EFFECT OF COMPLEMENTARY AND SOLE USE OF BIOCHAR, POULTRY DROPPINGS, UREA FERTILIZER AND THEIR COMBINATIONS ON SOIL PROPERTIES AND GROWTH PARAMETERS OF *Amaranthus cruentus*

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ABSTRACT

Pot and field experiment were conducted to determine the effects of complementary and sole use of biochar, poultry droppings, urea fertilizer and their combinations on soil properties and growth parameters of *Amaranthus cruentus*. Fifteen treatments comprising of the control (no amendment), sole applied biochar (B), poultry droppings (P), urea (U) and their combinations (½ B + ½ U, ¾ B + ¼ U, ¼ B + ¾ U, Full B + ½ U, ½ B + Full U, ½ B + ½ P, ¾ B + ¼ P, ¼ B + ¾ P, Full B + ½ P, ½ B + Full P and ½ B + ½ P + ½ U) were laid out in a Completely Randomized Design (CRD) and Randomized Complete Block Design (RCBD) in the screen house and field, respectively. The treatments were replicated three times. Biochar and Poultry manure were applied at a rate of 20 t/ha while urea was at 60 kg N/ha. Data collected were subjected to analysis of variance and means compared using Duncan New Multiple Range Test (DNMRT) at 5 % probability level. The results obtained from this study revealed that the combination of all three amendments reduced bulk density. It also showed that combined applications of the amendments especially the combination of biochar and poultry droppings improved soil chemical properties and growth parameters than sole application of any of them for both pot trial and field experiment. For pot trial there were improvements in TN, Av.P, exchangeable Mg, K, ECEC and BS, whereas for field experiment only Av. P was significantly improved among the soil chemical properties. Additionally, the combination of ½ B + ½ P + ½ U (10 t/ha biochar + 10 t/ha poultry droppings + 30 kg N/ha urea) as well as ½B+ Full P and ½B+ ½U were found to be consistent in improving both soil chemical properties and plant growth parameters of *Amaranthus*. Hence complementary use of the amendments is recommended as sustainable nutrient source for vegetable farmers in the study area.

Keywords: *Amaranthus cruentus, poultry droppings, biochar and urea fertilizer*

INTRODUCTION

Poor soil fertility status across tropical soils raises concerns about the sustainability of agriculture in this area and has spurred the development of management practices to restore or improve soil fertility status. Biomass burning (Edem *et al.,* 2012) coupled with the applications of chemical fertilizer usually caused air and ground water pollution by eutrophication of water bodies (Bhardwaj *et al.,* 2014), thus posing a serious threat to human health and environment. Beside, chemical fertilizers are associated with high cost, scarcity and causes soil acidity. In the face of these challenges, the exploration of sustainable and innovative solutions has become paramount (Ijah *et al*., 2018; Iren *et al* 2016; Iren and Uwah, 2018) .Among these solutions, biochar, a carbon-rich material derived from the pyrolysis of organic matter, has emerged as a promising means for addressing soil quality enhancement and crop productivity.

Application of biochar to soil with low fertility status has been shown to increase soil organic carbon (SOC), improve water holding capacity, nutrient retention, pH, microbial activity, soil structure (Biederman and Harpole, 2013; Chintala *et al.,* 2014). The complementary use of organic and inorganic maure to increase plant growth, biomass and crop yields has been demonstrated in a number of tropical agricultural studies (Novak *et al.,* 2009; Singh *et al.,* 2010).

In Nigeria, as in most other tropical countries of West Africa where the daily diet is dominated by starchy staple foods, vegetables are the cheapest and most readily available sources of important proteins, vitamins, minerals, and essential amino acids (Onwordi *et al.,* 2009). Of all vegetables, *Amaranthus* species including *Amaranthus cruentus* have high levels of essential micro-nutrients like iron, manganese and zinc (Mnkeni*et al.,* 2007).

The protein found in young plants of amaranthus can be important for people without access to meat or other sources of protein (Iren *et al.,* 2016a). Apart from its uses as a vegetable, it has also been used as an effective alternative to drug therapy in people with hypertension and cardiovascular disease (CVD). Despite the benefits of this crop, the yield per hectare in Nigeria is low. Therefore, the objective of this study is to determine the effects of complementary and sole use of poultry droppings, biochar and urea fertilizer on soil properties and growth parameters of *Amaranthus cruentus*.

MATERIALS AND METHODS

Description of the study area

The experiment was carried out in two phases; the first phase was pot experiment conducted in the screen house of the University of Calabar and the second phase was field experiment that was conducted at the Teaching and Research Farm of the University of Calabar. University of Calabar is situated between latitudes 5°32′ and 4°27′ N and longitudes 7°15′ and 90°28′E. Calabar is in a degraded rainforest vegetation zone of Nigeria, having a bimodal rainfall pattern. The soil of the area is classified as an Ultisol based on USDA system of classification (Soil Survey Staff, 1999).

Collection and preparation of research materials

Forty-five plastic buckets of 10 litres capacity were purchased and perforated at the bottom to allow for easy drainage and facilitate aeration. *Amaranthus* seeds were purchased from the National Root Crops Research Institute, Umudike,Urea fertilizer were purchased from the Agricultural Development Programme (ADP) office at Calabar. Poultry droppings were obtained from the University of Calabar Animal Farm while the wood biochar was locally made and crushed to fine powder of about 2 mm size. Topsoil (0 - 15 cm) was collected from the University of Calabar Teaching and Research Farm and the soil was thoroughly mixed, air dried, sieved using a 2 mm sieve. Ten kilograms (10kg) of the 2 mm sieved soil was weighed to each of the 10 litres capacity plastic buckets and placed in the screen house for the pot experiment.

The pot experiment was laid out in a completely randomized design (CRD) while the field experiment was laid out in randomized complete block design (RCBD) with 3 replicates. The same treatments were used for the pot and field experiments. The experiments (pot and field) consisted of fifteen (15) treatments that were replicated three times giving a total of forty five (45) experimental units for each of the experimental phases. The treatments included different combinations of biochar with urea and poultry droppings and also their sole use as presented in Table 1. Sole application of urea was at 60 kg N/ha while poultry droppings and biochar were singly applied at 20 t/ha.

FIRST PHASE: POT EXPERIMENT

Treatment allocations

To each of the experimental units containing 10 kg of soil, the various treatments were applied. Biochar and poultry droppings were applied to specified pots and thoroughly mixed with the soil, watered to field capacity and left for two weeks (2wks) before planting *Amaranthus* seeds. Urea fertilizer was applied to specified pots at 2wks after planting (WAP) by ring method.

Planting and maintenance of experimental units

The seeds of *Amaranthus* were mixed with river sand at the ratio of 3 parts *Amaranthus* seeds to ten parts river sand and then incorporated into the soil in the pots to ensure even distribution of the seeds. After planting the pots were watered. Few weeks after emergence, the plants were thinned down to two plants per pot. Weeding was done manually by hand removal.

SECOND PHASE: FIELD EXPERIMENT

Land preparation

The experimental site was manually cleared, tilled and demarcated into three blocks with each block consisting of 15 plots giving a total of forty-five (45) plots. Each bed size measured 1 m x 1 m (1 m^2). Alleyways between blocks were 1.5 m while those between plots were 0.6 m.

Treatment allocations for the field experiment

To each of the experimental units measuring 1 m^2, biochar and poultry droppings were spread out on each plot at specified rates of application and incorporated into the soil and was left for 2wks before planting *Amaranthus* seeds. Urea fertilizer was applied to specified plots at 2wks after planting (WAP) by band placement method.

Planting and maintenance of experimental units

After 2wks of organic manure application, *Amaranthus* seeds were mixed with dried river sand first before planting so as to ensure that the seeds are not planted too closely together. The mixture was about 70 % sand and 30 % *Amaranthus* seeds and was evenly distributed directly on drills at a distance of 10 cm between each row.

The seedlings were later thinned down to one plant per stand one week (1wk) after planting at a spacing of 10 cm between plants with planting distance of 10 cm x 10 cm giving a plant population of 100 plants per bed (1 m^2) and 1,000,000 plants per hectare. The plots were kept weed free throughout the crop growing period.

Records of agronomic parameters for Pot and field experiment

Data collection

Nine plants from the centre of each plot for field experiment (while for the pot experiment two plants were used) were tagged for growth parameters determination. Growth parameters data were collected from 3wks after planting (WAP) and subsequently at 1wk interval until the end of the experiment. The experiment ended when the *Amaranthus* plants were six weeks (6wks) old. The following parameters were observed per plant per experimental unit: Plant height was measured using a meter rule as the height from the base of the crop (ground level) to the tip of the plant. Number of branches and number of leaves was counted.Stem girth was measured at a point that is about 5 cm from the ground by tying a string around the plant stem and the length of the string read-off from a meter rule and the value in cm will be multiplied by a pie.

Soil sampling and processing

Composite soil samples were taken at 0 – 15 cm depth before the experiment and also from each experimental unit after the experiment to determine the physicochemical properties. The soil samples were later air dried, ground and sieved with 2 mm size sieve. The samples for analysis of organic carbon (OC) and total nitrogen (T/N)were further ground and sieved through 0.5 mm mesh.

Laboratory studies

Samples from soil, biochar and poultry droppings were subjected to chemical analysis using standard procedures as outlined by Udo *et al.* (2009). Particle size distribution was determined by Bouyoucous hydrometer method. Soil pH was determined using a ratio of 1:2 in soil-water medium and read with a digital pH meter. Organic carbon content was determined by Walkley-Black wet oxidation method. Total Nitrogen (N) was determined by the micro-kjedahl method. Available P was extracted using Bray 1 extraction method. Exchangeable cations were determined on extract obtained after leaching samples with one normal neutral ammonium acetate (1 *N*, NH_4OAC, pH 7.0) solution, Calcium and magnesium were determined by the EDTA titration method. Potassium and sodium were estimated by Flame photometer. Exchangeable acidity (H^+ and Al^{3+}) was determined by leaching 5g of soil sample with standard potassium chloride solution and the amount of exchangeable acidity determined by titration using 0.1*N* Na0H solution following procedure in Udo *et al.,* (2009). Effective cation exchange capacity (ECEC) was computed by summing up the ammonium acetate extracted base (exchangeable Mg, Ca, K, Na) and exchangeable acidity (H^+ and Al^{3+}). Base saturation was computed by dividing the sum of all the exchangeable cations (Ca, Mg, K and Na) by the effective cation exchange capacity (ECEC) and then the quotient was multiplied by 100. The biochar and poultry droppings were also analyzed for total nitrogen, phosphorus, potassium, calcium, magnesium, pH and organic carbon contents.

Statistical analysis

Data collected were subjected to analysis of variance using Genstat (2007) and the means compared using the Duncan New Multiple Range Test (DNMRT) at 5% level of probability. Table 2 shows the interpretation guide for evaluating the soil analytical data.

RESULTS AND DISCUSSION

Properties of the soil, biochar and poultry droppings used for the Study

The physicochemical properties of the soil before the study are presented in Table 2. The soil used before the experiment was loamy sand in texture with a bulk density of 1.22 g/cm^3. The soil was strongly acid with a pH value of 5.2 as rated by Adaikwu and Ali (2013) and reported by Ijah *et al*., (2021). The soil organic carbon (OC) was moderate with a value of 1.15% and the total nitrogen content (T/N) was low (0.08%) as reported by Ijah *et al.,* (2021) on acid soils of southeastern state. The available phosphorus (Av. P) content of the soil was high with a value of 31.02 mg/kg. Exchangeable bases such as calcium (Ca), potassium (K) and sodium (Na) were low with values of 2.4, 0.11 and 0.07cmol/kg, respectively while magnesium (Mg) was moderate (1.2 cmol/kg). Exchangeable acidity was low having values of 0.20 cmol/kg and 1.20 cmol/kg for aluminum (Al^{3+}) and hydrogen (H^{+}), respectively. Effective cation exchange capacity (ECEC)was low with a value of 7.24 cmol/kg, while base saturation (BS) was high with a value of 72.97%.

The chemical compositions of biochar, poultry droppings and urea are presented in Table 3. Poultry droppings used for the study contained 2.6 % N, 0.21 % P, 2.7 % K, 1.44 % Ca, 0.67 % Mg and 36.90 %organic carbon with an alkaline pH of 7.6 whereas biochar contained 1.0 % N, 0.05 % P, 1.72 % K, 1.92 % Ca, 1.05 % Mg and a very low organic carbon content of 3.59 %, with an alkaline pH of 7.8. The inorganic fertilizer source, urea contains 46 % N.

Influence of biochar, poultry droppings, urea fertilizer and their combinations on soil properties in the pot and field experiments

Pot experiment

Physical properties of the soil

Table 4 shows the particle size distribution and bulk density of the soil after experiment in the pot experiment. There was no significant change in the particle size distribution among treatments. The sand fraction dominated the soil separates still giving a loamy sand texture as before experiment. Bulk density of the soil after the experiment was different significantly among treatments. Soils treated with full B+½ P + ½ B + ½ P+½ U had the lowest bulk densities of 1.05 and 1.04 g/cm^3 and it differed significantly when compared with the control which was 1.22 g/cm^3. This agrees with the findings of Alberquerque *et al.* (2014) who reported that the bulk density of soil might decrease through addition of biochar due to its relative low bulk.

Chemical properties of the soil

The chemical properties of the soil after the experiment are shown in Table 4.The treatments applied significantly ($p<0.05$) increased the T/N content of the soil with the highest value (0.21%) obtained in soils treated with ¾ B + ¼ U (15 t/ha Biochar + 15 kg N/ha urea) and was significantly higher than the values obtained in other amended soils and control except soils amended with ¼B + ¾ U, Full B + ½ U, ½ B + ½ P, ¾B + ¼ P and ¼ B + ¾ P. The soil with the least T/N content (0.097%) was the one amended with urea alone (60 kg N/ha)but it was higher than the N- content before the experiment (0.08%). This could be as a result of uptake of nitrogen by the plants.

The highest value of Av. P (28.21 mg/kg) was obtained in soils treated with ¼ B + ¾ P (5 t/ha biochar + 15 t/ha poultry droppings) and it was not significantly higher than all other amended soils except those amended with ½ B + ½ P+ ½ U (10 t/ha biochar + 10 t/ha poultry droppings + 30 Kg N/ha urea) and ½ B + Full U (10 t/ ha + 60 kg N/ha urea) which had values of 10.00 and 9.00 mg/kg, respectively. However, there was generally, reduction in soil Av. P status compared with the initial value of 31.02 mg/kg before the experiment. This reduction might be attributed to the uptake of phosphorus by the *Amaranthus* plant.

The application of the amendments did not significantly ($p > 0.05$) increase the exchangeable Ca content of the soil. However, the highest value of exchangeable Ca content (5.80 cmol/kg) was obtained from soils treated with biochar alone at 20 t/ha. Mg content in the soil was highest in soil treated with urea alone. This is because the effect of the urea on Mg was increased as a result of entrapment in the cation exchange site, and was significantly ($p < 0.05$) different when compared with values obtained in other amended soils and the control except soil amended with Full B + ½ P.

The results showed that the treatments applied significantly ($p<0.05$) improved K content of the soil with the highest value of K (0.14 cmol/kg) in soils treated with B-alone, P-alone and U-alone while the lowest value of 0.10 cmol/kg was obtained in soils treated with ¼ B + ¾ U (5 t/ha B + 45kg N/ha Urea) and ½ B + Full P (10t/ha biochar + 20t/ha poultry droopings). The amendment increased the Na content of the soil with the highest value (0. 63cmol/kg) obtained from soil treated with Full B + ½ U (20 t/ha biochar + 30 kgN/ha urea). But it was not significantly ($p<0.05$) different from all other treatments except in soil treated with ¼ B + ¾ U (5 t/ha B + 45kg N/ha Urea).

The highest value for Aluminium (0.65 cmol/kg) was obtained from soil treated with poultry droppings only (20 t/ha) and this was significantly different from soil receiving all other treatments. The result showed a general reduction in H^+ content of the soil as compared to the hydrogen content of the soil before the experiment. The highest value for hydrogen content (1.12 cmol/kg) was obtained from the control and ½ B + ½ P (10 t/ha biochar + 30 kg N/ha urea) treated soil which was still less than 1.20 cmol/kg obtained before the experiment. The soil treated with biochar alone (20 t/ha) gave the lowest hydrogen content of 0.12 cmol/kg.

The amendments significantly ($p <0.05$) improved ECEC of the soil (Table 6) with the highest value of (9.77 cmol/kg) obtained from soils amended with urea alone (60kgN/ha). This is higher than the ECEC of the soil obtained before the experiment (7.24 cmol/kg) and control (8.37 cmol/kg). This agrees with the findings of Chukwu *et al.*(2012) and Iren *et al.* (2016) who both reported that the combination of inorganic and organic amendments improved the soil exchangeable Ca, K, Mg as well as ECEC. The treatments significantly ($p < 0.05$) improved the BS of the soil with the lowest value for BS (78.05 %) obtained from soils treated with ½ B + ½ U while the highest value (95.67 %) was obtained from soils treated with ¾ B + ¼ P (15 t/ha biochar + 5 t/ha poultry droppings).

The pH level of the soil was significantly increased when compared with the unamended soil (control)as shown in Table 5. Soil pH was raised from moderately acidic level (5.6) obtained before experiment to slightly acid pH level after experiment. The highest pH value was obtained in the soil amended with Full B + ½P (6.767), followed by ½B + Full P (6.700) and ¼B + ¾P (6.667) although not significantly different from each other but were significantly higher when compared to all the sole applied treatments, ½B + ½U, ¼B + ¾U, ½B + Full U, ½B + ½P + ½U and the control. However, all the treatments significantly increased the soil pH relative to the control except the soils treated with ½B + ½U, ½B + Full U and ½B + ½P + ½U. This confirms the assertion made by Chintala *et al*. (2014) who reported that biochar contains an ash component that is usually alkaline and could potentially increase soil pH if added to acidic soils. Soil OC (organic matter) contents were significantly ($P< 0.05$) increased by the application of Full B + ½U, ¾B + ¼U and½B + ½P and not by other treatments when compared with the control (Table 6). This is contrary to the report of Zheng *et al*. (2016) who reported decrease in soil organic carbon when biochar was applied. The highest soil organic carbon was obtained in pots amended with Full B + ½U and the least was from the urea alone treated soil. The same trend was obtained for soil organic matter content.

Effects of biochar, poultry manure and urea on soil physical and chemical properties
Field experiment

The application of biochar, poultry manure and urea amendments only significantly ($p\leq 0.05$) increased the soil Av. P, sand, silt and clay (Table 6). For changes in soil Av. P, soil amended with ¾B+¼P had the highest Av. P content (67.66 mg/kg) that was at par with P content in the control soil and other treated soils except those found in the soil amended with ½B+½U and Full B (20 t/ha B). However, there was no significant (p>0.05) difference in soil pH, OC, TN, Av. P, exchangeable Ca, Mg, K, and Na, exchangeable acidity Al^{3+} and H^{+}, ECEC, and BS between the amended soils and the control soil. Further result also showed changes in the composition of particle size fractions.

The highest sand contents were found in the control soil and soil amended with ½B+¼U, ½B+½P which were at par with other treated soil excepting Full B+½U. Also, the highest silt contents were found in soils amended with Full B+½U (15.33%) and ½B+ Full P (14.67%) which were at par with other treated soil including the control soil except soil amended with ½B+¼U (11.33%). For the clay contents, the soil amended with ¼B+¾U had the highest clay content of (7.70%) that was at par with the control soil (5.37%) and other amended soils excepting soil amended with ½B+ Full P (4.70%) and ½B+½P (4.70%). The results obtained here corroborate with the findings of Agegnehu *et al.* (2015) who reported improvement in soil properties following application of biochar.

Influence of biochar, poultry droppings, urea fertilizer and their combinations on growth parameters of A*marathus cruentus* in the pot and field experiments

Pot experiment result

Tables 7 and 8 show the influence of biochar, poultry droppings, urea fertilizer and their combinations on growth parameters of *Amaranthus cruentus* in pot experiment. Number of leaves per *Amaranthus* plant was not significantly (p > 0.05) affected by applied amendments at 4 weeks after planting (WAP) but at 6 WAP, significant increase was observed among treatments (Table 7). The highest number of leaves (38.67) was obtained from soil amended with a combination of ½ B + ½ P + ½ U (10 t/ha biochar + 10 t/ha poultry droppings + 30 Kg N/ha urea). Although the number of leaves produced were not more than those produced by plants treated with poultry droppings alone, (34.00) ¼ B + ¾ U and ½ B + Full P (29.33) but it was significantly more than those from other treatments and the control. The lowest (16.00) number of leaves per *Amaranthus* plant was from the control. A similar trend was observed for plant height. There was no significant difference (P <0.05) in plant height at 4 WAP. The highest plant height at 6 WAP (24.43 cm) was obtained from soil amended with ½ B + Full P (10 t/ha biochar + 20 t/ha poultry droppings). There was no significant (p > 0.05) difference in stem girth at 4 WAP. but at 6 WAP, the highest stem girth (2.37cm) was recorded in soil amended with ¼ B + ¾ P (5 t/ha biochar +15 t/ha poultry droppings). This was not significantly (p< 0.05) bigger than all other treated plants except the plants treated with ½ B + 4 urea (10 t/ha biochar + 60 kg N/ha) urea and control (Table 7). *Amaranthus* branches observed at 6 WAP showed that the amendments significantly (p < 0.05) improved the number of branches relative to control. The highest number of branches (8.00) was obtained from soil amended with ½ B + ½ P + ½ U (10 t/ha biochar + 10 t/ha poultry droppings + 30 kg N/ha urea) while the plants without amendment (control) had no branches at all (Table 8).

The non-significant increase in growth parameters assessed at the initial stage of growth could be attributed to slow mineralization of the amendments applied. The significant increase in growth at advanced stage of growth in treated soils shows the response of *Amaranthus* to applied nutrients. Positive responses of *Amaranthus* to applied nutrients have been recorded in many studies (Ullah *et al.,* 2008; Iren *et al.,* 2016a, b, c).

Field experiment results

Number of leaves

The application of amendments significantly (p≤ 0.05) increased the number of leaves (NL) in amended soils when compared with the control in both 4 and 6 weeks after planting (WAP) (Table 9). At 4 WAP, the highest number of leaves was obtained in the soil amended with ¼B+¾U which was not significantly (p≥0.05) greater than plants in all the treated soils and the control. However, the least number of leaves was observed in soil amended with ¼B+¾P. However, at 6 WAP, the least number of leaves were found in plot amended with sole biochar (20 t/ha of Biochar), whereas the highest number of leaves were obtained in the soil amended with ½B+ Full P which significantly (p≤ 0.05) gave more number of leaves than all the sole applied treatments, ½B+½U, ½B+¼U, B+½U, ½B+U, ½B+½P, ¾B+¼P, ¼B+¾P, Full B+½P, ½B+½P+½U and the control. Njoku *et al.* (2017) also attributed increase in vegetative growth of crops that received organic manure to increase in the amount of mineral nitrogen.

Plant height

The application of amendments significantly ($p \leq 0.05$) increased the plant height in amended soils when compared with the control in both 4 and 6 WAP. In 4WAP, the height of *Amaranthus cruentus* was significantly ($p \leq 0.05$) higher in all soils imposed with treatments excepting 1/4B+¾P (9.27cm),20t/ha B (1.73cm) and B+1/2U (10.23cm) relative to the control (Table 9). *Amaranthus cruentus* with the highest height of 14.33 cm was rooted in soil amended with 1/2B+P (10t/ha biochar + 20t/ha Poultry manure), which was closely followed by those in 20t/ha P (13.87 cm) and 1/2B+1/2P+1/2U (10 t/ha biochar+ 10t/ha + 30kg/N/ha (13.87 cm), and the least height of *Amaranthus cruentus* was found in the control plot (10.30 cm) which was at par with those rooted in1/4B+¾P, 20t/ha B, 1/2B+1/2U, 1/2B+1/4U,1/2B+1/2P, ¾B+1/4P, B+1/2P and B+1/2U. However, at 6 WAP, soil amended with 1/2B+P (10 t/ha biochar + 20t/ha poulry droppings) produced the tallest *Amaranthus cruentus* (37.73 cm) that was at par with soil amended with 20t/h P, 1/2B+1/2U, 1/4B+¾U, 1/2B+U, and 1/2B+1/2P+1/2U but significantly($p<0.05$) taller than those in control and 20t/h B, 60 kg N/ha U, 1/2B+¾U, B+1/2U, 1/2B+1/2P, ¾B+1/4P, 1/2B+¾P and B+1/2P. The least height of *Amaranthus cruentus* was found in soil amended with 1/4B+¾P (5t/ha biochar+ 15t/ha poultry manure),(15.87 cm) which was at par with the control plot.This observation corroborate with the findings of Oke *et al*. (2020) that nutrients from mineralization of organic manure promote growth and yield of cucumber.

Stem girth

The application of amendments significantly ($p \leq 0.05$) increased the stem girth of *Amaranthus cruentus* in amended soils when compared with the control in both 4 and 6 WAP (Table 9). At 4WAP, the soil amended with 1/2B+P ((10t/ha biochar+ 20t/ha poultry manure) produced the widest *Amaranthus cruentus* (1.7 cm) that was at par with soils amended with 20t/ha P, 1/2B+1/4U, 1/2B+¾U, 1/2B+U, 1/2B+1/2P and 1/2B+1/2P+1/2U but significantly($p<0.05$) wider than those in control and 20t/h B, 60 kg/ha U, 1/2B+1/2U, B+1/2U, ¾B+1/4P, and B+1/2P. Plant with the least stem girth of *Amaranthus cruentus* was found in soil amended with 1B+1/2P (20t/ha biochar + 10t/ha poultry manure) (1.33 cm) and the control plot. However, at 6 WAP, the soil amended with 1/2B+P (10t/ha biochar+ 20t/ha poultry manure) produced the widest *Amaranthus cruentus* (2.93 cm) that was at par with soils amended with 1/2B+1/2U, 1/2B+1/4U, 1/4B+¾U, 1/2B+U, 1/2B+1/2P, B+1/2P, and 1/2B+1/2U+1/2P, but significantly($p<0.05$) wider than those in control and 20t/ha B, 20t/ha P, 60 kg N/ha U, B+1/2U, ¾B+1/4P, and 1/4B+¾P. However, plant with the least stem girth of *Amaranthus cruentus*was found in soil amended with 20t/ha B (1.87cm) and the control soil.

Number of branches

The application of amendments significantly ($p \leq 0.05$) increased the number of branches of *Amaranthus cruentus* in amended soils when compared with the control at 6 WAP (Table 9). At 6WAP, the soil amended with 1/2B+1/2U+1/2P ((1/2 biochar+ ½ poultry manure (10t/ha biochar+ 10t/ha poultry manure +30kg/ha urea) produced plants with more branches (10.80) that were at par with soils amended with 1/2B+¾U, 60kg/ha U, 1/2B+1/2U, 1/2B+1/4U, 1/4B+¾U, and 1/2B+P. Plant with the least number of branches of *Amaranthus cruentus* was found in soil amended with 20t/ha B (2.27) which was at par with the control plot (3.80). Such increased vegetative growth with application of biochar and poultry manure has been demonstrated repeatedly in a number of studies (Adekiya *et al*., 2019; Njoku *et al*., 2017). Increased vegetative growth as observed in the study may be attributed to enhanced nutrient availability and improved soil properties as indicated by Adekiya *et al*. (2019).

SUMMARY AND CONCLUSION

The results obtained from this study revealed that the combination of all three amendments reduced bulk density. The combination of biochar and poultry droppings improved soil chemical properties and growth parameters than sole application of any of them for both pot trial and field experiment. For pot trial there were improvements in T/N, Av. P, exchangeable Mg, K, ECEC and BS, whereas for field experiment only avail P was significantly improved among the soil chemical properties. This study futher showed that the use of a combination of biochar with poultry droppings as well as with urea fertilizer enhanced growth of *Amaranthus* compared to sole application of any of them.

Recommendations

A combination of ½ B + ½ P + ½ U (10 t/ha biochar + 10 t/ha poultry droppings + 30 kg N/ha urea) as well as ½B+P (10 t/ha biochar + 20 t/ha poultry droppings) and ½B+½U (10 t/ha biochar + 30kgN/ha Urea) were found to be consistent in improving both soil chemical properties and plant growth parameters, hence it is recommended as nutrient source for vegetable farmers.

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Table 1: Treatments and quantity applied per hectare, per pot and per plot

Treatments	Quantity per hectare	Qty per pot (10 kg soil)	Qty per plot (1m x 1m)
Control (no amendment)	0	0	0
Biochar alone (full)	20 t/ha	100g	2kg
Poultry droppings alone (full)	20 t/ha	100g	2kg
Urea alone (full)	60 kg N/ha	0.65g	13.04g
½ Biochar + ½ Urea	10 t/ha B + 30kg N/ha U	50g B + 0.33g U	1kg B + 6.52g U
¾ Biochar + ¼ Urea	15 t/ha B + 15 kg N/ha U	75g B + 0.163g U	1.5kg B + 3.26g U
¼ Biochar + ¾ Urea	5 t/ha B + 45 kg N/ha U	25g B + 0.49 g U	0.5kg B + 9.78g U
Full Biochar + ½ Urea	20 t/ha B + 30 kg N/ha U	100g B + 0.33g U	2kg B + 6.52g U
½ Biochar + Full urea	10 t/ha B + 60 kg N/ha U	50g B + 0.65g U	1kg B + 13.04 U
½ Biochar + ½ P	10 t/ha B + 10 t/ha P	50g B + 50g P	1kg B + 1kg P
¾ Biochar + ¼ P	15 t/ha B + 5 t/ha P	75g B + 25 g P	1.5kg B + 0.5kg P
¼ Biochar + ¾ P	5 t/ha B + 15 t/ha P	25g B + 75g P	0.5kg + 1.5kg P
Full Biochar + ½ P	20 t/ha B + 10 t/ha P	100g B + 50g P	2kg B + 1kg P
½ Biochar + Full P	10 t/ha B + 20 t/ha P	50g B + 50g P	1kg B + 2kg P
½ Biochar + ½ P + ½ U	10 t/ha B +10 t/ha P + 30 kg N/ha U	50g B + 50g P + 0.33g U	1kg B + 1kg P + 6.52g U

B = biochar, U = urea, P = poultry droppings

Table 2: Properties of the soil before the experiment

Parameters	Value
Clay (%)	0.7
Silt (%)	13.0
Sand (%)	86.3
Texture	Loamy sand
Bulk density (g/cm^3)	1.22
pH (H_2O)	5.2
Organic carbon (%)	1.15
Organic Matter (%)	1.98
Total N (%)	0.08
C:N ratio	14
Available P (mg/kg)	31.02
Ca^{2+} (cmol/kg)	2.4
Mg^{2+} (cmol/kg)	1.2
K^+ (cmol/kg)	0.11
Na^+ (cmol/kg)	0.07
Al^{3+} (cmol/kg)	0.20
H^+ (cmol/kg)	1.20
ECEC (cmol/kg)	7.24
B.S (%)	72.97

Table 3: Chemical Composition of Biochar, Poultry Droppings and Urea Fertilizer

Amendments	Parameter (%)						
	N	P	K	Ca	Mg	pH (H_2O)	O.C (%)
Biochar (B)	1.0	0.05	1.72	1.92	1.05	7.8	3.59
Poultry droppings (P)	2.6	0.21	2.70	1.44	0.6	7.6	36.90
Urea fertilizer (U)	46	0	0	0	0	–	–

Table 5: Influence of sole and complementary use of biochar, poultry manure and urea On soil pH, organic carbon and organic matter (pot experiment)

Treatments	Soil properties		
	pH (H_2O)	O.C (%)	O. M (%)
Control	5.633 h	1.320 def	2.27 def
U – alone	6.167 def	1.167 f	2.01 f
B – alone	6.267 bcde	1.470 cdef	2.53 cdef
PM – alone	6.033 efg	1.380 def	2.38 def
½ B + ½ U	5.833 gh	1.280 def	2.21 def
¾ B + ¼ U	6.433 abcd	2.437 ab	4.20 ab
¼ B + ¾ U	6.233 cdef	2.113 bcde	3.64 bcde
Full B + ½ U	6.500 abc	3.060 a	5.27 a
½ B + Full U	5.933 fgh	1.217 ef	2.10 ef
½ B + ½ PM	6.567 ab	2.337 abc	4.03 abc
¾ B + ¼ PM	6.633a	2.140 bcd	3.69 bcd
¼ B + ¾ PM	6.667 a	1.973 bcdef	3.40 bcdef
Full B + ½ PM	6.767 a	1.673 bcdef	2.88 bcdef
½ B + Full PM	6.700 a	1.897 bcdef	3.27 bcdef
½ B + ½ PM + ½ U	5.733 gh	1.317 def	2.27 def
Mean	6.273	1.785	3.078
SD	0.394	0.664	1.44
CV	6.279	37.17	37.17

*Mean values followed by the same letter(s) within the same column are not significantly different according to DNMRT at 5 % probability.

Table 6: Influence of biochar, poultry droppings, urea fertilizer and their combinations on soil physico-chemical properties in field experiment

Treatment	Soil pH (H_2O)	OC (%)	TN (%)	Av. P (mg/kg)	Ex. K	Ex. Na	Ex. Ca (cmol/kg)	Ex. Mg	Ex Al^{3+}	Ex. H^+	ECEC	BS (%)	Sand	Silt	Clay
Control	6.033 a	1.373 a	0.1133 a	39.20 ab	0.1267 a	0.100 a	0.069 a	1.733 a	0.147 a	0.480 a	6.653 a	88.00 a	81.63 a	13.00 abc	5.37 ab
Biochar alone	5.933 a	1.323 a	0.1100 a	22.25 b	0.1200 a	0.093 a	0.049 a	1.467 a	0.120 a	0.607 a	5.873 a	87.33 a	80.63 ab	13.00 abc	6.37 ab
Poultry droppings alone	6.133 a	1.503 a	0.1267 a	50.21 ab	0.1200 a	0.097 a	0.131 a	1.133 a	0.133 a	0.520 a	5.470 a	87.00 a	80.30 ab	14.00 abc	5.70 ab
Urea alone	6.000 a	1.433 a	0.1200 a	38.25 ab	0.1100 a	0.090 a	0.083 a	0.933 a	0.147 a	0.607 a	5.407 a	85.00 a	80.97 ab	13.33 abc	5.70 ab
½ B + ½ U	5.867 a	1.300 a	0.1100 a	22.66 b	0.1133 a	0.090 a	0.111 a	1.133 a	0.160 a	0.620 a	6.070 a	85.00 a	80.53 ab	13.67 abc	5.80 ab
½ B + ¼ U	6.233 a	1.200 a	0.1000 a	58.91 ab	0.1200 a	0.097 a	0.096 a	1.333 a	0.000 a	0.560 a	6.710 a	90.67 a	81.63 a	11.33 c	7.03 ab
¼ B + ¾ U	6.067 a	1.317 a	0.1100 a	47.62 ab	0.1167 a	0.090 a	0.138 a	0.867 a	0.040 a	0.567 a	5.887 a	89.33 a	80.63 ab	11.67 bc	7.70 a
B + ½ U	6.200 a	1.410 a	0.1200 a	38.29 ab	0.1233 a	0.103 a	0.080 a	1.867 a	0.067 a	0.550 a	7.567 a	91.33 a	79.63 b	15.33 a	5.03 ab
½ B + U	6.300 a	1.357 a	0.1167 a	60.29 ab	0.1233 a	0.100 a	0.113 a	1.400 a	0.000 a	0.593 a	7.540 a	90.33 a	80.97 ab	13.67 abc	5.37 ab
½ B + ½ P	6.033 a	1.397 a	0.1167 a	50.79 ab	0.1267 a	0.103 a	0.150 a	1.333 a	0.027 a	0.667 a	6.923 a	88.67 a	81.63 a	13.67 abc	4.70 b
¾ B + ¼ P	6.200 a	1.335 a	0.1100 a	67.66 a	0.1200 a	0.087 a	0.064 a	1.547 a	0.000 a	0.613 a	6.087 a	90.00 a	80.63 ab	12.67 abc	6.70 ab
¼ B + ¾ P	5.800 a	1.340 a	0.1133 a	40.00 ab	0.1133 a	0.093 a	0.186 a	1.667 a	0.173 a	0.660 a	6.640 a	86.33 a	80.97 ab	13.33 abc	5.70 ab
B + ½ P	5.933 a	1.170 a	0.0967 a	54.62 ab	0.1300 a	0.100 a	0.120 a	1.867 a	0.053 a	0.573 a	7.523 a	90.67 a	80.63 ab	13.67 abc	5.70 ab
½ B + P	6.133 a	1.153 a	0.0967 a	28.12 ab	0.1167 a	0.093 a	0.167 a	1.533 a	0.081 a	0.447 a	6.697 a	91.33 a	80.63 ab	14.67 a	4.70 b
½ B + ½ P + ½ U	5.833 a	1.317 a	0.1133 a	40.48 ab	0.1100 a	0.080 a	0.122 a	1.933 a	0.147 a	0.520 a	6.590 a	89.00 a	80.63 ab	14.33 ab	5.03 ab

B = biochar, P = poultry droppings, U = urea fertilizer, OC = organic carbon, TN = total nitrogen, Av. P = available phosphorus, Ex. = exchangeable. ECEC = effective cation exchange capacity, BS = base saturation. Means with the same letter(s) within the same column are not significantly different at $p = 0.05$ using Duncan Multiple Range Test.

Table 7: Influence of biochar, poultry droppings, urea fertilizer and their combinations on number of leaves and plant height of *Amaranthus* (pot experiment)

Treatments	Mean number of leaves		Mean plant height (cm)	
	4 WAP	6 WAP	4 WAP	6 WAP
Control	12.67[a]	16.00[e]	9.30[a]	17.20[f]
B-alone (20 t/ha)	11.67[a]	18.67[de]	9.37[a]	17.90[def]
P-alone (20 t/ha)	10.67[a]	34.00[ab]	13.17[a]	22.53[b]
U-alone (60 kg N/ha)	9.67[a]	22.67[cde]	9.90[a]	22.37[bcd]
½ B + ½ U	11.33[a]	17.00[de]	8.90[a]	18.10[def]
¾ B + ¼ U	10.67[a]	17.00[de]	8.87[a]	15.30[ef]
¼ B + ¾ U	17.67[a]	34.00[ab]	10.67[a]	21.57[bc]
Full B + ½ U	11.33[a]	17.67[de]	10.13[a]	21.20[bc]
½ B +Full U	8.33[a]	21.33[cde]	10.53[a]	18.77[bcd]
½ B + ½ P	12.00[a]	20.00[cde]	11.33[a]	21.90[bc]
¾ B + ¼ P	8.33[a]	22.00[cde]	8.53[a]	13.10[cde]
¼ B + ¾ P	9.00[a]	16.67[de]	13.97[a]	22.63[ab]
Full B + ½ P	10.67[a]	26.33[bcd]	10.37[a]	19.53[bcd]
½ B + Full P	11.00[a]	29.33[abc]	13.93[a]	24.43[a]
½ B + ½ P+ ½ U	15.00[a]	38.67[a]	13.10[a]	23.30[a]

Means within a column not sharing a letter in common differ from each other significantly at 5% level of probability following Duncan New Multiple Range Test (DNMRT)

Table 8: Influence of Biochar, Poultry droppings, Urea Fertilizer and Their Combinations on stem girth and number of branches of *Amaranthus* (pot experiment)

Treatments	**Mean stem girth (cm)**		**Mean number of branches**
	4 WAP	**6 WAP**	**6 WAP**
Control	1.50[a]	1.67[c]	0.00[f]
B-alone (20 t/ha)	1.37[a]	1.93[abc]	2.00[def]
P-alone(20 t/ha)	1.53[a]	2.20[abc]	5.33[b]
U-alone (60 kg N/ha)	1.53[a]	2.20[abc]	3.67[bcd]
½ B + ½ U	1.43[a]	1.83[abc]	1.67[def]
¾ B + ¼ U	1.30[a]	1.77[bc]	1.00[ef]
¼ B + ¾ U	1.37[a]	2.07[abc]	7.67[a]
Full B + ½ U	1.60[a]	1.90[abc]	1.00[ef]
½ B +Full U	1.37[a]	1.73[c]	4.67[bc]
½ B + ½ P	1.80[a]	2.30[ab]	2.67[cde]
¾ B + ¼ P	1.37[a]	1.83[abc]	3.33[bcde]
¼ B + ¾ P	1.73[a]	2.37[a]	3.67[bcd]
Full B + ½ P	1.17[a]	2.10[abc]	2.67[cde]
½ B + Full P	1.77[a]	2.20[abc]	4.67[bc]
½ B + ½ P+ ½ U	1.60[a]	2.07[abc]	8.00[a]

Means within a column not sharing a letter in common differ from each other significantly at 5% level of probability following Duncan New Multiple Range Test (DNMRT)

Table 9: Influence of biochar, poultry droppings, urea fertilizer and their combinations on growth parameters of *Amaranthus* (field experiment)

Treatment	Number of leaves		Plant height (cm)		Stem girth(cm)		Number of branches
	4 WAP	6 WAP	4 WAP	6 WAP	4 WAP	6 WAP	6 WAP
Control	12.77 cd	20.87 cd	10.30 ef	18.67 ef	1.43 bc	1.87 c	3.80 de
Biochar (B) [20 t/ha]	11.97 cde	15.33 d	10.47 ef	19.03 ef	1.40 bc	1.83 c	2.27 e
Poultry droppings (P) [20 t/ha]	10.60 de	30.80 abc	13.87 ab	30.23 abc	1.47 abc	2.17 bc	6.20 bcd
Urea (U) [60 kg N/ha]	10.57 de	30.13 abc	12.03 cd	26.00 cde	1.43 bc	1.97 bc	7.07 abcd
½ B + ½ U	11.87 cde	32.73 abc	11.03 de	30.13 abc	1.40 bc	2.43 abc	8.27 abc
½ B + ¼ U	11.00 de	28.93 abc	11.10 de	27.40 bcde	1.50 abc	2.37 abc	8.33 abc
¼ B + ¾ U	17.33 a	29.73 abc	12.90 bc	29.07 abcd	1.47 abc	2.23 abc	7.80 abc
B + ½ U	11.43 cde	26.03 bcd	10.23 ef	20.37 def	1.43 bc	2.10 bc	5.33 bcde
½ B + U	10.78 de	32.37 abc	12.20 cd	30.93 abc	1.60 ab	2.67 ab	7.87 abc
½ B + ½ P	11.14 de	27.57 abcd	11.13 de	23.67 cdef	1.53 abc	2.30 abc	5.83 bcde
¾ B + ¼ P	12.53 cde	25.87 bcd	10.60 e	19.87 ef	1.40 bc	2.07 bc	4.70 cde
¼ B + ¾ P	10.33 e	20.10 cd	9.27 f	15.87 f	1.57 abc	1.93 bc	5.50 bcde
B + ½ P	11.00 de	29.97 abc	10.77 e	22.67 cdef	1.33 c	2.23 abc	5.60 bcde
½ B + P	13.33 bc	39.60 a	14.33 a	37.73 a	1.70 a	2.93 a	9.30 ab
½ B + ½ P + ½ U	15.00 b	34.33 ab	13.87 ab	36.13 ab	1.60 ab	2.67 ab	10.80 a

WAP = weeks after planting, NL = number of leaves, Plt.H = plant height, SG = stem girth, NB = number of branches. Means with the same letter(s) within the same column are not significantly different at p = 0.05 using Duncan Multiple Range Test.