NEMATODES AND SOIL HEALTH

Anes K.M.
Corresponding author's email: aneskm@gmail.com

Introduction

Nematodes are numerically the most abundant metazoans on earth and second only to insects, in terms of diversity of forms (species) is concerned. Nematodes dwell in all types of habitats on the earth, from ocean depths to tops of mountains, from hot water springs to icy Arctic and Antarctic, from barren lands to cultivated fields, and from meadows to tropical forests. Most of the nematodes are free living which feeds on microorganisms. Nematodes also parasitize plants and animals. The parasitic forms have been studied in greater detail since they directly affect the human beings, their domesticated animals and crops. There is hardly any animal on earth, which is free from one or the other kind of nematode infection.

Nematodes as bioindicators

Biotic indicators of soil ecological health or condition can be used to assess the current status of vital ecological processes in soil and change in processes through time. Any indicator should reflect the structure and (or) function of ecological processes and respond to changes in soil condition that result from land-management practices.

Soil fauna have advantages over soil microbes as bioindicators. First, by being one or two steps higher in the food chain, they serve as integrators of physical, chemical, and biological properties related with their food resources. Second, their generation time (days to years) is longer than metabolically active microbes (hours to days), making them more stable temporally and not simply fluctuating with ephemeral nutrient flushes. Nematodes, Collembola, and mites are three groups of mesofauna that have been considered for use as biological indicators. Of these three groups, nematodes have been evaluated most often for their use as indicators.

Since the 1970s, nematodes have been used as environmental biomonitors for aquatic systems. For example, Panagrellus redivivus has been used as a biomonitor to detect toxin concentrations that affect molting and organism size through stimulation, inhibition, or lethality, and provides a rapid bioassay that costs less than 10% of a Salmonella bioassay. The nematode has been used to determine toxic effects of about 400 single chemicals.

Nematodes have several biological features that reinforce their use as indicators. First, nematodes have a permeable cuticle, which allows them to respond with a range of reactions to pollutants and correspond with the restorative capacity of soil ecosystems. Second, some nematodes have resistant stages such as cryptobiosis or cysts that allow them to survive inactively during environmental conditions unfavorable to growth and (or) development. However, some nematode taxa such as Dorylaimidae have no resistant stages, which may make them more sensitive to environmental change. Finally, nematodes have heat shock proteins that are highly conserved. Expression of these proteins is enhanced when exposed to stresses such as heat, metal ions, or organic toxins. Perhaps these proteins could serve as biomarkers for ecotoxicological assessment of soils.

Nematodes can be used as effective soil health bioindicators because they are commonly found, easy to sample, and well classified into functional (feeding) groups, and nematode taxa are well classified. Nematodes have diverse life strategies, ranging from colonizers (short life but high reproduction rate) to persisters (long life, but low reproduction rate). Furthermore, they have the ability to respond readily to changes in the soil's physical and chemical properties. Some nematodes can survive harsh, polluted, or disturbed environments better than others, and some have short life cycles and respond to environmental changes rapidly (e.g., colonizers).

Understanding nematode life strategies whether colonizers or persisters can provide information about the level of soil disturbances. Most importantly, nematodes have numerous interactions with other soil organisms and play important roles in soil nutrient cycling. Therefore, nematode faunal analysis provides an insight into soil food web conditions and associated soil health.

In terms of function, nematodes have different life strategies and feeding behaviors in the soil food webs. For example, at the bottom of the food chain are fast growing, fast-breeding, bacteria-feeding nematodes (bacterivores) and at the top are slow growing, slow reproducing, predatory nematodes. Generally after a soil disturbance, the soil community is dominated by the fast-growing, bacteria-feeding nematodes, then it slowly transforms into a more diverse community consisting of nematodes with various feeding groups (i.e., bacterivores, fungivores, omnivores, and predatory nematodes). Omnivorous nematodes feed on various soil microbes including bacteria and fungi and smaller nematodes. Omnivorous and predatory nematodes are typically the last groups of nematodes to colonize a soil ecosystem after a disturbance.

Role of nematodes in soil mineralization

In general, a healthier soil is composed of a diverse mixture of nematode feeding groups. Availability of nutrients from soil organic matter to plants relies on the mineralization (release) of nutrients from the organic matter. When organic matter is first added into the soil, it is in a form that is unavailable for plant uptake until it is decomposed by bacteria or fungi. After initial decomposition, some organic matter will be converted into an inorganic form that plants can uptake. However, these same bacteria or fungi may tie up (immobilize) nutrients in the soil until they are grazed by bacterivorous and fungivorous nematodes. However, overgrazing by these nematode groups can reduce the overall activity of bacteria and fungi. Fortunately, in the hierarchy of the soil food web, predators such as omnivorous and predatory nematodes, and mites, feed on these bacterivorous and fungivorous nematodes, thus allowing more nutrients to be released into inorganic form for plant to uptake. Thus, an increase in predatory nematodes may contribute to increased nutrient mineralization and associated plant productivity.

Under field conditions, bacterivorous and predatory nematodes are estimated to contribute (directly and indirectly) about 8% to 19% of nitrogen mineralization in conventional and integrated farming systems, respectively (Beare, 1997). Nematodes contribute to nitrogen mineralization indirectly by grazing on decomposer microbes, excreting ammonium, and immobilizing nitrogen in live biomass (Beare, 1997; Ferris et al., 1998; Ingham et al., 1985). Predatory nematodes also regulate nitrogen mineralization by feeding on microbial grazing nematodes, a conduit by which resources pass from bottom to top trophic levels (Wardle and Yeates, 1993). Although plants depend on nitrogen for their survival and growth, ecological disruptions such as cultivation or additions of mineral fertilizer increase nitrogen availability, sometimes in excess of, or asynchronous with, plant needs. Increased availability of nitrate and ammonium is associated inversely with successional maturity of nematode communities in cultivated mineral soils for agricultural purposes (Neher, 2001).

Nematode community analysis

Comprehensive studies on nematode faunal analysis have been conducted over the last few decades to validate that nematodes are good soil health bioindicators. Four nematode community indices commonly used as soil health indicators are maturity index (MI), enrichment index (EI), structural index (SI), and channel index (CI). MI weighted mean of the colonizer-persister (c-p) values of nematodes in all trophic groups, it provides the stability of the nematode community in the soil food web. EI depicts whether the soil food web is enriched with nutrients, whereas SI illustrates if the soil communities are stable and stress enriched stable enriched stress depleted stable depleted Increase organic inputs EI Reduced tillage SI. A Simplified Food Web Structure on Enrichment Index (EI) and Structure Index (SI) trajectories 4 undisturbed. CI indicates whether the soil food web is diminished by stress or limited in nutrient resources. To give a general perspective, perennial cropping, reduced-till farming systems, and undisturbed natural ecosystems such as forests usually have higher MI and SI than most conventional tillage agro-ecosystems. Conversely, soil recently amended with manure or other organic matter with high N content would have higher EI than those fertilized synthetically. Soil that is drier or being fumigated would have higher CI than soil without external stress. Without high biological diversity, a soil ecosystem would be vulnerable to environmental changes, disturbances and other stresses. Nematode community indices were correlated with concentration of many soil nutrients, microbial biomass, plant growth, and even foliar insect damage. Therefore, using nematodes as bioindicators reflects both soil biotic and a biotic factors (e.g. toxin, nutrients), and provides insight into soil health.

Conclusion

In conclusion, it makes ecological sense to use nematodes as bioindicators of soil condition. Nematodes represent a central position in the soil food web and correlate with ecological processes such as nitrogen cycling and plant growth. Although there are few persons trained and few commercial laboratories available to identify free-living nematodes in large numbers of samples, nematode taxonomy is more extensively developed than the taxonomy for other soil fauna such as mites, protozoa, and collembolans. Priority research areas for implementation of nematodes as indicators of soil condition across large geographic scales include verification of life-history characteristics, feeding preferences, identification of key taxa, correlation of key taxa to disturbance, and calibration of indices relative to ecosystem, climate, and soil type.