NEMATODES AS INDICATORS OF SOIL HEALTH

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Why nematodes? Soil provides many ecological services essential for agriculture. Some services, such as soil mixing and the recycling of nutrients, are supplanted by farming practices. Other services, such as biodegrading pesticides and impeding nitrate leaching, are difficult to mimic so farmers rely on natural soil processes. The quality and 'health' of a soil can be evaluated by measuring variables reflecting the service, e.g. plant-available N, rates of decomposition, nitrate levels in groundwater, or by taking stock of the soil organisms that collaborate to provide the service. Microbes, particularly bacteria, are the life forms most responsible for mineralization, decomposition, regulation of noxious organisms, and immobilization of nutrients destined for groundwater, but they are difficult to capture and even more challenging to quantify. Larger life forms, such as beetles and earthworms, are relatively easy to study and their population dynamics may track that of microbes, but only loosely since they do not rely on microbes for their diet. The search for easy-to-study organisms with activities and abundance reflective of microbial communities led ecologists to nematodes, a most diverse and successful phylum only one step above microbes in the soil food chain and represented in every soil on earth.

Nematodes are worm-like invertebrates that number more than any other multi-cellular animal on earth. Nematodes live in animal or plant hosts, water, and soil. Although some nematode parasites of large animals can measure meters in length, most nematodes are less than one millimeter long, which accounts for soil populations as high as fifteen thousand per cup of soil. The majority of nematode species in soil eat bacteria, but some dine on fungi, some on plants, and others on animals, including fellow nematodes. They are perfectly suited for census studies because all soil dwelling nematodes, no matter their diet, are about the same size and captured in a single soil assay. Another feature that makes them amenable for study is that they can be 'sorted' into their different types by amateur taxonomists because their transparent bodies reveal mouthparts and digestive systems that are distinctive for the food they eat. Nematodes that eat bacteria have mouthparts completely different from those that eat fungi, which facilitates assigning specimens a trophic level function.

Nematodes that eat bacteria and fungi are not only useful to soil scientists as indicators of microbial abundance, but also to the microbial populations they eat. Nematodes ingest excess nitrogen in order to fulfill their need for carbon so even as they eat bacteria they expel nitrogen-rich wastes that are immediately available to the surviving bacteria (and plants) for growth and reproduction. Studies of microbial activity and biomass in the presence and absence of nematode predators show the value of predation for microbes, rates of decomposition, and nutrient turnover in soil. Given the diversity of diets within the nematode community, nematodes play vital roles in the soil food webs that provide infrastructure for ecological services. Indices based on nematode communities provide important insights into "who" is in the soil and importantly, "who" are they interacting with.

Procedures for using nematodes as ecological indicators: Soil samples are collected using standard practices for evaluating soil fertility. A general recommendation is to represent five acres by no fewer than 20 soil cores that can be bulked, mixed, and subsampled for nematode assay. Nematodes are collected from 100 cc of soil using only an incubation technique or a

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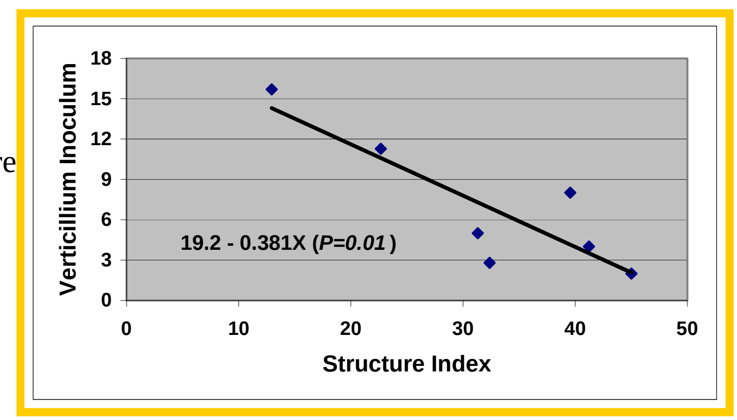
combination of sieving/centrifugation and incubation techniques. The nematodes recovered are stored in water and observed using a microscope. Only a portion of the nematodes, generally 100-200, are identified to the appropriate taxonomic or trophic grouping. These procedures are identical to those used to assay for plant pathogenic nematodes and can be performed at the same time.

Indices based on nematode communities: The total abundance of nematodes in a soil reflects general soil conditions and varies with percent organic matter, sand, pH, soil moisture, and other general attributes. Some nematodes are vulnerable to disturbance or pollution with pesticides or other chemicals and one active area of research is to identify species whose presence or absence is indicative of particular conditions. Indices based on taxonomic diversity, richness, and evenness have been applied to nematodes and the analyses consistent with studies for other organisms. The most widely used application of nematode census data involves grouping nematodes according to their ecological strategy. A "maturity index" (MI), developed by T. Bongers, is computed by calculating a weighted average for the community based on five groups that range from colonizers (short life cycles, high reproductive rate, ability to quickly exploit ephemeral resources) to persisters (long-lived nematodes that require more stable environments). Soils with low MI nematode communities tend to have suffered recent tillage or pesticide disturbance and have short simple food chains with a disproportionate representation of bacteria in the microbial community. The MI has been refined and serves as the basis for other indices that estimate the predominant decomposition pathways, food web status, and disturbance as reflected by the presence of opportunistic nematode species.

Application in Wisconsin: We've used nematode community analysis to compare the impact of different corn-based cropping systems on soil health, to monitor change due to the incorporation of cover crops, and to study the impact of soil fumigation on soil-borne disease in potato cropping systems.

Figure 1 shows the correlation between the nematode structure index, an estimate that increases in value when long-lived species with low fecundity predominate the community and the inoculum potential of the fungus responsible for Verticillium wilt, a chronic disease in Wisconsin potato fields. These data suggest that stable environments favoring nematode species susceptible to disturbance also favor the Verticillium fungus, which is known to be a poor competitor with other soil fungi. We are now determining if monitoring these soils for nematode community structure has predictive value for the potato early dying disease. This relationship could have practical value since it is much easier and reliable to monitor the abundance of nematodes versus fungi.

Figure 1. Propagules of *Verticillium dahliae* per gram of soil from potato fields with nematode communities composed primarily of short-lived opportunistic species (low structure index) or long-lived species sensitive to disturbance (high structure index).



Looking ahead: The impact of several plant parasitic nematodes for crop yields underscores the importance of evaluating soil for nematodes. The fact that a single assay can be used to diagnose the status of the soil food web as well as a specific pest problem encourages advances that facilitate the process. There are several labs that now offer nematode community analyses and more are likely to in the future. Currently, the technology is most used for research – to understand relationships among soil organisms and the impact of farming practices on soils. These studies reveal the biological complexity of soil and help us understand the "who, where, and why" of the ecological services we depend on. The challenge is to use this understanding to develop the means to monitor agricultural soils to protect those that are productive and to restore ecological functions to those degraded by misuse.

References

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