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ORIGINAL RESEARCH

Growth, yield and proximate composition of plantain, *musa species* cultivated on soils amended with crop residues

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Abstract

Purpose This study investigated the potentials of crop residues to improve the growth and yield of plantain as well as its proximate compositions.

Method Biochar, Cocoa pod husk and Rice bran were applied at the rates 4, 6, 8, and 10 tons per hectare after three weeks of sucker establishment on experimental plots. The experiments were carried out in two different locations; FUTA and Ejigbo, and were laid out in a completely randomized block design with four replications. The following growth parameters including leaf number, plant height, stem girth, leaf area, and sucker number were monitored for six consecutive months commencing from 90 days after sucker establishment while the yield parameters including bunch weight, finger number, finger girth, bunch length, and yield per hectare were determined during harvesting. These parameters were determined for both parents and ratoon. Also, the proximate composition of the plantain was determined.

Results There was no statistically significant difference for all the growth parameters determined in both FUTA and Ejigbo locations for both the parent and ratoon crops except the leaf area which increased significantly in amended soils compared to the control. All amendments produced higher bunch weight, finger number, and yield per hectare compared to the control. The different soil amendments did not alter the proximate compositions of the plantain significantly for the two locations.

Conclusion It is therefore concluded that crop residues especially cocoa pod husk at the rate of 10 tons/hectare be used as alternative to mineral fertilizers to enhance soil health and productivity.

Keywords Soil amendment, Biochar, Cocoa pod husk, Rice bran, Plantain

Introduction

Plantain is an important staple food for more than 50 million people in Nigeria, and other tropical nations, ranking third among starchy food after cassava and yam (Akinyemi et al. 2010). Aside its importance as a major staple food, plantain is a major raw material for several small and medium industries. The numerous uses of

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plantain have therefore resulted in imbalance in its production and demand. The global production of plantains and bananas in the year 2018 alone was estimated as 115.7 million metric tons with Asia and Africa accounting for more than 70 % of the global production (Statista 2020). Overall, the average yield per hectare of plantains and bananas has been estimated to range between 14-20 tons per hectare (FAO 2021). There is good evidence of increasing trend of per capita consumption of plantains and bananas over the years. The projected increasing demand therefore necessitated the need for sustainable agricultural practices that would improve the growth and yield of cultivated plantains.

Soil nutrient depletion has been identified as the major constraint to the sustainability of plantain yield and a factor in the loss of its perennial productivity (Meya et al. 2020). Currently, soil fertility management in plantain-based farming systems relies largely on applications of mineral fertilizers (Meya et al. 2020). However, the unregulated use of inorganic fertilizers has been linked to several human and environmental challenges such as death of beneficial soil microorganisms and water pollution. In addition, leaching increased the amount of nitrites in water bodies which may react with hemoglobin resulting in methaeglobinaemia (Tsion and Steven 2019). To circumvent these shortcomings, there is therefore the need to source for alternatives, and soil organic amendments fit nicely to meet these challenges.

The literature is quite rich on the potentials of organic amendments such as composted farmyard manure and green manure being able to improve soil fertility especially in the initial years of the crops (Gopinath et al. 2008; Ghosh and Devi 2019; Hammed et al. 2019).

Organic amendments improve soil fertility by enhancing the biological, physical and chemical properties of the soil like microbial population, bulk density, water-holding capacity, porosity, infiltration rates, electrical conductivity, soil pH, total carbon, etc. (Angelova et al. 2013; Cayci et al. 2017). Toward soil fertility improvement, ashing and composting of agro wastes had been conventional ways by which most of these organic nutrient sources are being incorporated in the soil as amendments. Ashing and composting involve complex procedures that are time-consuming, and scientifically difficult for most of local farmers to handle. It is therefore imperative to develop an innovation that could be easily adopted by the farmers. The present study therefore focuses on the impacts of soil amendment using crop residues like Biochar, rice bran, and cocoa pod husks applied (in their natural forms) in form of mulching on the growth, yield and proximate composition of plantain fruits.

Materials and methods

Experimental sites description

The study was carried out in two locations; Teaching and Research Farms of Osun State University, Ejigbo, Osun State (Lat. 7.9045° N, Long. 4.3052° E) and the Federal University of Technology, Akure, Ondo State (Lat. 7.3070° N, Long. 5.1398° E). The two locations are within the rain forest zone of southwest Nigeria, and about 370 m above sea level. The rainfall pattern in the areas is bimodal with average of 1200 - 1400 mm annually. The textural soil classes in the sites are sandy loamy for FUTA and sandy clay loam for Ejigbo. The sites had been under continuous arable crop cultivation in the last ten years, using majorly mineral fertilizer for soil nutrient replenishment. The map of the study area is shown in Fig. 1.

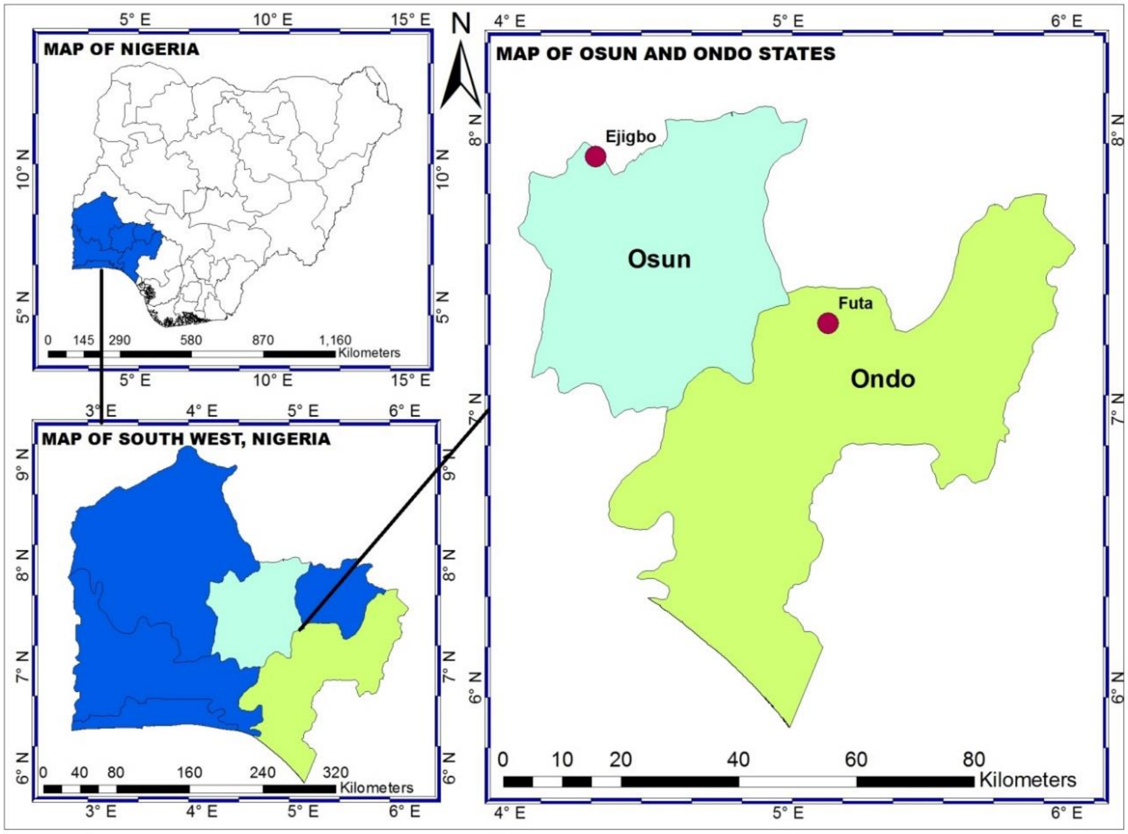

Fig. 1 Showing the map of the study locations

Soil sample collection and determination of nutrient compositions of the crop residues

Prior to crop establishment, composite soil samples were collected from thirty different spots at depths of 0 to 20 cm from each location for the determination of the physicochemical properties such as bulk density, porosity, volumetric water content, soil pH, total nitrogen, and organic carbon. Similarly, the analyses of nutrient and organic compositions of the crop residues under investigation were performed following the procedures described in AOAC (2003).

Field preparation and crop establishment

The experimental sites in the two locations were established in the month of May, 2017, and terminated after the harvesting of the ratoon crops in the month of October, 2019. The fields were ploughed and laid out into plots of 1 m inter plot spacing and 2 m spacing between replicates. Two healthy suckers were planted in 40 cm by 40 cm by 40 cm holes at 3 m by 3 m planting distance (1,111 plants per ha).

Collection of crop residues and preparation of biochar

Rice bran was collected from a local rice mill in Ede, Osun State, Nigeria while cocoa pod husk was collected from a cocoa plantation in Ifewara, Osun State, Nigeria. The mineral fertilizer (NPK 15-15-15) was purchased from a local retail agrochemical store in Ejigbo, Osun State, Nigeria. The collected cocoa pod husk and rice bran were sun-dried for three days after which the dry rice bran was packaged and stored in sack bags at room temperature until use while the cocoa pod husk was grounded into granule using electric mill machine. The ground cocoa pod husk was packaged into sack bags and stored until use.

The Biochar used in the study was locally produced from mango tree due to non-availability of Pyrolizer. Briefly, logs of wood were obtained from mango trees; anaerobic condition was created for the incomplete combustion of the woods by covering the logs with soils excavated from the surrounding while leaving some holes for the passage of air. Later, fire was introduced into the buried logs through the holes and the temperature was checked using a thermometer on the 2nd, 4th, and 6th days after the fire has been introduced into the system; the average temperature was found to be 150 ± 22 °C. The whole process was completed in seven days and summarized in Fig. 2.

Fig. 2 Steps in local production of biochar from mango tree (A): Arrangement of logs for local pyrolysis. (B): Logs were covered with soil and fire was introduced from within to create anaerobic wood combustion under 1500 ºC. (C): The process completed in the 7th day. (D): Harvesting of the Biochar

Experimental design and treatments application

The experimental design followed a completely randomized block design. After two weeks of planting, thinning was done to give room for the vigor plant after which crop residues; Biochar (BCH), Rice bran (RB) and Cocoa pod husk (CPH) were applied as organic amendments in the form of mulching on the soil surface. Also, NPK 15:15:15 fertilizer was applied in four splits as a positive control while the unamended soil was the negative control. The crop residues were applied at four different rates; 4, 6, 8, and 10 tonnes dry matter per hectare while mineral fertilizer was applied at three rates; 100, 200, and 300 kg NPK per hectare. A block contains 16 experimental units; this gives 64 experimental units in each location.

Cultural practice

Weeding was carried out at 4 weeks' interval during the rainy season and 8 weeks in the dry season. Dead and diseased leaves were pruned regularly while bamboos poles were used to prop bunch-bearing plants against lodging or breaking of psoudostem due to wind and heavy bunches. Desuckering was done at the inception of flowering, to give room for better utilization of nutrient for fruit formation. The plants were monitored for two consecutive cropping cycles (parent and ratoon).

Data collection

Data on vegetative growth parameters were collected 90 days after planting and were collected for six consecutive months at thirty days' interval. The growth parameters that were collected include plant height (cm) using measuring tape, stem girth (cm) using measuring tape, leaf number, leaf area (cm^2) and sucker number. Similarly yield indices such as bunch weight (kg), finger girth (cm), finger length (cm), finger number and yield per hectare were collected at harvesting for parent and ratoon crops.

Plantain proximate analyses

The proximate analyses of plantain samples were performed following the procedures by AOAC (2003). The moisture content was estimated by drying the samples in an oven at about 105 °C for 8 h until a constant weight was obtained. The difference in weight just before drying and after drying was the amount of moisture in the samples. The protein content was determined by micro Kjeldahl method. This involves the digestion of plantain samples by sulphuric acid in a micro Kjeldahl flask, and then diluting the digested sample with sodium hydroxide and distilled water. The released ammonia was collected in a boric acid solution and total nitrogen was determined titrimetrically. The ash content was determined after burning the samples for about 20 h at 550 °C till a white residue was obtained. The fat content was determined by grinding the dry samples into fine powders, and the fat extracted with chloroform and methanol mixture. The solvent was allowed to evaporate after extraction and the weight of the extracted material were recorded. The fibre content was determined by boiling about 5 g of the sample in 150 ml of 1.25 % H_2SO4 solution for 30 min under reflux. The boiled sample was washed in several portions of hot water using a two-fold cloth to trap the particles. The samples were then returned to the flask and boiled in 150 ml of 1.25 % NaOH for another 30 min under the same condition, they were thereafter washed severally in hot water and then allowed to drain, dry before being transferred to a weighing crucible where it was dried in the oven at 105 °C to a constant weight.

Statistical analyses

Data on growth and yield parameters, and proximate composition were subjected to a one-way analysis of variance, and means were separated using Tukey's tests. Data from the two locations for the growth and yield parameters were compared using T-test analyses. Statistical analyses were performed using the GraphPad Prism software (version 5). Data were reported as mean ± standard error, and statistical significance was assumed at $p < 0.05$.

Results and discussion

Physicochemical properties of soil

The data on the physicochemical parameters of the soil for the two locations prior to treatment application are shown on Table 1. Analysis of soil samples showed that there was a distinct variability in the textural classes of the soil from the two locations; Ejigbo soil is basic clay loam (pH 7.7) while FUTA soil is acidic sandy loam (pH 5.05). The acidic nature of FUTA soil could have been responsible for low availability of plant major elements and some cations both in quantity and quality (Wardle et al. 2008; Miller 2016; Feder et al. 2020). The trace elements were also present in low quantity except iron (Fe). This is an indication that the soils were low in fertility status and this is characteristic of tropical soils according to the report of Attoe et al. (2006).

Nutrient compositions of the crop residues

The data on the nutrient composition of the crop residues used for the soil amendments are shown on Table 2. The crop residues differed significantly in the values of most of the nutrients determined ($p < 0.05$) except for total nitrogen and calcium in which the values were similar. Cocoa pod husk had the highest values for most of the nutrients determined such as phosphorous, potassium, magnesium, copper, manganese and iron while Biochar had the highest value for organic carbon. The reason for the variations in the nutrient composition of the crop residues could be due to the fact that they were derived from different crops of varying chemical compositions. The relatively higher nutrient values recorded for cocoa pod husk in this study was consistent with the reports from other studies which also showed that cocoa pod ash is rich in major elements such as N, P, K, Ca, and Mg (Odedina et al. 2003; Ayeni et al. 2008; Adu-Dapaah et al. 1994). The nutrient composition of rice bran is majorly fibre of high lignin concentration (Liu et al. 2021). The high C:N in biochar and rice bran would support a longer time for decomposition and nutrient mineralization and could be the reason for their long term effects on the soil health properties (Campos-Vega et al. 2018; Liu et al. 2021).

Table 1 Physicochemical property of soil before treatment application

Soil properties	FUTA	EJIGBO
pH (water 1:1)	5.05	7.7
Electric conductivity	114	138
Total OC (g/kg)	12.0	13.4
Total N (g/kg)	0.28	0.45
Av.P (mg kg^{-1})	10.34	63.46
K (cmol/kg)	0.54	0.60
Mg (cmol/kg)	0.90	3.17
Ca (cmol/kg)	2.90	8.84
Na (cmol/kg)	0.25	0.29
CEC (cmol/kg)	4.59	12.9
Zn (mg/kg)	0.19	0.02
Mn (mg/kg)	2.85	0.37
Fe (mg/kg)	542.58	45.17
Cu (mg/kg)	0.04	0.22
Particles size (%)		
Sand	60.8	36.8
Silt	12	20
Clay	27.2	43.2
Textural class	Sandy loam	Clay loam

Effects of crop residues on growth parameters

The growth parameters of the parent and ratoon crops with respect to various soil amendments are presented in Tables 3 and 4, respectively. For the parent crops, there was no statistically significant difference in plant height in Ejigbo whereas soil amendment resulted in significant increase in plant height in FUTA compared to the control. The heights of plantain ranged from 100.88 cm to 127.38 cm in FUTA and 121.38 cm to 138.81cm in Ejigbo. Also, plant heights were significantly higher in Ejigbo compared to FUTA for all the amendments, and even the control. Similarly, soil amended with crop residues had significantly higher plant height for the ratoon crops in both FUTA and Ejigbo compared to the control.

The mean values of plant height for FUTA ranged from 94.00 to 111.00 cm while the values for Ejigbo ranged from 100.12 to 141.75 cm. Again, plant heights were significantly higher in Ejigbo compared to FUTA for all the amendments. The leaf number did not differ significantly among the treatment groups in both FUTA and Ejigbo for the parent and ratoon crops. Also, the leaf number was statistically the same at the two locations for all the treatment groups except for the control of the ratoon crops in which leaf number was significantly higher in Ejigbo. The lowest values of leaf number recorded for FUTA were 9.75 and 8.00 for parent and ratoon crops, respectively while the highest values were 11.06 and 10.44, respectively. For Ejigbo location, the lowest values of leaf number were 11.56 and 11.25, respectively while the highest values were 12.33 and 12.06, respectively. In both FUTA and Ejigbo locations, soil amendment with crop residues significantly increased the stem girth of the parent and ratoon crops in comparison to the control. To the most extent, the stem girth was the same at the two locations except for soil amended with biochar and control in which the stem girth was significantly higher in Ejigbo. All amendments resulted in significant increase in the sucker number compared to the control at the two locations for both the parent and ratoon crops. Again, for both the parent and ratoon crops, Ejigbo location had significantly higher sucker number compared to FUTA for all the amendments and the control. The sucker number ranged from 0.5 to 2.25 in FUTA and 4.25 to 9.09 in Ejigbo for the parent crops. For the ratoon, the sucker number ranged from 0.5 to 2.43 in FUTA and 6.50 to 8.19 in Ejigbo. For the parent crops, all amendment resulted in significant increase in leaf area in FUTA while there was no significant effect of soil amendment on leaf area in Ejigbo. For the ratoons, there was no significant effect of soil amendment on the leaf area for the two locations. Just as for the other growth parameters, Ejigbo location had significantly higher leaf area compared to FUTA for all the amendments and the control for both the parent and ratoon crops.

The growth parameters considered in the study showed that amendment of soil with crop residues produced better results in comparison to the control, and these effects were mostly comparable or better than those by mineral fertilizer. This agreed with the findings of Sombo and Ntamwira (2020) who reported that application of organic fertilizers enhanced growth parameters such as plant height, pseudostem circumference at flowering and number of leaves per plant of tomato. Similarly, the amendment of soil with Biochar significantly increased the leaf number and yield of lettuce in comparison to unamended condition (Trupiano et al. 2017). In another study, Oladele et al. (2019) reported a significant increase in the growth and yield of upland rice cultivated on alfisol in response to amendment of the soil with biochar. The improved growth of crops cultivated on soils amended with crop residues could be due to the fact that these organic amendments increased the water and nutrient holding capacity of the soils thus making both water and nutrients available to the crops (Hagemann et al. 2017).

Effects of crop residues on yield parameters

The yield parameters of the parent and ratoon crops with respect to various soil amendments are presented in Tables 5 and 6, respectively. The data on yield in term of tons per hectare at the different application rates of the crop residues were shown in Fig. 3 and Fig. 4 for FUTA and Ejigbo, respectively. For all the crop residues, the yield/hectare increased increasing application rate such that the yield per hectare was lowest at the application rate of 4 tons per hectare. In both FUTA and Ejigbo locations, soil amendment with crop residues significantly increased the bunch weight of the parent and ratoon crops in comparison to the control.

Table 2 Nutrient compositions of the crop residues used for the soil amendment

Treat-ment	Org C (%)	TN (g/kg)	P (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)
BCH	21.27± 0.96[b]	2.73± 0.16[a]	0.13± 0.10[a]	0.18± 0.01[b]	1.06± 0.02[a]	0.18± 0.01[b]	12.06± 0.03[b]	16.77± 0.25[a]	51.47± 0.84[b]	2.10± 0.26[a]
CPH	11.90± 0.20[a]	2.54± 0.06[a]	0.33± 0.10[a]	1.75± 0.05[c]	1.08± 0.01[a]	0.84± 0.03[c]	83.92± 0.47[c]	349.13± 1.09[c]	417.9± 2.23[c]	177.87± 1.29[c]
RB	10.73± 0.38[b]	2.84± 0.06[a]	0.11± 0.10[a]	0.03± 0.02[a]	1.29± 0.01[b]	0.05± 0.02[a]	4.45± 0.36[a]	139.97± 1.00[b]	14.47± 0.45[a]	155.57± 0.51[b]

Means with the same alphabets are not significantly different across the column. BCH: Biochar, CPH: Cocoa pod husk, RB: Rice bran.

Table 3 Effects of crop residues on the growth parameters of parent crops in FUTA and EJIGBO after 60 days of planting

Treat ment	Leaf number (N)		Plant height (cm)		Stem girth (cm)		Sucker (N)		Leaf area (cm^2)	
	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO
BCH	10.75± 0.55[aA]	12.13± 0.20[aA]	115.00± 7.93[bA]	134.45± 14.88[aB]	36.68± 1.46[bA]	37.63± 3.65[bA]	1.94± 0.37[bA]	7.94± 0.91[bB]	51.25± 2.27[bA]	61.25± 0.75[aB]
CPH	10.50± 0.65[aA]	12.19± 0.28[aA]	121.63± 7.92[bA]	133.25± 16.82[aB]	37.13± 2.38[bA]	39.00± 2.289[bA]	1.81± 0.39[bA]	8.80± 1.05[bB]	52.94± 1.85[bA]	67.56± 1..59[aB]
MF	11.06± 0.39[aA]	12.33± 0.48[aA]	127.38± 12.65[bA]	135.81± 13.39[aB]	39.33± 4.72[bA]	41.75± 2.50[bA]	2.25± 0.52[cA]	9.09± 1.64[bB]	54.67± 5.14[bA]	68.63± 1.29[aB]
RB	10.63± 0.61[aA]	12.00± 0.91[aA]	113.00± 5.83[bA]	131.38± 8.21[aB]	36.19± 1.56[bA]	38.87± 3.65[bA]	1.63± 0.35[bA]	7.19± 1.11[bB]	50.43± 2.93[bA]	65.31± 0.84[aB]
CL	9.75± 1.10[aA]	11.56± 0.27[aA]	100.88± 5.57[aA]	121.38± 12.65[aB]	21.50± 2.63[aA]	28.00± 3.76[aB]	0.50± 0.29[aA]	4.25± 2.56[aB]	41.25± 4.01[aA]	59.75± 0.69[aB]

BCH: Biochar, CPH: Cocoa pod husk, RB: Rice bran, MF: Mineral fertilizer, CL: Control; Means with the same lower case alphabets are not significantly different across the column while means with the same upper case alphabets are statistically the same for the same parameters between FUTA and Ejigbo along the row.

Table 4 Effects of crop residues on the growth parameters of ratoon crops in FUTA and EJIGBO

Treat-ment	Leaf number (N)		Plant height (cm)		Stem girth (cm)		Sucker (N)		Leaf area (cm^2)	
	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO
BCH	10.13± 0.18[aA]	11.88± 0.29[aA]	111.00± 4.44[cA]	141.75± 11.21[cB]	33.88± 1.41[bA]	35.56± 1.98[aA]	2.13± 0.24[bA]	6.81± 0.64[aB]	51.13± 1.03[cA]	64.87± 1.45[cB]
CPH	10.44± 0.20[aA]	13.50± 0.26[bA]	114.50± 4.30[cA]	188.92± 8.56[dB]	31.44± 1.16[bA]	40.25± 1.55[aA]	2.43± 0.22[bA]	7.06± 0.73[aB]	58.88± 1.43[dA]	67.93± 1.16[dB]
MF	9.75± 0.18[aA]	11.50± 0.29[aA]	100.92± 5.59[bA]	116.00± 6.83[bB]	33.92± 1.55[bA]	39.58± 2.07[aA]	1.92± 0.31[bA]	6.58± 0.66[aB]	48.83± 1.30[bA]	60.17± 1.47[bB]
RB	9.56± 0.20[aA]	12.06± 0.27[aA]	112.50± 3.77[cA]	139.12± 6.05[cB]	34.63± 1.21[bA]	39.69± 1.87[aA]	2.31± 0.25[bA]	8.19± 1.01[aB]	49.81± 1.10[bA]	64.19± 1.22[cB]
CL	8.00± 0.58[aA]	11.25± 1.11[aB]	94.00± 10.40[aA]	100.12± 5.99[aA]	27.50± 3.75[aA]	34.44± 1.72[aB]	0.50± 0.29[aA]	6.50± 0.96[aB]	36.00± 4.65[aA]	48.75± 1.79[aB]

BCH: Biochar, CPH: Cocoa pod husk, RB: Rice bran, MF: Mineral fertilizer, CL: Control; Means with the same lower case alphabets are not significantly different across the column while means with the same upper case alphabets are statistically the same for the same parameters between FUTA and Ejigbo along the row.

To the most extent, the bunch weight was the same at the two locations except for soil amended with biochar and mineral fertilizer in which the bunch weight was significantly higher in Ejigbo. There was no statistically significant difference in the bunch weight between the control and mineral fertilizer in the ratoons. All amendments resulted in significant increase in the finger number compared to the control at the two locations for both the parent and ratoon crops. For both the parent and ratoon crops, there was no significant difference in finger number in the two locations for all the amendments with the exception of control of ratoon crops which had higher finger number in Ejigbo. The finger number ranged from 18.25to 28.25 in FUTA and 17.25 to 31.81 in Ejigbo for the parent crops. For the ratoon, the finger number ranged from 14.50 to 27.13 in FUTA and 18.50 to 25.94 in Ejigbo. For the two locations, soil amended with crop residues significantly increased the finger length of the parent and ratoon crops in comparison to the control. There was no significant difference in the finger length between the two locations for all the soil amendments in the parent and ratoon crops. The finger length did not differ significantly between the control and mineral fertilizer in the ratoons. For the parent crops, soil amendment with Biochar and rice bran resulted in significant increase in finger girth compared to control in FUTA while there was no significant difference in the finger girth among the treatment groups in Ejigbo. For the ratoon crops, all amendments resulted in significant increase in the finger girth compared to the control at the two locations while there was no difference in the finger girth between the control and mineral fertilizer. In both FUTA and Ejigbo locations, soil amendment with crop residues significantly increased the yield per hectare of the parent and ratoon crops in comparison to the control. To the most extent, the yield per hectare was the same at the two locations for all the amendments. There was no statistically significant difference in the bunch weight between the control and mineral fertilizer in the ratoon. The yield indices in the soils amended with crop residues were significantly better than those of mineral fertilizers in ratoon crops while there was no difference in these indices in the parent crops for the two locations. The better performance of the crop residues could be attributed to the delay in the decomposition and mineralization of crop residues and the remaining of above- and below- ground decomposing residues of parent plant which synchronized with nutrient uptake by ratoon crops. Raphael (2006) and Rodrigues et al. (2010) reported that the residues from parent plant contribute to the nitrogen nutrition of ratoon crop. This also agreed with the findings of Teixeira et al. (2008), which reported that ratoon crop grows simultaneously with the decomposition of residues from the parent plant in a semi- perennial plantation, since just about 30% of the nitrogen content of the parent plant is exported by bunches at harvest (fruits + peduncle). Also, the ability of cocoa pod husk to perform better than the other crop residues with respect to yield parameters in ratoon crops could be as a result of its reduced lignification which makes its decomposition slower than other crop residues and was therefore able to release nutrients into the soil for a longer period (Campos-Vega et al. 2018; Stewart et al. 2015).

Effect of crop residues on proximate composition of plantain

The proximate compositions of the plantain pulps in Ejigbo and FUTA were as shown in Tables 7 and 8, respectively. There was no significant difference ($P \geq 0.01$) between the various soil amendments both FUTA and Ejigbo, with regards to the moisture content of plantain fruit. The moisture content ranged from 61.04 to 62.52 % in FUTA, while that of Ejigbo was 61.19 to 62.86 %.

Table 5 Effects of crop residues on the yield parameters of plantain parents in FUTA & EJIGBO at harvesting

Treat-ment	Bunch weight (kg)		Finger Number (N)		Finger Length (cm)		Finger Girth (cm)		Yield (t/ha)	
	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO
BCH	6.56± 0.41^{bA}	8.00± 0.67^{bB}	27.44± 2.42^{aA}	29.06± 2.33^{cA}	24.93± 1.42^{bA}	25.93± 1.52^{bA}	15.25± 1.57^{bA}	16.25± 0.57^{aA}	8.42± 0.37^{bcA}	8.50± 41^{bA}
CPH	6.56± 0.61^{bA}	7.19± 0.32^{bA}	26.93± 1.57^{aA}	30.31± 1.88^{cA}	26.71± 0.69^{cA}	28.81± 0.79^{cB}	17.07± 0.50^{aA}	16.77± 1.50^{aA}	8.98± 0.17^{bA}	9.98± 0.27^{bA}
MF	8.50± 0.38^{cA}	12.24± 0.69^{cB}	28.25± 2.37^{aA}	22.75± 1.51^{bA}	26.63± 0.73^{cA}	28.75± 0.93^{cB}	16.07± 1.35^{bA}	15.08± 0.45^{aA}	9.82± 0.31^{cA}	11.58± 0.41^{cA}
RB	6.44± 0.59^{bA}	7.130± 0.45^{bA}	24.56± 1.54^{aA}	31.81± 3.78^{cA}	23.36± 1.23^{bA}	24.37± 1.33^{bA}	15.93± 0.49^{bA}	16.93± 0.39^{aA}	8.46± 0.36^{bcA}	8.73± 0.25^{bB}
CL	3.90± 1.44^{aA}	4.00± 0.41^{aA}	18.25± 9.80^{bA}	17.25± 2.28^{aA}	19.50± 1.91^{aA}	21.50± 0.95^{aA}	12.00± 0.51^{aA}	13.00± 0.81^{aB}	5.280± 0.53^{aA}	5.30± 0.59^{aA}

BCH: Biochar, CPH: Cocoa pod husk, RB: Rice bran, MF: Mineral fertilizer, CL: Control; Means with the same lower case alphabets are not significantly different across the column while means with the same upper case alphabets are statistically the same for the same parameters between FUTA and Ejigbo along the row.

Table 6 Effects of crop residues on yield parameters of plantain Ratoon both in FUTA & EJIGBO

Treat-ment	Bunch weight (kg)		Finger Number (N)		Finger Length (cm)		Finger Girth (cm)		Yield (t/ha)	
	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO	FUTA	EJIGBO
BCH	8.037± 0.49^{bA}	8.67± 0.51^{bA}	24.88±1 .28^{bA}	25.44± 1.19^{bA}	24.69± 0.90^{bA}	26.69± 0.80^{bA}	16.33± 0.44^{bA}	17.43± 0.43^{bA}	9.90± 0.32^{bA}	9.50± 0.33^{bA}
CPH	9.95± 0.29^{bA}	8.24± 0.36^{bA}	27.13±1 .41^{bA}	25.56± 1.76^{abA}	24.31± 0.84^{bA}	27.31± 0.74^{bA}	19.12± 1.41^{bA}	20.52± 0.85^{bA}	10.12± 0.12^{bA}	13.13± 0.13^{cA}
RB	9.64± 0.48^{bA}	8.31± 0.38^{bA}	24.94±1 .98^{bA}	25.94± 1.61^{bA}	24.63± 0.98^{bA}	26.63± 0.96^{bA}	17.85± 0.43^{bA}	18.75± 0.45^{bA}	9.13± 0.12^{bA}	9.23± 0.11^{bA}
MF	4.258±0 .64^{aA}	6.41± 0.46^{aB}	20.42±1 .31^{bA}	21.42± 1.22^{bA}	18.08± 1.01^{aA}	22.06± 1.02^{aA}	13.23± 0.52^{aA}	14.33± 0.42^{aA}	5.14± 0.23^{aA}	6.19± 0.22^{aA}
CL	4.20± 0.69^{aA}	5.40± 0.71^{aB}	14.50±1 .44^{aA}	18.50± 1.67^{aB}	17.25± 1.55^{aA}	21.35± 1.54^{aA}	12.40± 1.14^{aA}	13.60± 1.19^{aA}	5.73± 0.19^{aA}	6.00± 0.00^{aA}

BCH: Biochar, CPH: Cocoa pod husk, RB: Rice bran, MF: Mineral fertilizer, CL : Control; Means with the same lower case alphabets are not significantly different across the column while means with the same upper case alphabets are statistically the same for the same parameters between FUTA and Ejigbo along the row.

Table 7 Effect of crop residues on the proximate composition of plantain (pulp) ratoon fruit Ejigbo

Treat-ment	Moisture content (%)	Ash (%)	Fat and oil (%)	Crude Protein (%)	Crude fiber (%)	Carbohydrate (%)
BCH	61.41±0.22^{a}	1.46±0.13^{ab}	2.19±0.17^{a}	2.72±0.19^{b}	0.82±0.03^{c}	31.14±0.42^{a}
CPH	61.19 ±0.97^{a}	1.72±0.19^{b}	2.42±0.08^{a}	3.16±0.09^{b}	0.97±0.03^{d}	30.93±0.14^{a}
MF	61.41±0.77^{a}	1.09±0.06^{ab}	1.89±0.14^{a}	2.43±0.22^{b}	0.80±0.02^{b}	31.75±0.19^{a}
RB	62.16±0.18^{a}	1.31±0.11^{ab}	1.81±0.11^{a}	2.84±0.14^{b}	0.98±0.03^{d}	30.75±0.25^{a}
CL	62.86±0.28^{a}	0.89±0.024^{a}	2.34±0.04^{a}	1.59±0.28^{a}	0.76±0.06^{a}	31.35±0.08^{a}

Means with the same alphabets are not significantly different across the column. BCH: Biochar, CPH: Cocoa pod husk, RB: Rice bran, MF: Mineral fertilizer, CL: Control.

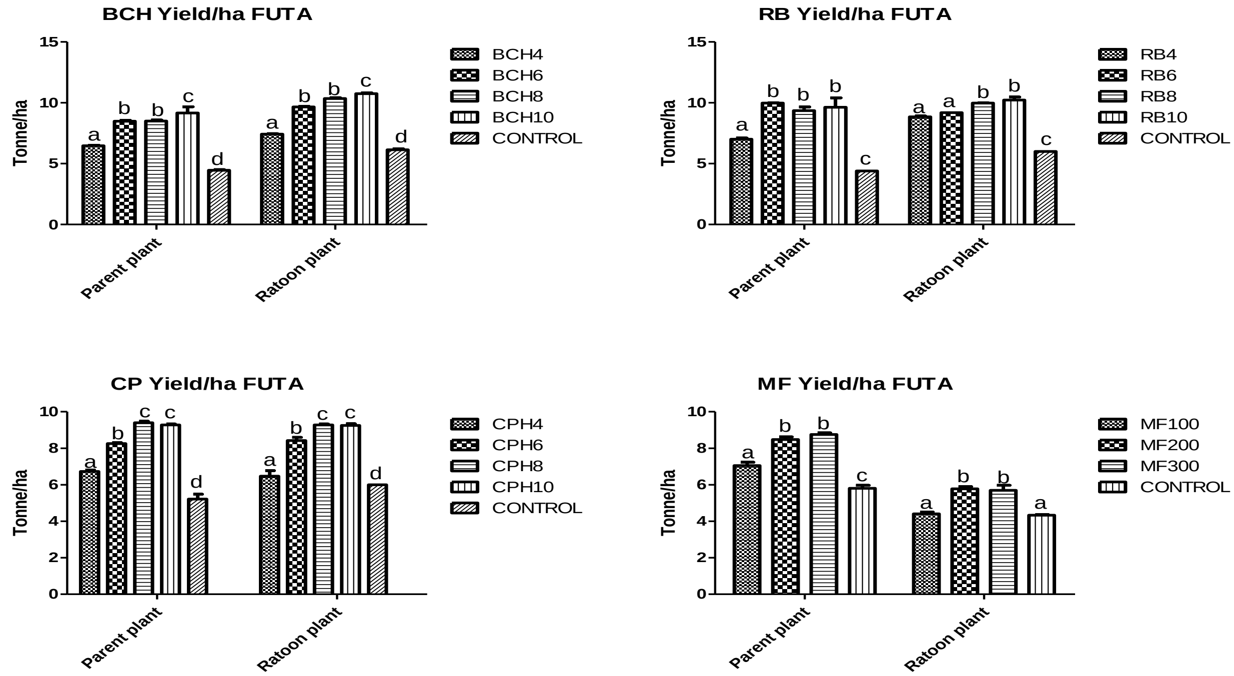

Fig. 3 The yield (tons per hectare) for the different soil amendments in FUTA location
Each bar is the mean ± standard deviation of four replicates. Bars with the same letters are not significantly different

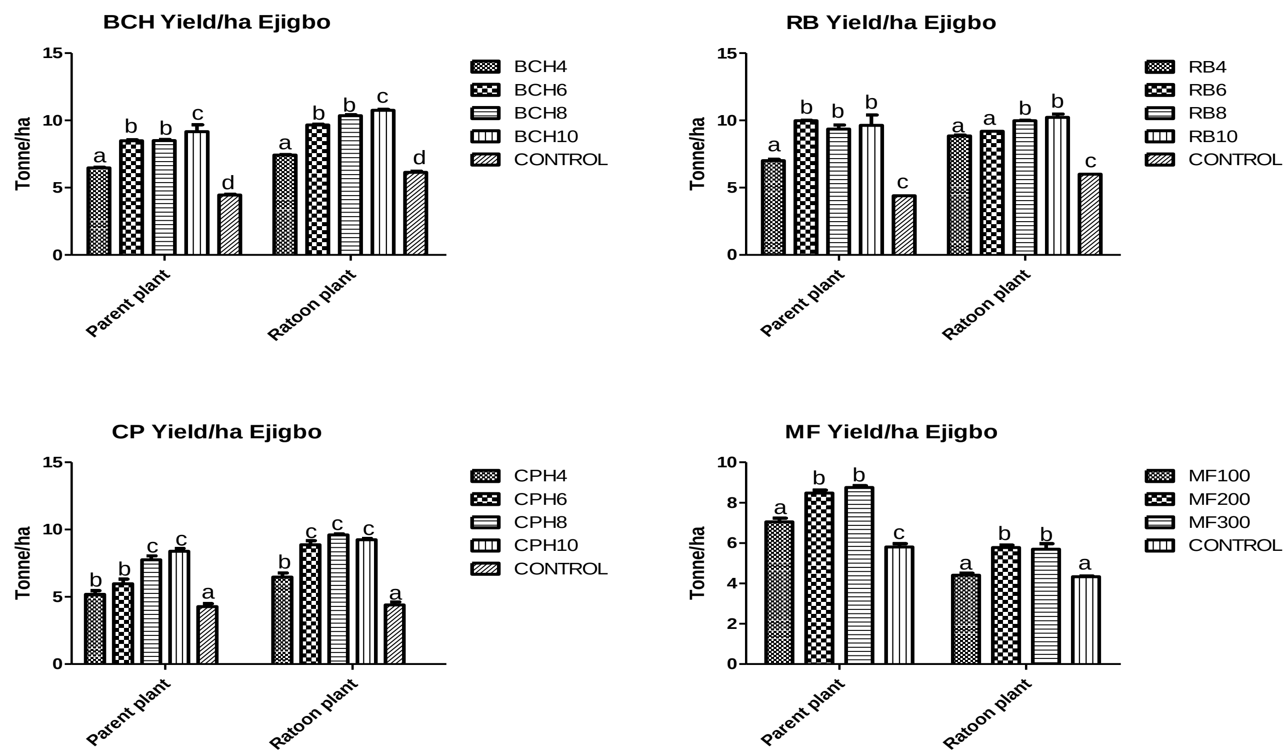

Fig. 4 The yield (tons per hectare) for the different soil amendments in Ejigbo location
Each bar is the mean ± standard deviation of four replicates. Bars with the same letters are not significantly different.

Table 8 Effect of crop residues on the proximate composition of plantain (pulp) ratoon fruit FUTA

Treat-ment	Moisture content (%)	Ash (%)	Fat and oil (%)	Crude Protein (%)	Crude Fibre (%)	Carbohy-drate (%)
BCH	62.52±0.44[a]	1.32±0.56[ab]	1.81±0.40[a]	2.72±0.70[b]	0.77±0.11[b]	30.69±1.23[a]
CPH	61.04 ±0.96[a]	1.64±0.82[b]	2.44±0.35[a]	3.18±0.40[b]	0.90±0.08[c]	30.92±0.69[a]
MF	61.67±1.03[a]	1.44±0.53[ab]	2.20±0.80[a]	2.75±0.68[b]	0.73±0.11[a]	31.18±2.10[a]
RB	61.46±0.37[a]	1.02±0.03[ab]	1.90±0.58[a]	2.36±0.88[b]	0.89±0.03[c]	31.80±0.97[a]
CL	62.04±0.21[a]	0.87±0.010[a]	2.34±0.05[a]	1.58±0.25[a]	0.72±0.06[a]	31.28±0.07[a]

Means with the same alphabets are not significantly different across the column. BCH: Biochar, CPH: Cocoa pod husk, RB: Rice bran, MF: Mineral fertilizer, CL: Control

The ash content did not differ significantly among the treatment groups for the two locations. The highest ash content recorded in FUTA and Ejigbo 1.64 and 1.72 %, respectively. The percentage of fat and oil produced in the two locations were not significantly different in both FUTA and Ejigbo locations. The range of fat and oil content recorded in FUTA was 1.81 to 2.44 % while that of Ejigbo was 1.81 to 2.42 %. For the two locations, soil amended with crop residues produced plantain with significantly higher crude protein content for the parent and ratoon crops in comparison to the control. The range of crude protein content recorded in FUTA was 0.72 to 0.90 %, while that of Ejigbo was 0.76 to 0.98 %. The crude fiber content followed a similar trend as that of crude protein in which soil amendment resulted in higher values of crude fiber. The range of crude fiber content recorded in FUTA was 0.72 to 0.90 %, while that of Ejigbo was 0.76 to 0.98 %. The percentage carbohydrate did not differ significantly among the treatment groups. The range of carbohydrate percentage recorded in FUTA was 30.69 to 31.80 %, while that of Ejigbo was 30.75 to 31.75 %. Overall, the results showed that the application of crop residues as soil amendment did not alter the proximate compositions of plantain except for crude protein and crude fiber. This was consistent with the findings of Ishmael (2011) and Onwuka and Onwuka (2005) which also reported no significant changes in the proximate compositions of plantain grown on amended soils.

Conclusion

In conclusion, the findings from this study indicated that the application of crop residues improved the growth and yield of plantain with magnitudes that are similar to those produced by mineral fertilizer. Considering the fact that the crop residues are environmentally friendly, and with little or no cost to the farmers, it is recommended that crop residues especially cocoa pod husk at the rate of 10 tonnes per hectare be used as alternative nutrient sources in replacement of mineral fertilizers.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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