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COMPARATIVE EFFECTS OF ORGANIC WASTES AND NPK FERTILIZER ON GROWTH, YIELD OF CARROT AND SELECTED SOIL CHEMICAL PROPERTIES IN THE RAINFOREST AGROECOLOGY OF NIGERIA

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ABSTRACT
The high cost and scarcity of mineral fertilizers in Nigeria awakes interest in research into the potential of organic wastes in enhancing soil productivity. Field experiments were conducted in the 2019 and 2020 cropping seasons to evaluate the potentials of poultry manure (PM), cocoa pod husk (CPH), and NPK 15:15:15 fertilizer in enhancing growth, root yield of carrot and soil nutrients status at Igba village (07^0 07^1N, 04^0 52^1 E) southwest Nigeria. The treatments involved control, 5and10 tha^{-1} PM, 5 and 10 t ha^{-1} CPH, 100 and 200 kg ha^{-1} NPK fertilizer. The seven treatments were laid out in a randomized complete block design and treatments were replicated three times. The soil at the site was acidic (pH 5.5), sandy in texture, and low in nitrogen (0.12 g kg^{-1}) and organic carbon (9.2 g kg^{-1}). Poultry manure, CPH, and NPK fertilizer significantly ($p < 0.05$) enhanced growth, leaf nutrients content, root yield of carrot, and soil nutrients status relative to the control. There were no significant ($p > 0.05$) differences in the effects of 10 t ha^{-1} PM and 10 t ha^{-1} CPH on growth parameters, leaf nutrients content, root yield characteristics of carrot, soil pH, exchangeable bases, total N, available P, and organic carbon. The effects of 10 t ha^{-1} each of PM and CPH on growth and root yield parameters of carrot compared favourably with 200 kg ha^{-1} NPK in the first cropping season but in the second cropping season, PM and CPH amended plots out-yielded NPK fertilizer amended plots. Poultry manure and CPH enhanced growth, leaf nutrients content, root yield characteristics of carrot, and soil nutrients status on a long-term basis than NPK fertilizer. The use of cheap and locally available PM and CPH is therefore recommended for the use of peasant farmers in the production of carrot.

Keywords: Comparative, Organic wastes, Root yield, Growth and Soil nutrients.

Introduction

Carrot (*Daucus carota L.*) is a popular root vegetable in high demand in Nigeria. The demand for carrots has exceeded its supply most especially in southern Nigeria, thereby, resulting in its high cost. Carrot production is mainly in northern Nigeria probably because of the favourable weather conditions for its production in certain periods of the year in some parts of northern Nigeria. In southern Nigeria, carrot production is not popular among the farmers, perhaps because of insufficient agronomic information about carrot production and as well as the weather conditions of southern Nigeria. The need to increase carrot production in Nigeria through agronomic research cannot be overemphasized. In general, one of the problems of low crop production in Nigeria is attributed to the low soil nutrient status. Also, the poor performance of crops is attributed to the low input crop production practices and the severe crop environmental stresses (Adeleye and Ayeni, 2010), Among crop production practices that could influence the growth and performance of crops is crop fertilization. In Nigeria, the low carrot yield has been attributed to the lack of high-yielding varieties as well as low soil nutrient status (Ahmed *et al.,* 2014). To obtain high yield and quality of carrots, good soil fertility is required. The need for improved soil management practices has led to external inputs from organic and inorganic sources to enhance soil productivity and high crop yield. The use of chemical fertilizer has been found to increase crop yield significantly for only a few years but in the long run leads to a decrease in crop yield due to the degradation of soil's physical and chemical properties (Adeoye *et al.*, 2008), The use of inorganic fertilizer recently in Nigeria is low due to its high cost, scarcity, poorly developed infrastructure for fertilizer distribution, marketing and the low economic situations of the peasant farmers. Hence, there is a need for comparative studies of the potential of cheap and locally available organic materials with inorganic fertilizers in combating soil fertility and crop production problems.

The use of cocoa pod husk (CPH) has been successfully tried as a bio-fertilizer for maize (Ayeni, 2010 and Akanbi *et al.*, 2014). It has been reported that the use of cocoa pod husk fertilizer does not contain substances that will pose environmental and human health risks (Campos-Filho *et al*., 2017), The increasing popularity of CPH as a bio-fertilizer for soil management justifies further investigation to ascertain that its application could enhance favourable soil properties and performance of carrot. In Nigeria, a huge amount of poultry manure (PM) is generated every year and heaped on dumpsites. Incorporating poultry manure into the soil for crop production has been found beneficial. Poultry manure has been found to improve soil's physical, biological, and chemical properties and enhance high-crop production (Adeniyan, 2008, Adeleye *et al.*, 2010., Amusan *et al.*, 2011).

In southwest Nigeria, research information on poultry manure in carrot production is scanty, hence, there is a need to further investigate the potential of poultry manure in enhancing soil nutrients status and yield of carrot. The present study aimed at evaluating the relative effects of poultry manure (PM), cocoa pod husk (CPH), and NPK 15: 15: 15 fertilizers on growth, leaf nutrients content, root yield of carrot, and soil chemical properties on an Alfisol in the rainforest agro-ecological zone of southwest Nigeria.

Materials and Methods

Description of the site

Field experiments were carried out in the 2019 and 2020 cropping seasons at Igba village, Ondo (Latitude 07^0 07^1 N, Longitude 04^o 52^1 E) in the rainforest zone of southwest Nigeria. The mean annual rainfall is about 1670 mm. The site enjoys a bimodal rainfall pattern with early rain occurring between March to July and late rain between August to October with five (5) months of dry season. The mean relative humidity is about 69 %, and the sunshine hours vary from 2.5 to 7hr and appeared lowest in July, August and September. The mean monthly temperature at the site of the field experiment is 27^0 C (FDACSA, 2021). The soil is sandy in texture and slightly acidic and classified as OxicTropuldalf (Alfisol) derived from quart, gneiss, and schist (Akinbola *et al.,* 2009), The site is located in the lowland rainforest agro-ecological zone of Nigeria with a semi-deciduous vegetation. The site has been previously cultivated for arable crops such as cassava, maize, and cocoyam and it has been under fallow for two years before the commencement of the field experiment. The monthly average air temperature, rainfall, and humidity at the site of the field experiments from sowing to harvesting (June – September) in 2019 and 2020 are shown in Table 1.

Table 1: Monthly Average Air Temperature, Rainfall and Relative Humidity at Igba site from Sowing to Harvesting in 2019 and 2020

Month	Temperature ^0C		Rainfall (mm)		Relative Humidity (%)	
	2019	2020	2019	2020	2019	2020
June	25.28	25.02	14.42	12.80	92.72	93.16
July	24,72	24.12	9.07	8.52	92.59	92.68
August	24,52	23.81	6.64	1.47	91.97	89.04
September	24.81	24.46	15.08	15.00	93.23	92.22

Source: Department of Aviation, Climatological Station, Akure, Ondo State (2021)

Treatments and Experimental Design

The treatments involved control, 5 t ha^{-1}, 10 t ha^{-1} PM, 5 t ha^{-1}, 10 t ha^{-1} CPH, 100 kg ha^{-1}, and 200 kg ha^{-1} NPK 15:15:15 fertilizer. Treatments were laid out in a randomized complete block design (RCBD) with three replications. A land area measuring 14 m by 8 m was used. The site was manually cleared, packed, and divided into three blocks and each block was demarcated by a 0.5 m wide alley way. Each block was further divided into seven plots of 2 m by 2 m, and each plot demarcated by 0.5 m wide alley way. Each plot was made into raised beds using traditional hoes. The raised beds were thoroughly pulverized and raked free of stones. The treatments were randomly assigned to the plots. Dried and ground PM and CPH were uniformly spread on the assigned plots and incorporated into the soil using a traditional hoe five (5) days before planting of carrot seeds while NPK 15:15:15 fertilizer was broadcasted on the assigned plots two (2) weeks after emergence of carrot seedlings. The carrot seeds were sown directly into the prepared beds by drilling in rows spaced 20 cm apart, which were later thinned three (3) weeks after the emergence of carrot seedlings to attain spacing of 20 cm apart. Weeding and other cultural operations were the same for all the treatments and were attended to regularly.

Pre-Treatment Soil Analysis

Pre-treatment soil surface (0 -15 cm) samples were collected using a soil auger, air-dried, and sieved using 2 mm mesh, and bulked and processed for routine chemical analysis of the initial soil characteristics. Soil particle size distribution was determined using the hydrometer method. Soil pH was determined at a 1:2 soil-water ratio using a glass electrode pH meter. Organic carbon was determined by dichromate oxidation method, total nitrogen by Kjeldahl digestion auto analyzer method, available P was extracted by Bray-1-method, and P in the extract was determined colorimetrically. Exchangeable cations by 1.0N NH_40Ac extraction. Calcium, magnesium, and manganese in the extract were determined by atomic absorption spectrophotometry. Cation exchange capacity was determined by the summation of NH_40Ac – extractable cations plus 1.0N KCl extractable acidity.

Growth and Yield Parameter

Ten carrot stands were randomly selected per plot and tagged for the estimation of growth and yield parameters. Leaf length, number of leaves per stand, and plant height were measured at 80 days after sowing of carrot seeds. Leaf length was measured using a meter rule, plant height was measured in cm from the ground level to the top of the shoot using a meter rule, while the leaves were counted. Shoot fresh weight was determined using a weighing balance, and the shoot dry weight was determined by oven drying 10 stands per plot to constant weight at 65^0 C. Root fresh weight was determined using a weighing balance in g per stand. Root diameter was measured at the widest middle portion of the root using a vernier caliper. The number of forked, cracked, and rotten roots were counted separately on a treatment basis as malformed roots, and percentage was calculated from the number of harvested roots. Root dry weight was determined by oven-drying roots to constant weight at 65^0 C. Marketable root yield was determined by weighing roots with no deformities like cracks, forking, malformation, and spots.

Leaf Nutrients Analysis

At harvest, matured leaves were collected from five (5) stands per plot, washed in water, oven-dried at 65^0 C for 48 hours, and ground for routine chemical analysis. The nutrients in the ash were then brought into the solution by the addition of 10 % HCl. Leaf N was determined using the Kjeldahl digestion method, phosphorus was determined colorimetrically by the vanadomolydate method, K by flame photometer, and Ca and Mg were determined by AAS (AOAC, 2000).

Post-harvest Soil Chemical Analysis

At the end of each cropping season, another set of soil samples (0 -15 cm) were collected on a treatment basis and per replicates and also processed for chemical analysis. Soil

pH was determined at a 1:2 soil water ratio using a glass electrode pH meter. Organic carbon was determined by dichromate oxidation method, total nitrogen by Kjeldahl digestion auto analyzer method, available P was extracted by Bray-1-method, and P in the extract was determined colorimetrically. Exchangeable cations by 1.0N NH_40Ac extraction. Calcium, magnesium, and manganese in the extract were determined by atomic absorption spectrophotometry. Cation exchange capacity was determined by the summation of NH_40Ac – extractable cations plus 1.0N KCl extractable acidity.

Data Analysis

Data on soil chemical properties, leaf nutrients content, growth, and yield parameters were subjected to analysis of variance using the Statistical Analysis System Institute Package – General Linear Model (SAS, 2000). Means were compared using Duncan's Multiple Range Test at a 5 % level of significance where the F-ratio was significant.

Results

Initial Soil Properties

Data on the initial physical and chemical properties of the experimental soil are presented in Table 2. The soil was acidic (pH 5.5.), high in sand particles, low in total nitrogen (0.12 g kg^{-1}), organic carbon (9.2 g kg^{-1}), available P (8.0 mg kg^{-1}), ECEC, exchangeable bases and high in micronutrients. The soil was sandy in texture.

Growth Parameters

The relative effects of poultry manure (PM), cocoa pod husk (CPH), and NPK 15:15:15 fertilizer on the growth parameters of carrots are shown in Table 3. Relative to control, plant height, leaf length, and shoot dry matter were significantly ($P<0.05$) influenced by PM, CPH, and NPK fertilizer. The number of leaves was not significantly ($P>0.05$) influenced by the soil amendments in the study. The plots amended with 200 kg ha^{-1} NPK fertilizer in the first cropping season (2019) had the best growth parameters in terms of plant height and, leaf length. However, the growth parameters of carrots in plots treated with 10 t ha^{-1} each of PM and CPH compared favourably in most of the carrot growth parameters measured with that of the plots amended with 200 kg ha^{-1} NPK fertilizer in the first cropping season. There were no significant (P>0.05) differences in the growth parameters of carrots for plant height, leaf length, and leaf number in plots amended with 5 t ha^{-1} PM and 5 t ha^{-1} CPH in the first cropping season. The lowest growth parameters came from the control plots at both cropping seasons.

Table 2: Initial Soil Physical and Chemical Properties at the Site of Experiment

Parameter	Value
Sand (g kg $^{-1}$)	942
Silt (g kg $^{-1}$)	15
Clay (g kg $^{-1}$)	43
Textural Class	Sandy
pH (H_2O) (1:2)	5.5
Organic carbon (g kg $^{-1}$)	9.2
Total nitrogen (g kg $^{-1}$)	0.1
Available phosphorus (mg kg^{-1})	8
Ca (cmol kg^{-1})	1.7
Mg (cmol kg^{-1})	0.3
Na (cmol kg^{-1})	0.4
K (cmol kg^{-1})	0.2
Exch. Ac. (cmol kg^{-1})	0.1
ECEC (cmol kg^{-1})	2.8
B. Sat (%)	96
Mn (mg kg^{-1})	18
Fe (mg kg^{-1})	27
Cu (mg kg^{-1})	3
Zn (mg kg^{-1})	4

Exch. Ac = Exchangeable acidity, ECEC – Effective cation exchange capacity, B.Sat = Base saturation

There were relative improvements in the growth parameters of carrots in plots amended with PM and CPH during the second cropping season (2020), while there were reductions in the growth characteristics of carrots in plots treated with NPK fertilizer in terms of plant height, leaf length and shoot dry matter. The growth characteristics of carrots, such as plant height, leaf length, leaf number, and shoot dry matter in plots treated with 10 t ha^{-1} each of PM and CPH were not significantly ($P>0.05$) different in the first cropping season. The mean plant height value for the two cropping seasons for 5 t ha^{-1} PM was 45.95 cm, while that of 10 t ha^{-1} PM was 52.83 cm. 5 t ha^{-1} CPH had a mean value of 47.71 cm for the two cropping seasons and 10 t ha^{-1} CPH had a means value of 48.39 cm for the two cropping seasons. The mean plant height for the two cropping seasons for 100 kg ha^{-1} NPK fertilizer was 45.36 cm, while that of 200 kg ha^{-1} was 45.92 cm.

Table3: Relative Effects of Poultry Manure, Cocoa Pod Husk and NPK 15:15:15 Fertilizer happening Growth Characteristics of Carrot

Treatment (t ha^{-1})	Plant height (cm)		Leaf length (cm)		Number of leaf		Shoot dry matter (%)	
	2019	2020	2019	2020	2019	2020	2019	2020
Control	44.31c	38.42d	28.91d	25.41d	7.12a	7.41a	9.10b	8.13c
PM_5	45.52b	46.41b	36.02b	36.72b	7.51a	7.66a	7.97c	8.87c
PM_{10}	52.61a	53.12a	36.81b	37.21b	7.54a	7.89a	10.12a	9.28b
CP_5	47.53b	48.01a	38.62b	39.12a	7.49a	7.64a	9.12b	9.21b
CP_{10}	48.29a	48.52a	37.21b	39.91a	7.51a	7.59a	10.45a	10.56a
F_{100}	48.00a	42.72c	34.12c	27.28d	7.44a	7.10a	8.87c	8.71c
F_{200}	51.60a	40.25c	40.91a	34.43c	7.64a	6.80b	10.00a	8.11c

Means with the same letter in a column are not significantly different at $p>0.05$.
CP_5 = 5 t ha^{-1} CPH, CP_{10} = 10 t ha^{-1} CPH, F_{100} = 100 kg ha^{-1} NPK fertilizer, F_{200} = 200 kg ha^{-1} NPK fertilizer

Root Yield Parameters

The effects of poultry manure (PM), cocoa pod husk (CPH), and NPK 15:15:15 fertilizer on carrot root yield characteristics are presented in Table 4. Relative to control, PM, CPH, and NPK fertilizer significantly ($P<0.05$) influenced carrot root yield parameters at both cropping seasons. The root length, root diameter, root yield, root dry matter, and percent deformed roots increased with the increasing levels of the inputs. In the first cropping season (2019), there were no significant ($P>0.05$) differences in root yield characteristics of carrots such as gross root yield, deformed roots, marketable root yield, and root dry matter in plots amended with 10 t ha^{-1} PM, 10 t ha^{-1} CPH and 200 kg ha^{-1} NPK fertilizer. However, in the second cropping season (2020), there were significant ($P<0.05$) differences in carrot root yield characteristics in plots amended with 10 t ha^{-1} PM, 10 t ha^{-1} CPH, and 200 kg ha^{-1} NPK fertilizer. There were no significant ($P> 0.05$) differences in carrot root yield characteristics in plots amended with 10 t ha^{-1} PM and 10 t ha^{-1} CPH at both cropping seasons.

The plots amended with 10 t ha^{-1} each of PM and CPH out-yielded the plots amended with 200 kg ha^{-1} NPK fertilizer. The plots amended with 5 t ha^{-1} PM compared favourably with the plots treated with 5 t ha^{-1} CPH in most carrot root yield characteristics measured at both cropping seasons. In the second cropping season, there were slight increases in carrot root yield parameters in plots amended with PM and CPH compared to the first cropping season. In contrast, there were reductions in carrot root yield parameters in plots amended with NPK fertilizer. Also, there was a reduction in deformed root yield in the second cropping season across the treatments compared with the first cropping season. At both cropping seasons, control plots consistently had the poorest carrot root yield characteristics. The mean gross root yield for the two cropping seasons for 5 and 10 t ha^{-1} PM were 19.85 t ha^{-1} and 22.62 t ha^{-1}, respectively. Also, for 5 and 10 t ha^{-1} CPH were 20.30 and 22.33 t ha^{-1}, respectively. While the mean gross root yield values for 100 and 200 kg ha^{-1} NPK fertilizer were 18.90 and 19.36 t, respectively. The mean values of marketable root yield for 5 and 10 t ha^{-1} PM were 18.65 and 21.90 t ha^{-1}, respectively, and also, for 5 and 10 t ha^{-1} CPH were 19.79 and 21.88 t ha^{-1}, respectively. While the mean marketable root yield for 100 and 200 kg ha^{-1} NPK fertilizer were 17.13 and 18.74tha^{-1}, respectively.

Table 4: Relative effects of Poultry Manure, Cocoa Pod Husk and NPK 15:15:15 Fertilizer on Yield Characteristics of Carrot

Treatment (t ha^{-1})	Root length (cm)		Root diameter (cm)		Root dry matter (%)		Gross root yield (t ha^{-1})		Deformed roots (%)		Marketable yield (t ha^{-1})	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Control	9.91c	9.12c	1.60c	1.48d	8.92b	8.21c	18.41c	15.46d	2.50b	1.58c	17.94c	15.22d
P_5	10.97b	11.18a	1.74b	1.78b	10.31a	10.61a	19.21b	20.50b	3.48a	2.19a	18.52b	18.78b
P_{10}	12.60a	12.98a	1.84a	1.90a	10.59a	10.62a	22.43a	22.85a	2.74b	1.72b	21.79a	22.01a
CP_5	10.61b	10.83b	1.69c	1.72b	11.25a	11.48a	20.01b	20.60b	3.10a	1.95b	19.38b	20.19a
CP_{10}	11.14b	11.36a	1.87a	1.91a	10.23a	10.54a	22.21a	22.64a	3.20a	2.02a	21.49a	22.18a
F_{100}	11.38a	9.90b	1.77b	1.50c	10.74a	9.13b	21.01a	16.80c	3.20a	2.02a	17.80c	16.46c
F_{200}	11.98a	9.58b	2.05a	1.64c	11.44a	9.15b	21.42a	17.12c	3.26a	2.05a	20.71a	16.77c

Means with the same letter in a column are not significantly different at $p>0.05$.
P_5 = 5 t ha^{-1} PM, P_{10} = 10 t ha^{-1} PM, CP_0 = 0 t ha^{-1} CPH, CP_5 = 5 t ha^{-1} CPH, CP_{10} = 10 t ha^{-1} CPH, F_{100} = 100 kg ha^{-1} NPK fertilizer, F_{200} = 200 kg ha^{-1} NPK fertilizer

Leaf Nutrient Contents

The relative influence of PM, CPH, and NPK 15:15:15 fertilizer on leaf nutrient contents is presented in Table 5. The data in the table indicated that leaf nutrient contents were significantly ($P \leq 0.05$) influenced by PM, CPH, and NPK fertilizer. The leaf N, P, K, Ca, and Mg were significantly higher in plots amended with PM, CPH, and NPK fertilizer compared with the control plots. The leaf N, P, K, Ca, and Mg increased with the increasing rates of PM, CPH, and NPK fertilizer. During the first cropping season (2019), the leaves N, P, and K in plots amended with NPK fertilizer were better than their corresponding contents in carrot leaves in plots amended with PM and CPH. The leaf N, P, K, Ca, and Mg in plots treated with 10 t ha^{-1} PM and plots amended with 10 t ha^{-1} CPH compared favourably with those of the carrot leaves in plots amended with 200 kg ha^{-1} NPK fertilizer in the first cropping season.

The leaf N, P, K, and Ca in carrot leaves in plots amended with NPK fertilizer and the control plots decreased in the second cropping season (2020) compared with their leaf contents in the first cropping season. Carrot leaves in the control plots had the lowest contents of N, P, K, and Ca when compared with carrot leaves in plots amended with NPK fertilizer, CPH, and PM. In the second cropping season, there were slight improvements in the leaf nutrient contents of carrots in plots treated with PM and CPH. The mean leaf N for the two cropping seasons for 5 and 10 t ha^{-1} PM were 0.64 and 0.68 %, respectively, while the mean leaf N in plots with 5 and 10 t ha^{-1} CPH were 0.64 and 0.65 %, respectively. The leaf N mean values for 100 and 200 $kgha^{-1}$ NPK fertilizer were 0.57 and 0.62 %, respectively. Also, the mean leaf P for 5 and 10 t ha^{-1} PM were 0.62 and 0.73%, respectively, while the mean leaf P for 5 and 10 t ha^{-1} CPH were 0.61 and 0.71 %, respectively, and the mean leaf P for 100 and 200 kg ha^{-1} NPK fertilizer were 0.61 and 0.64 %, respectively.

Postharvest Soil Chemical Properties

Tables 6 and 7 show the relative effects of PM, CPH and NPK 15:15:15 fertilizer on soil chemical properties at the end of 2019 and 2020 cropping seasons. At harvest, PM, CPH and NPK fertilizer had significant ($P \leq 0.05$) different effects on soil pH, total organic carbon, total N, available P, exchangeable bases (Ca, Mg, K, Na), exchangeable acidity and the micronutrients (Mn, Fe, Cu, Zn), at the end of first cropping season (2019), 10 t ha^{-1} PM had the highest soil pH, exchangeable bases (Ca, Mg, K), ECEC, total N, total organic carbon and available P, followed by 10 t ha^{-1} CPH. There were no significant ($P \geq 0.05$) differences in the effects of 10 t ha^{-1} PM and 10 t ha^{-1} CPH on soil pH, exchangeable bases, ECEC, total organic carbon, total N and available P at the end of the first cropping season (2019).The effect of 5 t ha^{-1} PM and 5 t ha^{-1} CPH compared favourably with 100 kg ha^{-1} NPK fertilizer on soil pH, exchangeable K, exchangeable acidity, total N and total organic carbon. The control plots had the lowest soil pH, exchangeable bases, ECEC, total N, total organic carbon, available P, and the highest exchangeable acidity and micronutrients (Mn, Fe, Cu, Zn).

Table 5: Relative Effects of Poultry Manure, Cocoa Pod Husk and NPK 15:15:15 Fertilizer on Leaf Nutrients Content of Carrot

Treatment (t ha^{-1})	N		P		K (%)		Ca		Mg	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Control	0.62b	0.62c	0.57d	0.48d	5.65c	5.42b	0.43b	0.41c	0.13b	0.12c
P_5	0.62b	0.65b	0.62c	0.62b	6.25b	6.51a	0.53a	0.55a	0.14a	0.14b
P_{10}	0.66a	0.70a	0.66b	0.79a	5.79c	6.53a	0.53a	0.63a	0.14a	0.16a
CP_5	0.64a	0.65b	0.59c	0.62b	5.88c	6.10a	0.51a	0.58a	0.13b	0.14b
CP_{10}	0.65a	0.64b	0.64b	0.71a	6.10b	6.39a	0.56a	0.56a	0.14a	0.15a
F_{100}	0.62b	0.52c	0.61c	0.61b	6.05b	5.91b	0.50a	0.49b	0.13b	0.13b
F_{200}	0.67a	0.58d	0.69a	0.59c	6.78a	6.28a	0.54a	0.49b	0.13b	0.12c

Means with the same letter in a column are not significantly different at p>0.05.
P_5 = 5 t ha^{-1} PM, P_{10} = 10 t ha^{-1} PM, CP_5 = 5 t ha^{-1} CPH, CP_{10} = 10 t ha^{-1} CPH, F_{100} = 100 kg ha^{-1} NPK fertilizer, F_{200} = 200 kg ha^{-1} NPK fertilizer

At the end of the second cropping season (2020), there were increases in soil pH, total organic carbon, available P, exchangeable bases, while there were significant reductions in exchangeable acidity, total N and the micronutrients in plots amended with PM and CPH. Also, there were significant reductions in total N, total organic carbon and available P in plots amended with NPK fertilizer compared with the first cropping season. Highest rate of PM consistently resulted in elevated soil pH, exchangeable bases, ECEC, total organic carbon, total N and available P. There were no significant (P >0.05) differences in the effect of 5 t ha^{-1} PM and 5 t ha^{-1} CPH on soil pH, exchangeable Mg, ECEC, total organic carbon, available P and the micronutrients. At both cropping seasons, control plots and the plots amended with NPK 15:15:15 fertilizer had relatively lower soil pH when compared with the plots amended with PM and CPH.

Table 6: Relative Effects of Poultry Manure, Cocoa Pod Husk, NPK 15:15:15 Fertilizer on Soil Chemical Properties (2019 cropping season)

Trt (t/ha)	pH	Ca	Mg	K	Na Cmol/kg	Ex.AC	ECEC	Base Sat.	Total N %	Total Org. C	Av.P	Mu	Fe Mg/kg	Cu	Zn

Control	5.57b	3.04c	1.69c	0.47c	0.41a	0.11a	5.72c	98.01a	0.13c	1.68c	16.91a	19.61a	16.41a	2.89a	2.99a
PM_5	5.90b	3.65a	1.77b	0.56b	0.38b	0.09b	6.45b	98.61a	0.15a	1.89b	23.32c	17.03b	15.02b	2.67b	2.68b
PM_{10}	6.27a	3.93a	1.80a	0.62a	0.39b	0.08c	6.82a	98.81a	0.15a	2.09a	27.71a	16.62c	13.61d	2.65b	2.52b
CP_5	6.06a	3.69a	1.76b	0.59a	0.39b	0.09b	6.52a	98.61a	0.14b	1.91b	23.41c	16.81c	14.42c	2.69b	2.61b
CP_{10}	6.02a	3.78a	1.83a	0.61a	0.41a	0.09b	6.71a	98.71a	0.15a	2.07a	26.52a	16.13c	14.61c	2.54b	2.55b
F_{100}	5.88a	3.48b	1.78a	0.56b	0.39b	0.09b	6.30b	98.51a	0.14b	1.92b	25.21b	17.81b	15.22b	2.73a	2.72a
F_{200}	5.91a	3.68a	1.80a	0.59a	0.40a	0.09b	6.58a	98.61a	0.14b	2.02a	25.64b	18.52a	15.71b	2.84a	2.76a

Means with the same letter in a column are not significantly different at ($p>0.05$).
P_5 = 5 t ha^{-1}, P_{10} = 10 t ha^{-1}, CP_5 = 5 t ha^{-1}, CP_{10} = 10 t ha^{-1}, F_{100} = 100 kg ha^{-1} NPK fertilizer, F_{200} = 200 kg ha^{-1} NPK fertilizer.
Trt = Treatment, Ex. AC. = Exchangeable acidity, ECEC = Effective cation exchange capacity, Base sat = Base saturation, Total organic C = Total organic carbon, Av. P = Available phosphorus

Table 7: Relative Effects of Poultry Manure, Cocoa Pod Husk, NPK 15:15:15 Fertilizer on Soil Chemical Properties (2020 cropping season)

Trt (t/ha)	pH	Ca	Mg	K	Na	Ex.Ac.	ECEC	Base Sat.	Total N	Total Org. C	Av.P	Mu	Fe	Cu	Zn
					Cmol/kg				%				Mg/kg		
Control	5.69b	3.29c	1.72c	0.48d	0.41a	0.10a	6.00c	94.68a	0.10d	1.62c	15.12d	17.80a	14.72a	2.68a	2.75a
PM_5	5.97b	3.61b	1.82a	0.58b	0.41a	0.10a	6.52b	98.44a	0.12c	1.92b	24.66b	17.73a	14.92a	2.68a	2.64a
PM_{10}	6.44a	3.97a	1.87a	0.63a	0.40a	0.08c	6.65a	98.83a	0.13b	2.13a	28.51a	15.88b	13.82b	2.59a	2.50b
CP_5	6.29a	3.84a	1.84b	0.62a	0.41a	0.09b	6.79a	98.66a	0.13b	1.96b	23.92b	16.15b	14.10a	2.60a	2.54b
CP_{10}	6.28a	3.95a	1.91a	0.63a	0.43a	0.09b	7.00a	98.71a	0.14a	2.13a	28.54a	15.68b	13.98b	2.48b	2.47b
F_{100}	5.85b	3.61b	1.75b	0.52c	0.40b	0.09b	6.38b	98.47a	0.10d	1.80b	22.43c	16.43b	14.92a	2.56a	2.62a
F_{200}	5.78b	3.63b	1.86a	0.59b	0.41a	0.09b	6.57b	98.56a	0.11c	2.00a	20.61c	17.41a	13.62b	2.67a	2.67a

Means with the same letter in a column are not significantly different at ($p>0.05$).
P_5 = 5 t ha^{-1}MP, P_{10} = 10 t ha^{-1}PM, CP_5 = 5 t ha^{-1}CPH, CP_{10} = 10 t ha^{-1}CPH, F_{100} = 100 kg ha^{-1} NPK fertilizer, F_{200} = 200 kg ha^{-1} NPK fertilizer.
Trt = Treatment, Ex. AC. = Exchangeable acidity, ECEC = Effective cation exchange capacity, Base sat = Base saturation, Total organic C = Total organic carbon, Av. P = Available phosphorus.

Discussion

The sandy nature of the soil at the site of the experiments could have led to the leaching of the essential soil nutrients. Sandy textured soils are susceptible to high leaching, which was probably responsible for the low nutrient status of the soil at the site of the experiments. Based on the critical level of nutrients established for arable crop production in southwestern Nigeria by Aduayi *et al*. (2002), the soil at the site of the field experiment is deficient in N, P, K, Ca, Mg and Organic carbon, but high in micronutrients. Therefore, a supplementary supply of plant nutrients from external sources would enhance optimum performance of carrots in the studied soil.

The positive response of carrot growth parameters in plots amended with PM, CPH, and NPK fertilizer could be due to the nutrients supplied to the soil by these soil amendments. The result conforms with the finding obtained by Alice *et al.* (2014) that organic and inorganic fertilizer application had a significant influence on the growth parameter of carrots. The low carrot growth parameters in the control plots imply that supplementary nutrients from external sources will enhance growth and yield of carrot. Improvements in the growth parameters of carrots obtained in the second cropping season in plots amended with PM and CPH could be due to the residual effects of PM and CPH. These agree with the view of Zingore *et al.* (2007) that the value of organic manures as bio-fertilizers extends considerably beyond the first year of application. The high response of carrot growth to NPK fertilizer in the first cropping season might be due to the high concentration and readily available forms of N, P, and K in the fertilizer. Also, reductions in the growth parameters during the second cropping season might be a result of exhaustion and leaching of the applied nutrients attributed to the sandy nature of the soil at the site of the field experiment. The yield parameters of carrots increased with the increasing levels of PM, CPH, and NPK fertilizer. This positive response of carrots in terms of root yield might probably be due to the low initial nutrient status of the experimental soil and the nutrients released to the soil by the inputs. The results conform with the finding of Idem *et al*. (2012) that crops respond more to fertilizer application in soils with extreme low nutrient content than in soils of high nutrient reserve. The reductions in yield parameters of carrots in the second cropping season in plots amended with NPK fertilizer in the first cropping season is an indication that NPK fertilizer does not enhance sustainable carrot production sustainably due to its poor residual effect and its adverse effect of increasing soil acidity. In contrast, improvements in root yield parameters of carrots in plots amended with PM and CPH at the second cropping season imply that they can sustain improved carrot root yield and soil productivity overtime. These observations conform with the results reported by Zakir *et al.* (2016) and Rahman *et al.* (2018) that the fertilizer efficiency of organic manures is more lasting than the inorganic fertilizer.

The percentage of malformed roots increased with increasing levels of the inputs, and deformed roots might be due to the improved soil moisture and nutrient contents of the amended plots. The improved moisture and nutrient contents might be responsible for the enhanced biological activities in the soil, which might be responsible for the increased percentage of malformed roots. This view is in line with the finding of Khairul *et al.* (2015) that the percentage of rotten roots increased due to higher N levels in organic manure amended plots. The reduction in the percentage of malformed roots at the second cropping season compared with the first cropping season might be attributed to the low soil moisture content as a result of the low rainfall in the July and August 2020 cropping season as against relatively high rainfall in July and August 2019 cropping season. Reduction in percentage of malformed roots might be because no treatment was applied in the second cropping season. This view is in line with the report of Alice *et al.* (2014) that too much water in the soil during the period of root expansion suppressed the storage root enlargement of carrots. The low root yield (15.46 – 22.85 t ha^{-1}) obtained in the study compared with the reported root yield range of 30-60 t ha^{-1} in Europe (WCM, 2013) might be attributed to the conditions including low initial nutrients status, acidic nature of the soil of the experimental site and the high monthly temperature range of 24.12 – 26.12^{0}C during the growing period of carrot (May – September). The influence of temperature on the root growth of carrots is critical. Hailu *et al.* (2008) and Alarm *et al.* (2010) documennted that temperatures above 25^{0}C limit carrot root yield and favour shoot growth than storage root growth. The favourable comparison between carrot root yield in organic manured plots and NPK-treated plots in the first cropping season might partly be due to the balance of nutrition provided by the organic manures. In support of this view, Ahmed *et al.* (2014) and Khairul *et al*. (2015) attributed the better performance of carrots in organic manured plots to the balanced nutrition provided by the manure.

The improvements in the leaf N, P, K, Mg, and Ca in plots amended with PM and CPH in the second cropping season could be attributed to their residual effect. This view agrees with the finding of Eghball *et al.* (2004) that organic manure helps in the gradual release of its nutrients into the soil, while the low leaf N, P, and K in the second cropping season in plots amended with NPK fertilizer in the first cropping season could be because these nutrients leached down the soil profile. Therefore, NPK fertilizer could not guarantee carrot production on a sustainable basis. Improvement in soil pH, total N, total organic carbon, available P, exchangeable bases, reductions in exchangeable acidity, and the micronutrients in plots amended with PM and CPH could be related to the nutrient composition of PM and CPH. In support of this view, Iremiren and Ipinmoroti (2014) and Iradhatullah *et al*. (2014) have reported that PM and CPH are composed of high-nutrient elements that are available for the growth of crops when added to the soil. These improvements in nutrient status imply that they are suitable soil fertilizer management for the sustainable production of carrots. In support of this view, Akanbi *et al*. (2014) found that CPH increased soil pH, N, P, Ca, and Mg, and reduced micronutrients. Also, Akande and Adediran (2004) found that poultry manure significantly increased soil pH, N, P, K, Mg, and Ca. The improvements in nutrient status in the second cropping season in plots previously amended with PM and CPH in the first cropping season could be attributed to the slow release of nutrients from the organic manures that prevented the nutrients from being leached down the soil profile. Hence, PM and CPH have a significant residual effect on soil fertility status. In support of this view, Adeoye *et al.* (2008) observed that organic manures provide nutrients slowly but maintain uniformity of supplying available nutrients throughout the growing season and have a residual effect on the soil nutrient status. Reductions in exchangeable K, total N, and available P in plots amended with NPK fertilizer in the previous cropping season could be due to the rapid rate of mineralization of NPK fertilizer that might have enhanced the rapid rate of nutrients release to the soil and their subsequent loss through leaching.

The higher soil pH in plots amended with PM and CPH might partly be due to the calcium supplied to the soil by the PM and CPH, making them suitable liming materials. In support of this, recent studies have shown that PM and CPH increased soil pH, organic carbon, N, P, and CEC (Mbah and Mbagwu, 2006; Ayeni *et al*., 2008). The lower soil pH in plots amended with NPK fertilizer might be attributed to the acid-producing N and P components of ammonium and sulphur contents of the materials in the formulation of NPK 15:15:15 fertilizer. This view conforms with the report of Azizi *et al*. (2016) that as the ammonium N in ammonium-based nitrogen fertilizer undergoes nitrification, hydrogen ions are released, resulting in increased soil acidity.

Conclusion

The findings in this study indicated that poultry manure and cocoa pod husk as bio-fertilizer enhance soil nutrient status, growth, and root yield of carrots on a long term basis than NPK 15:15:15 fertilizer. Therefore, these cheap and locally available organic wastes could replace the high cost and scarce mineral fertilizers in enhancing soil productivity and carrot production in the rainforest agro-ecological zone of southwest Nigeria.

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