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# Evaluation of sweet potato (*Ipomoea batatas* L.) performance and soil properties under tillage methods and poultry manure levels

**T. M. Agbede[1]* and A. O. Adekiya[2]**

**[1]Department of Agricultural Engineering Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria; [2]Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Ondo State, Nigeria**

**Abstract**: Research study on the effect of tillage systems and application rate of poultry manure on sweet potato (*Ipomoea batatas*) in Alfisol of southwest Nigeria is lacking. Field trials were conducted in 2006, 2007 and 2008 cropping seasons on an Alfisol (Oxic Tropuldalf) at Owo in rainforest zone of southwest Nigeria. The trials consisted of the factorial combinations of two tillage methods (manual clearing and conventional tillage) and four manure levels (0, 5, 10 and 15 t/ha) arranged in a randomized complete block design and replicated three times. Conventional tillage alone (CTo) resulted in lower soil N, P, K, Ca, Mg and soil organic C and better leaf N, P, K, Ca and Mg concentrations, growth and yield of sweet potato compared with manually cleared (MCo) plots. The better performance of sweet potato under conventional tillage (CTo) was adduced to reduced bulk density. Bulk density was negatively correlated with yield. Conventional tillage alone (CTo) improves sweet potato tuber yield by 62, 55 and 42% in 2006, 2007 and 2008, respectively compared with manual clearing alone (MCo). In both the manually cleared and conventionally tilled plots, soil organic C, N, P, K, Ca, Mg and water content increased with amount of poultry manure, while soil pH, bulk density and temperature were reduced. Yields given by 5, 10 and 15 t/ha poultry manure were not significantly different under both manually cleared and conventionally tilled treatments. Conventional tillage plus 5 t/ha poultry manure (CT+5 PM) produced the highest overall yield. Compared with manual clearing alone (MCo) and conventional tillage alone (CTo), conventional tillage plus 5 t/ha poultry manure (CT+5 PM) improved tuber yield of sweet potato by 117 and 43%, respectively. Therefore the use of 5 t/ha poultry manure with conventional tillage is recommended for sweet potato production on an Alfisol of southwest Nigeria.

**Keywords**: Tillage, sweet potato, poultry manure, bulk density, nutrient concentrations.

# تقييم البطاطا الحلوة (*Ipomoea batatas* لام) الأداء وخصائص التربة تحت طرق الحراثة ومستويات السماد الدواجن

**ت.م. اقبدي[1] و ا.و. اديكيا[2]**

**[1]قسم تكنولوجيا الهندسة الزراعية ، بلوتكنيك روفس قيوا ، وو, اقليم وندو , نيجيريا ; [2]قسم المحاصيل , التربة وادارة الافات ، الجامعة الفدرالية للتكنولوجيات ، اكوري ، اقليم وندو ، نيجيريا**

**الملخص**: هناك نقص في الدراسات البحثية عن تأثير نظم الحراثة ومعدل إضافة السماد الدواجن على البطاطا الحلوة (Ipomoea batatas)في جنوب غرب نيجيريا Alfisol وقد أجريت تجارب ميدانية في 2007 و 2006 و 2008 على مواسم الحصاد Alfisol ( Oxic Tropuldalf)في الغابات المطيرة في Owo منطقة جنوب غرب نيجيريا.وتألفت التجارب من مجموعتين من التجارب لمقارنة اثنين من طرق الحراثة (الحراثة اليدوية والحراثة التقليدية) ، وأربعة مستويات السماد العضوي (0 ، 5 و 10 و 15 طن / هكتار) مرتبة في تصميم قطع كاملة العشوائية وتكرارها ثلاث مرات . أدى الحرث التقليدية وحدها (CTo) في أقل مستوى من النيتروجين والفوسفور والبوتاسيوم والكالسيوم والمغنيسيوم والمادة العضوية في التربة ومستوىأفضل من تركيزات النيتروجين والفوسفور والبوتاسيوم والكالسيوم والمغنيسيوم في الأوراق بالإضافة لمعدلا نمو و محصول البطاطا الحلوة مقارنة بالحراثة اليدوية (MCo) . أدى تطبيق الحراثة التقليدية الى تحسين انتاجية درنات البطاطا بنسبة 62و 55و 42% في أعوام 2006و 2007 و 2008 على التوالي مقارنة بالحراثة اليدوية فقط. أظهرت النتائج أنه في كل من معاملتي الحراثية اليدوية و التقلينه في كل من معاملتي الحراثة اليدوية و التقليدية فقد ارتفعت مستويات C, N, P, K, Ca, Mg المادة العضوية و الرطوبة بزيادة كميات سماد الدواجن مع انخفاض حموضة التربة و الكثافة الظاهرية و الحرارة. و لم تظهر الانتاجية أي فروق معنوية بين معاملتي الحراثة عند مستويات سماد الدواجن المختلفة. أظهرت معاملة الحراثة التقليدية منفردة ومع إضافة 5طن من سماد الدواجن زيادة الانتاجية الكلية بنسبة 117 و 43% على التوالي. و لذلك يوصى باستخدام 5طن للهكتار من سماد الدواجن مع الحرا ثة التقليدية في انتاج البطاطا الحلوة في Alfisol جنوب غرب نيجيريا.

* Corresponding Author, Email: agbedetm@yahoo.com

## Introduction

With the increasing population pressure in tropical Africa, shifting cultivation is no longer sustainable and the length of traditional bush fallow for maintaining the productivity of the soil is becoming shorter (Mbah and Mbagwu, 2006). Therefore continuous cultivation of crop like sweet potato (*Ipomoea batatas* Lin) on the same land will lead to soil nutrient exhaustion and low yield. Moreso, sweet potato like any other root tuber crops is a heavy feeder exploiting greater volume of soil for nutrient and water (Osundare, 2004). Because of the fragile nature of tropical soils and especially Alfisol of the study area, appropriate and integrated soil management is necessary for sustaining high soil and crop productivity. According to Zingore et al. (2003), the soils are poor in organic matter and available nutrients and hence productivity and sustainability decline over time.

Two cultural practices that can moderate the soil organic matter, sustain the productivity of tropical soils and influence the performance of sweet potato is appropriate tillage and organic manure application. Nyakatawa et al. (2001) 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 after adopting appropriate tillage systems. Appropriate soil tillage or seedbed type can be a suitable alternative to enhanced nutrient availability to crop and therefore reduce money spend on chemical fertilizers (Adekiya and Ojeniyi, 2002).

The importance of no-tillage in soil and water conservation and growth and yields of crops in Nigeria had been reported (Ojeniyi and Adekayode, 1999; Agbede, 2008; Agbede and Ojeniyi, 2009). For large scale production of crops especially sweet potato, the use of mechanized tillage is inevitable. There had been no study to compare traditional farmers' manual clearing (zero tillage without mulch) with mechanized or conventional tillage as it affects the performance of sweet potato on Alfisol of southwest Nigeria. Few studies carried out were outside the Alfisol of southwest Nigeria. For example, Midmore (1991) in Peru, found no significant differences in root yield of sweet potato under row-ridge, two-row bed, on-the flat and row furrow. Study carried out on deep Ultisol of southeast Nigeria gave contradictory results when study showed that conventional tillage out-yielded no-tillage system (Anikwe and Ubochi, 2007). Therefore studies on the response of sweet potato to tillage methods have produced inconclusive and controversial results.

Organic manure on the other hand 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 (Obi and Ebo, 1995; Ikpe and Powel, 2003; Ano and Agwu, 2005). Large quantities of organic wastes such as poultry manure are available in urban centre in Nigeria where they pose disposal problems and environmental hazards and are effective source of nutrient for tuber crop like sweet potato. Ikpe et al. (1999) reported that about 75% of farmers in the forest zone of West Africa keep livestock predominantly goat and poultry. The use of poultry manure for sweet potato production has not received adequate research attention in southwest Nigeria. The application rate of poultry manure for sweet potato has not been documented. Farmers need to be given specific application rate on how organic manure should be applied. There has not been research study on the implications of tillage-poultry manure combination on soil properties and performance of sweet potato in southwest Nigeria. Therefore the aim of this study was to investigate effect of tillage methods (conventional tillage and manual clearing and different levels of poultry manure on the soil physical and chemical properties, leaf nutrient concentration, growth and yield of sweet potato.

## Materials and Methods

### Site description and treatments

A 3-year field experiment was carried out at Owo (7° 12'N, 5° 35'E) in the forest-savanna transition zone of southwest Nigeria in 2006, 2007 and 2008 growing seasons. The soil in Owo area is an Alfisol (Oxic Tropuldalf) (USDA) or Luvisol (FAO) derived from quartz, gneiss and schist. There are two rainy seasons, one from March to July and the other is from mid-August to November. The rainfall totals in 2006, 2007 and 2008 were 1241, 1335 and 1137 mm, respectively. The pan-evaporation values were 1339, 1295 and 1326 mm, respectively while the mean values of air temperature were 28, 30 and 29°C, respectively. Owo is located in the forest-savanna transition zone. The experiments followed 2 years of bush fallow. The values of the physical and chemical properties of the surface soil (0-20 cm) before experimentation were determined.

The trial each year consisted of 2 x 4 factorial combinations of two tillage methods (manual clearing and conventional tillage) and four poultry manure levels (0, 5, 10 and 15 t/ha). The eight treatments were (a) manual clearing alone (MCo): manual clearing with cutlass and packing away of the debris, (b) manual clearing plus 5 t/ha poultry manure (MC + 5 PM), (c) manual clearing plus 10 t/ha poultry manure (MC + 10 PM), (d) manual clearing plus 15 t/ha poultry manure (MC + 15 PM), (e) conventional tillage alone (CTo): ploughing to a depth of 20 cm followed by harrowing and ridging, (f) conventional tillage plus 5 t/ha poultry manure (CT + 5 PM), (g) conventional tillage plus 10 t/ha poultry manure (CT + 10 PM) and (h) conventional tillage plus 15 t/ha poultry manure (CT + 15 PM). The eight treatments were factorially arranged in a randomized complete block design and replicated three times. The same treatment was allotted to each plot for the 3 years of study.

**Planting of sweet potato and poultry manure application**

The experimental plot size in each trial was 12 m x 10 m. In order to minimize interference, there was a 4 m wide guard strip of sweet potato between blocks and 3 m between plots. After land preparation, planting of sweet potato vines (Owo local variety) about 40 cm long were done in May each year at a spacing of 1 m x 1 m giving a population of 10,000 plants/ha. Before application, the poultry manure was air-dried and sieved with 2 - mm sieve. The manure was applied in ring form at planting, thoroughly worked into the soil with a hoe. Weeding was done manually at 3 and 8 weeks after planting in each experiment.

**Determination of soil properties**

One month after planting sweet potato/poultry manure application, determination of certain soil physical properties in all plots commenced and this was done at one-month interval on four occasions for each year. Six samples (4 cm diameter, 10 cm high) were collected at 0-10 cm depth from each plot using a steel core sampler and were used for the evaluation of bulk density, total porosity and gravimetric water content after oven-dried at 100°C for 24 h. Total porosity was calculated from the values of bulk density and particle density. Soil temperature was determined at 15.00 h with a soil thermometer inserted to 10 cm depth. Six readings were made per plot at each sampling time at 1-month interval and mean data were computed.

Prior to commencement of experiment in 2006, soil samples randomly collected from 0-20 cm depth were thoroughly mixed inside a plastic bucket to form a composite which was later analysed for physical and chemical properties. At the beginning of harvest in 2007 (second crop) and 2008 (third crop) (i.e. 5 months after planting), another set of composite samples were collected per plot and similarly analysed for routine chemical analysis as described by Carter (1993). The soil samples were air-dried and sieved using a 2 mm sieve before making the determinations. Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996), total N was determined by micro-Kjeldahl digestion method (Bremner, 1996), available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank et al., 1998). Exchangeable K, Ca and Mg were extracted using 1.0 N ammonium acetate. Thereafter, K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method (Hendershot and Lalande, 1993). Soil pH was determined in soil-water (1:2) medium using the digital electronic pH meter (Ibitoye, 2006). Particle-size analysis was done using Bouyoucos hydrometer method (Sheldrick and Hand Wang, 1993). Soil bulk density was determined using the core method (Campbell and Henshall, 1991).

**Leaf and poultry manure analysis**

In 2007 and 2008, leaf samples were collected at 3 months after planting from five plants per plot for chemical analysis. Leaf samples were oven-dried for 24 h at 80°C and ground in a Willey-mill. Leaf N was determined by micro-Kjeldahl digestion method. Samples were dry ashed in a furnace at 450°C for 6 h and extracted using 10% HCl for determination of P, K, Ca and Mg. Leaf P was determined colorimetrically by the vanadomolybdate method, K was determined using flame photometer, and Ca and Mg were determined using atomic absorption spectrophotometer (AOAC, 1997). Air-dried and ground poultry manure samples were sieved through a 2 mm sieve and analysed for organic C, N, P, K, Ca and Mg using the method described by Okalebo et al. (1993).

**Growth and yield parameters**

Twenty plants were randomly selected per plot for the determination of growth and yield parameters. Leaf area (by graphical method) was determined at 3 months after planting while vine length and tuber weight were determined at harvest (i.e. 5 months after planting).

**Statistical analysis**

The data collected were subjected to analysis of variance (ANOVA) and the treatment means were separated using Duncan's multiple range test at 5% probability level (Hinkelman and Kempthorne, 1994).

**Results**

The data presented in Table 1 are the results of soil physical and chemical properties before the start of the experiment and the chemical composition of poultry manure used. The soil is sandy loam with pH of 7.1. The soil bulk density of 1.44 Mg $m^{-3}$ is high for sweet potato and other tuber crops (Agbede and Ojeniyi, 2003). The organic C of 2.71 g $kg^{-1}$ and total nitrogen of 0.15 g $kg^{-1}$ were low. The available P of 15.9 mg $kg^{-1}$ and the exchangeable bases (K, Ca, and Mg) were adequate. The poultry manure used was relatively high in N, P, K and Ca. The organic C, N, P, K, Ca and Mg constituents are expected to improve the fertility of the experimental soil and tuber yield of sweet potato.

**Soil physical properties**

Tillage methods significantly influenced soil temperature, bulk density, total porosity and water content in the 3 years considered (Table 2). Manual clearing alone (MCo) consistently produced the least soil temperature compared with conventional tillage alone (CTo). However, with the application of poultry manure, the least soil temperature was consistently recorded by (MC + 10 PM) and (MC + 15 PM) while the highest was recorded by CTo in all the treatments considered. There were no significant differences between soil temperatures of (MC + 10 PM) and (MC + 15 PM) and between (CT + 5 PM) and (CT + 10 PM). In the 3 years, tillage methods significantly influenced soil bulk density. MCo had higher bulk density when compared with CTo. With poultry manure application, the least value was consistently recorded by (CT + 15 PM) while the highest was recorded by MCo. There were reductions in soil bulk density with increasing levels of poultry manure. In the 3 years, the order were MCo > (MC + 5 PM), CTo and (MC + 10 PM) > (MC + 15 PM) and (CT + 5 PM) > (CT + 10 PM) > (CT + 15 PM).

**Table 1. Mean ± standard deviation of soil physical and chemical properties (0-20 cm depth) of the experimental site before planting in 2006 and chemical composition of poultry manure used in 2006, 2007 and 2008.**

| Soil property | | | Value |
|---|---|---|---|
| Sand (g $kg^{-1}$) | | | 690 ± 8.8 |
| Silt (g $kg^{-1}$) | | | 130 ± 5.6 |
| Clay (g $kg^{-1}$) | | | 180 ± 4.9 |
| Textural class | | | Sandy loam |
| pH (water) | | | 7.1 ± 0.3 |
| Bulk density (Mg $m^{-3}$) | | | 1.44 ± 0.04 |
| Total porosity (%, v/v) | | | 45.7 ± 0.5 |
| Organic carbon (g $kg^{-1}$) | | | 2.71 ± 0.06 |
| Total N (g $kg^{-1}$) | | | 0.15 ± 0.02 |
| Available P (mg $kg^{-1}$) | | | 15.9 ± 0.6 |
| Exchangeable K (cmol $kg^{-1}$) | | | 0.69 ± 0.02 |
| Exchangeable Ca ((cmol $kg^{-1}$) | | | 8.7 ± 0.3 |
| Exchangeable Mg ((cmol $kg^{-1}$) | | | 1.5 ± 0.04 |
| **Poultry manure** | | | |
| **Nutrient** | **2006 value** | **2007 value** | **2008 value** |
| pH | 6.8 | 6.9 | 6.8 |
| Organic C (%) | 29.5 | 23.6 | 27.1 |
| Nitrogen (%) | 4.31 | 3.03 | 3.23 |
| C:N | 6.8 | 7.8 | 8.4 |
| Phosphorus (%) | 0.83 | 0.72 | 0.61 |
| Potassium (%) | 2.2 | 2.4 | 1.9 |
| Calcium (%) | 1.4 | 1.5 | 1.8 |
| Magnesium (%) | 0.58 | 0.43 | 0.58 |

The bulk density recorded for the treatments were matched by the porosity recorded. MCo expectedly had the least porosity while (CT + 15 PM) had the highest porosity. Soil water content in the 3 years was in the decreasing order of (MC + 15 PM) and (MC + 10 PM) > (MC + 5 PM), (CT + 15 PM) and (CT + 10 PM) > MCo > (CT + 5 PM) > CTo.

## Soil and leaf nutrient concentrations

The effect of tillage methods and poultry manure on soil chemical properties is shown in Table 3. MCo had significantly higher concentration of soil organic C, N, P, K, Ca and Mg compared with CTo in both years. With applications of poultry manure, soil chemical properties tended to improve with increasing levels of poultry manure application. In all cases, concentrations of nutrients were lower in CTo compared with other treatments. There were percentage decreases in soil organic C over the years. The percentage decreases in soil organic C were 15.8 and 23.2% for MCo in 2007 and 2008, respectively, while the percentage decreases were 32.8 and 35.5% for CTo in 2007 and 2008, respectively. The values of soil pH between MCo and CTo in both years were not significantly different. Increasing the levels of poultry manure from 0 to 15 t/ha decreases soil pH. The least soil pH was recorded by (CT + 15 PM) and (MC + 15 PM) in both years.

Table 4 shows the effect of tillage methods and poultry manure on leaf nutrient concentration of sweet potato in 2007 and 2008. CTo produces significantly higher concentration of leaf N, P, K, Ca and Mg compared with MCo. The values of leaf N, P and K increases with the levels of poultry manure in both the manually cleared and conventionally tilled plots. In almost all cases, the values of leaf Ca and Mg between (MC + 5 PM), (MC + 10 PM) and (MC + 15 PM), and between (CT + 5 PM), (CT + 10 PM) and (CT + 15 PM) were not significantly different.

**Table 2. Effect of tillage methods and poultry manure on soil physical properties (0-10 cm depth).**

| Treatment | Bulk density (Mg m$^{-3}$) | | | | Total porosity (%v/v) | | | | Water content (g kg$^{-1}$) | | | | Temperature (°C) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | Mean | 2006 | 2007 | 2008 | Mean | 2006 | 2007 | 2008 | Mean | 2006 | 2007 | 2008 | Mean |
| MCo | 1.44a | 1.45a | 1.45a | 1.45 | 45.7f | 45.3f | 45.4f | 45.5 | 115c | 110c | 112c | 112 | 28.5b | 29.8b | 29.4b | 29.2 |
| MC + 5 t/ha PM | 1.26b | 1.26b | 1.26b | 1.26 | 52.5de | 52.5de | 52.5de | 52.5 | 140b | 134b | 137b | 137 | 25.1c | 27.9c | 26.5c | 26.5 |
| MC + 10 t/ha PM | 1.19bc | 1.19bc | 1.19bc | 1.19 | 55.1c | 55.1c | 55.1c | 55.1 | 156a | 149a | 152a | 152 | 22.1d | 25.0d | 23.8d | 23.6 |
| MC + 15 t/ha PM | 1.12cd | 1.12cd | 1.12cd | 1.12 | 58.1bc | 57.7bc | 58.4bc | 58.4 | 160a | 155a | 157a | 157 | 21.8d | 24.4d | 23.1d | 23.1 |
| CTo | 1.22b | 1.23b | 1.23b | 1.23 | 54.0cd | 53.6cd | 53.8cd | 53.8 | 90e | 85e | 87e | 87 | 32.7a | 34.5a | 33.6a | 33.6 |
| CT + 5 t/ha PM | 1.11cd | 1.11cd | 1.11cd | 1.11 | 55.1c | 55.1c | 55.1c | 55.1 | 102d | 101d | 101d | 101 | 29.1b | 31.1b | 30.2b | 30.1 |
| CT + 10 t/ha PM | 1.00e | 1.00e | 1.00e | 1.00 | 62.3ab | 62.3ab | 62.3ab | 62.3 | 130b | 131b | 130b | 130 | 28.1b | 30.3b | 29.3b | 29.2 |
| CT + 15 t/ha PM | 0.92f | 0.92f | 0.92f | 0.92 | 65.7a | 65.3a | 65.4a | 65.4 | 135b | 129b | 132b | 137 | 25.3c | 27.1c | 26.4c | 26.3 |

Means followed by the same letters (a-f) in a column are not significantly different at p=0.05 according to Duncan's multiple range test (DMRT). MC = Manual clearing; CT = Conventional tillage; PM = Poultry manure.

**Table 3. Effect of tillage methods and poultry manure on soil chemical properties (0-20 cm depth) in 2007 and 2008.**

| Treatment | pH (water) | | Soil organic C (g $kg^{-1}$) | | N (g $kg^{-1}$) | | P (mg $kg^{-1}$) | | K (cmol $kg^{-1}$) | | Ca (cmol $kg^{-1}$) | | Mg (cmol $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 |
| MCo | 7.0a | 7.0a | 2.34f | 2.20g | 0.15d | 0.12d | 15.3d | 12.3d | 0.60e | 0.51de | 8.2b | 8.0b | 1.4cd | 1.4c |
| MC + 5 t/ha PM | 6.9a | 6.6ab | 3.05c | 3.00c | 0.18bc | 0.15bc | 17.8bc | 14.4bc | 0.79c | 0.65c | 8.4b | 8.0b | 1.6b | 1.6b |
| MC +10 t/ha PM | 6.3bc | 6.2bc | 3.44b | 3.39ab | 0.19b | 0.16b | 18.9b | 15.3b | 0.90ab | 0.81a | 9.3a | 8.9a | 1.8a | 1.9a |
| MC + 15 t/ha PM | 6.2bc | 6.0c | 3.78a | 3.69a | 0.21a | 0.18a | 23.2a | 19.4a | 0.96a | 0.82a | 9.4a | 9.0a | 1.8a | 1.9a |
| CTo | 7.0a | 6.9a | 2.04g | 2.00g | 0.11e | 0.10e | 10.3f | 8.2f | 0.40g | 0.36f | 6.3d | 5.9d | 1.3d | 1.2d |
| CT + 5 t/ha PM | 6.8a | 6.7ab | 2.56de | 2.40e | 0.15d | 0.14c | 13.3e | 10.1e | 0.56ef | 0.50e | 6.9cd | 6.5cd | 1.5bc | 1.5bc |
| CT + 10 t/ha PM | 6.2bc | 6.1bc | 2.71d | 2.60d | 0.18bc | 0.17ab | 15.3d | 12.5d | 0.69d | 0.59d | 7.2c | 6.9c | 1.8a | 1.9a |
| CT + 15 t/ha PM | 6.0c | 5.9c | 2.99c | 2.89c | 0.18bc | 0.17ab | 15.4d | 12.5d | 0.81c | 0.74b | 7.3c | 6.9c | 1.8a | 1.9a |

Means followed by the same letters (a-g) in a column are not significantly different at p=0.05 according to Duncan's multiple range test (DMRT). MC = Manual clearing; CT = Conventional tillage; PM = Poultry manure.

**Table 4. Effect of tillage methods and poultry manure on leaf nutrient concentration of sweet potato in 2007 and 2008.**

| Treatment | N (g 100g$^{-1}$) | | P (g 100g$^{-1}$) | | K (g 100g$^{-1}$) | | Ca (g 100g$^{-1}$) | | Mg (g 100g$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 | 2007 | 2008 |
| MCo | 2.20g | 2.10g | 0.15e | 0.15e | 1.25f | 1.20f | 1.10d | 1.00d | 0.61d | 0.56d |
| MC + 5 t/ha PM | 2.45f | 2.35f | 0.18d | 0.17d | 1.46e | 1.40e | 1.22bc | 1.20bc | 0.69c | 0.68c |
| MC +10 t/ha PM | 2.70e | 2.60e | 0.20c | 0.20c | 1.60d | 1.56d | 1.22bc | 1.19bc | 0.72c | 0.69c |
| MC + 15 t/ha PM | 3.00d | 2.91d | 0.24b | 0.23b | 1.78c | 1.70c | 1.23bc | 1.20bc | 0.72c | 0.68c |
| CTo | 2.93de | 2.89de | 0.21c | 0.20c | 1.60d | 1.56d | 1.30b | 1.25b | 0.71c | 0.68c |
| CT + 5 t/ha PM | 3.30c | 3.21c | 0.24b | 0.23b | 1.85bc | 1.80bc | 1.44a | 1.39a | 0.79b | 0.76b |
| CT + 10 t/ha PM | 3.76ab | 3.55b | 0.27a | 0.26a | 1.98b | 1.90b | 1.45a | 1.39a | 0.88a | 0.85a |
| CT + 15 t/ha PM | 3.96a | 3.90a | 0.28a | 0.27a | 2.23a | 2.20a | 1.44a | 1.38a | 0.81a | 0.84a |

Means followed by the same letters (a-g) in a column are not significantly different at p=0.05 according to Duncan's multiple range test (DMRT).MC = Manual clearing; CT = Conventional tillage; PM = Poultry manure.

**Sweet potato performance**

Tillage methods and levels of poultry manure significantly influenced the growth and yield of sweet potato (Table 5). The growth indices are shown by vine length and leaf area. CTo significantly increased vine length and leaf area compared with MCo. With the application of poultry manure, vine length tended to increase with increasing level of poultry manure from 0 to 15 t/ha in both tillage methods. However, the leaf area given by 5, 10 and 15 t/ha poultry manure under conventional tillage were not significantly different, likewise leaf area given by 5, 10 and 15 t/ha poultry manure for manually cleared plots were not significantly different. Averaged over the 3 years, the correlation coefficient (r) of -1 and -1 were recorded between soil bulk density and vine length and leaf area, respectively for MCo and CTo. Tillage methods and poultry manure applications significantly influenced sweet potato tuber yield. CTo improved the yield of sweet potato by 61.9, 54.6 and 41.5%, respectively in 2006, 2007 and 2008 compared with MCo. Averaged over the 3 years, the correlation coefficient (r) of -1 was recorded between soil bulk density and tuber yield of MCo and CTo plots. Poultry manure application significantly improved tuber yield compared with MCo and CTo treatments. The yield given by 5, 10 and 15 t/ha poultry manure under the manually cleared plots were not significantly different, likewise yield given by 5, 10 and 15 t/ha poultry manure under the conventionally tilled plots were not significantly different. Compared with MCo and CTo, (MC + 5 PM) improved sweet potato yield by 71.9 and 13.1%, respectively and compared with MCo and CTo, (CT +5 PM) improved sweet potato tuber yield by 116.7 and 42.7%, respectively.

**Discussion**

Tillage methods significantly influenced soil physical properties. Manual clearing alone (MCo) gave relatively high soil bulk density, water content and low soil temperature compared with conventional tillage alone (CTo). The higher bulk density of MCo compared with CTo could be attributed to non-tillage and compaction. This observation implies that continuous exposure of untilled soil to rainfall without tillage will increase the bulk density of the soil. Agbede and Ojeniyi (2003); Bankole and Ojeniyi (2005) and Agbede (2006) had earlier reported higher bulk density for zero tillage compared with tilled soils in southwest Nigeria.

**Table 5. Effect of tillage methods and poultry manure on growth and yield parameters in 2006, 2007 and 2008.**

| Treatments | Vine length (m) | | | | Leaf area ($m^2$) | | | | Tuber weight (t $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | Mean | 2006 | 2007 | 2008 | Mean | 2006 | 2007 | 2008 | Mean |
| MCo | 1.75e | 1.59e | 1.67e | 1.67 | 0.60d | 0.58c | 0.59c | 0.59 | 10.78b | 10.50d | 10.25d | 10.57 |
| MC + 5 t/ha PM | 2.15d | 1.93d | 2.00d | 2.03 | 0.77c | 0.69b | 0.74b | 0.73 | 19.90b | 18.10b | 16.50b | 18.17 |
| MC +10 t/ha PM | 2.52c | 2.44c | 2.44c | 2.47 | 0.79c | 0.73b | 0.76b | 0.76 | 20.03b | 18.35b | 16.75b | 18.38 |
| MC + 15 t/ha PM | 2.90ab | 2.71ab | 2.80ab | 2.80 | 0.81c | 0.75b | 0.78b | 0.78 | 20.35b | 18.85b | 17.20b | 18.80 |
| CTo | 2.15d | 1.90d | 2.01d | 2.02 | 0.80c | 0.72b | 0.76b | 0.76 | 17.45c | 16.23c | 14.50c | 16.06 |
| CT + 5 t/ha PM | 2.51c | 2.40c | 2.40c | 2.44 | 0.94ab | 0.89a | 0.92a | 0.92 | 22.40a | 23.08a | 23.25a | 22.91 |
| CT + 10 t/ha PM | 2.89ab | 2.75ab | 2.82ab | 2.82 | 0.97ab | 0.92a | 0.95a | 0.95 | 23.00a | 23.63a | 23.23a | 23.29 |
| CT + 15 t/ha PM | 3.10a | 2.95a | 3.03a | 3.03 | 1.00a | 0.94a | 0.97a | 0.97 | 23.30a | 23.80a | 23.10a | 23.40 |

Means followed by the same letters (a-e) in a column are not significantly different at p=0.05 according to Duncan's multiple range test (DMRT). MC = Manual clearing; CT = Conventional tillage; PM = Poultry manure.

The higher water content of MCo compared with CTo is consistent with its lower porosity. The turbulent movement of atmospheric air into soils which enhanced water evaporation occurs through larger pores (Ojeniyi and Adekayode, 1999; Ojeniyi et al., 1999). Ojeniyi et al. (1999) found that for sandy soils of southwest Nigeria, water content increased with bulk density. Hillet et al. (1975) had earlier reported that no-till plots were protected by a layer of low conductivity (dry soil) on the surface which reduces evaporation losses. CTo had relatively high soil temperature compared with MCo. The relative high value of soil temperature caused by CTo is consistent with its relatively low soil water content. Other studies confirmed that tillage treatments did cause significant difference in absolute soil temperature (Ojeniyi, 1990; Adekiya and Ojeniyi, 2002; Agbede and Ojeniyi, 2003).

The application of poultry manure improved soil physical properties in manure plots compared with no manure (MCo and CTo) plots. The influence of poultry manure application in improving the soil physical conditions had been widely reported (Weil and Kroontje, 1979; Khaleel et al., 1981; Pagliai et al., 1987; Mbagwu, 1992; Akanni, 2005). The improvement in soil physical properties with increasing levels of poultry manure is attributable to increase in soil organic matter from the manure. The organic matter should have stabilized soil structure thereby reducing bulk density, increasing porosity and water content. Sommerfeldt and Chang (1985) found that surface (0-15 cm) soil bulk density decreased from 0.96 Mg $m^{-3}$ with no manure to 0.78 Mg $m^{-3}$ with 90 t $ha^{-1}$ (wet weight) manure application. Improved soil water content is attributable to mulching effect of organic manure and improved moisture retention and water acceptance as a result of improved soil structure and macroporosity (Aluko and Oyedele, 2005). The improvement observed in water content of the poultry manure treated plots relative to the untreated plots could also be attributed to the colloidal and hydrophobic nature of the manure.

The least values of soil organic C, N, P, K, Ca and Mg recorded for CTo could be adduced to inversion of top soil during land preparation which brought less fertile sub soil to the surface in addition to possible leaching (Ali et al., 2006). The decline in the nutrient reserves of the conventionally tilled plots could also be due to high destruction of the soil structure during the land preparation which encourages soil erosion that preferentially removes colloidal fraction with high "enrichment ratio" (Lal, 1976; Agbede, 2008), resulting in a progressive depletion of its nutrient reserves. Although, there was a decrease in soil organic C concentration with time, the reduction due to MCo was less compared with CTo. Therefore, tillage seems to have enhanced soil organic matter break down leading to a greater loss of soil organic matter in CTo plots (Doran, 1980; Lal, 1997; Agbede and Ojeniyi, 2009). A similar observation was made by Agboola (1981) and Agbede (2007) when they found that organic matter of tropical soils decreased less when no-tillage practices were used than when soils were ploughed.

Increased in soil nutrient contents adduced to poultry manure are consisted with analysis recorded for manure in the present work. The organic matter content of poultry manure decomposes and nutrients were released to soil. Hence, the finding that poultry manure increased soil organic C, N, P, K, Ca and Mg. This is consistent with the findings of kingery et al. (1993); Adeniyan and Ojeniyi (2005); Adenawoola and Adejoro (2005); Agbede et al. (2008) and Adekiya and Agbede (2009) that poultry manure improved soil organic matter, N, P, K, Ca and Mg concentrations. In both the manually cleared and conventionally tilled plots, increasing levels of poultry manure from 0 to 15 t/ha reduced soil pH. Ewulo et al. (2008) had earlier found that application of poultry manure in excess of crop requirement may lead to reduction in soil pH. The reduction in the soil pH could be due to the humic acid developed and carbon dioxide evolved in the process of the decomposition of the applied poultry manure. The significant higher leaf nutrient concentration of CTo compared with MCo was adduced to reduced soil bulk density (Agbede, 2006).

CTo significantly increased vine length and leaf area compared with MCo, this could be adduced to reduced bulk density and improved porosity due to tillage. The better yield of CTo compared with MCo was also due to reduced bulk density and increased porosity. Ravindran and Mohankumar (1985) and Howeler et al. (1993) also reported the superiority of planting sweet potato on ridges, raised beds or mounds (where bulk density is low) than on the flat. This was attributed to enhanced soil aeration, resulting from both a greater soil surface to soil volume ratio and a lower bulk density. These attributes would have enhanced root growth and nutrient uptake, hence better growth and tuber yield in conventionally tilled treatments than untilled treatments. Further evidence of the detrimental effect of high soil bulk density on sweet potato yield was reported by trials in the Philippines (Abenoja and Baterna, 1982). While erosion was least for zero tillage, root yields were reduced below those of tilled treatments owing to a high bulk density and high mechanical impedance. It was found that growth and yield parameters in both the tilled and untilled plots increased with poultry manure to 5 t/ha and that soil organic C, N, P, K, Ca and Mg increased with amount of poultry manure and bulk density and temperature were reduced while water content was increased. Therefore it is confirmed that poultry manure improved nutrient availability in soil and improved physical conditions leading to significant improvement in nutrient status, growth and tuber yield of sweet potato. The yield of sweet potato was optimum at 5 t/ha poultry manure. The reason that could cause lack of significant effect of sweet potato beyond 5 t/ha poultry manure could be due to soil acidity and nutrient imbalance. It was generally found that soil pH tended to be reduced with increasing amount of animal manure (Chang et al., 1991; Eghball and Power, 1999). High rate of poultry manure could have led to excessive release of carbon dioxide ($CO_2$) and probably nitrate ($NO_3^-$) into the soil leading to reduced pH. Excess N and P in the soil and acidity could cause nutrient imbalance in sweet potato and therefore resulting in the reduction in the uptake of certain nutrients (Obi and Akinsola, 1995; Eghball, 2002). Hence it was found in this work that leaf Ca and Mg of sweet potato were reduced at 15 t/ha poultry manure in both the manually cleared and conventionally tilled plots.

## Conclusion

Differences in soil bulk density caused by tillage induced variation in nutrient concentrations, vine length, leaf area and tuber weight of sweet potato. Higher growth and yield was obtained with conventional tillage with the lowest soil bulk density. Poultry manure is an effective source of N, P, K, Ca, Mg and organic C for increasing growth and yield of sweet potato. Because the yields given by 5, 10 and 15 t/ha poultry manure were not significantly different under both the manually cleared and conventionally tilled plots, high rates of poultry manure above 5 t/ha had no significant yield advantage. Therefore the use of 5 t/ha poultry manure with conventional tillage is recommended for sweet potato grown on Alfisol of southwest Nigeria.

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