FACT SHEET
APRIL 2022 | ©Perennia 2022

NEMATODES: SOIL PARASITES OF ROOTS

Plant Parasitic Nematodes

Plant parasitic nematodes are soil-inhabiting microscopic worms with a body length of less than 1 mm. They are ubiquitous, found in all climates and every type of soil. They use a stylet, a needle shaped structure, and a battery of proteinaceous enzymes to puncture and parasitize roots and underground parts (e.g., rhizomes, tubers) of live host plants. Based on their feeding behaviour, they can be classified into ectoparasites, migratory endoparasites and sedentary endo-parasites. The ectoparasites (e.g., Dagger nematodes; *Xiphinema* spp.)(Figure 1) remain in the soil and feed on the epidermal or the outer cortical cells of roots. Migratory endo-parasitic nematodes (e.g., Root lesion nematodes; *Pratylenchus* spp.) penetrate roots and feed on cell contents, but they remain mobile and can switch their feeding site. Sedentary endo-parasitic nematodes (e.g., Root knot nematodes and cyst nematodes) become sedentary after root penetration and remain associated with their feeding sites. A proper identification of nematode species diversity and population density are important aspects for their effective management.

Figure 1. *Microscope image of a dagger nematode (Xiphinema spp.).*

Nematode Damage and Symptoms

Plant parasitic nematodes rank amongst the most difficult pests to diagnose, identify and control due to their presence in soil. Their effects are often underestimated by farmers, agronomists and pest management consultants. Plant-parasitic nematodes have been reported to reduce global agricultural production by 12%, with annual crop losses worth $ 173 billion globally. The damage caused by nematodes is often non-specific and easily confused with symptoms of other abiotic or biotic stresses. For example, chlorosis of leaves may be confused with nitrogen deficiency, but nematodes may also be the cause. Similarly, a poor crop stand in small patches may be attributed to poor soil fertility or moisture stress, but nematodes can also cause identical symptoms. Some of the aerial symptoms (Figure 2 and 3) associated with nematode feeding of roots are chlorosis (yellowing) of foliage, patchy/stunted growth, wilting, leaf rolling, die-back of perennial or woody plants, reduced fruit and seed size, failure to respond to fertilizers, higher density of weeds than actual crop and greater disease incidence to other fungal and bacterial pathogens. Below-ground symptoms on the roots may be more specific and require uprooting of plants without damaging their root system. The symptoms on roots (Figure 4 and 5) may include galling, shortened, stubby or abbreviated roots, excessive root branching, root lesions, tuber necrosis, tuber cracking, forking of carrots, cysts or 'pearly' root and altered root architecture.

***Figure 2**. Chlorosis and reduced growth in onions (left side is displaying nematode related damage, right is healthy with limited nematode related damage).*

***Figure 3**. Patchy growth and stunting of apple nursery plants.*

***Figure 4**. Stubby roots of apple due to root lesion nematode.*

***Figure 5.** Carrots infected with root knot and root lesion nematodes.*

Hosts of Plant Parasitic Nematodes

Plant parasitic nematodes differ in their host range. Some species of root knot nematodes (*Meloidogynes arenaria, M. hapla, M. incognita, and M. javanica*) have a wide host range (500 plus). However, some species have a restricted host range (*M. partityla*, *M. kralli*, and *M. ichinohei*). Similarly, potato cyst nematode (*Globodera rostochiensis* and *G. pallida*) has a restricted host range (Solanaceous family members), whereas *Heterodera schachtii* (Beet cyst nematode) can parasitize about 218 plant species.

Sampling for Plant Parasitic Nematodes

The nematode populations are not evenly distributed in the field, and the number of soil samples from an area will determine the precise estimate of its population density. Nematodes are quite sensitive to environmental conditions, so sampling should occur when soil temperatures are consistently 10°C and the soil is moist. It is very important to follow a consistent sampling style and pattern (Figure 6). Larger fields should be divided into units of 1 hectare, and these units should be sampled separately. Generally, 10 to 50 sub-samples (cores) are taken from 0.5-1.0 hectare of land at a soil depth of 10-20 cm. Soil sub-samples can be taken using an auger, corer, spade, or similar implement that is suitable for the crop being sampled. Sub-samples are combined and mixed, after which a composite sample of 1-2 kg is submitted to the lab within 24 hours for estimating nematode population density. Soil samples should be put into a plastic bag, and stored under shade or in an insulated container. The root sample should always accompany soil; otherwise, nematode can desiccate and die. Care should be taken not to sample dead plants and from too wet/dry soil.

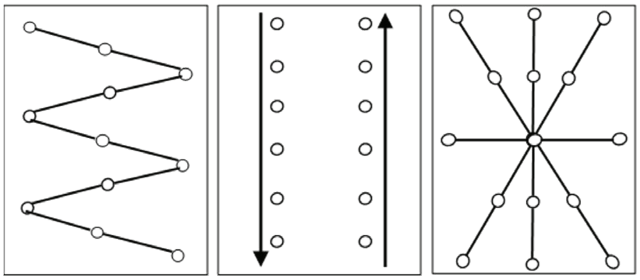

***Figure 6**. Different sampling schemes for taking a systemic soil sample for nematode analysis.*

Accurate estimates of nematode population density will ensure the success of IPM practices, and it will require analysis of soil samples from a standardized lab. In reality, the relationship between nematode numbers and yield is quite complex, and it depends on prevailing field conditions such as soil texture, soil pH, cultivar resistance status, soil nutritional status and available moisture. Sandy soils inherently have less moisture and limited nutrients available, and, in this case, the economic threshold of nematodes will be low. But clay loam soils hold more moisture and nutrients, and the crop can tolerate a much higher number of nematodes, which will determine if a control strategy should be implemented or not. Some of the important cultural control strategies include using nematode-free planting stock, following a proper crop rotation, using well-drained soils with limited periods of soil saturation, and maintaining soil structure by adding organic matter.

Integrated Pest Management Practices

Understanding plant parasitic nematodes host range can help in their effective management by including a proper crop rotation in the integrated pest management (IPM) program. Select cover crops (Figure 7) can act as non-host/non-susceptible to nematodes and limit their survival and reproduction. For example, the Canadian Forage Pearl Millet 101 (CFPM 101) effectively reduces the population density of root lesion nematodes. Likewise, Sudan grass, barley, oats and rye are effective in reducing the population density of root knot nematodes. In addition, Marigold has been proven to be effective against different species of parasitic nematodes. Therefore, correct species identification of plant parasitic nematodes is crucial to devise any control strategies. The importance of correct species identification and recommending a crop rotation can be deciphered by the following example of two root lesion nematode species. Research on the host range of root lesion nematode has shown that field pea, narrow leaf lupin and fava bean can limit the population density of *P. neglectus* but are highly susceptible to *P. penetrans*.

***Figure 7**. Nova Scotia demonstration site: vegetable field rotation, from left, brown mustard (common), fall rye, pearl millet, "bare ground"/volunteer wheat, sorghum-Sudangrass, brown mustard (Centennial).*

Nematode control options depend upon the intensity of cropping and the value of the crop. In the case of field crops, the use of nematicide is not cost-effective on a large area. Thus, the use of crop rotation and resistant varieties seem to be a good strategy. In the case of intensively managed fruits and vegetables, tree fruit (Figure 8), and ornamental crops, nematicides and soil fumigants had been preferred. But due to health and environmental concerns, many of the effective fumigants such as methyl bromide have been withdrawn from the market, and more attention has been given to IPM where available control options are used in a compatible manner to reduce the nematode population density based on a tolerable economic threshold. The success of IPM depends on sampling protocols for estimating nematode population density and its distribution pattern, as this information will establish a relationship between nematode density and its impact on yield.

Figure 8*. Orchard field preparation demonstration trial comparing the effect on nematodes of pre-plant cover crop (brown mustard), pre-plant fumigation (black tarp), and post plant treatments bare ground).*

Nematicides are chemical compounds that are lethal to nematodes (prevent respiration), whereas the 'nematistat' are chemical compounds that at sub-lethal doses disrupt nematode behaviour and they are unable to locate their host plants. The biochemical effect of nematistat is reversible, and the nematode population often bounces back after few months. Nematicides can be applied as pre-plant soil fumigants where the entire field is treated and sealed, or they can be applied on the foliage, chemigation or in drenches. Soil fumigation is a technique whereby chemical liquids, or solids, are incorporated into the soil where they volatilize, move through air spaces in the soil as a gas and provide control of a range of pests, weeds and disease. Some of the examples of fumigant nematicides are chloropicrin, metam sodium and dazomet. The effectiveness of soil fumigants can be greatly influenced by several soil factors: texture, structure, organic matter, moisture content and temperature at the time of application. Coarse-textured soils can generally be fumigated more easily than fine-textured (clay) soils, as the coarse sandy soils contain more voids per unit volume. Unfortunately, this also makes them more reliant on good sealing. Clay and organic matter can adsorb large quantities of the applied chemical, making it necessary to apply it at a higher rate.

Similarly, soil compaction can restrict gaseous movement and result in poor fumigant penetration and thus poor nematode control. It is useful to maintain soil moisture between 30-70% of field capacity. The label should be followed strictly as subsequent planting shortly after fumigation can cause phytotoxicity in emerging young plants. The application method depends on the crop of interest and nematode species. It is recommended to incorporate nematicides to a depth of 5-15 cm depending upon crop and nematode species being addressed. A shallow incorporation will not treat enough soil to give satisfactory returns in terms of crop yield and nematode control.

An integrated approach should be targeted to maintain the nematode population density below economic thresholds. Reliant only on nematicide can disrupt the soil health by targeting beneficial micro-organisms in the soil. It is important to estimate nematode population density and its species diversity before planting from a recognized lab such as Perennia's Plant Health Lab.