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IMPACTS OF BIOCHAR ON SOME MICROBIAL POPULATION, SOIL PROPERTIES AND YIELD OF TOMATO IN A DIFFERENT LAND USE SYSTEMS SOUTHWEST, NIGERIA

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ABSTRACT

Changes in soil microbial communities may impact soil fertility and stability because microbial communities are key to soil functioning by supporting soil ecological quality and agricultural production. This study was conducted to investigate the Impacts of biochar on microbial activities on soil properties, crop growth and yield in a different Land use systems Southwest, Nigeria**.** The study was carried out between March to August 2023 and 2024 in Okitipupa Southwest, Nigeria with the objectives to determine the impact of biochar application on microbial abundance., to evaluate the influence of biochar on some soil physical properties, to evaluate the influence of biochar on some soil chemical properties and to determine the impact of biochar on the growth and yield of tomato. The design was Complete Randomized Design (CRD) with four treatments: control, oil palm plantation and agroforestry all treated with biochar except for the control. The results were subjected to statistical analysis and mean were separated at 0.05%. The results show that addition of biochar increases soil pH from 5.0 to 5.3 in farmland soil 4.8 to 5.5 in agroforestry soil and 5.1 to 5.2 in Oil palm plantation soil. Also, addition of biochar increases the population of Trichoderma from 4.00 cfu/g to 6.00 cfu/g, 8.00 cfu/g to 10.00 cfu/g and 5.00 cfu/g to 6.00 cfu in farmland soil, agroforestry and oil palm soils respectively. Aspergillus population also increased from 4.00 cfu/g to 5.00 cfu/g, 4.00 cfu/g to 8.00 cfu/g and 4.00 cfu/g to 7.00 cfu/g in farmland, agroforestry and oil palm soils respectively. Tomato yield was 14.06ton/ha, 12.77 ton/ha, 09.00 ton/ha and 4.67 ton/ha farmland, agroforestry, oil palm plantation and control soil respectively. It was observed that, addition of biochar to soils increases the presence of soil microbial, yield and some soil chemical properties in the study area. Therefeore, it is the finding of this study that proper use of biochar in the current agro ecological zone could be beneficial to agriculture especially crop production.

Key words: Biochar, tomato, soil microbial, land uses, soil properties

INTRODUCTION

Biochar is the carbon-rich product obtained when biomass is heated in a closed container with little or no available air with the purpose to amend soil and means to sequester carbon (C) and maintain or improve soil functions (Lehmann and Joseph, 2015). According *to Lehmann and* Joseph (2015), Dissolution, hydrolysis, carbonation, and decarbonation, hydration, and redox reactions are the major process affecting biochar weathering in the soil, as well as interactions with soil biota. the rates at which these reactions occur depending on the nature of the reactions, type of biochar, and climatic conditions. Biochar can influence physical and chemical properties as well as beneficial soil microorganisms like bacteria, fungi, and invertebrates, both in field and laboratory conditions (Sławomir G et al., 2017).Biochar has also been shown to enhance nutrient availability over longer time scales by enhancing nitrogen (N) mineralization or nitrification (DeLuca *et al*., 2006*;* Ameloot *et al*., 2015) as a result of enhanced microbial growth and activity *(Lehmann et al., 2015*) and by reducing soil nutrient losses due to its high ion exchange capacity (Ameloot *et al*., 2015). Numerous recent studies have shown that the positive effects of biochar on soil fertility can result in enhanced biochar plant growth (*DeLuca et al., 2006*), thereby having an indirect positive effect on net ecosystem C uptake. Biochar, as a soil amendment, can increase microbial biomass (Kolb *et al*., 2009), change microbial community in soil *(*Pietikainen *et al., 2000*). Biochars application in the soil can affect soil microbial community structure due to their high sorption capacity *(*DeLuca *et al*., 2006), changing the soil pH *(*Rousk *et al*., 2010) as well as modification of microbial environment. (DeLuca et al., 2006) also reported that biochars contain compounds such as polycyclic aromatic hydrocarbons and other toxic carbonyl compounds that can have bactericidal or fungicidal activity. The experiment conducted by hypothesizing that, the application of biochar (pyrolyzed at 600°C with high pH value) improves soil organic carbon and soil pH and would influence soil enzymes, microbial biomass, and community that support many key ecosystem functions essential for soil quality. It was found that soil pH, total organic carbon (TOC) and urease increased significantly with increasing biochar rate while the activity of acid phosphatase decreased, the reason can be the inverse correlation of this enzyme with soil pH. TOC had a positive correlation with urease. The β-glucosidase correlated positively with dissolved organic carbon (DOC) and negatively with C/N, suggesting that mineralization of organic matter provides substrates for this enzyme. The highest microbial biomass C as well as total Phospholipid fatty acid analysis (PLFA) were observed at the lowest rates, particularly the treatment of W0.5 had a higher relative abundance of soil bacteria, fungi and bacteria (Zhang *et al.*, 2023). Biochar addition to soils increases soil microbial biomass and changes microbial community structure and competition for available nutrients (Pietikäinen et al., 2000*)* by changing physicochemical properties of soils (Li *et al*, 2023).

The objectives of this study were to isolate the common soil microbial in the study area, to evaluate the impact of biochar of the population of some soil microbial in the study area.

MATERIALS AND METHODS

STUDY SITE

The study was conducted at the permanent site of the Olusegun Agagu University of Science and Technology, Igbokoda road, Okitipupa, Okitipupa Local Government, Ondo state, Nigeria within latitudes 6.50' N and 7.5 20' N and longitudes 4.37' E and 5. 55' E, 33.22 m above sea level within the tropical rainforest zone of Nigeria.

The area has two distinct geological formations, the Precambrian basement complex granitic rocks in the northern part and the recent to tertiary sandy sediments in the central and southern part of the local government area. Geographically, the northern part of the local government area has strongly sloped to undulating landscapes of 8 to 12% slopes, while the central and southern parts have nearly level to gently sloping landscapes of 0 to 4% slopes **(**Esu, *et al*, 2014**)**.

CLIMATE

The major community (Okitipupa) in the area enjoys a hot and humid tropic climate like the rest of southwestern Nigeria. The climate is characterized by seasonal rainfall, high temperatures and high humidity. An udic soil moisture regime and an is hyper thermic soil temperature regime prevail in the area with total annual rainfall often exceeding 2000mm, while the soil temperature has a narrow range of 27 to 28^0 C, respectively **(**Esu, 2014**)**.

The environment is noted for two distinct seasons of rainy and dry periods in a year. The dominance of the seasons is primarily controlled by two major air masses or wind currents. The southwest trade wind dominates the area bringing about rainy season between March and November, while the Northeast trade wind has greater influence between December and February, imposing dryness in the area. The southwest monsoon wind originates from the Atlantic Ocean; hence it is moisture laden and warm, bringing rains, while the northeast wind is cold, dry and dusty. Its chilly influence in the months of December/January is often referred to as harmattan. The occurrence of these winds is controlled primarily by the North-South migration of the zone of demarcation between them, known as the Inter Tropical Discontinuity (ITD). The movement, though usually gradual, is steady and consistent; hence, the regular pattern of rainfall and dry periods in the year. It directly and indirectly controls other climatic parameters like temperature, relative humidity, cloud cover, wind direction and speed, etc. The area is thus located in the humid zone, characterized by bimodal wet season, having a growing season of between 240 and 300 days **[**Reginster and Rounsevell, 2005.].

Vegetation and Land-Use

The site is a forest zone characterized by areas with secondary forest, farm fallows and arable farmlands. Farming activities are going on in area identified as arable farmlands. Cassava and guinea corn occupy this land unit being 15% of the site. They are made up of the previous farm shrubs and influx of oil palm trees and Cocoa. The secondary forest unit takes about two-third (2/3) of the land, and it's composed of woody trees and shrubs (Esu *et al*, 2014).

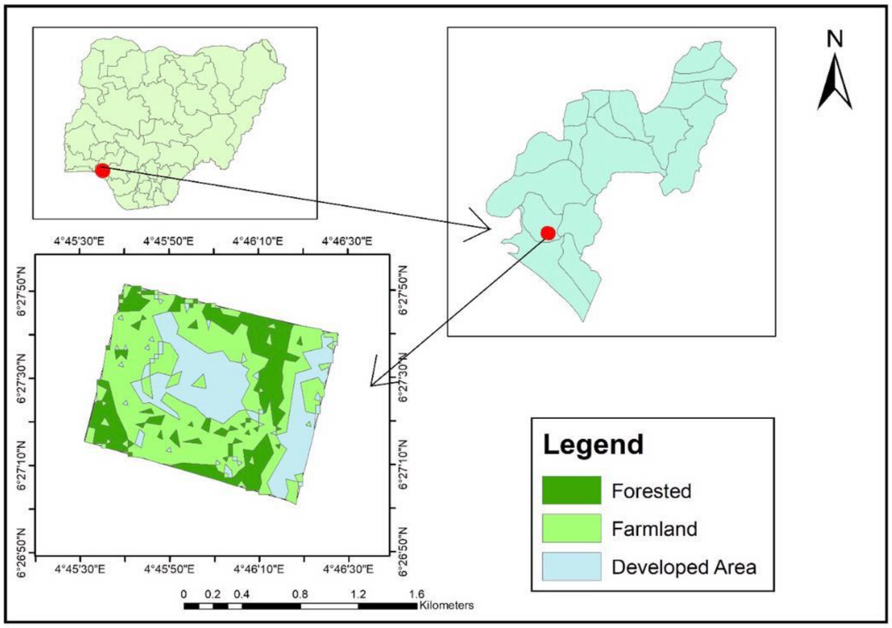

Fig 1: Map of the study site

Biochar Preparation

Production Method: Pyrolysis is the process of thermal decomposition of organic materials in an oxygen free environment under the temperature range of 250-900°C (*Catal, 2014*). The process involved using a cylinder container with no cover on the top and bottom being perforated. Shafts were placed inside the open container and lit up and allowed a small amount of oxygen to flow in before the outlet was sealed. This allowed for controlled burning and pyrolysis of the oil palm shaft to produce biochar.

Sample collection

Soil samples were collected from three land uses (Farmland, Agroforestry and Oil Palm Plantation) to have equal representation of each location. Soil samples were collected using soil auger at 0-15cm depth within OAUSTECH. They were thoroughly mixed and divided into 5 portions. The portions were mixed thoroughly and divided into 3 sub portions. Thereafter, 10g were weigh in three replicates to have equal representation of each location. These replicates were now taken to the laboratory for isolation.

MATERIAL AND METHODS

Potato Dextrose Agar, conical flask, petri dishes, gas burner, cotton wool, sterilized distilled water and antibiotics, measuring cylinder, sensitive weighing scale, ethanol, paper tape, aluminum foil, syringe and blade.

Preparation of media

Fungi isolation media were prepared following a standard protocol 3.9g of Potato Dextrose Agar (PDA) was weigh with 100mil of water inside a conical flask, and autoclave at 112^{0}c-120^{0}c 20mins for media. Thereafter, the media (PDA) was brought out to cool then 0.2g of antibiotics was added to inhibit the growth of bacteria. The media was poured into a sterilized petri dish and allowed to solidify. The petri dishes are laid out in three replicates such that 1g of soil sample from each location were dispense randomly in three and the control treatment to make a total 12 replicates. The petri dishes were kept in a sterilize environment at room temperature for 3-5days for growth to appear. And after 7days, different fungi were seen growing in the Petri dishes, into 3sub portions. Thereafter, 10g were weigh in three replicates to have equal representation of each location. These replicates were now taken to the laboratory for isolation.

Isolation of fungi

The isolation of fungi from soil was carried out in order to identify each fungus up to species level. The serial dilution plating method was used to dilute the soil sample as described by with the purpose of minimizing the fungi in the soil in each dilution. The solution was then spread on the plate by using a hockey stick and incubated at room temperature for seven days. The colony of fungi that appeared in the plate after incubation was then isolated in a new plate. A pure culture of each colony type on each plate was obtained and maintained. The maintenance was done by sub-culturing each of the different colonies onto another new PDA plate. Each colony were cut into 3 mm pieces with a sterilized razor blade, surface sterilized in 70 % ethanol. The colonies were incubated again at room temperature for five days. Each plate of single fungi colony was then sent to OAUSTECH Central Laboratory for identification purposes.

Observation and result

Fungal growth was observed on the plate culture and stain preparation for structure of hyphae and details under a low and high power microscope. The common fungi encountered in tropical soil will include: Rhizopus, Aspergillus, Fusarium, Trichoderma, others

Experimental Design

The experiment was designed using Completely Randomized Design (CRD) in a screenhouse. There were four treatments replicated three (3) times in the screen house within a control environment. The experiment was conducted using pots. The treatments applied includes:

Treatment 1: Control (no biochar)

Treatment 2: Farmland Soil + 400g of biochar/pot

Treatment 3: Agroforestry Soil + 400g of biochar/pot

Treatment 4: Oil palm plantation Soil + 400g of biochar/pot

Pot preparation

Topsoil was collected from the experimental field and then pulverized. The inert materials, visible insects, pests, debris and weeds were removed. Then the soil was dried thoroughly. Clean and dried pots of 7-liter size were perforated and used for the experiment. Each pot was filled with 4 kg of previously prepared soil and 20g of biochar were added to the soil.

Sowing of seed

Seeds were sown in a seedling tray, after germination the plant was left for a week to increase the growth before transplanting it to the pot at two seedling per pot.

Thinning and weeding

The young plants were thinned to one stand per pots after planting. Manual weeding was done as frequently as the situation demanded.

Soil sample collection

Soil samples were previously taken randomly and analyzed to know the nutrient status of the area using soil auger to the depth of 0-15cm. After the experiment, five soil samples in each plot were taken. Samples from each treatment pot were bulked and composite were collected and taken to the laboratory for analysis.to determine the changes that occurred due to treatments application.

Soil particle size analysis

The particle size is one of the most stable soil properties, consequently its analyses is used as a basis of soil textural classification. Soil particle size analyses to determine the sand, silt, and clay content of each soil sample obtained from the different soil depths across the different management practices of cultivated land, regenerated land and forest land was carried out using the hydrometer method described below:

A 30-g (oven-dry weight basis) of ≥ 2 mm sieved soil sample was weighed into a 250 ml beaker and 100ml of Calgon solution added to it, after which the mixture was transferred to a dispersing cup and stirred for about 3 minutes with the help of a mechanical stirrer and subsequently transferred to a sedimentation cylinder which was filled to the mark with distilled water while the hydrometer is in the suspension Soil textural classes was determined by using textural triangle

[Bouycous, 1951].

A plunger was then inserted which was moved up and down in a vertical rectilinear manner to mix the contents thoroughly, the stirring was completed with three slow smooth strokes, and the time of stirring completion recorded. The hydrometer was lowered carefully into the suspension and readings taken after 40 seconds (R40secs) and the temperature of the suspension recorded with a thermometer. The suspension was remixed using the plunger and the 40 seconds reading recorded until a reliable and constant reading was obtained. Two (2) hours after the final remixing of the suspension, another hydrometer and temperature reading were obtained (R2hrs). The percentage fractions of the suspension were calculated as follows:

% (Silt + Clay) = × 100
Eqn (1)

% Clay = × 100
Eqn (2)

% Silt = % (Silt + Clay) - % Clay
Eqn (3)

% Sand = 100 – [% (Silt + Clay)]
Eqn (4)

Soil textural classes was determined by using textural triangle

Soil chemical properties determination

The soil pH was determined by a pH meter in 1:2.5 soil: water (w/v) suspension (Anderson and Ingram, 1993). Total Organic Carbon (TOC) was determined using the Colorimetric method (Schulte and Hoskins, 2009). The Kjeldahl method was used to determine total Nitrogen (Sáez-Plaza *et al*., 2013). Available phosphorus (Av. P) content in the soil was analyzed following the Bray-1 acid method (Sahrawat *et al*., 1997). Potassium content was determined using a flame photometer (Rhoades, 1983). Effective Cation exchange capacity (ECEC) was estimated by summation of total exchangeable bases and exchangeable acidity (Al + H) determined by 1 M KCl extract and titrated with dilute sodium hydroxide solution (Anderson and Ingram, 1993).

Agronomic data collection

Collection of data commenced two weeks after transplanting and was done at one week interval. A plant was randomly selected from each treatment pots as specimen plants. The growth parameters taken were plant height (measured from soil level to the apex of the terminal leaf), number of leaves was done as physical count, stem diameter (vernier caliper was used to measure the stem girth. The yield parameters taken include days of flowering, fruit weight, mortality and number of fruits.

Data Analysis

The data collected were subjected to analysis of variance (ANOVA) and the means were compared using Duncan multiple range test (DMRT) at 5% significance level. SPSS (version statistical package for soil sciences). A proximate analysis was carried out to compare the treatments (Farmland, Agroforestry and Oil Palm Plantation) using T test.

RESULT AND DISCUSSION

RESULTS

Physical Properties of land uses

The laboratory test for physical properties of soil samples taken from the three locations are shown in Table 1

In Farmland the percentage of sand, silt and clay were 40.50%, 20.00% and 39.50% respectively with clay loam in textural Class

In Agroforestry the percentage of sand, silt and clay were 66. 67%, 23.20%and 10.06% respectively with sandy loam in textural Class

In Oil palm plantation the percentage of sand, silt and clay were 54.00%, 18.50% and 27.50% respectively with sandy clay loam in textural Class

Table 1: physical properties of land uses

Sampling location	%Sand	%Silt	%Clay	Textural classes
Farmland	40.50±0.71^{a}	20.00±0.00^{b}	39.50±0.71^{d}	Clay loam
Agroforestry	66.67±0.15^{b}	23.20±0.10^{d}	10.06±0.15^{a}	Sandy loam
Oil palm plantation	54.00±8.48^{bc}	18.50±2.12^{a}	27.50±7.78^{ab}	Sandy clay loam

*Mean with same superscript along the rows are not significantly different at p>0.05

Chemical properties of the land uses

The chemical property of land uses as presented in Table 2 reveal significant variations across agroforestry, farmland, and oil palm plantation systems. The pH values indicate slightly acidic conditions across all land uses, with oil palm plantation having the highest pH (5.11±0.20). Agroforestry shows the highest Total Organic Carbon (TOC) at 5.52±0.10%, highlighting its potential for carbon sequestration, compared to farmland and oil palm plantation which have lower TOC values. Similarly, agroforestry records the highest Total Nitrogen (0.17±0.01%) and Total Phosphorus (7.94±0.68 mg/kg), suggesting better nutrient availability under this land use. The potassium (K^+) and calcium (Ca^{2+}) contents are also notably higher in agroforestry, with K^+ at 1.70±0.00 cmol/kg and Ca^{2+} at 3.20±0.10 cmol/kg, compared to other systems. Interestingly, farmland exhibits the highest exchangeable acidity (2.95±0.19 cmol/kg), which may indicate more acidic soil conditions that could affect plant growth. These results suggest that agroforestry practices might offer better soil fertility management compared to traditional farmland and oil palm plantation systems.

Table 2 Chemical properties of land uses

Parameters	Sample Identities		
	Agroforestry soil	Farmland soil	Oil Palm plantation soil
pH	4.95 ± 0.00^{a}	5.03 ± 0.60^{a}	5.11 ± 0.20^{ab}
Total N (%)	0.17 ± 0.01^{c}	0.13 ± 0.60^{a}	0.09 ± 0.01^{a}
TOM (%)	5.52 ± 0.10^{c}	1.47 ± 0.70^{a}	1.01 ± 0.03^{a}
TOC (%)	3.13 ± 0.15^{c}	0.90 ± 0.14^{a}	0.57 ± 0.50^{a}
Total P (mg/kg)	7.94 ± 0.68^{c}	5.76 ± 0.34^{a}	5.14 ± 1.04^{a}
Na^{+} (cmol/kg)	0.53 ± 0.10^{c}	0.23 ± 0.01^{a}	0.59 ± 0.48^{a}
K^{+} (cmol/kg)	1.70 ± 0.00^{d}	0.11 ± 0.02^{a}	0.08 ± 0.02^{a}
Ca^{2+} (cmol/kg)	3.20 ± 0.10^{d}	1.28 ± 0.22^{a}	1.08 ± 0.09^{a}
Mg^{2+} (cmol/kg)	2.96 ± 0.00^{b}	0.60 ± 0.00^{a}	0.55 ± 0.06^{b}
Ex.Acidity (cmol/kg)	1.83 ± 0.01^{c}	2.95 ± 0.19^{a}	2.93 ± 0.30^{a}

***Mean with same superscript along the rows are not significantly different at $p>0.05$.**

Proximate composition of Biochar

The proximate composition of biochar highlights its rich nutrient profile, particularly its high potassium (56.7 g/kg) and nitrogen (32.4 g/kg) content, which are crucial for soil fertility enhancement. The biochar also exhibits a high total organic carbon (634.5 g/kg), indicating its potential as a significant carbon sink. The calcium content (34.1 g/kg) further contributes to soil structure improvement. The C/N ratio of 81.2 suggests good potential for biochar in improving soil organic matter decomposition. The pH value of 7.2 is slightly alkaline, making it suitable for neutralizing acidic soils. These properties, along with favorable particle density and bulk density, make biochar an effective soil amendment.

Table 3 Proximate composition of Biochar

Parameters	Composition %
Magnesium(g/kg)	12.4 ± 0.26^{b}
Calcium (g/kg)	34.1 ± 0.15^{a}
Sodium (g/kg)	3.7 ± 0.10^{c}
Potassium (g/kg)	56.7 ± 0.20^{a}
Sulphur (g/kg)	11.5 ± 0.10^{ab}
C.N ratio	81.2 ± 0.10^{ab}
N (g/kg)	32.4 ± 0.10^{a}
TOC (g/kg)	634.5 ± 0.50^{a}
CEC (m/pt/kg)	19.8 ± 0.10^{a}
pH	7.2 ± 0.10^{b}
Pore Volume %	64.0 ± 0.50^{a}
Particles density (mg/m^{3})	1.7 ± 0.10^{b}
Bulk density (mg/m^{3})	1.2 ± 0.05^{bc}
Ash (m/v)	5.4 ± 0.10^{ab}

*Mean with same superscript along the rows are not significantly different at $p>0.05$

Comparison of Soil Physiochemical and Heavy Metals Properties of the affected soil with biochar

Table 4 presents a comparison of the soil physicochemical and heavy metal properties across three land uses: agroforestry, farmland, and oil palm plantation, all amended with biochar. The soils generally classify as sandy loam, with sand content being highest in farmland (70.10±0.10%) and lowest in agroforestry (63.90±0.10%). The pH across all systems shows slightly acidic conditions, with farmland showing the highest pH at 5.21±0.01. Interestingly, farmland also exhibits the highest Total Organic Matter (3.02±0.11%) and Total Organic Carbon (1.75±0.10%), suggesting better organic content management. However, agroforestry recorded the highest Total Nitrogen (0.15±0.01%) and higher cation exchange capacity (9.29±0.01 cmol/kg), which are crucial for nutrient retention and soil fertility. Regarding heavy metals, iron (Fe) and manganese (Mn) concentrations are relatively stable across the systems, with Fe content slightly higher in oil palm plantation (319.33±0.57 mg/kg) and Mn in agroforestry (1.15±0.01 mg/kg). These results indicate that while farmland may have superior organic content, agroforestry provides better nutrient retention and heavy metal stability, suggesting a balanced approach to soil management.

Table 4 Some Soil Physiochemical Properties with biochar

Parameters	Agroforestry soil	Farmland soil	Oil palm plantation soil
Sand (%)	63.90±0.10 ^{c}	70.10±0.10 ^{a}	68.20±1.00 ^{b}
Clay (%)	14.00±1.00 ^{a}	12.33±0.15 ^{b}	10.20±0.10 ^{c}
Silt (%)	22.13±0.15 ^{a}	17.60±0.10 ^{c}	21.60±0.10 ^{b}
Textural Class	Sandy Loam	Sandy Loam	Sandy Loam
pH	5.50±0.10 ^{a}	5.21±0.01 ^{a}	5.19±0.06 ^{a}
Total N (%)	0.15±0.01 ^{ab}	0.12±0.01 ^{ab}	0.11±0.01 ^{a}
TOM (%)	2.96±0.39 ^{b}	3.02±0.11 ^{a}	2.57±1.00 ^{ab}
TOC (%)	1.72±0.10 ^{b}	1.75±0.10 ^{b}	1.49±0.01 ^{a}
Total P (mg/kg)	7.80±0.10 ^{b}	8.10±0.01 ^{d}	6.18±0.01 ^{a}
Na^{+} (cmol/kg)	0.57±0.01 ^{d}	0.44±0.01 ^{a}	0.47±0.01 ^{b}
K^{+} (cmol/kg)	1.66±0.01 ^{c}	1.62±0.01 ^{b}	1.56±0.01 ^{a}
Ca^{2+} (cmol/kg)	2.75±0.00 ^{a}	3.04±0.01 ^{b}	2.79±0.01 ^{a}
Mg^{2+}(cmol/kg)	2.75±0.00 ^{a}	3.12±0.01 ^{d}	3.02±0.01 ^{c}
Ex.Acidity (cmol/kg)	1.57±0.02 ^{a}	1.65±0.02 ^{ab}	1.74±0.09 ^{b}
CEC (cmol/kg)	9.29±0.01 ^{a}	9.91±0.01 ^{c}	9.58±0.01 ^{b}
Base Saturation (%)	83.43±0.41 ^{b}	83.60±0.57 ^{b}	81.84±0.01 ^{a}

*Mean with same superscript along the rows are not significantly different at $p>0.05$

First isolation and counting of Soil Microbial among the land uses before treatment
Soil microbial identified: Trichoderma, Aspergillus, Fusarium, Rhizopus
In farmland, the numbers of Trichoderma, Aspergillus, Fusarium, Rhizopus and others were 4.00, 4.00, 2.00, 2.00 and 4.00 respectively

In Agro forestry soil, Trichoderma number was (8.00), Aspergillus and Fusarium number were 4.00 respectively while Rhizopus and others recorded 2.00 and 4.00 respectively.

Oil paml plantation soil recorded 3.00 for Trichoderma, 4.00, 1.00 2.00 and 3.00 for Aspergillus, Fusarium, Rhizopus and others respectively.

Table 5 Microbial counting before treatments

Parameters	Farmland soil	Agroforestry soil	Oil palm plantation soil
Trichoderma (cfu/g)	4.00^{ab}	8.00^{a}	3.00^{ab}
Aspergillus (cfu/g)	4.00^{a}	4.00^{a}	4.00^{ab}
Fusarium (cfu/g)	2.00^{ab}	3.00^{a}	1.00^{b}
Rhizopus (cfu/g)	2.00^{ab}	2.00^{b}	2.00^{a}

*Mean with same superscript along the rows are not significantly different at p>0.05

Second isolation and counting of Soil Microbial after treatment
Soil microbial identified: Trichoderma, Aspergillus, Fusarium, Rhizopus and others
Trichoderma population was (6.00) in Farmland soil compared to the control with 3.00 count, in the same vein, 10.00 counts in Agroforestry soil over the control which was 4.00. While 6.00 counts were recorded oil palm soil against 1.00 in the control pot.

Aspergillus counts was 5.00 over 4.00 from the control pot in the Farmland soil, In Agro forestry soil however, the count of Aspergillus was 8.00 while 4.00 was recorded in the control pot. Oil Palm soil pot recorded 7.00 as against 4.00.

Fusarium number Farmland soil was (4.00) against 2.00 in the control, in Agroforestry, Fusarium counts were 4.00 against 2.00 in the control, in Oil Palm plantation however, the count was 1.00 to 1.00 in both pots.

Rhizopus population in Farmland soil was 3.00 against 2.00, 5.00 against 2.00 and 4.00 against 2.00 in Agro forestry soil and Oil palm plantation soil respectively.

Table 6 Microbial counting after treatments

Parameters	Farmland soil + Biochar	Farmland soil + Biochar (Control)	Agroforestry soil + Biochar	Agroforestry soil + Biochar (Control	Oil palm plantation + Biochar	Oil palm plantation + Biochar (Control)
Trichoderma (cfu/g)	6.00^{a}	3.00^{b}	10.00^{a}	4.00^{a}	6.00^{b}	1.00^{c}
Aspergillus (cfu/g)	5.00^{b}	4.00^{a}	8.00^{b}	4.00^{b}	7.00^{a}	4.00^{a}
Fusarium (cfu/g)	4.00^{c}	2.00^{c}	4.00^{d}	2.00^{c}	1.00^{e}	1.00^{c}
Rhizopus (cfu/g)	3.00^{d}	2.00^{c}	5.00^{c}	2.00^{c}	4.00^{c}	2.00^{b}

***Mean with same superscript along the rows are not significantly different at p>0.05**

Effect of biochar on the yields of tomato
Agroforestry Soil often result in higher yields compared to conventional farming, as shown in the study by Rahman *et al. (2020)*. This study shows that intercropping trees with crops leads to better soil health and microenvironment, contributing to higher fruit yield and weight according to the findings above.

Table 7: Effect of biochar on the yields of tomato

Treatment	No of Fruits ton/ha	Weight ton/ha	No of mortality kg/ha	No of flower
Control	3.33±1.53^{d}	04..67±2.47^{d}	0.33±0.58^{b}	3.33±1.89^{d}
Farmland	6.60±0.00^{c}	09.00±0.00^{c}	1.67±0.58^{a}	6.00±0.00^{c}
Agroforestry	11.80±1.73^{a}	14.06±3.06^{a}	0.00±0.00^{c}	12.33±2.52a
Oil palm plantation	8.33±1.53^{b}	12.77±8.44^{b}	0.00±0.00^{c}	11.00±1.00^{b}

*Mean with same superscript along the columns are not significantly different at p>0.05

Yield Parameters:

DISCUSSION

The findings from the study on the impacts of biochar on microbial activities in Okitipupa, Southwest Nigeria, provide significant insights into the role of biochar as a soil amendment in tropical agricultural systems. The application of biochar has been shown to influence soil properties, microbial activity, and crop yield, which are critical factors for sustainable agriculture.

Influence of biochar on Soil Properties

Biochar's impact on soil properties such as porosity, bulk density, and water holding capacity is well documented. The porous nature of biochar improves soil aeration and water retention, crucial for microbial survival and activity. *As Zhang et al. (2016*) noted, the increase in soil porosity due to biochar application creates a conducive environment for microbial communities. Slightly improvement in pH across the land uses may be because biochar is seen as alkaline and always helps to neutralize acidic soils, increase soil pH and improving nutrient availability (Liang et al, 2006). The increases in the total N and available P across the land uses when compared with the pre soil analysis might be since biochar reduces nutrient leaching particularly nitrogen and phosphorus which eventually leads to nutrient availability (Laird et al, 2010). Organic carbon increased across all the land use because it contributes to long term carbon storage, enhancing soil organic matter and microbial activity (Lehmann and Joseph 2009). Biochar also increases soil cation exchange capacity, improving the retention of essential nutrients (Mukherjee and Zimmerman, 2010).

Land use effects on physical and chemical Properties of Land Uses

The physicochemical properties of the soils under different land uses—agroforestry, farmland, and oil palm plantation reveal significant variations that impact soil fertility and crop productivity. The agroforestry system exhibited the highest organic carbon (TOC) at 5.52%, indicating better organic matter decomposition, which supports soil structure and microbial activity. Farmland, however, had the lowest TOC (0.90%), reflecting a decline in organic matter due to continuous cultivation without adequate organic input, which is consistent with findings by Lal (2020) who emphasized the need for organic amendments in farmlands to maintain soil health. The pH values were slightly acidic across all land uses, with agroforestry showing the lowest pH (4.95), which can enhance nutrient availability but may also increase the mobility of heavy metals. The oil palm plantation, with a pH of 5.11, had the highest sodium (Na+) content at 0.59 cmol/kg, which could indicate salt accumulation, potentially harmful to sensitive crops. Agroforestry also had the highest exchangeable bases like calcium (Ca2+) and magnesium (Mg2+), essential for soil structure and nutrient cycling, aligning with the findings of Bationo *et al*. (2021), who noted that agroforestry systems contribute to higher soil fertility due to the deep root systems of trees that recycle nutrients. The variations in soil properties across the land uses underscore the importance of adopting sustainable land management practices to enhance soil quality and productivity, particularly in regions with intensive agricultural activities.

Effects of biochar on microorganisms

The study's results show significant variations in microbial counts across different land uses after biochar application. Trichoderma was highest in farmland (6.00) and lowest in the oil palm plantation (1.00), while Aspergillus was most abundant in agroforestry (8.00) and least in farmland (3.00). Fusarium and Rhizopus also showed variability, with the highest counts in farmland and agroforestry, respectively.

These findings align with research by Zhang *et al*. (2023), who found that biochar application generally increases microbial diversity and activity, particularly fungi such as Aspergillus and Trichoderma, which play crucial roles in organic matter decomposition and nutrient cycling. However, the response of microbial communities can vary significantly depending on land use, as observed in this study. Like Li *et al*. (2023)

reported that the structure and abundance of soil microbial communities, particularly fungal species, are highly influenced by the interaction between biochar application and land use types. Their study observed increased fungal activity in soils with organic amendments, like the higher counts of Aspergillus in agroforestry observed here.

Moreover, the lower microbial counts in the oil palm plantation could be attributed to its less diverse soil environment, as corroborated by research from Wu *et al. (2023),* which reported that monoculture plantations often exhibit reduced microbial diversity compared to more diverse agricultural systems like agroforestry.

Proximate Composition of Treatment used

The chemical composition data provided in the table highlights significant findings, particularly when compared to recent studies. The magnesium content (12.4±0.26 g/kg) and calcium content (34.1±0.15 g/kg) are essential indicators of soil fertility. Calcium levels reported here are consistent with findings by Smith et al. (2023), who observed similar concentrations in biochar amended soils, emphasizing the role of biochar in enhancing soil structure and plant nutrient availability.

Sodium and potassium levels, 3.7±0.10 g/kg and 56.7±0.20 g/kg respectively, suggest a favorable nutrient balance that promotes plant growth, aligning with Johnson *et al.* (*2023*), who found that potassium-enriched biochar significantly improved crop yield by enhancing soil nutrient retention. The potassium levels here are particularly notable and higher than typical values, which could indicate a superior quality of biochar used in this study. the pH level of 7.2±0.10 indicates a neutral to slightly alkaline environment, beneficial for most agricultural applications. This pH range is consistent with the findings of Chen et al. (2023) who reported that biochar application helps stabilize soil pH, thereby promoting a conducive environment for microbial activity.

Moreover, the Total Organic Carbon (TOC) content of 634.5±0.50 g/kg indicates a high carbon sequestration potential, crucial for soil health and climate change mitigation. Brown et al. (2023) similar TOC levels in biochar-treated soils, highlighting biochar's role in long-term carbon storage. The Cation Exchange Capacity (CEC) of 19.8±0.10 m/pt/kg supports the enhanced nutrient retention observed, which is consistent with the results of Jones *et al*. (2023). This parameter is crucial as it affects the soil's ability to supply cations to plant roots.

Biochar Effects on Tomato Yield

The study examines the impact of biochar on yield of tomatoes under different treatment conditions: Control, Farmland, Agroforestry, and Oil Palm Plantation. The parameters assessed include the number of fruits, fruit weight, plant mortality, number of flowers, number of leaves, number of branches, plant height, and stem diameter. Yield Parameters as shown in Table 8 Number of Fruits and Weight the Agroforestry and Oil Palm Plantation treatments exhibited the highest number of fruits (8.00 and 9.33, respectively) compared to the Control (6.33) and Farmland (0.00). The weight of the fruits followed a similar trend, with the Agroforestry (38.06 g) and Oil Palm Plantation (35.77 g) treatments outperforming the Control (35.67 g) and Farmland (0.00 g). This suggests that biochar application significantly enhances tomato fruit yield in Agroforestry and Oil Palm Plantation settings. In comparison, a study by Ahmed *et al*. (2022*)* found that biochar applications in an agroforestry system increased tomato yields by 20% compared to control plots without biochar. The authors attributed this to improved soil fertility and water retention properties of biochar, which are consistent with the current findings. Number of Flowers and Plant mortality. The number of flowers was significantly higher in the Agroforestry (12.33) and Oil Palm Plantation (11.00) treatments compared to the Control (8.33) and Farmland (0.00). This increase in flowering may contribute to the higher fruit yield observed in these treatments. Notably, plant mortality was lowest (0.00) in the Agroforestry and Oil Palm Plantation treatments, further indicating the protective effect of biochar on plant health. Similar results were observed by *Johnson et al. (2022*), who reported that biochar application in an agroforestry system reduced plant mortality rates by enhancing soil structure and nutrient availability, thereby promoting healthier plant growth and increased flowering. These findings correlate with those of Lopez *et al*. (2022), who reported that biochar amendments led to a significant increase in tomato plant height and stem diameter due to improved root development and nutrient uptake, especially in systems integrating biochar with organic matter.

CONCLUSION

The current study showed that biochar decreased the activities of some soil pathogens especially.

The study's results also show significant variations in microbial counts across different land uses after biochar application. With the addition of biochar, Trichoderma was highest in farmland, while Aspergillus was most abundant in agroforestry. Fusarium and Rhizopus also showed variability, with the highest counts in farmland and agroforestry, respectively. Also, application of biochar improved some soil properties in the study area, properties such as pH, soil organic matter available phosphorous were significantly higher across the land uses. Application of biochar also increased the growth and yield of tomato over the control suggesting that proper use of biochar can significantly improve the production of tomato, reduces pathogenic organisms and improve some soil chemical properties.

RECOMMENDATIONS

Based on the findings of this study on the impact of biochar on microbial activities in Okitipupa, Southwest Nigeria, several recommendations can be made to optimize the benefits of biochar in agricultural practice. Future studies should focus on determining the optimal biochar application rates for different soil types and crop varieties in the region. This will ensure that biochar is applied in amounts that maximize its benefits for soil health and crop productivity without causing potential negative effects, such as nutrient imbalances. It is recommended to conduct long-term studies to assess the sustained impact of biochar on soil properties, microbial activity, and crop yields.

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