Peertechz

International Journal of Agricultural Science and Food Technology

LIFE SCIENCES GROUP

ISSN: 2455-815X DOI: https://dx.doi.org/10.17352/ijasft

Research Article

Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (*Brassica oleracea* L.)

Amankwaah Frederick[1], Eric Adjei[2]*, Abdul Aziz Khalid[3], Kwadwo Gyasi Santo[3], Novor Samuel[3], Ben Amoah[4], Alexander Danson-Anokye[2] and Adu Poku Isaac[5]

[1]Cocoa Marketing Company, Kumasi, Ghana

[2]Department of Agriculture, Berekum East Municipal Assembly, Berekum, Ghana

[3]Department of Horticulture and Crop Production, School of Agriculture and Technology, University of Energy and Natural Resources, Sunyani, Ghana

[4]Soil Research Institute, Kwadaso-Kumasi, Ashanti Region, Ghana

[5]Glenn High School, Winston Salem, NC, USA

Received: 09 February, 2024
Accepted: 08 March, 2024
Published: 09 March, 2024

***Corresponding author:** Eric Adjei, Department of Agriculture, Berekum East Municipal Assembly, Berekum, Ghana, E-mail: przyeric@yahoo.com

ORCiD: https://orcid.org/0000-0002-1432-5645

Keywords: Biochar; Nitrogen; Cabbage; Corn cob; Nutrient uptake; NPK; Yield

Abstract

Few studies have examined how fertilizers affect soil chemical properties, cabbage (Brassica oleracea L.) yield, and nutrient uptake in Ghana. This study examined how corn cob biochar (CCB) and NPK (15:15:15) fertilizer affected cabbage growth, yield, soil chemical properties, and nutrient uptake. The study was conducted during the 2021 major season at Soil Research Institute, Kwadaso. A 3×3 factorial experiment set out in a Randomized Complete Block Design with three replications was conducted. The treatments applied were control (No fertilizer), 50% NPK, 100% NPK, 2,500 kg ha^{-1} CCB, 50% NPK + 2,500 kg ha^{-1} CCB, 100% NPK + 2,500 kg ha^{-1} CCB, 5,000 kg ha^{-1} CCB, 50% NPK + 5,000 kg ha^{-1} CCB and 100% NPK + 5,000 kg ha^{-1} CCB. Application of 100% NPK resulted in the largest (2.99 cm) stem diameter. Application of 100% NPK + 5,000 kg ha^{-1} CCB resulted in the tallest plants (42.3 cm) and cabbage leaf spread (71.23 cm). Application of 100% NPK + 5,000 kg ha^{-1} CCB resulted in the largest cabbage head circumference (67.43 cm). The 100% NPK + 2,500 kg ha^{-1} CCB gave the highest yield (40679 kg ha^{-1}). 100% NPK + 2,500 kg ha^{-1} CCB increased nitrogen uptake, 50% NPK + 5,000 kg ha^{-1} increased phosphorus and calcium uptake, 100% NPK + 5,000 kg increased potassium uptake, and 50% NPK + 2,500 kg increased magnesium uptake. Therefore, it is suggested that CCB and NPK fertilizers be applied to enhance the soil's physical and chemical properties, nutrient uptake, and other factors contributing to cabbage growth and yield.

Introduction

Vegetable farming has emerged as a major industry in Ghana's urban and peri-urban areas in recent decades. Cabbage belongs to the *Brassicaceae* family along with radish, cauliflower, and brussels sprouts [1]. It is widely used in traditional cooking, both in cooked dishes and in raw salads. Cabbage is one of the most widely consumed foreign vegetables in Ghana. It is commonly grown in continuous cropping on insufficiently fertile soils, with irrigation at the start and rain at the end. In practice, farmers typically use organic fertilizers in conjunction with NPK or NPK alone. Employing biochar as a soil supplement has attracted significant interest over the past 20 years due to its agronomic and environmental benefits in agro-ecosystems [2]. Biochar, according to research [3], can improve the soil's physical and chemical properties, increase the availability of nutrients to plants, and increase the number and activity of soil microbes. When combined with organic or inorganic fertilizers, new research suggests that adding biochar to the soil can improve its physical, chemical, and biological qualities and promote plant growth.

Corn cob material is easily accessible from a number of farms that have emerged in recent years throughout Ghana,

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203

including Kumasi. Improvements in specific surface area, cation exchange capacity, bulk density, pH, water, and nutrients in the soil matrix are associated with the beneficial effects of biochar on plant growth and soil microbial population [4]. As a result, it is critical to assess the effects of combining biochar and NPK application on ferric acrisol as there is a significant issue on how to increase food production to meet Ghana's growing population. Due to factors such as high acidity, low organic matter content, low active clay minerals, and low concentrations of the three main macronutrients, nitrogen (N), phosphorus (P), and potassium (K), a significant portion of Ghana's agricultural land is inherently poor. Other factors contributing to the decline in soil fertility include crop nutrient removal and losses due to soil erosion. As a result, most soils lack vital plant nutrients required for optimal crop growth, resulting in low agricultural yield.

Fertilizer application boosts crop yields quickly. Mineral fertilizers help African urban farmers maintain soil productivity. Most peasant farmers in developing countries can't afford artificial fertilizers, so they are turning to organic materials to grow nutrient-rich crops. However, misuse of chemical fertilizers can lower plant quality and increase disease susceptibility, a major drawback. Chemical fertilizers cause soil aggregate instability, loss of organic matter, increased soil acidity, and increased erosion [5]. These chemical fertilizers may harm the ecosystem by leaking nitrate into water, eutrophicating surface waterways, and affecting public health. Based on the above challenges of chemical fertilizer use and depleting resources for sustainable crop production, an integrated approach that uses both chemical and organic fertilizers and increases nutrient and water use efficiency by smallholder farmers is needed for sustainable soil fertility management. Biochar and other organic amendments ensure this. Thus, the study determined the optimal biochar and NPK application rate best for improving cabbage growth and yield in Ferric Acrisol soil. Biochar and NPK fertilizer were hypothesized to boost cabbage growth and yield.

Materials and methods

Description of study location

The experiment was conducted at Soil Research Institute (SRI), Kwadaso, which is about 8 kilometres from Kumasi-. Geographically, the region is situated between longitudes 01º.39' and 01º.42' west of the Greenwich meridian and latitudes 06º 39' and 06º 43' north. It is located in the semi-evergreen forest zone of Ghana [6]. Rainfall in the area is distributed bimodally. While the major rainy season lasts from March through July, the minor rainy season begins in September and lasts through November. There is a brief dry period in August. The average monthly temperature ranges from 24ºC to 28ºC, and the average annual precipitation is roughly 1500mm. The relative humidity is typically high, reaching about 90% in the morning and between 60 and 70% in the afternoon. The investigation was conducted on the Asuansi soil series, which Adu [7] designated as Typic Haplustult by the USDA and Ferric Acrisol by FAO [8]. This soil belongs to the Offin Compound Association and is specifically found at the upper to medium slope of the Kumasi - Asuansi/Nta soil association Figure 1.

Experimental design and treatments

The experiment was arranged in a Randomized Complete Block Design with three replications. The field was divided

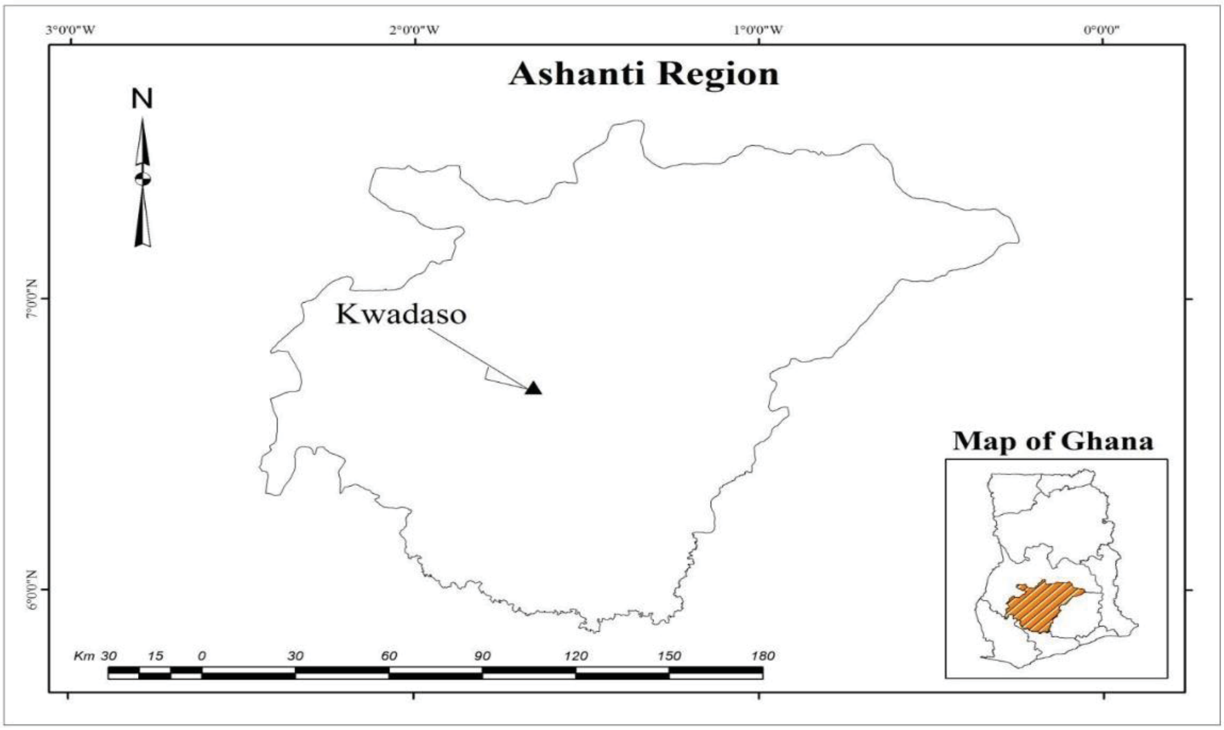

Figure 1: Location of the study area [9].

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203

into plots measuring 2.0m × 2.4m, with a 1 m alley between blocks and 0.5m alley between plots. The treatments applied are shown in Table 1.

Soil sampling analysis

The results of soil analysis conducted before treatment application are presented in Table 2. Before planting the cabbage, the nutritional content of the soil was assessed by taking five soil samples from the plot at a depth of 0 - 20 cm using an auger. To eliminate the larger particles, a composite sample was first sieved using a gyrator sieve shaker with a 2mm mesh size. The sample was then left to dry for one hour. Physico-chemical parameters of the composite soil sample were examined using accepted practices. After harvest, soil samples were taken and examined again. The soil samples were examined in a lab at the Soil Research Institute in Kumasi for pH, total nitrogen, organic carbon, available phosphorus, total exchangeable bases, effective cation exchange capacity, texture, and bulk density.

Production and properties of Corn Cob Biochar (CCB)

The corn cob material used to make the CCB for this investigation was sourced from a maize shelling facility near the Soil Research Institute. At the Soil Research Institute in Kumasi, Ghana, a slow pyrolysis batch kiln was used to pyrolyze the maize cob feedstock at a temperature of 450 ºC after it had been air dried to a moisture content of 15%. With a resident time of 48 hours, the charring process led to a 65% feedstock weight loss and a 35% biochar recovery yield. The charred cob biochar was sprinkled with water and allowed to cool for three hours after the charring process was finished. When it was ready for field application, it was milled and kept in sacks. All the sacks' contents were sampled for the charred corn cobs, homogenized, and ground to a thickness of less than 2mm for chemical analysis. The chemical properties of the CCB produced and used are presented in Table 3.

Table 1: Treatment Combinations and Coding.

Code	Treatments and rate of application	Letter codes
T1	Control treatment	Control
T2	45 kg ha^{-1} Urea + 30 kg ha^{-1} Triple Super phosphate + 30 kg ha^{-1} Muriate of potash	50% NPK
T3	90 kg ha^{-1} Urea + 60 kg ha^{-1} Triple Super phosphate + 60 kg ha^{-1} Muriate of potash	100% NPK
T4	2,500 kg ha^{-1} corn cob biochar	2,500 kg ha^{-1} CBB
T5	45 kg ha^{-1} Urea + 30 kg ha^{-1} Triple Super phosphate + 30 kg ha^{-1} Muriate of potash + 2,500 kg ha-1 corn cob biochar	50% NPK + 2,500 kg ha^{-1} CBB
T6	90 kg ha^{-1} Urea + 60 kg ha^{-1} Triple Super phosphate + 60 kg ha^{-1} Muriate of potash + 2,500 kg ha-1 corn cob biochar	100% NPK + 2,500 kg ha^{-1} CBB
T7	5,000 kg ha^{-1} corn cob biochar	5,000 kg ha^{-1} CBB
T8	45 kg ha^{-1} Urea + 30 kg ha^{-1} Triple Super phosphate + 30 kg ha^{-1} Muriate of potash + 5,000 kg ha-1 corn cob biochar	50% NPK + 5,000 kg ha^{-1} CBB
T9	90 kg ha^{-1} Urea + 60 kg ha^{-1} Triple Super phosphate + 60 kg ha^{-1} Muriate of potash + 5,000 kg ha-1 corn cob biochar	100% NPK + 5,000 kg ha^{-1} CBB

Table 2: Initial soil chemical and physical properties.

Chemical Properties	Values	Physical Properties	Values
pH (1:2.5, H_2O)	5.48	Sand (%)	72.00
Organic carbon (%)	1.43	Clay (%)	14.00
Total nitrogen (%)	0.13	Silt (%)	14.00
CEC (Cmol/kg^{-1})	4.64	Texture	Sandy loam
Available P (ppm)	17.84	Bulk density (gcm^{-3})	1.43

Table 3: Chemical properties of corn cob biochar (CCB).

Chemical properties	Values
pH (1:5 H_2O)	11.3
EC (1:5 H_2O)	5.7 dS/m
Carbon	380 (g kg^{-1})
Nitrogen	20 (g kg^{-1})
Phosphorus	17 (g kg^{-1})
Potassium	38 (g kg^{-1})
Calcium	64 (g kg^{-1})
Magnesium	10 (g kg^{-1})
Ash	235 (g kg^{-1})
C: N Ratio	19.1

Nursery and management of seedlings

Oxylus cabbage seeds were sown by drilling in prepared seed beds that measured 1.2m × 3m. The seed beds were shaded with palm fronds. The palm fronds were removed after emergence and utilized to build shade 2m above the seed beds. Weak and deformed seedlings were removed, and the seedlings were pricked out seven days after emergence. Nets were built around and over the seedling beds to prevent insect infestations.

Land preparation and transplanting

When the seedlings were four weeks old, they were transplanted at a spacing of 40cm × 60cm. There were five rows with four plants in each row making a total of 20 plants on each plot. In order to protect the seedlings from bacterial and fungal diseases, Bypel was applied 48 hours before transplanting, and the seedlings were watered right away with a watering can. Two weeks following transplanting, fertilizer applications were done using 90 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5, and 60 kg ha^{-1} K_2O for 100% NPK plots and 45 kg ha^{-1} N, 30 kg ha^{-1} P_2O_5, and 30 kg ha^{-1} K_2O for 50% NPK plots. Two halves of nitrogen were applied. Two weeks after transplanting, a third of the N fertilizer dose was applied, and five weeks later, the remaining third was applied as a top dress. Regular shallow hoeing was done as necessary to control weed growth. Bypel insecticide was sprayed on cabbage plants at a dosage of 20g per 15 litres of water every two weeks to combat insect pests such as caterpillars, diamondback moths, mole crickets, etc.

Measurement of growth parameters

The agronomic growth data were measured at 28, 42, 56, and 68 days after transplanting. The following data were measured: in each plot, 5 plants were randomly tagged for

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203

data collection. Plant height was measured by tagging five plants, measuring their heights using a tape measure from the soil's surface to the tip of the plant. The mean height was then computed for each plot. The stem diameter of the five plants was measured using a caliper. The average per plant was calculated. The leaf spread was measured in two directions (north-south and east-west) and the mean of the measurement was used as the leaf spread of the plant. The agronomic yield data were determined after harvesting and this was done in the laboratory. Yield parameters taken included fresh leaf weight, head circumference, and fresh head yield weight. The cabbage head circumference was measured at harvest. The cabbage head circumference was measured along their vertical axis using a Vernier caliper. A total of 5 cabbage heads were sampled from each treatment and averages for each of the plots were recorded. Harvesting was done 90 days after transplanting. 5 cabbage plants were picked through balloting. Each of the fresh cabbage was weighed using a Top pan balance. The weight of the 5 cabbage plants was summed up and the average was calculated for each of the plots. Nutrient uptake was measured by multiplying the yields from the various treatments by the concentrations of the individual nutrients - N, P, K, Ca, and Mg, nutrient uptake was estimated.

$$\text{Nutrientuptake}\left(\text{kg / ha}^{-1}\right) = \frac{(\% N, P, K, Ca, P, Mg * Yield)}{100}$$

Where;

% N, P, K, Ca, P, Mg = their nutrient content in cabbage.

Soil chemical properties analysis: After clearing the land for the experiment, some soil samples were taken to the Soil Science Laboratory, Kwadaso Agric College, Kumasi for the initial soil analysis to determine the following physical parameters of the soil:

Soil pH: Based on the assumption of a 1:2.5 soil-to-water ratio, the soil's pH was assessed using a Suntex pH (mv) Sp meter with the model number 11082 (McLean). The soil was mixed with 50 ml of clean water in a 100 ml mug. The mixture was continuously agitated for 20 minutes before allowing it to stand for 15 minutes. To calibrate the pH meter, buffer solutions with pH values of 4.0 and 7.0 were used. The pH was determined by inserting the electrode into the upper portion of the suspension.

Total nitrogen: The Kjeldahl digestion and distillation method was used to determine the total nitrogen [10]. A 500 ml Kjeldahl assimilation bottle was filled with a 10g lump of soil. Copper sulphate, sodium sulphate, and selenium were combined with a spatula, and then a 30 ml concentration of H_2SO_4 was added. The soil was digested to a perpetual pure green colour; the mixture was heated strongly. The digest was allowed to cool after which it was transmitted to a 100 ml volumetric container. Purified water was added to constitute the target. The digest was divided into an aliquot of 10 ml, which was then transferred to a Tecator distillation flask. A solution of 40% NaOH in 20 milliliters was added. The outcome was that steam, released from the Foss Tecator apparatus, filled the flask. The ammonium distillate was collected in a 250 ml flask with 15 ml of 4% boric acid and markers such as bromocresol green and methyl red. With HCl solutions containing 0.1 M, the distillate was titrated. Assay procedures included blank digestion, distillation, and titration [11].

Calculation

$$\%\text{N} = \frac{\left(\text{A} - \text{B}\right) \times 14 \times M \text{ x}100}{1000 \times 1}$$

Where:

A = Titration was done with ml HCl

B = Blank titration was done using ml HCl

14 = Atomic weight of nitrogen

M = Concentration of HCl used in titration

l = Weight of soil sample in grams (10.0 g)

Soil organic carbon: Walkley-Black wet oxidation technique was used to quantify the amount of organic carbon in the water [12]. A blank sample was also set up and 2 g of soil sample was measured into a 500 ml Erlenmeyer container. Both flasks containing the soil and the blank had a 10 ml solution of 0.1667 M K_2Cr2O_7. The next step was to add 20 cc of concentrated sulfuric acid. The compound was left to stand for 30 minutes on an asbestos sheet. After adding 200 ml of purified water and 10 ml of concentrated orthophosphoric acid to the mixture, it was allowed to cool. The excess dichromate ion in the combination was back-titrated with 1.0 M ferrous sulphate solution in the presence of a diphenylamine indicator until the color changed from blue-black to greenish. Similar to that, a decision was reached without any dirt.

Calculation:

$$\% C = \frac{(\text{m.e.K}_2 Cr_2 O_7 - m.eFeSO_4) \times 0.003 \times 1 \cdot 32 \times 100}{\text{Weight of soil (g).}}$$

Where;

m.e. = molarity of solution × ml of solution used.

0.003 = milli-equivalent weight of C in grams (12÷4000)

1.32 = correction factor used

Carbon stocks were estimated by the formula:

Carbon stocks = SOC (%) × soil bulk density (Mg m^{-3}) × sampling depth (cm)

Effective cation exchange capacity (ECEC): Effective cation exchange capacity was calculated by adding exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+) and exchangeable acidity (Al^{3+} and H^+).

ESP was calculated by the formula: ESP = (Na^+/CEC) × 100

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203

SAR was calculated by: SAR = $Na^+ / [(Ca^{2+} + Mg^{2+})/2]^{0.5}$

Determination of total exchangeable bases: Total exchangeable bases (calcium, magnesium, potassium, and sodium) content in the soil was evaluated in 1.0 M ammonium acetate (NH_4OAc) extract [13].

Statistical analysis

GenStat Statistical Package Version 12.01 was used to perform an Analysis of Variance (ANOVA) on the data collected on parameters related to cabbage growth and yield (version 2008). Duncan Multiple Range Test (DMRT) is used to compare treatment averages at a 5% level of significance.

Results

Treatment effects on vegetative growth

Stem diameter: The stem diameter of cabbage was significantly ($p < 0.05$) influenced by the treatments **(Figure 2)**. The application of 100% NPK, 100% NPK + 2,500 kg ha^{-1} CCB, and 100% NPK + 5,000 kg ha^{-1} CCB gave similar ($p > 0.05$) stem diameter. Also, the 50% NPK + 5,000 kg ha^{-1} CCB and 50% NPK + 2,500 kg ha^{-1} treatments were similar and significantly higher than 5,000 kg ha^{-1} CCB, 2,500 kg ha^{-1} CCB, 50% NPK and control. The control plants had the least stem diameter of 2.07cm.

Plant height: The application of 100% NPK + 5,000 kg ha^{-1} CCB resulted in significantly ($p < 0.05$) highest (42.3 cm) plant height. The application of 50% NPK + 5,000 kg ha^{-1} CCB, 100% NPK + 2,500 kg ha^{-1} CCB, and 50% NPK + 5,000 kg ha^{-1} CCB and 100% NPK gave similar effect on plant height, but differed from other treatments, except 100% NPK + 5,000 kg ha^{-1} CCB. The control plants were the shortest, with an average height of 31.4 cm **(Figure 2).**

Leaf spread: The results showed that leaf spread was significantly affected by treatment application ($p < 0.05$) with 100% NPK + 5,000 kg ha^{-1} CCB treatment having the largest leaf spread (71.23), while the control recorded the least leaf spread of 55.53 cm **(Figures 3,4).**

Treatment effects on yield parameters

Head circumference, fresh leaf weight, and fresh head yield: The head circumference of the harvested cabbage was significantly ($p < 0.05$) affected by the soil amendments **(Table 4).** Application of 100% NPK + 5,000 kg ha^{-1} CCB resulted in the highest (67.43 cm) cabbage head circumference. Treatments 50% NPK + 5,000 kg ha^{-1} CCB and 50% NPK + 2,500 kg ha^{1} CCB had similar effects, but varied from other treatments. Likewise, 5,000 kg ha^{-1} CCB and 100% NPK recorded similar effects but differed from other treatments. The control recorded the least head circumference of 45.5 cm. The various treatments applied significantly ($p < 0.05$) influenced fresh leaf weight. Application of 100% NPK + 5,000 kg ha^{-1} CCB resulted in the highest fresh leaf weight (24074 kg ha^{-1}). Plots treated with 50% NPK + 5,000 kg ha^{-1} CCB and 50% NPK + 2,500 kg ha^{-1} CCB had similar effects, but differed from all other treatments.

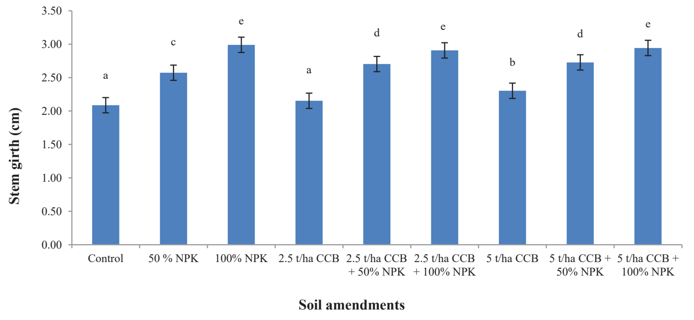

Figure 2: Interaction effects of fertilizer treatments and corn cob biochar on stem diameter.

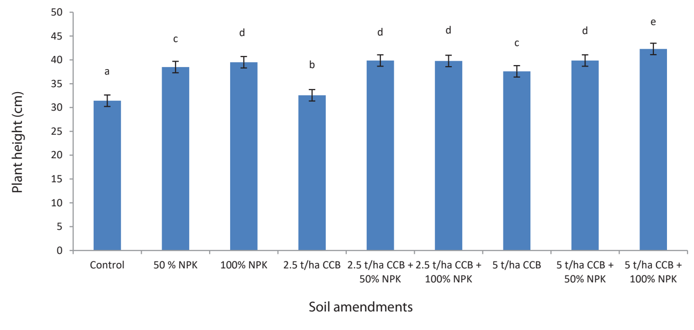

Figure 3: Interaction effects of fertilizer treatments and corn cob biochar on plant height.

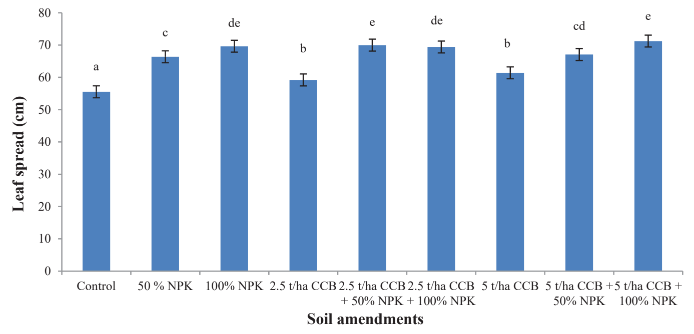

Figure 4: Interaction effects of fertilizer treatments and corn cob biochar on leaf spread.

The control plot recorded the least fresh leaf weight of 7235 kg ha^{-1}. The application of 100% NPK + 2,500 kg ha^{-1} CCB recorded the highest head yield (40679 kg ha^{-1}) which was significantly different ($p < 0.05$) from all other treatments. All other treatments differed ($p < 0.05$) from each other. The control treatment recorded the least head yield (19691 kg ha^{-1}).

Treatment effects on Nutrient uptakes

Nitrogen, phosphorus, potassium, calcium, and magnesium uptake: The effect of the soil amendments on nitrogen uptake was found to differ considerably ($p < 0.05$) (Table 5). Among the treatments, the plants treated with 100% NPK + 2,500 kg ha−1 CCB had the maximum nitrogen uptake (849.6 kg ha−1) of all the plots. The 100% NPK + 5,000 kg ha^{-1} CCB and 50% NPK + 2,500 kg ha^{-1}; 50% NPK + 5,000 kg ha^{-1} CCB and 100% NPK were similar, but higher than the other treatments, except 100% NPK + 2,500 kg ha^{-1} CCB. The least amount of nitrogen (318.6 kg/ha) was found in the control

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203

Table 4: Effect of fertilizer treatments on head circumference and fresh head yield of cabbage.

Soil amendments	Head circumference (cm)	Fresh head yield (kg ha^{-1})
Control	45.50^a	19691^a
50 % NPK	58.00^c	32284^d
100% NPK	61.30^d	35679^e
2.5 t/ha CCB	53.43^b	25926^b
2.5 t/ha CCB + 50% NPK	62.90^e	36667^f
2.5 t/ha CCB + 100% NPK	64.40^f	40679^h
5 t/ha CCB	60.67^d	30926^c
5 t/ha CCB + 50% NPK	62.97^e	39877^g
5 t/ha CCB + 100% NPK	67.43^g	36420^{ef}
p - value	<.001	<.001

Averages within a column with the same letters do not differ significantly at the 5% level of probability

Table 5: Effects of the soil amendments on N, P, K, Ca, and Mg uptake.

Soil amendments	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	Ca uptake (kg/ha)	Mg uptake (kg/ha)
Control	318.6^a	65.6^a	320.9^a	102.9^a	86.2^a
50%NPK	548.3^c	125.0^{cd}	727.5^b	371.6^{bc}	167.9^b
100% NPK	789.4^f	131.3^d	721.1^b	368.2^{bc}	207.2^c
2.5 t/ha CCB	516.2^b	99.2^b	727.3^b	254.8^b	153.8^b
2.5 t/ha CCB + 50% NPK	745.6^e	140.9^e	1020.8^d	413.4^{cd}	396.9^f
2.5 t/ha CCB + 100% NPK	849.6^g	173.6^g	1178.7^e	522.4^{de}	244.0^d
5 t/ha CCB	621.0^d	118.9^c	840.4^c	438.0^{cd}	235.9^d
5 t/ha CCB + 50% NPK	800.0^f	184.0^h	1166.4^e	612.5^e	290.3^e
5 t/ha CCB +100% NPK	749.7^e	165.1^f	1337.5^f	444.8^{cd}	246.4^d
p - value	<.001	<.001	<.001	0.009	<.001

Averages with the same letters within a column are not significantly different at a 5% probability level

plants. The results indicated that, the various soil amendments significantly (p < 0.05) increased phosphorus uptake (Table 5). Plots treated with 50% NPK + 5,000 kg ha^{-1} CCB gave the highest phosphorus uptake (184 kg ha^{-1}) by the cabbage plant. However, there was no significant difference between the 50% NPK and 100% NPK. The control plants had the least phosphorus uptake (65.6 kg ha^{-1}).

Different soil amendments produced significantly different potassium uptake (p < 0.05). The maximum potassium uptake (1337.5 kg ha^{-1}) was observed in the plot treated with 100% NPK + 5,000 kg ha−1 CCB. The application of 50% NPK, 100% NPK, and 2,500 kg ha^{-1} gave a similar effect on potassium uptake but varied significantly from the other treatments. The control plants had the least potassium uptake (320.9 kg ha^{-1}). The maximum calcium uptake was observed with the application of 50% NPK + 5,000 kg ha^{-1} CCB, which was comparable to 100% NPK + 2,500 kg ha^{-1}, but differed significantly from all other treatments (612.5 kg ha^{-1}). Similar effects were observed on plots treated with 2,500 kg ha^{-1}, 100% NPK, and 50% NPK. Moreover, there were no significant differences among 100% NPK + 5,000 kg ha^{-1} CCB, 5,000 kg ha−1 CCB, 100% NPK + 2,500 kg ha^{-1} CCB, or 50% NPK + 2,500 kg ha^{-1} CCB (p > 0.05). The least calcium uptake occurred in the Control plants (102.9 kg ha^{-1}).

The highest magnesium uptake (396.9 kg ha^{-1}) by the cabbage was obtained from the plants treated with 50% NPK + 2,500 kg ha^{-1} CCB, which also varied significantly (p < 0.05) from all other treatments. For 100% NPK + 5,000 kg ha^{-1} CCB, 5,000 kg ha^{-1} CCB, and 100% NPK + 2,500 kg ha^{-1} CCB, similar results were obtained. Once more, the effects of applying 50% NPK and 2,500 kg ha^{-1} CCB were similar but significantly higher (p < 0.05) than the other treatments. The least amount of magnesium was absorbed in the control plants (86.2 Kg ha^{-1}).

Treatment effects on Soil chemical properties

Soil pH, total nitrogen, available phosphorus, organic carbon total nitrogen, total exchangeable bases and effective cation exchange capacity: It was shown that the effects of the different soil amendments on soil pH varied significantly (p < 0.05). The highest pH was measured in the 50% NPK + 5,000 kg ha^{-1} CCB and was significantly higher than that of the control, the 50% NPK, and the 100% NPK. The control had the lowest pH value (5.79). Plots treated with 100% NPK + 5,000 kg ha^{-1} CCB had the highest effects on soil nitrogen, which differed significantly (p < 0.05) from all other treatments. The plot amended with 100% NPK had similar effects as 100% NPK + 2,500kg ha^{-1} CCB but varied significantly (p < 0.05) from all the other treatments. The application of 2,500kg ha^{-1} CCB also gave the least total nitrogen (0.15%). The control treatment gave similar available phosphorus relative to all other treatments, except 100% NPK + 2,500 kg ha^{-1} CCB, 50% NPK + 5,000 kg ha^{-1} CCB and 5,000 kg ha^{-1} CCB. Available P was highest in treatment with 100% NPK + 2,500 kg ha^{-1} CCB (31.10 ppm), while the control had the least available phosphorus of 17.52 ppm. The control plot was significantly different (p < 0.05) from the other treatments, except 2,500 kg ha CCB, 5, 000 kg ha CCB, and 50% NKP + 5, 000 kg ha CCB. However, the 50% NPK gave the highest organic carbon content (1.78%), while the control treatment had the least (263.3%).

The effect of 50% NPK + 2,500 kg ha^{-1} CCB was similar to 50% NPK + 5,000 kg ha^{-1} CCB but varied significantly from all other treatments for total exchangeable bases. Likewise, the control treatment had similar effects to 5,000 kg ha^{-1} CCB but differed significantly from all other treatments. The highest total exchangeable bases were recorded in plots treated with 50% NPK + 2,500 kg ha^{-1} CCB, while the control plot had the least (2.74 cmol kg^{-1}). The effective cation exchange capacity of the soil changed significantly after soil amendments were applied (p < 0.05) **(Table 6)**. In comparison to all other treatments, the plots that received 100% NPK plus 2,500 kg ha−1 CCB (4.57 cmol kg^{-1}) were different. In comparison to 5,000 kg ha^{-1} CCB, the application of 50% NPK had similar effects, although it differed from all other treatments. Treatment with 100% NPK + 2,500 kg ha^{-1} CCB (4.57 cmol kg^{-1}) had the highest effective cation exchange capacity, while the control had the least (3.27 cmol kg^{-1}).

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203

Table 6: Effects of the soil amendments on soil pH, total nitrogen, available phosphorus, organic carbon total nitrogen, total exchangeable bases, and effective cation exchange capacity after treatment application

Soil amendments	pH (1:2.5 H_2O)	Total nitrogen (%)	Available P (ppm)	OC (g kg^{-1})	TEB (cmol (+) kg^{-1})	ECEC (cmol (+) kg^{-1})
Control	5.79[a]	0.17[ab]	17.52[a]	0.49[a]	2.74[a]	3.27[a]
50 % NPK	5.96[a]	0.16[ab]	20.89[ab]	1.78[b]	3.15[c]	3.61[d]
100% NPK	5.94[a]	0.19[d]	19.00[ab]	1.76[b]	2.93[b]	3.39[b]
2.5 t/ha CCB	6.03[ab]	0.15[a]	19.70[ab]	1.30[ab]	2.91[b]	3.73[e]
2.5 t/ha CCB + 50% NPK	6.04[ab]	0.16[a]	23.46[abc]	1.76 [b]	3.43[e]	3.47[bc]
2.5 t/ha CCB + 100% NPK	6.33[b]	0.19[cd]	31.10[c]	1.63[b]	3.26[cd]	4.57[f]
5 t/ha CCB	6.04[ab]	0.17[bc]	27.25[bc]	0.86[ab]	2.83[ab]	3.66[de]
5it/ha CCB + 50% NPK	6.34[b]	0.16[ab]	27.23[bc]	1.59[ab]	3.33[de]	3.52[c]
5 t/ha CCB + 100% NPK	6.19[ab]	0.22[e]	21.97[ab]	1.63[b]	3.17[c]	3.48[bc]
p - value	0.044	0.040	0.007	0.161	<.001	<.001

At the 5% probability level, averages containing the same letters in a column are not statistically different

Discussion

Effect of treatments on growth parameters of cabbage

Stem diameter: Masto, et al. [14] linked the various nutrients found in plant tissues after the application of soil amendments to the intricate physiochemical features of biochar, which may be implicated in the biochar-soil-plant interaction system. Moreover, additional biochar-mediated improvements in soil chemical characteristics such as increased soil nutrient content, CEC, and fertilizer usage efficiency, may potentially be responsible for the improved growth of cabbage after applying biochar [15].

Plant height: The findings of this study support those of earlier researchers who found that organic manure releases nitrogen more slowly than inorganic fertilizer [16,17]. The shortest plant height was observed in plots without fertilizer [18]. By supplying the essential nutrients for plant growth and development, Van Zwieten, et al. [15] found a positive influence of biochar and other organic amendments on the plants. This was attributed to the compost and biochar's high nutritional contents.

Leaf spread: The increased leaf spread caused by the application of the 100% NPK + 5,000kg ha^{-1} CCB can be attributed to the biochar's relatively high concentrations, the capacity of moisture, and the nutrient contents available to the plants. This result is consistent with a study by Tariku, et al. [19] which showed improvements in growth parameters after applying charcoal to garden peas. This may be because an adequate moisture supply led to an increase in plant height, as discussed by Kumar, et al. [20]. According to Abiven, et al. [21], the application of biochar improved soil properties like pH, water-holding capacity, and CEC, which increased crop responses in terms of growth and production.

Effect of treatments on yield of cabbage

Effect of treatments on head circumference and fresh head yield of cabbage: Compared to the soil amendments, which increased the cabbage's head circumference, and fresh head yields, the control treatment had the least head circumference, leaf biomass, and fresh head yields (Table 4). Changes in yield may result from the various forms of biochar used since the agronomic value of biochar depends on the type of biomass feedstock used, its nutritional content, and the pyrolysis temperature at which it is generated [22]. Additionally, elements including the quantity of applied biochar, the biochar's properties, and the type of soil it is applied to all have impacts on how much crop output is affected by biochar [23].

The results showed that as compared to the control, the usage of biochar and inorganic fertilizer significantly ($p < 0.05$) boosted yield. An earlier study showed that the use of biochar could improve the efficacy of chemical fertilizers [24]. This could be a result of the synergistic effect between organic and inorganic fertilizers, which enhance crop performance. Although the combined effects of biochar, inorganic fertilizers, and organic manure are unknown, a recent study has confirmed the benefits of biochar and inorganic fertilizers applied together [25,26].

The higher yield response of cabbage due to the combined application of CCB and NPK fertilizers supports the findings of Akolgo, et al. [27], who observed a 7.7% increase in cabbage yield after applying 20 t/ha^{-1} of sawdust biochar on loamy soil in Ghana. The divergence of the yield may also be caused by the different soil parameters observed. Despite having a favorable conditioning impact on soils, biochar may not be the only source of nutrients due to its relatively low nutrient content and resistance to biodegradation. The only organic additives had a lower level, possibly because manure is slow in releasing nitrogen following mineralization. These results corroborated those of previous studies [16,17], which discovered that manure provided slower nitrogen release than inorganic fertilizers.

To increase agricultural output, biochar has been applied to a variety of crops, including cowpea [28] maize [29], soybean [30], and radish [31]. Approximately 40 t/ha^{-1} of cabbage was produced in the Dar-Es-Salaam region, whereas 30 t/ha^{-1} of *A. cruentus* shoots was produced in Benin and Nigeria [32]. The increases in the dry matter that happened following the addition of soil amendments might be attributed to the benefits of biochar, such as its capacity to elevate soil pH, retain nutrients and moisture, and offer nutrients for plants to absorb and utilise [33]. Additionally, the improved growth traits including an increase in height, leaf spread, and stem girth may be responsible for the increases in dry matter yield. Tammeorg, et al. [34] and Liang, et al. [35] both found that using biochar enhanced seed yield and shoot biomass production. Other trials employing rice husk biochar showed increases in crop yields for rice, lentils, spinach, cabbage, maize, and cabbage [36-39]. According to our findings, compost and biochar treatments increased crop output in comparison to the control. Recently, higher yields of the cabbage variety "Veneza Roxa" were observed using chicken manure, followed by cattle manure, bounce back, and inorganic fertilizer, in decreasing order [40]. In research evaluating the impact of utilizing organic and inorganic fertilizers on the production and nutritional value of head cabbage, Prabhakar, et al. [41] found that higher yields with better quality heads were obtained with integrated nutrient management and organic treatments as compared to crop-grown with only chemical fertilizers.

Effect of treatments on nutrient uptake

Nitrogen uptake: The data showed that the application of inorganic fertilizer and biochar significantly boosted nitrogen absorption in comparison to Control. Carter, et al. [37] also showed that the combined application of biochar and organic fertilizer changed soil structure and improved soil chemical properties. This is evident that organic and inorganic fertilizers work together to improve crop performance. Although the combined effects of biochar, inorganic fertilizers, and organic manure are unknown, recent studies have confirmed the synergistic benefits of biochar and inorganic fertilizers [25,26].

Phosphorus uptake: The explanation for the comparatively high nutrient uptake by plants grown with biochar and mineral fertilizer may be attributed to the maximal macronutrient uptake with the integration of biochar and inorganic fertilizers. As a result, in addition to enhancing soil quality, micronutrients and macronutrients were added to the soil, increasing nutrient uptake by plants and promoting healthy plant growth. A study on the impact of bioslurry manure on carrots was undertaken by Jeptoo, et al. [42], and the findings were consistent with those of the current study. The finding is also in line with those of Chan, et al. 2008 [31] and Van Zwieten, et al. [15] who found that applying biochar to cabbage and radish plants, greatly enhanced the uptake of nutrients. Because of its enormous surface area, stronger negative surface charge, and higher charge density, biochar has a greater capacity to absorb nutrients per unit of carbon than other types of soil organic matter, [43]. According to Novak, et al. [44], the use of biochar promotes P absorption because the soil pH is raised and its exchangeable acidity is decreased [22,45]. One advantage of organic additions is that they have a different method for releasing phosphorus and a lower danger of subsequent binding than fertilizers made from inorganic sources, like rock phosphate. P uptake increases with rice husk BC [39].

Potassium uptake: The observed increases in the soil's uptake of potassium may be the result of the amendments' increased fertility and productivity. It is possible to research the synergistic advantages of using biochar and NPK together as a practical way to improve soil potassium uptake. The findings are in line with those of other studies, which found that nutrients provided by manure released their nutrients more gradually than those provided by inorganic fertilizer [16,17].

Magnesium uptake: The least amount of magnesium was absorbed, 86.2 kgha^{-1}, by the Control. This is in addition to the fact that organic manure is made from plant or animal sources which contain elements that improve soil fertility Yohannes [46].

Effcts of treatments on soil chemical properties

Soil pH: The ability of biochar to eliminate restrictions on soil acidity through improved soil pH is one of the key advantages it has for tropical soils [47]. The soil's ability to lime by displacing acidic cations from the exchange sites to lessen soil acidity and the contents of exchangeable acidity and Al could be the cause of the observed increases in soil pH. One of the biochar's key advantages for tropical soils is its ability to loosen soil acidity constraints by raising soil pH [47]. The liming qualities of these amendments could be responsible for the observed changes in soil pH. By removing the acidic cations from the exchange sites, these qualities could lower the quantity of exchangeable acidity and Al as well as the acidity of the soil. According to Nguyen and Lehmann [48], a year of incubation showed that the pH following biochar application declined with oak wood biochar that was in mineral from pH 4.9 to 4.7 but increased with maize stover biochar that was mineral-rich, from pH 6.7 to 8.1. Thus the type of feedstock could affect the pH following biochar application.

Total nitrogen: Because biochar is known to contain trace levels of both organic and inorganic nitrogen, it is possible that the ash content of the biochar contributed to the observed increases in the total nitrogen in the 100% NPK + 5,000 kg ha^{-1} CCB treatment [49]. According to Chan, et al. [31], the total N content of an Alfisol increased as the rate of biochar was increased. The outcome is consistent with research by Wells, et al. [50]. This is also in agreement with Efthimiadou, et al. [51], who indicated that the application of biofertilizers causes an increase in soil total N. According to the research evaluation by Clough and Condron [52], biochar's effects on N immobilization and crop absorption are often inconsistent. These authors came to the conclusion that particular soil and biochar combinations are closely related to changes in N dynamics caused by biochar. Composted waste should be applied at reasonably high rates to crops in order to augment their N requirements and achieve yields that are comparable to those obtained with commercial fertilizer levels that are advised [53].

Available phosphorus: The considerable increases in accessible P caused by the application of 100% NPK + 2,500 kg ha^{-1} CCB might be largely attributed to the matching rises in soil pH. It is believed that the lower solubility of Al caused by rising soil pH is the cause of the mechanism that increased the amount of accessible P. However, Chan, et al. [31], have also noted rising amounts of accessible P and rising biochar inputs as they were seen. Additionally, studies have shown that improving soil with compost and other materials improves the availability of vital nutrients including nitrogen (N), phosphorous (P), and carbon (C) in gardens, farms, and other landscaping systems [54].

The ability of biochar to increase extractable P (PO_4) levels in the soil solution, either directly through its anion exchange capacity or by affecting the availability of the cations (Fe^{2+}, Al^{3+}, and Ca^{2+}), has increased the quantity of soil P that is readily available. The fact that with P, soil P availability has increased is another factor [55]. This is made feasible by an elevation in soil pH caused by biochar, which bonds these metal cations

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203

together to prevent P from interacting with them and inhibits P from precipitating in solution by forming actinide. According to Arif, et al. [56], CCB has high soil nutrients that can be extracted, including P, K, Ca, and Mg.

Melese, et al. [57] have proposed that the P deficit in acid soils can be improved by applying mineral P fertilizer together with other amendments. Again, the organic materials may have decreased the soil's ability to bind phosphate and increased the amount of phosphate that was available by forming complexes (or chelates) with Fe and Al ions in the soil solution, preventing the precipitation of phosphate and also lowering the toxicity of Fe and Al, competing with P for absorption sites, and/or solubilizing P from insoluble Ca, Fe, and Al phosphate This results is in line with that of Iyamuremye and Dick [58], who discovered that organic compounds can increase P availability, decrease soil P-absorption capacity, improve P recovery, or lead to greater P usage by plants.

Organic carbon: The 2,500 kg ha^{-1} CCB, 5,000 kg ha^{-1} CCB, and 50% NPK + 5,000 kg ha^{-1} CCB were not different from the control, which had the least organic carbon content of 0.49. However, in conditions with high background levels and/or significant fluctuation, increases in soil organic carbon following low or moderate application rates may not be visible or noticeable [59]. The inherent quality of the amendment affects how quickly it decomposes and how much soil organic carbon remains over time [60]. Organic amendments contain carbon that was first fixed by photosynthesis in plants. The acceleration of SOC decomposition in response to additional carbon (C) intake is assumed to be caused by alterations in the constitution of the microbial community. In savannah soil, the addition of cellulose increased the rate of humus degradation by 55%, according to a study by Fontaine, et al. [61]. Kuzyakov, et al. [62] showed that the addition of glucose to the soil caused the Black Carbon (BC) in the soil to undergo enhanced breakdown, which provided additional support for this. The relatively slow rate at which the BC had decomposed in comparison to the glucose led them to the conclusion that the BC's decomposition was caused by the microorganism's metabolites following glucose decomposition. Because biochar contains the highest amount of stable carbon of all the mineral components present in the ash, and because CCB treatment greatly enhanced the SOC concentration [63]. The 38% carbon content of the CCB employed in this study, when combined with the biochar's resistance to breakdown, significantly increased the amount of organic carbon in the soil. Arif, et al. [56] also noted an increase in SOC following the addition of biochar.

Total exchangeable bases: The increase in total exchangeable bases at the addition of 2.5 t/ha^{-1} CCB + 50% NPK is supported by Adeniyan, et al. [64], who found that soil exchangeable bases increased when the biofertilizer was applied alone or in combination with the lime and P fertilizer. Ullah, et al. [65] study indicated that the effects of bio slurry on soil properties support the findings of the current investigation into total exchangeable bases and water retention.

Effective cation exchange capacity (ECEC): Increases in charge density per unit surface of organic matter (higher degree of oxidation), surface area for cation adsorption, or a combination of the two, according to Atkinson, et al. [66], are what led to increases in CEC. Oladele, et al. [67] claim that adding biochar increased CEC, improving the fertility of severely depleted tropical soil; the rise in CEC brought on by the addition of biochar further supports this claim.

Conclusion

The application of 50% NPK + 5,000 kg ha^{-1} CCB influenced soil pH, 100% NPK + 5,000 kg ha^{-1} CCB increased soil nitrogen, the 100% NPK + 2,500 kg ha^{-1} CCB increased soil phosphorus and ECEC, while the 50% NPK + 2,500 kg ha^{-1} CCB increased exchangeable bases. The combined application of 100% NPK + 2,500 kg ha^{-1} CCB increased nitrogen uptake, 50% NPK + 5,000 kg ha^{-1} CCB increased phosphorus and calcium uptake, 100% NPK + 5,000 kg ha^{-1} CCB increased potassium uptake and 50% NPK + 2,500 kg ha^{-1} CCB increased magnesium uptake. The combined application of 100% NPK + 5,000 kg ha^{-1} CCB improved growth, and increased the yield of cabbage. Also, the application of 100% NPK + 2,500 kg ha^{-1} CCB increased the total yield of cabbage. In order to enhance the soil's chemical characteristics, and the ability of cabbage plants to absorb nutrients and grow well, this study recommends the application of biochar made from corn cobs along with NPK fertilizer. Future investigations into this work could focus on the measurement and capture of some of the main gases linked with global warming such as CO_2, CH_4, and different nitrogen oxides.

Author contributions

Conceptualization: A.F., E.A., B.A., A.A.K., K.G.S., N.S., D.A., and I.A.P. were involved in developing the initial concepts and ideas for the research. Methodology: A.F., E.A., and B.A. contributed to designing the methodology and experimental design for the study. Formal analysis: A.F., E.A., and B.A. conducted the formal analysis of the data collected during the research. Resources: A.F., E.A., and B.A. provided the necessary resources for carrying out the research. Data curation: A.F., E.A., and B.A. were responsible for organizing and managing the research data. Writing – original draft preparation: E.A. wrote the initial draft of the research manuscript. Writing – review and editing: A.F., E.A., B.A., A.A.K., K.G.S., N.S., D.A., and I.A.P. reviewed and edited the manuscript for accuracy and clarity. Visualization: A.F., E.A., B.A., D.A., and I.A.P. created visual representations of the data and findings. Supervision: A.A.K., K.G.S., and N.S. provided oversight and guidance throughout the research process.

Data availability statement: A formal written request to the corresponding author can access the study's data, which is stored locally.

References

1. Franzke A, Lysak MA, Al-Shehbaz IA, Koch MA, Mummenhoff K. Cabbage family affairs: the evolutionary history of Brassicaceae. Trends Plant Sci. 2011 Feb;16(2):108-16. doi: 10.1016/j.tplants.2010.11.005. Epub 2010 Dec 21. PMID: 21177137.
2. Wu P, Wang H, Ata-Ul-Karim ST, Singh BP, Wu T, Liu C. A scientometric review of biochar research in the past 20 years (1998–2018). Biochar. 2019; 1(1):23–43.

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203

3. Jaafar NM, Clode P, Abbott L. Microscopy observations of habitable space in biochar for colonization by fungal hyphae from soil. Journal of Integrative Agriculture. 2014; 13(3): 483-490. https://doi.org/10.1016/S2095-3119(13)60703-0

4. Thies J, Rillig MC. Characteristics of biochar: biological properties. In Biochar for Environmental Management: Science and Technology, J. Lehmann and S. Josep, Eds., Earthscan, London, UK. 2009.

5. Mutegi EM, Kungu JB, Muna M, Pieter P, Mugendi DN. Complementary effects of organic and mineral fertilizers on maize production in the smallholder farms of meru south district, Kenya. Agricultural Sciences. 2012; 3(2): 2121-229.

6. Taylor CJ. The vegetation zones of the Gold Coast. Gold Coast Forestry Department. Bulletin No. 4, 1952; 11.

7. Adu SV. Soils of Kumasi Region, Ghana. Memoir No. 8, Soil Research Institute, Kumasi, Ghana. 1992

8. FAO (1988). FAO UNESCO Soil Map of the world. Revised Legend. Reprinted with corrections. World Soil Resources Report 60. FAO, Rome.

9. Calys-Tagoe E, Sadick A, Yeboah E, Amoah B. Biochar effect on maize yield in selected farmers fields in the northern and upper east regions of Ghana. J Expt Agric Int. 2019; 30 (6):1–9. http://doi:10.9734/JEAI/2019/44168.

10. Bremner JM, Mulvaney CS. Nitrogen-Total. In: Methods of soil analysis. Part 2. Chemical and microbiological properties, Page, A.L., Miller, R.H. and Keeney, D.R. Eds., American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin. 1982; 595-624.

11. Okelabo JR, Gathua KW, Woomer PL. Laboratory Methods of soil and plant analysis: A working manual, TSBF, Nairobi, Kenya. 1993

12. Nelson RS, Sommers K. Soil Fertility and Fertilizers 4th Edition Macmillan: New York. 1982.

13. Black CA. Methods of soil analysis. Part I, American Society of Agronomy. Madison, Wisconsin, USA. 1965; 1572.

14. Masto RE, Ansari MA, George J, Selvi V, Ram L. Co-application of biochar and lignite fly ash on soil nutrients and biological parameters at different crop growth stages of Zea mays. Ecol Eng. 2013; 58:314–22. doi: 10.1016/j.ecoleng.2013.07.011.

15. Van Zwieten L, Kimber S, Morris S, Chan KY, Downie A, Rust J. Effects of biochar from slow pyrolysis of paper mill waste on agronomic performance and soil fertility. Plant Soil. 2010; 327(1–2):235-246. doi: 10.1007/s11104-009-0050-x

16. Iqbal A, He L, Khan A, Wei S, Akhtar K, Ali I, Ullah S, Munsif F, Zhao Q, Jiang L. Organic Manure Coupled with Inorganic Fertilizer: An Approach for the Sustainable Production of Rice by Improving Soil Properties and Nitrogen Use Efficiency. Agronomy. 2019; 9(10):651. https://doi.org/10.3390/agronomy9100651

17. Baghdadi A, Halim RA, Ghasemzadeh A, Ramlan MF, Sakimin SZ. Impact of organic and inorganic fertilizers on the yield and quality of silage corn intercropped with soybean. PeerJ. 2018 Oct 26;6:e5280. doi: 10.7717/peerj.5280. PMID: 30386686; PMCID: PMC6204818.

18. Tekulu K, Taye G, Assefa D. Effect of starter nitrogen and phosphorus fertilizer rates on yield and yield components, grain protein content of groundnut (Arachis Hypogaea L.) and residual soil nitrogen content in a semiarid north Ethiopia. Heliyon. 2020 Oct 3;6(10):e05101. doi: 10.1016/j.heliyon.2020.e05101. PMID: 33033762; PMCID: PMC7533362.

19. Tariku B, Shiferaw T, Muluken T, Firew K. Effect of Biochar application on growth of garden pea (Pisum sativum L.) in acidic soil of Bule Woreda Gedeo Zone Southern Ethiopia. Int J Agron. 2017: 8. doi: 10.1155/2017/6827323.

20. Kumar R, Mishra SK, Singh K, Al-Ashkar I, Iqbal MA, Muzamil MN, Habib Ur Rahman M, El Sabagh A. Impact analysis of moisture stress on growth and yield of cotton using DSSAT-CROPGRO-cotton model under semi-arid climate. Peer J. 2023; 11: e16329. https://doi.org/10.7717/peerj.16329

21. Abiven S, Hund A, Martinsen V, Cornelissen G. Biochar amendment increases maize root surface areas and branching: a shovelomics study in Zambia. Plant Soil. 2015; 395(1–2):45–55. http://doi:10.1007/s11104-015-2533-2.

22. Wang Y, Hu Y, Zhao X, Wang S, Xing G. Comparisons of biochar properties from wood material and crop residues at different temperatures and residence times. Energy Fuels.2013; 27(10):5890–9.

23. Chen Y, Jiang Z, Wu D, Wang H, Li J, Bi M, Zhang Y. Development of a novel bio-organic fertilizer for the removal of atrazine in soil. J Environ Manage. 2019 Mar 1;233:553-560. doi: 10.1016/j.jenvman.2018.12.086. Epub 2018 Dec 28. PMID: 30597348.

24. Yin D, Yang X, Wang H, Guo X, Wang S, Wang Z, Ding G, Yang G, Zhang J, Jin L, Lan Y. Effects of chemical-based fertilizer replacement with biochar-based fertilizer on albic soil nutrient content and maize yield. Open life sciences. 2022; 17(1): 517–528. https://doi.org/10.1515/biol-2022-0057

25. Sohi SP, Krull E, Lopez-Capel E, Bol R. Chapter 2 - A Review of Biochar and Its Use and Function in Soil. In Advances in Agronomy Academic Press. 2010; 105: 47-82.https://doi.org/10.1016/S0065-2113 (10)05002-9

26. Xie WJ, Wang HY, Xia JB, Yao ZG. Influence of N, P, and K application on Zea mays L. growth and Cu and Pb accumulation. Plant Soil Environ. 2011; 57: 128-134.

27. Akolgo GA, Kemausuor F, Awafo EA, Amankwah E, Atta Darkwa T, Essandoh EO. Biochar as a soil amendment tool: effects on soil properties and yield of maize and cabbage in Brong-Ahafo Region, Ghana. Open J Soil Sci. 2020; 10 (3):91–108. http://doi:10.4236/ojss.2020.103005.

28. Yeboah E, Asamoah G, Ofori P, Amoah B, Agyeman K.. Method of biochar application affects growth, yield and nutrient uptake of cowpea. Open Agriculture.2020; 5: 352-360. 10.1515/opag-2020-0040.

29. Rodríguez L, Salazar P, Preston TR. Effect of biochar and biodigester effluent on growth of maize in acid soils. Livestock Research for Rural Development. 2009; 21: Article #110. http://www.lrrd.org/lrrd21/7/rodr21110.htm. (October 2009).

30. Tagoe S, Horiuchi T, Matsui T. Effects of carbonized and dried chicken manures on the growth, yield, and N content of soybean. Plant Soil. 2008; 306: 211–220.

31. Chan KY, Van Zwieten L, Meszaros I, Downie A, Joseph S. Using corn cob biochars as soil amendments. Soil Research. 2008; 46(5): 437.

32. Schippers RR. Legumes Africains Indigenes, Presentantion Des Especes Cultivees. Margrave Publishers-CTA 2004.

33. Lal R. Managing soils and ecosystems for mitigating anthropogenic carbon emissions and advancing global food security. Bioscience. 2010; 60: 708–721.

34. Tammeorg P, Simojoki A, Mäkelä P, Stoddard FL, Alakukku L, Helenius J. Short-term effects of biochar on soil properties and wheat yield formation with meat bone meal and inorganic fertilizer on a boreal loamy sand. Agric Ecosyst Environ. 2014; 191:108–16.

35. Liang F, Li G, Lin Q, Zhao X. Crop yield and soil properties in the first 3 years after biochar application to a calcareous soil. J Integr Agric. 2014; 13(3):525–32. doi: 10.1016/s2095-3119(13) 60708-x.

36. Abrishamkesh S, Gorji M, Asadi H. Bagheri-Marandi G, Pourable A. Effects of rice husk biochar application on the properties of alkaline soil and lentil growth Plant Soil and Environment. 2015; 61 (11): 475-482.

37. Carter S, Shackley S, Sohi S, Suy TB, Haefele S. The impact of biochar application on soil properties and plant growth of pot grown cabbage (Lactuca sativa) and cabbage (Brassica chinensis). Agronomy. 2013; 3: 404–418.

38. Haefele SM, Konboon Y, Wongboon W, Amarante S, Maarifat AA, Pfeiffer EM, Knoblauch C. Effects and fate of biochar from rice residues in rice-based systems. Field Crops Res. 2011; 121:430–440. http://doi:10.1016/j.fcr.2011.01.014.

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203

39. Nguyen BT, Lehmann J, Hockaday WC, Joseph S, Masiello CA. Temperature sensitivity of black carbon decomposition and oxidation. Environ Sci Technol. 2010 May 1;44(9):3324-31. doi: 10.1021/es903016y. PMID: 20384335.

40. Masarirambi MT, Hiawe M, Oseni OT, Sibya TE. Effects of Organic Fertilizers on Growth, Yield, Quality and Sensory Evaluation of Red Cabbage (Lactuca sativa L.) Veneza Roxa. University of Switzerland Horticulture Department, Faculty of Agriculture. Consumer Science Department. Agriculture and Biology Journal of North America. 2010. Doi: 10.5251/abjna

41. Prabhakar MAK, Nair SS, Hebbar P, Paneerselvam KS, Shivashankara GA, Geetha RS. Rajeshwari, Praveen Kumar Effect of Organic Farming Practices on Yield and Quality of Cabbage (Brassica oleracea Var. Capitata L.).Int J Curr Microbiol App Sci. 2020; 9(7): 615-620. doi: https://doi.org/10.20546/ijcmas.2020.907.069

42. Jeptoo A, Aguyoh JN, Saidi M. Improving carrot yield and quality through the use of bio slurry manure. Sus Agric Res. 2013; 2(1):164-172.

43. Liang B, Lehmann J, Solomon D, Kinyangi J, Grossman J, O'Neill B, Skjemstad JO, Thies J, Luizão FJ, Petersen J, Neves EG. Black Carbon Increases Cation Exchange Capacity in Soils. Soil Science Society of America Journal. 2006; 70(5), 1719–1730.

44. Novak JM, Busscher WJ, Laird DL, Ahmedna M, Watts DW, Niandou MAS. Impact of biochar amendment on fertility of a Southeastern coastal plain soil. Soil Sci. 2009; 174: 105–112. doi:10.1097/ SS.0b013e3181981d9a.

45. Lehmann J, Kern DC, German LA, McCann J, Martins GC, Moreira A. Soil fertility and production potential. In: J. Lehmann, D.C. Kern, B. Glaser and W.I. Woods (eds.), Amazonian Dark Earths: Origin, Properties, Management, Dordrecht, Kluwer Academic Publishers. 2003; 105-124.

46. Gelaye Y. Effect of combined application of organic manure and nitrogen fertilizer rates on yield and yield components of potato: A review, Cogent Food & Agriculture. 2023; 9: 1. DOI: 10.1080/23311932.2023.2217603

47. Nigussie A, Kissi E, Misaganaw M, Ambaw G. Effects of biochar application on soil properties and nutrient uptake of lettuces (Lactuca sativa) grown in polluted soils. American-Eurasian Journal of Agriculture and Environmental Science. 2012; 12(3):369-376.

48. Nguyen BT, Lehmann J. Black carbon decomposition under varying water regimes. Org Geochem. 2009; 40: 846– 853.

49. Giardina CP, Sanford RL, Døckersmith IC, Jaramillo VJ. The effects of slash burning on ecosystem nutrients during the land preparation phase of shifting cultivation. Plant and Soil. 2000; 220(1/2): 247–260. http://www.jstor.org/stable/42950718

50. Wells AT, Chan KY, Cornish PS. Comparison of conventional and alternative vegetable farming system on the properties of a yellow earth in New South Wales. Agric Eco Environ. 2000; 80(1/2):962-966.

51. Efthimiadou A, Bilalis D, Karkanis A, Williams BF. Combined Organic/ Inorganic Fertilization Enhances Soil Quality and Sustainability of Sweet Maize Crop. Australian Journal of Crop Science. AJCS. 2010; 4(9): 722-729.

52. Clough TJ, Condron LM. Biochar and the nitrogen cycle: introduction. Journal of Environmental Quality. 2010; 39: 1218–1223

53. Wolkowski RP. Nitrogen management considerations for landspreading municipal solid waste compost. J Environ Qual. 2003 Sep-Oct;32(5):1844-50. doi: 10.2134/jeq2003.1844. PMID: 14535328.

54. Fortuna A, Harwood R, Kizilkaya K, Paul EA. Optimizing nutrient availability and potential carbon sequestration in an agroecosystem. Soil Biol Biochem. 2003; 35(8): 1005–1013.

55. Gundale MJ, DeLuca TH. Charcoal Effects on Soil Solution Chemistry and Growth of Koeleria Macrantha in the Ponderosa Pine/Douglas-Fir Ecosystem. Biology and Fertility of Soils. 2007; 43: 303-311. https://doi.org/10.1007/s00374-006-0106-5

56. Arif M, Ilyas M, Riaz M, Ali K, Shah K, Haq IU. Biochar improves phosphorus use efficiency of organic-inorganic fertilizers, maize-wheat productivity, and soil quality in a low fertility alkaline soil. Field Crop Res. 2017; 214: 25–37. http://doi:10.1016/j.fcr.2017.08.018

57. Melese A, Markku Y, Yitaferu B. Effects of lime, wood ash, manure and mineral P fertilizer rates on acidity related chemical properties and growth and P uptake of wheat (Triticum aestivum L.) on acid soil of Farta District, Northwestern Highlands of Ethiopia. International Journal of Agriculture and Crop Sciences. 2015; 8: 256–269.

58. Dick RP, Iyamuremye F. Organic Amendments and Phosphorus Sorption by Soils. Advances in Agronomy. 1996; 56: 139-185.

59. Viaud V, Angers DA, Parnaudeau V, Morvan T, MenasseriAubry S. Response of organic matter to reduced tillage and animal manure in a temperate loamy soil. Soil Use Manage. 2011; 27: 8493.

60. Lashermes P, Benoı ̂t B, Herve E. Breeding coffee (Coffea arabica) for sustainable production. In M. Jain, and P. M. Priyadarshan, eds. Breeding Plantation Tree Crops: Tropical Species. 2009; 525–544.

61. Fontaine S, Bardoux G, Benest D, Verdier B, Mariotti A, Abbadie L. Mechanisms of the priming effect in a Savannah soil amended with cellulose. Soil Science Society of America Journal. 2004; 68(1): 125-131.

62. Kuzyakov Y, Subbotina I, Chen H, Bogomolova I, Xu X. Black carbon decomposition and incorporation into soil microbial biomass estimated by 14C labeling. Soil Biology and Biochemistry. 2009; 41(2), 210–219.

63. Yuan JH, Xu RK, Zhang H. The forms of alkalis in the biochar produced from crop residues at different temperatures. Bioresour Technol. 2011 Feb;102(3):3488-97. doi: 10.1016/j.biortech.2010.11.018. Epub 2010 Nov 12. PMID: 21112777.

64. Adeniyan OA, Ojo AO, Akinbode OA, Adediran JA. Comparative study of different organic manures and NPK fertilizer for improvement of soil chemical properties and dry matter yield of maize in two different soils. Journal of Soil Science and Environmental Management. 2011; 2(1): 9–13.

65. Ullah MS, Islam MS, Islam MA, Haque T. Effects of organic manures and chemical fertilizers on the yield of brinjal and soil properties. J Bangl Agril Univ. 2008; 6(2): 271–276.

66. Atkinson CJ, Fitzgerald JD, Hipps NA. Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. Plant Soil. 2010; 337: 1-18.

67. Oladele S, Adeyemo A, Awodun M, Ajayi A, Fasina A. Effects of biochar and nitrogen fertilizer on soil physicochemical properties, nitrogen use efficiency and upland rice (Oryza sativa) yield grown on an Alfisol in Southwestern Nigeria. Int J. Recycle Org Waste Agric. 2018; 336: 1-11. doi: 10.1016/j.geoderma. 08.025.

Citation: Frederick A, Adjei E, Khalid AA, Santo KG, Samuel N, et al. (2024) Influence of biochar and NPK on soil chemical properties, growth and yield of cabbage (Brassica oleracea L.). Int J Agric Sc Food Technol 10(1): 021-031. DOI: https://dx.doi.org/10.17352/2455-815X.000203