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Roles of biochar produced from animal and plant wastes on okra (*Abelmoschus esculenta*) growth in Umudike area of Abia State, Nigeria

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Abstract: In Abia State Nigeria with emphasis on Umudike area, lots of agricultural wastes are being generated. It is against this backdrop that a pot trial was conducted at the experimental field of College of Crop and Soil Sciences, Michael Okpara University of Agriculture Umudike, with the aim of investigating the effect of biochar produced from different animal and plant wastes on growth and yield of okra plant. The treatments were a control (without biochar) and biochar produced from animal wastes sources namely; Bone waste, Cow dung, Goat droppings, Pig waste and Poultry droppings. Others were produced from plant wastes sources namely; Cocoa pod, Palm bunch, Saw dust, Rice mill husk, Ukpo shell (*Mucuna Flagellipes)* and Wood shaving. The treatments were applied at the rate of 3t/ha (whose equivalent was 86g) to 10kg of soil weighed into pots and replicated 4 times in a Completely Randomized Design. The test crop was okra (*Abelmoschus esculenta*) and the effects of the treatments were determined on its top biomass dry matter yield, number of leaves, the height, stem girth at 2, 4, 6 and 8 weeks after planting. Biochar produced from poultry manure feedstock significantly ($p \leq 0.05$) increased the plant height at eight weeks after planting among the animal feedstock biochar. It gave a value of 50.68cm over that of the control which was 25.8cm. Among the plant feedstocks biochar, the application of Ukpo shell (*Mucuna Flagellipes)* significantly ($p \leq 0.05$) increased the plant top biomass dry matter yield with a value of 8.1g/pot as compared to the control value of 4.4g/pot. The top biomass dry matter significantly ($p \leq 0.05$) and correlated positively with number of leaves and plant height. The result showed that among the animal feedstock and plant feedstock biochar, poultry manure and Ukpo shell (*Mucuna Flagellipes)* respectively improved most of the plant parameters measured. Further research investigation in the field with the treatments is recommended.

Keywords: Biochar, animal feedstock, plant feedstock, okra and plant parameters.

Introduction

Food insecurity is one of the challenges facing the world and Africa in particular today. Major causes of food insecurity are soil degradation and infertility [1]. When the soil is degraded, there will be reduction of the biological and economic productivity potentials of the land [2]. Activities such as deforestation, continuous cultivation of same piece of land, accelerated runoff and erosion among others give rise to soil degradation [3] and [4]. Soil infertility on the other hand is caused by intensive weathering, leaching, acidity and nutrient mining through crop removal without appropriate replenishment [5].

Establishing crops like okra on soils with declined fertility will affect the crop's level of productivity. Low production of Okra will directly affect its utilization. Okra as a vegetable is very important in the diet of an average Nigerian. This is because vegetables provide the body system with vitamins and minerals. To maintain a healthy population, there is need to find ways of increasing the productivity of okra and at the same time restore the degraded and infertility of the soil.

One of the ways employed to restore the degradation and infertility of the soil is by the use of amendments in form of agricultural and domestic solid wastes [6]. These wastes can be categorized into animal or plant origin. Some of the animal origin wastes include manure and waste from livestock farms while that of the plant origin is residues of plants after harvest.

The animal and plant origin wastes are applied to the soil directly and these take longer time to decompose and release its nutrient contents to the crops [7]. These have discouraged most farmers in using them because they will wait longer for the results of the applied wastes to manifest on their crops.

It is therefore imperative to find the appropriate ways of converting these wastes into materials that will make their nutrients readily available to the crops and at the same time reduce the amount of carbon dioxide released into the atmosphere, which increases the global warming [8]. One of the ways of reducing the production of carbon dioxide when materials are heated is by subjecting the materials to pyrolysis process. This process will reduce the release of carbon dioxide into the atmosphere and at same time produce substances that are rich in nutrients. These substances known as biochar have been reported to increase the fertility of the soil [9] and [10]. Using the waste converted into biochar to produce okra in the southeast Nigeria has not been fully exploited. The objective of the study was to determine the effect of biochar produced from animal and plant wastes respectively that will increase the okra production in Southeast Nigeria.

Materials and Methods

A pot trial was conducted at the experimental field of College of Crop and Soil Sciences, Michael Okpara University of Agriculture Umudike (latitude 05°29`N and longitude 07°33`E). Umudike has an elevation of 122m above sea level, with mean annual rainfall of 2117mm, distributed over nine to ten months in a bimodal rainfall pattern starting from April to July and August to October. The monthly minimum air temperature at Umudike ranged from 20°C to 24°C while the monthly maximum air temperature ranged from 28°C to 35°C [11].

The soil used was collected in March 2014 from a depth of 0-20cm from the Eastern experimental farm (latitude 05°27`N and longitude 07°32`E) of Michael Okpara University of Agriculture, Umudike. The soil samples were air- dried, passed through 5mm sieve mesh and the pre-treatment analysis carried out. Ten kilogram of the soil samples were weighed into 12 liter pots and used for the investigation.

The treatment comprised of a control (no amendment), five types of biochar produced from five animal manure feed-stocks and six types of biochar made from plant feedstock. They were passed through the pyrolysis drum at the temperature of 450°C. The animal biochar were produced from Bone (BN), Cow dung (CD), Goat droppings (GD), Pig waste (PS) and Poultry droppings (PT). Those of the plant feed-stocks were

Cocoa pod (CP), Palm bunch (PB), Saw dust (SD), Rice mill husk (RMW), Ukpo shell (*Mucuna Flagellipes)* (UKP) and Wood shaving (WS). The treatments were applied on dry basis at the rate of 3t/kg whose equivalent was 86g per pot. They were randomly assigned to the pots and replicated four times in a Completely Randomized Design.

The test crop was okra (*Abelmoschus esculentus*) and it was collected from the Agronomy Department of College of Crop and Soil Science, Michael Okpara University of Agriculture Umudike. Three okra seeds were planted and later thinned down to two seed per pot. The plant parameters measured were plant height, number of leaves and stem girth at 2, 4, 6, and 8weeks after planting (WAP). Top biomass dry matter was also measured at harvest.

The data generated were subjected to analysis of variance (ANOVA) for CRD while the means were separated using the Fisher's Least Significant difference (LSD).

Results

The effect of the animal manure biochar on the number of leaves recorded at weeks after planting is shown on Table 1. The result showed that there were no significant differences among the treatments at 2 weeks after planting. At 4 weeks after planting, pig waste and poultry droppings biochar significantly ($p \leq 0.05$) increased the number of leaves. At 6 and 8 weeks after planting of okra, all the treatments showed significantly ($p \leq 0.05$) higher number of leaves over the control. Among the treatment means, pig manure and poultry droppings had significantly ($p \leq 0.05$) higher number of leaves. For the interaction between treatments and weeks of planting, bone, cow dung, goat dung, pig waste and poultry manure biochars significantly ($p \leq 0.05$) increased the number of leaves at 8 weeks after planting.

Table 1: Number of Okra leaves as affected by the applied different animal wastes biochar at weeks after planting.

Treatments	Weeks After Planting				
	2	4	6	8	Mean
Control	3	5	7	9	6
Bone	3	6	9	11	7
Cow dung	3	6	9	11	7
Goat dung	3	6	9	11	7
Pig waste	4	7	9	11	8
Poultry droppings	4	7	9	11	8
Mean	3	6	9	11	
$LSD_{(0.05)}$	Ns	0.8	0.5	0.4	

Lsd ($p \leq 0.05$) for the treatments (T)= 0.26, lsd ($p \leq 0.05$) for weeks (W) = 0.33, lsd ($p \leq 0.05$) TxW = 0.67

At four, six and eight weeks after planting as shown on Fig 1, the okra height was significantly ($p \leq 0.05$) increased by poultry manure biochar. This was followed by the plants that received pig waste biochar. The highest plant height value was recorded at eight weeks after planting.

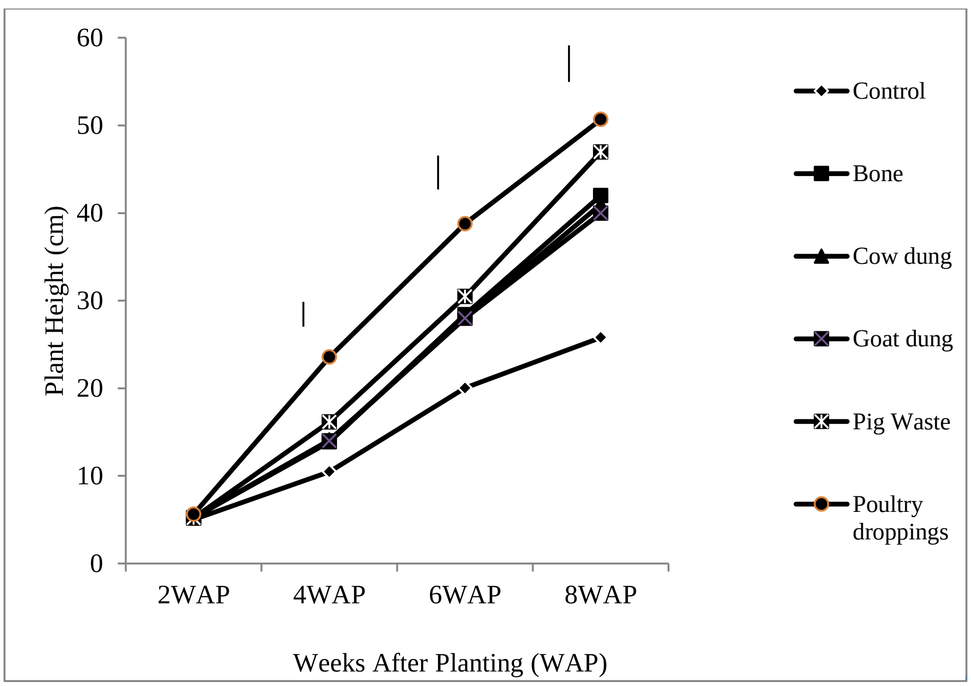

Fig 1: Okra plant height as affected by the applied different animal wastes biochar at weeks after planting. Vertical bars represent Lsd at $p \leq 0.05$.

The only significant (p≤0.05) value for the effect of the treatment (Fig 2) on plant stem girth was recorded at the eight week after planting with the poultry manure giving the highest significant (p≤0.05) value.

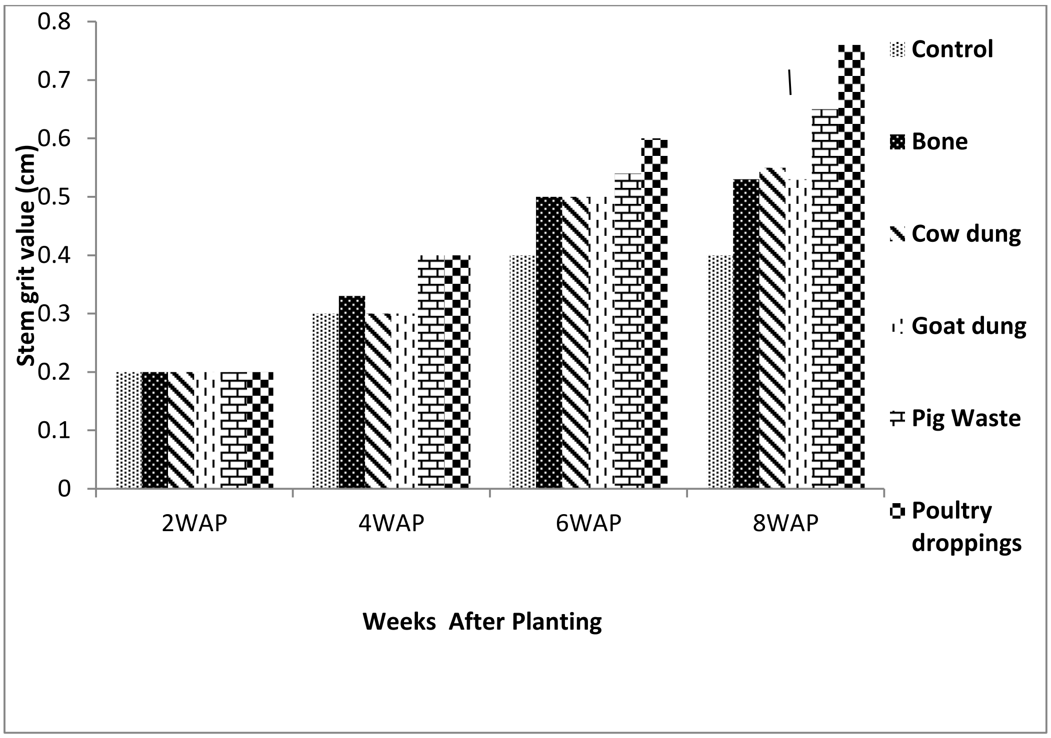

Fig 2: Okra plant stem girth as affected by the applied different animal wastes biochar at weeks after planting. Vertical bar represents lsd at (p≤0.05)

The application of poultry manure biochar (Fig 3) significantly (p≤0.05) increased the okra top biomass dry matter yield. The percentage increase of poultry manure over pig waste biochar was 9.57%, its increase over goat dung biochar was 28.14% and over Cow dung biochar was 22.61%. Poultry manure biochar percentage increase over bone biochar and control, were 23.41% and 49.01% respectively.

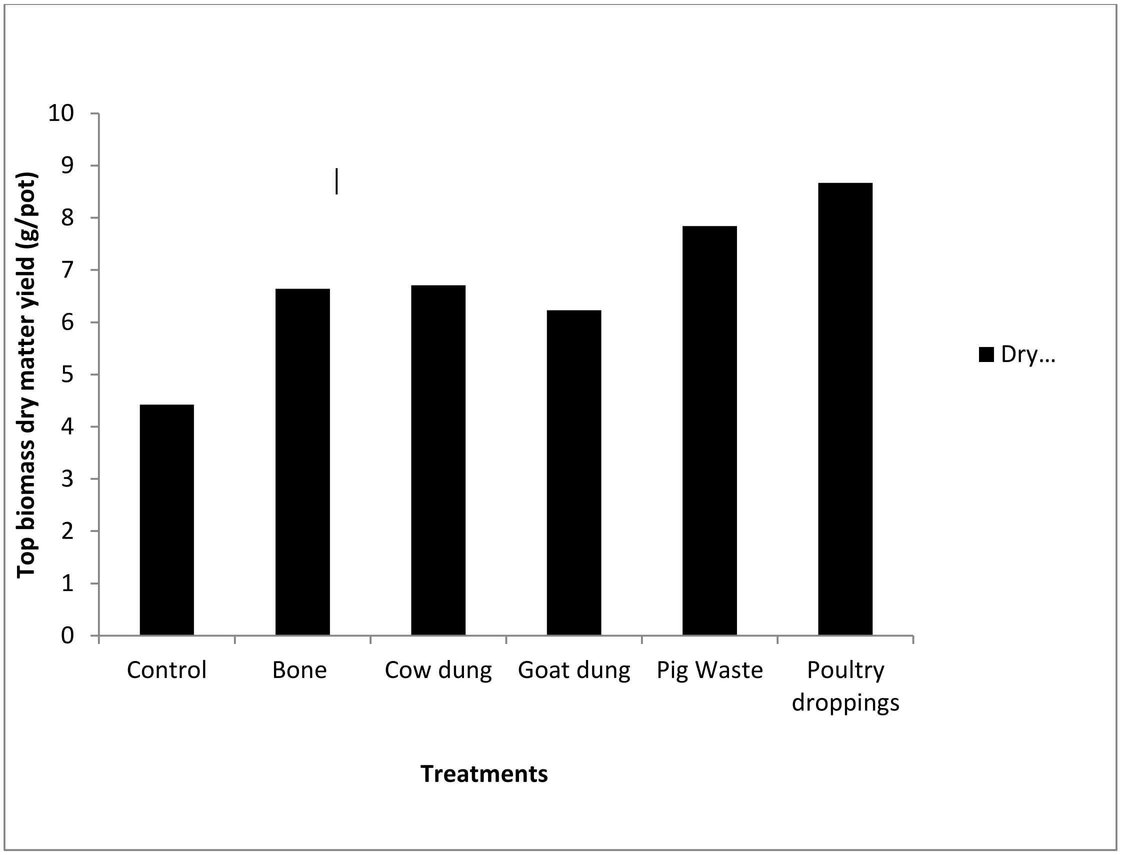

Fig 3: Treatments effect on top biomass dry matter yield (g/pot) of okra. Vertical bar represents lsd at ($p \leq 0.05$)

The result of the number of okra leaves as affected by the different plants wastes biochar is shown on Table 2. The result shows that there were no significant differences among the treatments and weeks of application.

Table 2: Number of Okra leaves as affected by the application of different plants wastes biochar at weeks after planting.

Treatment	Weeks After Planting				
	2	4	6	8	Mean
Control	3	5	7	9	6
Cocoa pod husk	4	6	8	10	7
Palm Bunch	4	7	8	10	7
Saw Dust	4	6	9	11	7
Rice Husk	3	6	9	11	7
Mucuna flagellipes	4	6	9	11	7
Wood shaving	3	7	9	11	7
Mean	4	6	8	9	
Lsd ($p<0.05$)	Ns	ns	ns	ns	

Fig 4 has the effect of the treatments on okra height at 2, 4, 6 and 8 weeks after planting. The result showed that at 6 and 8 weeks after planning, mucuna flagellipes biochar significantly ($p\leq05$) increased the plant height. It was also observed that the values of the plants that received mucuna flagellipes were higher than the other treatments throughout the weeks after planting. The okra heights were increased as the weeks of the okra growth increased.

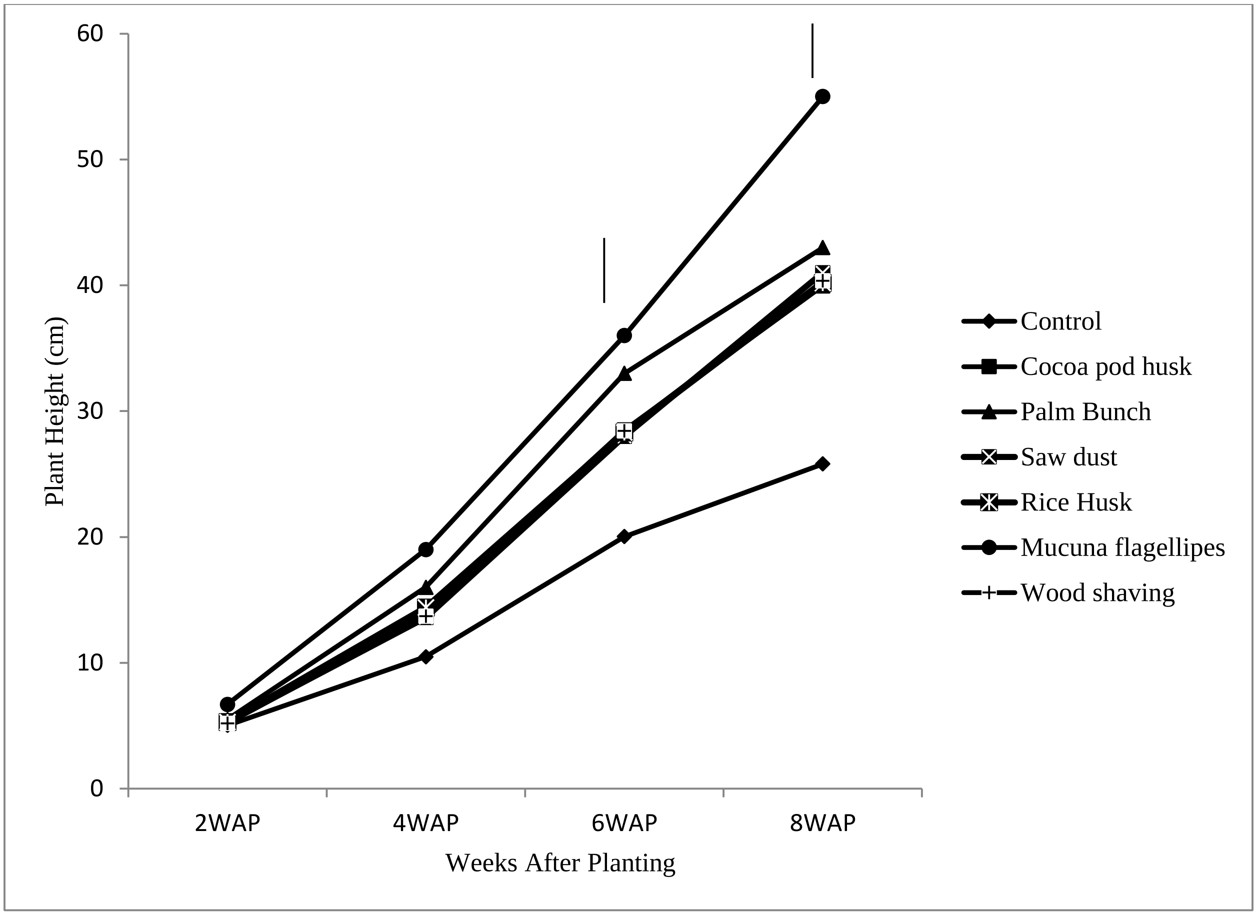

Fig 4: Okra plant height as affected by the applied plant wastes biochar at weeks after planting. Vertical bars represent LSD at p $\leq$0.05

At 6 weeks after planting (Fig 5) cocoa pod husk biochar significantly ($p \leq 0.05$) increased the stem girth. Mucuna flagellipes significantly ($p \leq 0.05$) increase the stem girth at 8 weeks after planting .The highest stem girth size was seen at 8 weeks after planting.

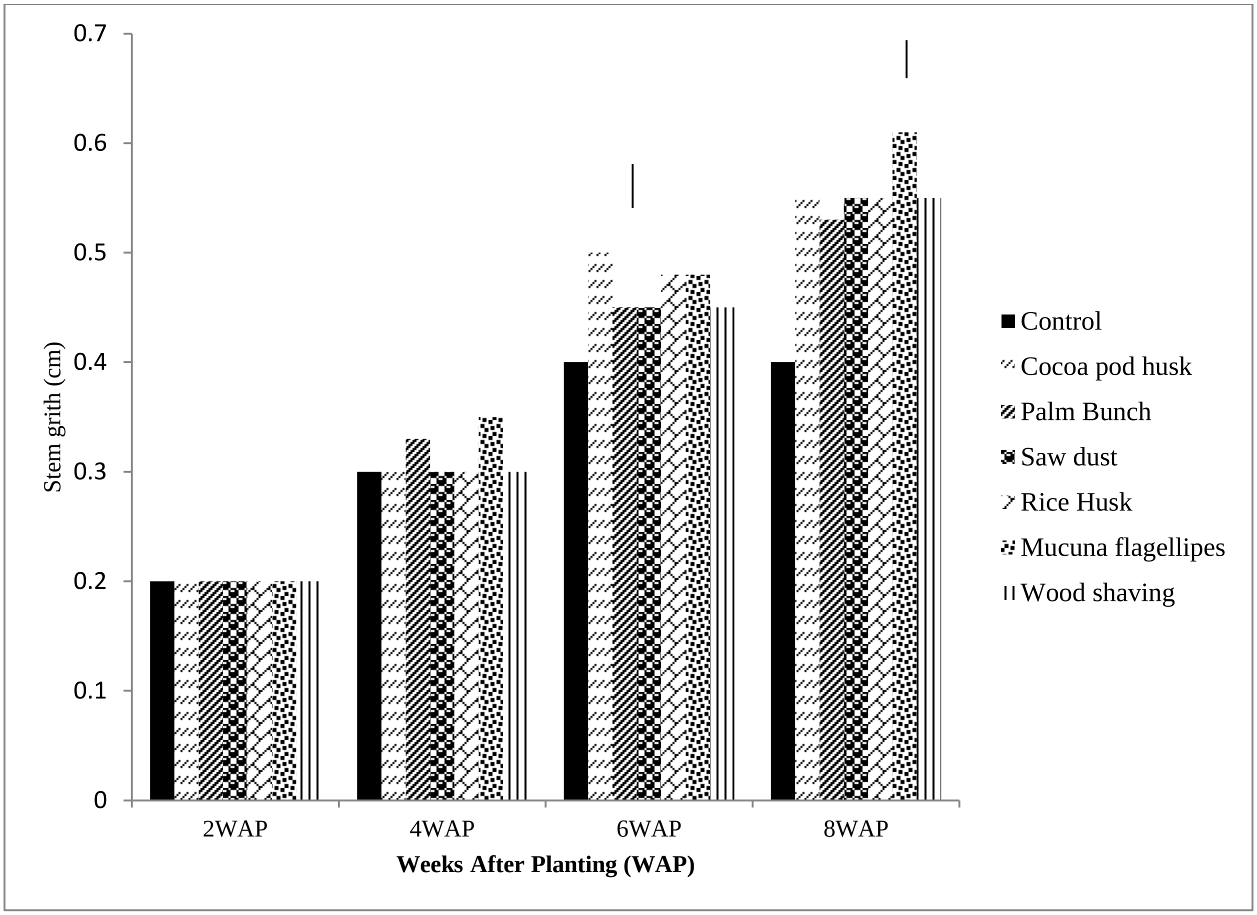

Fig 5: Okra plant stem girth as affected by the applied different plant wastes biochar at weeks after planting. Vertical bar represents lsd at ($p \leq 0.05$)

The applied mucuna flagellipes biochar (Fig 6) significantly ($p \leq 0.05$) increased the top biomass dry matter yield over the other treatments applied. This was followed by the palm bunch biochar.

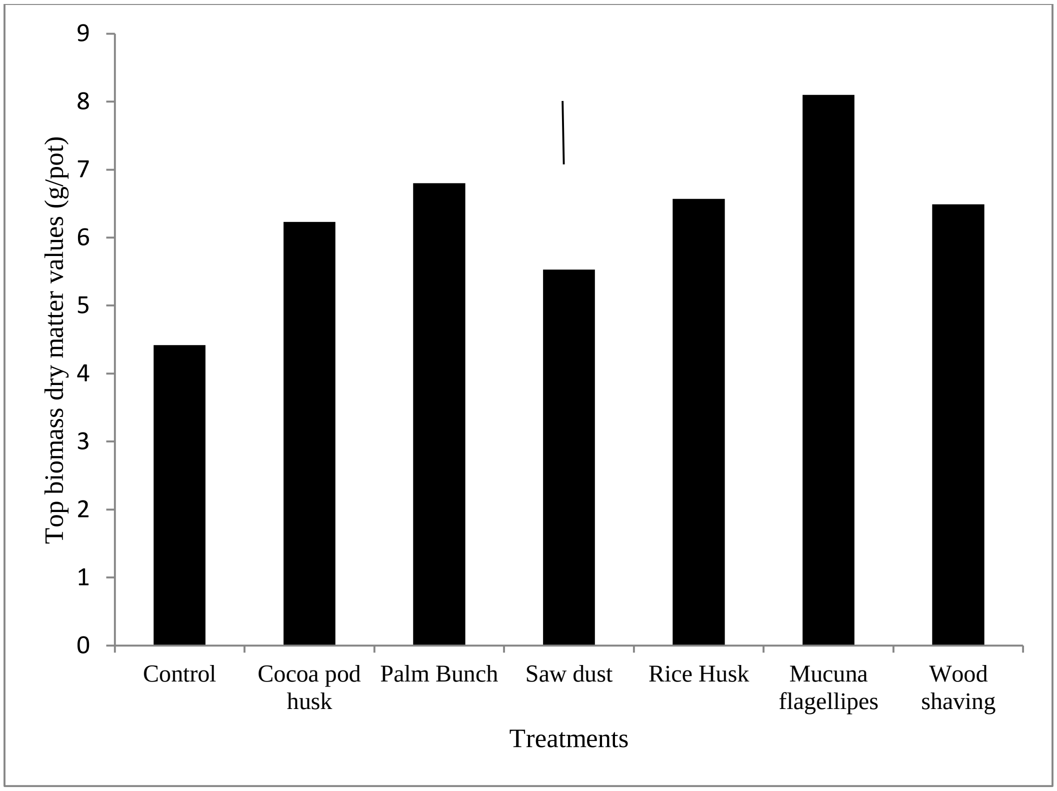

Fig 6: Treatments effect on top biomass dry matter yield (g/pot) of okra. Vertical bar represents lsd at ($p<0.05$)

The Pearson correlation between soil properties and plant parameters is shown on Table 3. Soil pH in water significantly ($p \leq 0.05$) and positively correlated with the top biomass dry matter yield. It also correlated positively and significantly ($p \leq 0.001$, $p \leq 0.01$ and $p \leq 0.001$) with stem girth, number of leaves and plant height respectively. Exchangeable acidity was highly significant ($p \leq 0.001$) but negatively correlated with the stem girth, number of leaves and plant height. It correlated negatively and significantly ($p \leq 0.05$) with top biomass dry matter yield. Available phosphorus significantly ($p \leq 0.05$) and positively correlated with the entire plant parameters. Nitrogen and organic carbon significantly ($p \leq 0.001$) and positively correlated with the top biomass dry matter yield, stem girth, number of leaves and plant height.

Table3: Pearson correlation between soil properties and plant parameters

Plant parameters	Soil Properties pH(H_2O)	EA	Av.P	N	OC	Ex.Ca	Ex. Mg	Ex. K	Ex. Na
Top dry biomass	0.66^{*}	-0.55^{*}	0.63^{*}	0.71^{***}	0.70^{***}	0.66^{*}	0.52^{ns}	0.86^{***}	0.83*
Stem girth	0.88^{***}	-0.88^{***}	0.62^{*}	0.89^{***}	0.90^{***}	0.84^{***}	0.89^{*}	0.45^{ns}	0.82*
No of Leaves	0.86^{**}	-0.93^{***}	0.57^{*}	0.84^{***}	0.86^{***}	0.89^{***}	0.90^{**}	0.41^{ns}	0.78*
Plant Height	0.92^{***}	-0.97^{***}	0.67^{*}	0.90^{***}	0.91^{***}	0.92^{***}	0.89^{**}	0.58^{*}	0.88*

*** = Significant at P < 0.001, ** = Significant at P < 0.01, * = Significant at P < 0.05

ns = not significant

Exchangeable calcium significantly correlated with top biomass dry matter yield at $p \leq 0.05$ and the other parameters measured at $p \leq 0.001$. No significant differences existed between exchangeable magnesium and top biomass dry matter yield though they were positively correlated. Number of leaves and plant height significantly ($p \leq 0.01$) and positively correlated with the exchangeable magnesium while stem girth had a positive correlation at a significant level of $p \leq 0.05$ with exchangeable magnesium. There were positive correlation among exchangeable potassium and the plant parameters. The levels of significance were $p \leq 0.001$ and $p \leq 0.05$ for top biomass dry matter yield and plant height respectively. Exchangeable sodium had a significant ($p \leq 0.05$) and positive correlation with all the plant parameters tested.

From the correlation matrix of plant parameters shown on Table 4, top biomass dry matter yield was significant at $p \leq 0.05$ and correlated positively with number of leaves and plant height. It had no significant effect on stem girth though positive. The stem girth correlated positively but not significant with number of leaves and plant height.

The number of leaves was highly significant ($p \leq 0.001$) and positively correlated with plant height.

Table 4: Pearson correlation matrix of plant parameters

Plant parameters	Top biomass	Stem girth	No of Leaves	Plant Height
Top biomass	-			
Stem girth	0.59^{ns}	-		
No of Leaves	0.41^{*}	0.92^{ns}	-	
Plant Height	0.62^{*}	0.94^{ns}	0.96^{***}	-

Discussions

The result of the experiment showed that the application of biochar made of plants and animals' origin increased the plant parameters over the control. This result was in agreement with the results gotten by [12] and [13], who also observed that the application of biochar increased the plant parameters. They worked on using biochar as a soil amendment for sustainable agriculture and found the agronomic values of green waste biochar as a soil amendment in their respective works. To further confirm that biochar increased the plant parameters, the correlation result showed that most of the soil properties significantly and positively correlated with the plant parameters. The increase in the soil properties that resulted in the increase of most of the plant parameters measured would have possibly come from the applied biochar. Biochar produced from poultry manure and pig waste feedstocks were able to increase most of the plant parameters tested. Some researchers such as [14], [15] and [16] who worked with different animal manure, reported that the most outstanding manure in terms of improvement of soil properties and plant parameters was poultry manure. They attributed the performance to many essential plant nutrients that it contained when compared to other manure types. This may also be the reason why the biochar produced from poultry manure and pig waste showed better improvement of the plant parameters when compared to the others tested.

Among the biochar produced from the plants feedstock, mucuna flagellipes feedstock biochar significantly increased most of the parameters tested over the other plant feedstocks biochar. The outstanding performances of Mucuna flagellipes may be because it is a protein and belongs to the leguminous family. Similar result of legumes performing better than other non-leguminous residue was reported by [17]. In their work on the amelioration effects of low temperature biochar generated from nine crop residues on an acidic Ultisol, they observed that the application of biochar from legumes increased the soil pH in acidic soil. When the soil pH is increased, most soil nutrients are available for crop assimilation which will then be translated into increased growth and yield.

The soil properties that correlated positively with the yield parameters imply that as the soil properties were increasing the yield parameters were also increasing. Therefore the addition of biochar produced from these materials, impacted positively on the plant parameters by supplying the needed plant nutrients. The positive correlation between the top biomass dry matter yield and the number of leaves and plant heights shows that they contributed to the weight of the top biomass dry matter yield. It would also be deduced that the higher that plants increase vertically the more the number of leaves. This explains why there was a positive and highly significant relationship between the number of leaves and plant height.

Conclusion

From the study it can be concluded that the application of biochar produced from animal and plant feedstocks increased the okra growth, number of leaves, stem girth and top biomass dry matter yield over the control. It was further observed that biochar produced from poultry manure feedstocks increased the plant parameters tested and this was followed by pig waste biochar. Among the biochar produced from plant feedstocks, mucuna flagellipes increased the values of the parameters measured among the plant biochars. The study showed the promising potentials of poultry manure, pig waste and mucuna flagellipes waste biochar in increasing okra production in Umudike area of Abia State, Nigeria. A long term field experimental study using biochar produced from the animal manure and plant feedstocks at different rates is important to further ascertain the prospective of the material in the study area.

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