Nematodes as soil health indicators

Can we solve the soil puzzle for to optimise plant growth?

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Soil is an important microbiome for life. It supports plant growth, which in turn acts as a centre of activity for a plethora of soil biota. As a result, soils have been a key subject for science. Geophysical, chemical and biological aspects all play a role in what defines a soil. Gathering knowledge on the interactions between soil aspects brings us step-by-step closer to fully understanding how soil works. Nematodes are commonly found soil inhabitants that occupy all most key trophic levels. As such, nematodes can be used as reference organisms to deepen our understanding of soil. However, before nematodes can be used as indicators, one needs to detect them first.

Soil as a living organism

Soil is defined as the upper layer of earth that supports plant growth. This fact alone already makes soil an important subject in agriculture. Without a nutritious soil, crops cannot grow. The ability of soils to sustain plant growth is influenced by a myriad of factors, including physical, chemical and biological factors (Sassenrath et al., 2018).

The physico-chemical aspects of soil, such as composition, water retention and nutrient availability, are readily explored based on the abundantly available literature on the topic. However, the soil is still one of the most complex biomes we know of from a biological perspective. Biological aspects of soil are hard to assess, as soil organisms all influence one another, as well as the environment itself (Kibblewhite et al., 2008; Lehman et al., 2015). For that reason, reference organisms are used to identify the occupied roles in a soil ecosystem (Cluzeau et al., 2012).

Soil health

As mentioned before, soils rely on several interconnected aspects to support life. Therefore, it is difficult to evaluate how a soil performs based on just a few metrics. Therefore, the term soil health was described. Soil health is defined as the ability of soil to function as a living ecosystem to provide for a wide biodiversity and sustainable agriculture (Doran & Zeiss, 2000; Gao et al., 2020; Kibblewhite et al., 2008). For soil health assessment, four metrics are used to evaluate how healthy a soil is (Kibblewhite et al., 2008):

1. Carbon transformation
2. Nutrient cycling
3. Soil structure maintenance
4. Regulation of soil biota

With these metrics, the abstract concept of soil health is made specific.

Role of nematodes in soil health assessments

Nematodes are microscopically small roundworms. They can be found on each continent and occupy most key trophic levels. Due to their great abundance and diversity, many nematodes have been clearly described at genus level. These aspects give nematodes a great potential as soil health indicators (Bongers & Ferris, 1999, Melakebarhan et al., 2021). By analysing their life cycles, one can correlate the presence of nematodes with the presence of other soil organisms and chemicals. As a results, an indicatory food web can be constructed with the nematode as the centre piece (Gao et al., 2020; Wagg et al., 2014). This already covers point 4 of the soil health metrics.

Additionally, nematode community compositions have been correlated with mineral and nutrient cycling (Neher, 2001) and carbon aggregation in the soil (Martin & Sprunger, 2021). As a result, nematodes are an almost ideal indicator organism for soil health assessments. However, before one can analyse soil health this way, the nematode community needs to be identified first.

Identification of nematode taxa

Soil nematode communities can be analysed to identify the taxa within the community. Since the 19th century, nematodes were identified based on their morphological characteristics through microscopic analyses (Seesao et al., 2017). This way of identifying nematodes is falling out of fashion and makes way for molecular techniques, like Next Generation Sequencing (NGS). Metabarcoding through NGS can be used to identify taxa. Hereby, a highly conserved gene sequence is analysed for its variety in certain regions of the gene. These varieties are then used as a barcode to identify an organism, in this case members of a nematode community (Capra et al., 2016; Kawanobe et al., 2021; Morise et al., 2012; Sikder et al., 2020).

In the end, sequence analysis of soil nematode communities tell which taxa are present in the soil. These taxa can then be correlated to an ecosystem function. However, this assessment only explains the qualitative aspect of the nematode community. Fortunately, soil nematode communities can also be quantified.

Quantification of nematode communities

To quantify soil nematode communities, Real-time PCR can be used. Hereby, a set of primer pairs targets and amplifies DNA from the main representatives of each trophic level in the soil nematode community. The Real-time PCR can quantify the present DNA to assess the relative abundance of the trophic levels in a soil nematode community. In the future, the measured amount of DNA may even be related to the absolute number of nematodes in the sample.

Future prospects of nematode-based soil health assessments

Nematodes are clearly harbour a great potential as soil health indicators. Currently, this practice is still poorly studied. With modern and future methods, nematode communities can be assessed with increased ease. Despite the possibility to assess nematode communities, more specific correlations need to be made between community and soil health metrics. Once these correlations have been established, it is only a matter of connecting the dots to develop a suitable soil health index.

Soil health is only at the start of uncovering the secrets the soil has to offer. Most studies cover linear interactions between soil organisms and characteristics. However, the soil is so complex that no linear interactions could fully explain it. In the future, multi-dimensional studies that integrate multiple soil organisms and geophysical-chemical properties can be used to explain the inner workings of soil in greater detail. Nematodes are, again, a key player, due to their wide niche occupation. Nematodes can be integrated into soil interaction webs to ultimately assess soil health for ecological and agricultural use.

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