
The Role of Nematodes in Soil Fertility

Howard Ferris
Department of Nematology
University of California
Davis, CA 95616
(hferris@ucdavis.edu)

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Four of every five multicellular animals on the planet are nematodes. Many species are well known as important and devastating parasites of humans, domestic animals and plants. However, most species are not pests; they occupy any niche that provides an available source of organic carbon in marine, freshwater and terrestrial environments. There may be 50 different species of nematodes in a handful of soil and millions of individuals can occupy 1 m^2. Of the nematodes in soil that do not feed on higher plants, some feed on fungi or bacteria; others are carnivores or omnivores.

Nematodes respond rapidly to disturbance and enrichment of their environment; increased microbial activity in soil leads to changes in the proportion of opportunistic bacterial feeders in a community. Over time the enrichment opportunists are followed by more general opportunists which include fungal feeders and different genera of bacterial feeders (Bongers and Ferris, 1999). This succession of nematode species plays a significant role in decomposition of soil organic matter, mineralization of plant nutrients and nutrient cycling (Ingham et al, 1985; Hunt et al, 1987; Griffiths, 1990).

Bacterial-feeding nematodes have a higher carbon:nitrogen (C:N) ratio (± 5.9) than their substrate (± 4.1) 12 (Ferris et al., 1997), so that in consuming bacteria they take in more N than necessary for their body structure. The excess nitrogen is excreted as ammonia (Lee and Atkinson, 1977; Rogers, 1989). The C:N ratio of fungal-feeding nematodes is closer to that of their food source (Chen and Ferris, in press). However, for nematodes of both feeding habits, a considerable proportion of the C consumed is used in respiration (perhaps 40 % of the food intake (Ingham et al, 1985; Marchant and Nicholas, 1974)). The N associated with respired C that is in excess of structural needs is also excreted. The excreted N is available in the soil solution for uptake by plants and by microbes. Because microbivorous nematodes exhibit a wide range of metabolic rates and behavioral attributes, the contribution of individual species to nitrogen cycling and soil fertility may vary considerably.

By developing C and N budgets for individual nematode species, we calculated that the bacterial-feeding nematode community in the top 15 cm of a field soil mineralized N at rates increasing to 1.01 µg-N g-soil-1 d-1 in the rhizosphere (Ferris et al., 1995, 1996, 1997). In microcosm experiments we determined that rates of N mineralization by bacterial-feeding nematode species of different body size ranged between 0.0012 and 0.0058 m g-N nematode^{-1} d^{-1}, mainly as NH_4^+ (Ferris et al, 1998). The amount of N as NH_4^+ released from microcosms in which barley straw was colonized by the fungus *Rhizoctonia* sp. was always greater in the presence of the fungal-feeding nematode *Aphelenchus avenae* (Chen and Ferris, 1998).

In three years of field experiments we have demonstrated that N-availability in organic and low-input tomato production is enhanced by an abundance of microbial-feeding nematodes. The challenge is to manage the system so that those nematodes are in abundance at the start of the growing season. In our agricultural system we have shown that the constraining factor is usually soil moisture availability in the late summer and early fall of the previous year. By irrigating the soil at that time we can increase microbial activity and decomposition of crop residues. That provides substrate for the bacterial-feeding nematodes so that their population levels increase and remain at high levels until the next spring. In some cases the amount of C available to fuel the microbial community is also limiting and it may be necessary to incorporate organic material. Necessary approaches will vary with cropping system and climatic zone, but management of soil to enhance activity of bacterial- and fungal-feeding nematodes can increase soil fertility.

Soil nematode communities may also provide useful indicators of soil condition. Nematodes vary in sensitivity to pollutants and environmental disturbance. Recent development of indices that integrate the responses of different taxa and trophic groups to perturbation provides a powerful basis for analysis of faunal assemblages in soil as *in situ* environmental assessment systems. Application of nematode faunal composition analysis provides information on succession and changes in decomposition pathways in the soil food-web, nutrient status and soil fertility, acidity, and the effects of soil contaminants (Bongers and Ferris, 1999).

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Bacterial-feeding Nematodes and Soil Fertility

Soil fertility is a key determinant of the success of a farming system. Management systems that rely on organic i
have different dynamics of soil nutrient availability than systems receiving mineral sources. These dynamics are, as o
especially in the Mediterranean irrigated systems found in the Central Valley of California.

Though biological processes control the availability of many soil nutrients, interest in the soil biological commun
because high levels of mineral fertilizer overshadow or inhibit biological activities. Heavy applications of pesticides a
community and decrease rates of certain key processes, for example N mineralization. An understanding of soil biolo
cover crop systems where one relies on below-ground biota to liberate plant nutrients. Cover crops provide organic fo
quickly metabolized to inorganic nitrogen and other nutrients, primarily by bacteria and fungi. N is also mineralized
fungi, such as protozoa and microbivorous ("microorganism eating") nematodes, graze on prey which contain more N
predators. Although more research attention is given to the plant parasitic nematodes, microbivorous organisms make
nematode community. Excess N generated by grazing is released to the soil and becomes available for plant uptake.
cropping systems receiving organic inputs, it is important to understand what factors control the timing and release of
processes and how this relates to crop uptake requirements.

During the transition from a conventional to low input or organic management systems, there are many changes i
biological properties of soil. The changes result in part from significantly higher inputs of carbon associated with orga
reduction or termination of pesticide use. Studies from other regions of the U.S. indicate that it takes several years of
previously conventional soils to begin to function successfully in terms of nutrient cycling. Protocols of the Californi
(CCOF) Association require a three year transition period of organic management before a farm can be certified as org
requirement is driven primarily by the need to eliminate pesticide residues, this period may also allow time for the soil
to the higher rates of nutrient cycling required in an organic system. Limitation of crop growth due to nitrogen deficie
recognized problem during the transition period, but less is known about other nutrient limitations.

The transition period from conventional to organic farming can be problematic with regard to soil fertility. A nev
mineral fertilizers and pesticides, thus he or she may be more vulnerable to crop loss than the conventional farmer. Th
transition period when the soil biota may not be able to support the rates of cover crop decomposition needed to provic
in the early growing season. The low-input provides an alternative system, though lacking the economic incentives of
mineral fertilizer amendments and pesticides can be used as needed. On-farm comparisons of organic and convention
that organically-managed soils typically have lower inorganic N pools, higher microbial activity, and greater abundanc
feeding nematodes than conventional.

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