PLANT AND SOIL NEMATODES

BIOLOGICAL CONTROL OPTIONS FOR PLANT-PARASITIC NEMATODES: BIONEMATICIDES OR A CONSORTIUM OF NATURAL ENEMIES ACTING TOGETHER IN A HEALTHY SOIL?

In many modern crop production systems, chemical pesticides are the primary means of keeping plant-parasitic nematodes under control. However, these chemicals are sometimes toxic to humans, may persist in the environment for many years, and are usually detrimental to non-target organisms. Thus, growers and the wider community are demanding safe and effective biological products that can be applied in much the same way as chemicals. This fact sheet looks at whether this approach is likely to be successful against plant-parasitic nematodes, or whether enhancing the natural suppressive services that keep nematodes under control in healthy soils is a better approach.

The biopesticide market

Although biopesticide sales are only a small proportion of worldwide pesticide sales, the market is changing rapidly. Major chemical companies are moving to biologicals and many small companies are also marketing biological products because they are seen as 'safe' and 'environmentally sound'. Thus, the global biopesticide market, which was worth about US$5 billion per annum in 2020, is expected to grow at an annual rate of more than 10% over the next few years.

Biological products for nematode control

A huge range of fungi, bacteria, mites, and predatory nematodes are known to parasitise or prey on plant-parasitic nematodes or have other detrimental effects. Two books (Askary and Martinelli, 2015; Bilgrami and Khan, 2022) provide information on these organisms, but focus on issues such as mass production, formulation, commercialisation, packaging, quality control, shelf-life, registration, and application methods. Thus, biological control of nematodes is simply viewed from a commercial perspective: can the organism be mass produced and sold as a biological nematicide?

I would argue that this is the wrong approach for several reasons. First, it will be impossible to mass produce some biocontrol agents and dispense them in a commercially acceptable manner (e.g. certain groups of mites and predatory nematodes). Second, a range of products will be required for nematodes that have quite different life cycles and habitats, and so the cost of producing and distributing these relatively specific nematode-control products to a small component of the pesticide market will be prohibitive. Third, it will be difficult to establish an introduced organism in the ecologically complex and highly competitive rhizosphere environment where plant-parasitic nematodes are living and feeding.

As the production of biological products for nematode control is only likely to be successful in specific and quite limited circumstances, the remainder of this fact sheet focuses on an alternative approach that is more likely to be more effective.

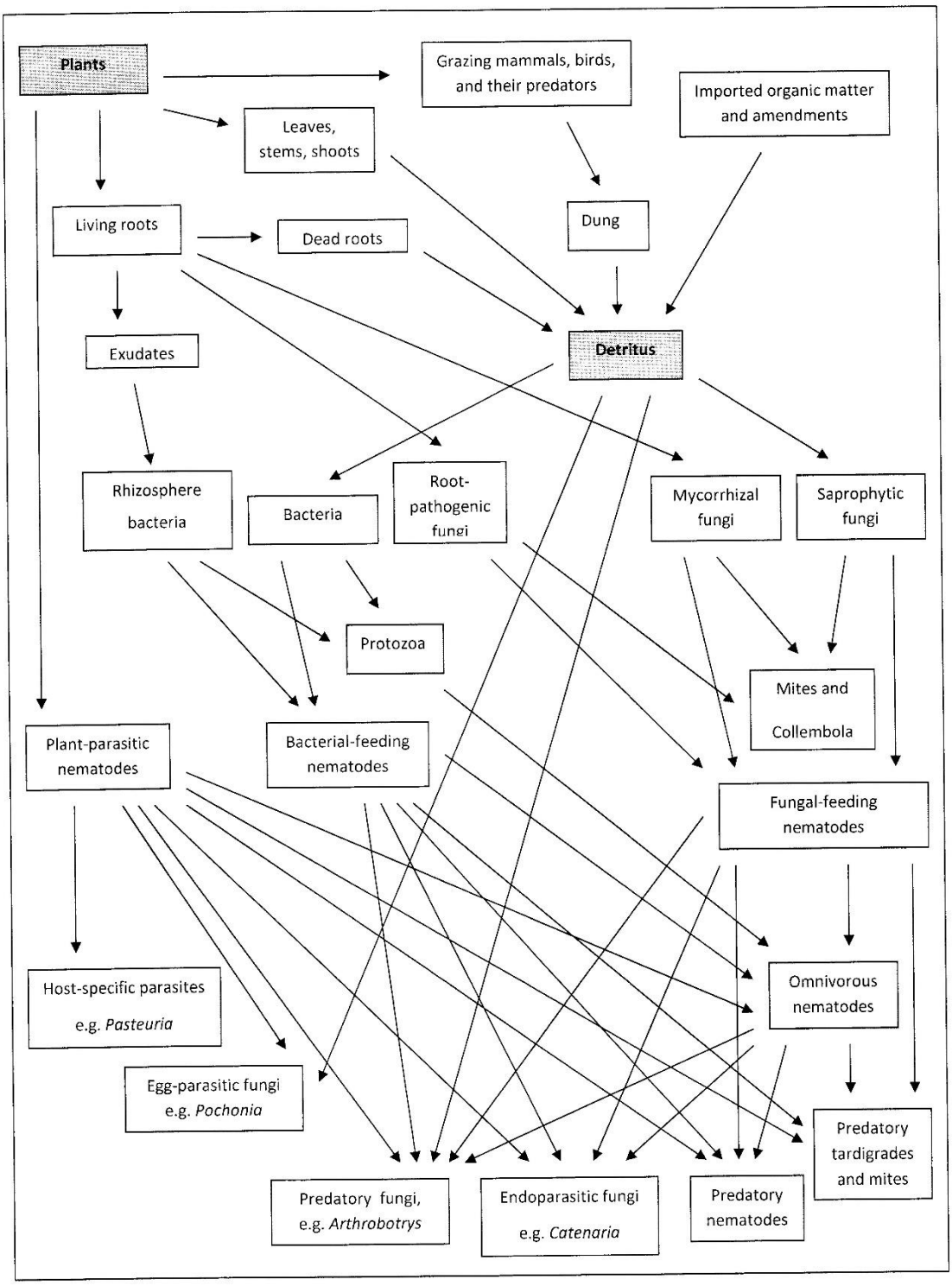
The soil biological environment in natural ecosystems and agricultural soils

The relatively stable behaviour of animal populations in natural environments and healthy soils should serve as a reminder that in nature, all organisms are subject to a constant series of checks and balances. Populations of individual species do not increase indefinitely but are constrained by the community of organisms that live with them. Cyclic changes in populations will occur but provided there is no major change in the environment, populations will fluctuate between certain upper and lower limits. This phenomenon, commonly referred to as 'the balance of nature', stabilises animal population densities and it applies to all organisms, including plant-parasitic nematodes. The problem in agriculture is that the soils in which crops are grown are biologically degraded, and so the regulatory mechanisms that should be keeping plant-parasitic nematodes under control are not operating effectively. Thus, I would argue that biological control is really about maintaining, restoring, or enhancing the natural suppressive mechanisms that exist in all soils.

Organic matter-mediated biological suppression

As shown in the soil food web diagram below, inputs of organic matter play a key role in enhancing a soil's capacity to suppress populations of plant-parasitic nematodes. Organic matter from plants and detritus is decomposed by bacteria and fungi, and they are then consumed by protozoans, free-living nematodes, microarthropods, and other soil organisms. The free-living nematodes, together with the plant parasites,

then become a food source for nematophagous fungi, nematodes, mites, and tardigrades, and their feeding activities cause nematode populations to decline. As this whole process is dependent on inputs of organic matter, it is sometimes referred to as 'organic matter -mediated biological suppression'.



A diagrammatic representation of a soil food web showing that inputs of organic matter from plants and detritus produce a diverse community of organisms that parasitise or prey on plant-parasitic nematodes

Farming systems to enhance nematode-suppressive services

The problem in most cropped soils is that levels of soil organic carbon have declined markedly, and so nematode suppressive services are no longer operating effectively. The most practical way of overcoming this problem is to reduce the frequency and duration of bare fallow periods and include perennial forages, high residue crops and cover crops within the farming system. Successive inputs of organic amendments at affordable application rates will also be useful. When used collectively, these practices are the first step towards increasing levels of soil organic matter and enhancing a soil's suppressiveness to nematodes.

The second step involves reducing tillage, as conventional tillage causes greater losses of soil organic matter than any other farm management practice. When soils are no longer tilled, decomposition proceeds more slowly because crop residues remain on the soil surface rather than being incorporated into the soil. Reducing tillage also has profound effects on the detritus food web, the most obvious effect being retention of larger organisms such as predatory and omnivorous nematodes, microarthropods, enchytraeids, earthworms, beetles, and spiders that are often killed when soil is tilled.

Once the first steps have been taken to improve the biological health of the soil, other beneficial practices included in the table below can then be integrated into the farming system to further improve the activity and diversity of the soil biological community. This community of organisms will provide many benefits, but from a nematological perspective, the following three are important.

- Populations of plant-parasitic nematodes will be suppressed to some extent
- The crop will benefit from the nutrients mineralised by free-living nematodes
- Tolerance to any damage caused by plant-parasitic nematodes will improve due to improvements in the physical and chemical health of the soil

Generalised effects of agricultural management practices on nematode-suppressive services

Tactics detrimental to the organisms that provide nematode suppressive services	Tactics that tend to enhance nematode suppressive services
• Frequent tillage, aggressive tillage	• No-till, minimum till, strategic tillage
• Bare fallows	• Cover crops
• Monoculture	• Diverse crop rotations, intercropping, a pasture phase in the rotation
• Random traffic from farm machinery	• Controlled traffic
• Removal of crop residues	• Retention of crop residues as mulch, amending soil with organic matter
• High inputs of inorganic fertilisers at a single time	• Banded fertilisers, split fertiliser applications, controlled release formulations, organic fertilisers, manures
• Weeds controlled primarily with herbicides	• Weeds controlled primarily by mulching and/or cultural methods
• Pests and diseases controlled with pesticides	• Integrated pest management

Conclusions

When a farming system is modified to improve soil biological health, populations of plant-parasitic nematodes will be suppressed by a consortium of organisms that are adapted to the local environment. Suppression is less likely to occur when a bionematicide is applied, as the introduced biocontrol agents will find it difficult to compete with the huge number of organisms already established at the root/soil interface.

Literature cited

Askary TH, Martinelli PRP (2015) Eds. *Biocontrol Agents of Phytonematodes*. CAB International, Wallingford.
Bilgrami AL, Khan A (2022) Plant nematode biopesticides. Elsevier, Academic Press.

Further reading

More detail on the issues discussed in this fact sheet can be found in the following book chapter.

Stirling GR (2011) Biological control of plant-parasitic nematodes: an ecological perspective, a review of progress and opportunities for further research. In: Davies, K. & Spiegel, Y. (eds) *Biological Control of Plant-parasitic Nematodes: Building coherence between microbial ecology and molecular mechanisms*. Springer, Dordrecht, pp. 1-38.

Author: Graham R Stirling, Plant and Soil Nematodes. **Contact details:** graham.stirling@biolcrop.com.au