PLANT AND SOIL NEMATODES

NEMATODES: ONE OF THE MOST USEFUL INDICATORS OF A SOIL'S BIOLOGICAL STATUS

Bacteria and fungi are the most abundant organisms in soil and it is often assumed they provide the best indication of a soil's biological status. However, the problem with measuring soil bacteria and fungi is that they occur in enormous numbers and there are thousands of different species. Also, their life cycles are relatively short and so bacterial and fungal populations change rapidly in response to changes in environmental conditions such as moisture and temperature. Nematodes are generally considered to be better biological indicators and this fact sheet explains how they can be used to check whether a soil is in good condition from a biological perspective.

Why are nematodes good biological indicators?

There are several reasons why nematodes are commonly used as biological indicators.

- Nematodes occur in all soils. Even in relatively poor soils, there will be up to a million individuals in every square metre
- Nematodes are readily extracted from soil and their food sources can be determined by looking at their mouth parts under a microscope (see Fact Sheet PSN 023)
- Nematodes feed on plant roots and all the organisms that live in soil (e.g. bacteria, fungi, algae, diatoms, protozoans, rotifers, tardigrades, arthropods, oligochaetes, and nematodes). Thus, the number and types of nematodes in soil is determined by the availability of these food sources
- Nematode numbers fluctuate in response to the population dynamics of the organisms they consume, and are also influenced by the soil physical and chemical environment

What is nematode community analysis?

Nematode community analysis involves collecting a representative soil sample from a field, extracting the nematodes, counting them, and identifying the nematodes present to genus or family level. However, specialist taxonomic skills are required to identify nematodes to that level, and so categorising the nematodes by their feeding habits is an alternative. Six nematode feeding groups occur in soil (plant parasites, plant associates, bacterial feeders, fungal feeders, omnivores, and predators), and they can be differentiated by observing the oesophagus and mouth parts.

Understanding the life histories of various nematode groups is also useful when interpreting the results of a nematode analysis. A coloniser-persister (cp) scale is commonly used, where nematode families and genera are given a cp rating of 1 to 5 that is related to their rate of reproduction.

- Colonisers (cp-1) are small nematodes with high reproductive rates, and they complete their life cycles in only a few days. They feed opportunistically on the bacteria associated with decomposing organic matter and colonise habitats following disturbance or after a new food source becomes available.
    - The most common colonisers are a group of bacterivores known as **enrichment opportunists**. These nematodes produce large numbers of eggs, and so populations increase rapidly when a bacterial food source is available. These conditions occur when organic matter is added to soil or is incorporated into the soil by tillage. Nematodes feed on the bacteria associated with decomposing organic materials, and their populations increase to very high densities within a few days. When microbial biomass decreases, they cease feeding and become dormant.
- Persisters are at the other end of the reproductive spectrum (cp-5). They are large nematodes that may take up to several months to complete their life cycles. These nematodes are very sensitive to disturbance, and once lost from the soil food web it may take months or years for them to return.
    - Omnivores feed on many different soil organisms, but being relatively large, they will be affected by the tillage practices often used in agriculture. They are also sensitive to pollutants and to excessive inputs of nitrogen fertiliser. Their presence indicates that the

soil food web is diverse and relatively stable, whereas their absence is a warning sign that the soil biology has been disrupted or is depleted.

- Predators prey on other nematodes. Some have an open mouth armed with teeth, while others use a spear to pierce their prey or feed on nematode eggs. Most predatory nematodes have relatively long life cycles and are sensitive to pollutants, and so they have similar characteristics to omnivores.

What information can be gained from nematode community analysis?

Counting the nematodes extracted from soil and then subdividing them by feeding group and life-cycle length is a good way of obtaining a picture of what is happening within the soil food web. Some examples of the type of information that can be obtained from nematode community analysis are given below.

- A high ratio of bacterial- to fungal-feeding nematodes indicates that organic matter is predominantly being decomposed by bacteria rather than fungi, and that rapid nutrient cycling is occurring. It is also indicative of high nitrogen inputs or recent tillage.
- A predominance of fungal-feeding nematodes indicates that the detritus decomposition channel is dominated by fungi, and that biological nutrient cycling will be relatively slow.
- Low populations of omnivorous nematodes indicate that the soil biology is being affected by pollutants or excessive fertiliser inputs. It also indicates that the soil may have been subject to disturbance through practices such as tillage.
- High populations of omnivorous and predatory nematodes indicates that the soil is biologically complex and resilient, and has some innate capacity to suppress populations of plant-parasitic nematodes and other soil borne pathogens

The table below provides an example of what is commonly seen when Australian soils are assessed. The nematode community in many agricultural soils is dominated by plant parasites, and the few free-living nematodes that are present are predominantly bacterivores. In contrast, healthy soils have many more free-living nematodes and a more balanced nematode community, with relatively few plant-parasitic nematodes and a greater range of free-living nematodes.

A healthy soil	Typical agricultural soils
>25 free-living nematodes/g soil (but with no predominant feeding group)	2-10 free-living nematodes /g soil
Plant parasites comprise <10% of the nematode community	50-80% of the nematodes are plant parasites
A good balance between fungal- and bacterial-feeding nematodes	More than 80% of the nematodes are bacterivores (i.e. relatively few fungal-feeding nematodes)
Reasonable numbers of omnivorous and predatory nematodes	Omnivorous and predatory nematodes rarely seen

Nematode community analysis from a grower's perspective

There are many tests that can be done to assess the health of a soil but growers interested in a soil's biological status should certainly consider submitting a sample to a nematologist with expertise in identifying plant-parasitic and free-living nematodes. A simple nematode community analysis such as the one discussed above should be relatively inexpensive and will give the grower some indication of the biological health of the soil in the field from which the sample was obtained.

The reason such results will not be definitive is that the nematode community is influenced by many factors, but particularly soil type and climate. For example, a clay loam soil will not sustain the same range of nematodes as a nearby sandy loam, even if the cropping program and management practices are similar. Differences in the nematode community will also occur if the soil type at two nearby locations is the same, but different amounts of rainfall are received. Thus, how does a grower use nematode community analysis to determine whether the management practices being used on the farm are having a beneficial or detrimental effect on the soil biological community?

The best way to address this issue is to sample a permanent pasture that is growing at a nearby location with a similar soil type and climate. Provided the pasture has been consistently productive, has been in place for many years, and has never been disturbed by tillage or high inputs of fertiliser or pesticides, it will be supporting the type of nematode community that is optimal for that location. Collect samples from the pasture, have them analysed, and compare the results to those obtained from similar soil types on the farm. If the results indicate that soils on the farm are not as healthy as the soil under the pasture, then aim to improve the situation by modifying soil and crop management practices.

Although nematode community analysis is a worthwhile test to assess soil health, it is important to also measure soil carbon levels. Carbon is the food source that sustains the soil biological community, and it is the first parameter that should be measured. Differences in soil carbon content will indicate whether the soil at one location is healthier than another location, or whether the health of a soil that is being monitored regularly is gradually improving over time. Once the results of carbon analyses have been interpreted, the results of nematode community analyses can be used to determine whether plant-parasitic nematodes are likely to be causing damage, whether nutrients are being mineralised rapidly, whether the soil has a good balance between bacteria and fungi, and whether the soil biological community has the potential to suppress pest outbreaks.

Further reading

Sanchez-Moreno S, Ferris H (2018) Nematode ecology and soil health. In Sikora et al. (eds.) *Plant parasitic Nematodes in Subtropical and Tropical Agriculture.* 3rd edition. CABI, Chapter 3, pp. 62-86.

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Other nematology fact sheets in this series can be accessed at: https://www.appsnet.org/nematodes