EVALUATION OF SOIL CHEMICAL PROPERTIES AND CARROT PERFORMANCE UNDER INTEGRATED NUTRIENTS MANAGEMENT ON AN ALFISOL IN SOUTHWEST NIGERIA

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ABSTRACT

Field trials were conducted in 2019 and 2020 to evaluate the effects of the integrated application of poultry manure (PM) and NPK fertilizer on soil chemical properties, growth, and yield of carrots. Poultry manure at three levels (0, 5, 10 t ha^{-1}) was integrated with NPK fertilizer at three levels (0, 100, and 200 kg ha^{-1}) in a factorial experiment arranged in a randomized complete block design. Each treatment was replicated three times. Data collected were analyzed using the Statistical Analysis System Institute Package. The results showed that the soil at the site of the experiment was low in nitrogen (0.8 g kg^{-1}), and available P (5mg kg^{-1}). Integrated application of PM and NPK significantly (P $\leq$0.05) improved soil pH, total N, and available P better than their sole application. Plots with the sole application of NPK had higher exchangeable acidity than plots with the integrated application of PM and NPK. Carrot growth parameters were better enhanced in plots with integrated application of PM and NPK fertilizer than the plots with the sole application of either of the amendments. There were reductions in growth and yield parameters in plots with the sole application of NPK fertilizer in the second cropping season whereas, improvements in growth and yield parameters were observed in plots with integrated application of the amendments. Integrated application of PM and NPK improved soil nutrient status, growth, and root yield of carrots better than their sole application. Hence, integrated nutrient management is ideal for maintaining soil quality and optimum carrot production.

Keywords: ***Soil chemical properties, carrot performance, poultry manure, NPK 15:15:15 fertilizer, integrated application, sole application.***

INTRODUCTION

Carrot (*Daucus carota*) is one of the highly treasured vegetables in great demand in all parts of Nigeria. However, its production is mainly from the northern part of Nigeria. In Nigeria, carrot yield is reported to be low due to scarcity 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 to facilitate the production and translocation of carbohydrates from leaves to roots (Gatsinzi *et al*., 2016). Carrot performs best in well-drained sandy or sandy loam soils with less water-holding capacity that will enhance proper aeration, root development and nutrient uptake (Wagini and Abubakar, 2015). Carrot grows well in high nutrient status and less acidic soils, a pH of 6.5 – 7.0 is reported to be ideal for high carrot production (Alice *et al*., 2014). Nitrogen, phosphorus, and potassium are the major limiting nutrients relating to the growth, development, and yield of carrots (Appiah *et al*., 2017). Response of carrots to both organic and inorganic fertilizers; depends on the initial nutrient status of the soil (Ahmed *et al.*, 2014). The soils in Nigeria are of low base status and apart from being deficient in bases, they often exhibit Al-toxicity (Salako, 2008). Soils in Nigeria are highly leached and acidic as a result of their sandy texture coupled with the high torrential pattern of rainfall leading to the leaching of exchangeable bases. The need for improved management practices led to external inputs from organic and inorganic sources to enhance soil productivity and crop yield. In Nigeria, the use of poultry manure in backyard vegetable crop production is common and has proven to supply the required nutrients, improve soil structure, and increase microbial population and crop yield (Mbah and Mbagwu, 2006; Adeleye *et al*., 2010; Rahman *et al*., 2018). However, the sole use of organic sources of nutrients in large-scale farming is accompanied by some problems such as bulkiness, high cost of transportation, and application of the manure. Inorganic fertilizers have had a very significant impact on crop production in Nigeria. Productivity increases associated with the use of mineral fertilizers are undisputable (Akanbi *et al*., 2010; Amusan *et al.*, 2011). However, the sole use of inorganic sources of nutrients continuously is found to increase crop yield only for a few years but on a long-term basis, it leads to decreasing base saturation, acidification, and nutrient imbalance (Adeoye *et al.*, 2008, Adeleye and Ayeni, 2009). Hence, sustainable crop production is not feasible with dependence on inorganic fertilizers alone (Adeoye *et al.*, 2008; Zakir *et al*., 2012). In Nigeria, the high cost of inorganic fertilizer, and its scarcity, coupled with the problems associated with the sole use of organic manures in large-scale farming has awakened interest in integrated management systems for improving soil fertility. Integrated nutrient management is a low-cost effective technology for restoring soil health through the combined use of organic and inorganic fertilizers in the supply of nutrients to crops (Mostafa, 2020). An integrated nutrient management system ensures the buildup of soil productivity and quality on a long-term basis (Adeniyan and Ojeniyi, 2005). A combination of high-quality organic manures with inorganic fertilizers is a valuable alternative for maintaining soil quality for sustainable crop production (Habimana *et al*., 2014; Sarma *et al*., 2015).

In Nigeria, research work on carrots is very scanty, particularly in the southwestern region that belongs mainly to the rainforest agroecological zone. Few studies conducted on the response of carrots to fertilizer were mainly centered on the inorganic nitrogenous fertilizer in northern Nigeria (Ahmed *et al.*, 2014). Furthermore, studies on the growth and yield of carrots are few. A desire for a better understanding of the effects of the combined use of poultry manure and NPK 15:15:15 fertilizer on soil properties and crop performance prompted the present study. Integrating poultry manure with inorganic fertilizer is considered likely to ameliorate the deleterious effects of the sole use of inorganic fertilizer on soil chemical properties and improve carrot yield. Therefore, this study was designed to evaluate the effects of the integrated application of poultry manure and NPK 15:15:15 fertilizer on soil chemical properties, growth, and yield of carrots in the rainforest agroecological zone of Nigeria.

MATERIALS AND METHODS

Description of the Site

Field trials were conducted in the 2019 and 2020 farming seasons in Adeyemi Federal University of Education Teaching and Research Farm, It lies between Latitude 07º 04` – 07º 06`N and Longitude 04º 49` - 04º 50`E in the rainforest agroecological zone of Nigeria. The mean annual rainfall is about 1650 mm precipitated in 210-240 days (Mid-March – Mid-November). The site enjoys a bimodal rainfall pattern with early rain occurring between March to July and late rain between August to October with a short dry spell in August. The mean relative humidity is about 69% and the mean monthly temperature at the site of the field experiment is 27^0C, February and March are the hottest months with mean daily temperatures of 28 and 29^0C respectively (FDACSA, 2021). The soil at the site is sandy in texture and moderately acidic pH of 6.2, classified as Oxic Tropuldalf (Alfisol). The geology of the site is dominated by crystalline rocks, which form part of the basement complex of southwest Nigeria (Akinbola *et al.*, 2009). The site is located in the lowland rainforest of Nigeria with semi-deciduous vegetation. The site has been previously cultivated for arable crops and the site has been under fallow for two years before the commencement of the experiment the fallow vegetation comprises siam weed, wild sunflower goat weed, and interspersed with shrubs of diverse species.

Treatments and Experimental Design

The study was a factorial experiment that involved two factors (poultry manure (PM) at three levels (0, 5, and 10 t ha^{-1}) and NPK 15:15:15 fertilizer at three levels (0, 100, and 200 kg ha^{-1})) replicated three times and fitted into randomized complete block design. This produced nine (9) treatment combinations given a total of 27 experimental units. A total land area of 14m by 5m was marked out for the experiment, the site was manually cleared, packed, and divided into three blocks and each block was demarcated by 0.5m wide alleyways. Each block was further divided into nine (9) plots of 1m x 1m and also demarcated by 0.5m wide alleyways. The plot was made into 27 raised beds of 1m x 1m each with a traditional hoe. The raised beds were thoroughly pulverized and raked free of stones to allow good root development. A well-cured, dried, and ground poultry manure was uniformly spread on the plots and incorporated into the soil at the rates of 0, 5, and 10 t ha^{-1} with hand hoe five (5) days after land preparation. The same plot of land was used for the second cropping season and no treatment was applied at the second cropping season Carrot seeds (Thema variety) were sown directly to the prepared beds by drilling in rows spaced at 20cm apart, a week after poultry manure application. The carrot seedlings were later thinned two (2) weeks after the emergence of carrot seedlings to attain a spacing of 20cm apart. NPK 15:15:15 fertilizer was applied three (3) weeks after emergence of carrot seedlings by band placement. Weeding and other cultural operations were the same for all the treatments and were attended to regularly.

Growth and Yield Analysis

Ten (10) carrot stands were randomly selected per plot and tagged to estimate growth and yield parameters. Leaf length, number of leaves, and plant height were measured at 40, 60, and 80 days after sowing of carrot seeds. Shoot fresh weight was determined using a weighing balance. Also, shoot dry weight was determined by oven drying five (5) stands per treatment and per replicates to constant weight at 65^0C. Carrot root yield parameters were taken at harvest on a treatment basis using the same 10 tagged stands. Root fresh weight was determined using a weighing balance in g per stand. Root diameter was measured at the fattest 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 the percentage was calculated from the number of total roots at harvest. Root dry weight was determined by oven-drying roots to a constant weight at 65^oC. The percent dry matter yield of roots was calculated as:

$$\%\,dry\ matter = \frac{Dry\ weight\ of\ root}{Fresh\ weight\ of\ root} x \frac{100}{1}$$

Marketable root yield was determined by counting roots with no deformities like cracks, forking, and malformation and without spots in relation to the total number of roots harvested.

Soil Analysis

Ten (10) pretreatment soil surface (0-15cm) core samples were collected randomly from the experimental site using a soil auger, bulked, air-dried, and passed through a 2mm-sieve for routine chemical analysis to obtain the initial soil physical and chemical properties. Another set of surface (0-15cm) soil samples were collected on a treatment basis and per replicate at harvest and processed for chemical analysis for post-harvest soil chemical properties. Soil pH was determined at a 1:2 soil-water ratio using a glass electrode pH meter, and total nitrogen by the Kjeldahl digestion method (Bremner, 1996). The particle size distribution was done using the hydrometer method (Gee and Or, 2002). Organic carbon was determined following the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996). Available P was extracted by Bray-l-method and P in the extract was determined colourimetrically (Frank *et al*., 1998). Exchangeable Ca, K, Mg, and Na were extracted with 1.0N NH_4OA_C (Ammonium acetate). The K and Na in the extract were read using a flame photometer, while Ca and Mg were read using an Atomic Absorption Spectrophotometer (AAS) (Hendershot *et al*., 2008). Exchangeable acidity was determined from 1.0 N KCl extract and titrated with 0.1 N HCl (Maclean, 1982), ECEC was by summation of 1.0 N NH_4OA_C extractable bases plus 1.0 N KCl extractable acidity. The micronutrients (Fe, Cu, Zn, and Mn) were extracted by 0.1 N HCl and were read using AAS (AOAC, 2000). Percent base saturation was obtained by dividing the total exchangeable base (TEB) by the Cation exchange capacity (CEC) and multiplying by 100.

Data Analysis

Statistical analysis was performed on the measured soil chemical properties, growth, and yield variables using the Statistical Analysis System Institute Package-General Linear Model (SAS, 2002) for the analysis of variance. Means were compared using New Duncan's Multiple Range Test at a 5% level of significance.

RESULTS

Table 1 shows the initial physical and chemical properties of the soils of the experimental site before land preparation. The soil was sandy in texture, slightly acidic, low in total nitrogen, available phosphorus, organic carbon, effective cation exchange capacity (ECEC), exchangeable magnesium (Mg), exchangeable potassium (K), and exchangeable calcium (Ca). The micronutrients such as iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn) were high. All the nutrients were compared with the critical level of nutrients established by Aduayi *et al.* (2002) for arable crops in southwest Nigeria. These include 3 % for organic matter, 0.15 % for total N, 10-15 mg kg^{-1} for available P, 0.45 cmol kg^{-1} for K, 0,30 cmol kg^{-1} for Mg, 2.5 cmol kg^{-1} for exchangeable Ca, 4.5-10 mg kg^{-1} for Fe, 0.2 – 10, mg kg^{-1} for Zn, 0.0-5.0 mg kg^{-1} for Mn and 0.2-1.0 mg kg^{-1} for Cu.

Tables 2 and 3 show the effect of PM and NPK 15:15:15 fertilizer integration on soil chemical properties at the end of the 2019 and 2020 cropping seasons respectively. At the end of the first cropping season, relative to control, soil chemical properties such as soil pH, exchangeable bases, total N, total organic carbon, available P, exchangeable acidity, and ECEC were significantly ($P \leq 0.05$) increased by the integrated application of PM and NPK 15:15:15 fertilizer.

Table 1: Initial Soil Physical and Chemical Properties of the Experimental Site

	Value
Sand (g kg $^{-1}$)	902
Silt (g kg $^{-1}$)	56
Clay (g kg $^{-1}$)	42
Textural Class	Sandy soil
pH (H_2O) (1:2)	6.2
Organic carbon (g kg $^{-1}$)	6.8
Total nitrogen (g kg $^{-1}$)	0.8
Available phosphorus (mg kg^{-1})	5.0
Ca (cmol kg^{-1})	1.5
Mg(cmol kg^{-1})	0.2
Na (cmol kg^{-1})	0.4
K (cmol kg^{-1})	0.2
Exch. Ac. (cmol kg^{-1})	0.1
ECEC (cmol kg^{-1})	2.3
B. Sat (%)	97
Mn (mg kg^{-1})	15
Fe (mg kg^{-1})	19
Cu (mg kg^{-1})	2.3
Zn (mg kg^{-1})	3.2

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

Integrated application of PM and NPK fertilizer significantly ($P \leq 0.05$) increased exchangeable bases, ECEC, total N, total organic carbon, and available P better than the sole application of either PM or NPK fertilizer. The plots with the sole application of NPK 15:15:15 fertilizer had lower soil pH, exchangeable bases, ECEC, total organic carbon, and available P than the plots with the integrated application of PM and NPK fertilizer. Plots with the sole application of PM had higher soil pH, ECEC, organic carbon, available P, and lower exchangeable acidity and micronutrients than the plots with the sole application of NPK fertilizer. The effect of the treatments on the measured soil chemical variables was significantly different ($P < 0.05$). Plots with the integrated application of 10 t ha^{-1} PM with 200 kg ha^{-1} NPK had the highest values of soil pH, exchangeable bases, ECEC, total N, available P and the lowest values of exchangeable acidity and the micronutrients.

At the end of the second cropping season, plots with the integrated application of 10 t ha^{-1} PM and 200 kg ha^{-1}NPK 15:15:15 fertilizer consistently had the highest values of soil pH, exchangeable bases, ECEC, total N, available P, total organic carbon, and the lowest exchangeable acidity and micronutrients. At the end of the second cropping season, there were no significant ($P \geq 0.05$) differences in soil pH, exchangeable bases (Ca, Mg, K, Na), ECEC, total N, Mn, and Fe in plots with the integrated application of 5 t ha^{-1} PM and 200 kg ha^{-1}NPK 15:15:15 fertilizer and plots with the integrated application of 10 t ha^{-1} PM and 200 kg ha^{-1} NPK. Plots with the sole application of NPK 15:15:15 fertilizer had lower soil pH, total N, total organic carbon, available P, and higher exchangeable acidity and micronutrients than plots with the sole poultry manure application at the end of the second cropping seasons.

Table 2: Effects of Poultry Manure and NPK 15:15:15 Fertilizer Integration on Soil Chemical Properties at the experimental Site in 2019 Cropping Season

Trt (t ha^{-1})	pH	Ca	Mg	K	Na	Ex.Ac	ECEC	Base Sat	Total N	Total Org C	Av. P	Mn	Fe	Cu	Zn
		⟶			cmol/kg	⟵	⟶		%	⟵	⟶		mg/kg	⟵	
P_0F_0	6.2b	1.58d	0.30d	0.25d	0.36b	0.09b	2.58c	96.4a	0.06f	0.45d	7.71f	18.91a	2.11a	2.24a	2.13a
P_0F_{100}	6.3b	1.69c	0.31c	0.31b	0.39ab	0.09b	2.79b	96.9a	0.09c	0.48d	10.01e	17.12b	1.93a	2.32a	1.94b
P_0F_{200}	6.3b	1.63c	0.32c	0.33b	0.37b	0.10a	2.75b	96.3a	0.11b	0.51c	11.12e	18.31a	2.12a	2.52a	2.25a
P_5F_0	6.5a	1.66c	0.33c	0.30c	0.39ab	0.07d	2.76b	97.3a	0.07e	0.54c	13.61d	17.12b	1.37c	2.07b	1.55d
P_5F_{100}	6.4b	1.82b	0.37b	0.35a	0.38b	0.09b	3.02a	97.1a	0.10c	0.59b	18.20b	18.51a	1.44c	2.10b	1.77c
P_5F_{200}	6.3b	1.80b	0.39a	0.37a	0.41a	0.08c	3.07a	96.8a	0.11b	0.61b	18.91b	19.32a	1.79b	2.19b	1.92b
$P_{10}F_0$	6.6a	1.73b	0.33c	0.32b	0.41a	0.07d	2.87b	97.3a	0.08d	0.58b	16.50c	15.51c	1.50c	1.78c	1.71c
$P_{10}F_{100}$	6.5a	1.82b	0.39a	0.36a	0.39ab	0.07d	3.03a	97.7a	0.11b	0.66a	26.12a	13.72d	1.67b	1.84c	1.99b
$P_{10}F_{200}$	6.6a	1.93a	0.42a	0.38a	0.41a	0.08c	3.22a	97.6a	0.12a	0.71a	25.80a	14.81c	1.71b	1.83b	1.92b
SE$\pm$	0.04	0.01	0.01	0.01	0.01	0.003	0.02	0.09	0.003	0.006	0.43	0.44	0.03	0.04	0.04

Means with the same letter in a column are not significantly different at $p \geq 0.05$.
P_0 = 0 t ha^{-1} PM, P_5 = 5 t ha^{-1} PM, P_{10} = 10 t ha^{-1} PM, F_0 = 0 kg ha^{-1} NPK, F_{100} = 100 kg ha^{-1} NPK, F_{200} = 200 kg ha^{-1} NPK.
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 3: Effect of Poultry Manure and NPK 15:15:15Fertilizer Integration on Soil Chemical Properties at the experimental Site in 2020 Cropping Season

Trt	pH	Ca	Mg	K	Na	Ex.Ac	ECEC	Base Sat	Total N	Total Org C	Av. P	Mn	Fe	Cu	Zn
(t ha^{-1})					cmol/kg				%			mg/kg			
P_0F_0	6.24b	1.63c	0.31d	0.26c	0.38b	0.09b	2.67c	96.45b	0.07f	0.43e	7.31f	18.77a	2.12a	2.23a	2.03a
P_0F_{100}	6.27b	1.76b	0.33c	0.32b	0.40a	0.10a	2.89b	96.91b	0.08e	0.43e	9.87e	18.06a	1.94b	2.33a	2.07a
P_0F_{200}	6.34b	1.68b	0.33c	0.33b	0.38b	0.10a	2.83b	96.30b	0.09d	0.47d	10.78e	18.36a	2.14a	2.53a	2.22a
P_5F_0	6.82a	1.74b	0.35c	0.32b	0.41a	0.08c	2.90b	97.27a	0.10c	0.56c	14.65d	16.22b	1.30e	1.97b	1.48e
P_5F_{100}	6.71a	1.90a	0.39b	0.37a	0.40a	0.09b	3.15a	97.06a	0.11b	0.62b	19.33b	17.90a	1.40d	2.04a	1.72c
P_5F_{200}	6.63a	1.85a	0.41a	0.39a	0.43a	0.09b	3.18a	96.79b	0.12a	0.64b	20.08b	14.10c	1.73c	2.12a	1.86c
$P_{10}F_0$	6.89a	1.81a	0.34c	0.34b	0.42a	0.08c	2.99b	97.39a	0.11b	0.60b	17.54c	14.73c	1.43d	1.69c	1.63d
$P_{10}F_{100}$	6.89a	1.90a	0.41a	0.38a	0.41a	0.08c	3.17a	97.72a	0.12a	0.70a	26.54a	13.31d	1.63c	1.78c	1.93b
$P_{10}F_{200}$	6.87a	2.02a	0.44a	0.40a	0.43a	0.08c	3.37a	97.57a	0.12a	0.74a	27.37a	14.33c	1.65c	1.78c	1.63d
SE$\pm$	0.06	0.02	0.01	0.01	0.03	0.003	0.03	0.10	0.01	0.01	0.46	0.39	0.03	0.004	0.04

Means with the same letter in a column are not significantly different at $p \geq 0.05$.

P_0 = 0 t ha^{-1} PM, P_5 = 5 t ha^{-1} PM, P_{10} = 10 t ha^{-1} PM, F_0 = 0 kg ha^{-1} NPK, F_{100} = 100 kg ha^{-1} NPK, F_{200} = 200 kg ha^{-1} NPK. 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.

The effect of poultry manure and NPK 15:15:15 fertilizer integration on the growth characteristics of carrots is shown in Table 4. Relative to control, the integrated application of PM and NPK 15:15:15 fertilizer significantly ($P \leq 0.05$) influenced growth parameters such as plant height, leaf length, and shoot dry matter yield of carrots. Growth characteristics of carrots were better enhanced in the plots that received integrated application of PM and NPK 15:15:15 fertilizer than the plots with the sole application of either PM or NPK 15:15:15 fertilizer at both cropping seasons. Plots treated with 10 t ha^{-1} PM integrated with 200 kg ha^{-1}NPK 15:15:15 fertilizer had the best growth parameters in terms of plant height, leaf length and shoot dry matter at both cropping seasons. There were reductions of 12 - 16% in the growth parameters of carrots at the second cropping season in plots that received the sole application of NPK 15:15:15 fertilizer. Also, there were relative improvements in the growth characteristics of carrots in plots treated with the sole application of PM and the plots with the integrated application of PM and NPK 15:15:15 fertilizer during the second cropping season. There were no significant differences ($P \geq 0.05$) in the growth parameters of carrots in plots treated with the integrated application of 10 t ha^{-1} PM and 200 kg ha^{-1}NPK 15:15:15 fertilizer and the plots treated with the integrated application of 5 t ha^{-1} PM and 200 kg ha^{-1} NPK at both cropping seasons. The mean plant height values for the two cropping seasons for P_0F_0, P_0F_{100}, P_0F_{200}, P_5F_0, P_5F_{100}, P_5F_{200}, $P_{10}F_0$, $P_{10}F_{100}$ and $P_{10}F_{200}$were 27.1, 29.2, 32.85, 31.90, 34.10, 37.0, 35.25, 39.10 and 39.3, cm respectively.

Table 4: Effect of Poultry Manure and NPK 15:15:15 Fertilizer Integration on 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
P_0F_0	29.03c	25.23c	23.82c	20.21c	7.24a	6.88b	8.77b	5.46b
P_0F_{100}	32.81b	25.61c	28.91b	25.71b	7.94a	7.38b	9.95b	6.12a
P_0F_{200}	36.22a	29.52b	30.13a	26.23b	7.63a	7.17b	9.47b	6.11a
P_5F_0	31.61b	32.23b	26.81b	27.32b	7.94a	8.02a	9.48b	6.04a
P_5F_{100}	33.92b	34.32ab	27.82b	28.13ab	8.05a	8.13a	11.13a	6.46a
P_5F_{200}	38.13a	35.91a	31.03a	29.61a	8.15a	8.23a	10.3a	6.07a
$P_{10}F_0$	33.91b	36.62a	29.61a	30.22a	7.82a	8.05a	8.97b	6.81a
$P_{10}F_{100}$	38.92a	39.33a	30.33a	30.61a	7.83a	8.14a	12.1a	6.47a
$P_{10}F_{200}$	38.91a	39.71a	32.22a	32.52a	7.91a	8.11a	10.9a	6.41a
SE$\pm$	1.32	1.34	0.68	0.72	0.32	0.33	0.47	0.49

Means with the same letter in a column are not significantly different at $p \geq 0.05$.

P_0 = 0 t ha^{-1} PM, P_5 = 5 t ha^{-1} PM, P_{10} = 10 t ha^{-1} PM, F_0 = 0 kg ha^{-1}NPK 15:15:15 fertilizer, F_{100} = 100 kg ha^{-1}NPK 15:15:15 fertilizer, F_{200} = 200 kg ha^{-1}NPK 15:15:15 fertilizer

The interaction effect of the integrated use of poultry manure and NPK 15:15:15 fertilizer on the root yield characteristics of carrots is shown in Table 5. Relative to control, carrot root yield characteristics were significantly ($P \leq 0.05$) influenced at both cropping seasons. Integrated application of PM and NPK 15:15:15 fertilizer significantly ($P \leq 0.05$) influenced root length, root diameter, root dry matter, deformed roots, gross root yield and marketable root yield. Root yield parameters were better enhanced in plots with the integrated application of PM and NPK 15:15:15 fertilizer than the plots with the sole application of either PM or NPK 15:15:15 fertilizer at both cropping seasons.

The plots with the integrated application of 10 t ha^{-1} PM and 200 kg ha^{-1}NPK 15:15:15 fertilizer consistently had the best carrot root yield characteristics. This was followed by the plots treated with the combined application of 10 t ha^{-1} PM and 100 kg ha^{-1}NPK 15:15:15 fertilizer. However, there were no significant differences (P> 0. 05) between the root yield characteristics of carrots in terms of root length, root dry matter, and marketable root yield in plots with the integrated application of 5 t ha^{-1} PM and 200 kg ha^{-1}NPK 15:15:15 fertilizer and that of the plots with the integrated application of 10 t ha^{-1} PM and 200 kg ha^{-1}NPK 15:15:15 fertilizer at both cropping seasons. At the second cropping season, there were reductions of 10 – 21 % in carrot root yield characteristics in plots with the sole application of NPK 15:15:15 fertilizer, while at the same time, there were improvements in carrot root yield characteristics in plots with the integrated application of PM and NPK 15:15:15 fertilizer. The mean values of gross root yield for P_0F_0, P_0F_{100}, P_0F_{200}, P_5F_0, P_5F_{100}, P_5F_{200}, $P_{10}F_0$, $P_{10}F_{100}$ and $P_{10}F_{200}$ for the two cropping seasons were 20.03, 20.92, 20.71, 22.13, 26.72, 26.91, 24.51, 28.32 and 29.51 t ha^{-1}, respectively. Malformed roots increased with increased rates of the integrated application of PM and NPK 15:15:15 fertilizer at both cropping seasons.

Table 5: Effect of Poultry Manure and NPK 15:15:15 Fertilizer Integration 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
P_0F_0	8.78c	8.08b	1.34d	1.31c	8.14b	7.49b	21.05c	18.95d	1.70c	1.07c	20.69c	18.74c
P_0F_{100}	9.92b	9.13b	1.51c	1.39c	8.69b	7.99b	22.60c	19.21d	1.96c	1.23c	22.17b	18.97c
P_0F_{200}	10.05a	9.25b	1.68c	1.56c	9.32a	8.57b	22.80c	18.74d	2.66b	1.68b	22.19b	18.43c
P_5F_0	9.11b	9.47b	1.40d	1.46c	9.19a	9.56a	21.75c	22.62c	1.78c	1.12c	21.31b	22.37b
P_5F_{100}	10.80a	11.02a	1.66c	1.69b	9.65a	9.84a	26.40b	26.93b	2.40b	1.51b	25.76a	26.52a
P_5F_{200}	11.55a	11.67a	1.93b	1.95b	9.77a	9.87a	26.60b	27.17a	2.62b	1.65b	25.91a	26.72a
$P_{10}F_0$	10.40a	10.82ab	1.66c	1.73b	10.18a	10.58a	24.05b	25.01b	2.50b	1.58b	23.45b	24.61b
$P_{10}F_{100}$	11.81a	11.93a	2.34a	2.38a	10.32a	10.67a	28.10a	28.66a	2.68b	1.69b	27.41a	28.18a
$P_{10}F_{200}$	12.09a	12.33a	2.38a	2.40a	9.78a	10.07a	29.45a	29.74a	4.76a	2.99a	28.52a	28.85a
SE$\pm$	0.72	0.73	0.50	0.51	0.79	0.79	2.95	2.88	0.27	0.24	2.68	2.64

Means with the same letter in a column are not significantly different at $p \geq 0.05$.

P_0 = 0 t ha^{-1} PM, P_5 = 5 t ha^{-1} PM, P_{10} = 10 t ha^{-1} PM, F_0 = 0 kg ha^{-1}NPK 15:15:15 fertilizer, F_{100} = 100 kg ha^{-1}NPK 15:15:15 fertilizer, F_{200} = 200kg ha^{-1}NPK 15:15:15 fertilizer.

DISCUSSION

The soil at the site of the experiments has a sandy texture, soils of this nature are characterized by low water and nutrient holding capacities and high leaching potentials. The slightly acidic nature of the soil might be attributed to the coarse nature of the soil, which should have encouraged the leaching of exchangeable bases. Based on the established critical level of nutrients for arable crops in southwest Nigeria by Adeoye and Agboola (1985), and Aduayi *et al.* (2002), the soil at the experimental site is deficient in N, P, K, Ca, Mg, and organic carbon but high in micronutrients. The high content of micronutrients especially Fe could have influenced the fixation of phosphorus thereby resulting in the low available P of the experimental site.

The improvements in soil pH, N, K, Ca, and Mg in plots with the sole application of poultry manure (PM) relative to the control plots are indications that it could serve as a valuable source of macro and micronutrients in crop production. In support of this view, Akande and Adediran (2004) found that poultry manure significantly increased soil pH, N, P, K, Mg, and Ca. Also, improvements in nutrient status in the second cropping season could be attributed to the slow release of nutrients from PM, which must have prevented the nutrients from being leached down the soil profile. 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 at the same time, have a residual effect on the soil nutrient status. Reductions in total N, available P, exchangeable K, and soil organic carbon at the end of the second cropping in plots with the sole application of NPK 15:15:15 fertilizer could be attributed to the rapid rate of nutrients released from the inorganic fertilizer to the soil and their subsequent loss through leaching resulting in a reduced residual effect. In contrast, the slow release of nutrients from PM prevents rapid loss of nutrients from the soil. The decrease in the soil pH of the plots with the sole application of NPK 15:15:15 fertilizer might be attributed to the acid-producing N and P components of ammonium and sulphur contents of the materials (urea and single super phosphate) used 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 ion [H^+] is released, which increases soil acidity. Mineralization of NPK 15:15:15 fertilizer will release acidic radicals into the soil, and these radicals will react with hydrogen ions [H^+] in the soil solution leading to the formation of acid compounds in the soil which will make the soil become acidic. The integration of PM and NPK 15:15:15 fertilizer might have hastened the mineralization of PM, thereby leading to the release of more nutrients to the soil. In support of this view, Adeoye *et al*. (2008), Islam *et al* (2015) and Khairul *et al.* (2015) noted that integrated application of organic and inorganic manure hastened minralization of the organic component of the integration. Hence, the integrated application of PM and NPK fertilizer was found to be more beneficial than the sole application of either of them in terms of nutrient supply and balanced nutrition, and this, might be the reason for the best growth and root yield obtained in plots with the integrated application of PM and NPK fertilizer.

The positive response of carrots to the integrated application of PM and NPK 15:15:15 fertilizer could be attributed to the complementary nutrients supply from these amendments to the soil for the uptake of carrots. NPK fertilizer component of the integration releases a high content of three major nutrients N, P, and K which are complimented with other essential macro and micro-nutrients from the poultry manure, thereby providing balanced nutrition for the crop. Also, the accelerated mineralization of PM might have made more nutrients available for the uptake of carrots. the results obtained conform with the results of Ahmad *et al*. (2014), Habimana *et al*. (2014), Islam *et al.* (2015) and Khairul *et al*. (2014) that integrated application of organic with inorganic fertilizer enhanced growth and yield of carrots. Carrot growth parameters were significantly enhanced in plots with the sole application of NPK 15:15:15 fertilizer in the first cropping season, this enhancement might be attributed to the high concentration and readily available forms of N, P and K in the fertilizer. Also, reductions in the growth parameters at the second cropping season might be as a result of exhaustion and leaching of the applied nutrients attributed to the sandy nature of the soil of the experimental site. While, the low response of carrot growth parameters in plots with the sole application of PM in the first cropping season as compared with the plots with sole application of NPK 15:15:15 fertilizer might be attributed to the low and slow release of nutrients from the PM, a substantial time is required for nutrients to be released from organic manures.

Carrot root yield parameters increased with the increasing rates of PM, NPK 15:15:15 fertilizer, and their integrations. The response of carrot in terms of root yield might probably be due to the low initial nutrient status of the experimental soil and the balanced nutrients released to the soil by the integrated application of PM and NPK 15:15:15 fertilizer. The increase in yield in plots with combined application of PM and NPK 15:15:15 fertilizer conforms with the findings of Makinde *et al.* (2007) and Uko *et al*. (2008) in vegetable crops. The low yield of carrots in the first cropping season in plots with the sole application of PM implies that the sole application of poultry manure is not effective in enhancing high carrot root yield on an immediate basis. Also, the improvements in root yield parameters in the second cropping season are an indication that PM has a high residual effect on root yield and soil productivity on a long-term basis. These observations might be attributed to low nutrient content and the slow nutrient release from organic manures. These findings are in agreement with the results reported by Amusan *et al*. (2011), Zhang *et al*. (2016), and Rahman *et al*. (2018) that the fertilizer efficiency of organic manures is more lasting than that of inorganic fertilizer. Also, in contrast, the reductions in yield parameters of carrots in plots with the sole application of NPK 15:15:15 fertilizer in the second cropping season is an indication that the exclusive use of NPK 15:15:15 fertilizer is not effective in enhancing sustainable carrot production on a long-term basis. Better yield parameters obtained with the integrated application of PM and NPK 15:15:15 fertilizer could be attributed to the utilization of the balanced nutrition (micro and macro-nutrients) from PM and macro-nutrients from NPK 15:15:15 fertilizer. These views agree with the view of Ahmad *et al*. (2014) and Khairul *et al*. (2015) that better performance of carrots in plots with the integrated application of organic and inorganic fertilizers could be attributed to the balanced nutrition provided by the organic manures and the inorganic manures. Integrated application of 5 t ha^{-1} PM and 200 kg ha^{-1} of NPK 15:15:15 fertilizer produced optimum yield of carrot roots. This is in agreement with the results obtained by Habimana *et al.* (2014). They observed that the increased soil N, P, K, Ca, Mg and coupled with the high uptake of these nutrients may be responsible for the enhanced yield characteristics of carrots.

The percentage of malformed roots increased with increasing rates of PM, NPK 15:15:15 fertilizer, and their integrations, the increased malformed roots may be attributed to the improved soil moisture content of the amended plots. The improved moisture content might be responsible for the enhanced biological activities in the soil, which might partly be responsible for the increased percentage of rotten roots. Also, improvements in the nutrient content of the amended plots might be responsible for the enhanced biological activities that led to the malformation of carrot roots. This view is in line with the finding of Khairul *et al.* (2015) that the percentage of malformed roots increased due to higher N levels in plots amended with poultry manure.

The carrot root yield obtained in this study was low compared with the reported root yield range of 30-60 t ha^{-1} in Europe (WCM, 2013). The low root yield obtained might be attributed to the conditions including the low initial nutrient status and the acidic nature of the soil at the experimental site. Also, the high monthly mean temperature of 27^0C of the experimental site might have contributed to the low root yield obtained. The influence of temperature on the root growth performance of carrots has been reported to be critical. Many researchers have suggested a temperature range of 15-25^0C for optimum growth and root yield of carrots, temperature above 25^0C has been reported to limit carrot root yield and favour shoot growth over storage root growth (Hailu *et al*., 2008; Alarm *et al.*, 2010 and Wafaa, 2013).

CONCLUSION

Integrated application of poultry manure and NPK 15:15:15 fertilizer enhanced soil nutrients status, growth, and root yield of carrot better than the sole application of either of the amendments, hence, integration of poultry manure and NPK 15:15:15 fertilizer will be a useful alternative to the sole use of inorganic fertilizer for maintaining soil quality and optimum productivity of carrots.

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