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Evaluation of Varietal Effect and Different Manure Sources on the Soil Chemical Properties, Growth and Yield of Sweet Potato (*Ipomea batatas L.*) in Ishiagu, Southeastern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author JCN designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author POO managed the literature searches, analyses of the study performed the spectroscopy analysis and author OCO managed the experimental process and author CIK identified the species of plant. All authors read and approved the final manuscript.

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ABSTRACT

The research was conducted at the Research and Teaching Farm of the Federal College of Agriculture, Ishiagu, Southeastern Nigeria, to investigate the effect of manure sources on soil chemical properties, growth and yield of two sweet potato varieties in Ishiagu. A Split-plot in a randomized complete block (RCBD) was used. Two sweet potato varieties (TIS 87/0087 and UMUSOP) constituted the main plot, whereas the amendments that constituted the sub-plots were applied as follows: *Moringa* leaves ML) at 5 t/ha, Neem Leaves (NL) at 5 t/ha, Poultry dropping (PD) at 10 t/ha, Rice husk dust (RHD) at 10 t/ha, Rice husk ash (RHA) at 10 t/ha, NPK Fertilizer (15:15:15) at 400 kg/ha and 0 t/ha (control). Each of the seven (7) treatments in the sub-plot was

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replicated three (3) times in each of the main plot. The crop was planted on the spacing of 30 cm x 100 cm inter and intra respectively. Soil chemical properties evaluated were pH, organic carbon, total nitrogen and cation exchange capacity (CEC). The growth and tuber yield parameters measured include: Vine length (cm) and weight of tuber t/ha. The soil amendments showed significant effect on the soil pH, organic carbon, total nitrogen and cation exchange capacity (CEC). The result indicated that application of organic manure significantly ($P<0.05$) increased the selected soil chemical properties, growth and yield parameters of sweet potato varieties. This study revealed the superiority of organic manure sources in the improvement of some chemical properties of the soil and in production of sweet potato in Southeastern Nigeria.

Keywords: Moringa leaves; sweet potato; amendments; organic manure; tuber yield; chemical properties.

1. INTRODUCTION

1.1 Background of the Study

Sweet potato (*Ipomea batatas L.*), is the fifth most important food crops after rice, wheat, maize and cassava [1]. Continuous cultivation of crop like sweet potato (*Ipomoea batatas* Lin) on the same land will lead to soil nutrient exhaustion and low yield. Moreover, sweet potato like any other root tuber crops is a heavy feeder exploiting greater volume of soil for nutrient and water [2]. Therefore, there is need to improve on the soil condition in which the crop is grown to obtain optimum yield. The tubers are used as a subsidiary food after boiling, baking and frying. Tubers are also form of an industrial raw material for the production of starch, alcohol, pectin etc. Besides energy provider, it is a good source of minerals and vitamins. Orange flesh sweet potatoes are rich in ß-carotene (precursor for vitamin A) [3]. Sweet potato provides as much protein as cereals and beans per hectare [4]. It has a high nutritional value that provides a good source of energy supplying sugars as well as other carbohydrates, calcium, iron and some minerals. Potassium is one of the most important essential nutrient elements in root and tuber crops production [5]. Despite its nutritional and industrial utilization in Nigeria, the production level is still low and was left in the hands of the poor resource farmers.

With the increasing population pressure in Nigeria, shifting cultivation is no longer sustainable and the length of traditional bush fallow for maintaining the productivity of the soil is becoming shorter [6,7]. Therefore, continuous cultivation of crop like sweet potato (*Ipomoea batatas* Lin) on the same land will lead to soil nutrient exhaustion and low yield. Moreover, sweet potato like any other root tuber crops is a heavy feeder exploiting greater volume of soil for nutrient and water [2,7]. Intensive and conscientious efforts are being made to resuscitate the declining soil fertility so as to meet the challenge of providing food for the increasing population. The soils of the area, Southeastern Nigeria are poor in organic matter and available nutrients and hence productivity and sustainability decline over time [8].

Nyakatawa et al. [9] suggested that it is possible to increase yields of crops on physically degraded soils by using organic resources such as manure for soil fertility improvement. Organic manure is known to be effective in maintenance of adequate supply of organic matter in soils with attendant improvement in soil physical and chemical conditions and enhanced crop performance [10-12].

There have not been much research studies on the implications of different manure sources on soil properties and performance of sweet potato in southeastern Nigeria. Therefore the aim of this study was to investigate varietal effect and different manure sources on the soil chemical properties, growth and yield of sweet potato.

2. MATERIALS AND METHODS

2.1 Location of Experimental Site

The experiment was conducted at the Research and Teaching Farm of the Federal College of Agriculture, Ishiagu, Southeastern Nigeria. The area lies between latitude 5º 55´ N and 6º 00´ N and longitudes 7º 30´ E and 7º 35´ E in the Derived Savannah Zone of Southeastern Nigeria. The mean annual rainfall for the area is 1350 mm, spread from April to October with average air temperature being 29ºC. The underlying geological material is Shale formation with sand intrusions locally classified as the 'Asu River' group. The soil is hydromorphic and belongs to

the order Ultisol. It has been classified as Typic Haplustult [13].

The rainfall of Ishiagu comes between April and October with June having the highest rainfall of 430.4 mm within the period of study (Fig. 1). The highest mean maximum air temperature was obtained in February and March (36ºC) with its lowest in October (30ºC) (Fig. 3). The relative humidity ranged from 36% in July to 97% in the month of September within the period of study (Fig. 2).

2.2 Field Study

The experiment was arranged in split-plot in a randomized complete block design (RCBD) with seven treatments including the control replicated three times. The amendments used were; poultry dropping (PD) @ 10 t/ha; Neem leave – *Azadirachta indica* (NL) @ 5 t/ha; Moringa leave - *Moringa oleifera* (ML) @ 5 t/ha; Rice husk dust (RHD) @ 10 t/ha; Rice husk Ash (RHA) @ 10 t/ha; NPK fertilizer @ 400 kg/ha and the control (CT) with no amendment.

The treatments were incorporated into the soil a week before planting except N.P.K fertilizer that was applied 2 weeks after vine sprouting. The materials used for the amendments were sourced within the Institution except the NPK 15:15:15 fertilizer purchased from the market. Sweet potato vine (cultivar TIS 87/0087 (pink fleshed) and UMUSOP (Orange fleshed) were obtained from National Root Crops Research Institute, Umudike (NRCRI), Abia State, Nigeria.

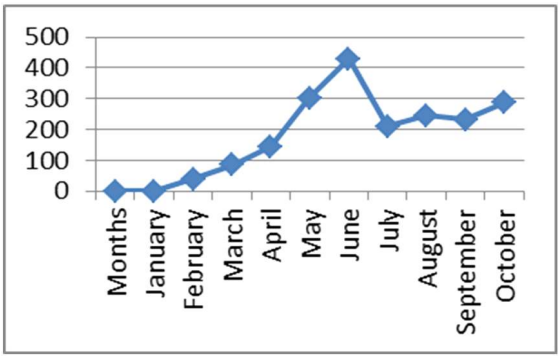

Fig. 1. Monthly mean rainfall of Ishiagu location in 2014

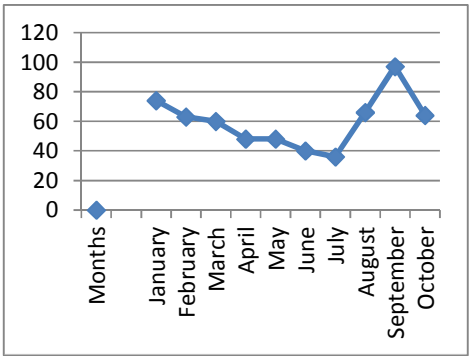

Fig. 2. Monthly relative humidity of Ishiagu location in 2014

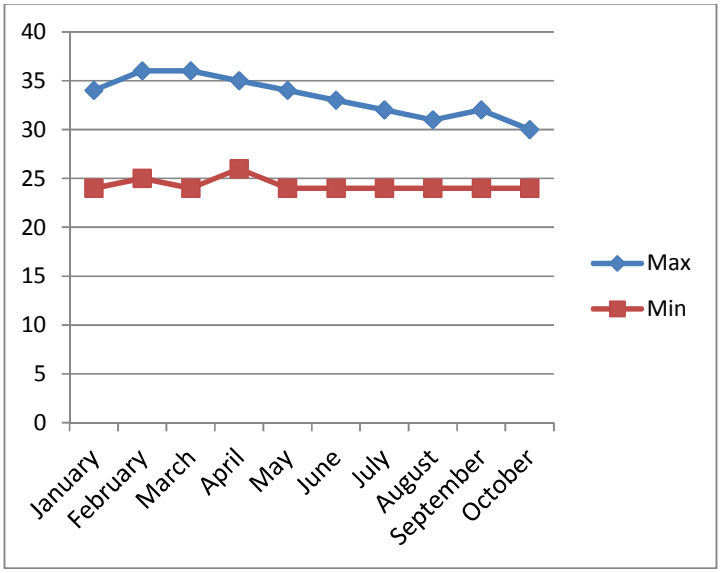

Fig. 3. Mean Monthly Temperature of Ishiagu location in 2014

2.3 Data Collection: Plant Parameters

Measurements were taken from the following parameters;

(1) Vine length: This was measured by using measuring tape and was measured the longest vine from the base to the apex region. At 4, 6, 8, 10 and 12 weeks after sprouting
(2) Weight of tuber at harvest: This was obtained by using a weighing balance to determine the field weight.

2.4 Soil Sampling and Laboratory Techniques

At the commencement of the experiment (before amendments of the soil), a composite sample from five random points was collected using a soil auger at 0 – 20 cm depth. At harvest, another set of soil samples were collected from individual plots to determine changes that occurred due to treatments application. The soil samples were air-dried and sieved with 2 mm sieve. Soil fractions less than 2 mm from individual samples were then analyzed using the following methods; Particle size distribution of less than 2 mm fine earth fractions was measured by the hydrometer method as described by Gee and Bauder [14]. Soil pH was measured in a 1:2.5 (soil: 0.1 M KCl) suspensions. The soil OC was determined by the Walkley and Black method as described by Nelson and Sommers [15]. Total nitrogen was determined by semi-micro kjeldahl digestion method using sulphuric acid and $CuSO_4$ and Na_2SO_4 catalyst mixture [16]. Exchangeable bases were determined by the method of Thomas [17]. The CEC was determined by the method described by Rhoades [18], while exchangeable acidity (EA) was measured using the method of McLean [19]. Available phosphorus was measured by the Bray II method [20].

2.5 Data Analysis

Statistical analysis of all the data was performed using GENSTAT 3 7.2 Edition. Statistical differences among treatment means were estimated and compared using Least Significant Difference (LSD) and all inferences were made at 5% Level of probability.

3. RESULTS AND DISCUSSION

3.1 Effect of Different Manure Sources and Variety on the Selected Soil Chemical Properties

The physical and chemical properties of the soil before application of amendments are shown on Table 1. The soil is sandy-loam with a total percent of sand as 75%, 17% silt and 8% clay. The soil is slightly acid with a pH of 5.2. The organic carbon and total nitrogen of the soil were 0.57% and 0.070%, respectively. The analysis indicated that the studied soil was moderate in exchangeable bases. In addition, the cation exchange capacity was very low, while the available phosphorous was high in the studied soil.

Table 1. Some physical-chemical properties of the soil (0-20 cm) soil depth

Soil properties	Values
Clay (%)	8
Silt (%)	17
Fine sand (%)	45
Coarse sand (%)	30
Textural class	Sandy loam
pH (H_2O)	5.2
Organic carbon (%)	0.57
Total nitrogen (%)	0.070
Exchangeable bases ($cmolkg^{-1}$)	
Sodium (Na^+)	0.24
Potassium (K^+)	0.28
Calcium (Ca^{2+})	1.80
Magnesium (Mg^{2+})	2.00
Cation exchange capacity ($cmolkg^{-1}$)	6.80
Exchangeable acidity ($cmolkg^{-1}$)	1.20
Available phosphorous (mg/kg)	31.71

The results (Table 2) showed no statistical difference ($P< 0.05$) among the two varieties of sweet potato on the soil pH. It was observed generally that all the treated plots had significantly higher pH values ($p < 0.05$) varying from 4.9 – 6.5 than the control plots. The significant improvement made by RHA on the pH agrees with the findings of Abyhammer et al. [21]; Markikainen, [22] and Nwite et al. [23]; who stated that ash amendment could induce a pH increase by as much as 0.6 – 1.0 units in humus soils. The general significant improvement made by soils treated with amendments over the control on the soil pH is in conformity with the findings of Opara-Nnadi et al. [24] who reported pH increase following the application of organic

wastes. The result also showed a significant (P<0.05) improvement on the soil pH by the interaction of the sweet potato varieties and the amendments within the period of study.

The results (Table 2), showed a significant (P<0.05) difference on soil organic carbon by the two varieties of sweet potato used with UMUSOP variety improving the organic carbon significantly higher. The results indicated that the amendments also statistically improved the organic carbon pool higher than the control with rice husk dust relatively increasing the percentage organic carbon pool in the soil than other manure sources. Soil organic carbon improved significantly (P<0.05) by the interaction between the sweet potato varieties and amendments.

The results (Table 3) showed no significant difference (P<0.05) among the two varieties on the soil total nitrogen. It was obtained that soil total nitrogen was statistical (P<0.05) improved by the application of the amendments with rice husk dust (0.074%) and moringa leaf (0.073%) performing significantly higher. The interactions of the varieties and the amendments did increase the soil total nitrogen significantly (P<0.05) within the period.

The results (Table 3) showed no significant difference (P<0.05) on the cation exchange capacity by the two varieties of sweet potato used. It was obtained that amendments statistical (P<0.05) increased the cation exchange capacity (CEC) with poultry dropping increasing the CEC significantly higher, followed by plots treated with moringa leaves. The results indicated that amended plots improved the CEC higher than the control plots. Hulugalle and Maurya [25], reported increase in soil CEC and other soil nutrients on residue treated soils compared to the untreated ones. The interaction of the varieties and the amendments also showed significant improvement on the cation exchange capacity within the period.

3.2 Effect of Different Manure Sources and Variety on the Growth and Yield of Sweet Potato

The results (Table 4) showed that there was significant ($p < 0.05$) difference among the two varieties of sweet potato on the 4^{th}, 6^{th} and 8^{th} week after planting with TIS 87/0087 variety giving the highest vine length with the period of the study. The results (Table 4) indicated a significant ($p < 0.05$) improvement on the vine length by the manure application on the 4^{th} and 6^{th} week after planting with poultry dropping improving the vine length of the crop significantly ($p < 0.05$) higher than other amendments within the period. All the treated plots significantly ($p < 0.05$) increased the vine length of sweet potato relative to the control as the values ranged from 26.48 cm to 51.30 cm for the 4^{th} WAP and 59.9 cm to 82.1 cm for 6^{th} WAP. It was observed that the interaction of sweet potato varieties and soil amendments significantly improved the sweet potato vine length within the period of 4^{th} and 6^{th} WAP.

Table 2. Effect of amendments and varieties of sweet potato on soil pH (H_2O) and organic carbon (%) (0-20cm) soil depth

Varieties	Amendments							Mean
	CT	ML	NL	NPK	PD	RHA	RHD	
Soil pH								
Tis	4.9	5.3	5.5	5.4	5.8	6.2	5.3	**5.4**
UMU	4.9	5.0	5.4	5.3	6.0	6.5	5.4	**5.5**
Mean	**4.9**	**5.2**	**5.5**	**5.4**	**5.8**	**6.2**	**5.3**	
$LSD_{0.05}$ for varieties					**NS**			
$LSD_{0.05}$ for Amendments						**0.2370**		
$LSD_{0.05}$ for varieties x Amendments interaction						**0.3150**		
OC								
Tis	0.353	0.377	0.310	0.757	0.513	0.540	0.757	**0.515**
UMU	0.620	1.019	0.847	0.907	0.757	0.873	0.920	**0.899**
Mean	**0.487**	**0.698**	**0.579**	**0.832**	**0.635**	**0.707**	**0.839**	
LSD 0.05 for varieties					**0.0362**			
LSD 0.05 for Amendments					**0.0875**			
LSD 0.05 for varieties x Amendments interactions					**0.1157**			

NS = non-significant, CT= Control, ML = Moringa leaf, NL = Neem leaf, NPK = nitrogen, phosphorous, potassium, PD = Poultry dropping, RHA = Rice husk ash, RHD = Rice husk dust, Tis = Tis 87/0087 variety, UMU = UMUSOP variety, LSD = Least significant difference, OC = organic carbon

Table 3. Effect of amendments and varieties of sweet potato on soil total nitrogen (%) and cation exchange capacity (cmolkg^{-1}) (0-20cm) soil depth

Varieties	Amendments							Mean
	CT	ML	NL	NPK	PD	RHA	RHD	
Soil TN								
Tis	0.055	0.063	0.084	0.051	0.065	0.065	0.064	**0.064**
UMU	0.062	0.084	0.053	0.060	0.064	0.047	0.087	**0.065**
Mean	**0.058**	**0.073**	**0.069**	**0.056**	**0.064**	**0.056**	**0.074**	
LSD $_{0.05}$ for varieties					**NS**			
LSD $_{0.05}$ for Amendments						**0.005950**		
LSD $_{0.05}$ for varieties x Amendments interaction						**0.007833**		
CEC								
Tis	6.33	8.97	8.87	7.13	10.67	7.13	11.63	**8.68**
UMU	5.93	11.93	7.13	6.86	11.03	11.13	7.53	**8.79**
Mean	**6.13**	**10.45**	**8.00**	**6.97**	**10.85**	**9.13**	**9.58**	
LSD 0.05 for varieties					**NS**			
LSD 0.05 for Amendments					**1.387**			
LSD 0.05 for varieties x Amendments interactions					**1.817**			

NS= non-significant, CT= Control, ML = Moringa leaf, NL = Neem leaf, NPK = nitrogen, phosphorous, potassium, PD = Poultry dropping, RHA = Rice husk ash, RHD = Rice husk dust, Tis = Tis 87/0087 variety, UMU = UMUSOP variety, LSD = Least significant difference, TN = total nitrogen, CEC = cation exchange capacity

Table 4. Effect of amendments and varieties on the sweet potato vine length at various weeks after planting (WAP) (cm)

Varieties	Amendments							Mean
	CT	ML	NL	NPK	PD	RHA	RHD	
4WAP								
TIS	28.80	46.47	45.50	40.40	61.17	47.07	45.63	**45.00**
UMU	24.17	42.03	41.23	35.93	41.43	41.73	41.93	**38.35**
Mean	**26.48**	**44.25**	**43.37**	**38.17**	**51.30**	**44.40**	**43.78**	
LSD $_{0.05}$ for varieties					**3.706**			
LSD $_{0.05}$ for Amendments						**5.190**		
LSD $_{0.05}$ for varieties x Amendments interaction						**6.997**		
6WAP								
TIS	88.8	87.7	73.7	79.0	91.1	85.8	87.9	**84.8**
UMU	30.9	70.2	73.5	64.5	73.2	77.0	73.9	**66.2**
Mean	**59.9**	**78.9**	**73.6**	**71.7**	**82.1**	**81.4**	**80.9**	
LSD 0.05 for varieties					**6.28**			
LSD 0.05 for Amendments					**8.66**			
LSD 0.05 for varieties x Amendments interactions					**11.68**			
8WAP								
Tis	217.8	220.0	208.8	233.6	238.1	232.5	215.3	**223.7**
UMU	72.5	112.5	155.9	131.0	120.4	125.7	128.5	**120.9**
Mean	**145.2**	**166.3**	**182.3**	**182.3**	**179.3**	**179.1**	**171.9**	
LSD 0.05 for varieties					**3.21**			
LSD 0.05 for Amendments					**NS**			
LSD 0.05 for varieties x Amendments interactions					**NS**			

NS= non-significant, CT= Control, ML = Moringa leaf, NL = Neem leaf, NPK = nitrogen, phosphorous, potassium, PD = Poultry dropping, RHA = Rice husk ash, RHD = Rice husk dust, Tis = Tis 87/0087 variety, UMU = UMUSOP variety, LSD = Least significant difference, WAP = Weeks after planting.

Table 5 showed the effect of amendments and crop varieties on the vine length of the sweet potato on the 10th and 12th weeks after planting. Sweet potato varieties indicated a significant ($p < 0.05$) differences on the sweet potato vine length for the 10th and 12th weeks of study. The results

Table 5. Effect of amendments and varieties on the sweet potato vine length at various weeks after planting (WAP) (cm)

Varieties	Amendments							Mean
	CT	ML	NL	NPK	PD	RHA	RHD	
10WAP								
Tis	276.0	258.4	249.5	288.4	300.2	279.4	258.1	**272.8**
UMU	76.5	178.8	168.4	144.6	198.0	172.5	150.6	**155.6**
Mean	**176.3**	**218.6**	**209.0**	**216.5**	**249.1**	**225.9**	**204.3**	
LSD 0.05 for varieties					**5.43**			
LSD 0.05 for Amendments					**23.17**			
LSD 0.05 for varieties x Amendments interactions					**30.43**			
12 WAP								
Tis	319.3	319.2	328.2	344.4	373.4	324.1	358.4	**338.2**
UMU	101.0	193.9	194.5	187.8	243.2	193.4	191.3	**186.4**
Mean	**210.1**	**256.5**	**261.3**	**266.1**	**308.3**	**258.8**	**274.9**	
LSD 0.05 for varieties					**62.78**			
LSD 0.05 for Amendments					**38.32**			
LSD 0.05 for varieties x Amendments interactions					**NS**			

NS= non-significant, CT= Control, ML = Moringa leaf, NL = Neem leaf, NPK = nitrogen, phosphorous, potassium, PD = Poultry dropping, RHA = Rice husk ash, RHD = Rice husk dust, Tis = Tis 87/0087 variety, UMU = UMUSOP variety, LSD = Least significant difference, WAP = Weeks after planting.

(Table 5) showed that TIS 87/0087 (pink fleshed variety) increased the vine length significantly ($p < 0.05$) higher than UMUSOP (orange fleshed variety). The results (Table 5) also indicated a statistical ($p < 0.05$) increase on the vine length of the sweet potato due to the amendments application on the 10^{th} and 12^{th} weeks after planting. Generally, it was obtained that all the amended plots significantly increased the vine length higher than the control plots with poultry dropping amended plots improving the vine length statistical ($p < 0.05$) higher than other amended plots including the control. The mean vine length values varied from 176.3 cm to 249.1 cm on the 10^{th} WAP and 210.1 to 266.1 cm on the 12^{th} weeks after planting. However, the results (Table 5) showed that interaction of the varieties and amendments did show significant difference on the 10^{th} week, but could not show any significant improvement on the 12^{th} WAP.

The result (Table 6) indicated a significant ($P<0.05$) difference among the two varieties of the sweet potato on the yield in the study. The results showed that even though TIS 87/0087 variety vegetatively performed creditably and significantly ($p < 0.05$) higher than UMUSOP variety, result on the yield showed a negative transmission of this attribute of TIS 87/0087 to the yield of the crop as UMUSOP variety yielded significantly ($p < 0.05$) higher than the TIS 87/0087 variety. The high yielding orange flesh varieties are fertilizer responsive. Research evidences indicate that the application of inorganic fertilizers increases root yield which is not in line with the result of this study [26].

Table 6. Effect of amendments and varieties of sweet potato on the tuber yield (t/ha)

Varieties	Amendments							Mean
	CT	ML	NL	NPK	PD	RHA	RHD	
Tis	3.47	5.90	7.23	6.03	7.83	6.10	6.07	**6.09**
UMU	3.60	7.17	8.73	6.27	10.07	7.10	6.87	**7.11**
Mean	**3.53**	**6.53**	**7.98**	**6.15**	**8.95**	**6.60**	**6.47**	
LSD 0.05 for varieties					**0.561**			
LSD 0.05 for Amendments					**1.509**			
LSD 0.05 for varieties x Amendments interactions					**NS**			

NS= non-significant, CT = Control, ML = Moringa leaf, NL = Neem leaf, NPK = nitrogen, phosphorous, potassium, PD = Poultry dropping, RHA = Rice husk ash, RHD = Rice husk dust, Tis = Tis 87/0087 variety, UMU = UMUSOP variety, LSD = Least significant difference.

Table 6 indicated a significant improvement on the yield due to the application of the amendments. The results showed that plots amended with poultry dropping significantly ($p < 0.05$) increased the sweet potato yield higher than other amendments, followed by plots treated with neem leaf. Consequently, the interaction between the varieties and amendments showed no significant ($p < 0.05$) increase in the yield of the sweet potato tuber.

4. CONCLUSION

The result indicated that TIS 87/0087 had significantly wider spread than UMUSOP Variety, but UMUSOP yield was significantly better than TIS 87/0087. The results revealed that application of organic manure did significantly increase some selected chemical properties of the soil better than inorganic fertilizer. It was obtained that moringa plant (*Moringa oleifera*) can as well be used for improving the fertility status of a soil. The results indicated that poultry dropping performed statistically better than other manure source used in this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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