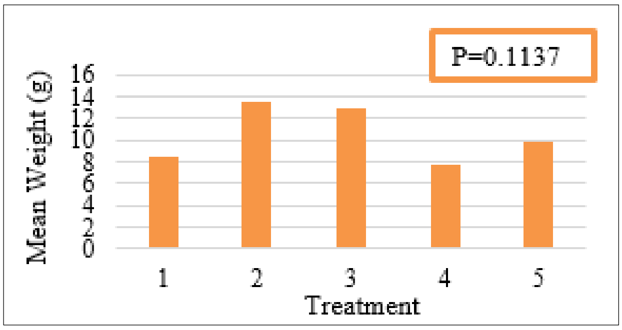


Figure 8 Mean Shoot Dry Weight per Treatment

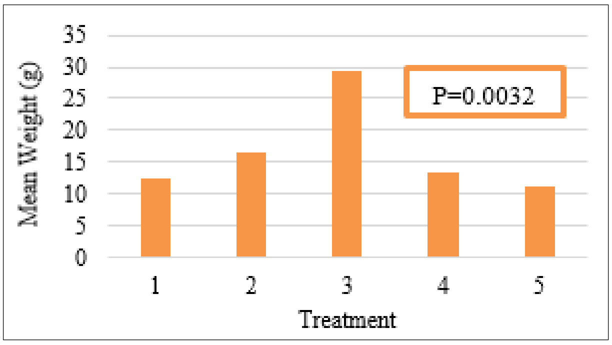


Figure 9 Mean Root Fresh Weight per Treatment

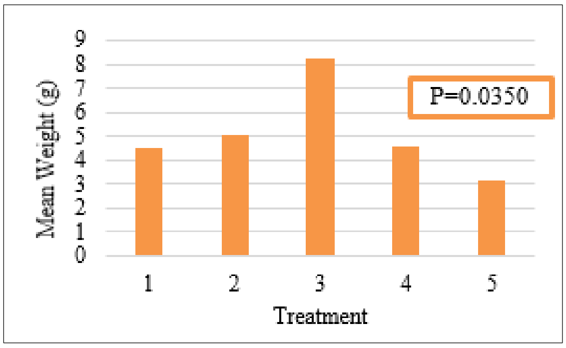


Figure 10 Mean Root Dry Weight per Treatment

The Figure 9 and 10 of the clustered columns depicts the mean root fresh weight and dry weight per treatment, respectively. The findings of this study revealed that significant differences ($p<0.05$) existed between the various treatments for the root fresh weight and root dry weight respectively. The fresh root for treatment 3 had the most weight when compared to the other treatments, while treatment 5 had the least weight. The dry root for treatment 3 had the greatest mass, while treatment 5 had the least weight.

3.2 Shoot Length

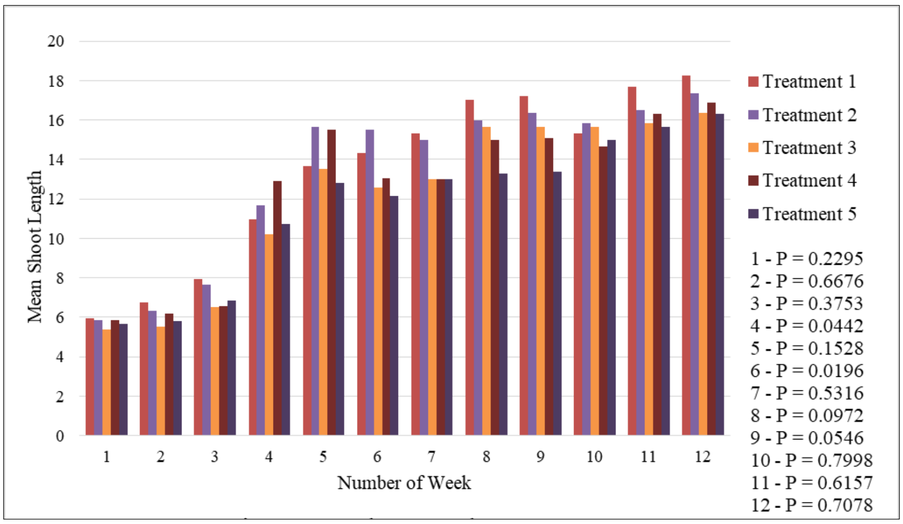


Figure 11 Mean Shoot Length per Treatment

The Figure 11 of clustered column displays the mean shoot length per treatment for twelve (12) consecutive weeks. The results revealed that no significant differences (p>0.05) existed among most treatments for the 12 weeks. Weeks 1, 2, 3, 5, 7, 8, 10, 11, and 12 were not significantly different, while weeks 4, 6, and 9 exhibits significant differences (p<0.05) among the spiked treatments. For most of the weeks, treatment 1 had the greatest shoot length as compared to the other treatments, while treatment 3 and 5 had the shortest shoot length, however, it fluctuated at some points.

3.3 Reproductive Parameters

3.3.1 Average Diameter of Fruits

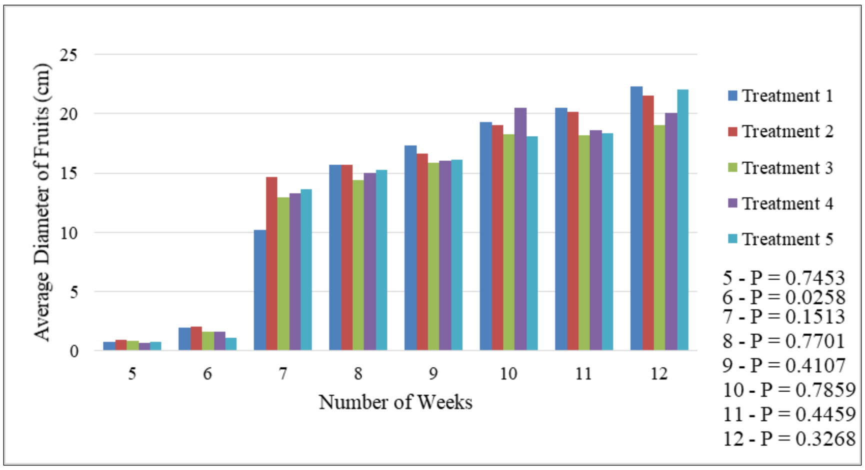


Figure 12 Average Diameter of Fruits

The Figure 12 of clustered column is depicting the average diameter of fruits (sweet peppers) for 12 consecutive weeks. The results showed that there was no significant difference (p>0.05) among the various treatments, except for week 6. From week 5 to 7, treatment 2 had the greatest diameter, whereas, for the remaining weeks' treatment 1 had the greatest diameter. The fruits from treatment 3 had the smallest diameter.

3.3.2 Number of Seeds

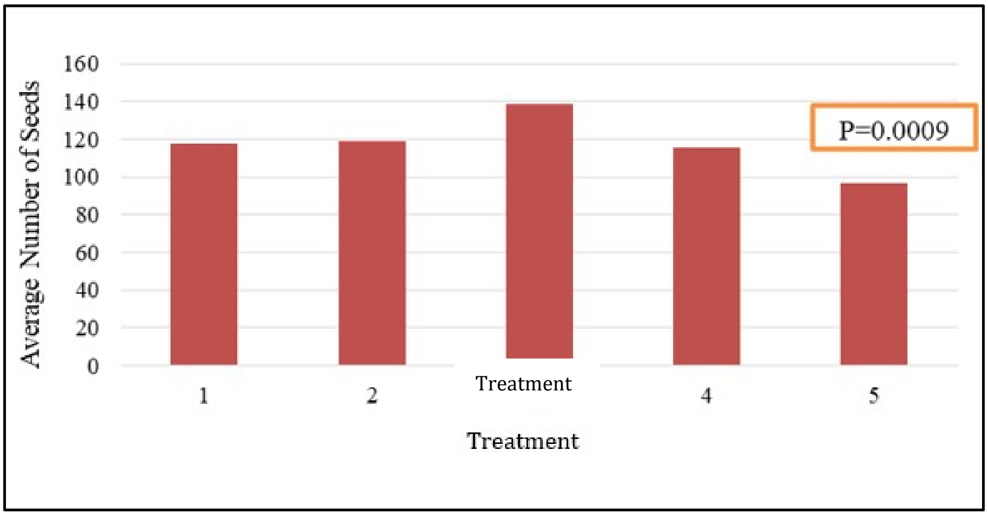


Figure 13 Average Number of Seeds

The Figure 13 of clustered column illustrates the average number of seeds found in the sweet peppers for the different treatments. The results highlighted that a significant difference (p<0.05) existed among the various treatments. Fruits from treatment 3 had the most seeds when compared to the other treatments, while treatment 5 had the least seeds.

3.3.3 Number of Fruits

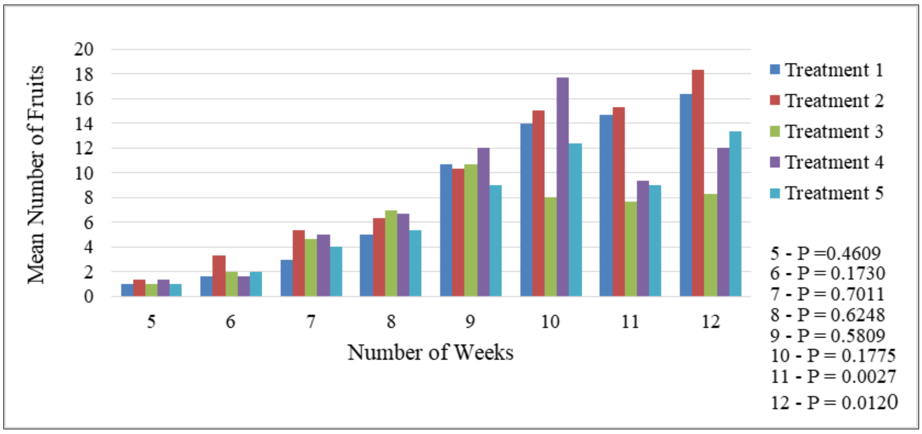


Figure 14 Mean Number of Fruits

The Figure 14 of clustered column demonstrates the average number of fruits for the different treatments. The findings highlighted that no significant differences (p>0.05) existed among the treatments for the various weeks, except for week 11. Overall, the treatment with the most fruits was treatment 2, however, it fluctuated at some point, when compared to the other treatments.

To evaluate the changes in soil quality, before and after the production of sweet peppers, when mixed with various rates of biochar

3.4 Soil parameters before cultivation

Table 2 The value of each parameter for the given treatments

	SOIL PARAMETERS						
TREATMENTS	**Moisture Content (%)**	**Bulk Density (g/cm³)**	**Particle Density (g/ml)**	**Porosity (%)**	**Hydrophobicity (sec)**	**pH**	**E.C. (µs)**
1	23.53 ±0.52	75.14 ±1.61	0.1367 ±0.005	72 ±0.33	28.150 ±4.02	6.7167 ±0.2	55.2 ±0.85
2	25.42 ±6.30	76.03 ±1.72	0.1467 ±0.005	71 ±0.33	20.557 ±2.28	6.8767 ±0.02	82.3 ±0.7
3	25.02 ±2.90	76.43 ±4.72	0.1467 ±0.005	71 ±1.33	19.000 ±1.10	7.0700 ±0.03	86.1 ±0.25
4	18.69 ±5.70	81.13 ±4.01	0.18 ±0.01	69 ±1.00	16.913 ±0.73	9.0567 ±0.04	1139.7 ±39.5
5	18.29 ±4.90	83.61 ±3.16	0.1467 ±0.005	69 ±0.67	19.177 ±4.5	9.0500 ±0.05	61.4 ±0.55
	P= 0.3510	P= 0.0700	P= 0.0010	P=0.2068	P= 0.0363	P= 0.0000	P= 0.0000

P>0.05 – no significant difference; P<0.05 - significant difference; P=0.00 – a highly significant difference

The Table 2 is showing the physical characteristics of the soil before cultivating sweet peppers. Based on our observed results, the treatment with the greatest moisture content was treatment 2, while treatment 5 has the lowest moisture content. Treatment 5 had the greatest bulk density, while treatment 1 had the lowest bulk density. The treatment with the greatest particle density was treatment 4, and the lowest was treatment 1. The treatment with the most pore space was treatment 1, and the least were treatments 4 and 5. The treatment with the most water phobic property was treatment 1, while treatment 4 displayed less hydrophobicity. Treatment 4 had the highest pH, indicating its alkaline content, while treatment 1 was the least alkaline. The treatment with the highest saline content was treatment 4, while treatment 1 had the lowest salinity.

Table 3 The value of each parameter for the given treatments

	Soil Parameters						
Treatments	**Organic Carbon (%)**	**Nitrogen (ppm)**	**Potassium (ppm)**	**Calcium (ppm)**	**Manganese (ppm)**	**Copper (ppm)**	**Iron (ppm)**
1	1.280	124.60	43.00	1400	559.80	0.23	4.77
2	1.087	135.20	222.64	1600	437.70	0.41	4.20
3	0.945	144.41	725.70	1200	466.60	0.19	3.03
4	2.759	235.50	2040	1000	53.16	0.73	18.01
5	0.759	104.11	141.8	1200	520.10	0.35	4.20

The Table 3 is showing the chemical characteristics of the soil before the production of sweet peppers. The treatment with the most organic carbon was treatment 2, while treatment 5 had the least organic carbon. Treatment 4 had the most nitrogen, while treatment 5 had the lowest nitrogen content. The most potassium was found in treatment 4, the least was found in treatment 1. Treatment 2 had the most calcium, while treatment 4 had the smallest amount. The greatest amount of manganese was found in treatment 1, while the least was found in treatment 4. Copper was present the most in treatment 4, while it was at its lowest in treatment 3. Treatment 4 was rich in iron, while treatment 3 was very poor.

3.5 Soil parameters after cultivation

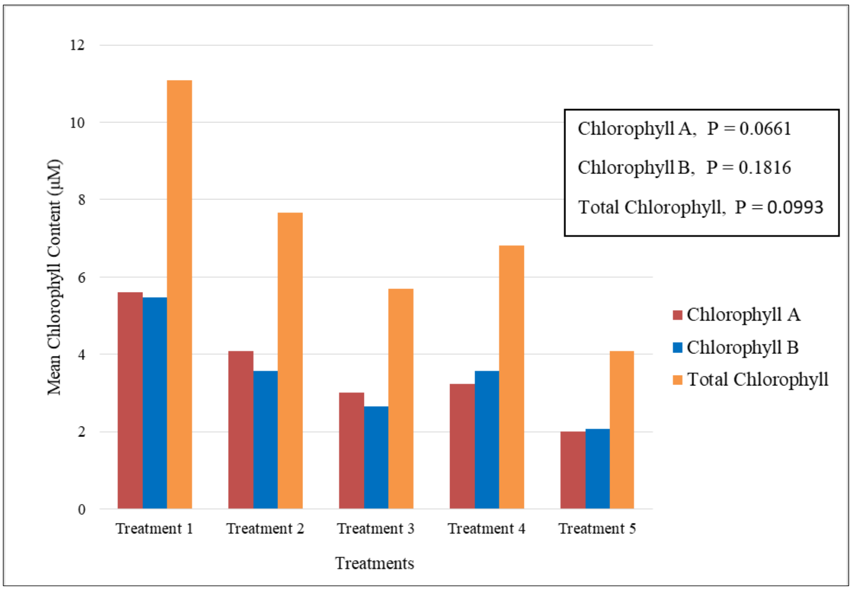
Table 4 The value of each parameter for the given treatments

Treatments	**SOIL PARAMETERS**						
	Moisture Content (%)	**Bulk Density (g/cm³)**	**Particle Density (g/ml)**	**Porosity (%)**	**Hydrophobicity (sec)**	**pH**	**EC (µs)**
1	11.770 ±5.14	90.267 ±5.4	0.1367 ±0.005	66 ±1.33	32.350 ±3.26	8.3500 ±0.145	34.367 ±5.2
2	5.390 ±3.83	88.487 ±5.6	0.1367 ±0.005	66 ±1.33	23.793 ±3.6	8.2000 ±0.105	35.100 ±8.25
3	5.443 ±2.0	90.347 ±3.2	0.1433 ±0.005	66 ±0.67	21.300 ±3.75	8.1100 ±0.04	29.967 ±6.95
4	7.840 ±2.1	85.617 ±6.6	0.1400 ±0.000	68 ±1.33	17.843 ±1.27	7.9767 ±0.015	27.600 ±4.9
5	2.417 ±2.75	89.580 ±3.9	0.1600 ±0.000	66 ±1.00	20.150 ±4.68	8.0067 ±0.035	37.567 ±4.4
	P=0.1222	P=0.2611	P=0.0018	P=0.3442	P=0.0141	P=0.0019	P=0.4886

$P>0.05$ – no significant difference; $P<0.05$ - significant difference; $P=0.00$ – a highly significant difference

The Table 4 is showing the physical characteristics of soil after cultivating sweet peppers. Based on the results obtained, the treatment with the greatest moisture content was treatment 1, while treatment 5 has the lowest moisture content. Treatment 3 had the greatest bulk density, while treatment 4 had the lowest bulk density. The treatment with the greatest particle density was treatment 5 and the lowest was treatment 1 and 2 with the same amount. The treatment with the most pore space was treatment 4, and the least were treatments 1, 2, 3, and 5. The treatment with the most water phobic property was treatment 1, while treatment 4 displayed less hydrophobicity. Treatment 1 had the highest pH, indicating its alkaline content, while treatment 4 was the least alkaline. The treatment with the highest saline content was treatment 5, while treatment 4 had the lowest salinity.

To quantify changes in the chlorophyll content of sweet pepper leaves, as a measure of photosynthesis, when grown under different treatments



Note: Treatment 5 was the control.

Figure 15 The Mean Chlorophyll Content per Treatment

The Figure 15 of clustered column depicts the mean chlorophyll content of the sweet pepper leaves per treatment. The results reveal that no significant differences ($p>0.05$) existed between the various treatments. Chlorophyll was present in all the leaves tested but in varying amounts. Overall, treatment 1 had the most chlorophyll in the leaves, as compared to treatments 2, 3, 4, and 5, while treatment 5 had the least chlorophyll.

4 Discussion

Generally, the findings of this study revealed that the effectiveness of coconut biochar might be serving as an altering agent in the soil and on the growth performance of sweet peppers (*Capsicum annuum* L.). Coconut biochar and soil-biochar mixture were tested for physicochemical characteristics, while fruits were tested for nutrient contents and leaves were tested for chlorophyll content. Also, vegetative and reproductive parameters were recorded.

The study of the physicochemical properties of coconut biochar as a means of amending soil quality for enhanced cropping of sweet peppers (*Capsicum annuum* L.) showed an appreciable variation in the various parameters under study. The vegetative and reproductive differences were observed in the sweet peppers for the application of the various treatments. No major statistical significance ($p>0.05$) was seen between the various growth parameters involved in this study (Figure 5 to Figure 6), however, a few parameters, such as the mean number shoot length, seeds, fruits, diameter of fruits, exhibited minor statistical significance ($p<0.05$) among the various weeks.

Further, physicochemical characteristics of the soil impact crop productivity (Benjamin *et al*., 2003). Research revealed that biochar contributes to an improvement in the physical and chemical properties of soil, and therefore influences the yield of crops. The physicochemical characteristics of the soil before cultivating sweet peppers for our study are shown in Tables 2 and 3 respectively, followed by the physicochemical characteristics of the soil after cultivating sweet peppers in Tables 4 and 5 respectively. Based on the findings, moisture content, particle density, porosity, E.C., N, K, Ca, Mn, and Fe decreased, while bulk density, hydrophobicity, pH, O.C., and Cu increased after cultivating the sweet peppers.

The application of biochar to the soil improves soil moisture content, because biochar is highly porous, and depending on particle size and geometry, it may enhance the volume of soil inter-pores (Liao & Thomas, 2019). Research conducted by Karim *et al*., 2020, found that biochar added to the soil increases the soil moisture content by an average of 11% in plots receiving biochar, however, in our study, moisture content decreased after cultivation. This may have been as a result of the pepper plants taking up excessive water or water may be lost due to evapo-transpiration.

4.1 Chlorophyll a

Biochar treatments impact the chlorophyll a content of the sweet pepper variety used in this study as shown in Figure 7. The presence of chlorophyll a in sweet pepper leaves increased tremendously with the addition of biochar. As shown in Figure 7, the chlorophyll a content in the treatments varies and was higher when the 15 g biochar was used, however, no statistical significance (P = 0.0661) existed between the various treatments for chlorophyll a. This implies that plants respond to treatments differently. Studies conducted found that an increase in biochar application, decreases chlorophyll content. Asai and others, (2009), found that soil altered with high concentrations of biochar reduce chlorophyll content in leaves. Lower chlorophyll contents are the results of biochar application (Asai *et a*l., 2009).

4.2 Chlorophyll b

Chlorophyll b is needed for chlorophyll a to function effectively. It transfers energy to the reaction site. In the reaction centre, photosynthetic activities occur (Taiz and Zeiger, 1991). Fertilizer application impact chlorophyll b in the sweet pepper leaves (Figure 7). It has shown that plants grown in synthetic fertilizer (N.P.K.-15:15:15) showed higher chlorophyll b when compared to plants grown in biochar treatments, however, no statistical significance (P = 0.1816) existed between the treatments. Synthetic fertilizer (N.P.K. -15:15:15) may have had an effect on the leaves of the pepper plants that may have influenced photosynthetic activities positively. Studies conducted by Skwaryło-Bednarz & Krzepiłko, (2009), found similar results when NPK was added to the Rawa variety of amaranth (*Amaranthus cruentus* L.). The greatest increase in chlorophyll b was found after the application of 70 kg N, 50 kg P, and 50 kg K. Also, El-Mogy and others, (2019), found that chlorophyll b content increased in long green pepper plants with the addition of potassium fertilizer. Further, the increase in total chlorophyll content in treatment 4 in the leaves was probably generated by the level of NPK fertilization.

4.3 Total chlorophyll

Total chlorophyll in plants is a reflection of the overall chlorophyll content present in the leaves. In this study, the use of biochar produced high levels of total chlorophyll content for the sweet pepper leaves in treatment 1 (15 g biochar), when compared to plants grown under treatment 2 (30 g biochar) and 3 (45 g biochar) and the control. Overall, no statistical significance (P = 0.0993) existed between the treatments for total chlorophyll in the sweet pepper leaves. High levels of total chlorophyll content for treatment 1 may have been due to the nutrients content of the 15 g biochar that was used, along with the nutrients present in the soil. The quantity of nutrients that were present in the 15 g biochar may have been ideal for the plants to carry photosynthetic activities since the total chlorophyll content decreased for treatments 2 and 3 that used 30 g and 45 g of biochar respectively. Mohawesh *et al*., (2018), found similar results when sweet peppers and tomatoes were grown on biochar made from broccoli residue under a greenhouse. They found that the total chlorophyll contents decreased drastically with high levels, (5.0%), of biochar on sweet peppers and tomatoes.

5 Conclusion

Growth parameters, nutrient quality, and chlorophyll content were accounted for, along with biochar and soil-biochar characteristics. The results revealed that biochar did not play a significant role in enhancing the yield of crops and amending soil characteristics of the sweet peppers. However, there were minor enhancements among the treatments used. Treatment 2 (30 g biochar) impacted the vegetative and reproductive parameters of the sweet peppers positively, while treatment 3 (45 g biochar) produced the greatest quantity of seeds (138) and mass of sweet peppers (138.457 g). With the application of the biochar, soil pH and organic carbon values increased after the cultivation of sweet peppers (pH: T1 = 8.3500, T2= 8.2000, T3 = 8.1100), (OC: T1 = 1.643%, T2 = 1.249%, T3 = 1.857%). Also, biochar application in the quantity of 30g impacted the protein, lipid, carbohydrate, and vitamin C content of the sweet peppers. Further, chlorophyll A, chlorophyll B, and total chlorophyll content increased tremendously with biochar applications in the quantity of 15g. Overall, our findings show that biochar applications resulted in minor changes in the growth performance of sweet peppers.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have no conflict of interest to declare.

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