Migratory Soil Nematode Feeding Group Fauna and Their Spatial Distribution in a Sampled Portion of a Cultivated Farmland within University Of Maiduguri, Maiduguri, Nigeria

By

Ozurumba L.N.
Usman D.D.
Migratory Soil Nematode Feeding Group Fauna and Their Spatial Distribution in a Sampled Portion of a Cultivated Farmland within University Of Maiduguri, Maiduguri, Nigeria

*1Ozurumba L.N. and 2Usman D.D.

1Parasitology Unit, Department of Biological Sciences, University of Maiduguri, Maiduguri, Nigeria.
2Department of Biological Sciences, University of Maiduguri, Maiduguri, Nigeria.

Corresponding Author’s E-mail: nnadiutoln@gmail.com, phone: +234 703 6018 070.

ABSTRACT

Systematic sampling was engaged to determine the migratory soil nematode fauna with respect to functional feeding groups, present in a cultivated farmland within the University of Maiduguri, using two methods which were the sieving and extraction tray methods. This was done to determine the abundance of the various migratory soil nematode feeding groups, their spatial distribution and trophic structure within a measured sampling plot of 9m by 8m (72m²).

Nematodes can be classified into functional feeding groups based on their feeding habits, which can often be deduced from the structure of their mouth parts. Five groups of these soil nematodes were recorded, implying that nematodes that are both beneficial and harmful to plant fauna were present in the sampled area.

Soil nematodes were recorded along all five horizontal sampling plains (coded as SMA-SME). On each of these five horizontal plains – with each containing ten (10) sampling points, some of the sampling points did not record nematodes. Bacteria feeders recorded the highest %abundance of 26.3% while Omnivore feeders had the least % abundance of 11.6%. The combined abundance of bacterial and fungal feeders was 43.2%, which represents the nematode groups that help in re-cycling of nutrients through the provision of nitrogen in the soil. The trophic level stratification based abundance in terms of ratio of soil nematode groups was 7:2 for ratio of “2nd + 3rd trophic levels” to “1st trophic level”, a value that indicates that the combined activities of soil nematode groups in the 1st and 2nd trophic levels may assist in soil quality maintenance activities which may also help check the activities of those of the 1st trophic level (Herbivore feeders). The major plant parasitizing nematodes (Herbivore feeders) accounted for 23.2% of the total abundance of these migratory soil nematode groups. However, out of the total of 50 sampling points examined from the marked out portion on the farmland, 15 points (30%) recorded no nematodes while 35 points (70%) recorded soil nematodes indicating a significant spatial spread or representation of these migratory soil nematode groups. Thirty percent (30%) of the sampling points recorded two groups of these soil nematodes and 2% recorded three groups. The nature of the compositional aggregations may likely allow for ecosystem related interactions between different soil nematode groups which could be useful for support of soil fertility related activities.

Key words: Aggregates, trophic, spatial, extraction, migratory, ecosystem, nematodes, soil.

INTRODUCTION

Nematodes are invertebrate roundworms that inhabit marine, fresh water and terrestrial environments. They comprise the Phylum Nematoda (or Nemarta) which includes parasites of plants and animals, including humans as species that feed on bacteria, fungi, algae and on other nematodes. Four out of every five multi-cellular animal on the planet are nematodes (Platt, 1994).

Majority of nematodes are microscopic, averaging less than a millimeter in length, but some of the animal parasites are quite large and readily visible to the naked eye (Lavelle and Spain, 2001). They range in size from 3mm to 8m. Nematodes are found in almost all habitats, but are often overlooked because most of them are microscopic in size. The living soil nematodes are non-segmented worms typically 1/500 of an inch in diameter and 1/20 of an inch (1mm) in length. Animal and plant nematode parasites are of direct importance in agriculture, the environment, and in human health. However, numerous nematodes in the environment are not parasites. Nematodes that feed on other organisms are important participants in the cycling of minerals and nutrients in the ecosystem that is fundamental to
other biological activities. Some of these nematodes may have major roles in decomposition, including biodegradation of toxic compounds (Lavelle and Spain, 2001). In fact, the incidence of certain nematode species is sometimes used as an indicator of environmental quality. Insect parasitic nematodes can be of importance in regulating insect populations, and are being used in the biological control of insect pests (Maggenti, 1981).

Soil is an excellent habitat for nematodes and 100cc of soil may contain several thousands of them. Because of their importance to agriculture, much more is known about plant-parasitic nematodes than about the other kinds of nematodes which are present in soil. These few species responsible for plant diseases have received a lot of attention, but it appears less is known about the majority of the nematode community that plays beneficial roles in soil.

Various authorities distinguish among 16 to 20 different Orders within the Phylum Nematoda. Only about 10 of these Orders regularly occur in soil. Typical five Orders comprising soil nematodes are listed as follows: Tylenchida, Triplonchida, Dorylaimida, Aphelenchida, and Rhabditida. They are particularly common in the soil and the first three listed above have various characteristics that distinguish them, such as the nature and structures of the cuticle, cephalic frame, excretory pore, oesophagus, nerve ring, pre-rectum, testis, copulatory supplements, and phasmid. Typical species of the first three orders are Pratylenchus brachyurus (a plant parasitic nematode), Paratrichodorus minor (stubby root nematode) and Xiphinema index respectively.

Identification of these groups appears extremely difficult, and there seem to be only a few nematode taxonomists in the world, who can formally describe new species of free living nematodes to science. Most nematode ecologists tend to identify soil nematodes to family or genus levels.

Soil-inhibiting nematodes can also be classified according to their feeding habits. This classification is particularly useful to ecologists in understanding the positions of nematodes in soil food webs. Several important feeding groups of nematodes commonly occur in most soil. In addition, algivores (nematodes that feed on algae) and various stages of insect and animal parasites occasionally are found in soil. Nematode feeding groups are also called trophic groups by some authors (Freckman, 1982). The functional feeding groups of soil – inhabiting nematodes are: Herbivore soil nematodes (also called plant feeders), Bacteriovore soil nematodes (bacteria feeders), Fungivore soil nematodes (fungi feeders), Predator soil nematodes (predator feeders), and Omnivore soil nematodes (omnivore feeders).

Herbivore feeders which could be ecto-parasites or endo-parasites have members that include those in the Orders Tylenchida, Aphelenchida and Dorylaimida. Bacteria feeders which could be beneficial and participate in the decomposition of organic matter comprise members such as those in the Order Rhabditida. Fungal feeders are very important in decomposition of organic matter with members found in the Order Aphelenchida. Predator feeders feed indiscriminately on both plant and free living nematodes, the Order Mononchida, which are exclusively predacious, and those of Order Dorylaimida contain nematodes in this feeding group. Omnivore feeders may feed on more than one type of food material; some of these nematodes may ingest fungal spores as well as bacteria, with some member of the Order Dorylaimida which may feed on fungi, algae and other animals being in this group (Yeates et al, 1994; Ugarte and Zaborski, 2012).

In an extensive survey of savannah zone of northern Nigeria, Wilson (1962) reported the occurrence of three species root knot soil nematode, namely Meloidogyne incognita, Meloidogyne javanica, and Meloidogyne arenaria with Meloidogyne javanica having wider distribution frequency. In another study by Olowe (2004) on occurrence and distribution of Meloidogyne spp in Cowpea growing areas of Nigeria, M.incognita (51.8%) was the most prevalent, followed by M.javanica and in terms of distribution they tended to be common in Guinea savanna of the middle belt (north-central), while mixed populations of M.javanica, M.arenaria and M.incognita was 4.0%. Caveness (1965) in his survey of Guinea and Sudan savannah of Nigeria showed that plant parasitic nematodes are known to occur widely and nematodes encountered were the spiral nematode Helicotylenchus species, Meloidogyne javanica, Heterodera juvenile and Hoplolaimus spp, while the root lesion nematodes like Pratylenchus species, Tylenchorhynchus spp, Tylenchus spp, Xiphinema spp, Longidorus spp and Trichodorus spp are more common. Studies have also showed that Meloidogyne species were recorded at lake Alau and Gamboru Ngala in Northern Nigeria, where topographic elevations are less than 300m with annual mean minimum temperature of 18-21°C and mean annual rainfall of 600-800mm (Caveness, 1976).

Soil nematodes, especially bacteria and fungal-feeding nematodes, can contribute to maintaining adequate levels of plant available in farming systems relying on organic sources of fertility (Ferris et al, 1998). The process of converting nutrients from organic to in-organic form termed mineralization is an important fertility maintenance process in soil because plants take up nutrients from the soil primarily in in-organic forms.

Currently, there is no chemical that can eliminate nematodes that damage crops without associated negative effects on the ecosystem and man, but there are several natural remedies that can help to control nematodes. Some of these remedies include: planting nematode-resistant crops like corn, onions, garlic and nematode-resistant tomatoes can be grown; removal of any crop plants that are suffering from nematode infestation to prevent the spread of these damaging worms; planting (growing) marigolds once infested crop plants are removed. Marigolds
exude a chemical that is toxic to nematodes and can help rid the soil and surrounding plants of any remaining worms. Though some plant nematodes have been implicated in parasitic infestation of a fruit crop like Pineapple, causing poor yield and reduced sucker production (Daramola et al, 2013).

The results from this study may add to the body of knowledge on the types of migratory soil nematode groups found in soil samples from the study area, and their relative abundances. Based on the objectives of this study, it may also help provide insight on the quality of the soil and nature of possible involvement of nematode groups in soil food web related through interactions through an assessment of the trophic structure among other features.

Aims and Objectives of the Study

- To identify (based on feeding groups) and determine the relative abundance of each of the groups of migratory soil nematodes.
- To examine the nature of spatial distribution and the profile of aggregation of migratory soil nematode feeding groups on the sampled plot and its implication on the ecosystem.
- To examine the trophic structure of the soil nematode community, implication on the soil quality and assess this phenomenon from line of beneficial (soil quality enhancer groups) and non-beneficial nematode groups (or plant parasitic groups).

Limitation of Study

The sample space used is not very high to completely generalize the results in certain areas of its discussion. However, the results and certain areas of the analysis and accompanying discussions appear to provide clues that could serve as leads for studies by other scientists who pick interest in this area of heminthology/nematology research.

MATERIALS AND METHODS

The Study Area: Brief History and Biogeography

Maiduguri is the capital city of Borno State. It is located on latitude 11.5° North and longitude 13.2° East. It occupies an area of 50,778 square kilometers. It is the largest town in north Eastern Nigeria. Borno State is bordered by republic of Niger to North, Chad to the North-east and Cameroon to the East.

Modern Maiduguri was founded in 1907 when the British installed the century capital of Borno, to Maiduguri. The traditional name of the new settlement was Yerwa. It was established near the old town of Maiduguri, founded in 1672.

The climate of Maiduguri is favourable with a mean annual maximum temperature of 34.8°C. The months of March and April are the hottest periods of the year with temperatures ranging between 30°C and 41°C. It is usually cold and dry during the hamarttan, with November to January being the coldest months.

Maiduguri is a town with tourist attractions. The Shehu’s palace is significantly noted by tourists from all parts of the world. The Maiduguri museum, situated within fifteen minutes drive from the University campus, preserves collections from the history of Borno. Other places of interest in Maiduguri include the Kyarimi park (Zoo), and Lake Alau along Bama road.

Collection of Samples

Soil samples were systematically collected (Okafor, 1992; Coyne et al, 2007; Singh and Nath, 2010) from a particular farm plot that had just been cultivated with crops such as maize and groundnut and harvest already carried out, opposite one of the student’s hostel within University of Maiduguri, between the hours of 11:00am and 2pm, on the 10th day of March, 2012.

The size of the plot from which samples were collected - measured 9m by 8m (72 sq metres), of which a total of fifty (50) samples were collected from the farmland: 10 samples on each of five horizontal plains, using 1metre spacing horizontally and 2metre spacing vertically.

A 100metre measuring tape and stick pegs were used for measurements of distances and demarcations of sampling points respectively. Soil samples were collected from the farmland using hand trowel in a systematical sampling procedure, at a depth of 10cm to 15cm below the soil surface using a hand trowel.
Storage of Collected Soil Samples

The nematodes in the soil samples were preserved in as much physiologically active state as possible until they were to be processed for extraction for soil nematodes. Thus, the samples collected were kept in transparent polythene-nylon bags while exposure of soil samples to direct sun rays was avoided as nematodes are thin-walled and short-lived micro-organisms. Improper handling such as exposure to high temperature or improper storage may result in high mortality rate which may lead to poor extraction that could affect results.

Soil samples were processed for presence of Nematodes by extractive bioassay. If the samples were to be stored for days or weeks, they are best placed in a cold room (about 40-50°F) or in an un-exposed cool place at room temperature.

Methods for Extraction of Soil Nematodes

The methods (of two types) used for extraction of soil nematodes in the laboratory were the sieving method (extracts sedentary and migratory nematodes) which was sequentially followed by the extraction tray methods (extracts migratory nematodes) (Coyne et al, 2007). There are other methods, but the chosen ones worked with were the ones that appear accessible to utilize when this study was carried out.

(A) Sieving Method: About 200ml of water was poured into a container or cup, the sample was taken gradually and poured into the cup to displace the water to a marked level of 300ml. This means that 100ml volume of soil was measured. The content of the cup was mixed. Water was poured into a bucket to a marked level in it. Then, the entire content was poured into the bucket of water. The contents in the bucket were thoroughly mixed with the hand and the mixed content left for 30 seconds. The content from the bucket was poured through two sieves placed on top of each other into a container at the bottom of the second sieve below; the sieve on top had a wider mesh size than the one below which was of a very tiny mesh size. The contents from the two sieves were carefully washed from back into a small cup. Also, we ensured that the content from the front of the sieves were emptied into the same cup. Then, the content in the container which had some water and debris that have passed through the two sieves was poured again into another bucket that contained water - up to the same marked level. The content was mixed, left for 30 seconds and poured again through two sieves that were laid on top of each other. The debris content of sieves as earlier described was washed into the same cup. The extracted content in the cup was left and set aside for the next stage of extraction for migratory soil nematodes using the extraction tray method. This process above was repeated for each of the collected soil samples.

(B) Extraction Tray Method: This method is basically a continuation of the entire process of extraction of soil nematodes (it extracts migratory nematodes). We obtained a plastic sieve, and lined the entire surface on the inside with tissue paper. Then this set-up was placed on top of a tray (or it could be placed on top of a white plastic horizontal plate). The content of the final extraction products from the sieving method previously carried out was poured on top of the tissue paper that has been laid inside a plastic sieve. This was carefully done to ensure that the tissue paper did not fall inside. This set-up was left for about 36hours and was occasionally checked to ensure that the water in the tray was not dry. If it was found to be dry, little water was poured on it through the side of the tray. After 36hours, the remaining water in the plastic sieve was carefully drained from the bottom on to the extraction content already in the tray. The entire extraction from the plastic tray was poured into a small plastic cup and the entire content in the cup left to settle overnight till the following day. Then, the clearer top layer was decanted through a sieve of very small mesh size and kept in a small storage plastic or bottle, while retaining the suspension in the cup below. A drop of 5% formalin was added into the final extracted product that was kept in the small storage plastic containers or bottle. The extracted materials was then covered and labeled appropriately to correspond with the sections on the plot from which it was collected. This process was repeated for each of the collected soil samples.

Observation of the extracted content in the labeled bottle containers

The contents in each of these plastic containers were gradually poured into a clean and clear petri-dish and placed on top of the stage of a stereo-microscope binocular microscope to screen the entire content under the microscope for these migratory soil nematodes.

One of the limitations in the extraction process is the possibility of losing some soil nematodes during the extraction procedures.
Nematode Identification

During examination of extracts from processed soil samples under the microscope, nematodes were identified based on their functional feeding groups. The morphological structures were considered alongside other factors like structure of stylet found in the anterior region or mouth part, body wall, cuticle and hypodermis. Also, the presence and nature of the digestive, excretory and the reproductive systems aided in identifications that distinguished them from other worm-like bio-fauna found in the soil samples. The presence of a stylet indicates that the observed species are soil nematodes, which may be parasitizing or not parasitizing plants.

Thus, phenotypic criteria played a prominent role in the identification of these soil nematodes (Robertson and Freckman, 1995).

Based on these functional feeding groups, soil nematodes were identified and classified as either Bacterivores, Fungivores, Herbivores, Omnivores or Predator feeders (Ugarte and Zaborski, 2014).

Statistical Analysis

Data obtained from the field and laboratory experiments were entered into Microsoft Excel 2007 edition statistical package and utilized to analyze the results. Chi square was used to investigate for possible association between the identified five groups of nematodes on one hand and the abundance and spatial related occurrence of nematode groups in the 50 sampling points engaged. Test of skewness of distributions was used to assess for the degree of asymmetry of distribution around the mean values for abundance of nematode groups and occurrence of nematode groups in total number or sampling points on the field. Correlation coefficient analysis (“Spearman Rank” and “Pearson product moment”) were engaged to assess the relationship between abundance of nematode groups and the occurrence of nematode groups in the 50 sampling points engaged. Percentages and bar chart were utilized to graphically present the trophic structure of the migratory soil nematode groups to assist in giving insight into the nature of what the quality of the soil could be and the nature of feeding interactions between these soil nematode groups.

RESULTS

The data obtained the following observations on the various soil samples have been represented in form of tables as follows:
Table 1: Number of soil nematodes counted and percentage occurrence for each of the functional feeding groups of nematodes

<table>
<thead>
<tr>
<th>Functional feeding group of soil nematode</th>
<th>SMA</th>
<th>% Occurrence</th>
<th>SM B</th>
<th>% Occurrence</th>
<th>SM C</th>
<th>% Occurrence</th>
<th>SM D</th>
<th>% Occurrence</th>
<th>SME</th>
<th>% Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria feeders</td>
<td>7</td>
<td>29.1</td>
<td>4</td>
<td>21.5</td>
<td>5</td>
<td>21.7</td>
<td>5</td>
<td>31.2</td>
<td>4</td>
<td>30.7</td>
</tr>
<tr>
<td>Fungal feeders</td>
<td>3</td>
<td>12.5</td>
<td>5</td>
<td>26.3</td>
<td>4</td>
<td>17.3</td>
<td>2</td>
<td>12.5</td>
<td>2</td>
<td>15.3</td>
</tr>
<tr>
<td>Herbivore feeders</td>
<td>5</td>
<td>20.8</td>
<td>6</td>
<td>31.5</td>
<td>3</td>
<td>13.4</td>
<td>5</td>
<td>31.2</td>
<td>3</td>
<td>23.7</td>
</tr>
<tr>
<td>Omnivore feeders</td>
<td>2</td>
<td>8.3</td>
<td>2</td>
<td>10.5</td>
<td>4</td>
<td>17.3</td>
<td>2</td>
<td>12.5</td>
<td>1</td>
<td>7.6</td>
</tr>
<tr>
<td>Predator feeders</td>
<td>7</td>
<td>29.1</td>
<td>2</td>
<td>10.5</td>
<td>7</td>
<td>30.4</td>
<td>2</td>
<td>12.5</td>
<td>3</td>
<td>23.7</td>
</tr>
<tr>
<td>Total count of nematodes</td>
<td>24</td>
<td>99.8</td>
<td>19</td>
<td>99.85</td>
<td>23</td>
<td>99.74</td>
<td>16</td>
<td>99.9</td>
<td>16</td>
<td>99.74</td>
</tr>
</tbody>
</table>

SMA to SME: are the five groups of horizontal sampling columns
Each of these 5 groups has 10 sampling points of equal distances between them.
Table 2: Percentage occurrence (abundance) based on count of soil nematode for each of the groups of soil nematodes

<table>
<thead>
<tr>
<th>Functional feeding groups of soil nematodes</th>
<th>Number of soil nematodes counted</th>
<th>% Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria feeders</td>
<td>25</td>
<td>26.31%</td>
</tr>
<tr>
<td>Fungal feeders</td>
<td>16</td>
<td>16.84%</td>
</tr>
<tr>
<td>Herbivores feeders</td>
<td>22</td>
<td>23.16%</td>
</tr>
<tr>
<td>Omnivores feeders</td>
<td>11</td>
<td>11.58%</td>
</tr>
<tr>
<td>Predator feeders</td>
<td>21</td>
<td>22.11%</td>
</tr>
<tr>
<td>Total count of soil nematodes</td>
<td>95</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Spatial distribution of observed and counted nematode for each of functional feeding groups soil nematodes

<table>
<thead>
<tr>
<th>Horizontal sampling columns</th>
<th>SAMPLING POINTS (1 TO 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>SMA</td>
<td>B₃H₁</td>
</tr>
<tr>
<td>SMB</td>
<td>B₂F₁</td>
</tr>
<tr>
<td>SMC</td>
<td>H₁</td>
</tr>
<tr>
<td>SMD</td>
<td>0</td>
</tr>
<tr>
<td>SME</td>
<td>H₁B₁</td>
</tr>
</tbody>
</table>

SUMMARY:
NO Nematodes group observed in sampling point: 15 = 30%
1: One soil nematode groups observed in a sampling point: 19 = 38%
2: Two soil nematode groups observed in a sampling point: 15 = 30%
3: Three soil nematode groups observed in a sampling point: 1 = 2%
50: Total of fifty sampling points in sampled plot.

Key:
F: Fungivores; H: Herbivores; O: Omnivores; B: Bacteriovores; P: Predator feeders.
The sub-scripts (such as B₃ with 3 as the sub-script here) represent the count of number of the nematode feeding groups observed.

Table 4: Distribution of number of nematode feeding groups observed within the fifty (50) sampling points

<table>
<thead>
<tr>
<th>Soil nematode functional feeding groups</th>
<th>Occurrence or count within 50 sampling points</th>
<th>Total sampling points</th>
<th>% occurrence in 50 sampling points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria feeders</td>
<td>14</td>
<td>50</td>
<td>28%</td>
</tr>
<tr>
<td>Fungal feeders</td>
<td>10</td>
<td>50</td>
<td>20%</td>
</tr>
<tr>
<td>Herbivore feeders</td>
<td>15</td>
<td>50</td>
<td>30%</td>
</tr>
<tr>
<td>Omnivore feeders</td>
<td>5</td>
<td>50</td>
<td>10%</td>
</tr>
<tr>
<td>Predator feeders</td>
<td>8</td>
<td>50</td>
<td>16%</td>
</tr>
</tbody>
</table>

Total number of horizontal sampling columns: Five
Total number of sampling point per horizontal columns: Ten
In 50 sampling points, 15 points had no soil nematodes, 35 points had soil nematodes.
Therefore, spatial representation in sampling plot of soil nematodes with respect to points of sampling was = 35/50x100 =70%
DISCUSSION

Soil nematodes were recorded along all five horizontal soil sampling positions (SMA, SMB, SMC, SMD and SME). On each of the horizontal plains of the sampling points, some of the ten (10) sampling points did not record nematodes, (Table 1 and Table 3).

As observed from Table 2, bacteria feeders recorded the highest % occurrence of 26.31%, omnivores feeders had the least % occurrence of 11.58%, fungal feeders recorded % occurrence of 16.84%, herbivores feeders 23.16%, while for predators feeders it was 22.11%. In grasslands, a teaspoon of dry gram soil may contain 50 to 500 nematodes, while agricultural soils generally support less than 100 nematodes per teaspoon of dry-gram sampled soil, while forest soils may contain several hundred per teaspoon (Ingham, 2012). The soil samples were collected from a study area in the sahel vegetational belt, which is not as humid as the forest soil and may not harbour as much as possibly observable in forest and guinea savanna soils, except when the norm has been affected by other factors.

The figures observed in this study appear not to deviate from these general observations. Deviations may occur in soil whose soil biota community may have been altered by distortions on soil ecosystem be a myriad of human factors, such as pollution and agricultural farming methods, which were not a feature in the sampled soil of the study area.

A CHI square test revealed no significant degree in association between soil nematode groups on one hand and the abundance and spatially related occurrence of nematodes in 50 sampling points on the other hand ($X^2$tabulated = 9.488 & 14.860 @ $P_{0.05}$ & $P_{0.005}$ respectively; $X^2$calculated = 0.8322 ; df= 4) (MEExcel 2007; and Okafor, 1992).

Spearman Rank order and Pearson product moment correlation coefficient values between abundance of nematodes and spatially related occurrence of nematodes in 50 sampling points were $r = +0.89$ and $r = +0.82$ respectively, indicating a high positive relation between abundance of soil nematode feeding groups and spatially related occurrence of nematodes in 50 sampling points.

The ‘skewness’ of distribution of the data combined for abundance of soil nematode feeding groups from the highest to the least values and spatially related occurrence of nematodes in 50 sampling points was +0.1881. The skew value for abundance from highest to the least values for nematode feeding groups was -0.7124 while the skew value for three trophic levels of Herbivore feeders, Bacteria + Fungal feeders, and Predator + Omnivore feeders was -1.6030. These skew values characterized the degree of asymmetry of distribution around the related mean values, with positive skew values indicating distribution with an asymmetric tail that extends towards more positive values and the negative skew values indicating asymmetric and tail extending towards more negative values.
Though herbivores were found in 15 (30%) of the 50 sampling points, while Bacteria feeders were observed in 14 (28%) of those sampling points (Table 4). Bacteria feeders recorded the highest occurrence (26.3%) based on count of nematodes observed for each of the feeding groups (Table 2). The observations of fairly dominant level of occurrence of herbivores may be due to the presence of crops that were grown for subsistence on the plot and only recently harvested. De Vries et al (2010) reported from their study that legume presence appear to reduce fungal biomass, favouring more of a bacteria dominated soil microbial community, as legumes are known to influence ecosystem nitrogen uptake rates directly through biological nitrogen fixation.

Each of these groups of soil nematodes play their various roles in the soil; for instance, bacteria and fungi feeders, can contribute to maintaining adequate levels of plant-available nitrogen in the soil. Nematodes are also beneficial in the decomposition of organic matter. Predatory nematodes are of interest because of their role in regulating the population of prey or other organisms; they can help moderate the population growth of bacteria, fungi feeding nematodes and protozoa and help to regulate the population of plant-parasitic nematodes. Omnivores and herbivores soil nematodes contribute directly to nutrient mineralization through their feeding interactions.

Spatial related observations from Table 3, show that no nematode group or groups were observed in 15(30%) of the sampling points. In 19(38%) of the sampling points (out of the total 50 sampling points) one group of soil nematode was observed, and this was the highest recorded. In another 15(30%) of the sampling points, 2 groups of soil nematodes were observed. In 1(2%) of the total of 50 sampling points, three groups of soil nematodes were observed and this was the lowest recorded. This has been presented on the spatial distribution of the observed and counted nematode number for each of the functional groups of nematodes on Table 3.

The spatial distribution of these soil nematodes showed aggregates and non-aggregated occurrences of these nematodes. Aggregates or clustering of nematode feeding groups were observed in 32% (30% + 2%, for 2 and 3 nematode groups respectively) out of the 50 sampling points on the field; while non-aggregated presence of nematode feeding groups occurred in 38% of the 50 sampling points. However, no nematode groups were observed in 30% of the sampling points (Table 3). With an occurrence of nematodes in 70% of the 50 sampling points, the spatial spread of occurrence of nematodes in the sampled points appear substantial.

A concentration of nematode feeding groups was not observed in any particular portion of the field, neither was there a concentration of aggregated groups of these nematodes in a portion of the field. This may perhaps be due to the characteristics of these groups of assayed nematodes, which are essentially migratory, especially after the second soil nematode extractive assay method (extraction tray method).

In respect of the occurrence of soil nematodes in fifty (50) sampling points, the lowest value was observed for omnivores and predators feeders (5(10%) and 8(16%) and respectively), and it was high for fungal, bacterial and plant feeders (10(19%), 14(28%) and 15(30%) respectively) (Table 4). The predator feeders with an abundance of 21(22.1%) seem to have an active role to play in the soil nematode group composition of this ecosystem in regulating the abundance and presence of plant herbivore feeding nematodes, while the high percentage of bacteria and fungal feeders help to regulate nutrients such as nitrogen, to support plant growth and health.

An examination of the function of these groups of soil nematodes at the several trophic levels of the food web reveal that 23.2% (22) occurrence based on count (abundance) of nematodes for the 1st trophic level which comprise mainly the herbivore feeders, 43.2% (41) in the 2nd trophic level made up of the bacteria and fungal feeders – their numerical strength in the soil reflecting the amount of bacteria and fungi in the soil (Ingham, 2012), and 33.7% (32) in the 3rd trophic levels which comprises the predator and omnivore feeders (Figure 1 and Table 2).

Nematodes may be useful indicators of soil quality; as their attributes of having diverse groups and types, coupled to the various functions at the different soil food web levels confer this attribute to them, which the trophic levels gives clue on. The numerical characteristics of nematode populations are known to vary with changes in land management methods which determine the soil micro-environment (Blair et al, 1996). The land management method tends to have a bearing on the soil quality or fertility. Invariably, farming systems (albeit land management methods) rely on organic and inorganic fertilizers (Feris et al, 1998). Thus, soil nematodes belonging to the 2nd trophic level had the highest abundance in % (43.2%), followed by the soil nematodes of the 3rd trophic level (33.7%) which are basically consumers some of which feed on the other nematodes of the first and second trophic levels. Thus, these nematode groups at the 3rd level may help to control the number and activity of herbivore-plant feeders on plants as the high % abundance of the bacteria and fungi feeders of the 2nd trophic level help in nutrient recycling activities in the soil. In addition, the impact of the trophic level soil nematode group abundance stratification ratio of 7:2 for 2nd + 3rd trophic level to 1st trophic level appear to be that which may assist in soil quality maintenance activities (Figure 1).
CONCLUSION

All five feeding groups of nematode were observed in the sampled and examined soil. The activity of some of the observed nematodes (bacteria and fungi feeders) are beneficial to soil fertility through recycling of nutrients while for one of the groups observed (herbivore feeders) - they may parasitize plants, yet some species among two of the observed groups (predator and omnivore feeders) may feed on other nematode groups, thereby helping in controlling the plant parasitic activities of one of the harmful groups to soil flora, such as agricultural crops. Thus, the assemblage of the composition of soil nematode groups in the sampled plot appears to have the capacity to form a community with diverse trophic structure in interactive soil biota ecosystem. This appears to be buttressed by an observation of aggregates of nematodes in some of the sampling points as a feature, while non-aggregates where also recorded alongside non-presence of nematode groups in some of the sampling points, soil nematodes were not observed. The spatial spread of soil nematodes in the sampled plot appear substantial and the abundance within the range of nematodes observable in soil at such a vegetational belt. These observations bear in mind that, the soil samples were collected using a systematic sampling method which has advantages for obtaining a good results and some limitations.

Challenges posed by the presence of soil nematodes may be experienced where good host crops are grown too frequently for long on the same land, albeit been determined by effectiveness of soil management methods. Planting of resistance varieties of crops help control some of the non-beneficial (harmful to soil flora) soil nematodes as a human created support to the natural control activities of some of the nematode feeding groups observed.

ACKNOWLEDGEMENTS

We appreciate Mr. Philip, a Laboratory technologist with the Department of Biological Sciences, University of Maiduguri, Nigeria, for provision of some of the laboratory materials utilized, which supported the ones we obtained.

CONTRIBUTIONS OF AUTHORS: Both authors contributed well to this study.

Author 1: Participated in the collection of soil samples, analysis of samples in the laboratory, wrote some portions of Introduction and results.

Author 2: Designed this experimental study, collected soil samples, provided the laboratory materials, supervised the study, analyzed the results, discussed the results and wrote the abstract.

BIOGRAPHY OF AUTHORS

Author 1: Usman Dauda D.

He completed his BSc Zoology from University of Maiduguri, Maiduguri in 2011 with 2nd Class grade, and had his BSc project in the field of Parasitology working on Nematology with Ozurumba L.N. as his supervisor by then. He is currently a Graduate Assistant, Department of Biological Sciences/Zoology with Taraba State University, Taraba State. He is married and with children.

Author 2: Ozurumba Leo Nnamdi

He graduated with PhD grade in MSc degree, finished among top 5/37 students in BSc degree-both from seasoned Nigerian Univs of Uni-Ibadan& OAU Ile-Ife in the ’90s, has Certificate training in Cellular& Molecular Immunology (Uni-Ib). He has been Resrch Asst at Uni-Ibadan (Cellular Parasitology; & Public Health) for 2yrs, Lectured on Part-time at Univ College Hospital Ibadan (Med Lab Sc);& on Full-time at Univ of Maiduguri (Bioscs)-for 5yrs.

He has published over 13 research articles in Nigerian Journals& abroad, published 2 books in Nigeria & Developed world in fields of Molecular Bio/Biotech relevant for BSc/BTech& PGD/MSc students. He has been Confidential Reviewer of Research Articles for Journals in Africa& Developed World- related to Parasitology & Medical Scs, Biology, Information Sc, Biotech, Molecular Bio& Stem Cell for at least 5yrs now-with useful experience. He has some management experiences at tertiary level.

He is a member of some professional science bodies like RSTMH (Full Fellow)-UK, SSTMP-Switzerland, Phagocyte Group- Europe& Nigerian PPSN- for over 8yrs now. He is involved in community development through
organizations like Rotary Club Int & Christian Agencies; involved in Christian soul winning privately under Christian organizations. He is engaged martially on path to family life; & very humble, social firm.

REFERENCES


