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# Research Article
# Soil Structure, Organic Matter and Microbial Diversity in Soil under Some Tropical Cover Crops

Bassey Udom and Anita Benwari

Department of Crop and Soil Science, University of Port Harcourt, Port Harcourt, Nigeria

## Abstract

**Background and Objective:** Cover crops can improve soil structure and contribute significantly to soil organic matter and fertility indices. The objective of this study was to investigate the effects of cultivated tropical cover crops on soil structure and microbial population and diversity in a sandy loam soil. **Materials and Methods:** Four cover crops: *Telfairia occidentalis* (Fluted pumpkin), *Vigna unguiculata* (Cowpea), *Colocythis citrillus* (Egusi melon) and *Ipomoea batata* (Sweet potato) were cultivated during the rains. Short-term changes in structural properties of the soil as well as microbial populations and diversity were measured and compared with the control plot without cover crop. **Results:** Cowpea and egusi melon increased soil organic matter (SOM) by 93.14 and 83%, respectively at 12 weeks after planting (WAP). Aggregate stability was increased by 106 and 145.3% in cowpea and sweet potato plots, respectively. Total heterotrophic bacteria (THB) and fungi (THF) were significantly ($p<0.05$) higher in cowpea and sweet potato soils. Leaf area index (LAI) and ground coverage (GC) for cowpea and sweet potato related to higher microbial population. **Conclusion:** Cowpea, sweet potato and egusi melon are suitable for recovery and improvement of soil structure and fertility indices and there should be incorporated into farming systems.

Key words: Bacteria, fungi, bulk density, aggregate stability, nutrient recovery

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Corresponding Author: Bassey Udom, Department of Crop and Soil Science, University of Port Harcourt, Port Harcourt, Nigeria Tel: +234 803 5402352



Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Micro-organisms which form the biological phase of the soil are usually found in the soil solid phase[1]. For example, in a complex soil environment, diversities of microbial communities that co-exist in the soil solid phase are in equilibrium among species and the complex environment[1]. They are connected to the maintenance of life in the earth[2] and responsible for the production of active compounds which can affect the development of other organisms, influenced soil aggregation and availability of essential compounds that tend to bind the soil particles together to form compound structures[3,4].

Cover crops are plantings between or within crops used to manage soil fertility, control nutrient leaching and soil erosion, suppress weed and enhance soil conservation without providing direct economic benefits[5,6]. The influence of cover crops on soil physical and chemical properties and consequently soil fertility and quality have been discussed[2,7,8]. For example, the microbial communities dominating a soil site were found to relate to types of soil cover and biochemical processes taking place in the soil. For the fact that each cover crop has its unique physiology, implies that soil micro-organisms may vary under specific cover crops. In the modifications of soil structure and fertility, no same species and member of soil micro-organisms have the same function under different cover crops[9].

There is a general knowledge that cover cropping has certain benefits and impact to soil microbiology, such as providing habitat for soil organisms and as food source for soil micro-organisms[6,8,9]. However, the influence of certain tropical covers such as *Telferia occidentalis* (Fruited pumpkin), *Colocythis citrillus* (Egusi melon), *Vigna unguiculata* (Cowpea) and *Ipomoea batata* (Sweet potato) on soil structure and microbial diversity is not well known. Thus, the objective of this study was to evaluate the effects of these cultivated cover crops on structural stability and microbial diversity of the soil.

## MATERIALS AND METHODS

**Study area:** The study was conducted at the Faculty of Agriculture Teaching and Research Farm, University of Port Harcourt, Rivers state, Nigeria (Latitude 04° 54 N, Longitude 07° 30). The mean annual rainfall in the area is about 2400 mm, starting in month of March-November with peaks in June and September and a short dry period in August usually known as August break[10]. Mean annual temperatures range from 22°C minimum to 31°C maximum. Relative humidity is generally high in the area with mean annual figure of about 85%. The soil is of recent alluvium, dominated by the coastal plain sands of the Niger Delta.

**Experiment layout and treatments:** The experiment was laid out in Randomized complete block design (RCBD) consisting of five treatments in three replications on a 0.664 ha land area. Treatments were: 1- Control plot without cover crop, 2-*Telfairia occidentalis* (Fluted pumpkin), 3-*Vigna unguiculata* (Cowpea), 4-*Colocythis citrillus* (Egusi melon) and 5-*Ipomoea batata* (Sweet potato). Planting of the cover crops was done during the early rains in May, 2016 and the experiment ended in April, 2017. The area was previously cultivated to maize and cassava.

**Soil sampling and earthworm counts:** Soil samples were collected before planting and at 4, 8 and 12 weeks after planting (WAP) at 0-15 cm top soil. A total of 135 soil samples were collected and transferred to the laboratory in labeled polythene bags for analysis. Cylindrical metal cores measuring 5×6 cm (diameter×height) were used to obtain undisturbed soils samples for determinations of bulk density, total porosity, water holding capacity and saturated hydraulic conductivity. Soil samples were collected in triplicates. Earthworm casts (biogenic deposits) were counted at 4, 8 and 12 WAP.

**Soil analytical methods:** Soil samples were air-dried at room temperature, crushed to pass through 2 mm sieve and stored in plastic containers for laboratory analysis using the following standard procedures.

Particle-size distribution was measured with hydrometer after sample dispersion with sodium hexametaphosphate[11]. Total porosity was calculated with core samples using the method[12] as:

$$\text{Total porosity (\%)} = \frac{\text{Volume of water at saturation}}{\text{Volume of bulk soil}} \times 100 \quad (1)$$

Water holding capacity (WHC) was calculated as:

$$\text{WHC} = \frac{\text{Mass of wet soil} - \text{Mass of dry soil}}{\text{Mass of dry soil}} \quad (2)$$

Bulk density was determined by the method[13] as:

$$\text{Bulk density} = \frac{\text{Mass of oven dried soil (g)}}{\text{Volume of bulk soil (cm}^3\text{)}} \quad (3)$$

**Aggregate stability:** Water stability of aggregates was measured by the wet sieving procedure[14]. In this procedure, 50 g of 4.75 mm dry sieved aggregates were placed in the top most of a cascade of sieves of 4 classes 2.0, 1.0, 0.5 and 0.25 mm, pre-soaked by capillary at 0 kpa in distilled water for 5 min before oscillated vertically in water 20 times, using 4 cm amplitude in a mechanical agitator. The remaining, stable aggregates on each sieve were oven-dried at 50°C for 24 h and weighed. The mass of aggregates <0.25 mm was obtained by the difference between mass of sample and the sum of sample weights collected on the 2.0, 1.0, 0.5 and 0.25 mm nest of sieves. Water stable aggregates were measured by the mean-weight diameter (MWD) and calculated by the following Eq.[15]:

$$MWD = \sum_{i=0}^{n} X_i \, W_i \quad (4)$$

where, $X_i$ is the mean diameter of any particular size range of aggregates separated by sieving and $W_i$ is the weight of aggregates in that size range as a fraction of the total dry weight of the sample analyzed.

**Soil pH:** Soil pH was measured with a glass electrode in a 1:2:5 soil/water solution[16].

**Organic carbon:** Organic carbon was determined by the Walkley and Black Wet oxidation method[17]/Organic matter content of each sample was obtained by multiplying percent organic carbon by a factor of 1.724.

**Bacteria counts and isolation:** Bacteria communities were determined using viable plate counts of the colony forming units (Cfus) from bacteria and propagules. The bacteria count and isolation were determined using the serial dilution and spread plate techniques in nutrient agar[17]. The samples were inoculated for 24 h and the bacteria were identified using the gram stain method[18].

**Fungal counts and isolation:** Fungal counts and isolation were determined using the serial dilution and spread plate technique on potato dextrose agar[19]. The samples were inoculated for 4 days and isolated colonies were identified using lacto-phenol and direct microscopic view[19].

**Plant parameters:** The percentage leaf coverage of the cover crops were measured. Leaf area index (LAI) for sweet potato was calculated using the following formula[20]:

$$\text{Leaf area (A)} = 0.565 \times p \times 620 \quad (5)$$

where, p is length and breadth of sweet potato leaves, 0.56 and 620 are constants which account for the irregularity of sweet potato leaves.

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area}}{\text{Land area}} \quad (6)$$

Leaf area of fruited pumpkin was estimated using the formula:

$$\text{Leaf area (A)} = 0.9467 = 0.2475LW = 0.9724LWN \quad (7)$$

where, N is the number of leaflet in an area A, L the length of the central leaflet and W the maximum width of central leaflet[21]. The leaf area of melon was estimated from the length of midrib of the central lobe as:

$$\text{Area (A)} = 30.53 + 7.41x \quad (8)$$

where, x is the length of the midrib of the central lobe.

**Statistical analysis:** Data was subjected to two-way analysis of variance (ANOVA) and differences in means were separated using least significance difference at 5% probability.

## RESULTS

The initial properties of the soil in Table 1 showed that the soil is sandy loam at the 0-15 cm with sand, silt and clay content of 618, 194, 188 g $kg^{-1}$, respectively. Saturated hydraulic conductivity (Ksat), total porosity, water holding capacity and mean weight diameter (MWD) of water stable aggregates were low (21.65 cm $h^{-1}$, 21.65 %, 0.16 g $g^{-1}$ and 0.70 mm), respectively. Initial total heterotrophic bacteria

Table 1: Some physical properties of the soil at beginning of experiment

| Soil properties | Values |
|---|---|
| Sand (g $kg^{-1}$) | 618.00 |
| Silt (g $kg^{-1}$) | 194.00 |
| Clay (g $kg^{-1}$) | 188.00 |
| Texture | Sandy loam |
| Saturated hydraulic conductivity (cm $h^{-1}$) | 21.87 |
| Total porosity (%) | 21.65 |
| Bulk density (g $cm^{-3}$) | 1.50 |
| Water holding capacity (g $g^{-1}$) | 0.16 |
| Mean weight diameter (mm) | 0.71 |
| pH ($H_2O$) | 4.30 |
| Organic matter (g $kg^{-1}$) | 35.70 |
| C:N ratio | 17.00 |

(THB) consisting of *Bacillus subtillis*, *Staphylococcus aureus*, *Streptococcus pyogenes*, *Pseudomonas putida* and *Micrococcus* spp. was $64\times10^3$ cfus $g^{-1}$ soil. While total heterotrophic fungi (THF) which made up of *Aspergillus niger, Rhizopus flavus, Fusarium oxysporium* and *Candida tropicalis* was $26\times10^3$ cfus $g^{-1}$ soil (Table 2).

**Effects on structural properties and soil organic matter:** The structural properties of the soil measured by saturated hydraulic conductivity, bulk density and water stability of aggregates, total porosity and water holding capacity of the soils are shown in Table 3. There were significant ($p<0.05$) changes in organic matter (OM) and structural properties of the soil compared to the control plots (Table 3). At 4 WAP, sweet potato and egusi melon induced significant ($p<0.05$) differences in water holding capacity (WHC), mean weight diameter (MWD) of water stable aggregates, saturated hydraulic conductivity and total porosity.

Table 2: Soil biological properties at the beginning of experiment

| Biological properties | Value (x$10^3$ CFUs $g^{-1}$ soil) |
|---|---|
| *Bacillus subtillis* | 16 |
| *Staphylococcus aureus* | 20 |
| *Streptococcus pyogenes* | 5 |
| *Pseudomonas putida* | 13 |
| *Micrococcus* spp. | 10 |
| Total heterotrophic bacteria | 64 |
| *Aspergillus niger* | 2 |
| *Rhizopus flavus* | 5 |
| *Fusarium oxysporium* | 7 |
| *Candida tropicalis* | 9 |
| Total heterotrophic fungi | 26 |
| Earthworm cast | Nil |

At 12 WAP, increases in SOM was in the order of cowpea >egusi melon >sweet potato >fluted pumpkin >control, while Ksat was in the order of cowpea > sweet potato >egusi melon >fluted pumpkin >control.

**Effects on total heterotrophic bacteria and fungi:** Total heterotrophic bacteria (THB) were significantly ($p<0.05$) higher in cowpea soils at 4, 8 and 12 WAP (Fig. 1). At 12 WAP, THB were 320 and $175\times10^3$ cfus $g^{-1}$ respectively, for cowpea and sweet potato compared to 25 x $10^3$ cfus $g^{-1}$ in control. The occurrence of total heterotrophic fungi (THF) was significant ($p<0.05$) higher in cowpea plots at 8 WAP ($p<0.05$), while egusi melon gave the highest THF of at 12 WAP ($29.9\times103$ CFUs $g^{-1}$at 12 WAP (Fig. 2).

**Effects on bacteria and fungi isolates:** The percentage occurrence of *Bacillus subtillis* was significantly higher ($p<0.05$) in egusi melon soils at 4 WAP (38%) and reduced to 29% at 8 WAP (Table 4). Whereas, *Staphylococcus aureus*, *Streptococcus pyogenes*, *Pseudomona putida*, *Aeromonas* spp. and *Actinomycaei* spp. were not significantly different in sweet potato and egusi melon soils at 4 WAP.

Percentage occurrences of fungi isolates (Table 5) *Rhizopus Flavus* and *Aspergillus* niger were significantly higher in sweet potato and cowpea soils at 4, 8 and 12 WAP (Table 5). Generally, soil fungi were significantly higher during 8 WAP corresponding to the flowering growth periods of most cover crops. *Candid tropicalis* (yeast) ranged from 10% in control plots to 55% in fluted pumpkin at 4 WAP while, *Fusarium oxysporium* decreased from 35% at 4 WAP to 22%

Table 3: Structural properties and organic matter of the soil at 4, 8 and 12 weeks after planting

| Cover crops | TP (%) | Ksat (cm $h^{-1}$) | BD (g $cm^{-3}$) | WHC (g $g^{-1}$) | MWD (mm) | OM (g $g^{-1}$) | Permeability class |
|---|---|---|---|---|---|---|---|
| **4 WAP** | | | | | | | |
| Fruited pumpkin | 38.0$^{b}$ | 12.13$^{a}$ | 1.36$^{a}$ | 0.29$^{b}$ | 0.87$^{a}$ | 22.0$^{b}$ | Slow |
| Sweet potato | 46.1$^{a}$ | 11.45$^{a}$ | 1.32$^{a}$ | 0.36$^{a}$ | 1.04$^{a}$ | 20.0$^{b}$ | Slow |
| Egusi melon | 45.6$^{a}$ | 10.55$^{a}$ | 1.46$^{a}$ | 0.25$^{b}$ | 1.08$^{a}$ | 28.0$^{a}$ | Slow |
| Cowpea | 40.0$^{b}$ | 10.26$^{a}$ | 1.45$^{a}$ | 0.28$^{b}$ | 0.79$^{b}$ | 24.0$^{a}$ | Slow |
| Control | 36.6$^{ab}$ | 8.01$^{b}$ | 1.47$^{a}$ | 0.22$^{b}$ | 0.77$^{b}$ | 18.0$^{ab}$ | Very slow |
| **8 WAP** | | | | | | | |
| Fruited pumpkin | 38.86$^{b}$ | 13.81$^{b}$ | 1.40$^{a}$ | 0.31$^{a}$ | 0.77$^{a}$ | 26.1$^{b}$ | Slow |
| Sweet potato | 47.31$^{a}$ | 13.67$^{b}$ | 1.38$^{a}$ | 0.38$^{a}$ | 1.13$^{a}$ | 22.5$^{b}$ | Slow |
| Egusi melon | 46.10$^{a}$ | 12.80$^{b}$ | 1.46$^{a}$ | 0.37$^{a}$ | 1.07$^{a}$ | 30.7$^{a}$ | Slow |
| Cowpea | 40.52$^{b}$ | 21.22$^{a}$ | 1.34$^{a}$ | 0.39$^{a}$ | 0.83$^{a}$ | 32.2$^{a}$ | Moderately slow |
| Control | 37.65$^{ab}$ | 8.11$^{ab}$ | 1.47$^{a}$ | 0.21$^{b}$ | 0.71$^{a}$ | 17.8$^{ab}$ | Very slow |
| **12 WAP** | | | | | | | |
| Fruited pumpkin | 39.84$^{b}$ | 24.41$^{b}$ | 1.38$^{a}$ | 0.35$^{a}$ | 0.88$^{b}$ | 24.8$^{b}$ | Moderately rapid |
| Sweet potato | 47.66$^{a}$ | 29.26$^{b}$ | 1.35$^{a}$ | 0.38$^{a}$ | 1.57$^{a}$ | 27.4$^{b}$ | Rapid |
| Egusi melon | 47.39$^{a}$ | 25.18$^{b}$ | 1.40$^{a}$ | 0.39$^{a}$ | 0.98$^{b}$ | 32.0$^{a}$ | Rapid |
| Cowpea | 41.68$^{a}$ | 33.41$^{a}$ | 1.34$^{a}$ | 0.42$^{a}$ | 1.32$^{a}$ | 33.8$^{a}$ | Rapid |
| Control | 35.11$^{b}$ | 7.53$^{ab}$ | 1.49$^{a}$ | 0.21$^{b}$ | 0.64$^{b}$ | 17.5$^{ab}$ | Very slow |

Mean with the same alphabet for each structural properties were not significantly different at $p>0.05$. TP: Total porosity, Ksat: Saturated hydraulic conductivity, BD: Bulk density, WHC: Water holding capacity, MWD: Mean weight diameter, OM: Organic matter

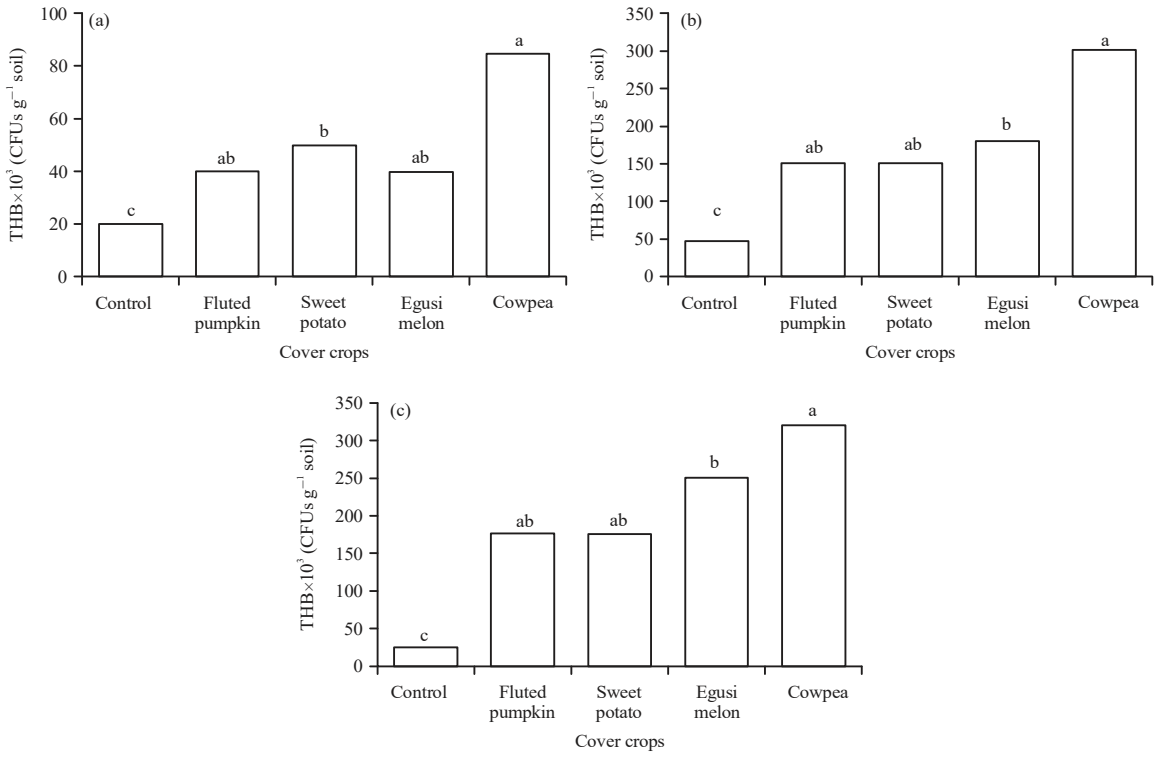


Fig. 1(a-c): Mean total heterotrophic bacteria under different cover crops at (a) 4 WAP, (b) 8 WAP and (c) 12 WAP
Means followed by the same alphabets were not significantly different at p>0.05

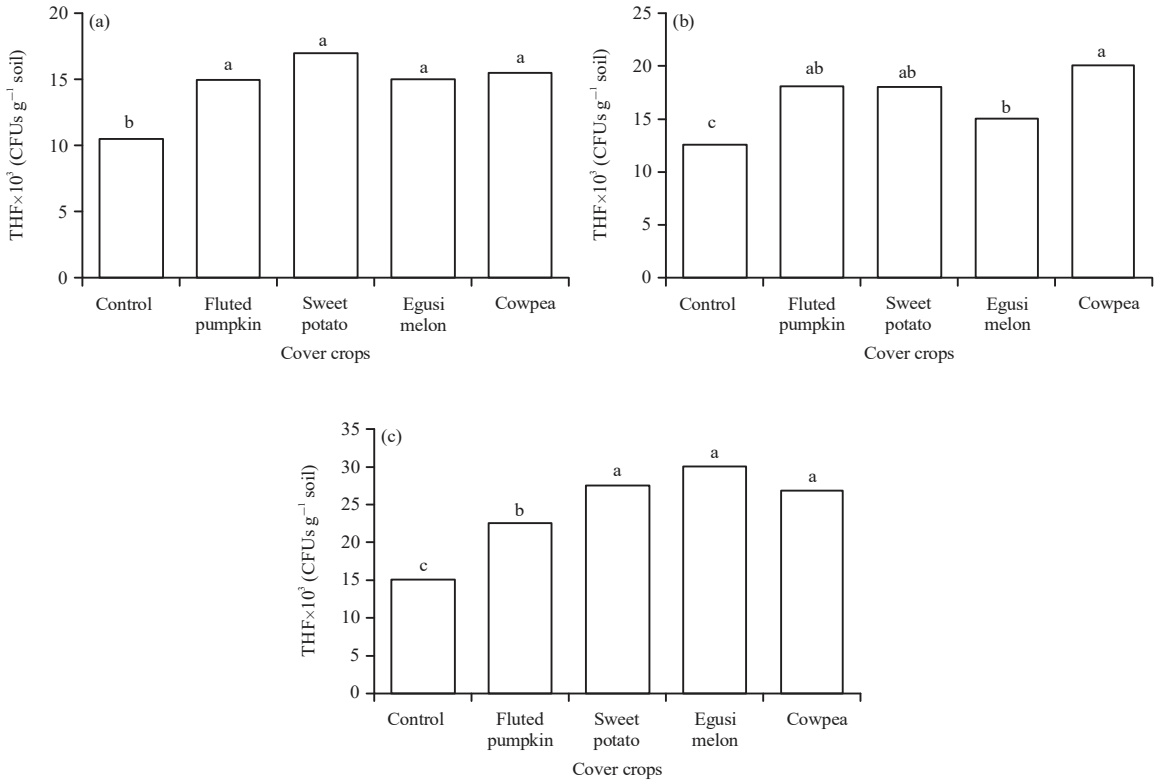


Fig. 2(a-c): Mean total heterotrophic fungi under different cover crops at (a) 4 WAP, (b) 8 WAP and (c) 12 WAP
Means followed by the same alphabets were not significantly different at p>0.05

Table 4: Percentage of occurrence of bacteria isolates under different cover crops at 4, 8 and 12 WAP

| Cover crops | *Bacillus subtillis* | *Staphylococcus aureus* | *Streptococcus pyogenes* | *Pseudomonas putida* | *Aeromonas* spp. | *Micrococcus* spp. | *Actinomyces israelii* |
|---|---|---|---|---|---|---|---|
| **4 WAP** | | | | | | | |
| Fluted pumpkin | 37$^{a}$ | 37$^{b}$ | 7$^{a}$ | 3$^{b}$ | 9$^{ab}$ | 5$^{a}$ | 3$^{b}$ |
| Sweet potato | 24$^{b}$ | 47$^{a}$ | 6$^{a}$ | 9$^{a}$ | 4$^{b}$ | 5$^{a}$ | 4$^{b}$ |
| Egusi melon | 38$^{a}$ | 30$^{ab}$ | 8$^{a}$ | 8$^{a}$ | 4$^{b}$ | 5$^{a}$ | 7$^{b}$ |
| Cowpea | 27$^{b}$ | 15$^{c}$ | 5$^{a}$ | 11$^{a}$ | 16$^{a}$ | 8$^{a}$ | 20$^{a}$ |
| Control | 14$^{ab}$ | 50$^{a}$ | 13$^{a}$ | 4$^{b}$ | 18$^{a}$ | 2$^{b}$ | -- |
| **8 WAP** | | | | | | | |
| Fluted pumpkin | 21$^{a}$ | 20$^{b}$ | 6$^{c}$ | 5$^{b}$ | 8$^{b}$ | 20$^{a}$ | 21$^{a}$ |
| Sweet potato | 22$^{a}$ | 24$^{ab}$ | 10$^{b}$ | 14$^{a}$ | 10$^{b}$ | 12$^{b}$ | 8$^{b}$ |
| Egusi melon | 29$^{a}$ | 18$^{b}$ | 19$^{a}$ | 16$^{a}$ | 6$^{b}$ | 6$^{ab}$ | 6$^{b}$ |
| Cowpea | 26$^{a}$ | 15$^{b}$ | 11$^{b}$ | 9$^{b}$ | 15$^{a}$ | 21$^{a}$ | 2$^{b}$ |
| Control | 27$^{a}$ | 33$^{a}$ | 14$^{b}$ | 16$^{a}$ | 3$^{ab}$ | 4$^{ab}$ | - |
| **12 WAP** | | | | | | | |
| Fluted pumpkin | 23$^{a}$ | 19$^{b}$ | 7$^{b}$ | 6$^{b}$ | 8$^{b}$ | 19$^{a}$ | 20$^{a}$ |
| Sweet potato | 20$^{a}$ | 22$^{b}$ | 10$^{b}$ | 13$^{a}$ | 10$^{a}$ | 11$^{b}$ | 13$^{b}$ |
| Egusi melon | 23$^{a}$ | 15$^{b}$ | 16$^{a}$ | 14$^{a}$ | 5$^{b}$ | 7$^{ab}$ | 20$^{a}$ |
| Cowpea | 22$^{a}$ | 13$^{b}$ | 10$^{b}$ | 8$^{b}$ | 11$^{a}$ | 17$^{a}$ | 17$^{a}$ |
| Control | 28$^{a}$ | 32$^{a}$ | 15$^{a}$ | 16$^{a}$ | 5$^{b}$ | 4$^{c}$ | - |

Means with the same alphabet for each bacterial isolates were not significantly different at p>0.05

Table 5: Percentage of occurrence of fungi isolates under different cover crops at 4, 8 and 12 WAP

| Cover crops | *Rhizopus flavus* | *Aspergillus niger* | *Fusarium oxysporium* | *Candida tropicalis* (yeast) |
|---|---|---|---|---|
| **4 WAP** | | | | |
| Fluted pumpkin | 24$^{b}$ | 27$^{b}$ | 16$^{b}$ | 33$^{a}$ |
| Sweet potato | 37$^{a}$ | 19$^{b}$ | 35$^{a}$ | 10$^{b}$ |
| Egusi melon | 30$^{a}$ | 23$^{b}$ | 17$^{b}$ | 28$^{a}$ |
| Cowpea | 35$^{a}$ | 28$^{b}$ | 11$^{b}$ | 26$^{a}$ |
| Control | 22$^{b}$ | 41$^{a}$ | 13$^{b}$ | 25$^{a}$ |
| **8 WAP** | | | | |
| Fluted pumpkin | 33$^{a}$ | 36$^{a}$ | 20$^{b}$ | 11$^{b}$ |
| Sweet potato | 37$^{a}$ | 28$^{b}$ | 28$^{a}$ | 7$^{b}$ |
| Egusi melon | 30$^{a}$ | 20$^{b}$ | 24$^{a}$ | 26$^{a}$ |
| Cowpea | 33$^{a}$ | 25$^{b}$ | 13$^{b}$ | 28$^{a}$ |
| Control | 24$^{b}$ | 38$^{a}$ | 14$^{b}$ | 24$^{a}$ |
| **12 WAP** | | | | |
| Fluted pumpkin | 31$^{a}$ | 33$^{a}$ | 22$^{b}$ | 15$^{b}$ |
| Sweet potato | 29$^{a}$ | 24$^{b}$ | 27$^{a}$ | 20$^{b}$ |
| Egusi melon | 23$^{a}$ | 20$^{b}$ | 20$^{b}$ | 37$^{a}$ |
| Cowpea | 31$^{a}$ | 22$^{b}$ | 19$^{b}$ | 28$^{ab}$ |
| Control | 25$^{a}$ | 37$^{a}$ | 16$^{b}$ | 23$^{ab}$ |

Means with the same alphabet for each bacterial isolates were not significantly different at p>0.05

Table 6: Mean percentage of ground coverage and leaf area index of the cover crops at 4, 8 and 12 WAP

| | Ground coverage (%) | | | Leaf area index | | |
|---|---|---|---|---|---|---|
| Cover crops | 4 WAP | 8 WAP | 12 WAP | 4 WAP | 8 WAP | 12 WAP |
| Fluted pumpkin | 42.45$^{b}$ | 74.61$^{b}$ | 74.20$^{b}$ | 0.36$^{ab}$ | 0.61$^{ab}$ | 0.82$^{ab}$ |
| Sweet potato | 19.57$^{ab}$ | 51.43$^{c}$ | 69.67$^{ab}$ | 3.76$^{a}$ | 9.14$^{a}$ | 9.08$^{a}$ |
| Egusi melon | 45.78$^{b}$ | 65.32$^{ab}$ | 80.00$^{c}$ | 1.20$^{b}$ | 7.80$^{b}$ | 6.00$^{b}$ |
| Cowpea | 90.20$^{a}$ | 96.00$^{a}$ | 95.70$^{a}$ | 0.43$^{ab}$ | 8.80$^{b}$ | 9.40$^{a}$ |

Means followed by the same alphabets within row and column for the same growth parameter were not significantly different at p>0.05

at 12 WAP. Earthworm activities measured by the number of casts were enhanced by the cover crops (Fig. 3) The highest number of earthworm casts of 35 was found in cowpea soils at 12 WAP followed by 28 for fluted pumpkin at 8 WAP. Cowpea and egusi melon increase percent ground cover at 12 WAP (Table 6). Cowpea attained LAI of 9.4 and corresponding 95.6% ground coverage at 12 WAP.

## DISCUSSION

The soil textural class was not altered by the cover crops because soil texture cannot be changed by mere anthropogenic activities such as cultivation but usually influenced by the parent material[22]. Improvements in the soil bulk density and water holding capacity due to the cover

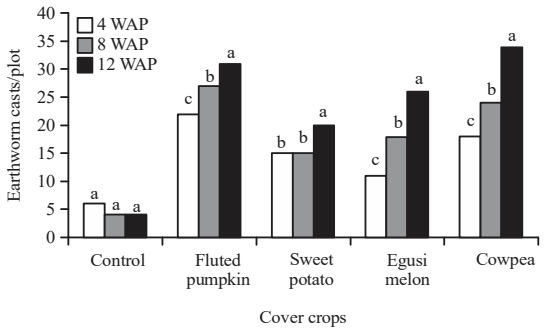


Fig. 3: Mean population of earthworm casts under different cover crops at 4, 8 and 12 WAP
Means followed by the same alphabet within column were not significantly different at p>0.05

crops was consistence with earlier findings[23], who reported significant improvements in soil physical properties such as bulk density and total porosity due to cover crops. Since in filtration rate of soil is usually related to the total porosity[24], the soil structure was improved by the cover crops through increase in mean weight diameter of water stable aggregates in Table 3.

High microbial population encouraged by the covers crop led to improvement in the soil structure through creation of macro-aggregates from micro-aggregates which acted as the building blocks of soil structure[23]. A good soil structure increased water infiltration and water holding capacity of soils[25]. Similar studies also adduced improved soil structure to the vast root network usually associated with cover crops which helped to anchor the soil in place, creating suitable habitat networks for soil macro fauna[26].

The high population of bacteria supported by the cowpea throughout the experiment could be attributable to its unique physiology[27]. The higher microbial populations obtained during the flowering period (8 WAP) further confirmed that microbial activities increased during flowering period and decreased at crop maturity stage[28,29]. They also found that the highest variations in micro-organisms occurred in younger plants than in older ones. Microbial diversity is an excellent indication of soil health[30]. Bacteria such as *Micrococcus* spp. and *Aeromanas* spp. were plant dependent because they were isolated in the soil after planting the cover crops[30]. Fungi species were generally fewer because these cover crops favoured the population and diversity of bacteria than the fungi.

Earthworms and their casts have been used as index of soil fertility and productivity and influenced certain soil ecological processes within their functional domain[31]. They tend to concentrate nutrients and resources that are further exploited by soil micro-organism communities[31]. Earthworm activities were higher due to the presence of the cover crops, which also led to higher biogenic deposits under the cover crop plots compared with the control. The highest number of casts found under the cowpea could be due to the high ground coverage of cowpea when compared to other cover crops.

## CONCLUSION

Conclusions drawn from this study are that: Cultivation of cowpea, sweet potato, fluted pumpkin and egusi melon improved aggregate stability, porosity and saturated hydraulic conductivity and induced proliferation of soil micro-organisms. Cowpea, sweet potato and fluted pumpkin stimulated maximum biological activities in the soil. Cowpea and egusi melon increased ground coverage that in turn increased the soil water holding capacity and earthworm casts. Therefore, introduction of these well-known cultivated cover crops that many researchers were not able to explore in farming systems would help improve soil structure and other ecological functions. They are needed for the maintenance of stable soil structure to prevent degradation of soil resources.

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