WOLKITE UNIVERSITY

COLLEGE OF AGRICULTURE AND NATURAL RESOURCE

DEPARTMENT OF NATURAL RESOURCES MANAGEMENT

SOIL PHYSICOCHEMICAL PROPERTIES, GROWTH AND YIELD OF BEETROOT (Beta vulgaris .*L*) AS AFFECTED BY BIOCHAR SOURCE AND RATE IN MESKAN DISTRICT, EASTERN GURAGE ZONE, CENTRAL ETHIOPIA

MSc. THESIS

BY

WELYOU MOHAMMED BESHIR

NOVEMBER 2023

WOLKITE, ETHIOPIA

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WELYOU MOHAMMED BESHIR

MAJOR ADVISOR: ISREAL ZEWDE (PhD)

CO- ADVISOR: ABDETA JEMBERE (ASSIST.PROF)

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APPROVAL SHEET

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I hereby certify that I have read and evaluated this Thesis entitled ‘‘Soil physicochemical properties, growth and yield of beetroot (beta vulgaris *.l*) as affected by biochar source and rate in Meskan District Eastern Gurage; Central Ethiopia

Prepared under my guidance by Welyou Mohammed. I recommend that it submitted as fulfilling the Thesis requirement.

ISREAL ZEWIDE (PhD) _______________ _______________

Major Advisor Signature Date

ABDETA JEMBERE_ (ASSIST.PROF _______________ _______________

Co-Advisor Signature Date

As members of the Board of Examiners of the MSc Thesis Open Defense Examination, We certify that we have read and evaluated the Thesis prepared by Welyou Mohammed and examined the candidate. I recommend that the Thesis be accepted as fulfilling the Thesis requirement for the degree of Master of Science in Soil science

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Final approval and acceptance of the Thesis are contingent upon the submission of its final copy to the Council of Graduate Studies (CGS) through the Graduate Committee (SGC) of the candidate’s School.

DEDICATION

I dedicate this thesis to my lovely wife and my family for their apprehension, prayer, patience, reassurance, and love in the success of my life.

STATEMENT OF AUTHOR

First, I declared that this thesis is the result of my genuine work and that I have duly acknowledged all sources of materials used for writing. I submitted this thesis to Wolkite University in partial fulfillment of the Degree of Master of Science in soil science, and it was deposited in the library of the University to be made available to borrowers for reference. I solemnly declare that I have not so far submitted this thesis to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Name: Welyou Mohammed Signature ______________________

Place: Wolkite University,

Date of Submission November 2023

BIOGRAPHICAL SKETCH

The author, Welyou Mohammed Beshir was born on October 12, 1996, G.C at Butajira town, Eastern Guraghe Zone, Central Regional State. He attended The Primary School at Dobena Secondary and his Secondary and Preparatory Schools at Butajira. And he joined Haramaya University College of Agriculture and Environmental Science in 2016.GC and graduated with a B.Sc. degree in plant science in 2018 G.C. Following graduation, he joined in Werabe University College of Agriculture and Natural Resources until 2021 G.C., when he went to Wolkite University's School of Graduate Studies to continue his studies toward a Master of Science in soil science.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
BD	Bulk Density
CEC	Cation Exchange Capacity
CRD	Completely Randomized Design
EC	Electrical conductivity
KARI	Kenya Agricultural Research Institute
LSD	Least Significant Difference
NAAIAP	National Accelerated Agricultural Inputs Access Programmer
NEMA	National Environment Management Authority
SSA	Sub -Sahara Africa
SIA	Sustainable Intensification of Agriculture
SOC	Soil organic carbon
SOM	Soil organic matter
SIA	Sustainable intensification of agriculture
TOC	Total Organic Carbon
TN	Total Nitrogen
WHC	Water Holding Capacity

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ABSTRACT

Biochar application has been widely suggested as a highly improving soil property and fertility replenishment option to promote sustainable agriculture. The biochar amendment in the soil has received more study in recent times to reclaim soil property and improve productivity. This study aimed to investigate the interaction effects of different sources (coffee husk, maize cob, and Enset leaf) and rates (0, 5, 7.5 and 10 t ha^{-1}) of biochar on soil chemical properties (pH, electrical conductivity (EC), organic carbon (OC), total nitrogen (TN), and available phosphorus (Av. P) cation exchange capacity (CEC), growth (plant height, leaf (number, length and area), and yield (beet diameter, weight per (plant and pot) of beetroot at Meskan District. A factorial pot experiment was conducted at the greenhouse, and the experiment was set up using a completely randomized design (CRD) with four levels of biochar and three types of biochar sources and replicated three. The ANOVA result indicates that a significant variation was observed at P<0.05 among the interaction effects of source and rate of biochar on soil chemical properties like (pH, EC, OC, TN, and Av. P and CEC). The result of the analysis of variance specifies that pH and EC show a significant difference at p<0.05 among the interactions of source and rate of biochar. The highest values of soil pH and EC were 7.69±0.075 and 0.25±0.008 μm cm^{-1}) respectively and the lowest was recorded in the control (6.46±0.075, 0.06±0.008μm cm-1) respectively. The ANOVA results also state that a significantly varied value was recorded within the interaction effect of different sources and rates of biochar on OC, OM, TN, Av.p., and CEC, and the highest value of OC, OM, TN, Av.p., and CEC was (7.93±0.15%, 13.68±0.29%, 0.76±0.01%, 21.5±0.49cmol. Kg-1and40.36±0.48mgkg^{-1}) respectively and the lowest value (2.29±0.15%, 3.92±0.29%, 0.17±0.01%, 13.84±0.49mg kg^{-1} and 28.68±0.48 cmol.Kg^{-1}) respectively was recorded as untreated treatment. The ANOVA result also indicates that a significant variation was observed (P<0.05) among the interaction effects of source and rate of biochar on growth and yield of beetroot, like plant height, number of leaves per plant, leaf area and length, beet diameter, and beet weight per plant and per pot. The result of analysis of variance table shows a significant variation in height. The highest value of plant height at the three growth stages was (25day, 50day and harvest) (18.56±0.67, 34.58±0.3and36.97±0.91 cm) respectively and the lowest value of plant height was (14.85±0.67, 25.88±0.3 and 35.43±0.91 cm), respectively, were recorded in control. Similarly, ANOVA showed that a significant difference value (P<0.001) resulted in a leaf (number, length and area) within the interaction effect of source and rate of biochar. The highest values were (19.66±0.48, 34.14± 0.26cm and 826.83±16cm^{-2}), respectively, and the lowest value (17.66±0.48, 29.04±0.26cm and 327.87±16cm^{2}) resulted in untreated soil. Likewise, a significant variation was obtained (P<0.001) on beet (diameter, weight per plant and pot) within the interaction of the source and the rate of biochar. The maximum value of (beet (diameter, weight per plant and pot)) was (6.61±0.013cm, 482.67±3.05g and 1458.33±10.91g) respectively, and the minimum value was (5.78±0.013cm, 343±3.05g, and 1062±10.91g) was recorded within the control. The economic analysis result shows the highest net benefit was 1012,725,480 ETB ha^{-1} obtained at soil treated with 7.5 t ha^{-1} Enset leaf biochar with an additional gain of, 21596% from every Birr invested .Finally, the study concludes that the interaction effects of different sources and the rate of biochar show a significant variation among soil chemical properties, growth and yield of beetroot in a pot experiment. Future studies should articulate the study's need for additional biochar sources by increasing the rate over a long period on research stations and farmers' fields in locations with diverse management practices.

Keywords: *biochar, pyrolysis, rate, reclamation, soil, source*

1. INTRODUCTION

The world's soils are under threat from erosion, acidification, salinization, nutrient imbalances, biodiversity losses, and contamination, among many others, which has resulted in a decline in productivity across many parts of the world (Montanarella *et al*.,2016). The rapidly increasing global population, climate change, and dwindling resources have made it very difficult to meet global food demand (Kang *et al*., 2017; Bass *et al.*, 2016). This increasing demand for food in the context of declining resources and changing climatic conditions brings to the fore the urgency of innovative techniques required for agricultural intensification(Burrell *et al*. 2016). Thus increasing the size of the land under cultivation and increasing the application of chemical fertilizers. To address the issue of food insecurity, sustainable intensification of agriculture (SIA) has been proposed. However, it is very expensive to use in suitable ways, and it results in poorly managed agricultural intensification, changes in soil property, and soil loss of its natural production potential. It can also negatively affect the ecosystem (Agegnehu *et al*.,2017; Kang *et al.*,2017). In most sub-Saharan African (SSA) countries, agriculture is the backbone of their economies. (Davis *et al*.,2017), However, changing soil properties, declining soil fertility, and reliance on the elective use of inorganic fertilizer and rain-fed agriculture represent major constraints to agricultural productivity in Ethiopia. For example, agriculture has contributed significantly to economic growth and employs more than half of the country's population. (Wandaka and Kimuyu, 2017).Given poor land practices and continuous cropping, the fertility of most soils in Ethiopia has been depleted (Wandaka *et al*.,2017).

This situation has led to excessive use of chemical fertilizers in many commercial agricultural fields, with attendant negative environmental consequences (Agegnehu *et al*., 2016). Various soil fertility improvement technologies have been tried as solutions, according to (Agegnehu *et al*., 2017;Trupiano *et al*., 2017; Cao *et al*., 2018; Mensah and Frimpong, 2018 & Manolikaki and Diamadopoulos, 2019a). Organic resources such as biochar and verm compost have been suggested as alternative options for improving soil quality to promote sustainable agriculture. (Rawat*et al*., 2019). Biochar is helpful to improve soil nutrients and enhance soil quality. It is a carbonaceous residue generated by heating biomass in the absence of oxygen with a process called pyrolysis, which transforms organic matter into a solid residue (biochar) and a vapor (Ahmad *et al*., 2014). It has been advised as a means to help overcome limitations common in tropical systems.

Which are recalcitrant forms of pyrogenic carbon produced via pyrolysis, i.e., the thermal degradation of biomass in atmospheres devoid of oxygen (Karim *et al*.,2020). They are porous and have high surface areas with substantial negative charges, properties that can substantially increase soil cation exchange capacity (CEC), nutrient and water retention, and the natural neutralizing ability of nutrients in the soil. (Hailegnaw *et al*., 2019.) Biochar is also capable of sorbing or otherwise reducing the bioavailability of a variety of phytotoxic soil contaminants, including residual pesticides, allelochemicals, metals, and salts. Freshly applied biochar readily leaches ash rich in carbonates of K, Ca, and Mg, which often significantly lime soils, which can enhance the availability of P and K in nutrient-deficient acidic tropical soils (Karim *et al*., 2020).

Biochar also enhances soil organic matter and may mitigate compaction in degraded tropical soils (Hailegnaw *et al*., 2019). Biochar also offers a potential solution to maintaining soil fertility: it has a higher CEC than most other forms of organic matter (OM), mobilizes pulses of nutrients, in particular base cations, and is resistant to mineralization (Bruun & El-Zehery, 2012). Data syntheses report the largest positive biochar effects on crops in tropical agricultural soils, resulting from strong liming and the supply of base cations to (relatively) acidic and nutrient-deficient tropical soils (Jeffery *et al*.,2017).Beetroot (*Beta vulgaris* L.), one of the major root vegetables grown throughout the world, has its origins in Germany. It belongs to the family Chenopodiaceae (Yordanova & Gerasimova 2018). Although it is typically grown as an annual crop, beetroot is biennial (Pandita *et al*. 2020). From the cultivation point of view, beetroot is easy to cultivate in the field and pot. It grows quickly, is highly productive, and is usually free of pests and diseases (Nottingham, 2021).

Though it is a cool season crop, it grows well in warm weather and thus can be grown during winter all across the plains of Nepal and it is a significant crop due to its financial and health benefits for small-scale farmers (Muthini *et al*. 2020a). It is mostly consumed as a salad vegetable, though the leaves can also be eaten as spinach. Recently, beetroot has been gaining popularity as a “superfood” due to its beneficial value for health. It has demonstrated tremendous significance for human health, including the prevention of cancer and blood pressure regulation (Pandita *et al*.2020). Its mineral richness and antioxidant qualities are the cause of this. When suitable agricultural management is used, beetroot can yield 40 tons per hectare (Vallespir *et al*. 2018). But low soil fertility and leaching of nutrients, which are the main problems in sub-

Saharan Africa (SSA), contribute to the reduction in beetroot yield and result in food scarcity (Tibesigwa *et al*. 2017). Low soil fertility is caused by farmers applying inappropriate fertilizers because of their high cost and demand, To promote beetroot development, farmers are compelled to utilize organic manure due to the high cost of synthetic fertilizers (Deuter and Grundy, 2004) it was used as test crop ,the study was initiated

1.1 General Objective

- To investigate the effects of biochar on soil physio-chemical properties, growth, and yield of beetroot in Meskan District

1.2 Specific Objectives

- To evaluate the effect of biochar, sources and rate on selected physiochemical properties
- To estimate the effect of biochar sources and rate on growth and yield of beetroot plant
- To evaluate the economic feasibility of biochar sources and rate on beetroot production

2. LITERATURE REVIEW

2.1 Brief History of the Use of Biochar

Smith in 1879 and Hartt in 1885 (Woods, 2003), described the existence of biochar as very fertile soils called Terra Preta do Indo in Portuguese (black earth) by the Indians of the Amazonia, although they could not prove their origins. Studies of these soils have revealed they have high organic matter, high moisture content, high water exchangeability, high cationic exchange capacity, and increased microbial activity (Lehmann & Joseph, 2009). It has been suggested that these fertile soils were attained by gradual deposition of burning vegetation and other biomass as well from remains of dead animals (Falcao, 2012).

The dark color of the Terra Preta has been attributed to the ancient farming practices of the Amazonian Indians such as slash and char (Talberg, 2009). There has also been evidence to suggest that biochar applications may have been deliberate considering the quantities present in those areas (Sohi *et al*., 2010) as one way to address the low soil fertility. For example, the abnormally high nutrient content of the Terra Preta has been attributed to deliberate processes such as slash and char, nutrient enrichment through composting and use of human excreta. There have also been records of similar soil types in other parts of the earth including Benin in West Africa and in the savannas of South Africa (Lehmann, 2007).

Recent discoveries of such soil types have been made in Mexico and Borneo (Sheil *et al*., 2012), in the United States (Skjemstad *et al*., 2002; Laird *et al*., 2009 and in JapanIshii and & Kadoya, 1994). These findings suggest that improving soil fertility by adding plant biomass was a common place around the world. In Finland and surrounding areas, there was a comparable practice called kytö. This was a kind of biochar` produced by burning of wood or peat, was used in Finland and nearby areas as a means of improving soil fertility and reducing the incidence of pests and diseases (Ahokas, 2012). The Dutch scientist Wim Sombroek in his publication 'Soils of the Amazon' noted these various soils and promoted the idea of developing new black earths as storages for carbon for intensive crop production (Woods & McCann, 1999).

2.2 Biochar Production and its Properties

The chemical composition of biochar includes carbon, hydrogen, sulfur, nitrogen, oxygen and minerals (Ca, Na, K, and Cl) in the ash fraction (Rawat *et al*., 2019). Biochar is a product of thermochemical decomposition of biomass (plant or animal) under limited oxygen from $250^{o}{}_{C}$ to > $900^{o}{}_{C}$ in a process known as pyrolysis (Bonanomi *et al*., 2017). According to Lehmann and Joseph (2015), the chemical properties of the organic carbon structure of the biochar are fundamentally different from those of the materials from which the biochar was produced. Biochar is highly porous, black in color, light weight, have a large surface area and has high pH; all these characteristics have positive effects on its application to soils (Rawat *et al*., 2019). Biochar has a higher specific surface area, and when applied to the soil will result in an increase in soil surface area (Lehmann and Joseph, 2015). A wide range of biomass such as maize cob, maize straw, rice husk, wheat straw, animal manure and other agricultural residues can be used as a feedstock for biochar production (Blanco-Canqui, 2017; Kiran *et al*., 2017).

However the nutrient composition of the biochar produced depend on the type of feedstock and the pyrolysis conditions (Shareef *et al*., 2018a). According to Shareef *et al*., (2018a) discovered that the pH of biochar produced from maize straw pyrolysis at $300^{o}C$ (9.42) was higher than the biochar produced from maize cob pyrolysis at $300^{o}C$ (8.63). They also reported an increase in biochar pH and ash content with increasing pyrolysis temperature. Due to the different properties of biochar as influenced by feedstock type and pyrolysis conditions, both positive and negative effect on soil quality and crop yield have been reported (Bass *et al*., 2016; Burrell *et al*., 2016).

Biochar can be produced on a large scale (cost-intensive) using large pyrolysis plants and higher amount of feedstock or on a small scale (low-cost) using locally modified stoves or kilns (Rawat*et al*., 2019). During pyrolysis, oil and gases are generated as by-products (Zhu *et al*., 2018). Pyrolysis classified as fast pyrolysis or slow pyrolysis depending on the temperature and time duration of heating. In fast pyrolysis, the feedstock is heated at temperatures above 500 $^{o}{}_{C}$ within a shorter time (heating rates $\geq 1000^{o}{}_{C}$ mm^{-1}). Slow pyrolysis uses temperatures of less than $500^{o}C$ and takes more time to fully pyrolysed (heating rates $\leq 100^{o}C$ mm^{-1}). The bio-oils produced during fast pyrolysis are more than the bio-oils produced from slow pyrolysis (Rawat, Saxena and Sanwal, 2019).

2.3 Effects of pyrolysis temperature

Three steps were involved in the formation of biochar: pre-pyrolysis, main-pyrolysis, and generation of carbonaceous soil products (Lee *et al*. 2017). The evaporation of moisture and light volatiles is responsible for the first stage, which lasts from room temperature to 200 degrees Celsius. Because of the moisture evaporating, bonds break and hydro peroxide, COOH, and CO groups are formed (Tomczyk *et al*. 2020) The second stage involved the rapid decomposition and volatilization of hemicelluloses and cellulose between 200 and 500^{o}C (Ding *et al*.2014) Degradation of lignin and other organic materials with stronger chemical connections occurs at the final stage (over 500^{o}C) (Cardenas-Aguiar *et al*.2017). There is a substantial correlation between alterations in the physicochemical properties and structure of biochar and the temperature of pyrolysis (Jindo *et al*.2017). The temperature at which biochar was pyrolyzed had a significant impact on its physicochemical characteristics, such as its surface area, pH, and functional groups, as well as how well it worked as a soil amendment (Ding *et al*.2014). Increases in surface area, carbonized fractions, pH, and volatile matter were seen at higher pyrolysis temperatures, but decreases in CEC and surface functional group content were noted.

2.3.1 Specific surface area

It has been discovered that raising the temperature of pyrolysis alters the surface area and porosity of biochar (Tomczyk *et al*. 2020) The most plausible causes of this are the creation of micro pores and the breakdown of organic materials (Tomczyk *et al*. 2020). Additionally, higher pyrolysis temperatures may cause the aromatic lignin core to be exposed and the aliphatic alkyls and ester groups to be destroyed, which could lead to an increase in surface area Ghani *et al*.(2013) have demonstrated that biochar becomes more hydrophilic and lignin does not change into a hydrophobic polycyclic aromatic hydrocarbon (PAH) at temperatures below 500^{o}C. Biochar is thermally stable and becomes more hydrophobic at temperatures over 650^{o}C (Ghani *et al*. 2013) Nonetheless, the surface's hydrophobicity or hydrophilicity does not clearly determine how aromatic chemicals sorb. As the temperature rises, the biochar's surface area grows. This is because pore-blocking materials are pushed off or thermally broken at higher pyrolysis temperatures, increasing the surface area that is accessible from the outside (Rafiq *et al*. 2016) .Through the progressive destruction of organic materials (cellulose, lignin), as well as the creation of vascular bundles or channel structure, pyrolysis may increase the surface area and pore volumes. Pyrolysis may increase the surface area and pore volumes through progressive degradation of the organic materials (cellulose, lignin) and the formation of vascular bundles or channel structure (Li *et al*. 2013; Zhao et al. 2017).Because of the cellulose's breakdown during pyrolysis, certain amorphous carbon structures are also created(Zhao *et al*. 2017) It has been stated that microspores may be formed by amorphous carbon structures. More pores and the release of volatile substances are produced by a greater pyrolysis temperature (Shaaban *et al*. 2014). According to Tomczyk *et al*. (2020), state that Biochar made from cottonseed hull (4.7 m^2/g) and chicken litter (17.7 m2/g) had low specific surface areas and low ash contents. Poultry litter (17.7m^2/g) and dairy manures (13.0m^2 /g). Adsorption capacity and the adsorbates' removal method have been found that significantly influenced by the kind and concentration of surface functional groups (Tomczyk and Boguta, 2020) Moreover, resistance to microbial degradation can be improved by increasing the structure's aromaticity as the pyrolysis temperature rises (Xie *et al*. 2015) discovered that because of its large surface area and significant micro pore growth, biochar generated at temperatures higher than 400^{o}C was more effective for sorption of both organic and inorganic contaminants. However, Tomczyk *et al*. (2020) demonstrated that at low pyrolysis temperatures (100–300^{o}C), the main sorption mechanism was the partitioning of organic and inorganic contaminants into non-carbonized biochar fractions made from pine needles, while at high temperatures (400–700^{o}C), the dominant sorption mechanism was adsorption onto porous carbonized fractions.

2.4 Effects of feedstock material

Biomass is a complex biological solid composed of once-living organic or inorganic elements. (Tomczyk *et al*. 2020) Biomass encompasses a wide range of waste materials, such as animal dung, waste paper, sludge, and various industrial wastes. This is because, like natural biomass, biomass materials are made up of both organic and non-organic molecules and can be converted into energy through processing (Tripathi *et al*. 2016). Biomass comes in two varieties: woody and non-woody. The majority of woody biomass is made up of tree and forestry wastes (Jafri *et al*.2018) . The characteristics of woody biomass include low ash and moisture content, high bulk density, high calorific value, and little voidage (Jafri *et al*. 2018) Animal dung, industrial and municipal solid waste, and agricultural residues and products are examples of non-woody biomass. (Jafri *et al*. 2018) it is thought to have high moisture and ash content, a poor calorific value, a low bulk density, and a larger voidage. The production of biochar is influenced by the moisture content (Sun *et al*. 2014). The moisture in biomass not only keeps char from forming but also increases the energy required to reach the temperature required for pyrolysis (Tripathi *et al*. 2016) .There is always a correlation between biomass and moisture and water content. The water contained in biomass can be found as free liquid water, chemically bound water that has been adsorbed within the biomass's pores, and water vapor (Tomczyk *et al*. 2020). In comparison to pyrolysis involving biomass with high moisture content, low moisture is dvised for the creation of biochar since it significantly reduces the heat energy and time required for the pyrolysis, making the process economically viable. (Tripathi *et al*. 2016) A broad variety of biomass moisture contents encourages the creation of biochar with various physicochemical properties. For instance, the surface chemistry of the pyrolytic charcoals was significantly impacted by the moisture level of the hardwood and softwood bark samples The surface of the charcoal gets more graphite-like and polyaromatic as the moisture content in the maple bark decreases, most likely because the pyrolysis process takes longer to complete once the water has evaporated (Tomczyk *et al*. 2020).

2.5 Effect of Biochar, Application on Soil Chemical Properties

Various scholars; (Bass *et al*., 2016; Bonanomi *et al*. 2017; Jeffery *et al*., 2017; Trupiano*et al*., 2017;Cao *et al*., 2018; Shareef and Filonchyk 2018a; Manolikaki and Diamadopoulos, 2019a & Sigua *et al*.,2019) have reported improvement in soil chemical properties following biochar applications. The reported improvement in chemical properties varied with biochar type, pyrolysis temperature, combined rates and soil type.

2; 5.1 Soil pH

An increase in pH following biochar application had been observed by many studies (Chintala *et al*.,2014; Bass *et al*., 2016; Kiran *et al*., 2017; Shareef *et al*., 2018a; Mensah and Frimpong, 2018) Biochar are mostly alkaline (pH >7) with higher base cation concentrations, and when applied to soils can release base cations into the soil solution to reduce acidity through proton consumption reactions (Chintala *et al*., 2014). In a pot experiment conducted by Mensah and Frimpong, 2018), the sole application of biochar was found to have increased soil pH from 4.8 to 6.1. The increase in pH in the biochar amended soils was attributed to the high pH of the biochar used in their experiment. It was concluded that biochar can be used as an alternative option to lime materials to ameliorate acidic soils. In a similar study conducted by (Shareef and Filonchyk, 2018a), pH of biochar amended soil was found to increase with increasing pyrolysis temperature. In their study, the highest pH was recorded in soils amended with biochar pyrolysis at 600^{o}C (11.03) followed by 300^{o}C (8.63). The combined application of biochar and compost was found to have recorded higher pH values than the control, but the differences were not significant. They explained that no significant differences observed at the trial completion could be due to the low application rates of biochar used. Since soil pH can change under changing climatic conditions and changing land-use practices, it is important that biochar effect on soil pH be assessed regularly in the long term to further understand the dynamics in pH of soils with differing acidity

2; 5.2 Electrical conductivity (EC)

In previous studies (Chintala *et al*., 2014; Burrell *et al*., 2016; Shareef and Filonchyk, 2018a), EC was found to have increased with an increasing application rate of biochar. Chintala *et al*. (2014) attributed the increase in EC to alkalinity, $CaCO_3$ content, proton consumption capacity, and base cation concentration of the biochar used in their study. They explained that biochar contains higher soluble salts which are released into the soil solution which could increase the soil EC. The increase in EC was also attributed by Shareef and Filonchyk (2018a) to the release of weakly bound ions of the biochar into the soil solution making it easy to be absorbed by the plant.

In a pot experiment conducted by Burrell *et al*.(2016) on 3 soil types (Planosol, Chernozem and Cambisol), EC was found to have increased significantly in the woodchip-biochar amended soils from 6.8 μscm^{-1} immediately after application to 113 μscm^{-1} 3 years after application. However, in the Chernozem and Cambisol, differences in EC after 3 years were not significant relative to the control. This supports the claim that biochar effect on soil properties are specific to soil type and amendment properties of production cannot be properly (Alkharabsheh *et al*., 2021)

2; 435 Total nitrogen (TN)

Nitrogen, being one of the most important macronutrients for crop growth and development is limited in most tropical soils. The C/N ratio is widely used as a factor to assess availability of nitrogen in soils. When the C/N ratio of organic material is greater than 10, N becomes immobile (Manolikaki and Diamadopoulos, 2019b), hence unavailable for plant use. This suggests that N losses in soil either by plant uptake or by leaching will be higher in un-amended soils than the biochar amended soils(Khan and Hossain, 2018). Previous studies (Chintala *et al*., 2014; Agegnehu *et al*., 2016; Khan *et al*., 2018; Manolikaki and Diamadopoulos, 2019b) have shown significant improvement in soil TN following the application of biochar. Agegnehu *et al*. (2016) found that applying biochar can increase soil TN by 14% to 29%. Schulz and Glaser (2013) also reported that biochar application can increase soil TN and correlates significantly with plant height and weight.

2; 5.4 Total carbon

In a field trial by Bass *et al*. (2016), the soil carbon content was increased significantly by all the organic amendments (biochar, compost and biochar-compost). Field trial, the average carbon stock had increased to 24.2, 8.4 and 17.6 t ha^{-1} for biochar, compost and biochar-compost respectively. They explained that the increase in carbon stock was seen in the significant increase in the %C and C/N ratio of the soil at the trial end. Other studies (Bayu and Amsalu 2016; Trupiano *et al.,* 2017; Mensah and Frimpong 2018; Manolikaki and Diamadopoulos 2019b) have also reported an increase in soil carbon content after biochar was applied.

According to Bayu and Amsalu (2016) applying different rates of biochar to acidic soils will significantly increase the mean soil carbon (OC) content, organic matter (OM) content and nitrogen (TN) content, Their findings indicated a percentage increase of 35.0% OC, 35.1% OM and 34% TN as a result of biochar application. (Mensah and Frimpong, 2018) found an increase in the carbon content of biochar amended soils and attributed the increase to the biochar's ability to enhance carbon accumulation and sequestration. In a similar study, Frimpong *et al.* (2016) obtained that organic carbon content of soils amended with cow dung and biochar were higher as compared to the control soil. Additionally, Trupiano *et al*. (2017) revealed that biochar amended soils have high soil carbon content than the un-amended soils, which is an indication that biochar applications to soils can enhance carbon accumulation and sequestration

2; 5.5 Available phosphorus (P)

Phosphorus and Nitrogen are important macronutrients, which are widely and heavily applied on agricultural fields. Phosphorus and nitrogen losses either through leaching or runoff in agricultural field represent a major environmental risk in most countries leading to eutrophication and deterioration of both surface and groundwater (Cao *et al*., 2018). It is apparent that sustainable farming practices are geared towards minimizing P losses in agricultural soils. Biochar application to soils had been reported to reduce P losses (Chintala *et al*., 2014; Cao *et al*., 2018). The ability of biochar to reduce P losses have been attributed to the high affinity of biochar for P which transforms P from readily available form to less available form (Cao *et al*., 2018). In a pot experiment, Mensah and Frimpong (2018) revealed that the application of biochar significantly increased the available soil P. The highest available P content was found in the biochar-added soils (722.1 to 760 mg kg-1) as compared to the control soils (570.4 to 593.8 mg kg^{-1}). They attributed the increase in available P to reduced Fe and Al activities as influenced by the increase in soil pH. Also, in a long-term field study on Ferralsol, (Agegnehu *et al*., 2016) discovered that biochar applied solely or in combination with compost increased soil available P by 59% -117%.

2; 5.6 Cation exchange capacity (CEC)

An increase in the CEC of biochar-amended soils can be attributed to negative charges released from the carboxyl groups of the organic matter. It was found that the untreated acidic soil had a 24.95 me/100 g level of CEC before biochar, and the 20 CEC level increased from 24.95 to 34.9 me/100 g (a 28.7% increase) after biochar application Nigussie *et al*. (2012) reported an increase in soil exchangeable bases in chromium-polluted soils in Ethiopia after applying biochar to the soil. The increase in exchangeable bases was attributed to the existence of ash in the biochar, which helps in continuous release of minerals like Ca and K for crop use. In a similarly, Mensah and Frimpong (2018) recorded higher significant exchangeable Ca and Mg value in soil types amended with 2% compost. They attributed the increase in Ca and Mg to the higher CEC of the compost used in their experiment. In another study, Cao *et al*. (2018) reported that an increase in

CEC in both low nutrient and high nutrient soils. They explained that the increase in CEC could be due to the higher carbon content of the biochar applied to the soil. CEC represents the nutrient retention capacity of a soil and therefore soil with low CEC will be horizontal to nutrient leaching. Biochar is porous in nature with the higher surface area which can retain more nutrients on its charged surfaces making nutrients less mobile (Rawat *et al.*, 2019). Bass *et al*.(2016) reported an increase in CEC by 27.5%, 24.7% and 4.1% in biochar, amended soils respectively. Also, in an incubation experiment, (Chintala *et al*.,2014) observed an increase in CEC continuously over the incubation period in all the biochar treatments. They attributed the increase in CEC to alkalinity, proton consumption capacity, and base cations concentration of the biochar

2.6 Effects of biochar on beetroot growth

Plant height and leaf area were greatly influenced by the application biochar at 5 and 10 t/ha. This is because which contributes to the improvement of nutrient absorption by plant roots. Similar findings were reported by Walter and Rao,(2015) who reported an increase in the height of sweet potatoes after application of biochar at 7 and 12 t/ha this growth to biochar's capacity to improve microbial activity and increasing soil aeration which allows root penetration to absorb beneficial nutrients to the plant. Results by Oladele *et al*. (2019) in Nigeria also revealed an increase in the growth of rice when biochar was added Similarly, Hamzah, and Shuhaimi, (2018) reported that when biochar at 8 t/ha was applied maize plants grew taller when compared to the control. Similar results were reported by Arif *et al*. (2017) who documented a significant increase in the height of maize after the application of biochar due to the ability of biochar to recycle organic matter in the soil. It has also reported that biochar as a soil amendment contributes to the absorption of heavy metals in agricultural soil. This explains clearly that biochar provided more nutrients for growth. This is because biochar applied as the soil amendment has the potential to improve some of the soil's chemical properties like pH, organic matter (OM) and microbial activity. As a consequence of the change in chemical properties, key soil processes like carbon mineralization and nutrient transformations could be increased in the soil (di Summa *et al.*, 2021),the utilization of biochar demonstrated a great impact to increase beetroot growth due to its capability to increase the soil's macro and micronutrients as well as soil texture and affects several processes in the soil like N cycling which improves fertility

2.7 Effects of biochar on the yield of beetroot

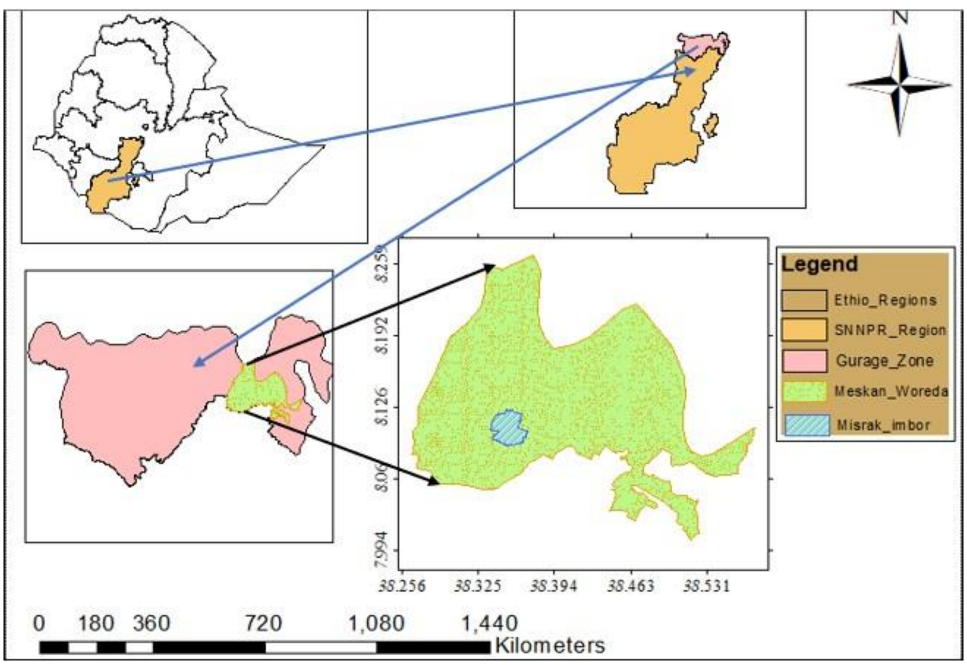
The application of charcoal dust (biochar) significantly increased the yield of beetroot. The results from this study noted an increase in growth and yield of beetroot with application of biochar. In Burkina Faso an increase in beetroot yield was recorded following application of biochar indicating the capability of biochar to improve soil property(di Summa *et al*. 2021). This soil conditioning brought on by the application of biochar is expected to also ameliorate the physical properties of the soil, promote unusual growth of the root, and increase the chemical properties such as soil nutrients availability (Arabi *et al*. 2018).

Additionally, the beneficial effects of biochar contributed to the improvement of soil microbial colony which normally plays a big role decomposition process leading to the increase in organic matter content in the soil. (Akoto-Danso *et al*. 2019 ; Gao *et al*. 2022) and (Diatta *et al*. 2020) have documented that biochar plays a very great influence on soil nutrient availability such as carbon and nitrogen as well as increasing the activities of the enzymatic in the soil which greatly affect the environment for crop growth The studies by Lychuk *et al*. (2015) and (Sekar *et al*. (2014) also accepted a rise in crop yield following an application of biochar The strong interactive effects of biochar rates (5, and 10 t ha^{-1}) on beetroot production can be attributed to the ability of biochar to supply nutrients to beetroot plants, condition the soil and increase nutrient-use-efficiency of the beetroot cultivar (Ahmed and Schoenau, 2015)

3. MATERIALS AND METHODS

3.1 Description of the Soil Sampling Area:

The experiment was conducted in the smallholder horticulture project in a greenhouse in Meskan district. It is geographically located at 08o 06′ 07.92″ to 08o 06′ 30″ N latitude and 38o 28′ 29.94″ to 38o 30′ 0″ E longitude and 133km South of Addis Ababa. It shares borders with Sodo Woreda in the North- East, Kokir Gedebano in the North-West, Muhurna Aklil in the West, Misrak Meskan & Silte in the South and Aliche in the South-West (MWFEDD, 2016). The experimental site receives an average rain fall of 1001-1200mm with the average temperature range between 7.5-17.5 ^{o}c. The soil of the study area was reported to be according to new Ethiopian soil study Ali *et al*.(2022) vertisoil & according to FAO Etric Cambisols Wrb. (2015) Its elevation ranges from 150–1500 mm above sea level. The altitude of the area is about 2144 meters above sea level. Soils were collected from cultivated land at a depth of 20 cm. The soil was air-dried, mixed thoroughly, and passed through < 2 mm sieve. The soil used for the experiment was characterized by a pH of 6.45; organic carbon was 2.21 g kg^{-1}.Total nitrogen was 0.19 g kg^{-1}. Av. P was 13.51 mg kg^{-1} the cation exchange capacity (CEC) of 22.17cmolckg^{-1})



Source: CSA Ethio shape file data 2017 wgs 1984

Figure 1 Location Map of Study area

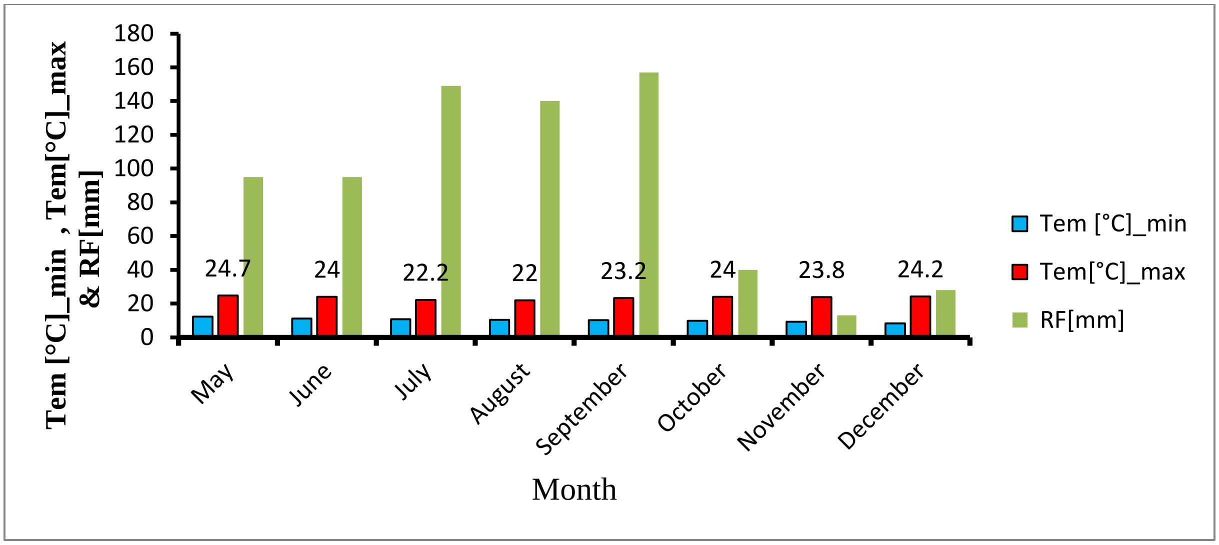


Figure 2 Monthly minimum, maximum temperature and rain fall of growing season of beetroot through new loclim software

3; 1.1 Farming Practices

About 53% of the District is covered by black soil (MWFEDD,2016). It is the dominant soil type in the lowland areas of the district. It was reported that black soil is the most fertile soil in the district and is known for its suitability for maize, wheat, vegetables, etc. Red soil covers about 22%, and it is found on riversides and eroded areas (highlands). It is suitable for deep-rooted trees like Eucalyptus and Junipersprocera (Tid). Gray soil covers about 25%; this soil type is found in the highlands of the district, and it is less fertile than the black soil. Hence, it is used widely for grazing, livestock herding, and afforestation.

3.2 Treatments and Experimental Design

A two-way pot experiment was conducted in a greenhouse in summer conditions. The experiment was set up using a completely randomized design (CRD) with four levels of biochar (0, 5, 7.5, and 10 t ha^{-1}) and three types of biochar sources (maize cob, coffee husk, and Enest leaf) and replicated three times. The experiment had a total of thirty-six treatment combinations. The treatment rate and type of feedstock arrangement are in (Table 1).

3.3 Preparation of Biochar

Coffee husk, Enset leaf and Maize cob biochar were prepared in Butajira Poly Technique Collage by using furnace with pyrolysis temperatures, 500°C and 3hrs.of residence time as suggested by Dume *et al*., (2016). The resulting biochar materials grounded and sieved through 2mm square-mesh sieve, and The reasons to select most of the sources of biochar were easily accusable as waste in the district

3.3.1 Physical and chemical properties of Biochar before experiment

The physical and chemical characteristics of the biochar samples were examined, included
To calculate the specific surface area (SSA), divide the total surface area (SA) by the mass (M)

SSA = **SA /M**

- Where SSA is the Specific Surface Area (m^2/kg)
- SA is the total surface area (m^2)
- M is the total mass (kg)

A portable pH meter was used to measure the pH. EC was determined using a conductivity meter with a 1:2.5 w/v water-biochar solution (HANNA Instruments) Water-biochar suspension at 1:.2.5 (w/v) after one hour of mechanical shaking .Olsen extractable phosphorus (P) was determined using Olsen P method (Olsen *et al*. 1954). Then, extracted P was filtered through What man filter paper 42 and P concentration was measured by addition of ammonium molybdate-ascorbic acid (mixed color developing reagents) using a spectrophotometer optimization with the wavelength 882 nm,

The Walkley and Blackan examination method determining OC content by proposed modification chromic acid titration method treating of biochar sample with $K2Cr_2O_7$ and H_2SO4. Finally Ortho phosphoric acid (H_3PO4) and diphenylamine was used as indicator just before titration ,then it was back titrated against standardized Ferrous sulphate solution ($FeSO4.7H_2O$), till to give sharper end point of green including to the blank the OC content. The percent OM was obtained by multiplying percent soil OC by factor of 1.724. Total nitrogen (TN) was analyzed using the Kjeldahl method by oxidizing the organic matter in the presence of catalyst mixture of selenium powdered treated with conc. H_2SO4 was to digest quantitatively to the macro-Kjeldahl. CEC were determined by flame atomic absorption spectrometer with the method of ammonium acetate extract method that the sample was mixed with sodium acetate at 150 rpm on a mechanical shaker for5 min sequentially with sodium acetate followed isopropanol then ammonium acetate to displace adsorbed sodium ions

3.3 Soil Sampling and Preparation

The top 0–20 cm pre-soil analysis soil sample was collected by using auger. The collected soil samples were air-dried, crushed by using mortar and pestle and then passed through a 2 mm square-mesh sieve.

3.4 Greenhouse Incubation of Soil Biochar Mixtures

The effect of different sources and the rate of the biochar produced at 500^{o}C pyrolysis temperatures on physio-chemical were examined through a greenhouse evolution experiment. Three kilograms of composite soil sample air-dried and crushed were filled into each pot (24 cm wide, 20cm long) and weighed in different beakers. Different sources of biochar (coffee husk, maize cob, and Enset leaf) were added at rates of 0, 5, 7.5 and 10 t ha^{-1}. The baseline reference for rating Mwadalu *et al*. (2021) he suggested that 7.5 t ha^{-1} was potentially effective and this rate was effective for his finding. The treatments' units were converted to hectare bases by assuming a plow depth of 20 cm and a bulk density of 1.13g cm^{-3} for the soil, which is equivalent to 0, 1.366, 2.049.and 2.732, g/kg, respectively, and thoroughly homogenized the biochar with the soil. The soil moisture was maintained at a constant weight at 60% (filed capacity) equal to 1.8L 3Kg^{-1}) throughout the experimental period. They were placed randomly and incubated in the Greenhouse for two months. At the end of two months, (100 g) of soil biochar mixture samples were taken from each of the pots and analyzed for selected soil physiochemical properties: textural analysis pH, OC, TN, Av. P, CEC, and EC were also analyzed as per the standard methods. The treatments' units were converted to hectare bases by assuming a plow depth of 20 cm and a bulk density of 1.13 g/cm3 for the soil. Beetroot (*Beta vulgaris* L.) was used as the test crop. Four seeds of beetroot plants were inserted into each pot after seedling, and one plant was thinned.

3.5 Treatments and Experimental Design

A two-factor pot experiment was conducted in a greenhouse in summer conditions. The experiment was set up using a completely randomized design (CRD) with four levels of biochar (0, 5, 7.5, 10 t ha^{-1}) and three types of biochar source (maize cob, coffee husk, Enest leaf) and replicated three times. The experiment there had a total of thirty-six (36) treatment combinations. Treatment rate and type feedstock arrangement (Table 1),

Table 1 Treatment combination of the Experiment

Rate of biochar t ha^{-1}	**Source of biochar**	**Treatment combination**	
0	Coffee husk	0 t ha^{-1}	Control
5	Coffee husk	5 t ha^{-1}	Coffee husk
7.5	Coffee husk	5 t ha^{-1}	Maize cob
10	Coffee husk	5 t ha^{-1}	Enset leaf
0	Maize cob	0 t ha^{-1}	Control
5	Maize cob	7.5 t ha^{-1}	Coffee husk
7.5	Maize cob	7.5 t ha^{-1}	Maize cob
10	Maize cob	7.5 t ha^{-1}	Enset leaf
0	Enset leaf	0 t ha^{-1}	Control
5	Enset leaf	10 t ha^{-1}	Coffee husk
7.5	Enset leaf	10 t ha^{-1}	Maize cob
10	Enset leaf	10 t ha^{-1}	Enset leaf

3.6 Experimental Procedures

The biochar used in this study was obtained from slow pyrolysis at 500°C with 3 hours of retention time, as suggested by Dume *et al*., (2016). After the pyrolysis, it was watered to cool down, and the biochar was ground to a uniform particle size (2mm) to have the same particle size as that of the soil (Bayu *et al*.,2015) before experimental use, then incorporate it with the soil and take it into the pot. After 60 days of analysis of the soil selected and physicochemical properties using R Studio version 4.2.3 to understand the improvement of the soil after the addition of biochar, four seeds of beetroot were taken into each pot to understand the effect of the sources and rate of biochar on the growth and yield of beetroot. After that, all management was conducted uniformly, and then, in the end, an analysis of the growth and yield of the beetroot parameters was conducted.

3.7 Data Collected

3; 7.1.Soil sample collection and Analysis

Soil samples were taken from the upper 0-20 cm of the experimental area using the zigzag sampling pattern applying Auger to collect a representative soil sample of the site before applying biochar, and after biochar for pre soil physiochemical property analysis. And 100g soil samples were taken in each pot after incubation Then air-dried, ground using a pestle and a mortar and is allow to pass through a 2 mm sieve, to analyzed selected physio-chemical properties of soil, after biochar application, namely soil textural analysis, soil pH, EC organic carbon, total nitrogen (N), available phosphorus (P), cations exchange capacity (CEC) and Total nitrogen (TN): The total nitrogen in the soil was determined by using Kjeldahl method (Jackson,1973) . Available phosphorus: P was determined using the Olsen method (Olsen *et al.*,1954). Organic carbon: OC was determined using (Walkey and Black 1934). pH: Soil pH was determined from the filtered suspension of 1:25 soils to water ratio using a glass electrode attached to a digital pH meter (potentiometer). Electrical conductivity meter (Cond 730, WTW Series) was used to measure the soil EC in a 1:5 (w/v) soil: water ratio suspension, by weighing 20 g of air-dried soil into a 250 ml PE bottle and adding 100 ml of deionized water Texture: was determined using hydrometer method (FAO,1974).Cation Exchange Capacity: was determined with Potassium chloride extraction.

3; 7.2 Beetroot growth and yield

Plant Height: Plant height was measured in three different stages: 25 days, 50 days, and at harvest, the plant height was measured from the soil surface level to the tallest drooping leaf of the plant using a long-meter rule. 2. Number of Leaves per Plant: the number of leaves per plant was counted at the maturity stage. 3. Leaf Length: Leaf length was measured using a ruler, then the average length was taken at the maturity stage. 4. Leaf area: mean leaf area of each plant measured by handheld leaf area meters

3.7.2.1 Beetroot Yield

1. 1. Beet Diameter: The beet diameter was measured using a Vernier caliper (Plate 14).
2. Weight of beet yield per plant: the weight yield per plant was measured in grams by randomly assigning two beets and taking their average weight. . Weight of beet yield per pot: measured in grams by takin all the beets of the plant in the pot

3.8. Partial budget analysis (Economic Analysis)

To estimate the economic significance of different treatments, partial budget analysis was employed to calculate the marginal rate of return (MRR) and economic analysis was made according to (CIMMYT, 1988).

A partial budget analysis require data (answer) for questions

1. What new or additional costs were be incurred by using additional technology?

2. What current returns was reduced or lost by using additional technology?

3. What new or additional returns were received by using additional technology?

4. What current costs was reduced or eliminated by using additional technology?

In this research, the additional costs incurred due to the use of biochar materials were biochar feedstock coast and labor coast, and the additional return was deceived to include increased yield by improving soil condition and soil fertility. It is computed in terms of the net change in profit (total benefit minus total cost) and the benefit/coast ratio (total benefit minus total cost) (Jack *et al.*, 2017). Adjusted yield (AY) = ABY= average beet yield (t ha^{-1}) - 10%, Gross Benefit (birr)/Ha (GB) = AY = adjusted yield (t ha-1), *current market price, which is equal to 1300 ETB/100kg. Total variable cost (TVC) = biochar feedstock coast + (biochar preparation + biochar application + labor coast), and Net Benefit (NB) (ETB/Ha =Gross Benefit (birr)/ha - Total variable cost (TVC)

Dominated (D): the treatment that is not acceptable due to its total variable cost being greater than the net benefit, Non-dominated (ND): the treatment that is acceptable due to its total variable cost Less than net benefit. Marginal cost (MC): the cost that increases due to an increasing level of treatment. Net benefit (NB): the benefit that non-dominated treatment

Marginal net benefit (MNB): the benefit that is gained by subtracting the next increasing net benefit of non-dominated treatment, and the marginal rate of return (MRR%) show how many times the net benefit has increased or a change from a higher marginal net benefit (MNB) to a lower one. Marginal net benefit (MNB): higher TVC to lower TVC. Non-dominated (ND) treatment: lower marginal net benefit (MNB) of non-dominated, respectively

3.9. Statistical analysis

Data was analyzed statistically using R Studio version 4.2.3 for the Windows statistical package (R Core Team, 2017). The means of parameters showing significance at the 5% level would be separated using Turkey's HSD test. All analyses took place at 5%, even if the ANOVA indicated a high level of significance.

4. RESULTS AND DISCUSSION

4.1. Description of Soil Chemical Properties of Experimental Site

The pre soil analysis result revealed that the contents of total nitrogen (TN) (0.19%), CEC (22.17 cmol (+) kg^{-1}) and available P (13.51 mg kg^{-1}) and 2.21% of OC the pre soil sample. According to the evaluation of Landon, (1984) and Ethiosis (2014) classified as soil organic carbon content of low (<2%), medium (2.10%) and high (>10%) . Hence, the study site had medium OC content before experiment (Landon, 1991). Agreeing to Havlin *et al*. (1999), total nitrogen content (TN) of a soil can be categorized as very low (<0.15%), low (0.15-0.3%), medium (0.3- 0.55%), and high (0.55-1.05%) and very high (>1.05%). As a result, the total nitrogen content of the soils of the study site was found low in total nitrogen content before biochar amendment.

(Ethiosis, 2014) ,(Subbiah and Asija,1956) and (Muhr *et al*.1963) ,Indicative ranges of available phosphorus have been established by scoring (0-15 mg kg^{-1}) (very low), (15-30 mg kg^{-1}) (low), (30-80 mg kg^{-1}) (optimum), (80-150 mg kg^{-1}) (high) and (>150mg kg^{-1}) very high. Based on this criterion, the available phosphorus content of the site was very low before experiment. The cation exchange capacity (CEC) is referred to be <4 indicate soil infertility minimum value (5-15 cmol kg^{-1}), optimum (15-25 cmolkg^{-1}) and high (25-40 cmol kg^{-1}) (Olsen *et al*.,1954) and (Landon,1984). Based on this criterion the CEC of study site medium or optimum (Table 2) shows pre soil analysis of study area .

Table 2 physicochemical properties of the pre-experimental soil

Physio-chemical Properties	Unit	Value		Reference/Citation
Sand	%	31	-	-
Silt	%	31	-	-
Clay	%	38	-	-
Textural class	-	clay loam	-	-
Bulk density(gcm^{-1})	(g/cm ^{3})	1.13	Low	FAO (2006c)
Soil reaction(pH)	Water(H_2O:2.5)	6.45	Moderately acidic	((Ethiosis) 2014)& (Brady 1985)
Electrical conductivity	(mS/cm /ds/m)	0.072	Salt free	((Ethiosis) 2014)) (Muhr *et al*. 1963)
CEC	cmolc kg^{-1}	22.17	Medium	(J. Landon 1991)
Organic carbon	(%)	2.21	medium	(JR Landon 1984)& ((Ethiosis) 2014)
Organic matter	(%)	3.82	Low	Tekalign (1991),
Total nitrogen	(%)	0.19	low	(Ethiosis) 2014), Subbiah & Asija (1956)
Available P(mg kg^{-1})	(mg/kg)	13.51	Very low	(Ethiosis) 2014),(Muhr *et al*. 1963)

Table 3 physicochemical properties of the biochar produced format 500°C

Parameter	Maize cob biochar	Enset leaf biochar	Coffee husk biochar
Specific surface area (cm^2 g^{-1})	19.27	20.88	28.40
pH-H2O (1:10)	10.24	10.67	11.74
EC (MS cmG1) (1:10)	1.31	2.75	6.87
CEC (me/100 g)	65.33	69.78	81.43
OC (%)	22.77	21.35	28.61
OM (%)	39.56	37.01	49.79
TN (%)	1.57	1.98	2.72
Av. P (mg kg g^{-1})	11.61	11.97	15.37

NB: CEC: Cation exchange capacity, OC: Organic carbon, OM: Organic matter, TN: Total nitrogen, Av. P: Available phosphorus, CHB=Coffee husk biochar, MCB= maize cob biochar and ELB=Enset leaf biochar

4.2 Effect of Source and Rate of Biochar on Soil Chemical properties

4.2.1 Effect of Different source and rate of biochar on soil solution (pH)

The soil pH before the experiment was 6.45, which was moderately acidic. The analysis of variance table shows that a significant soil solution (pH) difference (at $p<0.05$) was observed between the interaction of the source and the rate of biochar (Appendix 3). The highest mean values of pH (7.69±0.075) and (7.42±0.075), respectively, were recorded at 10 t ha-1 coffee husk. Enset leaf biochar, whereas the least pH (6.46±0.075) was recorded in control (Table 4). The reason that pH increased with the increasing application rate of biochar was that it had a weakly bonded carboxyl group and a high ability to neutralize acidic elements in the soil. A similar report was done by (Alburquerque *et al*., 2013b).

The application of the wheat crop biochar significantly increased soil pH from 6.5 in the control soil to 8.2 and 7.6 in the soil treated with the highest biochar application rate for olive tree biochar and wheat straw biochar, respectively ($P< 0.001$). These signified that an increase in soil pH due to the presence of exchangeable bases from silicates, carbonates, and bicarbonates in biochar can combine with H^+, controlling the soil pH. (Qian *et al*., 2015). The ANOVA table revealed that applying a high dose of biochar made the soil more alkaline. Sported by, Dume *et al*.(2016) reported that biochar application significantly affects soil pH and the highest (6.14) observed from the highest (15 t ha^{-1}) rate of biochar application on acidic soil. These results are in agreement with the work of (Wang *et al*., 2014) who reported that rice husk biochar increased soil pH by one unit compared to the control treatment; soil pH affects the mobility and availability of different nutrients and chemical elements in the soil. Additionally, application of biochar to soil increases the soil pH, although changes are strongly determined by the soil type, feedstock material, and the liming value of (DeLuca *et al*., 2015; Tian *et al*., 2017). Sported finding dune by (Martinsen *et al*., 2015) applied biochar rates derived from oil palm (Elaeis guineensis) shell, cacao shell (*Theobroma cacao* L.), and rice husk (*Oryza sativa* L.) to 31 acidic soils. They observed an increase in soil pH from 4.7 to 5 when cacao shell biochar was applied, which was greater than those obtained from oil palm shell and rice husk. Similarly, finding by, El-Naggar *et al*. (2018) reported a sharp increase in pH of untreated sandy soil after application of biochar made of umbrella tree (*Maesopsis eminii*) residues.

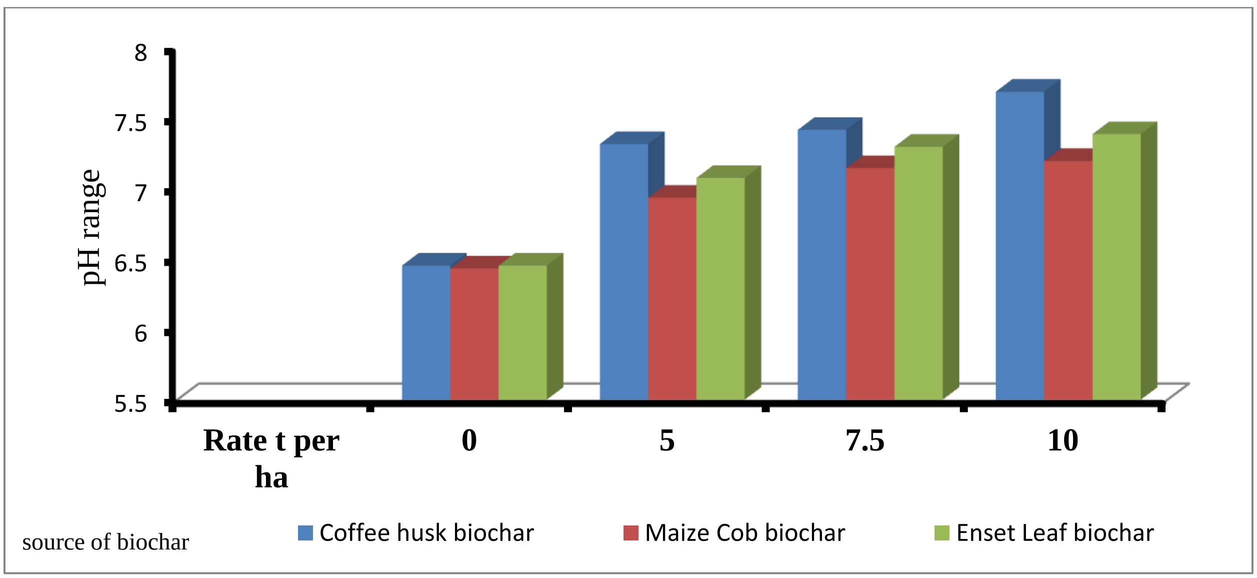


Figure 3 the interaction effect of source and the rate of biochar on soil pH

This finding in agreement with in a pot experiment conducted by (Mensah and Frimpong, 2018), Application of biochar increased soil pH from 4.8 to 6.1. They attributed the increase in pH in the biochar-added soils to the high pH of the biochar used for their experiment, and it was concluded that biochar can be used as an alternative to lime materials to ameliorate soil acidity. Biochar is mostly alkaline (pH > 7) with higher base cation concentrations. Consequently, Biochar was applied. Soils can release base cations into the soil solution to reduce acidity through proton consumption reactions, as indicated by (Chintala *et al*., 2014). Additionally, the liming ability of biochar varies based on the type of feedstock and pyrolysis temperature. Biochar was created at 550°C using waste wood chips and sludge from a paper mill's clarifier and enhanced solids reduction systems (Shankar *et al.*, 2023)

4; 2.2 Effect of Different source and rate of biochar on soil electrical conductivity (EC)

The analysis variance result shows a significant EC difference at $p< 0.05$ was observed between the interaction of source and rate of biochar (Appendix 4). The highest mean value was 0.25 ±0.008 $mScm^{-1}$, and the smallest was 0.06 ±0.008 $mScm^{-1}$, which was recorded in control (Table 4). The difference in EC was due to the ash content in biochar, which is important as a source of dissolved salt in soil. Electrical conductivity is the appearance of the natural capacity of soil, a means to carry stimulating current. Total dissolved salt relates closely to soil properties used to determine productivity. A similar study by (Albuquerque *et al.*,2013) Biochar addition also increased the electrical conductivity from 50 μScm^{-1} in the control soil to 104 and 70 μScm^{-1} in the soil treated with the highest biochar application rate for olive tree biochar and wheat straw biochar. The high-lignin feed stocks of cardboard woody biomass would increase the rate of biochar obtained on high EC, likely due to the extent of carbonization as reported by (Qian *et al*., 2015). A significantly EC difference ($p<0.05$) was observed between treatments (0.28±.15 $mScm^{-1}$) and control (0.11±0.003$mScm^{-1}$) on cabbage.

The variability of soil EC was observed among treatments of the effects of biochar application, which is due to the high amount of carbon dominated by organic carbon in biochar (Qian *et al*.,2015). In general, the results of the characterization studies of the biochar are clear demonstrations of the significant difference in the composition of biochar produced from different feeds tocks even when they are pyrolyzed at the same temperature, The finding was in agreement with previous studies. (Shareef *et al*., 2018b) and (Chintala *et al*., 2014) found that EC increased with increasing application rate of biochar. Moreover, Chintala *et al*.(2014) attributed the increase in EC to alkalinity, $CaCO_3$ content, proton consumption capacity, and base cation concentration of the biochar used in their study. They further explained that biochar contains higher soluble salts that are released into the soil solution, which increases the soil EC. The increase in EC was also attributed by Shareef *et al*. (2018b) to the release of weakly bound ions of the biochar into the soil solution making it easy to be absorbed by the plant

. Table 4 Effect of source and rates of biochar on soil PH and electrical conductivity (EC)

	Soil pH			**EC**		
Rate	**Coffee**	**Maize Cob**	**Enset Leaf**	**Coffee**	**Maize Cob**	**Enset Leaf**
0	6.46 ± 0.075^{g}	6.44 ± 0.075^{g}	6.46 ± 0.075^{g}	0.057 ± 0.008^{g}	0.060 ± 0.008^{g}	0.067 ± 0.008^{g}
5	7.32 ± 0.075^{c}	6.94 ± 0.075^{f}	7.08 ± 0.075^{ef}	0.087 ± 0.008^{f}	0.067 ± 0.008^{g}	0.083 ± 0.008^{f}
7.5	7.42 ± 0.075^{b}	7.15 ± 0.075^{de}	7.30 ± 0.075^{bcd}	0.17 ± 0.008^{d}	0.146 ± 0.008^{e}	0.15 ± 0.008^{e}
10	7.69 ± 0.075^{a}	7.20 ± 0.075^{cde}	7.39 ± 0.075^{b}	0.250 ± 0.008^{a}	0.20 ± 0.008^{c}	0.220 ± 0.008^{b}
LSD(0.05)		0.15			0.009	
CV (%)		4.29			7.12	
P- Value		**			**	

NB: Column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.05)= Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

4; 2.3 Effect of Different source and rate of biochar on Soil Organic Carbon (OC)

Analysis of variance revealed that a significantly difference was observed between interaction of source and the rate of biochar at $p<0.001$ on soil organic carbon (Appendix 4). The highest means value of organic carbon was ($7.93\pm0.15\%$) while, the lowest organic carbon

Was (2.29±0.15%) recorded from untreated soil (Table 5). The difference is that biochar is a source of stable carbon for the soil, and it increases the capacity of microbes to neutralize carbon in the soil by making the environment healthier. A comparative study by (Sarfraz *et al*.,2017) Total organic carbon contents were significantly increased by increasing the rate of biochar application in the soil, as the maximum mean value of organic carbon (0.92 ± 0.003%) and the minimum mean value of organic (0.43 ± 0.002%) were observed in treatment with the application of biochar at a rate of 2% (w/w). The increased rate of biochar in the soil, which increases the number of oxidized functional groups on the surface of biochar (such as carboxyl and hydroxyl groups), provides the basis for the increased CEC of biochar on the biochar surface of the soil (Sarfraz *et al*., 2017). A significant OC difference (at $p<0.05$) was observed between treatments (2.2±0.13%) and control (0.74±0.002%) on cabbage. The difference in OC was due to the addition of biochar, an important property for determining soil organic carbon retention, which was significantly enhanced by increasing the amount of biochar applied to the soil (Rehrah *et al*.,2014).

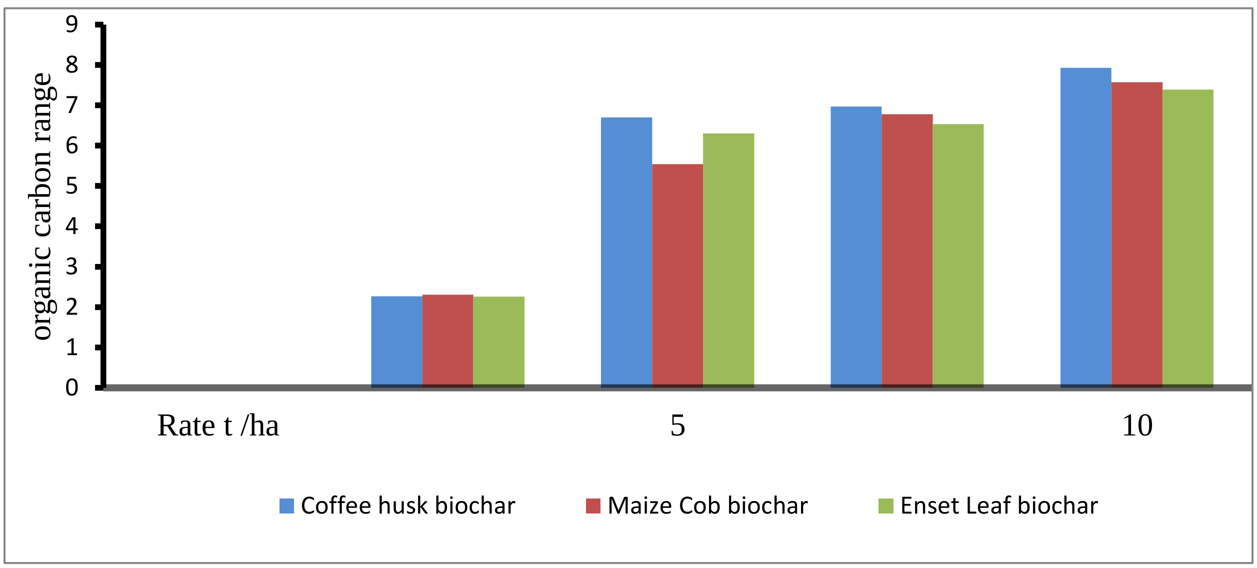


Figure 4 the interaction effect of source and the rate of biochar on soil organic carbon

This may perhaps be accompanied by high oxygen and carbon ratios (O:C) on the surface of charred materials as a result of the microbial degradation activities, further influenced by the high surface area and high charge density (Rehrah *et al*., 2014). Soil organic carbon and organic matter is main parameter that affects soil health, microbial activity, nutrient cycling, and water retention (Battaglia *et al*., 2021). Many studies have shown that biochar application can increase soil carbon content, improve water retention, and increase aggregate formation and stability (Diatta *et al*., 2020). However, these responses are highly dependent on the feedstock material utilized, the pyrolysis conditions and application rates, and the types of soil where biochar is applied (El-Naggar *et al*., 2018). Biochar contains highly stable forms of carbon when prepared at higher temperatures (above 400–500 °C). Such temperatures cause aromatization and loss of functional groups and the formation of larger complexes of aromatic rings, which are resistant to both biotic and abiotic degradation (Singh *et al*., 2022).

4; 2.4 Effect of Different source and rate of biochar on soil organic matter

The interaction between the source and rate of biochar on organic matter changed considerably at $p < 0.001$, according to the analysis of variance (ANOVA) results (Appendix 4). The control treatment had the lowest value of organic matter (3.92±0.26%) and the greatest value (13.68±0.26%). The breakdown of stable carbon in biochar may be the cause of the increased organic carbon and organic matter, which also increases the capacity of microorganisms to neutralize the synthesis of carbon. Sportive finding by (El-Naggar *et al*., 2018) observed that Umbrella tree (Maesopsis eminii), silver grass (Miscanthus sacchariflorus), rice straw, and crop residues   increases in the OM content of sandy soil (42–72%) and loam soils (32–48%). Similarly by Adekiya *et al*. (2020) reported that incorporation of 30 mg ha^{-1} of hardwood biochar increased the organic matter by an average of 77, 18, and 9% compared to the unamended control, 10, and 20 mg ha^{-1} of biochar across two years, respectively. A critical factor influencing the health of the soil, microbial activity, nitrogen cycling, and water retention is soil organic matter. Many investigations have revealed that adding biochar can increase soil carbon content, strengthen aggregate stability, and improve water holding ability. (Shankar e*t al.* ,2023).

Table 5 Effect of source and rates of biochar on soil organic carbon (OC) and organic matter (OM)

Rate t ha^{-1}	Organic carbon			Organic matter		
	Coffee	**Maize Cob**	**Enset Leaf**	**Coffee**	**Maize Cob**	**Enset Leaf**
0	2.27±0.15^{g}	2.31±0.15^{g}	2.26±0.15^{g}	3.92±0.26^{h}	3.99±0.26^{h}	3.91±0.26^{h}
5	6.70±0.15^{cd}	5.54±0.15^{f}	6.30±0.15^{e}	11.56±0.26^{ef}	9.56±0.26 ^{g}	10.87±0.26^{fg}
7.5	6.97±0.15^{c}	6.78±0.15^{cd}	6.53±0.15^{de}	12.03±0.26^{cd}	11.70±0.26 ^{d}	11.27±0.26^{e}
10	7.93±0.15^{a}	7.57±0.15^{b}	7.39±0.15^{b}	13.68±0.26^{a}	13.05±0.26 ^{b}	12.74±0.26^{bc}
LSD(0.05)		0.31			0.55	
CV (%)		3.23			3.24	
P- Value		***			***	

NB: - Column followed by the same letter(s) is not significantly different at 5% level of significance. LSD (0.05) =Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

4; 2.5 Effect of different source and rate of biochar on Soil total nitrogen (TN)

Analysis of variance indicates that a significant difference was observed between the interaction of source and rate of biochar at p< 0.001 on total nitrogen (Appendix 4). The highest mean value of total nitrogen content was 0.71± 0.01%, and the lowest value (0.17± 0.01%) was recorded with untreated soil (Table 6). The difference was due to biochar addition, which increased the nitrogen-neutralizing ability of microbes in the soil. These results are in agreement with the work of Jones *et al*. (2012) who reported that application of biochar to acidic soil could increase total nitrogen from 0.24 to 0.38 %.

Furthermore, Dume *et al*. (2016) reported that the application of coffee husk biochar produced at 500°C temperature and applied at a rate of 15 t ha^{-1} on the acidic soil could increase soil total nitrogen (0.32-0.58 %). Similar finding by Sarfraz *et al*. (2017) maximum soil N concentration was recorded where maximum rate of biochar was added in to the soil, and minimum N concentration (0.049±0.002%) was recorded in control treatment. The nitrogen being one of the major nutrients taken by the plants comparatively in large quantity is generally deficient in most of the acidic soil could be increased by biochar application together with fertilization might be due CEC of biochar could be potential to retain $NH4^{+}$ in the soil plants used directly or indirectly used as of nitrogen (Sarfraz *et al*., 2017). According to Sarfraz *et al*. (2017) a significantly TN difference was observed between treatments (0.23±0.010 %) and control (0.16±0.006%) on cabbage. The ash materials better reason for nitrogen retention in the soil and ultimately improved N recovery to amended acidic soil (Sarfraz *et al*., 2017).

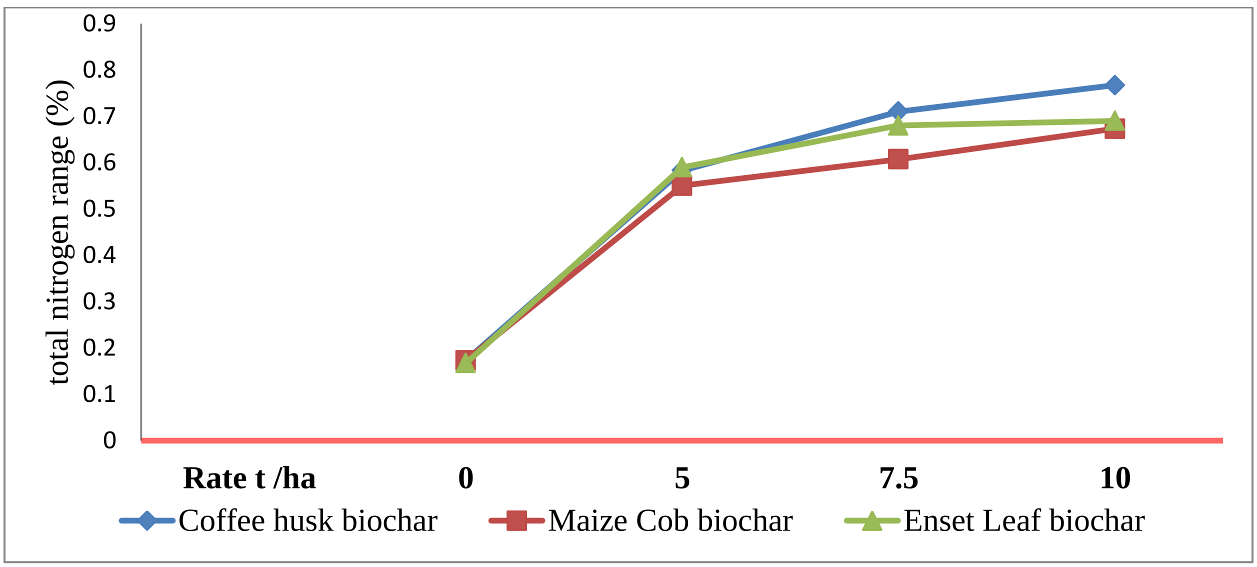


Figure 5 the interaction effect of source and the rate of biochar on soil total nitrogen

4; 2.6 Effect of different source and rate of biochar on carbon to nitrogen ratio (C: N)

The results of the analysis of variance showed that the interaction between the source and rate of biochar caused a substantial fluctuation in the carbon to nitrogen ratio at ($p<0.001$) (Appendix 5). The untreated soil had the highest carbon to nitrogen ratio (13.47±0.15) and the lowest mean value (10.35±0.15). This is because the biochar increased the microbes' ability to neutralize different nutrients, which led to a decrease in the carbon to nitrogen ratio. A low carbon to nitrogen ratio indicates a high ability to neutralize different organic remains.   According to the study, adding more biochar enhanced the C/N ratio in a considerable way. They explained that the increases in carbon reflected in the significant increases in % C and C/N ratio of the soil at the trial end. Previous studies (Mensah and Frimpong, 2018; have also reported increases in soil carbon content following application of biochar, compost and their combinations.

Table 6 Effect of different source and rates of biochar on soil Total nitrogen and carbon to nitrogen ratio

Rate t ha^{-1}	Total nitrogen (TN)			Carbon to nitrogen ratio (C:N)		
	Coffee	**Maize Cob**	**Enset Leaf**	**Coffee**	**Maize Cob**	**Enset Leaf**
0	0.173 ± 0.01^{f}	0.173 ± 0.01^{f}	0.167 ± 0.01^{f}	13.16 ± 0.15^{a}	13.30 ± 0.15^{a}	13.47 ± 0.15^{a}
5	0.583 ± 0.01^{d}	0.550 ± 0.01^{e}	0.590 ± 0.01^{d}	11.52 ± 0.15^{b}	10.07 ± 0.15^{de}	10.70 ± 0.15^{cd}
7.5	$0.710.01^{b}$	0.607 ± 0.01^{d}	0.680 ± 0.01^{c}	9.97 ± 0.15^{e}	11.20 ± 0.15^{bc}	9.61 ± 0.15^{e}
10	$0.7670.01^{a}$	0.673 ± 0.01^{c}	0.69 ± 0.01^{bc}	10.35 ± 0.15^{de}	11.25 ± 0.15^{bc}	10.66 ± 0.15^{cd}
LSD(0.05)	0.027	0.027	0.027	0.81	0.81	0.81
CV (%)	3.04	3.04	3.04	4.28	4.28	4.28
P- Value	***	***	***	***	***	***

NB:- Column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.05) =Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

4; 2.7 Effect of different source and rate of biochar on Soil Available Phosphorous Content,

Analysis of variance showed a significant difference between the interaction of source and rate of biochar on Soil Available Phosphorous at $p<0.001$ (Appendix 5 the highest mean value of available phosphorus (21.30±0.28 mg kg^{-1}) whereas the least value (13.84±0.28mg kg^{-1}) was recorded in the control treatment (Table7)

The difference between Av.P was due to the ability of biochar to reduce the sorption of phosphorus from other basic oxides. Similar study by Sarfraz *et al*(2017) soil available P shows From this study maximum soil available P concentration (7.1±0.14 mg kg^{-1}) was recorded with 2% (w/w) application of biochar while minimum concentration (5.77%) was recorded when no biochar was applied to the soil with 100% recommended dose of nitrogen fertilizer. Interestingly, biochar addition had positive effects on available P nutrition, being this result corroborated by the increase detected in the resin extractable phosphate concentration after biochar amending seems to represent a significant source of available P for crops (Alburquerque *et al*., 2013b).

The critical factor for enhancement of soil phosphorous was biochar application in the soil could decrease chemisorption' of phosphorous on iron oxide (Tang *et al*., 2013). A significantly P difference (at $p<0.05$) was observed between treatments (7.9±0.002mg kg^{-1}) and control (3.7±0.05 mg kg $^{-1}$) on red beet. Related report done by (Alburquerque *et al*., 2013b) biochar affected plant nutrient uptake by in-creasing P (olive tree pruning biochar) and wheat straw biochar) P< 0.001).The reason that P concentration shows increasing trend under different rate of biochar application presence of ash materials promote availability magnesium that play role on stronger retention of phosphorous (Sohi *et al*.,2009).The highest values of available phosphorous was recorded after application of 15 t ha^{-1} coffee husk biochar produced at 500°C temperature and after incubation for 2 months . The observed increase in available phosphorus could be due to the presence of phosphorous in the coffee husk. The increase in soil pH and CEC, that reduced the activity of Fe and Al, could also contribute to the highest values of available phosphorous in soils treated with biochar (Dume, *et al.*,2015.)

4.2.8 Effect of Different source and rate of biochar on cation exchange capacity (CEC)

Before the experiment, the cation exchange capacity (CEC) was (22.17cmolc$kg^{-1)}$,The outcome of the analysis of variance shows that the relationship between the source and rate of biochar showed a significant difference in cation exchange capacity ($p < 0.001$) (Appendix 5). Table 7 shows that the control treatment had the lowest value of cation exchange capacity soil (27.47±0.49 cmolc kg^{-1}), while the maximum mean value of CEC was 40.36±0.49 cmolc kg^{-1}. Similar sportive study by Sarfraz *et al*. (2017) reported the cation exchange capacity of soil was increased by increasing the rate of biochar application in the soil. Maximum CEC (26.2±1.05

cmolc kg^{-1}) was recorded where 2% (w/w) rate of biochar was applied in the soil and minimum CEC (13.7±1.76 cmolckg^{-1}) was recorded when no biochar was added to the soil. There had been 52.53% increase in soil CEC in biochar application at the rate of 2% over the control. Study by Qian *et al*. (2015) CEC increases with increasing of pH on the other hand in such lower rate of biochar CEC was shows negative influence on low pH. A significantly CEC difference (at $p<0.05$) was observed between treatments (36.4±4.32 cmolc kg^{-1}) and control (15.3±0.06 cmolckg^{-1}) on red beet. Similar Study by Sarfraz *et al*. (2017) found that biochar is applied to soil, the basic cations from the biochar discharged into the soil, replacing Al^{3+} and H^+ and enhancing the CEC of soil.

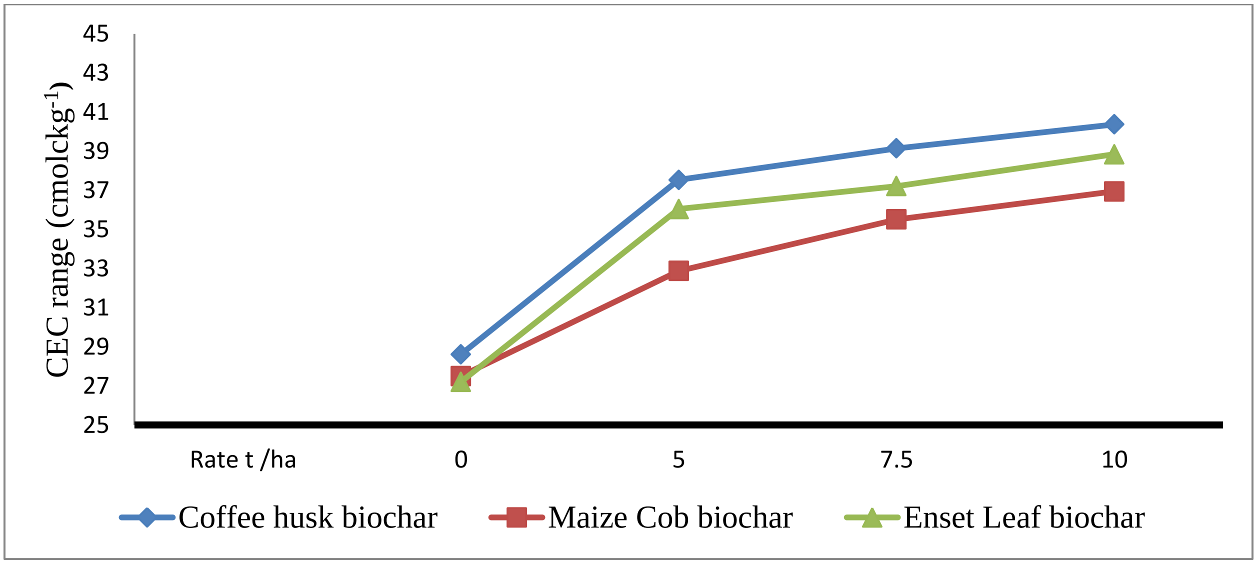


Figure 6 the interaction effect of source and the rate of biochar on soil cation exchange capacity

However , many studies have shown that biochar amendment can increase the CEC of soil (El-Naggar *et al*.,2018; Chathurika *et al*.,2016; Gao *et al*.,2017 and Pandit *et al*., 2018), which could be due to the presence of strong carboxylic and phenolic functional groups with negative charge on the surface of biochar particles (Palansooriya *et al*.,2019; Tian *et al*., 2017). A 21% increase in the soil CEC after biochar application compared to un-amended soil (control) indicated report by (Zhang *et al*., 2007; El-Naggar *et al*.,2018) applied biochar produced from rice straw, silver grass residues, and umbrella tree to sandy soils and reported CEC increases of 906, 180, and 130%, respectively, compared to un-amended. Soil CEC can be greatly increased. Due to the increased availability of nutrients, microbial activity typically rises as soil CEC increases, thus enhancing soil fertility (Shankar *et al*., 2023).The above table shows the mean separation of TN, Av.P and CEC, and there was a significant difference at $p<0.001$ between rate and source of biochar. Similar finding by Sarfraz *et al*., (2017) maximum soil N concentration was recorded where maximum rate of biochar and nitrogen fertilizer was added in to the soil and minimum N concentration (0.049±0.002%) was recorded in control treatment. Study by (Sarfraz *et al*., 2017) biochar is applied to soil, the basic cations from the biochar discharged into the soil, replacing Al^{3+} and H^+ and enhancing the CEC of soil.

Table 7 Effect of source and rates of biochar on soil total nitrogen available phosphorus and cation exchange capacity

	Available phosphorus (Av.P)			Cation exchange capacity (CEC)		
Rate	**Coffee**	**Maize Cob**	**Enset Leaf**	**Coffee**	**Maize Cob**	**Enset Leaf**
0	13.84±0.5[f]	14.07±0.5[f]	13.23±0.5[f]	28.62±0.48[g]	27.50±0.48[h]	27.21±0.48[h]
5	16.15±0.5[e]	18.18±0.5[d]	16.16±0.49[f]	37.53±0.48[c]	32.88±0.48[f]	36.04±0.48[de]
7.5	21.32±0.5[a]	19.01±0.5[cd]	18.71±0.5[d]	39.14±0.48[b]	35.51±0.48[e]	37.21±0.48[c]
10	20.74±0.5[ab]	19.92±0.5[bc]	20.89±0.5[ab]	40.37±0.48[a]	36.94±0.48[cd]	38.84±0.48[b]
LSD(0.05)	1.09	1.09	1.09	5.17	5.17	5.17
CV (%)	3.61	3.61	3.61	1.69	3.04	3.04
P- Value	***	***	***	***	***	***

NB: LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent.

4.3 Effect Different Source and Rate of Biochar on Growth and Yield of Beetroot.

4; 3.1 Effect of different source and rate of biochar on plant height (cm)

Analysis of variance shows that the plant height was significantly improved by the interaction effect of different sources and the rate of biochar at three growing stages (25 days, 50 days, and harvest). At the 25-day stage of growth, a significantly varied $p<0.05$ was observed among the interaction source and rate of biochar (Appendix 1). The highest mean value of plant height at the first stage was 18.56±0.6 cm, and the least value (14.86±0.67cm) was record control (Table 8)

At the 50-day stage of growth, plant height showed a significant difference ($p < 0.001$) between the interaction of source and rate of biochar (Appendix Table 1). The highest mean value of plant height at this growth stage was 34.58± 0.3cm, whereas the lowest value of height (28.8±0.3cm) was recorded within untreated soil (Table 9). At the final stages of growth, a significant plant height difference ($p < 0.001$) was observed between the interaction effect of the source and the rate of biochar (Appendix 1). The highest mean value of plant height at the maturity stage was 36.97±0.9 cm, and the least value of plant height (28.8±0.91cm) was recorded within the untreated treatment (Table 8), which is due to the neutralizing ability of biochar in a different nutrient because it increases the neutralizing ability of soil microbes. Sims observed that biochar has the greatest ability to enhance plant height, and nutrient content reduces exchangeable acidity, increases soil pH, and inherently contains significant amounts of plant nutrients Mg^{2+} due to the ash content of biochar (Mimmo *et al*., 2014)

Table 8 Effect source and rate of biochar on height of beetroot plant at different stage

	Height at 25 day			Height at 50 day			Height at maturity stage		
Rate t ha^{-1}	Coffee husk	Maize Cob	Enset Leaf	Coffee husk	Maize Cob	Enset Leaf	Coffee husk	Maize cob	Enset Leaf
0	15.8 ± 0.67^{def}	14.6 ± 0.7^{ghi}	14.9 ± 0.7^{fgh}	28.88 ± 0.3^{f}	28.9 ± 0.3^{de}	25.37 ± 0.3^{f}	32.35 ± 0.58^{c}	27.28 ± 0.91^{f}	29.28 ± 0.91^{e}
5	15.4 ± 0.7^{efg}	13.60 ± 0.6^{i}	14.0 ± 0.67^{hi}	25.86 ± 0.3^{f}	25.9 ± 0.3^{f}	25.82 ± 0.3^{f}	31.69 ± 1.2^{c}	27.33 ± 0.91^{f}	28.73 ± 0.91^{ef}
7.5	17.3 ± 0.67^{bc}	14.7 ± 0.7^{ghi}	16.2 ± 0.67^{bcd}	30.88 ± 0.3^{d}	28.5 ± 0.3^{e}	32.09 ± 0.3^{c}	34.66 ± 0.9^{b}	29.7 ± 0.9^{de}	31.60 ± 0.91^{c}
10	18.56 ± 0.67^{a}	17.0 ± 0.7^{bcd}	17.9 ± 0.67^{ab}	34.58 ± 0.3^{a}	28.7 ± 0.3^{de}	33.29 ± 0.3^{b}	36.97 ± 0.9^{a}	30.97 ± 0.9^{cd}	31.77 ± 0.91^{c}
LSD(0.05)	1.2	1.2	1.2	1.05	0.63	1.05	1.55	1.55	1.55
CV (%)	4.52	4.52	4.52	2.19	1.25	2.19	2.96	2.96	2.96
P- Value	**	**	**	***	***	***	**	**	**

NB:- Means in the column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Plant height of maize plants was significantly affected by the interactive effect of nitrogen levels and biochar rates (Sarfraz *et al*., 2017). Study conducted by Sarfraz *et al*.(2017) maize height ranged from 44.91±1.32 to 181±3.98 cm in height receiving biochar at the rate of 1% (w/w) and nitrogen at the rate of 50%. This result shows that the biochar application rate increases the vegetative growth due to the content of biochar. Likewise, Bass *et al*. (2016) reports that biochar application can improve the morphological characteristics of wheat growth and yield an increase in the number of leaves and number of fruit bearing branches. Many studies have shown that biochar amendments significantly increased the growth and biomass in various plant species (Seleiman *et al*.,2019; Solaiman *et al*.,2020). Incorporation of poultry litter biochar along with manure and fertilizers significantly enhanced biomass and fruit yield of cucumber (*Cucumis sativa* L.) by increasing soil WHC and nutrient concentration (Solaiman *et al*.,2020).

Yield of field mustard (*Brassica rapa* L.) was increased by 49% after the application of biochar compared to untreated soil with biochar (Khan *et al*.,2017). Furthermore soil amended with biochar increased the fresh and dry weight of maize by 50–55%. Moreover, sunflower growth and oil yield were increased under moderate and severe water deficit conditions after combined application of rice straw biochar and foliar spray of silicon (Seleiman *et al*., 2019). The report of this finding is similar to the result which is observed by (Nduka. *et al*., 2015) investigated the significant increase in plant height and stem diameter on cashew seedling growth as a result of coffee husk application to acid soil. The application of 12 t ha^{-1} of Lantana camara biochar significantly increased plant height as compared to other treatments (Bishwoyog *et al*., 2015). Most biochar treatment average plant height were higher than that of the control soil due to biochar used as soil amendment to improve soil quality used as neutralizing capacity (Sun *etal*., 2014). Additionally, (Shareef *et al*., 2018a) found that plant height was influenced by biochar application rate and pyrolysis temperature. In this study, plant height increased with increasing application of biochar and compost. At maturity (9WAG), BC gave the highest significant value followed by 40B but no significant differences were observed among 20B and C.

4; 3.2 Effect of different source and rate biochar on number of leaves per plant

Analysis of variance showed the number of leaves per plant was significantly varied (at p<0.05) by the interaction effect of different sources and, the rate of biochar at maturity stage (Appendix 2). The highest mean value of the number of leaves per plant (19.66± 0.47) and the smallest (Table 9). Biochar is used, as a soil amendment to improve soil physiochemical properties and increase microorganisms neutralizing ability. The results conformed to a rice-husk biochar tested in the lettuce-cabbage-lettuce cycle increased number of leaves in comparison to control treatments (Carter *et al*., 2013)

4; 3.3 Effect of different source and rate biochar on leaf length

The result of analysis variance states that the leaf length was significantly affected at p<0.001 between the interaction of source and, rate of biochar (Appendix 2). The highest mean value of plant leaf length was (34.21±0.26cm) and the lowest value of soil (29.04±0.26cm) of leaf length was record within the untreated treatment (Table 9). The variation of the result is due to biochar addition and it increases the vegetative growth because of the addition of different available nutrients to the soil as well as increased ability of microbes to neutralize different organs. Similar finding was done by (Badry and Salim 2016) reports biochar application can improve the morphological characteristics of wheat growth and yield by increase in the number of leaves and number of fruit bearing branches. This result shows that biochar application rate increases the vegetative growth due to nutrient contents of biochar .Further, interaction of biochar type and their application rates showed significant differences for the leaf length in 2^{nd}, 3^{rd}, 4^{th}, and 5^{th}weeks of cabbage (Sciences,2015).

4; 3.4 Effect of different source and rate of biochar on leaf area

Analysis of the variance table result shows significantly affected at p<0.001 leaf area was recorded by the interaction of different sources and rate of biochar at maturity stages of beetroot plant growth (appendix 2) the highest leaf area was(826.83±16cm^2) and the lowest leaf area was (327.87±16cm^2) recorded within untreated soil (Table 9). The difference is that biochar can neutralize soil nutrients and it increases the fertility status of the soil resulting in increased leaf length and width as well as the whole growth. The result was in agreement with study by Yeshitila & Taye (2016) the leave area of beetroot increased from length and width increase significant increase, by increasing the rate of biochar.

Table 9 Effect of different source and rates of biochar a on the Number of leaves per plant, leaf length and leaf area

	Number of leaf per plant			**Leaf length (cm)**			**Leaf area (cm^2)**		
Rate t ha^{-1}	**Coffee husk**	**Maize Cob**	**Enset Leaf**	**Coffee husk**	**Maize Cob**	**Enset Leaf**	**Coffee husk**	**Maize cob**	**Enset Leaf**
0	17.3±0.48[c]	17.6±0.48[bc]	17.6±0.5[bc]	29.04±0.26[e]	29.08±0.26[e]	28.0±0.26[f]	450.57±16[e]	260±16g	327.87±16[f]
5	15.3±0.48[e]	13.3±0.48[g]	14.3±0.48[f]	29.88±0.26[d]	25.12±0.26[i]	25.7±0.26[h]	451.53±16[e]	259.50±16[g]	323.23±16[f]
7.5	18.3±0.48[b]	16.33±0.48[d]	17.3±0.48[c]	31.92±0.26[b]	26.79±0.26[g]	31.9±0.26[b]	598.83±16[b]	435.40±16[e]	564.03±16[cd]
10	19.7± 0.5[a]	18.3±0.48[b]	19.3±0.48[a]	34.21±0.26[a]	29.86±0.26[d]	30.6±0.26[c]	826.83±16[a]	554.03±16[d]	589.03±16[bc]
LSD(0.05)	0.97	0.97	0.97	0.78	0.78	0.78	33.19	33.19	33.19
CV (%)	3.37	3.37	3.37	1.62	1.62	1.62	4.19	4.19	4.19
P- Value	***	***	***	***	***	***	***	***	***

[NB] Means in the column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

4.4 Effect of Different Source and Rate of Biochar on Yield of Beetroot plant

4; 4.1 Effect of different source and rate of biochar on beetroot diameter (cm)

The result specified by the ANOVA table the beetroot diameter or thickness was significantly affected at $p<0.001$ by the interaction influence of different sources and rates of biochar (Appendix 2). The highest mean value of beetroot diameter was (6.62±0.11cm) and the smallest value of beetroot diameter was (5.78±0.11cm) recorded within the control (Table 10). The difference is because of biochar can increase nutrient usability by the plant as a result of increasing microbes' ability to naturalize the dormant nutrient by its high carboxyl group in ash and it is preferred for cell division and root development. The finding is similar to the result of Nduka *et al*. (2015) investigated the significant increase in plant height and stem diameter on cashew seedling growth as a result of coffee husk biochar application to acid soil.

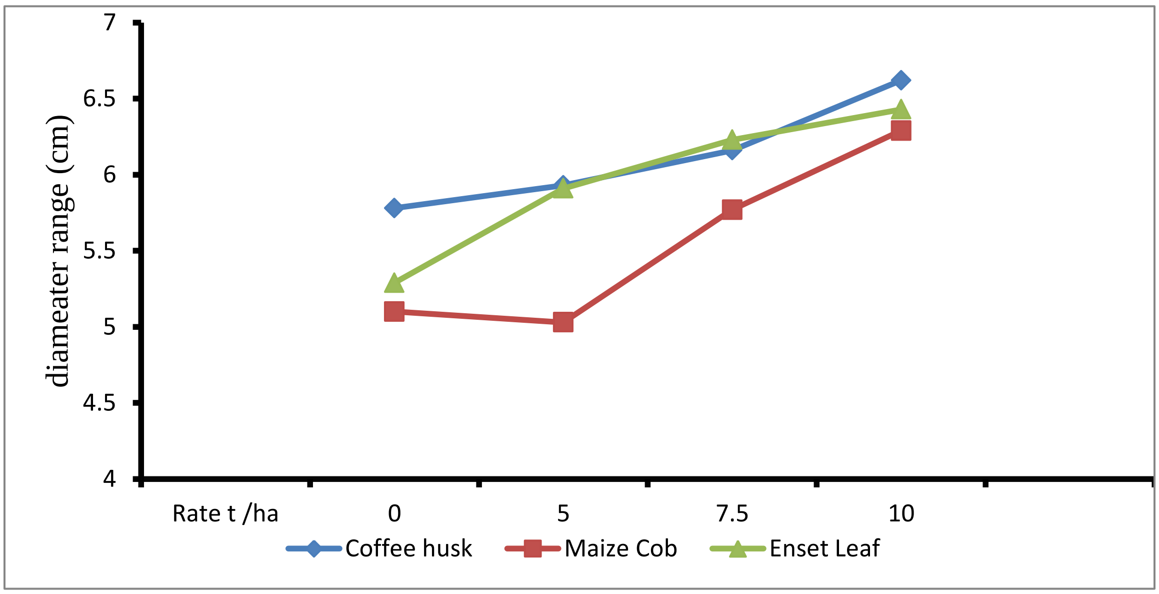


Figure 7 the interaction effect of source and the rate of biochar beet diameter

According Okokoh and Bisong (2011) reported the higher root diameter recorded may be attributed to enhanced cell division and quick cell multiplication. And also similar study done by (Okokoh and Bisong, 2011) reported poultry manure biochar application had significant influence on stem diameter and the result showed that the application of 10, 15 and 20 t ha^{-1} of poultry manure biochar resulted in sufficiently larger stem diameter than other treatments .Most biochar treatment average beet thickness were higher than that of the control soil due to biochar used as soil amendment to improve soil quality used as neutralizing capacity.

4; 4.2 Effect of different source and rate of biochar on beet fresh weight per plant (g)

The result of the ANOVA table suggests that the beet weight per plant was significantly affected at $p<0.001$ by the interaction of different sources and rate of biochar (Appendix 2). The highest mean value of fresh beetroot weight per plant was (482.67±14.55g) and the smallest value of (343±14.55g) beet weight per plant was record within the untreated soil (Table 10). The difference in the beet yield was due to the liming effect of biochar, which increased the nutrient availability and improved the soil's chemical properties for instance pH, total nitrogen, cation exchange capacity, and available phosphorus. Similar finding dune by Raboin *et al*. (2016) observed a maize yield increase ranging from 46 to 58% after applying biochar at 50 Mg ha^{-1} along with animal manure in acidic soil. Similarly Berihun *et al*. (2017) noted significant increase in grain yield of tef with increasing rates of biochar, also reported that application of biochar on maize grain yield had significant effect in subsequent years and maize yield increased with increasing biochar rate.

4; 4.3 Effect of Different source and rate of Biochar on fresh beet weight per pot (g/pot)

A result indicated by analysis of variance shows the total beetroot fresh weight per pot was significantly affected at $P<0.001$ by the interaction impact of different sources and rate of biochar (Appendix 3). The highest beetroot fresh weight per pot was (1458.33±23g) and the lowest value of (1016.33±23g) beet weight per pot was record within the untreated treatment. The difference was due addition of biochar caused the soil to increase nutrients in usable form like nitrogen, phosphorus, and carbon and increased soil cation exchange capacity as a result it improves root initiation and development. Similar results were suggested by (Anna and Maria, 2013; Raboin *et al*., 2016) observed a maize yield increase ranging from 46 to 58% after applying biochar at 50 Mg ha^{-1} along with animal manure in acidic soil. The increment in the yield was due to the liming effect of biochar, which increased the nutrient availability and improved the CEC of soil .Similarly finding by (Agegnehu *et al*.,2015) found 22 and 24% increase in seed and pod yields of peanut (Arachis hypogaea L.) grown on wood biochar amended soil at a rate of 25 Mg ha^{-1} compared to soil fertilized with inorganic fertilizers, and also recorded 98–150% increased maize yield, likely explained by the parallel increase in the plant water use efficiency between 91 and 139% as a result of manure biochar application

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Table 10 Effect of source and rates of biochar on the beet weight per plant, beet diameter and beet weight per pot

	Beet weight per plant (gm)			**Beet diameter(cm)**			**Beet weight per pot (gm)**		
Rate t ha^{-1}	**Coffee husk**	**Maize Cob**	**Enset Leaf**	**Coffee husk**	**Maize Cob**	**Enset Leaf**	**Coffee husk**	**Maize cob**	**Enset Leaf**
0	343±14de	354.3±14.55^{e}	347.3± 3.1^{f}	5.78±0.11^{d}	5.10±0.11^{ef}	5.29±0.11^{e}	1016.33±23^{e}	1062±23^{cde}	1039.67±23de
5	341.±14^{e}	300±14.55^{h}	339±14.55^{g}	5.93±0.11^{d}	5.03±0.11^{f}	5.91±0.11^{d}	1021.67±23^{e}	1074±23^{cd}	1046±23de
7.5	398.33±14^{b}	367±14.55^{d}	387±14.55^{c}	6.16±0.11^{c}	5.77±0.11^{d}	6.23±0.11^{bc}	1193.67±23^{b}	1097.67±23^{c}	1149.00±23^{b}
10	482.67±14^{a}	381.3±14.55^{c}	397.3±14.6^{b}	6.62±0.11^{a}	6.29±0.11^{bc}	6.43±0.11^{ab}	1458.33±23^{a}	1147.3±23^{b}	1182.33±23^{b}
LSD(0.05)	29.62	29.62	29.62	0.23	0.23	0.23	47.34	47.34	47.34
CV (%)	4.82	4.82	4.82	2.38	2.38	2.38	2.49	2.49	2.49
P- Value	***	***	***	***	***	***	***	***	***

4.5 Economic Analysis

The parietal budget analysis was used to identify treatments with the optimum return for the farmer's investment. The results of the partial budget analysis revealed that the highest net return of Birr 1012,725,480 (1ETB=0.01818USD) ha^{-1} was gained from the treatment received 7.5 t ha^{-1} of Enset leaf biochar and followed by1011,225,570 ETB was obtained from the treatment those received 10 t ha^{-1} maize cob biochar (Table 11). Therefore, the marginal rate of return was done based on a treatment to be considered worthwhile to farmers, that is 50% and 100% marginal rate of return (MRR) is the minimum acceptable rate of return (CIMMYT, 1988). Hence, it is important to compare treatments to remove undesirable treatments given economic profitability rather than only looking at the highest grain yield, because it may not be attractive if they require a very much higher cost.

Therefore, the maximum net benefit was 1012,725,480 ETB ha^{-1} gained at soil treated with 7.5 t ha^{-1} Enset leaf biochar the adoption of this treatment would give an additional gain of 21596% from every Birr invested in beetroot production. While the second highest net benefit fetched Birr 112,525,100 ETB net return ha^{-1} net benefits with an additional gain of 252447.08% from every Birr invested, was obtained at the application of 10 t ha^{-1} maize cob biochar. Therefore, the application of 7.5 tons per hectare of Enset leaf biochar and 10 tons per hectare of maize cob biochar was more economically attractive than all other treatments (Table11). It could be consider as the most profitable treatment. It has the highest return for the money invested in its production; it maximizes profit and output and minimizes costs. The application of different sources and rates was economically viable and had a positive marginal rate of returns. The economic analysis has led to suggest that the source of biochar maize cob and Enset leaf is 10 & 7.5 tons per hectare respectively. Sites are suitable for potential adoption by farmers and other economically viable treatments are listed in (Table 12).

Table 11 Summary of economic analysis of the interaction effects of different source and rates of biochar

Trt #	Treatment Combination	ABY (Kg/Ha)	AY(Kg/Ha)	Gross Benefit (birr)/Ha	CBP (ETB/Ha	CBA(ET/Ha)	TVC	Net Benefit (NB)(ETB/H)	Dominance
1	T1 control	765387	688848.3	895502790	0	0	0	895502790	D
2	T9 control	783218	704896.2	916365060	0	0	0	916365060	D
3	T5 Control	800040	720036	936046800	0	0	0	936046800	D
4	T2 CHB 5t ha^{-1}	769658	692692.2	900499860	1200	600	1800	900498060	ND
5	T3 MCB 5t ha^{-1}	809080	728172	946623600	1260	600	1860	946621740	D
6	T4 ELB 5t ha^{-1}	787987	709188.3	921944790	1320	600	1920	921942870	ND
7	T6 CHB 7.5t ha^{-1}	899231	809307.9	1052100270	1800	1200	3000	1052097270	D
8	T7 MCB7.5t ha^{-1}	826911	744219.9	967485870	1860	1200	3060	967482810	ND
9	T8 ELB7.5t ha^{-1}	865580	779022	1012728600	1920	1200	3120	1012725480	ND
10	T10 CHB 10t ha^{-1}	1098609	988748.1	1285372530	2400	1800	4200	1285368330	D
11	T11 MCB10t ha^{-1}	864299	777869.1	1011229830	2460	1800	4260	1011225570	ND
12	T12 ELB10t ha^{-1}	890689	801620.1	1042106130	2520	1800	4320	1042101810	D

Where, ABY= average beet yield (t ha^{-1}), AY= adjusted yield (t ha^{-1}), GB= gross benefit (ETB ha^{-1}), CBP= cost of biochar preparation (100 Birr man-day^{-1}), CBA= cost of biochar application (100 ET Birr man-day^{-1}), TVC= total variable cost (ET Birr ha^{-1}), NB= net benefit (ET Birr ha^{-1}), D= dominated, ND= non-dominated, 1Ethiopian Birr (ET) ≈ 0.01818USD. CHB=coffee husk biochar, ELB=Enset leaf biochar and MCB=Maize cob biochar

Table 12 Marginal rate of return on combined effects of different source and rate of biochar for Beetroot production

Treatment	TVC	MC	NB	MNB	MRR (%)
T2CHB 5t ha^{-1}	1800	120	900498060	46123680	768728
T4 ELB 5t ha^{-1}	1920	1140	921942870	130154400	120513.3
T7 MCB7.5t ha^{-1}	3060	60	967482810	45242670	754044.5
T8 ELB7.5t ha^{-1}	3120	1140	1012725480	272642850	252447.08
T11 MCB10 tha^{-1}	4260	1140	1011225570	30876240	514604

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The results of the study showed that the application of different sources and rates of biochar improves soil chemical properties, growth, and yield of beetroot. The result of the analysis of the variance table indicates that the soil chemical properties (pH, electrical conductivity, cation exchange capacity, organic carbon, total nitrogen, and available P) show significantly varied results recorded within the interaction impacts of different sources and rates of biochar. It also shows significantly affected growth and yield parameters like plant height, leaf (number per plant, length, and area), and beet (diameter, weight per plant, and pot) of beetroot by the interaction effect of sources and rates of biochar. The result of the ANOVA shows that the soil pH and electrical conductivity significantly change at $p<0.05$.Between the interaction impact of source and rate of biochar. The highest mean values of pH and EC were (7.69±0.075) and (0.25cμmcm^{-1}); the lowest values were (6.46±0.075 and 0.67±0.008μm cm^{-1}) pH and EC, respectively, recorded in untreated soil. The highest mean value of organic carbon and matter (7.9±0.15 and 13.61%) and the least value of organic carbon and matter (2.31±0.15 and 3.98%) resulted in control.

The result analysis of variance suggested that the soil total nitrogen, available phosphorus, and cation exchange capacity were highly significantly varied according to the interaction impact on different sources and rates of biochar. The highest mean value of total nitrogen, available P and CEC, was 0.76±0.013 % (21.08±0.49 ±0.49mg kg^{-1} and 40.37±0.48 kg^{-1}), respectively, and the lowest value was 0.17±0.013% (13.85±0.49 mg kg^{-1} and 28.62±0.48 cmolKg^{-1}), respectively, was recorded in untreated soil. The result of an analysis of the variance table states that there is a significant variation between the interaction of the source and rate of biochar on the growth and yield parameters of beetroot. The plant height significantly varied at three growth stages (at 25 days, 50 days, and harvest). The highest mean value of plant height was (19.89±0.66cm), (34.58±1.1cm), and (36.97.47±0.91cm), respectively, and the lowest value of plant height was (16.53±0.66cm), (25.66±1.1cm), and (29.28±0.91), respectively, which was within the control. The Nova suggested that the number of leaves per plant was significantly affected ($p<0.05$) by the interaction of different rates and sources of biochar. The highest mean value of the number of leaves per plant was (19.66±0.47), and the smallest value was recorded in control (17.33±0.47). It also indicates that leaf length was significantly affected ($p<0.001$) by the interaction effect of different rates and sources of biochar. The highest mean value of leaf length was (34.14±0.38) and the lowest value of leaf length was (29.04±0.38), which resulted in untreated soil. Also, ANOVA indicates that leaf area shows a significant difference ($p<0.001$) among the interaction impact of different rates and sources of biochar. The highest mean value of leaf area was 826.83±16 cm^2, and the least value was recorded in control (327.87±16 cm^2). The result of the analysis of variance also indicates that beet diameter is highly significantly affected by the interaction of rate and source of biochar. The maximum diameter was 6.61±0.01 cm, and the minimum value was 5.77±0.06 cm in control. The result obtained by the analysis of variance table suggested that the plant beetroot yield per plant and per pot was highly significantly influenced by the interaction of different rates and sources of biochar. The highest beetroot yield per plant and per pot was (482.67±14.55g) and (1458.33±23g), respectively, and the smallest beet yield per plant and per pot was (334.±3.14.55g) and (1039.67±23g), respectively, recorded within the untreated soil. Usually, the interaction of the source and rate of biochar (10 and 7.5 tons per hectare) significantly improved the selected chemical properties, growth, and yield of the beetroot plant. Coffee husk and Enset leaf are better biochar sources than maize cob. This study exposed several remarkable aspects of the interaction effects of different sources and rates of biochar on the chemical properties, growth, and yield of beetroot.

The study clearly showed that the chemical properties of biochar varied as a result of feedstock selection and application rate. This study thereby strongly suggests that an increased application of biochar, especially coffee husk biochar, can significantly improve soil fertility and soil chemical properties and hence lead to the enhanced growth and yield of beetroot plants. Moreover, many of the soil parameters were found to have a positive and significant correlation with beetroot growth and yield parameters. In addition, it investigates the interaction and impact of different sources and rates of biochar on soil chemical properties and the growth and yield of beetroot plants. The economic analysis has led to the suggestion that the sources of biochar, coffee husk, maize cob, and enset leaf are 10 and 7.5 tons per hectare, respectively. Sites are suitable for potential adoption by farmers and other economically viable treatments.

5.2 Recommendations

- The present study suggests that further investigation and resource development should be focused on the practical aspects of biochar handling, given the potential risks associated with dust and fire during biochar production. Because producing biochar carries some risk of fire and dust, this study suggested that more research be done and resources be developed on the practical aspects of handling biochar.
- It is recommended that further research be done on its integration into different types of management systems (urban administration in different waste management).
- Both governmental and non-governmental organizations would alter various black furnaces and stoves used to produce biochar for farmers, as well as the economics of biochar on farms and how it relates to soil management techniques like energy production.
- Administrators would support and encourage research on the application of various feedstock biochar at varying rates to improve the physicochemical properties of soil at the lowest feasible cost.
- Administrators would support a budget for sustenance and facilities for improving soil through investment, even though farmers consider these costs to be high.
- Since biochar has a longer environmental stability than other amendments, further long-term studies are required to determine the long-term effects of different feedstock biochar at different rates in the field. The shorter-term study results in a better yield in the greenhouse pot experiment.

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7. APPENDIX

Appendix 1 Analysis of variance of plant height (cm) at 25DAS, at 50 DAS at harvest, Number of leaf per plant

Source of variation		Height 25DAS		Height 50DAS		Height at harvest		Number leaf per plant	
	DF	MS	Pr>f	MS	Pr>f	MS	Pr>f	MS	Pr>f
Rate	3	20.52	<.0001	89.94	<.0001	32.61	<.0001	35.879	<.0001
Source	2	9.68	<.0001	23.29	<.0001	82.42	<.0001	4.75	<.0001
Source *rate	6	0.377	0.6241	9.63	<.0001	0.98	0.361	0.935	0.032
Error	24	0.51		0.38		0.84		0.33	
Total	35								
CV %		4.52		2.19		2.96		3.37	

appendix 2 Analysis of variance of leaf length (cm) and leaf area (cm^2),beet diameter (cm) Beet weight per plant (g) and per pot (g)

Source of variation		Leaf length (cm)		leaf area (LA c m^2)		Beet diameter (cm)		Beet fresh weight per plant (g)		Beet fresh weight per pot (g)	
	DF	MS	Pr>f	MS	Pr>f	MS	Pr>f	MS	Pr>f	MS	Pr>f
Rate	3	47.161	<.0001	209377	<.0001	1.9747	<.0001	19360.4	<.0001	98432	<0.001
Source	2	65.1	<.0001	128985	<.0001	1.057	<.0001	8802.19	<.0001	21413	0.001
Rate *source	6	1.184	0.0011	5348.03	<.0001	0.1223	0.0005	1334	0.0043	25398	<0.001
Error	24	0.22		388.08		0.019		309.11		180	
Total	35									1.19	
CV (%)		1.62		4.19		2.38		4.82			

Appendix 3 Analysis variance for soil reaction (pH), organic carbon (OC %) organic matter (OM %) and total nitrogen (TN %)

Source of variation		**Soil reaction(pH)**		**Organic carbon (OC %)**		**Organic matter (OM%)**		**Total nitrogen (TN%)**		**Carbon to nitrogen(C:N)**	
	DF	MS	Pr>f	MS	Pr>f	MS	Pr>f	MS	Pr>f	MS	Pr>f
Rate	3	1.67358	<0.001	50.29	<0.001	210.144	<0.001	0.54676	<0.001	17.51	<.0001
Source	2	0.25504	<0.001	0.609	0.001	1.743	<0.001	0.01023	0.001	0.379	0.2167
Source *rate	6	0.03196	0.02118	0.273	0.001	0.247	0.07105.	0.00246	0.001	1.39	0.0006
Error	24	0.01026		0.035		0.124		0.00036		0.23	
Total	35										
CV (%)		1.43		3.29		3.18		3.56		4.28	

Appendix 4 Analysis of variance for soil Electrical conductivity , Available phosphors (Av.P) and cation exchange capacity

Source of variation		Electrical conductivity (EC)		Available phosphorus (Av.P)		Cation exchange capacity (CEC)		Carbon to nitrogen (C:N)	
	DF	MS	Pr>f	MS	Pr>f	MS	Pr>f	MS	Pr>f
Rate	3	0.050521	<0.001	82.725	<0.001	210.136	<0.001	17.5158	<0.001
Source	2	0.001753	0.001	10.139	0.001	30.8732	<0.001	0.3796	0.222418
Source*rate	6	0.000460	0.0012	3.319	0.001	2.01846	0.0006.	1.3921	0.0008
Error	24	0.000086		0.425		0.331		0.23	
Total	35								
CV(%)		7.12		3.61		1.69		4.31	

Appendix 5 Analysis of variance for textural class of soil biochar mixture after two month incubation periods

Source of variation		**Sandy (%)**		**Clay (%)**		**Silt (%)**	
	DF	MS	Pr>f	MS	Pr>f	MS	Pr>f
Rate	3	1.48138	0.14399	0.56899	0.46749	0.26568	0.494
Source	2	0.80537	0.35525	1.32716	0.15281	0.43597	0.2788
Rate*source	6	0.68868	0.49442	0.74623	0.36665	0.43288	0.28
ERROR	24	0.74215		0.64788		0.32191	
Total	35						
CV(%)		2.79		2.04		1.96	

Appendix 6 Overview of   Soil sampling for soil analysis



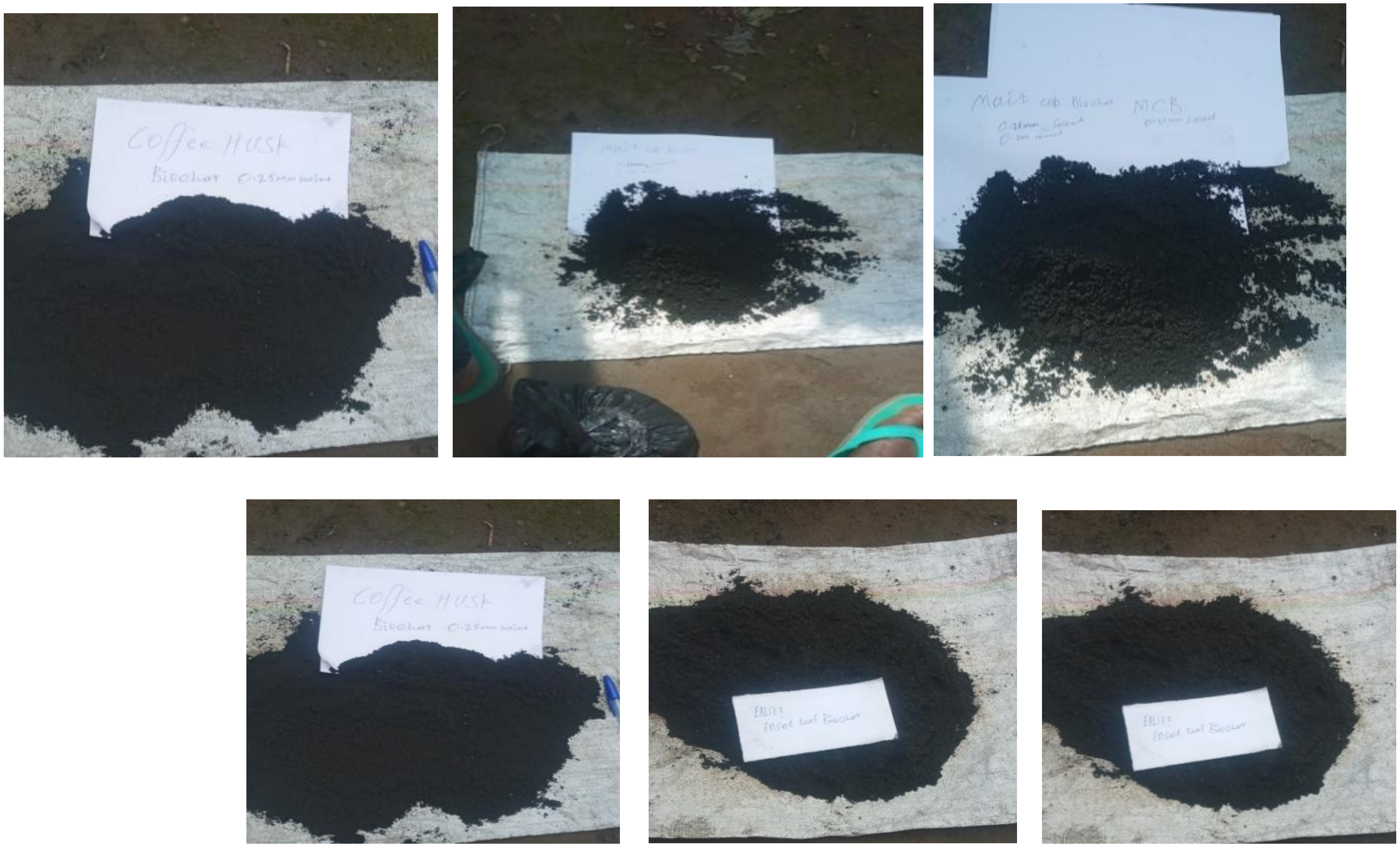




Appendix 7 Overview of Biochar Materials or source of biochar

Appendix 8 Overview of Biochar Production at 5000c pyrolysis temperature

Appendix 9 Overview of Produced Biochar after crashing



Appendix 10 Overview of Biochar and soil incorporating or collaborating

Appendix 11 Overview of soil preparation in pot & laving in greenhouse

Appendix 12 Overview of beetroot plant growing in pot

Appendix 13 correlation between parameter

Variable	sand	clay	silt	PH	OC	OM	TN	Av.P	CEC	EC	H1	H2	H3	NLPP	LL	LA	BDM	IBW	YYP
sand	1	-0.917	0.875	-0.620	-0.381	-0.380	-0.515	-0.754	-0.659	-0.567	-0.529	-0.641	-0.479	-0.779	-0.551	-0.795	-0.643	-0.318	-0.457
		0.001	0.004	0.101	0.352	0.353	0.192	0.031	0.076	0.143	0.177	0.087	0.230	0.023	0.157	0.018	0.085	0.442	0.255
clay		1	-0.972	0.435	0.223	0.222	0.288	0.534	0.419	0.428	0.260	0.419	0.262	0.624	0.418	0.574	0.415	0.264	0.209
			<.0001	0.282	0.596	0.597	0.489	0.173	0.301	0.290	0.534	0.301	0.531	0.098	0.303	0.137	0.307	0.527	0.620
silt			1	-0.252	-0.057	-0.056	-0.154	-0.406	-0.345	-0.265	-0.136	-0.297	-0.113	-0.459	-0.254	-0.451	-0.347	-0.049	-0.248
				0.548	0.893	0.895	0.715	0.318	0.403	0.527	0.748	0.475	0.790	0.252	0.544	0.262	0.400	0.908	0.554
PH				1	0.806	0.806	0.762	0.917	0.741	0.958	0.808	0.885	0.925	0.966	0.914	0.903	0.751	0.698	0.352
					0.016	0.016	0.028	0.001	0.035	0.000	0.015	0.004	0.001	<.0001	0.002	0.002	0.032	0.054	0.393
OC					1	1.000	0.944	0.842	0.765	0.836	0.922	0.892	0.667	0.779	0.944	0.817	0.791	0.502	0.488
						<.0001	0.000	0.009	0.027	0.010	0.001	0.003	0.071	0.023	0.000	0.013	0.019	0.205	0.220
OM						1	0.945	0.842	0.765	0.835	0.922	0.892	0.667	0.779	0.944	0.817	0.791	0.502	0.488
							0.000	0.009	0.027	0.010	0.001	0.003	0.071	0.023	0.000	0.013	0.019	0.205	0.220
TN							1	0.881	0.853	0.740	0.977	0.902	0.597	0.782	0.868	0.879	0.838	0.444	0.625
								0.004	0.007	0.036	<.0001	0.002	0.118	0.022	0.005	0.004	0.009	0.270	0.097
Av.P								1	0.859	0.891	0.927	0.970	0.834	0.938	0.910	0.995	0.925	0.484	0.638
									0.006	0.003	0.001	<.0001	0.010	0.001	0.002	<.0001	0.001	0.225	0.089
CEC									1	0.773	0.871	0.894	0.616	0.792	0.816	0.876	0.845	0.233	0.703
										0.025	0.005	0.003	0.104	0.019	0.013	0.004	0.008	0.578	0.052
EC										1	0.786	0.899	0.897	0.922	0.960	0.865	0.794	0.535	0.415
											0.021	0.002	0.003	0.001	0.000	0.006	0.019	0.172	0.306
H1											1	0.950	0.715	0.800	0.876	0.918	0.900	0.411	0.689
												0.000	0.046	0.017	0.004	0.001	0.002	0.312	0.059
H2												1	0.827	0.877	0.943	0.961	0.916	0.430	0.632
													0.011	0.004	0.000	0.000	0.001	0.288	0.093
H3													1	0.825	0.802	0.804	0.715	0.562	0.355
														0.012	0.017	0.016	0.046	0.147	0.388
NLPP														1	0.899	0.941	0.773	0.657	0.403
															0.002	0.001	0.025	0.077	0.322
LL															1	0.890	0.825	0.534	0.460
																0.003	0.012	0.173	0.252
LA																1	0.902	0.497	0.621
																	0.002	0.210	0.100
BDM																	1	0.138	0.862
																		0.745	0.006
IBW																		1	-0.318
																			0.443
YYP																			1

NB:- pH= soil solution or a measure of soil acidity and basicity EC = electrical conductivity OC = organic carbon TN= total nitrogen CEC= cation exchange capacity OM= organic matter AV.P = available, H1 =height at 25 days H2 = height at 50 days H3= height at harvest NLPP= number of leaf per plant LL= leaf length LA= leaf area BDM = beet diameter IBW individual beet weight or beet weight per plant YYP =yield per pot or beet weight per pot

The above table (12) shows correlation between soil ,growth and Yield parameter pH indicate that significantly and positively associated with, all growth parameter :- plant height ,leaf length ,leaf area ,number of leaf per plant , yield parameter :- beet diameter or beet thickness , weight of yield per plant (IBW) and soil parameter OC, TN, Av.P, CEC and yield per pot shows significantly and positively associated with soil parameter :- TN, Av.P CEC and yield parameter beet diameter

Appendix 14 Ten years monthly temperature and precipitation through new loclim software (Local Climate Information)

Month	Tem [°C]_min	Tem[°C]_max	Tem[°C]_mean	RF[mm]
January	9.3	25	16.3	40
February	10.1	25.1	17.7	38
March	10.6	24.8	19.1	92
April	11.3	25.1	18.5	121
May	12.3	24.7	18.7	95
June	11.1	24	17.7	95
July	10.8	22.2	16.3	149
August	10.3	22	16.5	140
September	10.1	23.2	17.5	157
October	9.8	24	17.2	40
November	9.3	23.8	17.2	13
December	8.3	24.2	16.5	28
Mean	10.28	24.01	17.43	84

^{o}C =Degree centigrade, Min=Minimum, Max=Maximum mm=millimeter