International Journal of Recycling of Organic Waste in Agriculture (2023)12: 367-379
Doi: 10.30486/IJROWA.2022.1945581.1376

ORIGINAL RESEARCH

Growth, yield and nutrient uptake of two tomato varieties using some agricultural wastes as nutrient sources on an Alfisol of derived savanna

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Received: 11 December 2021 / Accepted: 14 May 2022 / Published online: 06 November 2022

Abstract

Purpose Agricultural wastes are by-product of agricultural processing. These wastes could serve as alternative materials for soil amendment and nutrient sources for crop production. A screen house experiment was conducted for two successive seasons (2019 and 2020) to evaluate the performance of charred poultry feather waste and plantain peel as nutrient sources on the growth, yield and nutrient uptake of two varieties (Eva and Nemo-netta) of tomato.

Method Four levels each of charred poultry feather waste and plantain peel at 2, 5, 8, and 10 t PF ha^{-1}, control and 200 kg NPK ha^{-1} were used as treatments. The bags were arranged in a completely randomized design. Treatments were replicated four times.

Results The application of charred poultry feather waste and plantain peel significantly increased vegetative growth and yield parameters of tomato when compared with the control. Results also showed that combined application of the amendments compete favourably with the application of inorganic fertilizer. Higher values for all the parameters were observed when 5 t PP ha^{-1} + 5 t PF ha^{-1} was applied though similar values were found on the vegetative parameters with the applications of 2 t PP ha^{-1} + 8 t PF ha^{-1}, 10 t PP ha^{-1}, and 10 t PF ha^{-1}. Yield and micronutrient concentration of Eva was also found to be higher than that of Nemo-netta.

Conclusion The effects of 5 t PP ha^{-1} + 5 t PF ha^{-1} showed clear increase in vegetative, yield and nutrient uptake of Eva variety as compared to Nemo-netta.

Keywords Tomato varieties, Agricultural wastes, Performance, Mineral composition

Introduction

Agriculture is the production of food and related goods through farming. Agricultural activities produce a huge quantity of wastes which are referred to as agricultural wastes. Agricultural wastes are widely available, renewable, and virtually free, hence they can be an important resource (Sabiiti et al. 2005). In view of the high organic matter contents of agricultural wastes, they can be applied to the soil as amendments and as nutrient sources without any risk. (Kong 2014). Poultry feather and plantain peel are agricultural wastes because they are not the primary products. The recycling and composting of these agricultural wastes for farming activities reduces their volumes (Jakobsen 1995).

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Feather waste is a serious problem, a large quantity of which is produced annually worldwide by both the commercial processing industry and peasant poultry farmers (Rosik-Dulewska 2006). Feathers, because of their high keratin content, are insoluble, poorly susceptible to digestion by proteolytic enzymes, and other chemical or physical factors (Rodziewicz and £aba 2006).

Biochar is a carbon-rich and highly porous black material produced from the pyrolysis of biomass under oxygen-deficient condition (Brewer and Brown 2012). It can be produced from a range of feedstock, including forest and agriculture residues, such as straw, nut shells, rice hulls, wood chips/pellets, tree bark, and switch grass (Sohi et al. 2009). The porous structural arrangement of biochar encourages the biomass of shoot and root through rapid root increase and nutrient adsorption. Researchers have reported in different studies that biochar is capable of improving the water holding capacity and other physical characteristics of the soil thereby encouraging crop performance. Similarly, biochar improved plant nutrient absorption through gradual release of nutrients (Alling et al. 2014; Adekiya et al. 2018 and Oladele et al. 2019).

Plantain peel, an agricultural waste obtained after removing the fleshy inner portion are used as landfills, dumped in rivers and sometimes used as animal feed. Aduku (1993) and Ajasin et al. (2004) observed that plantain peels have some nutritional value, as they contain about 12% crude protein, 16% crude fiber, and 1300 kcal/kg dry matter-energy.

In developing and some developed countries, many of these agricultural wastes are still underutilized even though they contain high and varying levels of some macro and micronutrients suitable for improving soil fertility and increasing crop yields. The recycling and use of agricultural waste may therefore reduce the need for mineral-based fertilizer, which mostly depends on importation and have negative environmental impacts. In a bid to encourage the recycling and use of agricultural wastes, to improve soil fertility, increase crop yields and quality, screen house experiments were conducted to compare and determine the effects of two agricultural wastes (poultry feather wastes and plantain peel) as nutrient sources using two varieties of tomato as the test crops.

According to the hypothesis, both charred poultry feather waste and plantain peel contained macro- and micronutrients in varying amounts, as evidenced by the laboratory analyses, and thus the performance and nutrient use efficiency of the two tomato varieties will vary differently with different levels of amendments. This study was carried out to prove the validity of the hypothesis and determine which individual or combined amendments will be economical and sustainable for the production and good quality of the test crops.

Materials and methods

The geographical location of the study area

The experiment was carried out at the screen house of the Teaching and Research farm, Landmark University, Omu-Aran, Nigeria, with geographical coordinates of latitude 8° 8' 0'' North and longitude 5° 6' 0'' East in the transitional rainforest located at an elevation of about 555.85 m above sea level.

Soil potting/bagging and analyses

During each of the experimental year, ten kilograms of topsoil was collected (0-30 cm depth) using soil auger from the organic farm of Landmark University, mixed thoroughly, and filled into a perforated polythene bags of size 30 cm × 17 cm. Soil from the transplanting bags were randomly sampled for each of the experimental year, each sample was air-dried, sieved with a 2-mm sieve and taken to the laboratory for routine physical and chemical analyses as described by Carter (1993).

Sources of materials and processing

Poultry feather of freshly processed broiler birds was obtained from the commercial farm of Landmark University, Nigeria. The poultry feather was dried in an oven at 85 ºC for 1 hour in order to reduce the moisture content. The sample was put in a large-scale tube furnace made of stainless reactor. The tube furnace was supplied with a thermocouple to accurately measure the internal temperature. The samples were then pyrolyzed at temperatures of 400 ºC with a residence time of 30 min (Zonglin et al. 2020). After pyrolysis, the charred poultry feather was then cooled for 10 h, crushed, and ready for use. Plantain peel was collected from a plantain processing farm, Edidi, Kwara state, Nigeria. The peel was sun-dried for five days and milled. The determination of the mineral element compositions of both the charred poultry feather and milled plantain peel was carried out at the central laboratory of the University. Inorganic fertilizer was obtained from latest agro-chemical shop.

Nutrients analyses of charred poultry feather waste and dry plantain peel

Laboratory analysis of the amendments used for the experiments was carried out to determine the organic carbon (OC), pH, total N, P, K, Ca, Mg, Cu, Mn, Zn, and Na. Samples of the amendments were oven-dried for 24 h at 80 ºC and grinded in a Willey mill. These samples were analyzed for leaf N, P, K, Ca and Mg as described by Tel and Hagarty (1984). Nitrogen content of the samples were determined by the micro-Kjeldahl digestion method. Ground samples were digested with nitric-perchloric-sulphuric acid mixture for the determination of P, K, Ca and Mg. Phosphorus was determined colorimetrically using the vanadomolybdate method, K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method (AOAC 2006). The percentage of organic carbon in the sample was determined by the Walkley and Black procedure using the dichromate wet oxidation method (Nelson and Sommers 1996). Sample pH was determined by using a soil–water medium at a ratio of 1:2 using Jenway digital electronic pH meter model 3520 (Ibitoye 2006). The contents of Mg, Zn, Fe, and Cu were determined by an atomic absorption spectrophotometer (AOAC 2006).

Variety and characteristics of tomato seeds used for the experiments

The varieties of tomato used for the experiments were Eva and Nemo-Netta. The two varieties were adapted to a controlled environment, fruit imperishability over two weeks from the date of harvest (shelf life), and they attain maturity between 60 and 70 days after transplanting, with a long harvesting periods and high yield potential.

Raising and transplanting of seedlings

Seedlings were raised inside the screen house with the aid of grooved seedling starter tray having drain holes using sterile soil as nursery media. Each groove of the germinating tray was filled to ¾ capacity and slightly covered the remaining ¼ with the nursery media after seed sowing. The seedling starter trays were placed on an elevation above the ground level to improve drainage and reduce the incidence of waterlogging. Two vigorous and disease-free seedlings were transplanted in each planting bag twenty-one days after sowing, watered, and allowed to stabilize before thinning down to one seedling per planting bag.

Treatment combinations and experimental design

Four levels of each of the charred poultry feather and plantain peel at 2, 5, 8, and 10 t ha $^{-1}$ (Sikder and Joardar 2019) were used and combined as follows: - 5 t ha^{-1} PP + 5 t ha^{-1} PF (T_1), 8 t ha^{-1} PP + 2 t ha^{-1} PF (T_2), 2 t ha $^{-1}$ PP + 8 t ha $^{-1}$ PF (T_3), 10 t ha $^{-1}$ PP (T_4), 10 t ha $^{-1}$ PF (T_5), Control (T_6) and 200 kg NPK ha^{-1} (T_7). The bags were arranged in the screen house in accordance with a completely randomized design, using 30 cm by 60 cm inter- and intra-row spacing. Treatments were replicated four times.

Application of amendments and agronomic practices

Charred poultry feather waste and plantain peel were applied based on the layout two weeks before transplanting to allow for their nutrient releases, application of NPK 20:10:10 was carried out two weeks after transplanting to enable the stability of the transplanted seedlings. The equivalent of 10 t ha^{-1}, 8 t ha^{-1}, 5 t ha^{-1}, and 2 t ha^{-1} of charred poultry feather waste and plantain peel to 10 kg of soil per planting bag was 50 g, 40 g, 25 g, and 10 g respectively, while 200 kg NPK ha^{-1} is equivalent to 1 g per planting bag.

Regular irrigation with a small quantity of water was applied during the first one week after transplanting using the drip irrigation system, subsequent deep irrigation and one to two days' water stress was adopted to encourage deep rooting.

Training/staking, trellising and de-suckering were carried out on a weekly basis and as the need arose. Training helped the plants to grow vertically while trellising supported the plant to grow horizontally. These two activities helped in providing good aeration within the plants and in the screen house. It provided for easy management of the plants in the screen house, and it also prevented the fruits from touching the ground. De-suckering of the plants was also carried out with the aid of sterilized pruning tools by removing upcoming lateral shoots. The goal of de-suckering was to remove excess foliage that could reduce air circulation within the plants, prevent overshadowing of the lower parts of the plants, increase photosynthetic activity, and discourage fungal infection and flower abortion. Weeding was accomplished by manually picking emerged weeds from each pot at 2, 4, and 6 WAS intervals, and as the need arose.

Mature and ripped fruits were harvested at intervals of five days for four weeks before the experiment was terminated. Harvested fruits were weighed using OHAUS Corporation, USA precision balance, having a capacity of 2100 g and readable at 0.01 g. A sample of each treatment was thereafter taken to the laboratory for minerals determination.

Data was recorded on the following parameters: - plant height (cm), number of leaves, stem girth (cm), number of fruits/plant, weight of fruits /plant (g), and nutrient composition of tomato fruits.

Determination of nutrient compositions of tomato fruits

Mature and ripped fresh tomato fruits were collected based on treatments and taken to the laboratory of Landmark University, Nigeria for analysis. Selected fruit sample was dried ashed as described by Chapman and Pratt. (1961). Each ashed sample (1 g) was weighed into a 50 ml porcelain crucible and placed in a muffle furnace at 550 ºC for about 5 h, after which it was allowed to cool. The cooled ashed sample was mixed thoroughly with a plastic rod for 15 min in 5 ml portion of 2 N hydrochloric acid (HCl) and allowed to dissolve. The content in the porcelain crucible was then mixed with 50 ml of distilled water, allowed to stand for 30 min before using the supernatant (after filtering through Whatman No. 42 filter paper) for analyzing the nutrients. The contents of Mg, Zn, Fe, and Cu were determined by an atomic absorption spectrophotometer (AOAC 2006).

Statistical analysis

The experimental data obtained during the study were subjected to analysis of variance (ANOVA) using GenStat Discovery (2014).

Significant treatment means were separated using the Duncan Multiple Range Test (DMRT) at a probability level of 5%.

Results and discussion

Physical properties and nutrient status of the experimental soil

The physical properties and nutrient status of the experimental soil for 2019 and 2020 cropping seasons are as shown in Table 1.

The soil was a sandy loam texture, acidic (pH 4.4), and organic matter (2%) was at threshold. The concentration of total N at 0.1% was below the critical level for crop production, suggested as 0.2%, and the values for available P and exchangeable K, Ca, and Mg were close to the lower critical levels, suggested as 10.0 mg/kg for available P, 0.15 mg/kg for exchangeable K, 2.0 mg/kg for exchangeable Ca, and 0.40 cmol/kg for exchangeable Mg (Aboyeji 2021). The results of the soil analyses were also in agreement with Akanbi and Togun (2002), who reported that most African soils are deficient in essential nutrients due to weathering, leaching and intensive cultivation. The Zn value for the two years' analyses were also found to be below the recommended critical level as suggested by WHO/FAO (FAO/WHO 2010).

Table 1 Physico-chemical properties of the initial soil

Parameter	2019	2020	Parameter	2019	2020
Sand (%)	76	78	Organic matter (%)	2.04	2.07
Silt (%)	13	12	K (mg/kg)	0.13	0.13
Clay (%)	11	10	Ca (mg/kg)	1.95	2.00
Textural class	Sandy loam	Sandy loam	Mg (mg/kg)	0.32	0.33
pH (H_2O) 1:1	4.25	4.49	Available P (mg/kg)	9.15	9.12
Total nitrogen (%)	0.107	0.102	Zn (mg/kg)	0.35	0.41

Mineral components of the amendments used in the experiment

The results of the laboratory analyses of charred poultry feather waste and dried plantain peel are shown in Table 2. The results showed that both amendments contained varying values of macro and micro-nutrients needed for improved soil fertility and plant growth.

Effects of charred poultry feather waste and dried plantain peel on plant height (cm) of two varieties of tomato

Results showed that the effects of varieties were not significant and, at the same time, there were no significant interactions between varieties and amendments on plant height in both years of study (Table 3), however, plant height increased significantly among the amendments. During the initial stage of growth (2 WAT), there was no significant difference in plant height in both years, however, plants with applied treatments significantly increased in heights with the control having the least values. At 4 and 6 WAT during the two cropping seasons, plots treated with 5 t PP ha^{-1} + 5 t PF ha^{-1}, and NPK increased plant height similar to plants treated with 10 t PF ha^{-1} in 2019 and the application of 10 t PF ha^{-1} and 2 t PP ha^{-1} + 8 t PF ha^{-1} at 4 WAT in 2020.

Table 2 Mineral components of the amendments

Nutrients (mg/kg)	N	P	K	Ca	Mg	C	C:N	Cu	Fe	Zn
Plantain Peel (PP)	0.37	57.10	1.84	1.67	0.012	5.35	14.45	0.60	0.81	0.11
Poultry Feather (PF)	2.10	2.61	3.55	1.52	0.74	15.20	7.24	0.32	0.57	0.36

Table 3 Effects of charred poultry feather waste and dried plantain peel on plant height (cm) of two varieties of tomato in 2019 and 2020 cropping seasons

	Plant height (cm)					
	2019			2020		
Treatments	2 WAT	4 WAT	6 WAT	2 WAT	4 WAT	6 WAT
Varieties						
Eva	25.9a	87.2a	146.8a	23.6a	85.3a	147.4a
Nemo-netta	24.2a	87.5a	145.1a	22.3a	85.1a	145.5a
Amendments (ha^{-1})						
5 t PP + 5 t PF	29.0a	92.3a	169.0a	27.9a	89.5a	165.1a
8 t PP + 2 t PF	27.3ab	84.1b	162.2b	27.1a	87.8b	154.8b
2 t PP + 8 t PF	28.0a	89.1ab	160.8b	27.6a	90.7a	151.3b
10 t PP	29.7a	85.0b	159.9b	28.1a	84.3ab	150.8b
10 t PF	27.0ab	94.7a	157.2ab	27.3a	90.4a	152.9b
Control	27.7ab	68.0c	92.4c	25.2b	67.0c	111.9c
200 kg NPK	27.4ab	94.4a	171.2a	25.0b	91.2a	167.0a
Interaction						
Variety	ns	ns	ns	ns	ns	ns
Amendment	ns	*	*	ns	*	*
Variety*Amendments	ns	ns	ns	ns	ns	ns

Means in a column followed by the same letter(s) are not significantly ($P \leq 0.05$) different according to Tukey's test. *= Significant at 5 % level of probability, ns = not significant, WAT = Weeks after transplanting, PP = plantain peel, PF = charred poultry feather waste

Effects of charred poultry feather waste and dried plantain peel on the number of leaves of two varieties of tomato

The effects of varieties and interactions of varieties and amendments were not significant on the number of leaves of tomato (Table 4). There was no significant difference in the number of leaves with the application of different amendments at 2 WAT in both 2019 and 2020, except with the control and NPK, which gave statistically similar values. At 4 WAT, all treatments with charred poultry feather waste higher than 2 t ha^{-1} 5 t PP + 5 t PF, 2 t PP ha^{-1} + 8 t PF ha^{-1}, 10 t PP ha^{-1}, 10 t PF ha^{-1} positively increased the number of leaves, which was similar to the application of NPK. Control and NPK showed a significant reduction in the number of leaves at 6 WAT in both years.

Effects of charred poultry feather waste and dried plantain peel on stem girth of two varieties of tomato

Data on stem girth showed that amendments had significant effects while varieties and interactions of varieties and amendments did not show any significant effects on the stem girth (Table 5). Plants treated with 5 t PP ha^{-1} + 5 t PF ha^{-1}, 2 t PP ha^{-1} + 8 t PF ha^{-1}, 10 t PF ha^{-1}, and NPK had significantly greater stem girth at 4 WAT in 2019 and 6 WAT in 2020. Control treatment gave smaller stem girth in both 2019 and 2020 experimental years except at 2 WAT, where the values were similar to that of NPK treatment.

Tomato (*Solanum lycopersicum* L.), an important food crop, is commercially and cultivated in subsistence all over the world. Soil nutrient depletion resulting from erosion, continuous cropping, and imbalance of organic matter/nutrients, is affecting world agricultural productivity (Foley et al. 2005). Application of organic manure and/or agricultural wastes improved crop yield and quality by supplying the required plant nutrients, improvement of soil physical properties, and multiplication of microbes in the soil (Adeleye et al. 2010) as compared to the application of inorganic fertilizer which increases crop production but has negative environmental impacts (Vanlauwe et al. 2010).

Table 4 Effects of charred poultry feather waste and dried plantain peel on the number of leaves of two varieties of tomato in 2019 and 2020 cropping seasons

	Number of leaves					
	2019			2020		
Treatments	2 WAT	4 WAT	6 WAT	2 WAT	4 WAT	6 WAT
Varieties						
Eva	8.4a	30.2a	17.0a	8.0a	28.6a	15.6a
Nemo-netta	8.4a	30.2a	17.0a	7.9a	28.1a	16.0a
Amendments (ha^{-1})						
5 t PP + 5 t PF	8.3a	35.2a	20.3a	8.1a	29.7a	17.8a
8 t PP + 2 t PF	8.7a	30.5b	20.3a	8.1a	26.2b	16.8b
2 t PP + 8 t PF	8.7a	33.2a	17.7b	8.1a	32.0a	18.3a
10 t PP	8.7a	30.4b	17.7b	8.1a	26.4b	17.4a
10 t PF	8.7a	34.8a	19.5a	8.2a	30.3a	18.6a
Control	7.3b	20.3c	11.0c	7.1a	20.0c	11.3c
200 kg NPK	7.0b	33.3a	12.7c	7.1a	32.1a	12.4c
Interaction						
Variety	ns	ns	ns	ns	ns	ns
Amendment	*	*	*	ns	*	*
Variety*Amendments	ns	ns	ns	ns	ns	ns

Mean under the same column and having different letter differ significantly ($P \leq 0.05$) according to Tukey's test.

*= Significant at 5 % level of probability ns = not significant WAT = Weeks after transplanting, PP = plantain peel, PF = charred poultry feather waste

The study showed that application of charred poultry feather waste and dried plantain peel induced positive effects on the growth, yield and nutrient uptake of tomato. The better performance and nutrient uptake of the two tomato varieties could be ascribed to the continuous cultivation on the potted soil without replenishment which has depleted the soil nutrients. It could also be that the nutrients supplied by the two amendments were in the form that were readily available for the plant uptake (Aboyeji et al. 2018). Maximum vegetative parameters were observed with the application of charred poultry feather waste and varying rates of dried plantain peel. Ali et al. (2020) found that biochar has the ability to accumulate essential soil nutrients especially nitrogen, thereby increased the photosynthetic ability of plants. The positive effects of the amendments on the vegetative parameters could be attributed to the available nutrients which facilitated the process of photosynthesis, hence, increased the plant height, number of branches and stem girth. Plants ability to photosynthesize is mostly determined by the soil rhizosphere, soil moisture contents and nutrients availability (Van Roekel and Purcell 2016). It could also be as a result of the water holding capacity and physical properties of the charred poultry feather wastes which assisted in adsorbing nutrients and prolonging the retention time of nutrients. In their study on maize yield, Zheng et al. (2013) also found that application of biochar improved nitrogen adsorption by preventing leaching, increased soil water-holding capacity and bioavailability of plant nutrients.

Table 5 Effects of charred poultry feather waste and dried plantain peel on stem girth of two varieties of tomato in 2019 and 2020 cropping seasons

	Stem girth (cm)					
	2019			2020		
Treatments	2 WAT	4 WAT	6 WAT	2 WAT	4 WAT	6 WAT
Varieties						
Eva	0.7a	1.2a	1.3a	0.6a	1.0a	1.1a
Nemo-netta	0.7a	1.2a	1.3a	0.6a	1.0a	1.1a
Amendments (ha^{-1})						
5 t PP + 5 t PF	0.7a	1.2a	1.3a	0.6a	11.9a	11.7a
8 t PP + 2 t PF	0.7a	1.0b	1.2b	0.6a	10.5ab	10.0b
2 t PP + 8 t PF	0.7a	1.2a	1.1ab	0.6a	11.4a	11.4a
10 t PP	0.7a	1.0b	1.1ab	0.6a	10.4ab	10.0b
10 t PF	0.8a	1.2a	1.2b	0.6a	11.7a	11.7a
Control	0.5b	0.9c	0.9c	0.4b	9.0c	9.0c
200 kg NPK	0.5b	1.2a	1.3a	0.4b	11.2a	11.6a
Interaction						
Variety	ns	ns	ns	ns	ns	ns
Amendment	*	*	*	*	*	*
Variety*Amendments	ns	ns	ns	ns	ns	ns

Mean under the same column and having different letter differ significantly ($P \leq 0.05$) according to Tukey's test.

*= Significant at 5 % level of probability, ns = not significant, WAT = Weeks after transplanting, PP = plantain peel, PF = charred poultry feather waste

Effects of charred poultry feather waste and dried plantain peel on the yield of two varieties of tomato

Data in Table 6 shows that varieties and application of various amendments significantly influenced the yield of tomato fruits. A significantly higher number and weight of fruits were recorded when 5 t PP ha^{-1} + 5 t PF ha^{-1} and NPK were applied in both years, though, in 2019, there was no significant difference in fruit weight when 8 t PP ha^{-1} + 2 t PF ha^{-1}, 2 t PP ha^{-1} + 8 t PF ha^{-1}, 10 t PP ha^{-1} and 10 t PF ha^{-1} were applied. The least number and weight of fruits were recorded in the control plots during the two years of the study. The two-way ANOVA results showed that varieties, amendments, and the interaction of varieties and amendments were significant for the yield in both years. Poultry feather waste was pyrolyzed at temperatures of 400 °C with a residence time of 30 min to become biochar (charred poultry feather waste).

Biochar is known to absorb soil nutrients thereby increasing the nutrient concentration and retention of the soil rhizosphere. (Jia et al. 2015). It has also been proven that biochar has positive conditioning effect on soil, though limited as a nutrient supplier alone, due to its relatively low nutrient composition and recalcitrance to biodegradation (Partey et al. 2014). Laboratory analysis of dried plantain peel revealed that it contained high quantity of P. This might have improved root formation and assisted in nutrient uptake. In this study, combined use of charred poultry feather waste and dried plantain peel promoted root formation and penetration. Phosphorus is a mineral element that has been reported to be important for fruit growth and development. Enough quantity of P nutrition improves fundamental physiological processes such as photosynthesis, nitrogen fixation, flowering, fruiting, seed production and maturation. Aduayi et al. (2002) reported that P is the mineral nutrient needed in larger quantity by tomato plant compared to other macronutrients. Some positive effects of phosphorus on plant metabolic processes includes cell division, formation, expansion and carbohydrate movement (Marschner 1995). The results of the study indicated that, higher yield with the application of charred poultry feather waste and dried plantain peel yield might be due to the increase in plant height which promoted the photosynthetic rate of the plant leading to better assimilate production. The effects of application of nitrogen, phosphorus and potassium have been reported to increase production and assimilation of carbohydrate in fruits (Bidari and Hebsur 2011). Another possible reason might be due to adequate availability of N and P which were supplied by the application of the two amendments which promoted growth, flowering and fruiting. It was reported by Kumar et al. (2010) that N and P nutrition facilitated flower formation, flowering pattern and fruit setting of tomato leading to fruits with uniform size. Increased flower formation and tomato fruiting could also be as a result of synergistic effects of N and P on plant height, number of leaves and stem girth. (Aminifard et al. 2012). Researches have reported that the use of either sole biochar, biochar/organic or biochar/inorganic fertilizer have shown positive effects on plant performance (Dou et al. 2012; Chan et al. 2007). Increase in yield could also be attributed to the positive effects of co-application of charred poultry feather waste and dried plantain peel. Higher P supplied by dried plantain peel could have helped in the production and development of the roots. This was supported by Kamara et al. (2011), where they reported that application phosphorus facilitates root formation and encourages flowering leading to increased yield and yield attributes. It could also be ascribed to the physical characteristics, surface area and porous structure of charred poultry feather which provided good environment for root penetration and nutrient adsorption. Similar results were by Bruun et al. (2014), where they found that application of biochar facilitated root growth, hence increased photosynthesis, growth and crop yield.

Effects of charred poultry feather waste and dried plantain on micronutrients concentration (mg/100g) of two varieties of tomato

The pooled analysis for 2019 and 2020 of the effects of charred poultry feather waste and dried plantain peel on mineral concentration of two varieties of tomato is presented in Table 7. Compared with no amendment and plots applied with NPK which gave significantly lower values for mineral concentration, Mg, Zn, Fe, and Cu concentrations were significantly increased on plots applied with 5 t PP ha^{-1} + 5 t PF ha^{-1} for the two varieties, except for the Mg value of Eva. Plots applied with 8 t PP ha^{-1} + 2 t PF ha^{-1} and 10 t PP ha^{-1} significantly increased concentration values of Fe and Cu for the two varieties. Similarly, the concentration of Mg and Zn for the two varieties increased on plots applied with 10 t PF ha^{-1}. Combined application of charred poultry feather waste and dried plantain peel might have assisted in root proliferation, improvement in soil fertility and physical properties thereby promoting better adsorption of both macro and micro-nutrients for tomato as indicated in this study.

Table 6 Effects of charred poultry feather waste and dried plantain peel on the yield of Two varieties of tomato in 2019 and 2020 cropping seasons

	2019		2020	
Treatments	Average number of fruits/plant	Average weight of fruits/plant (g)	Average number of fruits/plant	Average weight of fruits/plant (g)
Varieties				
Eva	19.2a	1,067.9a	17.9a	1,061.3a
Nemo-netta	17.8b	977.9b	16.0b	1,026.9b
Amendments (ha^{-1})				
5 t PP + 5 t PF	21.7a	1,065.7a	19.6a	1,061.6a
8 t PP + 2 t PF	19.2b	1,034.7ab	17.2b	1,032.3b
2 t PP + 8 t PF	21.0a	1,031.3ab	16.9b	1,031.9b
10 t PP	19.0b	1,037.3ab	17.3b	1,029.2b
10 t PF	20.8a	1,050.0b	17.4b	1,014.7b
Control	14.0c	700.0c	14.2c	693.8c
NPK	21.5a	1,076.0a	20.2a	1,067.1a
Interaction				
Variety	*	*	*	*
Amendment	*	*	*	*
Variety*Amendments	*	*	*	*

Mean under the same column and having different letter differ significantly (P ≤0.05) according to Tukey's test.
*= Significant at 5 % level of probability, PP = plantain peel, PF = charred poultry feather waste

Table 7 Effects of charred poultry feather waste and dried plantain on micronutrients concentration (mg/100g) of two varieties of tomato (pooled analysis of 2019 and 2020 Cropping seasons)

	Mg		Zn		Fe		Cu	
Amendments (ha^{-1})	Eva	Nemo-netta	Eva	Nemo-netta	Eva	Nemo-netta	Eva	Nemo-netta
5 t PP + 5 t PF	0.20b	0.17a	0.32a	0.30a	0.48a	0.45a	0.13a	0.12a
8 t PP + 2 t PF	0.16c	0.15b	0.25b	0.25b	0.48a	0.46a	0.14a	0.12a
2 t PP + 8 t PF	0.20b	0.17a	0.32a	0.31a	0.45b	0.43b	0.11b	0.10b
10 t PP	0.15c	0.14b	0.22c	0.26b	0.49a	0.47a	0.15a	0.13a
10 t PF	0.22a	0.18a	0.33a	0.32a	0.40c	0.40c	0.11b	0.11a
Control	0.11d	0.10c	0.17d	0.15c	0.35d	0.33d	0.05c	0.04c
NPK	0.11d	0.10c	0.19d	0.17c	0.35d	0.34d	0.05c	0.05c
Daily Value mg/100g (DV)	50	50	20	20	30	30	50	50

Mean under the same column and having different letter differ significantly (P ≤0.05) according to Tukey's test.
Daily value source = USDA Food and Nutrient Database for Dietary Studies, PP = plantain peel, PF = charred poultry feather waste

The total area occupied by biochar is high hence, improved root proliferation and establishment of beneficial fungi (Hussain et al. 2017). Increased nutrient uptake by tomato plant could be due to a combined effect from charred poultry feather waste and dried plantain peel, which led to higher nutrients concentrations. It could also be attributed to the ability of charred poultry feather waste in harnessing and retaining the nutrients within the rhizosphere for a longer period of time. Growth and yield attributes of different crop varieties differ and are determined by the physiological process which is regulated by the effects of the plants' genetic make-up and the habitat. In this study, the two tomato varieties responded positively to the applied amendments. Differential performance of the two varieties could be as a result of differences in the genetic make-up, ability to adapt to changing environment and some physiological processes during the vegetative and yield stages of crop (Isah et al. 2014).

Conclusion

Combined application of charred poultry feather waste and plantain peel did not only increase vegetative and yield parameters but also compete favorably with the application of inorganic fertilizer in terms of all the parameters measured. Our findings revealed that higher values for all the measured indices occurred at the application of 5 t PP ha^{-1} + 5 t PF ha^{-1} though similar values were observed on plant height, number of leaves and stem girth with the application of 2 t PP ha^{-1} + 8 t PF ha^{-1}, 10 t PP ha^{-1}, and 10 t PF ha^{-1}. For all the applied amendments, yield and micronutrients concentrations of Eva were higher than that of Nemo-netta, though the micronutrients concentrations were not above the daily value as recommended by USDA (2020). It can therefore be concluded that Eva variety of tomato performed better than Nemo-netta when 5 t PP ha^{-1} + 5 t PF ha^{-1} was applied.

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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