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Assessment of Different Biochar and Composted Cow Dung on Soil Properties, Growth and Cob Weight of Maize

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Abstract

Crop production in tropical soils is constrained by low fertility. The scarcity and high prices of chemical fertilizers have added to the existing challenges. This study examined the influence of different types of biochar and cow dung compost on soil properties, growth and cob weight of maize. A polythene pot experiment was conducted at the screen house of the Institute of Ecology, Obafemi Awolowo University, Ile-Ife, Nigeria. The experiment was laid out in a completely randomized design. Amendments used were: (CDC), (CDB) and (MCB), which were applied singly at the rates of 0, 4, 8, 12, 16 $t.ha^{-1}$. The production of biochar from cow dung compost and maize cobs was done using a local charcoal-fired reactor. The feedstocks were slowly pyrolyzed at 350 ^{0}C and removed after 3hrs. The treatments were replicated twice. Soils amended with CDC had the highest growth parameters compared to other amendments. In the first season, CDC had a 22% increase in height compared to MCB. CDC had a height of 72 cm while MCB had the lowest height with 56 cm. The growth rate was as follows: CDC > CDB > MCB. CDC also increased cob weights when compared to other amendments. At 4 $t.ha^{-1}$, CDC had 2.20 g, CDB had 0.90 g while MCB had 0.47 g. Significant differences were observed among the treatments. However, it was observed that CDB increased soil chemical properties compared to other amendments. Soil properties such as organic carbon and total nitrogen were significantly improved in soils treated with CDB. This study concluded that cow dung biochar was better suited to improve soil properties while also improving crop growth compared to other amendments.

Keywords: organic fertilizer; maize productivity; soil fertility; agricultural feedstocks

Introduction

Maize ranks along with wheat and rice as the three most important cereals in the world. With nearly 1147.7 million MT of maize being produced by over 170 countries, and with an average productivity of 5.75 $t.ha^{-1}$ over an area of 193.7 million ha, its importance cannot be overemphasized (FAOSTAT, 2020). In Sub-Saharan Africa, maize is considered more important (Badu-Apraku et al., 2021).

Maize is a staple crop in Sub-Saharan Africa. It provides food security and serves as a source of livelihood for many families (Yacoubou et al., 2021). It is evaluated that more than 300 million Africans depend on maize as their major food crop. In 2018, the total maize production in Africa was estimated to be about 75 million tons. This accounts for 7.5% of the total maize production in the world (IITA, 2018).

In many countries in the sub-Saharan region, maize also serves as a major source of nutritious diet. For instance, 60% of the population consumes more than 100 g of maize per day. It supplies at least 30% of the total calorie intake to the consumer, a significant amount of energy (Goredema-Matongera et al., 2021). Maize is a major source of carbohydrates, and supplies other nutrients such as: protein, starch, fat and vitamins. Apart from that, maize is cultivated for other economic purposes such as animal feed and industrial products (Agarwal et al., 2019). However, despite its obvious economic and nutritional importance, maize production in the region has been threatened by low soil fertility.

One of the challenges of sustainable agriculture in tropical regions is low soil nutrients due to intense weathering and increased mineralization of soil organic matter (Dalling et al., 2016). The rapid mineralization of soil organic matter is caused by continuous cultivation, low soil organic matter, and soil nutrient imbalance (Erbaugh et al., 2019; Wamalwa et al., 2021). The nutrient deficiencies in theese soils constrain productivity and pose a threat to food security. Low soil organic matter reduces cation exchangeable capacity, organic carbon and affects the soil structure. This reduces the available soil nutrients needed for crop growth and yield (Fageria, 2012). This is a challenge that can be solved with application of an appropriate fertilizer.

Many smallholder farmers are experiencing low crop productivity due to inability to assess suitable fertilizers. This has added to the existing challenges (such as climate change and agricultural pest) faced by farmers. Climate change, for instance, increases volatility of crop yield, while one of the major causes of crop losses in Africa are agricultural pests (Botha et al., 2019). Food and Agriculture Organization of the United Nations forecasting that food insecurity in the region is poised to increase for the next 50 years, so it is necessary to ensure that necessary essentials such as fertilizers are available (FAO 2018). However, chemical fertilizers are scarce, while the available ones are sold for a high price (Martey and Kuwornu, 2021). However, there are better alternatives. Examples of those alternatives include organic fertilizers such as composted manure and biochar.

Many studies have reported that application of biochar has improved soil properties such as: pH, moisture capacity, and microbial activities (Mansoor et al., 2021). Biochar is also said to be a cost effective method of sequestering carbon in the soil. It helps prevent potential loss of carbon and reduces leaching in agricultural soils (Yang et al., 2021). Other studies also identified biochar as a good source of retaining soil nutrients (Karam et al., 2021). Hence, biochar could be a suitable replacement of part of the inorganic fertilizer requirement. However, the effectiveness of biochar in the soil could be dependent on its characteristics.

Biochar can be derived from different sources. Biochar could be produced from plant residues, grasses, wood wastes, animal manure, and wastes from sludge (Ghodake et al., 2021). Since biochar can be produced through different feedstocks, the biochar products will also have different characteristics (Das et al., 2021). For instance, biochar from plant residues are said to be low in potassium, phosphorus and nitrogen when compared to biochar from animal wastes. Their properties can also be influenced by factors such as temperature and duration of the pyrolysis (Kochanek et al., 2022). Their properties could also determine their various functions (Hassan et al., 2020). For example, biochar with high carbon content can be used as carbon fixation materials while others with higher nutrients could be used as soil fertilizers.

Composted manure is a more popular alternative when compared to biochar. The easy access to manure, and the absence of pyrolysis processes makes it preferable among local farmers. Over the years, composted manure has been established as a good source of nutrients for soils and plants (Antonious, 2018). Composted manure, devoid of pathogens found in fresh manure, helps reduce leaching of nitrogen in soils and flow of water across agricultural soils (Siedt et al., 2021). Composted manure also increases soil organic matter and help mitigate greenhouse gases (Flint et al, 2018). These have led to increased soil nutrients (macro and micronutrients) and improved soil physical properties. When compared to chemical fertilizers, soils treated with composted manure have higher soil organic matter, more soil microbes and increased soil nutrients (Liu, et al., 2021). Studies have also reported a higher calcium, potassium, magnesium and phosphorus in compost treated soils (Almeida et al., 2019). Application of compost also helps improve soil structure, lead to increased soil air, and improve soil water infiltration and retention. Other benefits of applying compost include lower bulk density, higher soil porosity, improved aggregate stability and hydraulic conductivity (Ozlu et al., 2019; Siedt et al., 2021). However, many studies have reported that composted manure unlike biochar decompose rapidly in tropical soils. Hence, this study compared the effect of biochar from different sources (cow dung and maize cobs), and composted manure (cow dung) on soil physicochemical properties. It also assessed their effects on growth, and cob weight of maize.

Materials and Methods

The study was carried out at the screenhouse of the Institute of Ecology and Environmental Studies, located at latitude 7°30’ 58.392’’ N and longitude 4°31' 50.750" E, with a mean elevation value of 278 m above sea level, Obafemi Awolowo University (OAU), Ile-Ife.

Collection and Preparation of Soil Amendments

The amendment’s feedstocks (maize cobs and fresh cowdung) were collected from the cropping site and beef unit of the Teaching and Research Farm, OAU, Ile-Ife. The fresh cowdung was composted aerobically for three months. The production of biochar was done using a local charcoal-fired reactor. Measured quantities of the composted cow dung and maize cobs (1 kg each) were charred to produce biochar. The feedstocks were slowly pyrolyzed at 350 ^{0}C, and the final product (biochar) was removed after 3 hours.

Seed Collection and Viability

Seeds of the test crop, maize variety ART/98/SW1 was obtained from the Institute of Agricultural Research and Training, Ibadan. Seed viability was performed on the maize seeds using germination test. Cotton wool was moistened with water, 50 randomly selected seeds of maize were placed inside, spread and covered in a petri dish. The treatments were replicated three times and the total number of seeds that germinated was counted on the fourth day. The mean percentage of the maize seed that germinated was 80%.

Experimental Design and Procedure

Surface soil was collected from an intensively cropped land, air-dried for 7 days and then sieved using a 2 mm mesh. The air-dried and sieved soil measuring 10 kilograms was filled into each polythene pot–space was left at the top to make allowance for watering. Each polythene pot was watered to a field moisture capacity. The treatments consist of three treatments, cow dung compost, cow dung biochar and maize cob biochar which were applied once. Soil amendment was incorporated into the soil and incubated for seven days. All treatments were applied at different rates (0, 4, 8, 12, 16 $t.ha^{-1}$) and replicated thrice to give a total of 45 experimental units. The experiment was arranged in completely randomized design. A week after manure incubation, the seeds of the test crops were sown and each of the pots was perforated at the base to avoid water logging and to increase the soil aeration. Seeds of the test crop were sown at three seeds per polythene pots and seedlings thinned to two stands per pot two weeks after sowing. Data on the growth parameters such as the number of leaves, plant height and stem girth was taken fortnightly. Number of leaves were counted and stem girths were measured using a pair of vernier calipers, and plant heights were measured with a graduated straight edge (ruler) from the base of the shoot at the soil surface to the tip of the highest leaf in the foliage of the crop. The experiment was repeated to determine the residual effect of the treatments.

Soil Sample Collection and Preparation

Composite soil samples were collected before planting and after harvesting during the experiment. Three soil samples were collected before planting to make up a composite sample while soil samples were also collected from each experimental pot at the end of the screenhouse experiment for post planting soil analysis. The soil samples were air-dried, crushed and sieved using a 2-mm mesh.

Soil Analysis

Particle size distribution was determined using the hydrometer method (Bouyoucus, 1962). Soil pH was determined in a 1:1 soil to water suspension using the Dwyer model WPH1 waterproof pH tester. Organic carbon was determined using the Degtjareff method (Walkley and Black, 1934). Total nitrogen was determined using the macro-Kjeldahl method (Jackson, 1962). Available phosphorus was determined using the Bray method (Bray and Kurtz, 1945). Exchangeable acidity was determined using the method by Anderson and Ingram (1993). Selected heavy metals were determined by measuring two grams of soil samples into a digestion tube. One tablet of selenium catalyst was placed inside the tube. Ten millimetres of concentrated perchloric acid and 10 ml of concentrated nitric acid in ration 1:1. The tubes were placed inside a digestion block and slowly digested. The digest was washed into 100 ml volumetric flask and made up with distilled water. The filtrate obtained from the pre-treated digested samples were analysed for some heavy metals using atomic absorption spectrophotometer (AAS) Buck Scientific Model 210 (VGR).

Chemical Analysis of The Soil Amendments

The total nitrogen present in the compost and biochar used for the experiment was determined using macro-Kjedahl method (Jackson, 1962). Available Phosphorus was determined by ascorbic acid molybdate blue method as described by Murphy and Riley (1962). The pH was determined in a 1 : 1 soil to water suspension using Dwyer model WPH1 water proof tester. Organic carbon was determined following wet digestion method as described by Walkey and Black (1934). After digestion with 1M ammonium acetate, Potassium was determined by reading with the flame photometer. Calcium and Mg was determined using the Buck Scientific 210/211 VGP AAS model after extraction with 1M ammonium acetate. Moisture and ash content were determined using standard methods.

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) and their treatment means was separated at 95% confidence limit using GraphPad Prism v.9.

Results

Properties of Soil Used for Experiment

The physical and chemical properties of soil used for the screenhouse study are shown in Table 1. The soil was sandy loam (proportions of sand, silt and clay were 794.00, 154.00, 52.00 $g.kg^{-1}$, respectively). Soil pH was near neutral, organic carbon was moderate, available phosphorus was marginal, and total nitrogen (1.60 $g.kg^{-1}$) was moderately low. Cation exchange capacity was also moderate (8 $cmol.kg^{-1}$) with Ca^{2+} dominating.

Properties of Amendments Used

Results showed all amendments were highly alkaline (Table 2). However, maize cob biochar had the highest pH (10.87) compared to others as shown in Table 2. Organic carbon were high with 280.80, 389.00, 465.30 $g.kg^{-1}$ for CDC, CDB and MCB respectively. C/N was high in all amendments, however MCB had the highest with 664. Total nitrogen and moisture contents were low in MCB when compared to other amendments.

Effects of Soil Amendments on Growth of Maize

The results indicated that application of amendments increased the growth rate of maize when compared to control (Figure 1-6). Soils amended with CDC had the highest plant height when compared to other amendments with MCB showing a lower height in comparison (Figure 1 and 2). For instance, at 4 $t.ha^{-1}$, soils treated with CDC had a height of 72 cm while soils treated with MCB had a height of 56 cm, a 22% decrease in height. The same observations were made during the second planting. The stem girths for soils with different showed no significant difference during both planting seasons (Figures 3 and 4). Across the two planting seasons and levels of treatments, there were varied values in the number of leaves (Figures 5 and 6) when amendments were compared. However, no significant differences were observed among the treatments.

Table 1. Physical and chemical properties of soil used in the screenhouse study

Parameter	Value
pH (1:1 Soil: H_2O)	7.10
Organic Carbon ($g.kg^{-1}$)	14.10
Total Nitrogen ($g.kg^{-1}$)	1.60
Available Phosphorus ($mg.kg^{-1}$)	24.65
Exchangeable Acidity ($cmol.kg^{-1}$)	
H^+	0.32
Al^{3+}	0.00
Exchangeable Cation ($cmol.kg^{-1}$)	
Ca^{2+}	5.73
Mg^{2+}	1.48
Na^+	0.43
K^+	0.36
Sand ($g.kg^{-1}$)	794.00
Silt ($g.kg^{-1}$)	154.00
Clay ($g.kg^{-1}$)	52.00
Texture	sandy loam

Table 2. Chemical properties of soil amendments used in the study

Chemical properties	Cowdung compost	Cowdung biochar	Maize cob biochar
pH	8.90	9.70	10.87
Total Nitrogen ($g.kg^{-1}$)	13.40	11.70	0.70
Organic Carbon ($g.kg^{-1}$)	280.80	389.00	465.30
C/N	21.00	33.00	664.00
Total Phosphorus($mg.kg^{-1}$)	794.80	789.60	719.00
Potassium ($cmol.kg^{-1}$)	12.80	12.50	11.20
Ash content (%)	61.11	81.92	82.00
Moisture Content (%)	8.48	6.48	5.90

Table 3. Physical and chemical properties of soil in the screenhouse

Treatments ($t.ha^{-1}$)	pH ($cmol.H_2O$))	OC ($cmol.g.kg^{-1}$)	TN ($cmol.g.kg^{-1}$)	AP ($cmol.g.kg^{-1}$)	EA	H	Ca ($cmol.kg^{-1}$)	Mg	K	Na	Mn	Fe ($cmol.g.kg^{-1}$)	Cu	Zn
Cowdung Compost														
0	7.10b	13.00c	1.34e	20.65a	0.28a	0.28b	5.73c	1.47a	0.36c	0.43c	35a	15a	3a	3.95b
4	7.76a	26.37a	2.91a	8.66d	0.31a	0.31a	6.68b	0.36c	0.35c	0.39d	25.36b	5.83b	0.13b	4.44a
8	7.13b	19.08b	2.07d	11.75c	0.15b	0.15c	5.41d	0.26d	0.33c	0.32e	25.52b	3.57c	0.12b	3.10b
12	7.65a	20.19b	2.17c	11.24c	0.15b	0.15c	6.87a	0.32c	0.41b	0.78a	39.31a	7.40b	0.08c	2.45b
16	7.46a	21.70b	2.37b	17.42b	0.27a	0.27b	6.84a	0.57b	0.90a	0.69b	35.89a	3.87c	0.14b	3.90b
Cowdung Biochar														
0	7.10b	13.00e	1.34e	20.65a	0.28a	0.28a	5.73d	1.47a	0.36b	0.43a	35a	15a	3a	3.95a
4	7.76a	44.69a	4.92a	6.78c	0.23b	0.23b	7.17b	0.46b	0.40a	0.39b	29.38b	6.84b	0.21a	2.21a
8	7.80a	27.73c	2.97c	11.89b	0.08c	0.08e	8.30a	0.32c	0.33b	0.27c	24.71c	8.10b	0.13b	1.77b
12	7.19b	20.18d	2.16d	8.26c	0.11c	0.11d	6.37c	0.30c	0.41a	0.29c	25.22c	7.90b	0.09b	2.04b
16	7.24b	31.05b	3.37b	5.27d	0.19b	0.19c	6.67c	0.09d	0.46a	0.34b	21.09d	5.79c	0.11b	3.24a
Maize Cob Biochar														
0	7.10c	13.00d	1.34d	20.6a	0.28a	0.28a	5.73a	1.47a	0.36b	0.43c	35a	15a	3a	3.95a
4	7.59a	25.01b	2.66b	7.05b	0.22b	0.22b	5.66b	0.23b	0.10e	0.29d	22.09b	6.28b	0.13b	2.71a
8	7.69a	18.97c	2.06c	5.71b	0.15c	0.15c	5.26c	0.15c	0.20d	0.32d	21.59b	7.10b	0.12b	2.70a
12	7.42b	24.11b	2.57b	5.57b	0.11c	0.11d	5.79a	0.12c	0.28c	0.82a	26.12b	8.10b	0.13b	2.57a
16	7.44b	29.85a	3.27a	5.64b	0.11c	0.11d	4.88d	0.08d	0.72a	0.65b	22.1b	7.30b	0.08c	3.29a

Note: Means followed by the same letter within a column in each block do not differ significantly at $P < 0.05$ according to Bonferroni's Multiple Comparison Test

Effect of Amendments on Soil Properties

The effect of different soil amendments on soil properties after planting is shown in Table 3. Soil with amendments had higher nutrient levels compared to control. Soil pH in amended soils became more alkaline when compared to control soils. Soil properties such as organic carbon and total nitrogen also increased. However, soil properties such as available phosphorus, and micronutrients such as Fe, Cu, and Mn were higher in controls compared to soils treated with amendments. It was observed that soils treated with cowdung biochar increased soil properties compared to other amendments. For example, at 8 $t.ha^{-1}$, soil pH was highest in CDB (7.80) compared to CDC (7.76). At 4 t ha^{-1}, soils treated with CDB also had a higher organic carbon (44.69 $g.kg^{-1}$) and CEC (8 $cmol.kg^{-1}$) compared to soils treated with MCB which was 44% and 21.5% lower in both parameters respectively. Soils treated with CDB also had higher total nitrogen and available phosphorus values when compared to other amendments.

Effect of Amendments on Cob Weight

The effect of soil amendments on cob weight is shown in Table 4. The cob weight of maize was highest under soils treated with CDC when compared to other amendments. The lowest values were recorded in soils treated with MCB. For instance, under 4 $t.ha^{-1}$, CDC treated soils was 65% higher than that of MCB treated soils. Significant differences were observed between treatments.

Discussion

Organic fertilizers are known to improve soil chemical

Table 4. Cob weight (g) of maize under screenhouse conditions

Treatments	Control	4 $t.ha^{-1}$	8 $t.ha^{-1}$	12 $t.ha^{-1}$	16 $t.ha^{-1}$
Cow dung compost	1.07a	2.20a	3.87a	2.17a	4.07a
Cow dung biochar	0.90b	0.90b	2.17b	0.87b	0.93b
Maize cob biochar	0.47c	0.77c	2.17b	0.80b	0.63c

Note: means followed by the same letter within a column in each block do not differ significantly at $p < 0.05$ according to Bonferroni's Multiple Comparison Test.

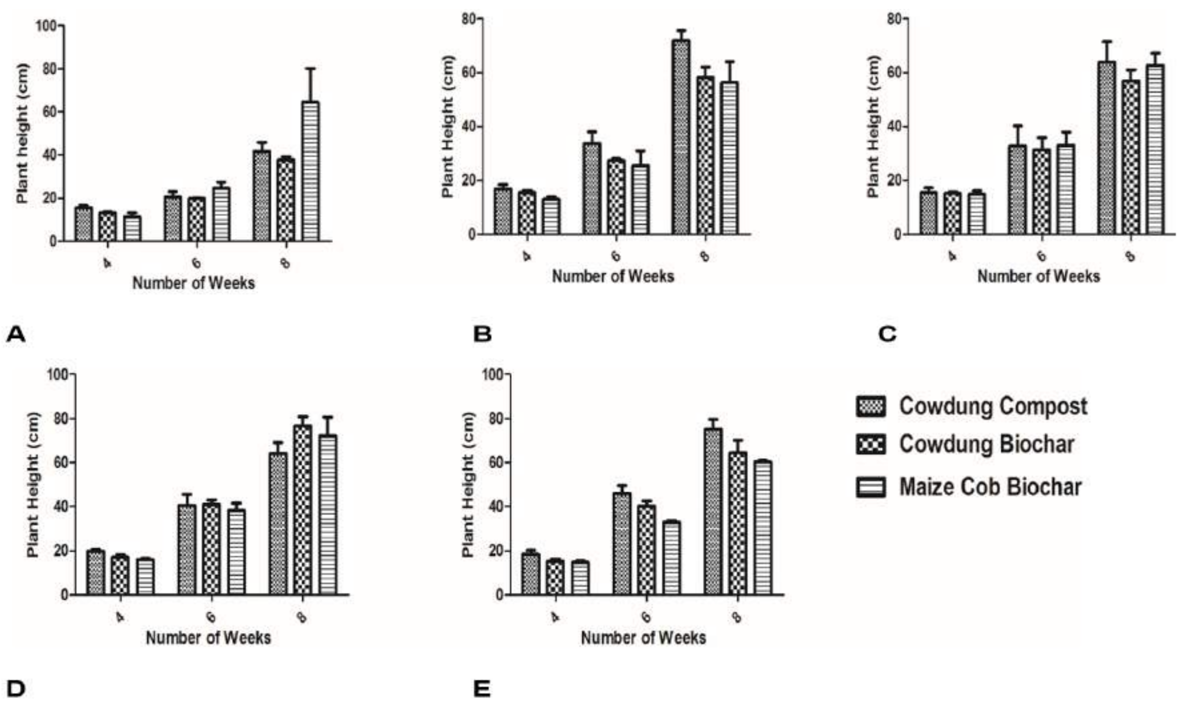

Figure 1. Plant heights of maize during first planting under screenhouse conditions. Plants heights were measured with a graduated straight edge ruler forthnightly.
A: control, B: 4 $t.ha^{-1}$, C: 8 $t.ha^{-1}$, D: 12 $t.ha^{-1}$, E: 16 $t.ha^{-1}$. Experiment was conducted twice using a completely randomized design. Bars indicates standard errors.

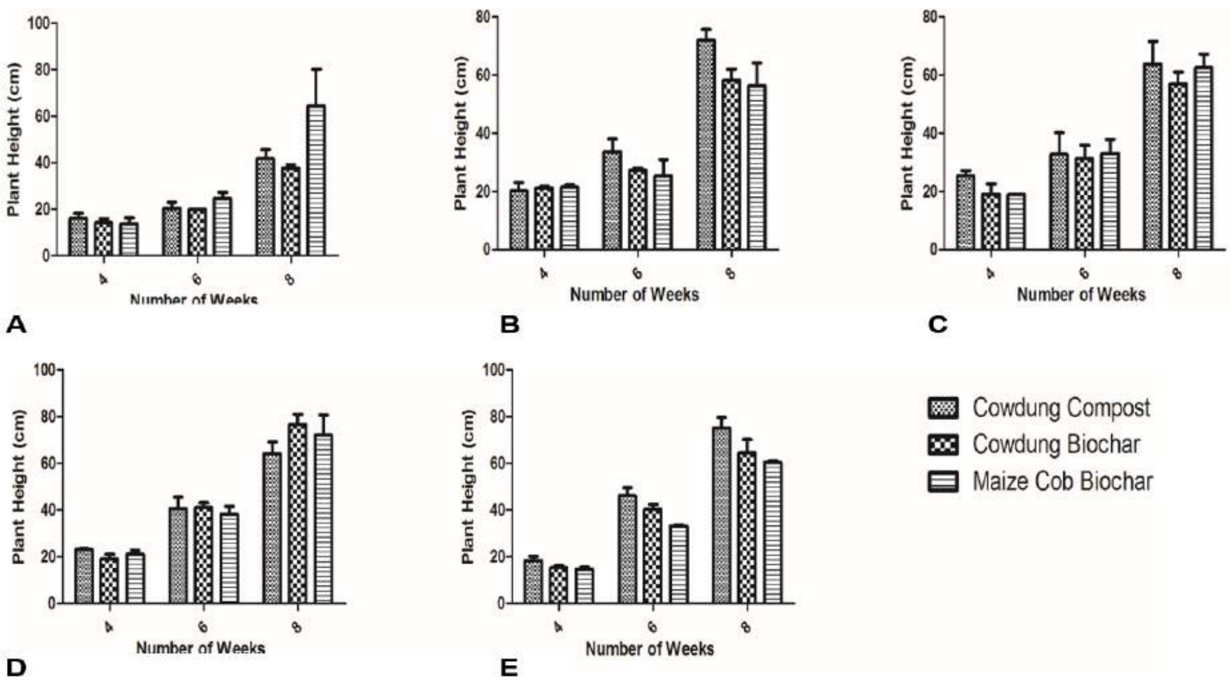

Figure 2. Plant heights of maize during second planting under screenhouse conditions. Plants heights were measured with a graduated straight edge ruler forthnightly.
A: control, B: 4 t.ha^{-1}, C: 8 t.ha^{-1}, D: 12 t.ha^{-1}, E: 16 t.ha^{-1}. Experiment was conducted twice using a completely randomized design. Bars indicates standard errors.

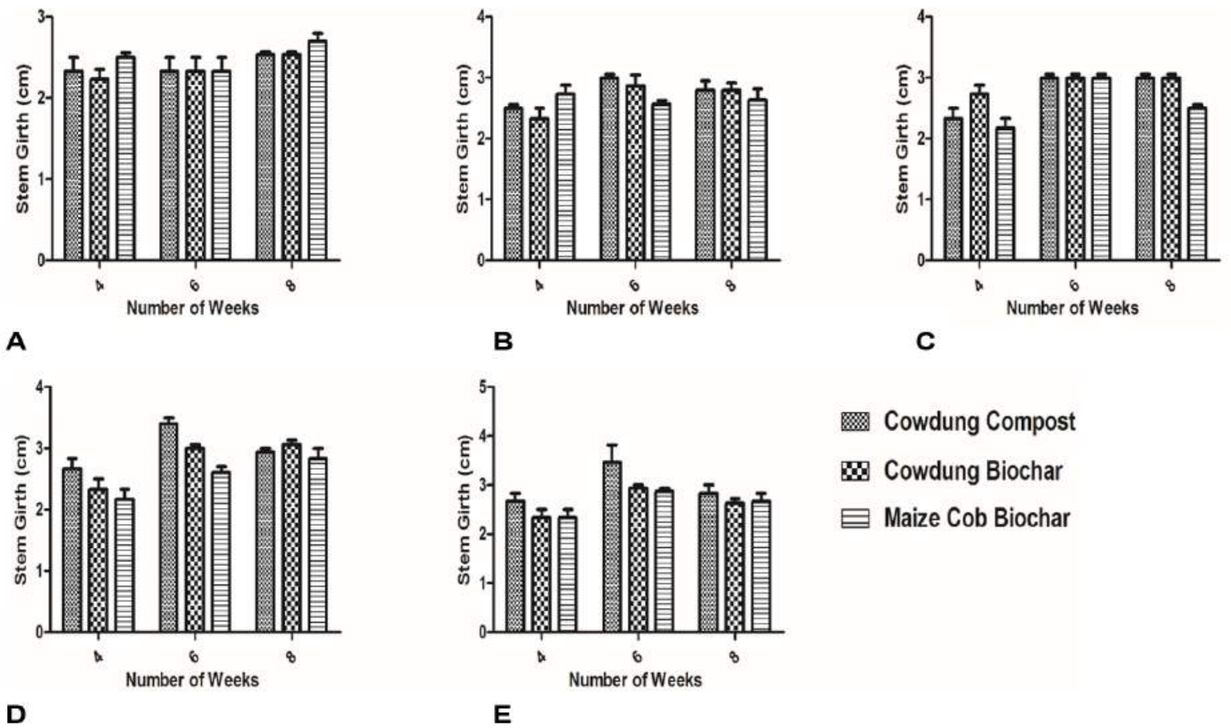

Figure 3. Stem girths of maize during first planting under screenhouse conditions. Stem girths were measured using a pair of vernier calipers forthnightly. A: control, B: 4 t.ha^{-1}, C: 8 t.ha^{-1}, D: 12 t.ha^{-1}, E: 16 t.ha^{-1}. Experiment was conducted twice using a completely randomized design. Bars indicates standard errors.

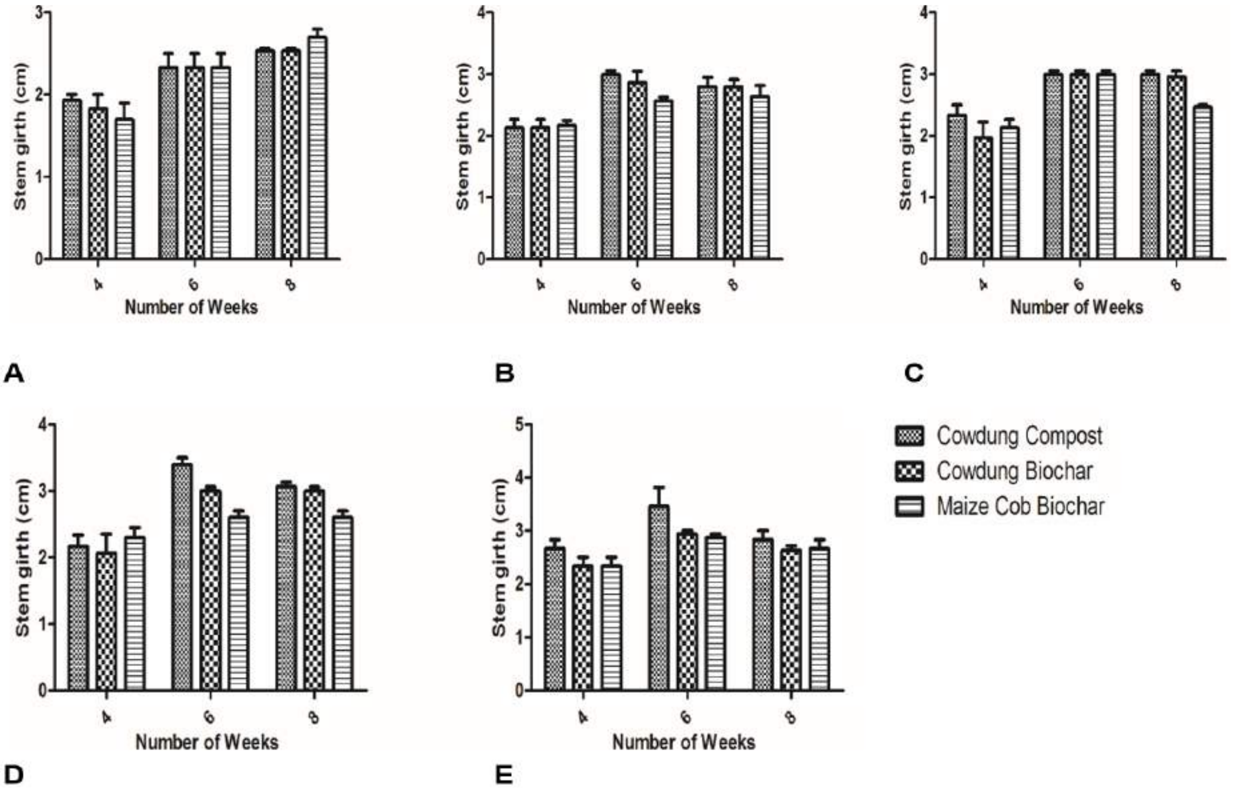

Figure 4. Stem girths of maize during second planting under screenhouse conditions. Stem girths were measured using a pair of vernier calipers forthnightly. A: control, B: 4 $t.ha^{-1}$, C: 8 $t.ha^{-1}$, D: 12 $t.ha^{-1}$, E: 16 $t.ha^{-1}$. Experiment was conducted twice using a completely randomized design. Bars indicates standard errors.

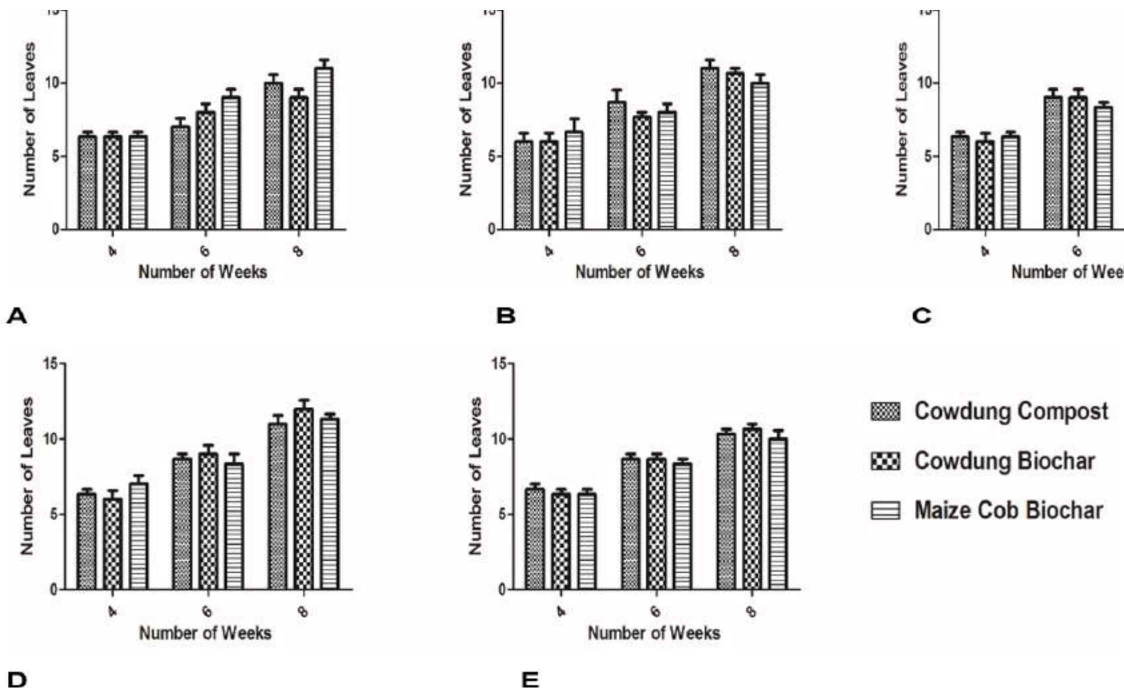

Figure 5. Number of leaves of maize during first planting under screenhouse conditions. Number of leaves were measured by counting each leaves per stand forthnightly. A: control, B: 4 $t.ha^{-1}$, C: 8 $t.ha^{-1}$, D: 12 $t.ha^{-1}$, E: 16 $t.ha^{-1}$. Experiment was conducted twice using a completely randomized design. Bars indicates standard errors

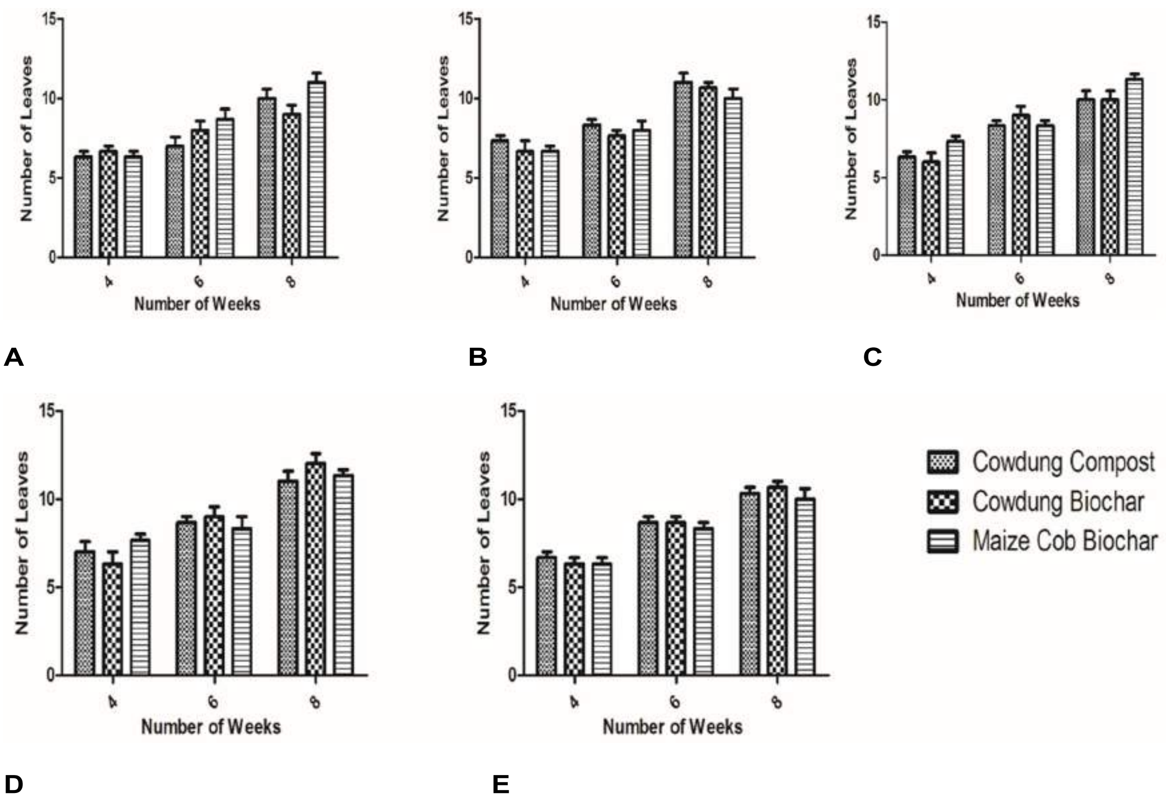

Figure 6. Number of leaves of maize during second planting under screenhouse conditions. Number of leaves were measured by counting each leaves per stand forthnightly. A: control, B: 4 t.ha^{-1}, C: 8 t.ha^{-1}, D: 12 t.ha^{-1}, E: 16 t.ha^{-1}. Experiment was conducted twice using a completely randomized design. Bars indicates standard errors.

properties and serve as a source of nutrients to plants. This study aimed at evaluating the effects of different amendments such as composted cowdung, cowdung biochar and maize cob biochar on soil properties and weight of maize cobs. This study revealed that soil amendments used were highly alkaline (Table 2), most especially the biochar amendments, which agrees with the work of (Agegnehu et al., 2015). He noted in his study that compost and biochar had a high soil pH. However, it was observed that biochar amendments had a higher pH when compared to compost. This agrees with the work of (Cox et al., 2021) who recorded a higher pH for biochar compared to chicken manure compost. The higher pH recorded for biochar could be due to the pyrolysis temperature. Pyrolysis reduces the amount of carboxyl groups and an increase in conjugated bases which susbsequently leads to a higher pH of biochar (Tag et al., 2016). The higher pH observed in maize cob biochar compared to other amendments could be due to its higher ash content (Nyambo et al., 2018). This is in line with the findings of (Berek and Hue, 2013). They noted in their study while investigating the capacity of six different biochar to improve the productivity of acid soils, that soil pH increased with an increase in ash content.

It was also recorded that organic carbon content in biochar were higher when compared to cowdung compost. This is due to a higher degree of polymerization that leads to a more condensed carbon structure compared to cowdung compost. For instance, in this study, maize cob biochar had a 40% increase in organic carbon compared to cowdung compost (shown in Table 2). This agrees with Domingues et al. (2017) who stated in his study that pyrolysis leads to a higher organic carbon due to higher degree of polymerization. Biomass when subjected to pyrolysis is converted to biochar with high fixed carbon content. However, the higher organic carbon and ash content observed in maize cob biochar may be due to the feedstock. Maize cobs have a high cellulose, lignin and hemicelluloses which will contribute to the thermal decomposition of corn cob feedstock and released of the volatiles (Danje, 2011). Feedstocks with higher lignin content could produce higher char yield during the pyrolysis process compared to feedstocks with lower lignin content (Shariff et al., 2016).

This study revealed that soil amendments increased crop productivity compared to control (Figures 1-6). Agronomic properties such as plant height, stem girth and number of leaves were improved compared to control. This could be attributed to the improved characteristics of the soil due to addition of amendments. However, biochar performed poorly when compared to cowdung compost. This could be due to the slow mineralization rate of biochar compared to cowdung compost. Lehmann et al. (2006) pointed out that whereas compost is easily degradable, biochar has an aromatic structure and a recalcitrant nature and is therefore very resistant to decomposition. The lower agronomic properties of maize shown by soils treated by maize cob char compared to other amendments may be due to the amendment's lower nutrient composition compared to other amendments (cow dung compost and cow dung biochar). Cob weights were also lower in plants grown on maize cob biochar. A low nutrient composition of an amendment could lead to a low nutrient uptake by plants (Lehmann et al., 2003). This could lead to lower plant growth and low yield of crops.

This study established that all amendments improved the soil properties compared to control (Table 3). The pH of soils increased due to the alkaline nature of the amendments. This agrees with Shetty et al. (2021) who stated in his study that biochar application can increase the pH of acid soils due to its alkalinity. This study also observed that soil organic carbon and total nitrogen were increased in the soil compared to control soils. The increase in organic carbon can be due to the addition of carbon from the compost and biochar amendments. Frimpong et al. (2016) also revealed in their study that C accumulation and sequestration in soils are stimulated by biochar and manure application. This proves that both cow dung and biochar enhanced carbon accumulation and sequestration in the soil. The increase in total nitrogen would be simply due to the additional N in the compost applied while biochar can release a small amount of nitrogen add up to the total nitrogen pool, as reported by Cui et al. (2017).

The study also demostrated that cow dung biochar enhanced the soil pH, total nitrogen and organic carbon compared to other amendments (Table 3). This could be due to the type of feedstock used for the biochar. Nutrient composition of biochars are dependent on the type of feedstocks. This also relates to their use for agricultural purposes. This disagrees with the study by Gunamantha and Widana (2018). They stated in their study that biochar from pig and cow manure was not consistent with their feedstocks. However, this study agrees with the earlier reports by Cely et al. (2015). They concluded in their study that biochar properties were strongly influenced by the feedstock.

Higher micronutrients, such as Fe, were observed in control soils compared to other treated soils (Table 3). This could be attributed to its parent material. The micronutrients in the soil and their availability to plants are determined by the minerals contained in the original parent material, and by the weathering processes that have taken place over the years. However, the amendments used were able to reduce the amount of micronutrients. This could be related to the increased soil pH found in the amended soils. As soil pH increased, the availability of iron, manganese, copper and zinc decreases. It was also revealed that amendments at 4 $t.ha^{-1}$ improves soil properties and crop growth compared to other rates. This is in contrast with Chivenge et al. (2011), who stated that continuous increase in organic fertilizer application rate might improve soil properties. An appropriate rate of fertilizer application is necessary for optimum crop productivity.

Conclusion

This study revealed that cowdung compost and biochar (cowdung biochar and maize cob biochar) improved crop growth, such as plant height, stem girth and number of leaves. Soil properties such as pH, organic carbon and total nitrogen were also higher in treated soils compared to control soils. However, soil chemical properties such as available phosphorus and micronutrients: Fe, Cu, and Mn, were lower in untreated soils compared to amended soils. Cob weight was also significantly higher in amended soils compared to control. This study, however, observed that cowdung biochar was better suited to improving soil properties and crop growth compared to other amendments. This suggests that it could have a slower mineralization rate compared to its feedstock (cow dung compost) while also improving crop productivity. Hence, there is a need for more study on the rate of mineralization of each amendment and how it can affect the crop growth on a long term. This study also suggests that organic amendments applied at 4 $t.ha^{-1}$ is the best application rate for crop and soil productivity. We propose a long term study to examine the long-term effects of the treatments on soil physicochemical properties and yield responses.

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