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Gut Microflora and Microfauna of Earthworm Species in the Soils of the Research Farms of the University of Agriculture, Abeokuta, Nigeria

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ABSTRACT

The present study investigated the microbial biomass (microflora and fauna) present in soil samples, gut sections and casts of earthworms collected from research farm areas on the campus of the University of Agriculture, Abeokuta. *Keffia proxipora*, *Libyodrilus violacaeus* and *Hippoporeria nigerea* were the earthworm species identified from the soil samples. Isolated microflora included bacteria, yeasts and moulds while microfauna identified were protozoa and nematodes. For all samples of soil, casts and earthworms, the differences observed in counts of microflora and microfauna were significant at a level of $p < 0.05$. Casts stored for 2 weeks had higher pH and bacterial counts than those obtained from fresh castings. However, the pH values and nitrogen contents of both the fresh and stored casts were significantly higher than those for un-ingested soil samples. Among the earthworms identified, *Libyodrilus violacaeus* recorded the highest values of microflora and microfauna counts, significantly higher than values obtained for the other earthworm species. The hind gut of *Libyodrilus violacaeus* also had the highest bacterial, protozoal and yeast counts as well as total viable counts of microflora. Both micro-flora and fauna were found to increase in numbers during gut passage in all worms collected except for nematodes which were observed to reduce significantly in numbers during gut passage, with total disappearance in the mid and hind gut sections of some earthworm species.

INTRODUCTION

Earthworms occupy a special place in the hierarchy of soil inhabitants having an almost universal distribution and occurring in large numbers (Edwards &

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Bohlen, 1996). They are prehistoric in origin, being part of the fundamental natural organic recycling and pathogen reduction systems of the soil. They are involved in one of the most critical jobs in the ecosystem. They recycle or reuse the basic materials that plants and animals need to survive. By eating waste materials from the soil, earthworms and other macrofauna such as termites, ants, Coleoptera, Myriapoda, Arachnida, and Dermaptera help to decompose the materials into smaller, simpler parts that can be re-used by other organisms (Mulongoy & Bedoret, 1989; Ouedraogo *et al.* 2004). Without this process of decomposition, the basic chemicals of life would stay locked up and unavailable for use by other organisms (Tinov & Scheu, 2000). It is increasingly recognized that soil fauna have a significant role in soil processes affecting nutrient availability and crop performance (Ouedraogo *et al.* 2006). Savin & Jose (2000) found that inorganic nitrogen levels were significantly higher in earthworm burrows relative to bulk soil. Worm Facts (2001) also noted that earthworms use organic matter as a source of nutrition but depend on micro-organisms such as bacteria, yeast and fungi for nutrients, which are extracted from the large quantities of micro-organisms ingested with materials as they pass through the worms' gut. Their casts are therefore commonly rich in plant nutrients. Edwards & Lofty (1972) had earlier stated that earthworms derive their nutrition from organic matter in the form of plant materials, living protozoa, rotifers, nematodes, bacteria, fungi and other micro-organisms, and decomposing remains of these large and small animals; most of these are extracted from the large quantities of soil that pass through the earthworm gut.

The earthworm gut is a natural bioreactor, which increases the beneficial microbial density in the material it excretes to 1000 times that of the surrounding soil (Savin *et al.*, 2004). Results of earlier studies have demonstrated that the feeding habits of earthworms allow for the ingestion of various kinds of organic matter, including dead plant materials and soil micro-organisms (bacteria, yeasts, protozoa). There is, however, a high degree of preferential feeding among earthworm species (Judas, 1992). This feeding habit has profound impact on the soil ecosystem functioning by affecting the availability of organic detritus that serves as food for soil microorganisms (Savin & Jose, 2000). Earlier work by the authors showed that *Libyodrilus violacaeus* occurs commonly in association with other earthworm species such as *Keffia proxipora*, *Millsonia nigra* and *Hippoporera nigereae* in soils collected from various areas within the campus of the University of Agriculture, Abeokuta (UNAAB), Nigeria (Idowu *et al.*, 2003). *Libyodrilus violacaeus* has also been found to be very rich in bacterial and fungal flora (Idowu *et al.*, 2003). The objectives of the present study were to examine in comparison the distribution of microflora and microfauna in the gut of earthworm species, soil, fresh and stored earthworm casts from the research farm area of the University of Agriculture, Abeokuta with a view to establish a proper database necessary for

building an ideal framework for the use of earthworms in organic agriculture in the University.

MATERIALS AND METHODS

Experimental site and sampling

The study was conducted at the University of Agriculture, Abeokuta, Nigeria (7° 10' N, 3° 2' W) at an elevation of about 500 m above sea level. Samples were collected from cultivated land (mostly with cassava) of the University research farm (soil texture – loamy to sandy loam). Soil sampling and specimen collection were done between November 2003 and June 2004. Soil and cast samples were collected from open fields. The soil samples were taken from up to 15 cm depth. Fresh casts lying on the soil surfaces were collected as cast samples. Soil and cast samples were collected in sterile polythene bags which were sealed before being placed in ice buckets. Earthworm specimens were also collected from the sampling locations by the wet sieving and handpicking method described by Senapati & Dash (1981) in sterile bottles with wire mesh covers. All samples were collected in triplicate, with three different samples collected randomly within a plot, from the research locations using sterilized soil diggers. Samples were collected early in the morning and taken immediately to the laboratory for analysis.

Description of Earthworms

Libyodrilus violacaeus (Beddard, 1894) (Indigenous species)

It has a length of 90–145 mm and a width of 3–5 mm. The prostomium is prolobous. It has an unpaired spermatheca located mid-ventral on the 13th segment. The female pores are small, oval opening on segment 15 while the male pore is situated on segment 17. The clitellum is prominent, saddle-shaped occupying segments 14–17.

Keffia proxipora (Segun & Owa, 1990) (Exotic species)

It has a length of 120–204 mm and a width of 2.4–3.5 mm. The prostomium is prolobous. The spermathecal pores are very closely paired located mid-ventral on the 19th segment. The female pores are paired; inconspicuous on the furrow of the 13/14 segments while the male pores are closely paired on the 17/18 intersegmental furrow. The clitellum is annular on segments 14–17.

Hipporera nigereae (Taylor, 1949) (Exotic species)

It has a length of 97–116 mm and a width of 1.7–3.2 mm. The prostomium is probolous. The spermathecal and female pores are combined on 13/14 furrow. The male pores are closely paired on the 17/18 intersegmental furrow. The clitellum is saddle-shaped on segments 13–18.

Dissection of earthworms

Each specimen to be dissected was washed in sterile distilled water, placed across the second, third and fourth fingers of the left hand (gloved) with the anterior end pointing forward (Segun & Owa 1990). The fine edge of a flamed pair of dissecting scissors was inserted into the ventral surface at the region of the clitella and with the body wall slightly raised up with the scissors; an incision was made longitudinally along the earthworm. Sterile dissecting pins were used to hold the earthworm down on a board, stretching out the body wall to expose the internal structures. The gut was then freed from surrounding blood vessels and nephridia with a flamed forceps and separated into three sections: foregut (segments 1–14), mid gut (segments 15–44) and hindgut (segments 44–anus). The gut sections were carefully placed in bottles containing 9 ml sterile distilled water for biological analysis.

Physico-chemical analyses

Soil and cast pH, moisture content and total nitrogen were determined. Replicate soil and casts samples were mixed thoroughly in distilled water (pH 7) to make the supernatant samples in the ratio 1:5 (w/v) soil (cast): water. The soil (cast)-water suspensions were used to determine soil pH by a combined glass electrode and a pH meter (Mettler-Toledo, Essex M3509 Type 340). Moisture contents of soil and cast samples were determined as percentages in replicates after drying the samples at 105°C for 24 h in a hot air oven (A.O.A.C., 1990). Total soil nitrogen was determined by the regular macro-Kjeldahl method (Jackson, 1962; Black, 1965). Cast samples were then stored in desiccators for 2 weeks before being analysed as above for physico-chemical parameters as well as total biomass of microflora and microfauna.

Biological analyses

Replicate portions of ten-fold dilutions of samples in sterile distilled water were made for soils, casts and contents of the three gut regions of the

earthworms. The preparations were homogenized under aerobic conditions (Karsten & Drake, 1995). For micro-fauna counts and characterization, a drop of each homogenized preparation was placed on a glass slide, covered with a cover slip and observed microscopically for motility, enumeration and possible identification. The organisms were then characterized by their micro-morphology and taxonomical features using the scheme of Karl (1973). Protozoa counts were taken by the MPN technique (Darbyshire *et al.*, 1974). For enumeration of microflora, 1 ml sub-samples were each taken from the above preparation and homogenized in 9 ml sterile distilled water to make ten-fold serial dilutions of up to 10^8 (0.1 ml aliquots) of the dilutions were each inoculated in duplicates by the pour plate technique on Sabouraud Dextrose Agar medium (Oxoid, U.K.) for isolation and enumeration of fungi, and Plate Count Agar (Oxoid, U.K.) for total viable counts of microorganisms, Nutrient agar and deMann Rogosa Sharpe (MRS) agar media for enumeration and isolation of bacteria (Oxoid, U.K.). Fungal plates were incubated at 30°C for 3 days while bacterial plates were incubated at 37°C for 3 days. At intervals, colony-forming units were determined by taking total counts on the incubated plates. Representative colonies emerging from the plates were grouped according to their cultural characteristics, purified by repeated sub-culturing and maintained on appropriate agar slants as stock cultures. The bacterial isolates were tested for Gram reaction (Claus, 1992), morphology, motility, catalase reaction, citrate utilization, coagulase production, starch hydrolysis and sugar fermentation (Seeley & Van Demark, 1972). The isolates were then identified with reference to Sneath *et al.* (1980). Yeast isolates were examined for assimilation of sugars, pseudomycelia formation, citrate utilization and urease production (Barnett *et al.*, 1990). The yeast isolates were then identified according to Kreger van Rig (1984) and Barnett *et al.* (1990). Moulds were identified by their micro-morphology as well as the colour and micro-morphology of their sporulating structures and conidia. Microscopic examination of young, actively growing moulds was on the basis of structures bearing spores and on the spores themselves, presence or absence of septation, rhizoid or other tissues (Barnett & Hunter, 1972).

Statistical analysis

Data were analysed with SPSS 10.0 for Windows software. One-way Analysis of Variance (ANOVA) was used to test for differences in numbers of microflora and micro-fauna among earthworm species, soils and casts. Bivariate correlation coefficient was used to test the relationships between flora and fauna counts in different species, soils and cast samples.

RESULTS

The microflora identified in this study belonged to three groups of organisms, namely bacteria, molds and yeasts, while the microfauna examined were protozoa and nematodes. The counts of microflora and microfauna in gut sections of these earthworm species are presented in Table 1. Counts were in the order of 10^4 . Bacterial counts were highest among the microflora and the values ranged from 0.42 in the fore gut section of *Keffia proxipora* to 2.13 in stored cast. For all samples of soil, casts and earthworms, the differences observed in counts of microflora and microfauna were significant at a level of $p < 0.05$. Casts stored for 2 weeks had slightly higher pH and bacterial counts but the differences were not significant compared with pH values obtained for fresh castings (Table 2). However, the pH values and nitrogen contents of both the fresh and stored castings were significantly higher than those for un-ingested soil samples.

Among the earthworms identified, *Libyodrilus violacaeus* recorded the highest values of microflora and microfauna counts, often significantly higher than values obtained for the other earthworm species. The hind gut of *Libyodrilus violacaeus* also had the highest bacterial, protozoal and yeast counts as well as total viable counts of microflora. Both micro-flora and micro-fauna were found to increase, sometimes significantly, in numbers during gut passage in all worms collected except for nematodes, which were observed to reduce significantly in numbers during gut passage, with total disappearance in the mid and hind gut sections of some earthworm species (Table 1). Table 3

TABLE 1
Counts of microflora and microfauna in gut sections of earthworms species.

Earthworm species	Bacteria	Moulds	Yeasts	Protozoa	Nematodes	Total viable counts
<i>Keffia proxipora</i>						
Fore gut	0.42 a	0.03 a	0.37 a	8.00 a	1.33 b	0.80 a
Mid gut	0.77 b	0.03 a	0.53 abc	12.67 abc	0.00 a	1.30 b
Hind gut	1.03 bc	0.04 a	0.70 cd	24.00 cd	0.00 a	1.73 cd \
<i>Libyodrilus violacaeus</i>						
Fore gut	0.87 bc	0.04 a	0.63 bcd	10.67 abc	1.33 b	1.50b c
Mid gut	1.07 cd	0.04 a	0.83 de	18.67 abcd	0.67 ab	1.90 d
Hind gut	1.43 e	0.03 a	0.93 e	28.00 d	0.33 a	2.37 e
<i>Hippoporeira nigereae</i>						
Fore gut	0.80 bc	0.03 a	0.43 ab	8.67 ab	0.67 ab	1.27 b
Mid gut	0.97 bc	0.03 a	0.83 de	12.67 abc	0.00 a	1.63 cd
Hind gut	1.30 de	0.03 a	0.93 e	23.00 bcd	0.00 a	2.23 e

Counts of microflora and total viable counts are in the order of 10^4 cfu⁻¹ml

Counts of protozoa and nematodes were taken as actual numbers of fauna observed

Means values having the same letter in the same column are not significantly different at a level $p < 0.05$.

TABLE 2

Physico-chemical properties and counts of microflora and microfauna in soil and cast samples collected.

Sample	Bacteria	Moulds	Yeasts	Protozoa	Nematodes	Total viable counts	Nitrogen content (%)	pH	Moisture content (%)
Un-ingested Soil	1.97 a	0.03 b	1.23 a	33.33 a	3.00 b	2.77 a	0.38 a	6.00 a	41.13 b
Fresh Cast	2.00 a	0.04 a	1.43 a	26.67 a	0.33 a	3.70 a	0.59 b	6.30 b	40.37 b
Stored Cast	2.13 a	0.03 a	1.33 a	14.33 a	1.00 a	3.57 b	0.55 b	6.33 b	39.23 a

Counts of microflora and total viable counts are in the order of 10^4 cfu⁻¹ml

Counts of protozoa and nematodes were taken as actual numbers of fauna observed

Means values having the same letter in the same column are not significantly different at a level of $p < 0.05$.

shows the list of isolated microflora and microfauna identified in earthworms, soil and casts samples collected. A total of 15 bacterial species belonging to 10 genera and four yeast species were isolated and characterized while five mould species were observed and identified. Micro-fauna identified included five species of protozoa and two species of nematodes. The bacterial isolates consisted of both gram positive and gram negative rods and cocci. The distribution of the isolated organisms in the various samples examined is shown in Table 4. Most of the organisms found in the soil were also found in the gut sections and castings of the earthworms. However, it was important to note that some organisms were found only in *L. violaceus* and castings but not in the other two species of worms isolated. For example, *Bacillus azotoformans* was found only in castings, mid and hind gut sections of *L. violaceus* alone. Also, *Streptococcus mutans* and *Rhizopus* spp. was found only in un-ingested soil and fore-gut of *Hippoporera nigrerea* alone. In addition, nematodes were not found in casts, mid and hind gut sections of most of the earthworms collected.

There was a significant and positive relationship at between the samples (soil, casts and earthworm) and the microflora and macrofauna encountered with the exception of the protozoal counts (Table 5). Further analysis revealed a strong relationship between earthworm and bacterial counts at $p < 0.01$ (Table 6).

DISCUSSION

The results of this study showed that similar organisms were found in the soil, gut sections and castings of the earthworms. The great similarity in the micro-organisms identified in soil samples with those identified in various gut

TABLE 3
Microflora and microfauna identified in earthworms, soil and casts samples collected.

Bacteria	Moulds	Yeasts	Protozoa	Nematodes
B1 <i>Acinetobacter calcoaceticus</i>	M1 <i>Aspergillus</i>	Y1 <i>Candida albicans</i>	P1 <i>Anoplophrya lumbrici</i>	N1 <i>Rhabditis</i>
B2 <i>Azotobacter chroococcum</i>	M2 <i>Fusarium</i>	Y2 <i>Pichia</i>	P2 <i>Icthyophthichius multifiliis</i>	N2 <i>Spirotera</i>
B3 <i>Azotobacter nigrificans</i>	M3 <i>Periconia</i>	Y3 <i>Saccharomyces</i>	P3 <i>Loxodes rostrum</i>	
B4 <i>Azotobacter palpali</i>	M4 <i>Pythium</i>	Y4 <i>Zygosaccharomyces</i>	P4 <i>Maupasella nova</i>	
B5 <i>Bacillus azotoformans</i>	M5 <i>Rhizopus</i>		P5 <i>Spirostomum ambiguum</i>	
B6 <i>Bacillus circulans</i>				
B7 <i>Bacillus subtilis</i>				
B8 <i>Clostridium absonum</i>				
B9 <i>Clostridium baratii</i>				
B10 <i>Halobacterium</i> spp				
B11 <i>Micrococcus lylae</i>				
B12 <i>Pseudomonas aeruginosa</i>				
B13 <i>Spirocheata</i> spp				
B14 <i>Staphylococcus aureus</i>				
B15 <i>Streptococcus mutans</i>				

TABLE 4
Distribution of microflora and microfauna in soil, casts and earthworm samples collected.

Sample	Bacteria	Molds	Yeasts	Protozoa	Nematodes
Un-ingested Soil	B1, B2, B3, B4, B6, B9, B11, B12, B13, B15	M1, M2, M3, M4, M5	Y1, Y2, Y4	P1, P2, P3, P4	N1, N2
Fresh cast	B1, B2, B3, B4, B5, B6, B8, B9, B11, B12, B15	M1, M2, M4	Y1, Y2, Y3, Y4	P1, P2, P3, P4	ND
Stored cast	B1, B2, B3, B4, B5, B6, B8, B9, B11, B12, B13	M1, M2, M3, M4	Y1, Y2, Y3, Y4	P1, P2, P3, P4	ND
<i>Keftia proxipora</i>					
Fore gut	B1, B2, B3, B4, B6, B9, B11, B12	M1, M3	Y1, Y2, Y3	P1, P2, P3, P4	N1, N2
Mid gut	B1, B2, B3, B4, B6, B11, B12	M1, M4	Y1, Y2, Y4	P1, P2, P3	ND
Hind gut	B1, B2, B3, B4, B6, B9, B12	M1, M4	Y1, Y2, Y3	P1, P2, P3, P4	ND
<i>Libyodrilus violaceus</i>					
Fore gut	B1, B2, B3, B4, B6, B9, B12	M1, M3	Y1, Y2, Y3	P1, P2, P3, P4	N1, N2
Mid gut	B1, B2, B4, B5, B6, B9	M1, M4	Y1, Y2, Y4	P1, P2, P3	N2
Hind gut	B1, B2, B3, B4, B5, B6, B9, B12	M1, M2, M4	Y1, Y2, Y4	P1, P2, P3, P4	N2
<i>Hippoporeia nigereae</i>					
Fore gut	B1, B2, B3, B4, B6, B8, B9, B11, B15	M1, M2, M4	Y1, Y2	P1, P2, P3, P4	N2
Mid gut	B1, B2, B3, B6, B9, B11	M1, M3, M4, M5	Y1, Y2, Y4	P1, P2, P3, P4	ND
Hind gut	B1, B2, B3, B4, B6, B9, B11	M1, M3, M5	Y1, Y2, Y3	P1, P2, P3, P4	ND

Isolate codes are as presented in Table 3.

TABLE 5
Correlations between samples and microflora counts.

Samples	Pearson Correlation Sig. (2-tailed)	Bacteria counts	Mould counts	Yeast counts	Protozoal counts	Nematode counts	Total viable counts
Samples	1						
Bacteria counts							
	N						
Mould counts							
	N						
Yeast counts							
	N						
Protozoal counts							
	N						
Nematode counts							
	N						
Total counts							
	N						

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed).

TABLE 6
Correlations between earthworm species and microflora counts.

	Earthworm Spp.	Bacteria counts	Mould counts	Yeast counts	Protozoal counts	Nematode counts	Total viable counts
Earthworm spp	1	.595 **	-.274	.569 **	.216	-.341	.589 **
		.001	.167	.002	.278	.082	.001
	N	27	27	27	27	27	27
Bacteria counts	.595 **	1	.064	.760 **	.582 **	-.315	.922 **
	.001		.751	.000	.001	.109	.000
	N	27	27	27	27	27	27
Mould counts	-.274	.064	1	.071	.040	.208	.140
	.167	.751		.725	.845	.299	.487
	N	27	27	27	27	27	27
Yeast counts	.569 **	.760 **	.071	1	.686 **	-.333	.766 **
	.002	.000	.725		.000	.090	.000
	N	27	27	27	27	27	27
Protozoal counts	.216	.582 **	.040	.686 **	1	-.230	.530 **
	.278	.001	.845	.000		.248	.004
	N	27	27	27	27	27	27
Nematode counts	-.341	-.315	.208	-.333	-.230	1	.384 *
	.082	.109	.299	.090	.248		.048
	N	27	27	27	27	27	27
Total counts	.589 **	.922 **	.140	.766 **	.530 **	.384 *	1
	.001	.000	.487	.000	.004	.048	
	N	27	27	27	27	27	27

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed).

sections of earthworm implies that the earthworms ingest with soil, detritus micro-organisms which might be of dietary requirement (Idowu *et al.*, 2005). Nematodes were not found in casts, mid and hind gut sections of most of the earthworms collected. This was in confirmation of previous reports that earthworms and their microflora are able to destroy nematodes during their passage in the earthworm's gut (Savin *et al.*, 2004).

Bacterial numbers increased significantly along gut sections of the earthworms identified. This is in agreement with previous reports that the numbers of bacteria contained in the ingested material increased by up to 1000 times while passing through the worm's gut (Pederson & Hendriksen, 1993). Total viable counts also increased significantly during gut passage which in agreement with Karsten & Drake (1995) who found that the intestine of worms examined displayed activities that would suggest the gut to be a microhabitat suitable for the proliferation of microorganisms. Earthworms affect many soil biological, chemical and physical properties. Several reports on analysis of worm castings, when compared with the parent soils, have revealed significant increases in colony forming units of microorganisms especially higher bacterial counts in earthworm casts than in soils (Lee, 1985; Daniel & Anderson, 1992; Pederson & Hendriksen, 1993). The hind gut of *Libyodrilus violacaeus* had the highest bacterial, protozoal and yeast counts as well as total viable counts of microflora. This could be because *L. violacaeus* is an indigenous worm while the other worms identified in this study are known to be exotic species to Abeokuta (Idowu *et al.*, 2003). Studies have shown that the conservation of indigenous invertebrate biodiversity should be an integral part of land management strategies in the humid forest zones, if the goal of increased crop-yield sustainability is to be realized (Lavelle, 1996; Lavelle *et al.*, 1998). Invasion of cleared forest by exotic species has been shown to have adverse consequences for soil structure (Barros *et al.*, 1996).

The castings of earthworms collected in this study had higher pH values than the surrounding un-ingested soil in confirmation of previous reports that casts are always more neutral than the soil from which the castings are formed (Idowu *et al.*, 2003). Just how this is accomplished is unproved scientifically, although it is hypothesized that the waste and soil, in passing through the intestine is neutralized by its secretions and by the ammonia excreted by the worm (Scheu, 1987). The pH of the casts increased further with storage, although not significantly compared with the fresh castings. The bacterial counts of the casts also increased with storage when compared with fresh casts and soil samples. These findings could represent strong justification for the use of earthworm cast to improve soil fertility. The substitution of vermicast for high-density chemical fertilizers will reduce nutrient loss with run-off. This has wide ranging implications for farmers and agriculturists. Edwards & Bates (1992) found that earthworms increased significantly the number, growth rate and yields of plant growing on inoculated sites. Grass production

doubled in New Zealand, a region that historically did not have earthworm's when European species were introduced. In Bangalore, India, earthworms successfully decomposed sugar factory residuals and turned them into a soil nutrient that allowed farmers using the materials to reduce chemical fertilizers by 50% (Logsdon, 1994).

Total soil nitrogen analysis of earthworm castings in comparison with un-ingested soil revealed that they are richer in nitrogen than surrounding soil. Both fresh and stored casts are more microbially active than the surrounding soil. Thus, there appears to be a sort of symbiotic association between earthworms and soil microflora resulting in improved soil condition expressed as high total nitrogen content. Previous studies have also reported similar trends with about three times more calcium, several times more nitrogen, phosphorus, and potassium (Mulongoy & Bedoret, 1989). This could be very important for soil fertility using vermicompost. A wide variety of microflora and fauna were isolated from soil, casts and earthworm gut in this study. Many of the species isolated have also been found in similar studies (Daniel & Anderson, 1992; Karsten & Drake, 1995). Savin *et al.* (2004) observed changes in microbial and microfaunal community composition in their leaf and worm treatments and suggested that the incorporation of litter into soil may be one of the more important mechanisms by which earthworms enhance nutrient dynamics.

It is known that earthworm-produced compost (vermicompost) dramatically increases germination and growth in many plants. Adding only 5% of the compost to commercial growing media (95%) can significantly increase plant growth (Edwards & Bohlen, 1996). The present study has also further demonstrated that the guts of earthworms are conducive for the proliferation of microflora. Earthworms are ideal managers whom man can employ to maximize growth of aerobic bacteria for waste processing. This is an important characteristic that could be employed in the use of earthworms as biological agents for the improvement of soil fertility. Farm residues can be processed *in-situ* by the beneficial soil bacteria which are "farmed" by the earthworms hatched from the cocoons in the vermi-castings. Where the original earthworms are not present in sufficient quantities, inoculation of vermi-castings may be necessary. The importance of macrofauna to the promotion of tropical soil fertility has been stressed (Lavelle *et al.*, 1998). The distribution, protection and stabilization of organic matter, the genesis of soil structure (macroaggregates), humification, the release of immobilized N and P, the improvement of drainage and aeration, and the increase in exchangeable cations have been demonstrated in soils modified by termites and earthworms (Mulongoy & Bedoret, 1989; Lavelle *et al.*, 1998)

Satchell & Martin (1984) found direct correlation between microbial population and enzyme activity. Microbes such as *Pseudomonas* spp., *Bacillus* spp. and *Aspergillus* spp. isolated in this study are known to mineralize phosphate. Vinotha *et al.* (2000) observed that increased amount of inorganic

P released during cast deposition was related to and preceded by increased microbial and phosphatase activity. High P_2O_5 content in casts supports the phosphatase availability which is required for growth of root, microbial enhancement and in turn, may help drive biological nitrogen fixation. Since the emphasis is now on organic matter rather than inorganic fertilizer for the improvement of soil fertility, there is the need now to explore the potentials of earthworms in soil fertility improvement especially in tropical Africa where the practice of vermicompost is virtually non-existent.

CONCLUSION

The study has revealed that earthworms harbour microorganism and the symbiotic relationship between them can be exploited for improvement in soil structure and fertility. The findings of this study can form part of the required database necessary for building an ideal framework for the use of earthworms in organic agriculture in this part of the world. It is also a fact that large number of farmers in the tropics have limited access to soil inputs especially fertilizer due to cost. Farmers can therefore be trained on how to exploit the potential of native earthworms and their associated microbes in improving soil fertility just by a simple vermicompost.

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