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Full Length Research

Effect of Tree Canopies and Leaf Litter on the Chemical Properties of Earthworm Casts of Umudike Soils

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The effects of tree canopies and leaf litter on the chemical properties of earthworm casts were studied at Umudike, Nigeria. These studies were carried out under some multipurpose tree canopies such as cacao (*Theobroma cacao* L.), breadfruit *(Treculia Africana* Decne *)*, avocado pear *(Persea Americana* Mill*)* and mango *(Mangifera indica* L.*)* and were compared with the casts of their open adjacent sites which were 10m away. Generally, casts under tree canopies had significantly (P<0.05) higher values of pH, organic carbon, organic matter, total N, exchangeable Ca, exchangeable K, exchangeable Na, effective cation exchange capacity (ECEC) and available phosphorus than the casts of their adjacent open sites. However, casts under cacao tree canopy had higher values of nutrient elements than those of mango, breadfruit and avocado pear, while casts outside tree canopies gave significantly (P<0.05) the least mean values. This study has shown that the integration of trees such as cacao on farms can help increase earthworm casts as well as the nutrient elements of the soils.

Keywords : Effect, tree canopies, leaf litter, chemical properties, earthworm cast.

INTRODUCTION

Earthworms are important biological resources that have great potential in agro-system because they significantly affect soil physical structure, nutrient cycling and promote plant growth (Choosai et al., 2010). However, earthworm is generally regarded as soil builder due to its effects on soil properties which include the creation of cast-aggregates that are usually enriched in organic matter. Earthworms contribute to cycling and accumulation of nutrients by casting at the surface more than their surrounding soils. Asawalam and Hauser (2001) noted that earthworm casts can influence positively the growth of plants in the tropics, most likely due to high concentration of plant available nutrients in the casts than those of their surrounding soils. Therefore, high surface casting activity of earthworm is desirable in low input agricultural systems to concentrate nutrients at the soil surface (Chaudhuri et al. 2008). Earthworm casts consist of mixed inorganic and organic materials from the soils that are voided after passing through the intestine. Surface casting is an essential function within earthworm communities that maintain their living. Also, earthworms enrich the cast indicating the increasing importance of earthworm surface casting which improves the decreasing soil fertility of the tropical soils (Ojimgba and Onyejiji, 2018; Hong et al., 2011). Thus, a high surface casting activity of earthworms is desirable in low input agricultural systems to concentrate nutrients at the soil surface. Among the soil microfauna, earthworms have been described as a keystone species as their activity helps to regulate soil fertility, water infiltration and soil detachability in agro-ecosystems (Ojimgba and Onyejiji, 2018; Hong et al., 2011). Basically, there are three types of earthworm casts: Spheroidal or sub-spheroidal pellets ranging from 1 to 20mm in diameter; paste-like slurries which form composite irregular shapes; tall heaps or columns with a range of shape (Ojimgba and Onyejiji, 2018).

Leaf litter is an important component of healthy soil. Decomposing leaf litter releases nutrient into the soil and also keeps it moist (Ojimgba and Nwaigbo, 2013). According to the authors, this decomposing leaf litter serves as great nesting material, hiding places and protected spots for animals, and therefore, provides the perfect habitat for a plethora of organisms including earthworm. The effects of litter may be modified by activities of ecosystem engineers such as earthworms. Dominant species of earthworms such as Lumbricus terrestris (Anecic) and Allolobophora chlorotica (Endogeic) control many community and ecosystem processes (Wardle, 2002). In a forest, leaf litter inputs to the forest floor serve as an important mechanism by which trees regulate ecosystem functions including nutrient and energy cycling, tree regeneration and the maintenance of biological diversity (Gillian and Roberts, 2003; Sayer, 2006; Belote and Jones, 2009). This bulk of organic matter nutrients that are added to the soil are located in the topsoil. From 18 locations of different closed natural forest types around the tropics, Lundgreen (1978) noted that average of 8.9 tonnes ha^{-1} yr^{-1} of litter dry matter added to the soil the following nutrients: 134kgha^{-1} N yr^{-1}, 7kgha^{-1} P yr^{-1}, 53kgha^{-1} yr^{-1}, 11kgCa ha^{-1} yr^{-1}, and 32kgMg ha^{-1} $yr^{-1.}$ Potassium, calcium, and magnesium, on the other hand, are concentrated in the biomass, except in high base status soils (Chijioke, 1980). That is why forest clearing leads to a considerable loss of nutrients-those in the biomass being “exported” from the system, and those in the soil being lost by leaching and runoff.

Earthworms are also responsible for mixing soil layers and incorporating organic matter into the soil (Ojimgba and Onyejiji, 2018). Charles Darwin referred to earthworms as ‘nature’s ploughs’ because of this mixing of the soil and organic matter (Hong et al., 2011). This mixing improves the fertility of the soil by allowing the organic matter to be dispersed through the soil and the nutrients held in it to become available to bacteria fungi and plants. *(Earthworm society of Britain)*. Despite the nutritional values of these trees in Nigeria, there is little information on their influence on the chemical properties of earthworm casts. Therefore, this study was to examine the effect of the tree canopies and their leaf litter on the chemical properties of earthworm casts under the trees and compare the values with those of their adjacent open sites.

MATERIALS AND METHODS

Study Area

The study was carried out in Umudike (5^0 25^1N 7^0 35^1E and 122 meters above sea level) which lies 8km South of Umuahia located in the rainforest ecological zone of southern Nigeria. The trees used for this study were located in Abia State University Research Farm. They were used to investigate the effect of tree canopies and leaf litter on the chemical properties of earthworm casts. The mean annual maximum temperature of the study site ranges from 30°C to 33°C and mean annual minimum, temperature ranges from 21°C to 29°C. The rainfall distribution pattern of the area is bimodal with a total annual mean of 1830 mm in the northern parts to 2188 mm in the Delta region (Odurukwe et al. 1995).

The soil is classified as Ultisol according to USDA and as an Acrisol according to FAO/UNESCO classification schemes, as summarized by Opara-Nadi (2000). The soil is characterized by inherent constraints such as low organic matter, poor structural stability, low nutrient, and water holding capacities, low clay activities and high susceptibility to soil erosion and drought stress (Opara-Nadi, 2000; Salau et al. 1992).

The vegetation of the study area is typical of tropical rainforest vegetation. The secondary bush which dominates the area is the remnant of the tropical rainforests which are fast disappearing in the area. Some of the forest species found in the area especially in the alley crops portion include:

Dactyladenia barteri, Mangifera indica,Pentaclethra macrophylla, Gliricidia sepium, Irvingia gabonensis and *Treculia africana.* Grasses and broadleaf weeds that dominate the entire area include: *Panicum maximum, Pennisetum purpereum, Cyperus spp* and *Axonopus compressus.* The broadleaf weeds are *Chromolaena odorata .Centrosema pubescens, Calopogonium mucunoides. Mucuna spp,* and *Aspillia africana*.

Cast Sample and Analysis

Casts samples were collected from under trees : Under Cacao Tree (UCT), Under Mango Tree (UMT), Under Breadfruit Tree (UBT), Under Avocado pear Tree (UAT) and their adjacent sites : Outside Cacao Tree (OCT), Outside Mango Tree (OMT), Outside Breadfruit Tree (OBT) and Outside Avocado pear Tree (OAT) 10 meters away from the canopy. The collected casts from under the selected tree canopies and their adjacent soils from different locations were used to determine the pH, organic carbon, total nitrogen, exchangeable bases (Ca, Mg, K, and Na), effective cation exchange capacity (ECEC), exchangeable acidity, organic matter, and available phosphorus.

Soil Reaction (pH)

Soil pH was determined in O.1 N potassium chloride (KCl) solution using a soil : liquid ratio of 1:2.5. 20g of soil sample was weighed into plastic beakers, distilled water of KCl was added and stirred for 30 minutes, then the pH values were read off using a glass electrode pH meter (McLean. 1982).

Organic Carbon (OC)

This was determined by the Walkley and Black method in which the soil organic matter was oxidized using 1N $K_2Cr_2O_7$ solution and concentrated H_2SO_4, and the percentage organic carbon found by titrating with IN ferrous ammonium sulphate solution ($Fe(NH_4)_2(SO_4)_2.6H_2O$) (Nelson and Sommers, 1982).

Organic Matter (OM)

The organic matter content was determined by multiplying the percentage organic carbon by the conventional "Van Bemmelen factor" of 1.724. The use of this factor is based on the assumption that soil organic matter contains 58% carbon.

Total Nitrogen (N)

This was determined by the micro-Kjeldahl method using $CuSO_4/Na_2SO_4$ catalyst mixture. The ammonia (NH_3) from the digestion was distilled with 45% NaOH into 2.5% boric acid and determined by titrating with 0.05N HCl.

Exchangeable Bases

Calcium (Ca) and magnesium (Mg) were determined by the complexometric titration method, while Sodium (Na) and potassium (K) were determined from 1N ammonium acetate (NH_4 OAc) using the auto electric flame photometer.

Exchangeable Acidity (EA)

Exchangeable acidity (H^+ and Al^{3+}) was determined using the titrimetric method. The Effective Cation Exchange Capacity (ECEC) was determined by calculation. (ECEC = ∑ bases + KCl – extractable (Al + H) values).

Available Phosphorus

Available phosphorus was determined by the extractant method – Bray's Method 11 (0.03N ammonium fluoride x 0.1N HCl). The ppm phosphorus was determined using a photo-electric calorimeter (Page et al. 1982).

Casts Chemical Analysis

All casts chemical analysis was carried out at the Soil Science Laboratory of National Root Crops Research Institute, Umudike, between June and July 2017. The cast samples were transported with an inert plastic container to the laboratory.

Data Analysis

The data that were obtained from the study were subjected to statistical analysis of variance (ANOVA) using the technique of Steel and Torrie, (1980). Each tree was replicated three times in a Randomized Complete Block Design (RCBD). The comparison of the mean values that were obtained was also compared using F-LSD at 5% probability level.

Table 1. Effect of Tree Canopies and Leaf Litter on the pH, Organic Carbon, Organic Matter, Exchangeable Acidity and Effective Cation Exchange Capacity of Earthworm Casts.

			Attribute		
		OC	OM	EA	ECEC
Tree Canopy	**pH (KCl)**	---------------------- % ---------		------ Cmol(+)kg^{-1} ---	
Under Mango tree (UMT)	**5.85^{b}**	**6.05^{bc}**	**10.43^{b}**	**0.63^{b}**	**10.77^{c}**
Outside Mango tree (OMT)	**4.40^{a}**	**2.20^{a}**	**5.52^{a}**	**1.83^{cd}**	**7.37^{a}**
Under Cacao tree (UCT)	**6.35^{c}**	**8.65^{d}**	**14.90^{c}**	**0.57^{a}**	**12.25^{d}**
Outside Cacao tree (OCT)	**4.50^{a}**	**2.35^{a}**	**4.05^{a}**	**1.78^{c}**	**8.67^{b}**
Under Breadfruit tree (UBT)	**5.75^{b}**	**6.90^{c}**	**11.88^{b}**	**0.60^{b}**	**10.87^{c}**
Outside Breadfruit tree (OBT)	**4.20^{a}**	**2.55^{a}**	**4.39^{a}**	**1.84^{d}**	**7.79^{ab}**
Under Avocado Pear tree (UAT)	**5.60^{b}**	**5.70^{b}**	**14.90^{c}**	**0.64^{b}**	**10.61^{c}**
Outside Avocado Pear tree (OAT)	**4.35^{a}**	**2.40^{a}**	**9.82^{b}**	**1.80^{cd}**	**7.21^{a}**
F-LSD$_{0.05}$	**0.39**	**0.39**	**2.85**	**0.06**	**1.03**

Means in the same column with different superscript are significantly different at P<0.05; OC= Organic carbon, OM= Organic matter, EA= Exchangeable acidity, ECEC= Effective cation exchange capacity.

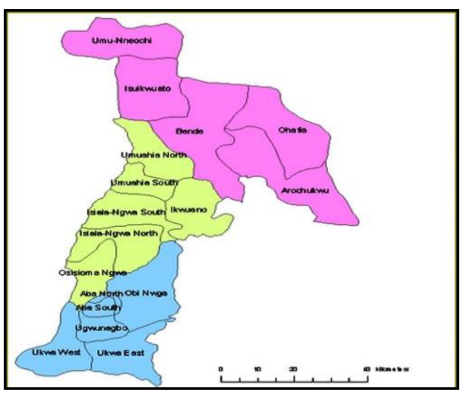

Figure 1. **Map of Abia State** showing Umudike the Project Site [Abia State University, Umuahia Campus, Nigeria] (Ojimgba and Mgbeahuru, 2018).

RESULTS

Effects of Tree Canopies and Leaf Litter on the Chemical Properties of Earthworm Casts

Generally, the results obtained in Table 1 and Figures 1, 2, 3, 4, 5, 6 and 7 shows there were significant changes in the chemical properties of the earthworm casts. The earthworm casts under tree canopies gave significantly (P<0.05) higher values of the chemical properties than the adjacent open sites. This could be attributed to the incorporation of the leaf litters into the soil which was being ingested by the earthworms as food and excreted in the form of feces.

pH, Organic Carbon, Organic Matter and Exchangeable Acidity of Earthworm Casts

Results presented in Table 1 showed significant differences (P<0.05) existing between the pH, organic carbon (OC), organic matter (OM) and exchangeable acidity (EA) as well as effective cation exchange capacity (ECEC) mean values of the earthworm casts under tree canopies and their adjacent sites. For example, the pH of the casts under canopies gave significantly higher values than those of the corresponding adjacent open sites. The values ranged between 4.20 and 6.35 for OBT and UCT, respectively. The relative improvement was in the following significant order: UCT>UMT=UBT=UAT>OCT=OMT=OAT=OBT. The treatments with equal signs gave statistically same values of pH. Therefore, the casts raised the pH value from 4.50 for outside cacao tree (OCT) to 6.35 for under cacao tree (UCT).

Similarly, the organic matter and organic carbon values of the earthworm casts followed the trend.

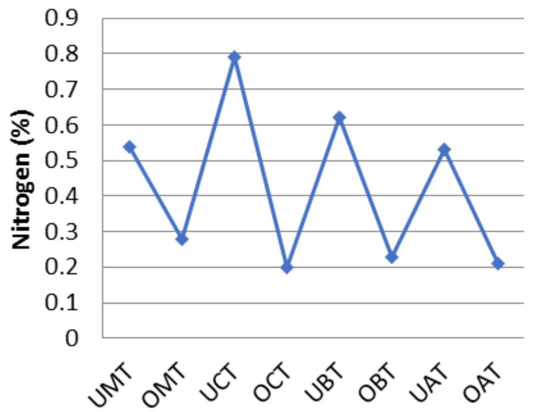

Figure 2. Percentage nitrogen content of Earthworm cast under and outside tree canopies.

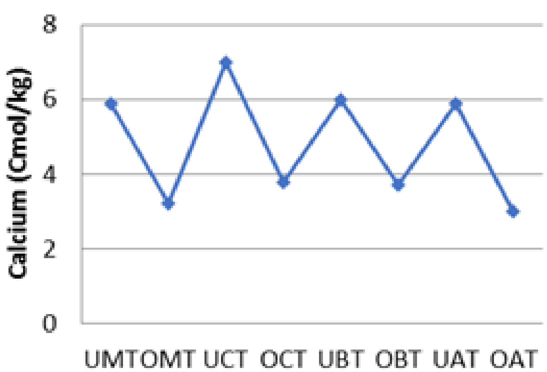

Figure 3. Calcium (Cmol/Kg) content of Earthworm cast under and outside tree canopies.

However, earthworm casts under the multipurpose tree canopies gave significantly ($P<0.05$) higher organic matter and organic carbon values than those of their adjacent open sites. The range improvement of organic matter due to casts is between 14.90 and 4.05% for under cacao tree (UCT) and the adjacent site (OCT), respectively. Organic carbon followed the same trend. This is confirmed by Jouquet et al. (2010). The statistically similar organic matter values of under-cacao (14.9%) and avocado pear (14.9%) trees gave higher values than those of mango (10.4%) and breadfruit (11.9%). Therefore, the activities of these earthworms with the leaf litter of these trees contributed to the reduction in the values of exchangeable acidity of these casts from 1.84 (OBT) to 0.57 (UCT).

Effect of Tree Canopies and Leaf Litter on the Total N, Ca, Mg, K, Na and Available Phosphorus of Earthworm Casts (under a tree and outside canopy)

Total Nitrogen

Figure 2 summarizes the effects of tree canopies and leaf litter on the total nitrogen of earthworm casts under the tree and its adjacent open site. The values of total N obtained during the study were significantly ($P<0.05$) higher under the tree canopies than the adjacent sites. The results of total nitrogen recorded in casts under cacao tree (UCT) (0.79%) were statistically higher than the values of nitrogen obtained in other trees, UBT (0.62%), UMT (0.54%) and UAT (0.53%). The least nitrogen value was obtained in soils outside Avocado tree, OAT (0.21%).

Exchangeable Calcium

Also the results obtained in Figure 3 summarize the effects of tree canopies and leaf litter on the exchangeable calcium of earthworm casts under tree and its adjacent open site. The values of exchangeable Ca obtained during the study were significantly ($P<0.05$) higher under tree canopies than the adjacent sites. The results also show that casts under cacao tree (UCT) (7.00 $CmolKg^{-1}$) gave significantly higher calcium values than casts under other trees, UBT (6.00 $CmolKg^{-1}$), UMT (5.90 $CmolKg^{-1}$), UAT (5.90 $CmolKg^{-1}$) and their adjacent sites.

Exchangeable Magnesium

The values of exchangeable Magnesium obtained were significantly ($P<0.05$) higher under the tree canopies than the results in their adjacent open sites (Figure 4). However, casts under cacao tree (0.33 $CmolKg^{-1}$) had significantly higher magnesium content than the statistically similar results of UMT (0.26 $CmolKg^{-1}$), UBT (0.25 $CmolKg^{-1}$) and UAT (0.23 $CmolKg^{-1}$). The least magnesium values were obtained in the adjacent open sites.

Exchangeable Potassium

In addition, the values of the exchangeable Potassium obtained under tree canopies in Figure 5 were significantly ($P<0.05$) higher than those of their

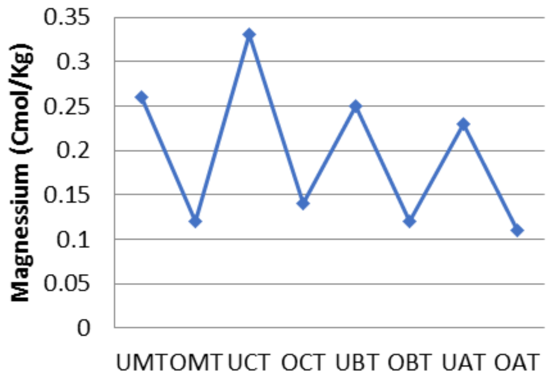

Figure 4. Magnessium (Cmol/Kg) content of Earthworm cast under and outside tree canopies.

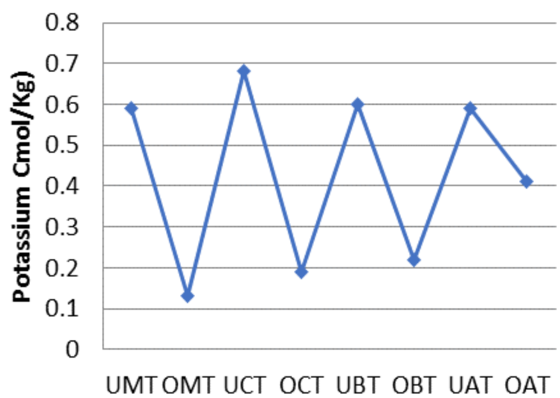

Figure 5. Potassium (Cmol/Kg) content of Earthworm cast under and outside tree canopies.

adjacent sites. Also, the statistically similar Potassium values of UCT(0.68 Cmol/Kg), UBT(0.60 $CmolKg^{-1}$), UMT(0.59 $CmolKg^{-1}$), and UCT(0.59 $CmolKg^{-1}$) were significantly higher than their adjacent open sites, OAT(0.44 $CmolKg^{-1}$), OBT(0.22 $CmolKg^{-1}$), OCT(0.19 $CmolKg^{-1}$) and OMT(0.13 $CmolKg^{-1}$).

Exchangeable Sodium

Figure 6 summarizes the effect of tree canopies and leaf litter on the exchangeable Na of earthworm casts under tree canopies and their adjacent open sites. The results obtained show that casts under tree canopies had significantly (P<0.05) higher sodium than their adjacent sites in the following order: UCT>UBT>UMT = UAT>OBT=OCT=OMT=OAT. However, casts under cacao tree (0.29 $CmolKg^{-1}$) gave significantly higher sodium values than those of UBT (0.24 $CmolKg^{-1}$), UMT (0.22 $CmolKg^{-1}$) as well as UAT (0.21 $CmolKg^{-1}$). Their adjacent open sites with statistically similar sodium values were the least.

Available Phosphorus

Also, in Figure 7, the values of available Phosphorus obtained were significantly (P<0.05) higher under tree canopies than their adjacent sites in the following order: UCT>UAT>UMT=UBT>OBT=OCT=OMT=OAT. The results of earthworm casts under tree canopies and their adjacent open sites followed a similar trend with that of sodium. However, the Phosphorus results obtained in UCT (48.15 $MgKg^{-1}$) were statistically higher than those in UAT (44.80 $MgKg^{-1}$), UMT (43.40 $MgKg^{-1}$) and UBT (43.20 $MgKg^{-1}$) as well as their adjacent open sites.

DISCUSSION

However, the leaf litter and the earthworms tremendously improved the pH, organic carbon, organic matter and the exchangeable acidity of the casts. Ojimgba and Onyejiji (2018) stated that earthworms play a major role in overall soil fertility and in many other ecosystem processes such as nutrient cycling and carbon storage. The very acidic nature of the adjacent bare soils according to Ojimgba and Mbagwu (2007) is as a result of a problem of exposure of very acidic subsoil due to erosion. They attributed these low values partly because the soils are heavily leached of the basic cations due to very heavy rainfall associated with the rainforest zone. The highest values of nitrogen (N), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), and phosphorus (P) obtained in casts under cacao tree (UCT) more than those of other trees and their adjacent sites were similar to the results obtained by Ojimgba and Onyejiji (2018) which showed that the number of earthworm casts under cacao canopy was significantly (P < 0.05) higher than those of breadfruit, avocado and mango in the following significant order: Cacao > Breadfruit > Avocado > Mango. However, the mango had the least number of earthworm casts number. The

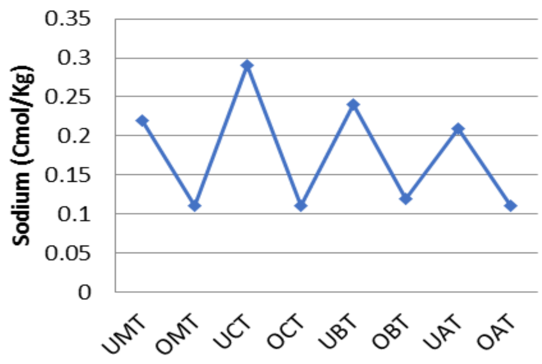

Figure 6. Sodium (Cmol/Kg) content of Earthworm cast under and outside tree canopies.

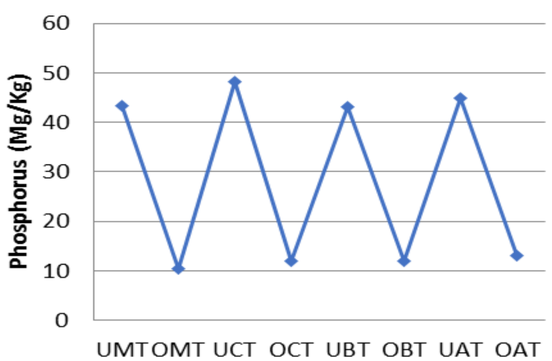

Figure 7. Phosphorus (Cmol/Kg) content of Earthworm cast under and outside tree canopies.

Earthworm

highest values of these plant nutrients observed in casts under cacao canopy may be due to the highest number of casts produced under that tree. Similarly, Barley (1961) opined that analysis of earthworm castings reveals that they are richer in plant nutrients than the surrounding soils, about three times more calcium and several times more N, P and K. Also, significant increase in available phosphorous in the casts under the trees canopies agrees with the findings of Chaudhuri et al. (2008) under rubber plantation.

CONCLUSION

This study had basic information on the effect of tree canopies and leaf litter on the chemical properties of earthworm casts under cacao, breadfruit, avocado pear, and mango canopies and their adjacent open sites in Umudike, Nigeria. The study has shown that the values of nutrient elements in earthworm casts under tree canopies were higher than those of their adjacent sites. Also, it was observed from the results of this study that casts under cacao canopy gave higher chemical properties than the rest of the trees. The results, therefore, pointed to the fact that tree canopies and their leaf litter improve the chemical properties of earthworm casts better than the casts in adjacent open site. The reason is because earthworm casts can effectively improve plant growth in the tropics most likely due to a higher concentration on plant available nutrients in them than their surrounding soils. This could also be attributed to the incorporation of the leaf litters into the soil which was being ingested by the earthworms as food and excreted in the form of feces.

RECOMMENDATIONS

i. The high nutrient of the tree canopies through their leaf litter can be utilized for arable crop production using the leaf litter either in situ or ex situ as organic manures.

ii. The authors, therefore, recommend that farmers should plant some of these multipurpose trees especially cacao along the contour bunds or boundaries as alley, prune them periodically or allow the leaves to fall and decay to improve the soil chemical properties through the actions of earthworms.

iii. I also encourage the conservation of earthworms and other organisms that enhance

Earthworms castings

decomposition.

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