



The impact of four levels of biochar on the growth and yield of *Lycopersicum esculentus* (okra)

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Abstract

In contrast to other Sub-Saharan nations in Africa, soils in Liberia are obviously depleted of vital plant nutrients due to a lack of soil amendments, soil erosion, and a dearth of farmers with the technical know-how to restore soil health. The impact of four degrees of wood biochar treatment on the growth and yield of okra was studied as a result. The experimental design for the study used the RCBD approach. The height of the plant, the number of leaves, the length and width of the leaves, the diameter of the stem, and the yield of the okra were the factors used to evaluate the growth and yield statistics.

According to the study's findings, 250g of applied biochar resulted in the vegetation's highest average plant height (17.2 cm), while 300g of applied biochar produced the most leaves (7.6 cm). However, the 300g of applied biochar had the longest leaf length (11.0 cm), while the 200g and 0g biochar had the highest stem girth values (2.9 cm, 2.8 cm, 2.8 cm, and 3.1 cm, respectively), and the 300g biochar had the highest average yield (10.0 kg/ha). The 300g of biochar used in this study shown a significant potential for okra productivity. Since both applications boost the growth and production of the research crop (okra), it can be inferred that biochar should be treated at 250g and 300g simultaneously for growth and productivity.

Keywords: Soil health, Soil structure, Biochar, Liberia

Introduction

The Malvacea family includes okra (*Lycopersicum esculentus*, L. (Moench). Okra comes in two cultivars: West African okra (*Abelmoschus caillei*) and *Lycopersicum esculentus* L. (Moench). Okra contributes significantly to the diets of many people by offering nutrients that are typically absent from most basic diets, such as carbohydrates, protein, fat, minerals, and vitamins. Every tropical and subtropical region of Asia and Africa has okra, which is a crucial vegetable crop (Bisht & Bhat, 2006) [4].

However, because it provides farmers with a source of revenue, its economic significance cannot be overstated. Many countries that grow okra in enormous amounts also use the crop's export as a cash stream. The leaves are occasionally used as cattle feed and are regarded as good fiber for the stem (Fagwalawa & Yahaya, 2016) [13]. Okra is a good source of calcium and potassium, and it also has a specific fiber that controls blood sugar levels while supplying sugar that is suitable for the bowels. Okra is also a strong source of mucilage from the roots, which can be used as a plasma substitute.

Additionally, the expansion of agricultural production affects everyone in the world, and this is only achievable with the introduction of cutting-edge technologies and environmentally friendly farming methods. Because plants require nutrients from the soil to thrive properly, this increase in crop productivity necessitates optimal soil fertility (Upadhyay, 2015) [37]. As the primary medium for agricultural growth and development, the soil is very important. The ability of the soil

to support crop growth without degrading or harming the ecosystem is emphasized by the need to understand the quality and health of the soil (Acton & Gregorich, 1995) [2]. According to a recent study, the 70% of Africans who depend on agriculture for their livelihoods are at risk since the continent's agricultural sector is experiencing enormous soil degradation. The population of Africa is expanding quickly (3% annually). The fertility of its agricultural land as a whole, however, is deteriorating (Diagana, 2003) [11]. Adding inputs to improve soil organic matter and health is one of the most environmentally friendly approaches to improve soil fertility in agricultural output (Tiwari et al., 2010) [36].

Biochar

Farming has made extensive use of biochar over the years. According to the International Biochar Initiative (2018) [19], this 2,000-year-old method turns agricultural waste into a soil enhancer that can store carbon, improve food security, boost soil biodiversity, and reduce deforestation. According to Lehmann and Josephs (2009), biochar may be able to reduce nutrient and agrochemical leaching, boost food production, and potentially even slow down global warming. In the anthropogenic soils of the Brazilian Amazon Basin, studies have revealed that carbonated materials from incomplete combustion of organic materials (biochar, black carbon, charcoal) are responsible for sustaining high levels of soil organic matter (SOM) or moisture and accessible nutrients. One way that biochar made from wood is generated is in the

traditional charcoal industry. According to numerous research, adding charcoal improves soil fertility and productivity while also having a good impact on soil characteristics (Fagbola & Dare, 2003) ^[12].

(International Biochar Initiative, 2018) ^[19] Biochar is successfully utilized in agriculture and horticulture activities as a soil supplement, resulting in higher yields. Biochar can also be sprayed to exterior walls using the so-called "pressure-spraying technique" after being coupled with lime. This kind of insulation absorbs dangerous volatile substances while maintaining a healthy indoor environment in buildings.

Recent research has shown that adding biochar to soils can help to enrich them and restore the natural balance in them while compensating for the nutrients that have been lost (Gadki, 2017) ^[15]. In addition to crop output, (Lehman et al., 2011) ^[25] conducted a study on biochar. The findings revealed that when applied at rates of 68t C ha⁻¹ to 135t C ha⁻¹, biochar addition boosted rice biomass by 17% and cowpea by 43%. The direct nutrient additions of P, K, and Copper (Cu) from biochar were blamed for this increase.

Another study (Iswaran et al., 1980) ^[21] found that the application of 0.5t ha⁻¹ resulted in a 51% increase in total biomass in soybean plants. The addition of biochar caused the volume and height of tea trees to rise by 20% and 40%, respectively, according to Hoshi (2001) ^[18]. The discovery of the remarkable, ideal qualities of the Amazon terra preta (Indian dark earth) can be linked to the growth in interest in biochar as a soil additive. Studies on the qualities of the soil indicate that the region's soils have a rich mineral composition as a result of agro-technical interventions made by Indian tribes before the arrival of Columbus. These treatments involved fertilizing the soil with charcoal, which has qualities similar to those of biochar. Between 450 BC and 950 AD, Indian tribes inhabited the Amazon region (Nanda et al., 2016) ^[27]. According to other studies of a similar nature, adding biochar to soil improves its physicochemical and biological characteristics, which improves agricultural yields (Graber et al., 2010) ^[17]. Due to its high chemical reactivity toward both organic and inorganic substances, such as heavy metals or plant pesticides, which are less readily accessible to plants after being fixed by biochar, biochar has a beneficial effect on soils (Inyang et al., 2012) ^[20]. The addition of biochar fertilizes the soil, affects carbon sequestration, and lowers emissions of nitrogen oxides and methane from soil surfaces resulting from natural putrefaction processes, according to another study (Verheijen, 2010) ^[39]. Methane and N₂O are both considered to be damaging greenhouse gases because of their significantly greater greenhouse potential than CO₂. A significant amount of natural carbon found in soils comes from the breakdown of biomass. It is a very unstable substance that is discharged into the atmosphere as temperatures rise during cultivation. Biochar reduces CO₂ emissions into the atmosphere to improve CO₂ sequestration in the soils because it can fix organic carbon and create stable structures (Lehman, 2011) ^[25]. As a soil amendment, charcoal has extremely little fertilizing potential. The disadvantage is brought on by the chemical makeup of the raw materials used in its manufacture, which are often deficient

in nutrients or are not readily accessible nutrients (Medyska-Juraszek, 2016) ^[26]. Biochar, on the other hand, has the ability to store both macro and micro elements in the soil due to its very porous structure. In addition to increasing the chemicals' absorption by plants, biochar's ability to exchange them lowers the likelihood that they would be transported into surface and subsurface waters or elute (Laird, 2008) ^[23]. The ion-exchange capacity of biochar is dependent on the pyrolysis temperature; the product's ion-exchange capabilities decrease over 600 °C (Lehman, 2007) ^[24]. The very porous structure of biochar, which promotes microbial growth and hence increases fertility, substantially facilitates the application of biochar as a soil amendment. The high specific surface and high porosity of biochar also increase the soils' ability to retain water (Abel et al., 2013) ^[1].

Biochar production

By pyrolyzing biomass material at temperatures between 250°C to 700°C without the presence of oxygen, biochar can be created (Yuan et al., 2014) ^[42]. Various biomass types, including as wood, woodchips, crop byproducts, manure, sawdust, and other animal wastes, can serve as the raw material or feedstock for the creation of biochar. The kind of feedstock utilized and the pyrolysis conditions used determine how effective biochar is as a soil amendment. The chemical composition, surface chemistry, nutritional composition, adsorption capacity, cation exchange capacity (CEC), pH, and physical structure of the biochar are all influenced by the features of the feedstock as well as the pyrolysis circumstances (Cimo et al., 2014) ^[9]. The biochar processing settings have an impact on the physical properties of biochar as well as pore size and number (Ronsse et al., 2013) ^[32]. In contrast, soil amended with biochar produced at lower temperatures (450 °C) occasionally repels water. For example, biochar produced at temperatures higher than 450 °C and added to soil may improve the internal drainage of the soil and render the water available to plants. Because higher temperatures cause these cellulose molecules to lose their structure and chemistry, biochar produced at temperatures below 300 °C contains cellulose components (Glaser & Birk, 2012) ^[16]. Because they have larger surface area for nutrient to be adsorbed (nutrient retention sites), soil amendments employing biochar generated at lower temperatures retain more soil nutrients (Glaser & Birk, 2012) ^[16]. In contrast, when the temperature of pyrolysis rises, the porosity of biochar increases as a result of the volatilization of tars within the pores and the escape of gases (Cantrell et al., 2007) ^[6].

Soil and Charcoal Mixture

According to Sharma et al. (2014) ^[34], the average thickness of biochar particles is lower than that of soil particles. As a result, adding biochar causes the soil's bulk density to drop. The energy needed for mechanical tillage is reduced in soils with decreased bulk density (Carter, 1990) ^[8]. However, when fine biochar particles are applied or when larger biochar particles break down in arable soils due to tillage and cultivation activities (Wang et al., 2013) ^[40], the broken down fine particles

can fill up tiny pores in the soil, increasing the bulk density of the biochar-soil mixture. Mechanical disturbances like freeze-thaw cycles or plowing in agricultural areas are likely to cause biochar particle size to decrease (Saran et al., 2009) [33]. Small biochar fractions may cause the soil pores to close and form a subsurface hardpan, according to scant research on agricultural methods that may affect the breakdown of biochar particles (Verheijen et al., 2010) [39]. The mechanical impedance of the soils has an impact on the lengthening and proliferation of roots. Increased mechanical impedance, decreased root growth, and decreased crop productivity are all effects of denser soil (Otto et al., 2011) [29]. The application of biochar itself carries a clear danger of compaction of the soil. The risk of compaction rises if biochar is applied with large gear while the water-filled soil pores are almost saturated (Carlos et al., 2012) [7]. The soil surface area and porosity are changed by biochar additives. According to Basso et al. (2013) [3], a soil-biochar mixture tends to increase the soil's water-holding capacity (WHC). The use of biochar has been demonstrated to increase soil water holding capacity (WHC) according to a comparison of soil water retention curves (Abel et al., 2013) [1]. However, because the water in the incredibly small saturated pores is held too tightly against the plant's uptake pressures, this extra water kept by the soil may not be easily accessible to the plants (Sohi et al., 2010) [35]. The overall volumetric water content increases as the percentage of biochar does.

Soil in Liberia

Because of less soil amendment application and soil erosion, Liberia's soils are obviously deficient of vital nutrients as compared to other Sub-Saharan African nations. Numerous techniques for improving soil have been developed with the goal of restoring soil fertility and national productivity. Chemical fertilizers are now being developed and used more frequently. Farmers in Suakoko, who lack access to resources, cannot, however, afford chemical fertilizers due to the hefty price tag. Productivity suffers as a result, endangering food security. Numerous natural resources are increasingly being utilised to increase soil fertility. The use of biochar on okra growth is the study's primary focus. The soil surface area and porosity are changed by biochar additives. When growing okra, a soil-Biochar mixture typically increases the soil's ability to retain water. The use of biochar as a soil supplement is a novel agricultural technology that is piquing the interest of numerous people all over the world. Therefore, it is necessary to carry out this investigation to ascertain how Biochar affects okra growth.

Materials and Methods

Study site

The study was conducted at the Cuttington University CASD Students Demonstration Site in Suakoko, Bong County, Liberia. The research site's soil is a yellowish brown tint and has sandy clay loams as its texture. The ground has good drainage. The region's average yearly temperature is between 19.3 and 30.7 °C. Upland farming is the main type of agriculture used in the area. The rainy season is when lowland farming is primarily carried out. Suakoko GPS coordinates are 6.99 N and 9.58 W.

Experimental design

The study's agricultural experimental design was the Randomized Complete Block Design (RCBD). In the investigation, four treatments were applied. Three replications of four blocks made up the entire field. There were so a total of 12 plots, each measuring 1.5 m by 1.5 m. A walkway measuring 0.6 meters between blocks and 0.3 meters between plots in a block was measured. In each plot, nine okra seeds were planted. The planting distance was 0.5 x 0.4 meters.

T₁ Control (0g Biochar /2/25m²)

T₂ 200g Biochar/2/25m²

T₃ 250g Biochar/2/25m²

T₄ 300g Biochar/2/25m²

Plant population: The total plant population of the study was one hundred and eight (108) plants.

Sampling size and sampling techniques: From each plot, three plants were chosen to collect data on. The sampling size was 36 plants. Three okra plants were chosen by simple random sampling from each of the twelve plots in order to gather data.

Data collection method

The following crop metrics were recorded: plant height, leaf length, leaf number, leaf width, stem circumference, and okra yield. A decameter was used to obtain experimental data.

Data analysis

For data analysis, JMP Software (version 11.0) was used. To recognize significance between treatment means, the Least Significant Difference (LSD) test was used. Analysis of Variance (ANOVA) test was also used to test for the p-value. The alpha level for the study was set at 0.05.

Results and Discussion

Results

Table 1: Differences in measurement of average plant height, number of leaves, leaf length, leaf width, stem circumference, and yield of okra

Treatments	Plant height (cm)	Number of leaves	Leaf length (cm)	Leaf width (cm)	Stem Circumference	Yield (g)
0g Biochar/2.25m ²	16.6 ^a	7.3 ^a	10.7 ^a	11.5 ^a	2.9 ^a	4.6 ^c
200g Biochar/2.25m ²	15.9 ^a	6.3 ^a	9.7 ^a	11.5 ^a	2.8 ^a	7.3 ^b
250g Biochar/2.25m ²	17.2 ^a	5.6 ^a	10.0 ^a	9.5 ^a	2.8 ^a	7.0 ^b
300g Biochar/2.25m ²	14.2 ^a	7.6 ^a	11.0 ^a	11.4 ^a	3.1 ^a	10.0 ^a

* Same letters are not significantly different at $p < 0.05$ significant level

The Table above illustrates the differences in measurement of average plant height, number of leaves, leaf length, leaf width, stem circumference, and yield of okra. Average plant height values measured for 0g biochar, 200g biochar, 250g biochar, and 300g biochar treatments are 16.6cm, 15.9cm, 17.2cm, and 14.2cm respectively. Recording average number of leaves the 0g biochar treatment had 7.3cm, 200 g biochar treatments had 6.3cm, 250g biochar treatment had 5.6cm, and 300g biochar treatment had 7.6. Average leaf length was also measured with the 0g biochar treatment measuring 10.7cm, 200g biochar measuring 9.7cm, 250g biochar measuring 10.0cm, and 300g

biochar measuring 11.0cm. For average leaf width, the 0g biochar treatment recorded 11.5cm, the 200g biochar treatment recorded 9.5cm, while 250g biochar treatment recorded 11.4cm respectively. The average values recorded for stem girth were 2.9cm, 2.8cm, 2.8cm, and 3.1cm for the 0g biochar, 200g biochar, 250g biochar, and 300g biochar respectively. For average yield of okra, the 0g biochar applied to a plot measures 2.25m² measured 4.6g, the 200g biochar treatments also measured 7.3g, the 250g biochar treatment measured 7.0g, and the 300g biochar treatment measured 10.0g/ha.

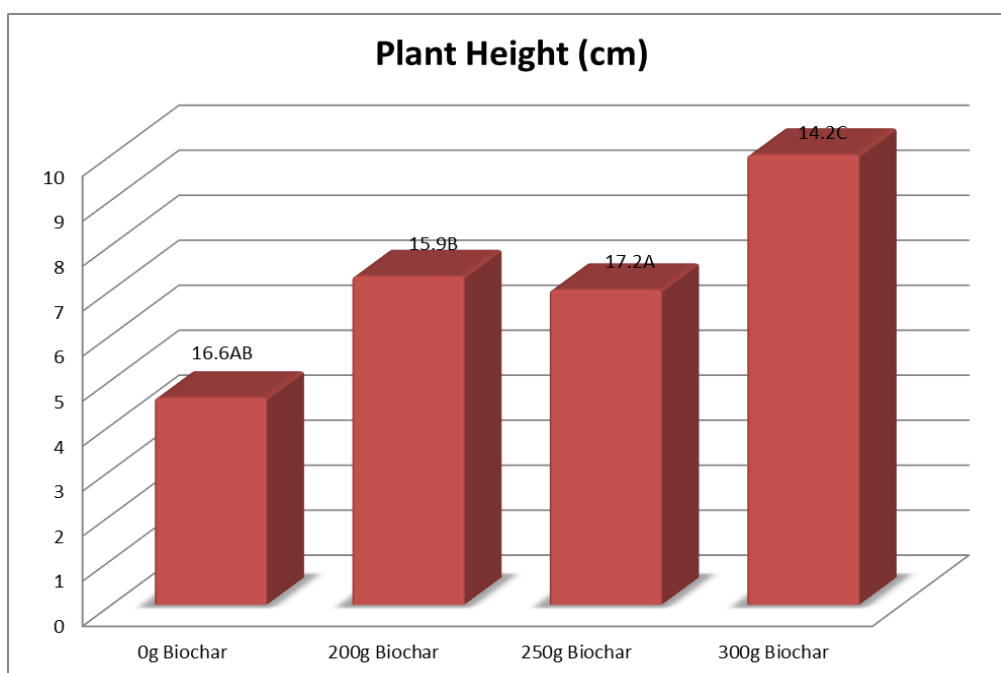


Fig 1: Plant Height (cm)

Means that begin with the same letter do not differ greatly. The graph up top shows the variations in Okra heights according to treatments. The changes are represented by the letters (A, AB,

BC, and C). The rise in the control plot may have resulted from some nutritional elements already present in the soil, which were outside of the researcher's control.

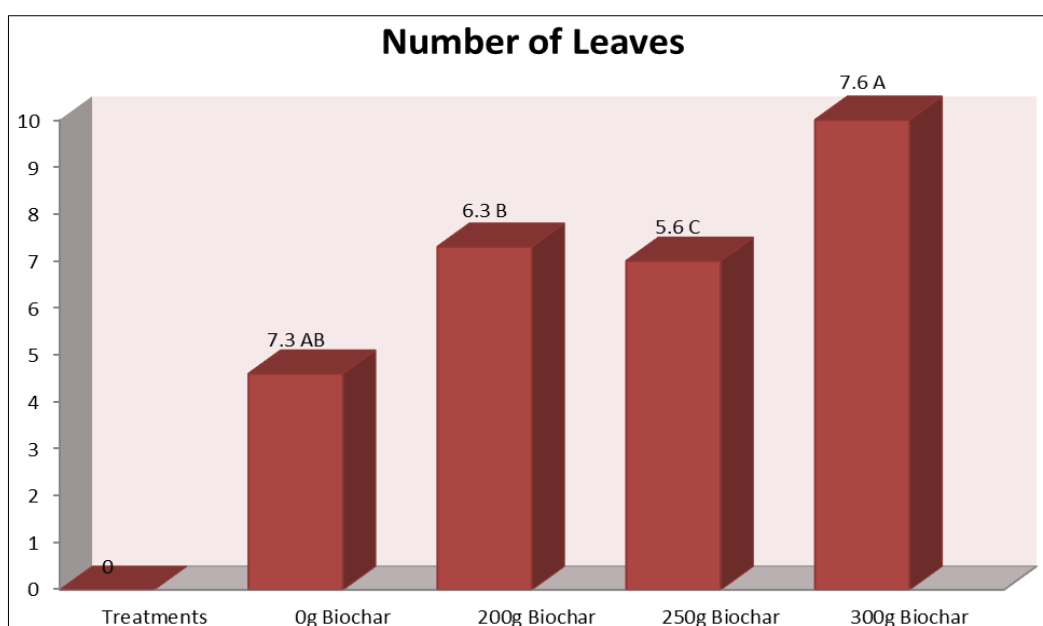


Fig 2: Numbers of Okra Leaves

Means that begin with the same letter do not differ greatly. Figure 2 illustrates the variations in yield and Okra production that were noticed. The graph demonstrates that there was a substantial difference in the number of leaves recovered from plots treated with 300g biochar as opposed to plots treated with

200g or 250g biochar. There were discrepancies between the applications of 0g and 300g of biochar, which may have been caused by some nutrients already present in the soil. The letters (A, AB, & C) in the graph above stand for these differences.

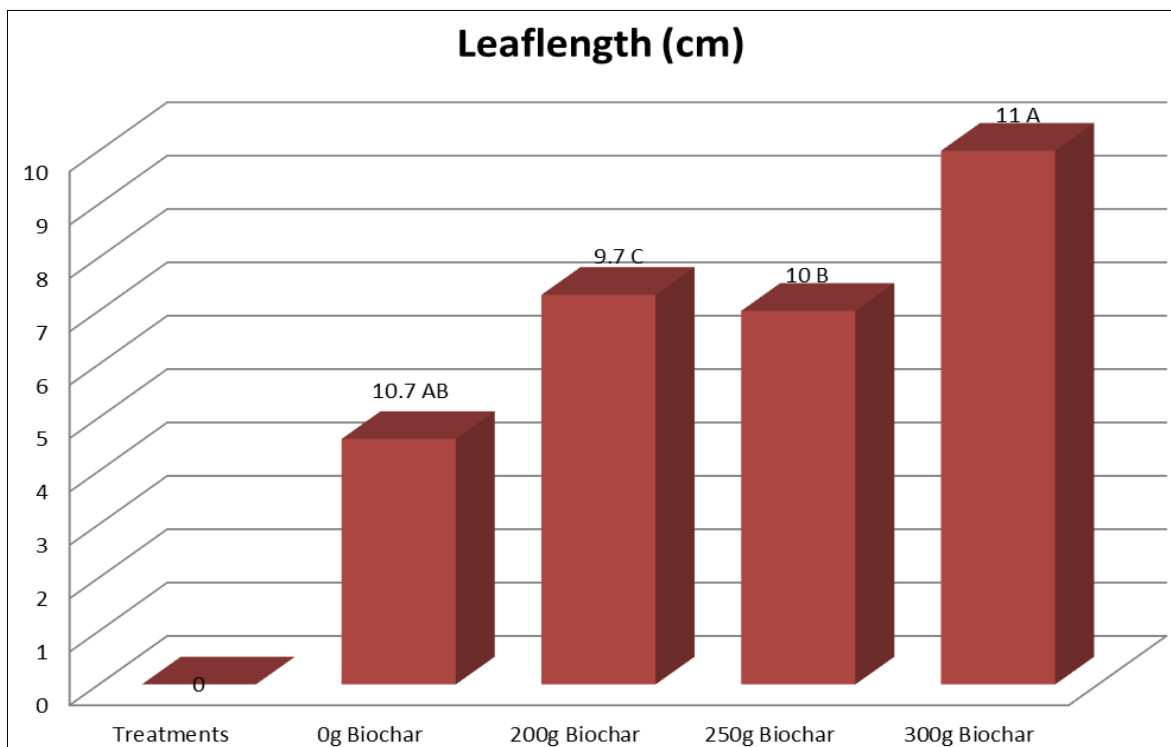


Fig 3: Leaf Length (cm)

Means that begin with the same letter do not differ greatly. Fig. 3 illustrates the variations in leaf length of the research crop (okra). The graph demonstrates that there is no discernible difference between the application of 200g and 250g of wood biochar; nevertheless, the plot treated with 300g of wood

biochar had the longest leaf length, followed by 0g wood biochar. Perhaps some of the soil's nutritional components are to blame for the variations in these results. The letters (A, AB, B&C) on the graph denote these differences.

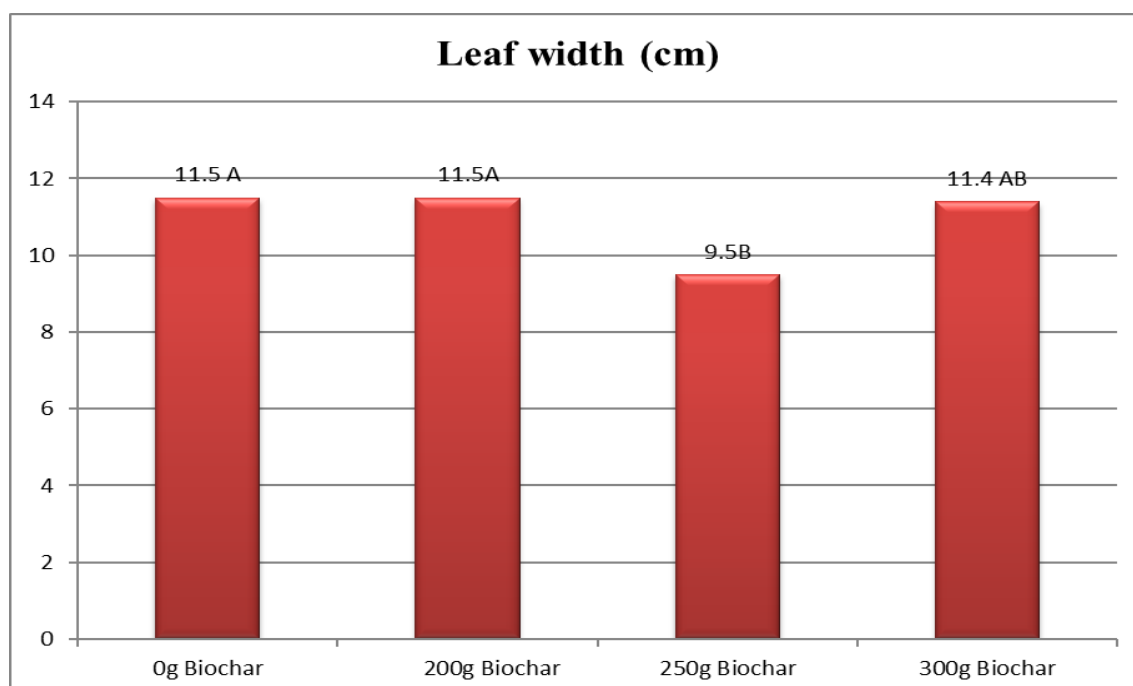


Fig 4: Leaf width (cm)

Means that begin with the same letter do not differ greatly. Fig. 4 illustrates the variations in leaf breadth of the research crop (okra). The graph demonstrates that there is no discernible difference between the application of 200g and 250g of wood biochar; nevertheless, the plot treated with 300g of wood

biochar had the broadest leaf width, followed by 0g wood biochar. Perhaps some of the soil's nutritional components are to blame for the variations in these results. The letters (A, AB, &B) on the graph denote these differences.

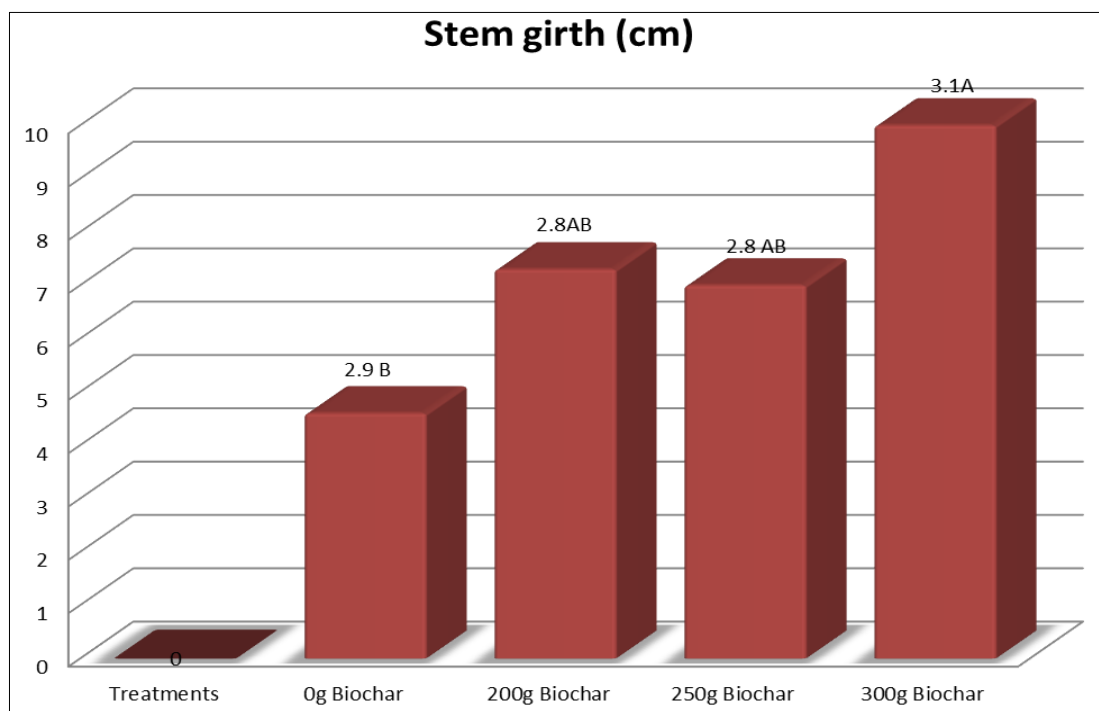


Fig 5: Stem Girth (cm)

Means for treatments that start with the same letter do not differ appreciably. According to Fig. 5, there were variations in the stem girth of the research crop (okra). However, the broadest stem girth was recorded in the plot treated with 300g of wood biochar, and the lowest was recorded in the plot by 0g wood

biochar. The graph demonstrates that there is no discernible difference between the application of 200g of wood biochar and 250g of wood biochar, which recorded the same results. The letters (A, AB, &B) on the graph denote these differences.

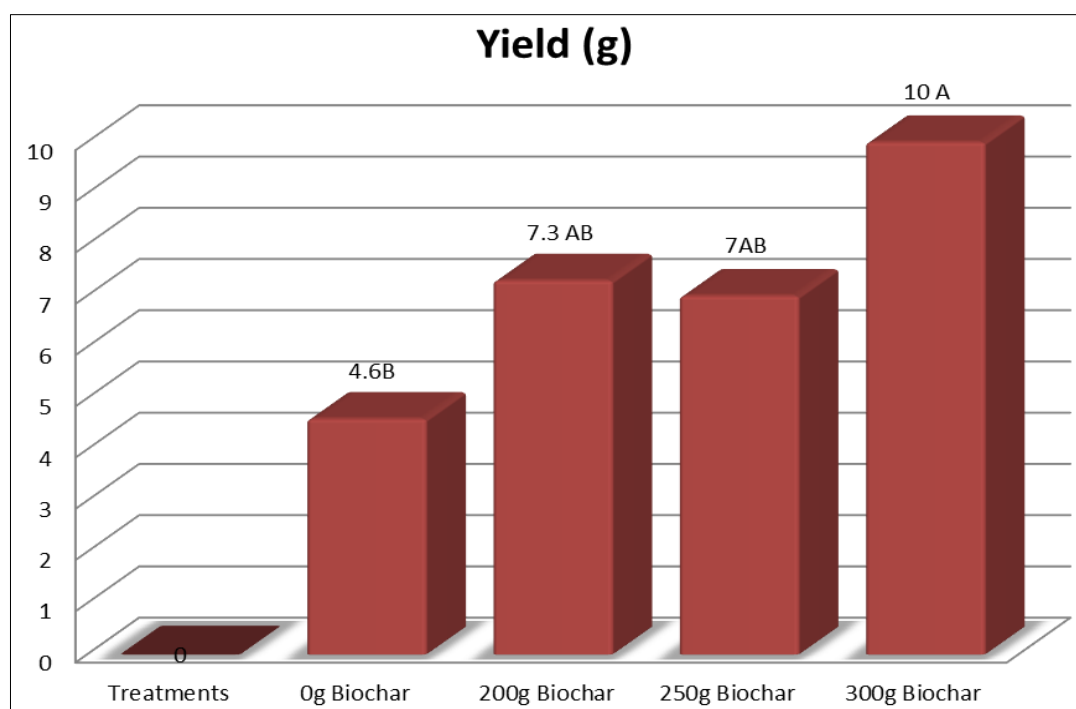


Fig 6: Okra Pods Yield

Means that begin with the same letter do not differ greatly. Fig. 6 illustrates the variations in pod length and yield that were found. The graph demonstrates that there was a substantial difference in the number of pods produced by plots treated with 300g of biochar as opposed to plots treated with 200g or 250g of biochar. The letters (A, AB, C) in the table denote these differences.

Discussion

Growth variables

Plant height treatments using 250g biochar/2.25m² measured the highest average value (17.2cm). However, there was no discernible change in plant height across treatments. The 300g biochar/2.25m² treatments reported the highest average number of leaves (7.6) per plant. Again, there was no discernible difference between the treatment values for the number of leaves. The 300g biochar/2.25m² treatments had the longest average leaf length (11.0cm) compared to the other treatments in terms of leaf length. However, there was no discernible distinction in the treatments' values when leaf length was measured. In terms of average leaf width, the control treatment (0g biochar/2.25m²) and the 200g biochar/2.25m² treatment both measured 11.5 cm and 11.5 cm, respectively.

There was no discernible difference in the measured values for leaf breadth. The 300g biochar/2.25m² treatments had the maximum stem circumference measurement (3.1 cm). Once more, there was no discernible difference between treatment values.

Yield variables

The 300g biochar/2.25m² treatments had the greatest average yield value (10.0), which was noticeably higher than the values for other treatments. However, because biochar increases okra productivity in farmers' fields, it is important to apply it at a rate of 300g/ha in order to maximize okra productions through organic farming.

Comparison with other studies

Because of its incredibly porous nature, which promotes microbial life and increases soil fertility, biochar is an excellent soil amendment. Most of the growth indicators tracked in this study saw an increase with the addition of Biochar.

The findings of this study do not agree with those provided by Hoshi (2001) [18]. Due to the addition of Biochar, (Hoshi, 2001) [18] observed a 20% rise in volume and 40% increase in height of tea trees. On the other hand, compared to the control treatment, an increase in Biochar did not result in taller plants in this study. In this study, the maximum result for plant height was obtained for the control treatment. Variations in the nutritional status at the time may be the cause of discrepancies in the results. According to a study on biochar by Lehman et al. (2011) [25], adding biochar boosted the biomass of cowpea and rice by 43% and 17%, respectively. According to (Graber et al., 2010) [17], adding biochar to soils improves their physicochemical and biological characteristics, which results in better crop yields. In this investigation, the 300g

biochar/2.25m² treatment levels recorded the highest yield, which was noticeably different from values recorded for other treatments. This proves the assertion. According to Basso et al. (2013) [3], a soil-biochar mixture tends to increase the soil's water-holding capacity (WHC). Ample water is easily accessible to plants throughout their whole life cycle when water retaining capacity rises. Water must be accessible to plants during flowering in order to increase output.

Conclusion

There has been a noticeable transition in modern agriculture from conventional inorganic farming to organic farming. Numerous researchers in the nation are still examining how beneficial organic farming is when compared to inorganic farming. The goal of this study was to evaluate the impact of biochar at four different application levels on okra production and growth. Plants treated with 300g biochar/2.25m² had greater values for the growth and yield characteristics (plant height, number of leaves, leaf length, leaf breadth, stem circumference, and yield) than plants treated with the other treatments. The treatment with 300g biochar/2.25m² of biochar had a more favorable impact on the growth and yield of okra. Therefore, it can be said that using 300g of biochar on 2.25 m² will effectively increase growth. Based on the findings of this study, it is advised that local farmers employ inexpensive organic fertilizers like biochar at a 300g application level, which was discovered in the current study, to improve soil fertility and sustainability.

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