Using nematodes as bio-indicators of soil health

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2nd Annual Soil Health Day
Joostenbergvlakte
March 2018
Contents

- What is soil health?
- How does soil biology work for you?
- How do you measure it?
- How do you achieve it?
- Why consider it?
- Root health
What is soil health?

Three components

- Physical
  - Texture & Pore size
- Chemical
- Biological
  - Soil biodiversity
  - Organic carbon
  - Microbial biomass
  - Pests and diseases

Nutrients

Soil health support centre: measuring the heartbeat of soil life
Nutrient cycling

Photosynthesis

\[ \text{CO}_2 \]

\[ \text{CH}_2\text{O} \]

(sugars, amino acids, organic acids)

Complex C:
(Cellulose, lignin, tannins)

Excretions include water soluble and root diffusible nutrients

Excretions include 9 to 30% N

Bacteria

Fungi

Protozoa

Nematodes

Sun energy
Carbon released by the plant

1. Root cap + epidermis cells
2. Insoluble glues
3. Soluble root exudates
4. Volatile organic C
5. C to mutualistic fungi
6. C from dead plant cells

How does it work / function?

Plant Soil (2009) 321: 5 - 33
How does it work / function?

Two examples

• Mycorrhizae
• Nematodes
Mycorrhizae
• Fungi that colonize plant roots
• Very common in soil
• Live together with most plant families – except Brassicas
• Form structures that take up nutrients more effectively – arbuscles, vesicles and hyphae
• Transfers phosphorous to plants - in return receive sugars from plant roots
Many reasons why mycorrhizae are important (16)…

A. Increased yield
B. Free phosphorous
C. Drought tolerance
D. Biocontrol
Lekberg and Koide (2005) examined 290 field and greenhouse experiments published between 1988 and 2003. They found that...

In general, increased root colonization resulted in a yield increase of 23% across all management practices.
Mycorrhizae – free phosphorous

Assimilated carbon

Nutrient supplementation

C

P

Arbuscule

Nutrient supplementation

Arbuscules

Vesicle

Root cells

Hyphae

AMF Structures

©Nemlab
Mycorrhizae – drought tolerance

How much water can they really provide to a plant?

Ruiz-Lozano & Azcon, 1995
Expansive AMF network signals the whole fungal network that it is being attacked. In turn a signal is switched on which allows the plants to turn on their defence mechanism.
What is a nematode?

- Microscopically small
- Unsegmented organisms
- Length between 0.1-1mm
- Vary in shape
- Occur in groundwater in the soil
- Feed on various organisms in the soil
What is a nematode?
<table>
<thead>
<tr>
<th>Nematode Feeding Group</th>
<th>Feeding Habits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unicellular feeders</td>
<td>Unicellular eucaryote feeding: yeast, algae, lichen</td>
</tr>
<tr>
<td></td>
<td>Feed on bacteria: use hollow tube</td>
</tr>
<tr>
<td>Bacterivores</td>
<td>Feed on fungi: stylet punctures hyphae</td>
</tr>
<tr>
<td>Fungivores</td>
<td>Feed on/in plant roots: use stylets</td>
</tr>
<tr>
<td>Herbivores</td>
<td>Feed on more than one type of food source: org. material etc</td>
</tr>
<tr>
<td>Omnivores</td>
<td>Feed on other nematodes: puncture with tooth</td>
</tr>
<tr>
<td>Predators</td>
<td>Feed on insects (and bacteria) no stylet</td>
</tr>
<tr>
<td>EPNs</td>
<td></td>
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</tbody>
</table>
The different nematode feeding groups - 7

- Feed on bacteria
- Extensions make wave-like movements

- Feed on fungi
- Stylet pierces hyphae

- Feed on plant roots
- Has a stylet

- Feed on other nematodes
- Tooth-like structure tears apart nematode

Free-living nematodes
Ecosystem service providers
– what can they do for you?

- Break down organic material
- Redistribute minerals and nutrients - can contribute between 9 to 30% of total mineralizable N to the soil
- Sequester carbon
- Improve soil structure
- Can regulate other diseases
- Can cause economic crop losses
Nematodes as bio-indicators of soil health

- simple / easy to sample and analyse
- relatively easy to measure
- have a best time to sample
- present in poor and healthy soils
- reliably assess impacts of practices
- provide useful information
- cost-effective test

Pick me!
The nematode faunal profile to measure soil health has a number of steps:

1. Identify nematodes to family level

2. Classify into feeding groups
The different nematode feeding groups

- **Unicellular feeders**
  - Unicellular eucaryote feeding: yeast, algae, lichen

- **Bacterivores**
  - Feed on bacteria: use hollow tube

- **Fungivores**
  - Feed on fungi: stylet punctures hyphae

- **Herbivores**
  - Feed on/in plant roots: use stylets

- **Omnivores**
  - Feed on more than one type of food source: org. material etc

- **Predators**
  - Feed on other nematodes: puncture with tooth

- **EPNs**
  - Feed on insects (and bacteria) no stylet
The nematode faunal profile to measure soil health has a number of steps:

1. Identify nematodes to family level
2. Classify into feeding groups
3. Allocate cp-values to each family
## Colonizer-Persister Scale

### cp value (1-5)

<table>
<thead>
<tr>
<th>Colonizer - cp1</th>
<th>Persister - cp5</th>
</tr>
</thead>
<tbody>
<tr>
<td>- short life cycle</td>
<td></td>
</tr>
<tr>
<td>- small body size</td>
<td></td>
</tr>
<tr>
<td>- highly prolific</td>
<td></td>
</tr>
<tr>
<td>- mainly bacterivores</td>
<td></td>
</tr>
<tr>
<td>- feed continuously</td>
<td></td>
</tr>
<tr>
<td>- longer life cycle</td>
<td></td>
</tr>
<tr>
<td>- larger body size</td>
<td></td>
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<tr>
<td>- less prolific</td>
<td></td>
</tr>
<tr>
<td>- mostly carnivores &amp; omnivores</td>
<td></td>
</tr>
<tr>
<td>- very sensitive to disturbances</td>
<td></td>
</tr>
</tbody>
</table>
The nematode faunal profile to measure soil health has a number of steps

1. Identify nematodes to family level
2. Classify into feeding groups
3. Allocate cp-values to each family
4. Calculate various indices using equations and the above
5. Draw up a nematode faunal profile model
6. Interpret the results
### Ecological Indices

<table>
<thead>
<tr>
<th>Index</th>
<th>Value %</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI = Structure Index (soil food web)</td>
<td>36.36</td>
<td>Soil food web structure increasing</td>
</tr>
<tr>
<td>EI = Enrichment Index</td>
<td>85.11</td>
<td>Enrichment highly N enriched but not decomposed</td>
</tr>
<tr>
<td>CI = Channel Index</td>
<td>0.0</td>
<td>Decomposition channel is bacterial</td>
</tr>
<tr>
<td>BI = Basal Index</td>
<td>13.73</td>
<td>Bacterial dominated system with abundant resources and fast nutrient turnover</td>
</tr>
<tr>
<td>FBI = Fungivore-Bacterivore Index</td>
<td>0.0</td>
<td>System busy recovering from stress</td>
</tr>
</tbody>
</table>
C. Nematode Faunal Profile Result

Sector A
- Enriched but unstructured
- Highly disturbed

Sector B
- Enriched and structured
- Low to moderate disturbance

Sector C
- Resource limited
- Structured

Sector D
- Resource depleted
- Minimal structure

Sweet Spot!

Aim for annuals
Aim for perennials
<table>
<thead>
<tr>
<th>TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvita 24 hour CO$_2$-C Burst test</td>
</tr>
<tr>
<td>Aggregate stability test</td>
</tr>
<tr>
<td>Haney Soil Health fertility analyses</td>
</tr>
<tr>
<td>Solvita SLAN Test</td>
</tr>
<tr>
<td>Standard chemical analyses using Mehlich 3 as extractant</td>
</tr>
<tr>
<td>Mycorrhizae colonization percentage</td>
</tr>
<tr>
<td>Nematode Soil Health Analyses</td>
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</tbody>
</table>
How do we achieve it?

**Cover!**

**Diversity**

**Living roots**

**Reduced tillage**
How do we achieve it?

- Compost – serves as an inoculant
- Cover ..... eg straw, wood chips, cuttings etc
- Cover crops
- Weeds
- Compost tea
- Vermicast
- Manure
Cover crop choices…

• Preferably a mix
• Include a grass, a brassica, a legume, a broadleaf (and a radish) …
• Issues addressed when selecting a choice:
  – reduce compaction
  – increase organic material (biomass)
  – stimulate soil biology
  – reduce erosion
  – add nitrogen
Root health

- ‘Plant Growth Promoting Rhizobacteria’ (PGPR’s) bv *Bacillus*
- Mycorrhizae
- Endophytes eg *Trichoderma* spp
- Root stimulants containing auxins & cytokinins
  = biological supplements or amendments

Mulch  Compost
Why consider soil health?

<table>
<thead>
<tr>
<th>Soil is a non-renewable resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic material content = humus = sponge</td>
</tr>
<tr>
<td>Increased water holding capacity</td>
</tr>
<tr>
<td>Excellent habitat for rich soil microbe diversity</td>
</tr>
<tr>
<td>Improved aggregate stability / soil structure</td>
</tr>
</tbody>
</table>

Together, the hyphae and glomalin form a sticky net that traps particles of sand, silt, clay and organic matter and holds them together to form lumps or aggregates of soil.
Healthy soils are the foundation for everything

**Carbon sequestration = helps climate change**

**Improved nutrient cycling**

**Decreased run-off and evaporation**

**Increased water infiltration – no crusting**

**Low weed and pathogen pressure**

**Resilience = ability to recover**

**Healthy soils are the foundation for everything**
Unlocking the soil health in South Africa!
Acknowledgements

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