

Accepted manuscript (author version)

To appear in International Journal of Recycling of Organic Waste in Agriculture (IJROWA)

Online ISSN: [2251-7715](#)

Print ISSN: [2195-3228](#)

This PDF file is not the final version of the record. This version will undergo further copyediting, typesetting, and review before being published in its definitive form. We are sharing this version to provide early access to the article. Please be aware that errors that could impact the content may be identified during the production process, and all legal disclaimers applicable to the journal remain valid.

Received: 31 Oct 2023

Revised: 06 Feb 2024

Accepted: 04 Jun 2024

DOI: [10.57647/ijrowa-a6re-9251](#)

ORIGINAL RESEARCH

Soil amendments and pepper variety effects on soil physicochemical properties and yield of pepper in Ishiagu, Southeastern Nigeria

John Chukwu Nwite

Department of Crop Production Technology, Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria.

*Corresponding author email: johnsmallpot@gmail.com

Abstract

Purpose: Poultry dropping and rice-mill wastes are generated in large quantities on daily basis in Ishiagu, Ebonyi State, Nigeria. These bio-wastes can improve soil quality and pepper production. Hence, this study seeks to evaluate the effects of amendments on soil physico-chemical properties and yield of pepper varieties.

Method: This experiment was carried out in the research farm of Federal College of Agriculture, Ishiagu, during 2020 and 2021 cropping seasons. Split-plot design replicated 3 times was employed. Two varieties of pepper (Yellow and Red) constituted the main plots, while six soil amendments occupied the sub-plots. Soil amendments employed were; poultry dropping (PD) at 10t/ha, rice husk dust (RHD) at 10t/ha, NPK 15:15:15 at 300kg/ha, PD at 5t/ha + RHD at 5t/ha, NPK 15:15:15 at 150kg + RHD at 5t/ha and control.

Results: Soil amendments improved soil pH, organic carbon (OC), total nitrogen (TN) and cation exchange capacity (CEC) in both cropping seasons. Pepper varieties influenced these soil properties in the 2021 cropping season, with yellow pepper showing higher soil pH, OC and CEC than red pepper (6.21 against 6.07, 14.07 against 12.24 g/kg and 16.13 against 15.47 cmol/kg), respectively. Soil amendments varied fresh pepper yields from 3.60 t/ha in NPK + RHD treated plots to 6.67 t/ha in PD plots compared to the control with 2.44 t/ha.

Conclusion: PD and PD + RHD increased the soil pH, OC, TN and CEC in both 2020 and 2021, making PD and its integration with RHD a sound strategy for improving soil attributes in the area. In 2020, yellow variety increased higher than red variety with PD and PD + RHD giving higher yield than other treatments. In 2021, yellow variety produced with NPK was similar to yellow variety and red variety produced with PD, but significantly higher than other treatments. Hence, the use of PD and its integration in producing yellow pepper variety on a long-term basis is an effective amendment procedure for pepper production in the area.

Keywords: Rice-mill waste, Cropping seasons, Inorganic fertilizer, Poultry dropping, Crop improvement, Soil fertility

Introduction

Pepper fruit (*Capsicum species*) is a very good relish in diets of many communities in Nigeria. In recent time, many families can hardly prepare any dish (food) without adding pepper because of its spicy nature, except for some people with ulcer cases. This has made the cultivation of pepper, especially the yellow variety, so common among the rural farmers in southeastern Nigeria. In spite of the nutritional and industrial benefits of the crop, its production is still relegated to the poor rural women farmers in the study area. Nigeria is known to be one of the major producers of pepper in the world accounting for about 50% of the African production (Idowu-Agida et al. 2010). According to Yahaya et al. (2010), the world production statistics in 2006 showed that Nigeria's pepper production was about 204,200 metric tons. While the dry fruit production figures for Nigeria in 2007 was 49,500 metric tons out of Africa's totals of 457,650 metric tons. Over the years, intensive cultivation of introduced high-yielding pepper varieties has resulted in depletion of mineral nutrients and hence increased soil acidity (Nwite et al. 2011). In view of this perpetrated problem, farmers in the study area find it difficult to produce crops economically without adding to the soil those elements that are limiting the growth and productivity of the crop through inorganic fertilizer application (Echezona and Nganwuchu, 2006).

Varietal analysis techniques according to Kahsay (2017) have been found to be useful tools to obtain precise information about the types of gene actions involved in the expression of various traits and to predict the yield performance of the progenies. He further stated that individual variety has its own significant effect on the yield and yield components. In this regard, traits mostly considered include, number of branches per plant (count), plant height, number of fruits per plant, days to maturity (count from days of transplanting), dry fruit yield per plant, fruit length and single fruit weight (Kahsay, 2017; Fekadu et al., 2008).

Pepper takes up a large amount of nutrients from the soil hence the need for the addition of nutrients to the soil to increase their growth and yield. Over the years, the intensive cultivation of introduced high-yielding pepper varieties has resulted in depletion of mineral nutrients and hence increased soil acidity (Nwite et al. 2011). In the understanding of this perpetrated problem, farmers in the study area find it difficult to produce crops economically without adding to the soil those elements that are limiting to the growth and productivity of the crop through

inorganic fertilizer application (Ekhuemelo and Olatunji, 2015; Echezona and Nganwuchu, 2006). Farmers involved in pepper production usually employ different means of enriching the soil which includes the incorporation of organic and inorganic fertilizers to improve the fertility status of the soil.

Umeugokwe et al. (2021) in their trial reported that the sustainability of crop production depends on soil fertility and its maintenance. They further opined that fertilizers help to improve soil fertility and sustain crop production. Aliyu (2002) in his own submission stated that the crop however responds to both organic and inorganic fertilizers and has been shown to respond positively to nitrogen and phosphorus fertilizers. Research has shown that continual application of inorganic fertilizer to our soil can cause a drop in pH around the pepper roots, increased soil acidification and degradation of the environment (Yap, 2012). Unavailability of commercial fertilizers poses a barrier to crop production among smallholder farmers (Lopez et al. 2009; Tanimu et al. 2007).

Incidentally, the supply of organic manure is not enough especially in urban areas to substitute the use of chemical fertilizer that has been increasing the acidity levels of tropical soils, as a quick means of restoring the soil fertility without possible increase in pH of the soils. The recent ban on the open grazing of cows in most parts of southeastern Nigeria due to insecurity challenges has led to increased demand and patronage of poultry products, leading to increased production and availability of the droppings in the area. Poultry droppings according to Ogunezi et al. (2019) are a popular bio-resource in soil fertility management. Rice mill industries in the study area on the other hand generate large quantities of fresh and partially burnt rice-mill wastes daily and these are either dumped to the detriment of the environment or burnt into ashes (Nwite et al. 2011). This rice husk dust can be used for the improvement of nutrient status of such soils as it contains those elements like Ca, Mg, S, Na, Cu, Mn, Fe, K, P, N and other elements necessary in plant nutrition and for soil improvement.

The dependence on sole application of either inorganic or organic amendment sources has been described as ineffective; due to fact that sole use of inorganic fertilizers are believed to contribute substantially to human, animal food intoxication and environmental instability/soil degradation. This informed the use of integrated nutrient management in recent agricultural practices for increased fertility status of the soil and crop improvement (Nwite et al. 2013).

Complementary use of organic and inorganic fertilizers; and/or sole use of organic fertilizers has been reported as soil fertility management strategy for crop production, correcting nutrient deficits associated with application of either of the sources alone and uptake of N, Ca and Mg by amarathus (Stephen, 2010; Makinde et al. 2011; Zhang and Fang 2007). Combined application of organic and inorganic fertilizers has agronomic benefits, including improved soil fertility and crop yield (Zhang and Fang 2007). Because different organic wastes influence the nutritional quality of crops differently, evaluating the performance of compositions of organic and organo-mineral fertilizer compared to conventional mineral fertilizer is needed (Nwite et al. 2013).

The present study aimed at evaluating the effects of soil amendments and pepper variety on selected soil physicochemical properties and yield of two varieties of pepper in degraded Ultisols of southeastern Nigeria.

Materials and methods

Description and location of experimental site

The study was carried out in the research farm of Federal College of Agriculture, Ishiagu, during 2020 and 2021 cropping seasons. The study area lies within latitude 05° 56' N and longitude 07° 41' E in the derived savannah zone of Southeastern Nigeria. The area has a mean annual temperature of about 30° C and rainfall of 1350 mm.

Geologically, the area is underlain by sedimentary rock derived from successive deposits of the cretaceous and tertiary period and lies within Asu River Group (Lekwa et al. 1995; Ezeh and Chukwu 2011).

Field study

A split-plot fitted with a randomized complete block design (RCBD) was used to study two factors. Two varieties of pepper (yellow pepper always known as sweet pepper and the red variety usually called the hot pepper) constituted the main plots as different soil amendments were assigned to the sub-plots. The six soil amendment sources used were replicated 3 times and these include; poultry droppings at 10 t/ha; NPK 15:15:15 fertilizer at 300 kg/ha; rice husk dust sole at 10 t/ha; NPK at 150 kg/ha + rice husk dust at 5 t/ha; poultry droppings at 5 t/ha + rice husk dust at 5 t/ha and the control. These amendment sources were equally repeated in the 2021 cropping season study.

Field preparation: The land was tilled with native hoe into suitable seed beds representing treatment plots measuring 1.8 m x 2 m with 0.5 m between plots and 1.0 m distance between blocks. The poultry dropping and rice husk dust were applied a week before transplanting while the NPK 15.15.15 was applied 2 weeks after transplanting. During transplanting, seedlings were uprooted late in the evening from the nursery beds and then transplanted early in the morning of the following day to the main fields so as to reduce transplanting shock. This was done at the depth of 4-6 cm with the spacing of 30 x 50cm inter and intra row spacing giving a total population of 24 plants per plot equivalent to plant population of 66,666 per hectare.

Data collection: Fresh weight of the pepper was measured at harvest by using a weighing balance of 50 kg scale to determine weight per plot, and later converted to tons per hectare. Harvesting of the fresh fruits was done at a period of 4 weeks starting from the 5th week after transplanting (WAT) and lasted till the 9th WAT. The harvesting of the fresh fruits was done at a 4 day interval from all the 24 plants per plot. The weights of the fresh fruits at different harvesting intervals were accumulated together and subjected to statistical analysis.

Soil Sampling and laboratory techniques

At the commencement of the experiment, a composite soil sample from random points was collected from the site at the research farm of Federal College of Agriculture, Ishiagu, using a soil auger at 0 – 20 cm soil depth. At the end of each harvest, another set of auger samples were collected from all the identified sampling points on each of the plots from the top (0-20 cm) soil depth for laboratory analysis.

The soil samples were air-dried and sieved through 2.00 mm sieve. Soil fractions less than 2.00 mm from individual samples were then analyzed using the following methods.

Particle size distribution of the samples was determined by the hydrometer method (Gee and Bauder 1986). Soil pH was measured in a 1:2.5 soil:0.1 M KCl suspension (McLean, 1982). The soil organic carbon (SOC) was determined by the Walkley and Black method described by Nelson and Sommers (1996). Total nitrogen was determined by semi-micro Kjeldahl digestion method using sulphuric acid and CuSO₄ and Na₂SO₄ catalyst mixture (Bremner and Mulvancy, 1982). Cation exchange capacity (CEC) was determined by the method described by Thomas (1982).

Data analysis

Data collected were analyzed using GenStat 3 7.2 Edition. Significant treatment means were separated and compared using Fisher's least significant difference (F-LSD) and all inferences were made at 5% levels of probability according to Obi (2002).

Results and discussion

Selected initial physical and chemical properties of the soil

The chemical properties of the studied soil before application of amendments are shown on Table 1. The soil is classified as sandy loam which has been reported to be an ideal soil for pepper production as it holds moisture fairly well with liberal supply of organic matter if properly maintained (Udoh et al. 2005; Ikeh et al. 2012). The soil analysis indicated that the studied soil is acidic and was low in soil organic carbon, total nitrogen and cation exchange capacity.

Table 1. Selected initial physical and chemical properties of the studied soil (0-20cm) depth.

Soil properties	Value
Clay (g/kg)	160
Silt (g/kg)	290
Fine sand (g/kg)	460
Coarse sand (g/kg)	90
Textural class	Sandy loam
pH (H ₂ O)	4.5
Organic carbon (g/kg)	1.197
Total nitrogen (g/kg)	0.140
Cation exchange capacity (cmol/kg)	10.60
Base saturation (%)	36.58

Organic amendments nutrient composition

Soil amendments comprised of rice husk dust (RHD) collected from a rice-mill industry near the study site. Others included poultry litter droppings (PD) and 15N–15P–15K. Chemical analysis of organic materials indicated that rice husk dust (RHD) had the highest organic carbon percent compared to poultry dropping (PD). It was obtained (Table 2) that PD had the highest contents of nitrogen, Calcium, phosphorous and magnesium. The analysis showed that RHD had the highest C: N ratio and C:P ratio which may have retrogressive impacts on nitrogen availability in the soil.(Table 2).

Table 2. Nutrient compositions (%) of the organic soil amendments of the study

Property	Amendments	
	Poultry dropping	Rice husk dust
Organic carbon	18.2	36.6
Nitrogen	2.5	0.84
Phosphorous	2.88	1.1
Calcium	16.4	0.88
Potassium	0.58	0.16
Magnesium	1.30	0.48
C:N ratio	7.28	43.57
C:P ratio	6.32	33.27

Soil amendments and pepper variety effects on soil physicochemical properties (Soil pH and organic carbon)

Soil pH

Table 3 shows that the soil pH in water did not vary significantly among the varieties of pepper studied in the 2020 cropping season. However, soils in the red pepper variety had higher pH value compared to the soils in the yellow variety. The results indicated that soil amendments significantly influenced the soil pH in 2020 cropping season with best improved pH (5.9) obtained from PD + RHD treated plots.

Soil pH was significantly improved among the varieties of pepper studied in 2021, as yellow pepper recorded a higher value of 6.21 compared to 6.07 obtained in red pepper cultivated plots. Results also recorded that in 2021, PD + RHD amended plots significantly increased the soil pH higher (7.07) than other amended plots. The implication of the result was that the good attributes of poultry dropping and rice husk dust when combined gave better improvement on pH of the soil, indicating its benefits as soil amendments in our soils especially the soils of southeastern Nigeria (Olowokere, 2004). Generally, it was obtained that all the amended plots significantly ($p < 0.05$) increased the soil pH higher than the untreated plots (Table 3).

Soil organic carbon

The results (Table 3) indicated that soil organic carbon (SOC) did not significantly improve in the 2020 cropping season between the varieties used. On the other hand, soil amendments used significantly influenced the values of the SOC. Also, all the amended plots except plots treated with poultry dropping (PD) improved the SOC higher relative to the untreated plots in the 2020 cropping season. The highest improvement recorded in sole RHD treated plots and its combination with other manure sources compared with PD and the control plots is not surprising because of the higher value of OC obtained in the RHD amendment material (Table 2). This result is in agreement with Nwite et al. (2017) who reported that the pattern of distribution of organic carbon in the organic soil amendments suggests a greater potential of RHD than PD to enrich the soil with plant nutrients, though slowly, as could be deduced from the high carbon:nitrogen ratio of the RHD compared with that of the PD. The finding is not in conformity with Ugwu et al. (2020) who submitted that, PD is widely used as manure source in soil-based media but the competitive use of this animal waste has led to its scarcity and high cost. The results revealed that yellow pepper in 2021 increased SOC higher (14.05 g/kg) than the red pepper variety (12.24 g/kg). This difference could be attributed to genetic influence. The results showed that there was a geometric increase on the SOC in PD plots when compared to the value obtained in the 2020 cropping season as it increased from 2.93 g/kg in 2020 season to 17.74 g/kg in 2021 season (Table 3). The results indicated that NPK treated plots and its combination with rice husk dust (NPK + RHD) did not improve the SOC higher than the untreated (control) plots in 2021 cropping season. The finding was in agreement with the submission of Nwite et al. (2013) who reported that the application of N–P–K alone mostly was unimpressive and may be linked to its inability to improve soil OC status.

Table 3. Soil amendments and pepper variety effects on soil physicochemical properties (Soil pH and organic carbon)

Variety	Soil amendments						Mean
	CT	NPK	PD	RHD	NPK + RHD	PD + RHD	
Soil pH (H₂O)							
Year 1 (2020)							
Yellow variety	5.8	5.3	5.7	5.3	5.5	6.0	5.6
Red variety	5.3	5.5	5.9	5.6	5.9	5.8	5.7
Mean	5.6	5.4	5.7	5.5	5.7	5.9	

LSD _(0.05) for variety					NS p value = 0.074		
LSD _(0.05) for amendments					0.1586 p value = <.001		
LSD _(0.05) for variety x amendment					0.2078 p value = <.001		
Year 2 (2021)							
Yellow variety	4.90	6.17	6.10	6.57	6.47	7.07	6.21
Red variety	5.33	6.13	6.10	6.10	6.27	6.50	6.07
Mean	5.12	6.15	6.10	6.33	6.17	7.07	
LSD _(0.05) for variety					0.1195 p value = 0.038		
LSD _(0.05) for amendments					0.3854 p value = <.001		
LSD _(0.05) for variety x amendment					NS p value = 0.138		
Soil organic carbon (g/kg)							
Year 1 (2020)							
Yellow variety	2.63	3.83	2.33	4.32	4.49	4.11	3.62
Red variety	2.32	3.95	3.53	4.43	5.31	4.01	3.93
Mean	2.47	3.89	2.93	4.32	4.90	4.06	
LSD _(0.05) for variety					NS p value = 0.325		
LSD _(0.05) for amendments					1.360 p value = 0.013		
LSD _(0.05) for variety x amendment					NS p value = 0.845		
Year 2 (2021)							
Yellow variety	7.80	9.57	21.47	17.21	11.42	16.81	14.05
Red variety	8.56	12.25	14.01	15.66	9.58	13.37	12.24
Mean	8.18	10.91	17.74	16.43	10.50	15.09	
LSD _(0.05) for variety					1.115 p value = 0.020		
LSD _(0.05) for amendments					4.339 p value = <.001		
LSD _(0.05) for variety x amendment					NS p value = 0.259		

CT = control; PD = poultry dropping; NPK = nitrogen, phosphorous, potassium; RHD = rice husk dust; LSD = least significant difference

Effects of different soil amendments and pepper varieties on total nitrogen and cation exchange capacity of the soil

Total nitrogen

The total nitrogen (TN) of the soil changed significantly among the two varieties of pepper studied in 2020 cropping season as the yellow pepper variety gave higher (0.928 g/kg) TN than the red variety with TN value of 0.886 g/kg (Table 4). The results also indicated that total nitrogen was significantly ($p < 0.05$) affected following the application of different soil amendments in the 2020 cropping season (Table 4). Poultry dropping (PD) amended plots significantly ($p < 0.05$) improved the total nitrogen higher (1.120 g/kg) than other amended plots. Generally, all the treated plots increased total nitrogen higher relative to the untreated plots in the first year (2020 year) of planting. Poultry dropping applied to yellow pepper variety plots significantly improved the TN (1.260 g/kg) compared to other treatment plots.

In 2021, there was no significant difference between the pepper variety plots as regards TN content (Table 4). However, there was a percentage increase of 28.1% TN in 2021 compared to the cropping season. Plots treated with poultry dropping (PD), rice husk dust (RHD) and PD + RHD in the 2021 cropping year showed similar values (1.258, 1.438 and 1.322 g/kg), respectively. It further showed that the mentioned amendments significantly ($p < 0.05$) increased the TN higher compared to other amendments. Their significant improvement on the TN higher than the sole NPK fertilizer and its integrated form with RHD could be attributed to its degrading effects as increased soil acidity and nutrient imbalance on a long-term basis (Nottidge et al., 2005; Omisore, 2010).

Cation exchange capacity (CEC)

Cation exchange capacity (CEC) was not improved in the 2020 cropping season between the two pepper varieties (Table 4). Soil amendments on the other hand significantly increased the CEC of the soil as 16.96 cmol/kg and 16.53 cmol/kg values were recorded in PD and RHD treated plots, which were statistically similar and higher compared to other amended plots. The findings showed the potentials of PD when combined with RHD in improving soil properties of the studied area (Adubasim et al. 2018). Generally, all the amended plots increased the CEC relatively higher than the untreated plots in the 2020 cropping season (Table 4). The results showed the needs for soil amendment applications in the study area for remediation of the degraded soil and crop improvement. This finding is in conformity with the submission of Hulugalle and Maurya (1991) who reported higher increase in soil CEC and other soil nutrients on treated soils compared to the untreated ones.

In 2021, CEC varied between the two varieties of pepper used as yellow pepper improved the CEC (16.13 cmol/kg) higher in the soil compared to red pepper (15.47 cmol/kg). Meanwhile, the highest significant improvement of CEC (18.60 cmol/kg) among the soil amendments was obtained from PD + RHD treated plots. This implies that integrated nutrient management is a better option than sole application of soil amendments for improvement of cation exchange capacity of the studied soil. Interactions in the study showed that the PD + RHD amendment applied in the red variety of pepper plots (red pepper variety x PD + RHD) did increase (21.20 cmol/kg) the CEC significantly higher than other interactions (Table 4).

Soil amendments and pepper variety effects on fresh fruit yield of pepper varieties (tons/ha)

Table 5 shows that the fresh fruits yield of the pepper varied significantly between the two pepper varieties in the 2020 cropping year, but did not significantly change in the 2021 cropping season. It was obtained that yellow pepper performed better (4.20 t/ha) than the red variety (2.51 t/ha) in the 2020 cropping season. The low yield obtained in red pepper variety plots in the two years of study might be genetic differences as different varieties respond differently to treatments in the same environment. The finding agrees with Appiraddy *et al.* (2008) who reported less adaptability and low genetic performance of the red pepper variety to local environmental conditions. The results revealed that amendments significantly influenced the fresh fruits yield as PD and PD + RHD amended plots with similar values of 4.32 tons/ha and 4.16 tons/ha, respectively, gave the highest significant yield improvement among the amendments in 2020 cropping season. The higher yield increase recorded in sole PD and its integration with RHD could be attributed to its short time mineralization and high nutrient loads. Ogunezi et al. (2019) has thus found utility of poultry droppings not only in agronomic production in low-fertility soils where unguided use could have adverse ecological effects, but also in bioremediation of polluted soils and in biogas production.

Table 4. Soil amendments and pepper variety effects on soil physicochemical properties (total nitrogen and cation exchange capacity (CEC))

Variety	Soil amendments						Mean
	CT	NPK	PD	RHD	NPK + RHD	PD + RHD	
Total nitrogen (g/kg)							
Year 1 (2020)							
Yellow variety	0.700	0.980	1.260	0.947	0.840	0.840	0.928
Red variety	0.837	0.980	0.980	0.840	0.840	0.840	0.886
Mean	0.768	0.980	1.120	0.893	0.840	0.840	
LSD _(0.05) for variety						0.02151 (p value = 0.014)	
LSD _(0.05) for amendments						0.02730 (p value = <.001)	
LSD _(0.05) for variety x amendment						0.03655 (p value = <.001)	
Year 2 (2021)							

Yellow variety	0.880	1.153	1.180	1.660	1.010	1.300	1.197
Red variety	0.860	1.067	1.337	1.217	1.253	1.343	1.179
Mean	0.870	1.110	1.258	1.438	1.132	1.322	
LSD _(0.05) for variety					NS (p value = 0.347)		
LSD _(0.05) for amendments					0.2462 (p value = 0.002)		
LSD _(0.05) for variety x amendment					NS (p value = 0.112)		
Cation exchange capacity (CEC) (cmol/kg)							
Year 1 (2020)							
Yellow variety	9.83	15.42	17.72	16.73	12.21	12.80	14.12
Red variety	10.67	12.80	16.20	16.33	13.27	14.20	13.91
Mean	10.25	14.11	16.96	16.53	12.74	12.80	
LSD _(0.05) for variety					NS (p value = 0.766)		
LSD _(0.05) for amendments					2.433 (p value = <.001)		
LSD _(0.05) for variety x amendment					NS (p value = 0.475)		
Year 2 (2021)							
Yellow variety	10.40	18.40	14.80	18.40	18.80	16.00	16.13
Red variety	8.00	16.80	18.40	12.80	15.60	21.20	15.47
Mean	9.20	17.60	16.60	15.60	17.20	18.60	
LSD _(0.05) for variety					0.4610 (p value = 0.025)		
LSD _(0.05) for amendments					0.3744 (p value = <.001)		
LSD _(0.05) for variety x amendment					0.5322 (p value = <.001)		

CT = control; PD = poultry dropping; NPK = nitrogen, phosphorous, potassium; RHD = rice husk dust; LSD = least significant difference

In 2021 cropping season, the best increase in fresh fruits yield which are statistically similar were recorded in sole PD and NPK 15:15:15 treated plots (6.67 tons/ha and 5.95 tons/ha), respectively, while the control and NPK + RHD amended plots with similar values (2.44 and 3.6 tons/ha) gave the lowest improvement on the fresh fruit yield (Table 5). In the same cropping season, sole NPK 15:15:15 fertilizer applied in yellow pepper plots (yellow pepper x NPK) significantly increased (9.04 ton/ha). The fresh fruit yields more than other interactions within the cropping season.

Conclusion

The study evaluated the effects of soil amendment sources on soil physicochemical properties and yield of pepper varieties in a rainfed cropping system. Generally, the treated plots had significantly higher yield compared with the untreated plot across the cropping seasons. It was obtained that PD increased pepper fresh fruit yield higher in both seasons than other amendments. It was recorded that yellow pepper variety produced with PD amendment significantly increased the fresh pepper yield higher in the first season of planting, while in the second cropping season, NPK treated plots increased the yellow pepper variety yield higher. On the other hand, red pepper variety grown where PD was applied increased yield significantly higher in the second season of cropping as the best yield improvement on the red pepper variety was obtained in plots amended with NPK + RHD.

Findings from the study showed that soil pH was best improved in PD + RHD amended plots, implying that co-application of PD and RHD is a better strategy for soil pH improvement in the study area. The study showed that as total nitrogen was enhanced higher in the second year by application of RHD, PD treated plots improved TN better in the first season. The results also indicated that while CEC was highly increased by PD treated plots in 2020, PD + RHD increased the CEC significantly higher in 2021. The implication of this result is that co-application of PD + RHD in the study soil has a positive long-term basis improvement on CEC.

Overall, continuous PD + RHD application can increase the soil fertility index and consequently increase pepper fresh yield in the area.

Table 5. Soil amendments and pepper variety effects on fruit yield of pepper (tons/ha)

Variety	Soil amendments						Mean
	CT	NPK	PD	RHD	NPK + RHD	PD + RHD	
Fruits yield weight (tons/ha)							
Year 1 (2020)							
Yellow variety	1.82	4.24	5.69	4.49	3.94	4.99	4.20
Red variety	1.23	2.14	2.96	1.67	3.76	3.32	2.51
Mean	1.52	3.19	4.32	3.08	3.85	4.16	
LSD _(0.05) for variety							1.199 p value = 0.026
LSD _(0.05) for amendments							1.068 p value = <.001
LSD _(0.05) for variety x amendment							NS p value = 0.084
Year 2 (2021)							
Yellow variety	3.65	9.04	6.54	4.18	4.08	4.29	5.30
Red variety	1.22	2.86	6.81	4.50	3.13	4.45	3.83
Mean	2.44	5.95	6.67	4.34	3.60	4.37	
LSD _(0.05) for variety							NS p value = 0.251
LSD _(0.05) for amendments							2.102 p value = 0.005
LSD _(0.05) for variety x amendment							3.443 p value = 0.029

CT = control; PD = poultry dropping; NPK = nitrogen, phosphorous, potassium; RHD = rice husk dust; LSD = least significant difference

References

- Adubasim CV, Igwenagu CM, Josiah GO, Obalum SE, Okonkwo UM, Uzoh IM, Sato S (2018) Substitution of manure source and aerator in nursery media on sandy-loam topsoil and their fertility indices 4 months after formulation. *Int J Recycl Org Waste Agricul* 7 (4):305-312. <https://doi.org/10.1007/s40093-018-0216-8>
- Aliyu L (2002) Growth and yield of pepper (*Capsicum annum L.*) as affected by nitrogen and phosphorus application and plant density. *Crop Res. Hisar* 23(3):467-475.
- Bremner JM, Mulvancy CS (1982) Total Nitrogen. In: Page AL, *et al.* (eds.). *Methods of soil analysis*. No. 9; part 2, Amer. Soc. of Agron. Inc, Madison, Wisconsin, USA. 595-624pp.
- Echezona BC, Nganwuchu OG (2006) Poultry manure application and varietal effects of Chilli-pepper (*Capsicum Species*) on insect pests and disease in a humid-tropical environment. *Agro Science* 5(2): 49-58. <https://doi.org/104314/as.v5i2.1550>
- Ekhuemelo C, Olatunji O (2015) Effect of soil amendments on disease and yield of two pepper varieties in Makurdi, Benue State, Nigeria. *Nig J Agric FE* 11(4):75-81.
- Ezeh HN, Chukwu E (2011) Small-scale mining and heavy metals pollution of agricultural soils: the case of Ishiagu Mining District, South Eastern Nigeria. *J Geo Min Res* 3(4):87-104.
- Fekadu M, Lemma D, Harjit S, Chemedo F, Roland S (2008) Genetic components and heritability of yield and yield related traits in hot pepper. *Res. J Agric Biol Sci* 4(6):803-809.
- Gee GW, Bauder JW (1986) Particle size analysis. In: Klute A, (ed). *Methods of soil analysis*, part 1: Physical and mineralogical properties. *Agronomy Monograph* No 9. Ameri Soc Agron., Madison. 91-100.
- Hulugalle NR, Maurya PR (1991) Tillage systems for the West African semi-arid tropics. *Soil Till Res* 20(2-4):187-199. [https://doi.org/10.1016/0167-1987\(91\)90039-Z](https://doi.org/10.1016/0167-1987(91)90039-Z)
- Idowu-Agida OO, Nwaguma EI, Adeoye IB (2010) Cost implication of wet and dry season pepper production in Ibadan, Southwestern Nigeria. *Agric Biol J North America* 1(4): 495-500.
- Ikeh AO, Ndaeyo NU, Uduak IG, Iwo GA, Ugbe LA, Udoh E, I.Effiong GS (2012) Growth and yield responses of pepper (*Capsicum frutescens L.*) to varied poultry manure rates in uyo, southeastern Nigeria *ARPN J Agric Biol Sci* 7(9): 735 – 742.
- Kahsay Y (2017) Evaluation of hot pepper varieties (*capsicum species*) for growth, dry pod yield and quality at M/Lehke District, Tigray, Ethiopia. *Int J Eng Deve Res IJEDR* 5(3): 144 – 152.

- Lekwa GAO, Nnodi AC, Okafor EJ, Chata CU Ahumibe, Lekwa MO (1995) Detailed soil survey and land capability evaluation of Federal College of Agriculture Site, Ishiagu - Final report, Pedro-agro technical services (Nig) Ltd, Oweeri Pp 12-21.
- Lopez R, Padilla E, Bachmann S, Eichler-Loebermann B (2009) Effects of biomass ashes on plant nutrition in tropical and temperate regions. *J Agr Rural Dev Trop Sub-trop* 110(1):51–60.
- Makinde EA, Ayeni LS, Ojeniyi SO (2011) Effects of organic, organo-mineral and NPK fertilizer treatments on the nutrient uptake of *Amaranthus cruentus* (L) on two soil types in Lagos, Nigeria. *J Central Europ Agric* 12(1):114–123. <https://doi.org/10.5513/JCEA01/12.1.887>
- McLean EO (1982) Soil pH and lime requirement. In: Page AL, Miller RH, Keeny DR, (eds.). *Methods of soil analysis, part 2*. Am Soc Agron Madison 199-224.
- Nelson DW, Sommers LE (1996) Total carbon, total organic carbon and organic matter. In: sparks DL, (ed). *Methods of soil analysis part 3 chemical methods Agronomy monograph N0.9 Amer Soc Agron, Madison; 961-1010*.
- Nottidge DO, Ojeniyi SO, Asawalam DO (2005) Comparative effect of plant residue and NPK fertilizer on nutrient status and yield of maize in humid ultisol. *Nig J Soil Sci* 15:1-8.
- Nwite JC, Igwe CA, Obalum SE (2011) The contributions of different ash sources to the improvement in properties of a degraded Ultisol and maize production in southeastern Nigeria. *Am-Eurasian J Sustain Agr* 5 (1):34–41.
- Nwite JC, Keke CI, Obalum SE, Essien JB, Anaele MU, Igwe CA (2013) Organo-mineral amendment options for enhancing soil fertility and nutrient composition and yield of fluted pumpkin. *Int J Veget Sci* 19 (2): 88-199. <http://dx.doi.org/10.1080/19315260.2012.705233>
- Nwite JC, Obalum SE, Igwe CA, Wakatsuki T (2017) Interaction of small-scale supplemental irrigation, *sawah* preparation intensity and soil amendment type on productivity of lowland sawah-rice system. *South Afri J Plant Soil*. Pp 1 -10. <http://dx.doi.org/10.1080/02571862.2017.1309468>
- Obi IU (2002) Statistical methods of detecting differences between treatment means and research methodology issues in laboratory and field experiments. Optimal International Ltd., 113 Agbani Road Enugu, Nigeria.
- Ogunezi KC, Okebalama CB, Obalum SE (2019) Optimum poultry droppings rate for coarse-loamy Ultisols based on soil macro-aggregation and fertility indices and evaluation using cucumber (*Cucumis sativus*). Presented under Understanding Nigerian Soils for Sustainable Food & Nutrition Security and Healthy Environment, the 43rd Annual Conference of Soil Science Society of Nigeria (SSSN), 15-19 July 2019, University of Agriculture, Makurdi, Benue State, Nigeria.
- Olowokere FA (2004) Effects of different levels of poultry based organo-mineral fertilizer and weeding interval on the growth and yield of Okro. Proceedings of the 29th Annual conference of the soil science society of Nigeria. 6-10th Dec. Abeokuta, Nigeria.
- Omisore JK (2010) Effect of fertilizer application on the growth and yield of maize in Nigeria. *J Agric Sci* 107:573–578.
- Stephen NA (2010) Effect of complementary use of organic and inorganic fertilizers on the growth and yield of Fluted pumpkin (*Telfairia occidentalis*) in an Ultisol. <http://www.crescentbloom.com/plants/Genus/.TIE/Telfairia.htm>
- Tanimu J, Iwuafor ENO, Odunze AC, Tian G (2007) Effect of incorporation of leguminous cover crops on yield and yield components of maize. *World J Agr Sci* 3(2): 243–249.
- Thomas GW (1982) Exchangeable cations. In: Page AL, Miller RH, Keeny DR (eds.), *Methods of Soil Analysis, Part 2*. Am. Soc. Agron. Monogr. Maidison, pp: 159 –165.
- Udoh DJ, Ndon BA, Asuquo PE, Ndaeyo NU (2005) *Crop production techniques for the tropics concept*. Publications Limited, Lagos, Nigeria, 465pp.
- Ugwu VU, Nnadi AL, Adubasim CV, Sato S, Igwenagu CM, Obalum SE, Igwe CA (2020) Organic-waste aerator could completely displace poultry-droppings manure in nursery media based on coarse-textured soil: evidence with cashew seedlings. In: Baiyeri KP, Aba SC (eds.), *Sustainable Horticulture Production System Intensified* (pp. 941-951), Proceedings of the 38th Annual Conference of the Horticultural Society of Nigeria (HORTSON), University of Nigeria Nsukka, 25-31 October 2020.

Umeugokwe CP, Ugwu VU, Umeugochukwu OP, Uzoh IM, Obalum SE, Ddamulira G, Karwani GM, Alenoma G (2021) Soil fertility indices of tropical loamy sand as influenced by bambara groundnut variety, plant spacing and fertilizer type. *Agro-Science* 20 (1): 65-71. <https://dx.doi.org/10.4314/as.v20i1.11>

Yahaya RA, Aliyu L, Mahmud M (2010) Effects of sheep manure and intra row spacing on yield and yield components of Chilli Pepper (*Capsicum Frutescence* L.) at Samaru, Zaria, Nigeria. *Production Agriculture and Technology*. 6 (2):45-50. Publication of Nasarawa State University, Keffi. (Online copy available at www.patnsukjournal.net/currentissue)

Yap, AC (2012) Impact of different fertilization methods on the soil, yield and growth performance of Black Pepper (*Piper nigrum* L.). *Malaysian J Soil Sci* 16:71 – 87.

Zhang M, Fang L (2007) Effect of tillage, fertilizer and green manure cropping on soil quality at an abandoned brick making site. *Soil Tillage Res* 93(1):87-93. <https://doi.org/10.1016/j.still.2006.03.016>