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Research Article

Biochar and/or Compost Applications Improve Soil Properties, Growth, and Yield of Maize Grown in Acidic Rainforest and Coastal Savannah Soils in Ghana

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Use of biochar for soil fertility improvement is gaining popularity due to its potential to improve soil quality, increase crop yield, and sequester carbon from the atmosphere-biosphere pool into the soil. A 40-day pot experiment was carried out to investigate the effects of corncob biochar and compost applied alone (at a rate of 2%, w/w) or in combination (1% of each, thus 1% compost + 1% biochar) on soil physicochemical properties, growth, and yield of maize on two soils of contrasting pH and texture collected from the Rainforest and Coastal Savannah agroecological zones of Ghana. Biochar and compost applied alone or in combination significantly increased soil pH, total organic carbon, available phosphorus, mineral nitrogen, reduced exchangeable acidity, and increased effective cation exchange capacity in both soils. Additionally, combined application and single application biochar or compost additions increased the plant height, stem girth, and dry matter yields of two maize (local ("*ewifompe*") and hybrid (*Obaatanpa*)) varieties used in the study. The study showed that biochar applied alone or in combination with compost offers the potential to enhance soil quality and improve maize yield.

1. Introduction

In sub-Saharan African (SSA), soil fertility decline, mainly through continuous cultivation and rapid organic matter mineralization, causes food insecurity and poverty [1, 2]. Smallholder agricultural production systems in most SSA countries including Ghana are characterized by low productivity due to low and erratic rainfall patterns, outdated agricultural practices, and low application of nutrient inputs. Agricultural intensification in Ghana highly depends on chemical fertilizer application. However, inorganic fertilizer use in Ghana is limited due to high cost, unreliable supply, and hence poor accessibility to the smallholder farmers. According to Zheng et al. [3], the use of biochar as a soil amendment is an innovative and promising soil fertility replenishment option to promote sustainable agriculture. Biochar is a form of charcoal produced through thermochemical decomposition of biomass under low or no oxygen conditions, a process referred to as pyrolysis [2, 3]. Biochar application has been reported to improve soil quality by raising soil pH [4], increasing moisture holding capacity [2], stimulating activity of more beneficial fungi and microbes [3], improving cation exchange capacity [5, 6], and retaining nutrients [7]. Incorporated biochar can also sequester carbon from the atmosphere-biosphere pool and transfer it to soil [8, 9]. Unlike compost which decomposes rapidly in humid tropical soils, biochar decomposes slowly in the soil as it contains high recalcitrant C content. The residence time for wood biochar, for instance, is in the range of 100 to 1000s of years, which is approximately 10–1000 times longer than residence times of most soil organic matter [2]. Therefore, biochar addition to soils could provide a potential sink for carbon and increase soil nutrient availability for crop use due to its higher nutrient retention and sorption capacity.

Furthermore, application of biochar to soils has been identified as a low-cost technology that can stabilize organic carbon, reduce greenhouse gas emissions [10], improve soil physical and chemical properties, and boost crop yield and productivity [11, 12] and farm incomes. Biochar application can lead to a reduction in inorganic fertilizer use by farmers [2]. Biochar research is a recent development in Ghana and so there is a paucity of information regarding its effects on soil properties, crop growth, and crop yield in Ghanaian soils.

Glaser and Birk [13] and Glaser et al. [14] reported that sole biochar application, in most cases, did not provide any substantial amount of nutrients. Other studies showed that combined application of compost and biochar enhanced soil quality, increased plant growth, provided positive synergistic effect on soil nutrient contents under field conditions, resulted in reduction of fertilizer input application, improved nutrient use efficiency, stabilized soil structure, and improved water retention capacity [13, 15–18]. Owing to the stability of biochar carbon, applying biochar with compost can enhance compost properties, leading to higher added value and a much better carbon sequestration potential compared to individual mixing of biochar or compost with soil [13, 15–18]. This study investigated the effects of corncob biochar and compost applied alone or in combination on some soil physicochemical properties, growth, and yield of maize grown on two Ghanaian soils collected from the Rainforest (Aiyinase in Western Region) and Coastal Savannah (Cape Coast in Central Region) agroecological zones.

2. Materials and Methods

2.1. Soils and Amendments. Soil samples (0–20 cm) from arable fields in Cape Coast and Aiyinase belonging to the coastal savannah and the tropical rainforest agroecological zones, respectively, were used for the study. The Cape Coast soil is classified as Alfisols [19], and the Aiyinase soil is classified as Haplic Ferralsol [20]. The physicochemical properties of the two soils are presented in Table 1.

The corncobs and composts were collected from the University of Cape Coast Teaching and Research Farm. The biochar was produced from corncobs pyrolyzed at 350°C in Lucia Biomass Pyrolytic Stoves (World Stove, Italy). The properties of the corncob biochar and compost amendments are summarized in Table 2.

2.2. Experimental Design, Treatments, and Planting. The compost and/or biochar was thoroughly mixed with 10.34 kg of air-dry soil (<2 mm) and kept in plastic pots of 9.4 m^3 volume. Biochar and compost were applied sole or in combination as 2% weight by weight compost: soil basis. The treatments involved in the experiment, compost only, biochar only, compost and biochar, and control, are presented in Table 3.

Each treatment was replicated three times, giving a total of 48 pots. The control and biochar-compost mixture-treated soils were repacked in the pots to a bulk density of 1.1 $g{\cdot}cm^{-3}$, and water was added to bring the soil water content to 20%.

Table 1: Physicochemical properties of the Cape Coast and Aiyinase soils used in the study.

Soil property	Aiyinase	Cape Coast
Available P ($mg{\cdot}kg^{-1}$)	7.9	16.4
TOC (%)	0.2	1.4
pH (H_2O)	4.7	5.0
Mg^{2+} ($cmol{\cdot}kg^{-1}$)	0.2	1.6
Ca^{2+} ($cmol{\cdot}kg^{-1}$)	0.9	2.8
K^+ ($cmol{\cdot}kg^{-1}$)	0.1	0.6
Na^+ ($cmol{\cdot}kg^{-1}$)	0.2	0.6
$H^+ + Al^{3+}$ ($cmol{\cdot}kg^{-1}$)	0.9	0.1
CEC ($cmol{\cdot}kg^{-1}$)	1.4	5.6
ECEC ($cmol{\cdot}kg^{-1}$)	2.3	5.8
TN (%)	0.0	0.1
Clay (%)	14.2	12.6
Silt (%)	2	23.2
Sand (%)	83.7	64.2

Table 2: Chemical properties of biochar and compost used in the experiment.

Property	Biochar	Compost
Available P ($mg{\cdot}kg^{-1}$)	88.2	353.7
TOC (%)	70.1	23.6
pH (H_2O)	7.0	5.3
Mg^{2+} ($cmol{\cdot}kg^{-1}$)	12.0	22.7
Ca^{2+} ($cmol{\cdot}kg^{-1}$)	44.3	162.7
K^+ ($cmol{\cdot}kg^{-1}$)	39.4	10.8
Na^+ ($cmol{\cdot}kg^{-1}$)	32.6	9.7
$H^+ + Al^{3+}$ ($cmol{\cdot}kg^{-1}$)	11.3	12.7
ECEC ($cmol{\cdot}kg^{-1}$)	139.6	218.5
Total nitrogen (%)	0.9	4.2

Table 3: Application rates (%) of biochar and compost used in the pot experiment.

Treatment	Application rate (%, w/w)
Compost only	2
Biochar only	2
Compost + biochar	1 + 1
Control	0

The water filled pore space (WFPS) was calculated using the following formula:

$$\text{water filled pore space} = \frac{\text{volumetric water content}}{\text{total porosity}} \times 100. \quad (1)$$

But, total porosity = 1 – (bulk density/particle density). Bulk density and particle density were 1.1 $g{\cdot}cm^{-3}$ and 2.65 $g{\cdot}cm^{-3}$, respectively.

The control and biochar- and/or compost-amended soils were incubated for two weeks at 20% WHC and 25°C temperature prior to sowing the maize test crop. During the incubation period, the pots were kept in a dark room for 14 days in a completely randomized design. At the end of the two weeks, soil samples from each treatment were collected and analyzed in the laboratory for pH, available P, total carbon, exchangeable acidity, exchangeable cations, effective cation exchange capacity, and mineral/available nitrogen contents. At the end of the two weeks' incubation period, three maize seeds were sown to a depth of 4 cm in the pots and thinned to one plant per pot 5 days after seedling emergence.

2.3. Laboratory Analyses and Plant Data Collection. Samples of the two soil types, prior to treatment application and at the end of the 14-day incubation period, the biochar and compost, were analyzed. The pH of the soils was measured in a 1 : 2.5 (w/v) soil : water ratio, with a pH meter [21]. Available P was analyzed using the Bray 1 acid method [22]. Soil extraction for exchangeable cations (Ca, Mg, K, and Na) analyses was done using the NH_4OAc method at pH 7 [23]. Soil exchangeable acidity was determined by the titration method described by Robertson et al. [24]. Soil organic carbon concentration was determined by the Walkley–Black method [25]. The NH_4^+ and NO_3^- in the soil sample were determined using the method described by Rowell [26], and soil mineral nitrogen was calculated as the sum of the NH_4^+ and NO_3^- concentrations.

Plant height, stem girth, and number of leaves were collected at weekly intervals up to the end of the experiment. The number of fully developed leaves was counted on weekly basis until the aboveground biomass was harvested. Plant height was measured with a graduated straight edge (ruler) from base of the shoot at the soil surface to the tip of the highest leaf in the foliage of the crop. Stem girth was measured using a pair of vernier calipers. The maize plant was harvested by cutting the plant at the soil level 37 days after emergence. The dry matter of the shoot biomass was determined by drying the aboveground maize plant in an oven at 60°C until constant dry weight was attained.

2.4. Statistical Analyses. One-way analysis of variance (ANOVA) was performed to assess the significant differences in soil and plant parameters between different treatments using the GenSTAT Version 15.1. Mean comparison was also made using Fisher's protected test for least significant difference after treatments were found significant at $P < 0.05$.

3. Results and Discussion

3.1. Effects of Biochar and/or Compost Applications on the Soil pH. The effect of biochar and/or compost applications on the soil pH of the Aiyinase and Cape Coast soils after the 14-day incubation period is shown in Figure 1. The results revealed a significant ($P < 0.01$) increase in the soil pH following sole and combined applications of compost and biochar in both soils. In the Aiyinase soil, the highest soil pH was recorded in the 2% sole biochar treatment, while the lowest value was recorded in the control. The soil pH increase was in the order B20 > BC > C20 > B0. Likewise, in the Cape Coast soil, the highest pH (6.1) was observed in soils treated with sole biochar, followed by the combined biochar and compost treatments (5.7). Soils with no amendments applied and soils amended only with compost had the least soil pH of 4.8.

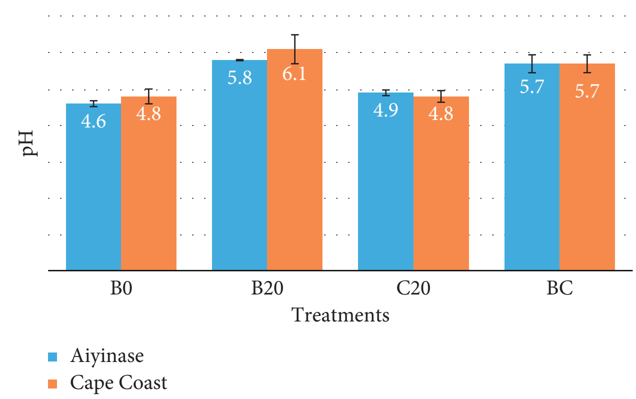

Figure 1: Changes in soil pH of the Aiyinase and Cape Coast soils following application of corncob biochar and/or compost 14 days after incubation. B0 = control with no amendments; B20 = biochar 2%, w/w; C20 = compost 2%, w/w; BC = combined biochar and compost rate 1% compost + 1% biochar. Error bars represent standard deviation of the means.

The increases in soil pH due to sole application of biochar could be attributed to the high pH of the biochar used in the experiment. The pH of the biochar was 7.0 compared to that of the compost which was 5.3. The findings agree with those of Nigussie et al. [27] who attributed increased soil pH in biochar-amended soil to ash accretion. They further explained that ash residues are highly dominated by carbonates alkali and alkali earth metals. In this study, the ash content was not quantified, but given the conditions under which the biochar was produced, it is likely that the final product will contain some amount of ash. Zwieten et al. [28] pointed out that incorporated biochar can increase soil pH through its liming effects. In the study, soil pH in all the biochar- and/or compost-amended soils was above the threshold level pH below which Al^{3+} toxicity (4.8–5.0) occurs as mentioned by Zweiten et al. [28]. Nigussie et al. [27] attributed the increase in soil pH found in biochar-amended soils to the high surface area and porous nature of biochar that increases the cation exchange capacity (CEC) of soils, which binds Al and Fe with the soil exchange sites. This study further observed reduction in exchangeable acidity ($H^+ + Al^{3+}$) in the biochar- and/or compost-amended soils (range between 0.14 and 0.25 $cmol \cdot kg^{-1}$) than in the unamended soils (0.75 $cmol \cdot kg^{-1}$), which further explains the reason for increased acidity in the untreated soils compared to treated soils. The pH values observed in this study are also consistent with those found by Nigussie et al. [27], Zhang et al. [29], Agusalim et al. [30], and Zheng et al. [3], who concluded that biochar application can improve soil quality by increasing soil pH, which suggests that biochar could be used as an alternative option to lime materials to raise pH of acidic soils.

3.2. Soil Available Phosphorus. The application of biochar and compost, alone or in combination, significantly ($P < 0.01$) increased the soil available phosphorus contents

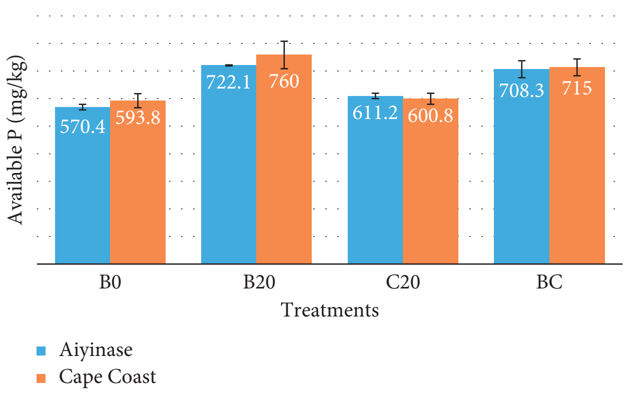

FIGURE 2: Changes in soil available phosphorus of Aiyinase and Cape Coast soils following application of corncob biochar and/or compost 14 days after incubation. B0 = control with no amendments; B20 = biochar 2%, w/w; C20 = compost 2%, w/w; BC = combined biochar and compost rate 1% compost + 1% biochar. Error bars represent standard deviation of the means.

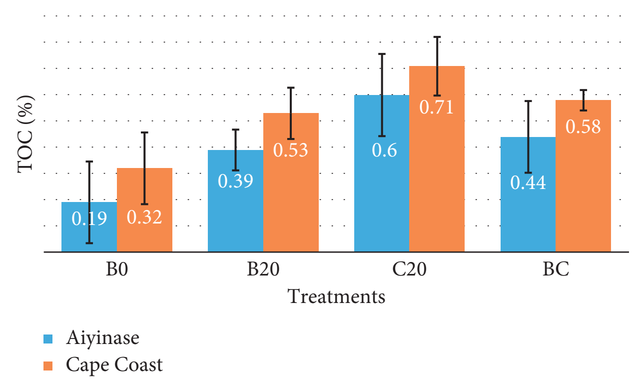

FIGURE 3: Changes in soil total organic carbon of Aiyinase and Cape Coast soils following application of corncob biochar and/or compost 14 days after incubation. B0 = control with no amendments; B20 = biochar 2%, w/w; C20 = compost 2%, w/w; BC = combined biochar and compost rate 1% compost + 1% biochar. Error bars represent standard deviation of the means.

in both the Aiyinase and Cape Coast soils (Figure 2). In both soils, the highest soil available P content was observed in the 2% sole biochar treatment. The increases in the soil available P observed in the soils, especially in the Aiyinase soils, could be attributed to reduced Fe and Al activity due to increase in the soil pH (4.8–5.8) and exchangeable bases/cation exchange capacity. In a similar study, Sasmita et al. [31] found that application of biochar with or without organic fertilizer linearly increased the soil available P in Indonesia acidic soil medium during a 15-day incubation period. Similar to the findings of this study, which found relatively higher concentrations in combined biochar and compost treatments for both the Aiyinase acidic soil and Cape Coast soil, Sasmita et al. [31] further reported a synergistic effect between biochar and organic fertilizer in increasing the soil available P.

Increase in soil pH would have reduced sorption of the soil available P. Agegnehu et al. [32], Nigussie et al. [27], and De Luca et al. [33] reported a greater soil available P contents in biochar-amended soils compared to unamended soils and attributed the improvement to biochar's capacity to retain and exchange phosphate ions due to its positively charged surface sites.

3.3. Soil Total Organic Carbon (TOC). The results showed that application of biochar and compost, alone or in combination, increased soil TOC contents in both the Aiyinase and Cape Coast soils (Figure 3). However, no significant differences were found among the TOC contents of the amended soils. In a similar incubation study, Frimpong et al. [34] found that TOC contents were higher in soils treated with cow dung and biochar than those of the control. Additionally, Trupiano et al. [15] found that application of compost and biochar, alone or in combination, increased soil TOC content than that in the unamended soils, which is indicative that biochar and/or compost applications to soils can enhance C accumulation and sequestration.

3.4. Soil Exchangeable Bases and Exchangeable Acidity. Results showing the effects of biochar and/or compost addition on soil exchangeable bases of both Aiyinase and Cape Coast soils are presented in Table 4. Compared to the control treatment, application of these amendments, alone or in combination, increased the exchangeable Ca, Mg, K, and Na contents in both soils. The highest Ca and Mg contents were observed in soils treated with 2% compost in both the Aiyinase and Cape Coast soils. These increments observed may be related to the exchangeable Ca and Mg, as well as the ECEC contents of the compost used in the experiment. Compared to the biochar, the compost used had greater proportions of exchangeable Ca and Mg, 162.7 and 22.7 $\text{cmol}\cdot\text{kg}^{-1}$, respectively. According to Fischer and Glaser [18], lone compost application has a liming effect due to its richness in alkaline cations such as Ca, Mg, and K, which are liberated from organic matter due to mineralization. In the Aiyinase soil, the highest exchangeable K content was found in the 2% biochar treatment, whereas the least was found in the control. In the Cape Coast soil, the highest exchangeable K content was recorded in the combined compost and biochar treatments. In a pot experiment, Nigussie et al. [27] found that biochar applied to chromium-polluted soils improved the soil exchangeable bases and crop yield of *Lactuca sativa* in Ethiopia. They concluded that the increase in the exchangeable bases was as a result of the presence of ash in the biochar which helps in the immediate release of mineral nutrients like Ca and K for crop use.

In terms of soil exchangeable acidity, combined biochar and compost recorded the least value and control soil with no amendments had the highest value for the acidic Aiyinase soil. The reduction was in the order BC < B20 < C20 < B0. The reduction in the soil exchangeable acidity in the amended soils may be due to the higher cation exchange capacity (CEC) of the compost and biochar, which has the capacity of binding Al and Fe with the soil exchange sites. For the Cape Coast soil, exchangeable acidity decreased in the order B20 < B0, BC < C20. Sasmita et al. [31] made similar observation in a 15-day incubation experiment using

Table 4: Changes in soil chemical properties of the Aiyinase and Cape Coast soils (exchangeable acidity, exchangeable cations, and ECEC) following application of biochar and/or compost 14 days after incubation.

Treatment rate	H + Al ($cmol{\cdot}kg^{-1}$)		Ca ($cmol{\cdot}kg^{-1}$)		Mg ($cmol{\cdot}kg^{-1}$)		K ($cmol{\cdot}kg^{-1}$)		Na ($cmol{\cdot}kg^{-1}$)		ECEC ($cmol{\cdot}kg^{-1}$)	
	AN	CC	AN	CC	AN	CC	AN	CC	AN	CC	AN	CC
B0	0.75	0.15	1.07	2.21	0.29	1.15	0.15	0.42	0.26	0.32	2.52	4.26
B20	0.17	0.11	1.20	2.00	0.40	0.83	1.36	1.12	0.71	1.03	3.84	5.08
C20	0.25	0.28	3.07	4.40	1.81	1.76	0.68	1.04	0.84	0.97	6.64	8.45
BC	0.14	0.15	2.93	4.29	0.72	1.55	0.81	1.35	0.64	1.22	5.25	8.56
LSD, 0.05	0.22	0.13	1.23	0.89	1.21	0.63	0.50	0.77	0.61	0.66	1.18	0.61
F. Pr.	<0.001	0.06	0.01	<0.001	0.07	0.04	0.00	0.11	0.23	0.06	<0.001	<0.001

AN = Aiyinase soil; CC = Cape Coast soil; B0 = control with no amendments; B20 = biochar 2%, w/w; C20 = compost 2%, w/w; BC = combined biochar and compost rate 1% compost + 1% biochar; LSD = least significant difference at 0.05.

rice husk biochar and attributed the reduction in the soil exchangeable Al to the liming effect from biochar. Also, the reduction of the exchangeable $H^{+} + Al^{3+}$ content by biochar could be due to the formation of Al complex by the oxidized organic functional groups such as carboxylic and phenolic at the biochar surface as pointed out by Vithanage et al. [35].

3.5. Effective Cation Exchange Capacity (ECEC). The results indicated that effective cation exchange capacity (Table 4) of both the Cape Coast and Aiyinase soils was significantly increased upon application of biochar and/or compost amendments at $P < 0.01$. In the Aiyinase soil, the highest ECEC was observed in the sole compost treatment, but in the Cape Coast soil, the highest ECEC was found in the combined compost and biochar treatments. This observation could be attributed to the exchangeable acidity, pH, and exchangeable cation concentration differences of the Aiyinase and Cape Coast soils. The Aiyinase soil was found to be strongly acidic, with a higher concentration of exchangeable acidity and therefore contained relatively smaller concentrations of basic cations than the Cape Coast soil. Both the compost and biochar provide relatively higher amount of basic cations to reduce exchangeable acidity ($H^{+} + Al^{3+}$) and raise the ECEC reflected in the higher pH Cape Coast soil.

Overall, biochar or compost, applied alone or in combination, significantly increased the ECEC of both the Cape Coast and Aiyinase soils. Biochar has the potential to raise the soil CEC due to its highly porous nature and higher surface area, which increases its surface sorption ability and base saturation. Liu et al. [16] and Mando and Zombré [36] indicated that compost amendment results in an increase of CEC due to input from stabilized OM being rich in functional groups such as carboxylic and phenolic acid groups being released into the soil exchange sites. The results obtained in this study agree with the findings by Liu et al. [16], who found that sole application of compost and in combination with biochar increased soil ECEC than that of the control plot with no treatment.

Combined applications of biochar and compost have numerous benefits compared to the mere mixing of biochar or compost with soil. These benefits, according to Liu et al. [16], include enhanced nutrient use efficiency, biological activation of biochar, and better material flow management; enhanced C sequestration by establishment of stable biochar-compost complexes and thus negative priming; enhanced provision of plant-available nutrients by biological N fixation; reduced nutrient leaching; and combined nutrient supply, compared to individual compost and biochar applications.

3.6. Effects of Biochar and/or Compost Applications on Soil Mineral Nitrogen. Application of biochar and/or compost led to significant ($P < 0.01$) increases in the soil mineral nitrogen concentrations measured at the end of the 14-day incubation period than in the control (Figure 4). In the Cape Coast soils, biochar and compost applied alone or in combination led to significant ($P < 0.05$) increases in the soil available nitrogen concentrations both in the first week and at the end of the 14-day incubation period than in the control soil. The increases in the soil available N concentration followed the order BC > C20 > B20 > B0.

The increased soil mineral nitrogen concentration found in the Cape Coast soils between the first and second weeks after the compost application compared to that in the sole biochar treatment is due to the fact that the compost contains relatively higher inherent N concentration and has a higher rate of nitrogen mineralization than biochar, which has a very higher C : N ratio and a lower rate of mineralization. Lehmann et al. [6] pointed out that whereas compost is easily degradable, biochar has an aromatic structure and a recalcitrant nature and is therefore very resistant to decomposition. In this regard, Duku et al. [2] reported that biochar application in soils minimizes ammonium loss through leaching and NH_3 volatilization. De Gryze et al. [10] also opined that biochar decreases the possibility of nutrient losses in soils and enhances nutrient recycling, resulting in positive impacts on crop yields in the long run through slow release to the soil.

3.7. Effects of Biochar and/or Compost Applications on Agronomic Performance of Maize. The effects of biochar and/or compost applied alone or in combination on the growth performance of maize: dry matter yield, number of leaves, plant height, and stem girth of the two maize varieties (local variety *ewifompe* and hybrid variety *Obaatanpa*), cultivated on two soil types—Aiyinase and Cape Coast soils—are presented in Tables 5 and 6, respectively. The application of biochar and/or compost resulted in significant ($P < 0.01$) increases in the number of plant leaves, plant height, and stem girth of both local and improved varieties in the Aiyinase soil.

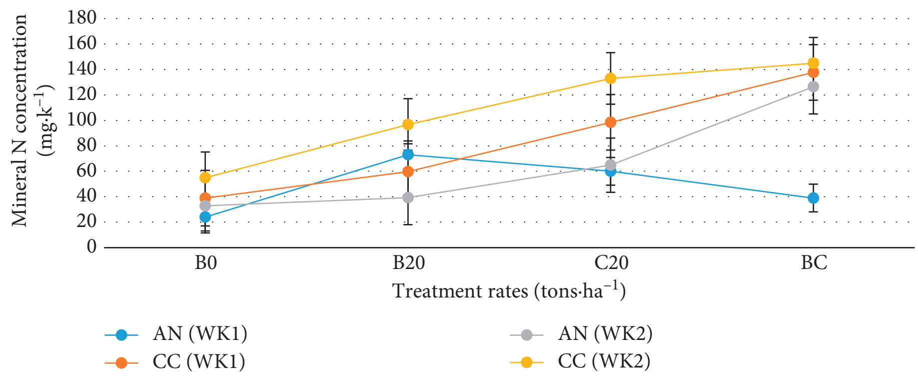

Figure 4: Soil mineral nitrogen concentration in Aiyinase and Cape Coast soils following application of biochar and/or compost 14 days after incubation. B0 = control with no amendments; B20 = biochar 2%, w/w; C20 = compost 2%, w/w; BC = combined biochar and compost rate 1% compost + 1% biochar. Error bars represent standard errors of the means.

Table 5: Effects of biochar and/or compost applications on the plant growth performance of maize crop (local and improved varieties) grown on the Aiyinase soil over 40-day period.

Treatment rate	Dry matter (g)		Number of leaves		Plant height (cm)		Stem girth (mm)	
	Improved variety	Local variety	Improved variety	Local variety	Improved variety	Local variety	Improved variety	Local variety
BC	1.3a	231.2b	3.00a	10.33b	24.7a	141.7b	3.83a	20.17b
B0	10.6a	306.8b	5.67b	12.00bc	59.3b	168.7b	10.00b	22.67bc
C20	318.4b	11.9a	10.33c	6.00a	163.3c	60.3a	23.17c	8.50a
B20	319.2b	251.2b	11.33c	12.67c	171.3c	165.3b	24.67c	24.20c
LSD, 0.05	75.9	146.1	2.31	2.24	17.55	40.21	5.16	3.21
F. Pr.	<0.001	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

B0 = control with no amendments; B20 = biochar 2%, w/w; C20 = compost 2%, w/w; BC = combined biochar and compost rate 1% compost + 1% biochar; LSD = least significant difference at 0.05. Means with different letters differ significantly at $P < 0.05$ and with same letters do not differ significantly.

Table 6: Effects of biochar and/or compost applications on the plant growth performance of maize crop (local and improved varieties) grown on the Cape Coast soil over 40-day period.

Treatment rate	Dry matter (g)		Number of leaves		Plant height (cm)		Stem girth (mm)	
	Improved variety	Local variety	Improved variety	Local variety	Improved variety	Local variety	Improved variety	Local variety
BC	193.5b	1.82a	10.33b	3.00a	139.3b	20.33a	18.50b	5.93a
B0	288.2bc	97.10c	11.00b	9.67c	170.3c	104.67c	21.00b	17.17c
C20	386.5c	66.73bc	10.67b	6.33b	191.0c	78.67b	25.33c	12.00b
B20	36.4a	28.94ab	5.33a	6.33b	82.7a	78.67b	12.83a	12.00b
LSD, 0.05	99.5	62.33	2.49	1.33	21.07	20.02	3.32	4.97
F. Pr.	<0.001	0.03	0.00	<0.001	<0.001	<0.001	<0.001	0.01

B0 = control with no amendments; B20 = biochar 2%, w/w; C20 = compost 2%, w/w; BC = combined biochar and compost rate 1% compost + 1% biochar; LSD = least significant difference at 0.05. Means with different letters differ significantly at $P < 0.05$ and with same letters do not differ significantly.

The increase (e.g., length, etc.) recorded in the maize grown in biochar- and/or compost-amended soils could be attributed to the increased soil pH and hence higher P availability following application of biochar or compost amendments. Oguntunde et al. [37] studied the effects of charcoal on growth and yield of maize in a Ghanaian soil and attributed the significant maize growth rate they observed in the biochar-amended soils compared to the control to biochar's ability to increase the soil pH; exchangeable cations such as Ca, Mg, K, and Na; and soil available P in these sites compared to adjacent soils with no biochar. Sohi et al. [38] reported that biochar can act as soil conditioner, which improves soil water holding capacity, enhances soil nutrient retention, and boosts plant growth. In the Cape Coast soils, plant height and stem height were greatest in the improved varieties grown in sole compost-amended soils.

The overall results showed that application of biochar had a more remarkable effect on the growth performance of maize varieties grown on the Aiyinase soil than those grown on the Cape Coast soil. This could be due to acidity differences between the two soil types. Whilst the pH of the Aiyinase soil was strongly acidic (pH 4.7), the pH of the Cape Coast soil was moderately acidic at pH 5. According to Duku et al. [2], the impact of biochar application is most seen in highly degraded acidic or nutrient-depleted soils. Results from Jeffery et al.'s [11] study also show that biochar can be a useful tool to improve crop yield in nutrient-poor and acidic soils. They concluded that biochar application is, therefore, crucial considering that approximately 30% of the world's soils are acidic, including more than 50% of potential arable land.

4. Conclusion

The study showed that biochar and compost applied alone or in combination significantly increased soil pH, total organic carbon, available phosphorus, mineral nitrogen, reduced exchangeable acidity, and increased effective cation exchange capacity in both the Rainforest and Coastal Savannah soils. Additionally, the biochar and compost additions increased the growth response (plant height and stem girth) and dry matter yield of both local and improved maize varieties. Therefore, the study demonstrated that biochar applied alone or in combination with compost offers potential to enhance soil quality and improve crop yield. In response to question about duration, we only speak to observations made in our study. This is a preliminary finding. We propose a longer term study to examine the long-term effects of the treatments on soil physicochemical properties and yield responses.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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