THE ROLE OF NEMATODE PREDATION IN SOIL FOOD WEBS

IRDA SAFNI, SP, MCP.
Fakultas Pertanian
Jurusan Hama dan Penyakit Tumbuhan
Universitas Sumatera Utara

1. Introduction

Food webs occur naturally between organisms that occupy the habitats in an ecosystem. Similarly, food webs occur in the soil environment between the plants and soil organisms. Soil food web is very important in agroecosystem, because the plants will not obtain enough nutrients for growth without the soil food web. Therefore, soil food web can be used as an indicator of the ecosystem health (Ingham, 1996).

According to Bloem et al (1997), soil food web is “a network of consumer resource interactions among different functional groups of soil organisms”. There are some process occur in the soil food web, namely decomposition of organic matter, mineralization of nutrients, cycling of mineral nutrients, and flowing of energy and nutrients between functional groups of organisms. Mineralization, which is the conversion of complex biopolymer into CO₂, H₂O, mineral N, P, and other mineral elements, is done by microbes, microbivores (grazers), and predators (Bloem et al., 1997). Then the primary decomposers (bacteria and fungi) release mineral nutrients for the growth of both plants and microbes (Ingham, 1996).

There are a lot number of microorganisms live freely in the soil, including beneficial species of bacteria, fungi, nematodes, and protozoa that make interactions among them. They give contribution to ecosystem with decomposing soil organic matter and mineralizing nutrients that depend on the population size, rate of energy use, and their ability to affect the functioning of the organisms (de Ruiter and Neutel, 1997).

In general, there are two groups of soil inhabitants, namely:

1. Fauna that occupy the soil solution
   e.g. protozoa, nematodes, and some of the enchytracid
2. Fauna that occupy the mineral soil
   e.g. collembola, mites, insect larvae, earthworms, and vertebrates (Benckiser, 1997).

Nematodes, microorganisms like-worms that live freely in the soil environment, marine and fresh water, are one of the soil microorganisms which have important role in the soil food web. In the soil, nematodes have a function to decrease the remains of larger animals and plant tissues (Dropkin, 1980).

This essay will describe the important roles of nematodes in the interaction among the soil microorganisms in soil food webs.
2. **The categorization of trophic groups of nematodes**

Based on feeding habits, nematodes, which are recognized as the major consumer group in the soil, can be divided into five categories, namely:

1. **Plant-feeding nematodes** (root-feeding nematodes; phytophages; plant parasites)
2. **Fungal-feeding nematodes** (fungivores; mycophages)
3. **Bacterial-feeding nematodes** (microbivores; bacterivores)
4. **Predatory nematodes**
5. **Omnivorous nematodes** (Zunke and Perry 1997; Norton and Niblack 1991; and Ingham 1996)

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**Figure 1.** Diagram of soil food webs from the Lovinkhoeve Experimental Farm (Netherlands) (de Ruiter *et al.*, 1997)

Plant-feeding nematodes which feed on higher plant usually have stylets to suck the nutrients from the plants which have a wide diversity of size and structure. This group of nematodes have an ability to cause plant disease and reduce crop yield (Yeates 1971 in Ingham, 1996)

Fungal-feeding nematodes, which feed on fungal mycellium, hyphae, conidia, including plant pathogenic fungi, have "protusible hollow stylets". For example, *Aphelenchus sp.*, *Aphelenchoides hamatus* (Zunke & Perry 1997; Ingham 1996)

Bacterial-feeding nematodes which feed on bacteria and other microflora have "a simple, open and unarmed stoma in the form of cylindrical or tringulartube, terminating in a teeth valve-like apparatus" (Nicholas 1975 in Ingham 1996). For example, *Acrobeles spp.* which are mainly live in sandy soil, *Bunonema sp.* which is found in moss, decaying vegetable matter, cow dung and rotting wood of bark beetle tunnels, *Rhabtis sp.*, *Acrobeliodes tricornis*, *Caenorhabditis elegans*, *Panagrolaimus subelongatus* (Zunke & Perry 1997; Laakso & Setala 1999).
Predatory nematodes that feed on other nematodes have "a large stylet or a wide cup-shaped cuticular line stoma armed with powerful teeth" (Nicholas 1975 in Ingham, 1996). For instance, *Mononchus spp.*, *Parazercon radiatus*. Omnivorous nematodes feed on algae, bacteria, fungi, protozoas, rotiferas, tardigrads, etc. For instance, *Dorylaimus spp.*, *Lysigamasus lapponicus* which feed on microarthropods (Laakso & Setala, 1999).

Figure 2. Interaction among organisms in soil food web. Arrows indicate the direction of the influence; + and - indicate a positive and negative effect. Bact = bacteria; Fungivore Nemas. = fungivorous nematodes; Inverts. = invertebrates; Myco. = mychorrhizae; Nema. Paras. = parasites and predators of nematodes; Omnivores Nemas. = omnivorous nematodes; Organic = organic matter; Plant para. Nemas. = plant parasitic nematodes; Pred. Nemas. = predatory nematodes (Freckman and Caswell 1985 in Norton and Niblack, 1991).

3. **Ecological importance of nematodes**

The nematodes species live in a variety of habitat, such as prairies, woodland, cultivated fields, etc. The abundance of nematodes depend on many factors, such as soil texture, soil structure, air and soil temperature, rainfall, soil moisture, evaporation, soil conductivity, pH, plant material and topography (Wallace, 1973).

Nematodes can be abundant in areas with a particular condition. In an experiment, Neher and Blair (1997) found that the number of nematodes increases in habitats with least moisture, and the number of nematodes decreased considerably in the aquatic areas. Temperature also affects the abundance of nematodes in the soil. The change of moisture and temperature may cause preventing the nematodes from persisting in the soil. For example, moisture and temperature become fluctuated due to the cultivation, and as a result the soil
structure changes. Consequently, the diversity of nematodes in the agricultural ecosystem is lower than in natural ecosystem (Norton and Niblack, 1991).

Besides that, nematode biomass also influence with the soil porosity. The total soil biomass was greater in sandy soils (0.6% of biomass C) than in loamy soils (0.3%) or clay soils (0.1%) lead to the influence of nematode (Badgett and Griffiths, 1997). This can occur because of the movement of the nematodes through soil pores. The nematodes can move in the soil more easily and more quickly.

Another factor that may affect the nematodes abundances is the soil depth. There are greatest numbers of nematodes at 5-10 cm depths and they decrease at 0-2.5 cm or warmer surface soil (Neher and Blair, 1997). It can occur due to the soil profile or different layers in forest litter (Bardgett and Griffiths, 1997). Besides that, some species of nematodes prefer different soil depth (Wallace, 1973)

4. The role of nematode in the soil

In the soil food web, the main function of nematodes is to decompose organic matter and mineralize nutrients. However, they can not decompose the organic matter or influence the mechanical and physical of the soil directly (Nielsen1967). There are several factors of indirect effects of microbial-feeding nematodes, namely, “the modification of the microbial community, accelerated turnover of microbial cells, and the inoculation of new substrates”. Consequently, bacteria and fungi as primary decomposer have important role of decomposition.

Primary decomposition begins with the living plant or with dead plant remains. After the organic matter is decomposed, the amount of organic matter, the availability of organic chemicals, and the ability of number of microorganisms decomposing substrate are reduced considerably.

According to Bardgett and Griffiths (1997), the consumption of microbial-feeding nematodes is:
5%-8% : organic matter input
5%-25% : the bacterial standing crop
4%-22% : contribution to total net nitrogen mineralization
10% : the ecological growth efficiency (production per consumption)

Compared to the five categories of nematodes, microbial-feeding nematodes (bacterivores, fungivores, and omnivores) and plant-feeding nematodes are more important in decomposition and nutrient mineralization than predatory nematodes. It probably leads to the abundance of the nematodes in environment, their high turnover rate, and the strong interactions with soil microbes (Laakso and Setala, 1999). Another reason is that the nematodes’ food comes from the microorganisms, microflora, and higher plants in the soil (Nielsen, 1967).

In addition, there is significant effect among bacterivores , fungivores, and predatory nematodes. In their experiment, Laakso and Setala (1999) found that predatory nematodes could be important regulators of microbial-feeding nematodes, because they can reduce the microbiovores’ biomasses.

Due to the feeding habits of nematodes are different, they are also have different role in soil food web. Plant-feeding nematodes are usually live in grass fields or other habitats with many vegetations (Nielsen, 1967). Of all nematodes, plant-feeding nematodes are deleterious to the plant growth, because they can
decrease the productivity of the plants with damaging the root systems. There are several control of plant-feeding nematodes, such as vesicular-arbuscular Mycorrhizal fungi, nematode trapping fungi, or other fungi and bacteria which can prevent the presence of the nematodes (Ingham, 1996).

Bacterial-feeding nematodes are dominant in forest litter, compost heaps, and agriculture and grassland systems (Ingham 1996; Nielsen 1967). This group of nematodes usually consume 106 bacteria per day, as a result net nutrient immobilization can increase whereas nutrient mineralization decrease (Ingham, 1996). The number of bacterivores can increase with the presence of plant-feeding nematodes which due to the greater distribution of the food source in the soil (Griffiths and Bardgett, 1997).

Fungal-feeding nematodes are dominant in the soil that is dominated by fungi, such as conifer and deciduous forests. The fungivores can consume the cytoplasm in 10-50 meters of hyphal length per day (Ingham, 1996). Both bacterivorous and fungivorous have more important role in soil food web rather than other types of nematodes. A large percentage of nitrogen is released by this group of nematodes when attacking their prey (Ingham, 1996).

Both predatory nematodes and omnivorous nematodes do not give as great contribution as bacterial-feeding nematodes and fungi-feeding nematodes. However, they also affect the chain of food in the soil. In his study, Laakso and Setala found that predatory nematodes could become important regulators for bacterial-feeding nematodes and then can affect the microbial activity. In contrast, omnivorous nematodes did not have strong effect on fungi-feeding nematodes (Laakso and Setala, 1999).

Table 1 below shows the nitrogen mineralization rates from different type of nematodes.

<table>
<thead>
<tr>
<th>Nematodes</th>
<th>CPER</th>
<th>LH-IF</th>
<th>LH-CF</th>
<th>HSB-NT</th>
<th>HSB-CT</th>
<th>KS-BO</th>
<th>KS-B120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbivores</td>
<td>1.12</td>
<td>0.16</td>
<td>0.12</td>
<td>0.11</td>
<td>0.10</td>
<td>0.004</td>
<td>0.06</td>
</tr>
<tr>
<td>Bacterivores</td>
<td>12.93</td>
<td>0.88</td>
<td>0.88</td>
<td>0.87</td>
<td>2.27</td>
<td>2.03</td>
<td>2.38</td>
</tr>
<tr>
<td>Fungivores</td>
<td>0.22</td>
<td>0.08</td>
<td>0.06</td>
<td>0.05</td>
<td>0.03</td>
<td>0.26</td>
<td>0.16</td>
</tr>
<tr>
<td>Predators &amp; omnivores</td>
<td>0.35</td>
<td>0.06</td>
<td>0.07</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Nitrogen Mineralization Rates (kg ha\(^{-1}\) yr\(^{-1}\)) of nematodes in different food web (CPER: Central Plains experimental Range-Colorado, USA, LH: Lovinkhoeve; IF: integrated farming; CF: conventional farming; HSB: Horseshoe Bend-Georgia, USA; CT: conventional tillage, NT: no-tillage; KS: Kjettslinge-Sweden; BO: without fertilizer; B120: with fertilizer)

5. Conclusion

Soil food web is a natural network of consumer resource interactions among different functional groups of soil organisms which occur in the soil ecosystem. There are several number of organisms contribute in this web, such as protozoa, nematodes, collembola, mites, insect larvae, earthworms, bacteria, and fungi.
Nematodes, which have a great number and live freely in the soil food web in decomposing soil organic matter and mineralizing nutrients.

Based on the feeding habits, there are five categories of nematodes, namely plant-feeding nematodes, fungal-feeding nematodes, bacterial-feeding nematodes, predatory nematodes, and omnivorous nematodes. Among all categories, bacterial-feeding nematodes and fungal nematodes have more important role of decomposing and mineralizing than other types of nematodes, and plant-feeding nematodes give negative effect on plant growth.
REFERENCES


