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FACT SHEET

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APPLE REPLANT DISEASE IN NOVA SCOTIA

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INTRODUCTION

Apple trees that have poor health and productivity when planted on old orchard soil often suffer from apple replant disease. Replant disease is established in all apple growing regions of the world, including orchards in Nova Scotia. In a perennial system like tree fruit, failure to manage replant disease will restrict productivity for the life of the tree (15+ years).

The disease is caused by several pathogens and parasites whose existence and role in growth reduction can vary by region and site. The disease may be present even when standard practices for control are followed. Standard practices are currently based on limited knowledge of the disease, so as knowledge improves, management practices will also adapt. This factsheet will discuss the biology and the applied management of apple replant disease in Nova Scotia.

DISEASE SYMPTOMS

Replant disease is not new, but it has become more prevalent with investment by the apple industry in orchard renewal using high-value varieties in high-density plantings. During the early years of a young orchard planting, the goal is to encourage tree growth. Apple replant disease can significantly restrict tree growth **(Figure 1).**

Figure 1. *Greenhouse trial in 1999 showing a) untreated topsoil from Nova Scotia orchard, b) sterilized topsoil from Nova Scotia orchard, c) untreated potting mix.*

The symptoms of apple replant disease include:

- Stunted tree growth and poor shoot growth
- Uneven growth within rows (aggravated differences during years with water stress)
- Short internodes
- Small root systems and decaying roots
- Few new lateral or feeder roots (witch's broom appearance)
- Death of young trees
- Two to three years late into production
- Lower yield than healthy trees

The symptoms can be mistaken for poor-quality nursery stock, nutrient deficiency and root rot.

THE CULPRITS: PATHOGENS AND PARASITES

Replant disease is complex because it is caused by several pathogens and parasites acting together, including some that have not yet been identified. The causal organisms are specific to each region, and in Nova Scotia the disease is attributed to the pathogens – Pythium, Phytophthora, Rhizoctonia, Cylindrocarpon, and the parasite – root lesion nematode (Pratylenchus penetrans). Knowledge of the soil biology of apple replant disease can help drive decision-making to maximize productivity in an orchard.

PATHOGENS

Pythium, Rhizoctonia, Phytophthora and *Cylindrocarpon* are commonly present in soil systems, and cause disease when a plant's defenses are poor. In the absence of a plant host, they persist in soil for many years in protective structures. Periods of sustained soil moisture can activate and distribute these pathogens. Poor growth in apple trees can be related to the infection of young tissue like root tips, and the release of systemic toxins and growth-inhibitors.

ROOT LESION NEMATODES

Of the parasitic nematodes, the root lesion nematode is the most economically important for apple trees in the Annapolis Valley. In the fall of 2017, several orchards in NS reported damage to young trees due to high populations of root lesion nematodes on replant sites. Reports of root lesion nematodes in orchards of the Annapolis Valley date back to at least 1976.

The root lesion nematode is a worm-like organism that is invisible to the naked eye, and lives in soil and plant root tissues **(Figure 2).** Nematodes become active when the soil warms up in spring, live inside roots especially during hot, dry summers and continue to be active in the fall before the soil freezes. They are not overly mobile and stay within 1-2 meters of the root zone they infect. When the root is depleted of nutrients, the nematodes begin feeding on a neighbouring tree.

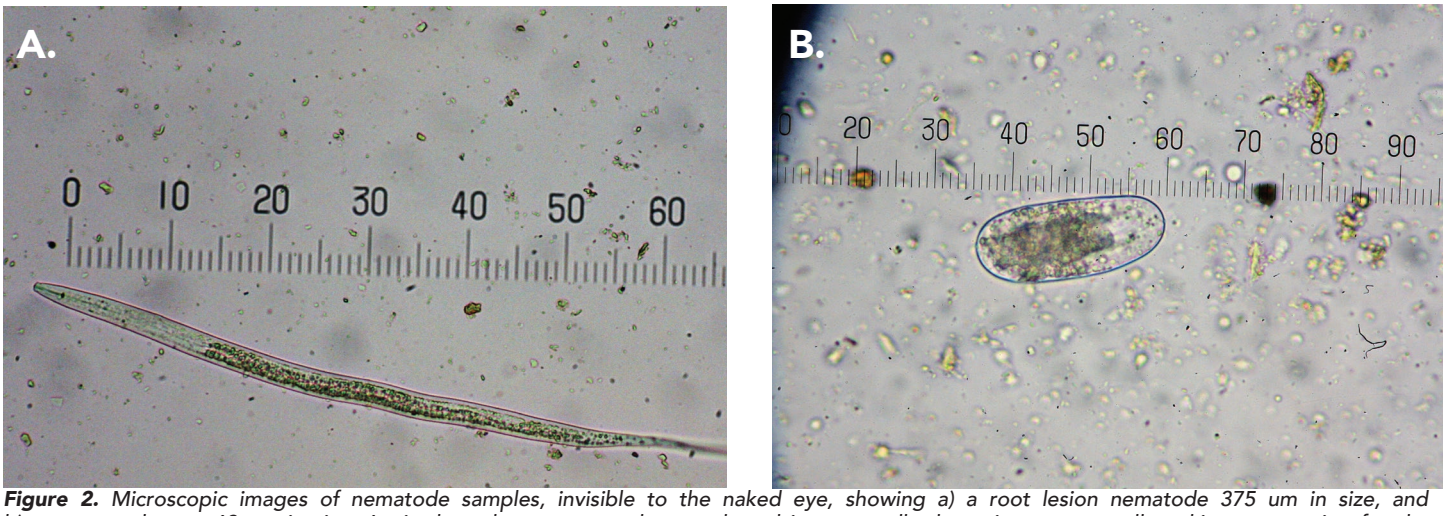

Figure 2. *Microscopic images of nematode samples, invisible to the naked eye, showing a) a root lesion nematode 375 um in size, and b) a nem-atode egg 63 um in size. A pin-shaped structure at the mouth end is repeatedly thrust into a root cell, making an opening for the nematode to enter and eat. Root lesion nematod.*

The root lesion nematode parasitizes tree roots by penetrating the root tissue and feeding inside root cells, thereby stunting trees. The most noticeable symptom of nematode damage in orchards is a random distribution of stunted trees, where high populations of nematodes have parasitized specific trees (**Figure 3**). Nematode feeding constricts the roots causing the plant to respond by growing new roots, which creates an extensively branched root system **(Figure 4**). The wounds created by nematodes are also entry points for plant pathogens that compound the problem.

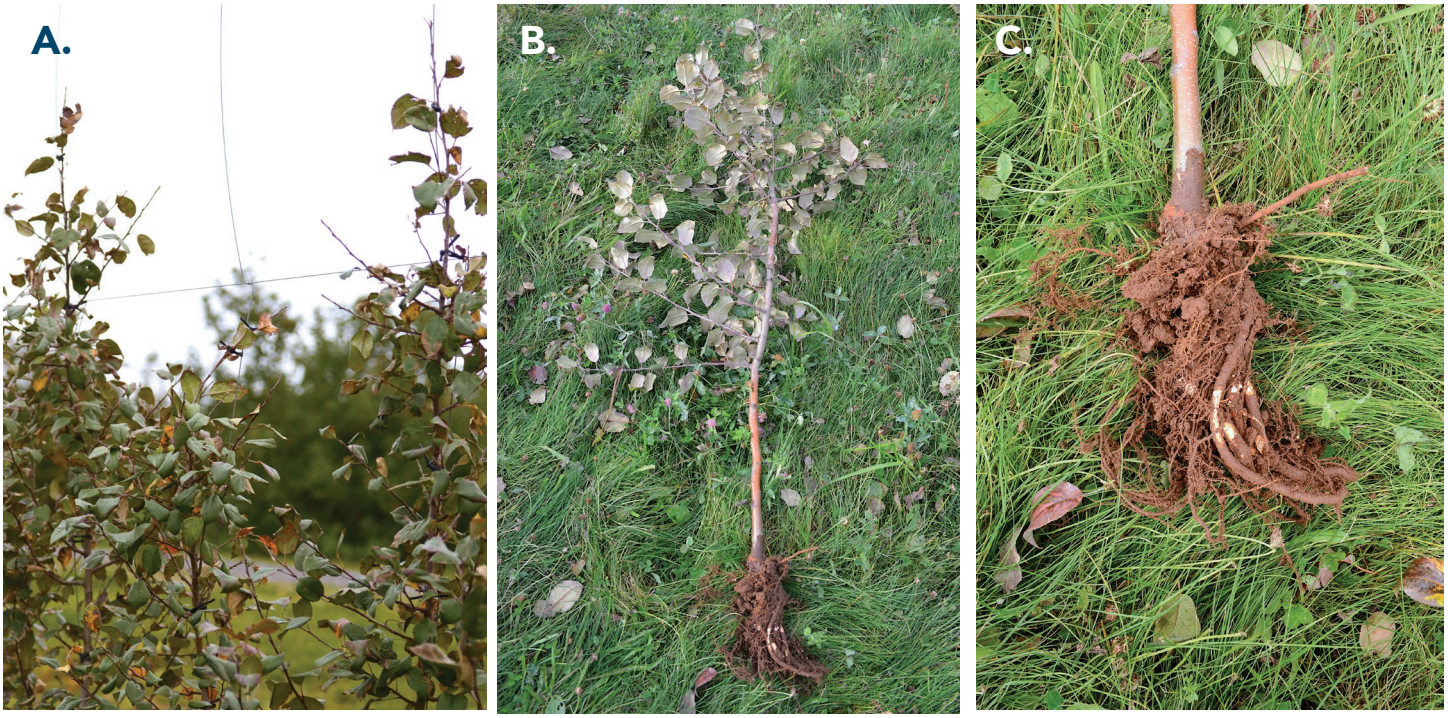

Figure 3. *Symptoms of feeding damage caused by high populations of root lesion nematode including a) uneven plant growth and weakening in areas of high nematode populations, b) stunted tree growth due to poor root structure, and c) "witch's broom" appearance of roots with excessive branching but lacking fine feeder roots.*

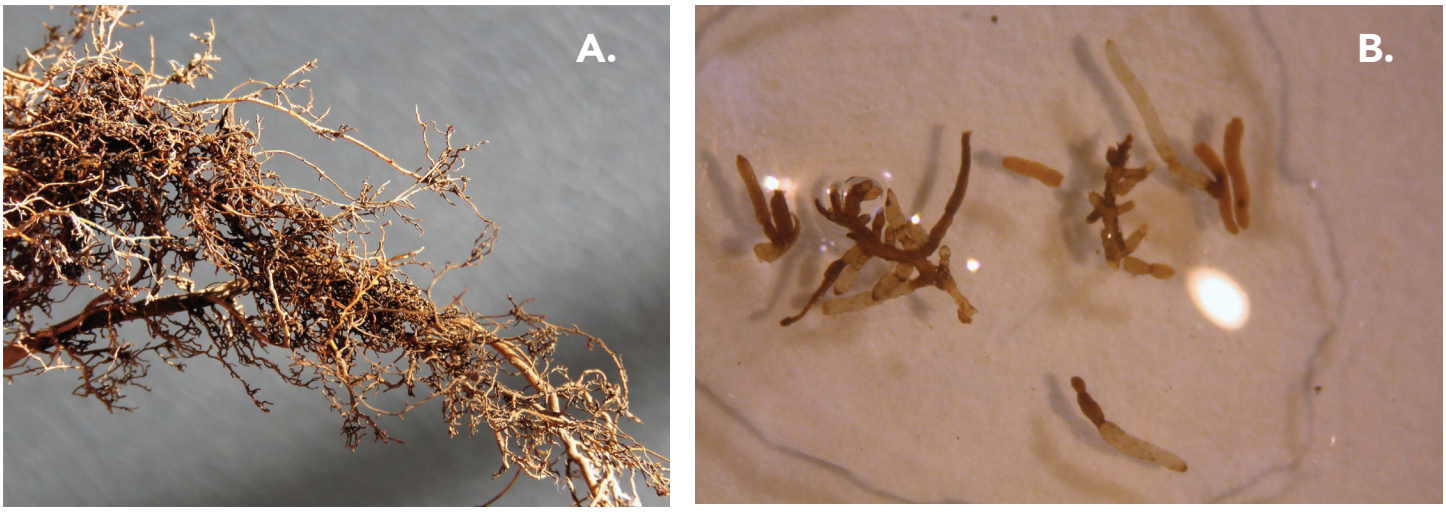

Figure 4. *The root of a young apple tree showing a) extensive branching following root lesion nematode feeding, and b) damage on the fine feeder roots. Pythium and Rhizoctonia were also colonizing the roots – the classic trio in replant disease. Photos by Paul Hildebrand, Hildebrand Disease Management.*

BEST MANAGEMENT PRACTICES

The cause of apple replant disease varies by region and site. Site-specific management, using a series of steps, can help lessen the disease pressure so trees can reach their potential **(Figure 5)**. The emphasis is on prevention and pre-plant management because limited practices are available to manage replant problems after plants are established.

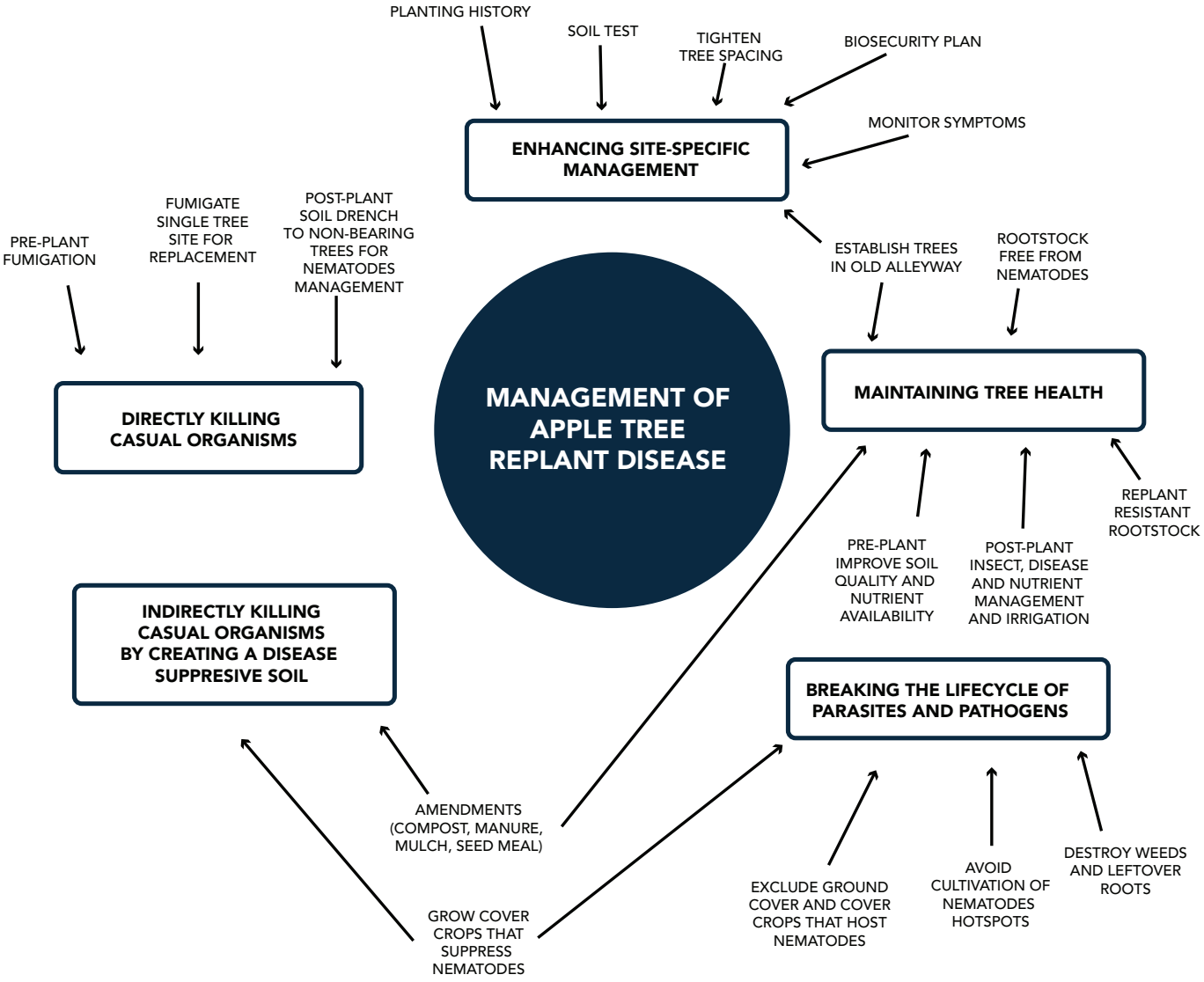

Figure 5. *Management practices as they relate to each of the five main techniques that control apple replant disease. An integrated approach uses several techniques to improve the opportunity for successful control of apple replant disease, which is represented by the pentagon linking the techniques.*

STEP 1: DIAGNOSIS OF PROBLEMS PRE-PLANT

- If apple trees have grown on a particular site in the last 30 years, then newly planted trees are at risk of apple replant disease. In Nova Scotia, hundreds of replant soil tests were done between 1993 and 2004 and replant disease was always present.
- Sites with sandy soils are more prone to nematodes but clay and clay-loam soils should still be tested. Sample for nematode presence and density by collecting root or soil samples from an orchard block. Refer to Appendix A for information on soil and root samples.
- Identify biosecurity risks such as fields with transmittable diseases and insects. Create a biosecurity plan. More information on biosecurity in horticulture crops can be found in the Perennia factsheet: Biosecurity is Important in Horticulture Crops Too.

STEP 2: PRE-PLANT MANAGEMENT

Fumigation

- Apple growers are advised to fumigate the soil before replanting an orchard. The goal of soil fumigation is to reduce pest populations to give young trees the opportunity to grow, unhindered, before parasite and pathogen populations re-establish. Review Scotian Gold's best management practices for fumigation and plan how to prepare the soil for fumigation.
- At the time of publication, apple replant disease has mainly been treated by the use of pre-plant soil fumigation because fumigation offers the most consistent control of replant disease.
- Methyl bromide was very effective but it was discontinued from registration in 2005. The discontinuation of chemical fumigants and pesticide products leads to uncertainty about their availability in the future.

Field Preparation

- Destroy leftover roots from orchard crops as they harbour parasites and pathogens.
- Improve soil quality and nutrient availability to provide trees with the necessary resources for healthy growth.
- Practice weed management as many weeds are nematode hosts.
- Avoid soil cultivation of a known nematode hotspot to prevent enlarging the area of infestation.

Cover Crops

- Growing specific cover crops can reduce field populations of nematodes. Choose varieties that are known for suppressing nematodes and manage weeds to exclude nematode hosts. The following crops have reduced nematode populations, and are recommended for nematode suppression in Ontario.
    - Canadian Forage Pearl Millet 101: A poor host that inhibits reproduction of nematodes
    - Specific sorghum x sudan-grass (sudex) hybrids (Pioneer 877F): Produces compounds that kill nematodes and suppress soil-borne diseases when the crop is cut green and residue is incorporated within 2 hours. More information on sudex in orchards can be found through PennState Extension.
    - African marigold cultivars (Crackerjack, Creole): Root exudates kill nematodes.
    - Oilseed radish and oriental mustard cultivars (Caliente, Cutlass, Forge): Produces compounds that kill nematodes when the crop is cut green and incorporated immediately.
- Depending on field conditions, multiple years of a cover crop may be needed to suppress nematode populations below economic thresholds prior to planting. Soil sample for nutrients and nematode counts – before and after cover cropping – to determine if desired outcomes have been achieved.
- Root lesion nematodes have a wide plant host range. Exclude cover crops that host parasitic nematodes such as clovers, buckwheat and more.
- Cover crops add organic matter to the soil system, however, incorporating green material into soil can increase the short-term presence of Pythium and Rhizoctonia.

Amendments

- Composts, manures, mulches and seed meals add organic matter to the soil, improving the soil's physical, chemical, and biological properties. A healthy soil is conducive to healthy tree growth and may even become suppressive to disease if it supports beneficial soil organisms.
- Organic amendments can give inconsistent results, given the many unknown factors in replant disease and variable composition of amendments.
- Highly degraded composts add organic matter without risking an increase in pathogens.

STEP 3: PLANTING MATERIAL AND ORCHARD ESTABLISHMENT

- Start with certified nematode-free rootstock that is grown by a reputable commercial nursery.
- Establish new orchard in an old orchard alleyway, if possible.
- Tighten tree spacing on a replant site as trees will be smaller and take longer to fill the space relative to trees on virgin land. Trees on replant sites will not reach their biological potential, even when standard practices to suppress replant disease are followed.
- Consider replant-resistant rootstock. The Geneva breeding program claims that the following rootstocks are tolerant to the classic replant pathogens: G.41, G214, G.935, G.202, G.30, G.210, and G.969. The selections are not widely available from nurseries.

- At this time, no apple rootstocks show resistance or tolerance to nematodes. G.935 and G.202 were susceptible to root lesion nematode on replant sites in NS.
- Choose ground cover between orchard rows that does not host nematodes. Options include creeping red fescue and perennial ryegrass. The commonly-used Kentucky bluegrass hosts root lesion nematodes.

STEP 4: POST-PLANT MANAGEMENT

- Follow a biosecurity plan to prevent the spread of nematodes within and between blocks, and between orchards. Clean soil off of equipment that has visited an infected field, most importantly during wet conditions when soil clings to equipment.
- Practice weed management to limit nematode hosts.
- Practice disease, insect and nutrient management, and irrigation to encourage tree health.
- Monitor for apple replant symptoms. Root tissue can be tested for nematodes to diagnose a problem with tree growth (Appendix A).
- If trees show symptoms of nematode infestation, Vydate is currently the only chemical that is registered to provide control. Vydate can be applied as a soil drench to non-bearing fruit trees in spring. It will control nematodes but not pathogens. Always read and follow the label.
- If a tree has died from nematode infestation, the single-tree site must be fumigated prior to replant. Vydate is currently registered for this use.

ALTERNATIVES TO FUMIGATION?

OPTIONS AND REQUIREMENTS

Alternatives to fumigation could include targeted chemicals, cultural practices, and biological control. However, methods with a narrow-spectrum of activity are not expected to work when used alone. In some cases, narrow-spectrum methods have suppressed replant disease but are unlikely to show consistent and effective results under a wide range of soil systems. Note that alternatives to fumigation need to be effective and reliable for their widespread adoption as there are limited ways of mitigating pathogens and nematodes after orchards are established.

DISEASE-SUPPRESSIVE SOILS

In theory, a soil that is suppressive to replant disease could be produced by encouraging populations of beneficial soil organisms that prey on pests. Such a long-term strategy may improve tree establishment and enhance production on replant sites. Short-term methods are also under investigation to amend the soil for specific improvements to soil biology prior to orchard renewal. The goal of soil management is to create soil systems that keep pest populations in check.

Fumigation removes a broad spectrum of good and bad soil organisms. A fumigated soil tends to control replant disease for up to one year, giving young trees an opportunity to establish. Eventually, the soil biology rebuilds and pests recolonize the system, preventing trees from reaching their biological potential. At present, the trees on a replant site are always inferior to trees established on virgin land.

PROMISING RESEARCH

In Nova Scotia, composted hog manure applied during deep ripping was as effective as Telone C-17 fumigation in increasing yield of apple trees planted in replant disease soil. The reason for the response is unknown, however, the large volume of compost applied in the tree row might have displaced diseased soil. Nonetheless, addition of organic matter like compost is likely to improve soil properties.

In Washington State, brown mustard (common and centennial) seed meal was as effective as Telone-C-17 during tree establishment, and by the fourth growing season the growth and yield was best for soil that was amended with seed meal. The seed meal treatments also supported soil organisms that were suppressive to root lesion nematodes (nematode predators and egg parasites) and Pythium (pathogen parasites).

MAJOR STUMBLING BLOCKS

There are currently no recommendations for effective and reliable alternatives to soil fumigation. Major stumbling blocks prevent alternatives to broad-spectrum fumigation from being developed and implemented. The use of alternatives is a good idea in theory, but in practice more needs to be learned about the soil biology in orchard replant soils. With more research, the future might hold effective alternatives to fumigation.

APPENDIX A - SAMPLING FOR NEMATODES

Collect root or soil samples from an orchard block to test for the presence of nematodes. Keep the following notes in mind as you collect samples.

- **Cost:** The Agriculture and Food Laboratory in Guelph, ON, offers nematode tests. Nematode count in soil is $49.20 per 1 L sample of soil. Nematode count in root tissue is $75.30 per 20-30 g sample. Website: **https://afl.uoguelph.ca/soil-testing-services** Phone 1-877-863-4235 or email: **aflinfo@uoguelph.ca** (Prices given at time of publishing)

- **Timing:** Root and soil samples are best when collected in the spring (May-June) or during the fall (September-October). Samples should not be collected when fields are very wet or if soil is frozen.

- **Care:** Place root or soil samples in a plastic bag, and do not freeze or expose them to heat or direct sunlight.

- **Labelling:** Label with a waterproof marker to indicate sampling date, location, and your contact name. Write a sample number that corresponds with the health status of the tree (i.e. 1 for infected and 2 for healthy), so the sample is unknown to the lab technician which prevents bias. Record the details of each sample in your files.

DIAGNOSING NEMATODES PRE-PLANT

A soil sample can be taken whether or not crops are present. However, a soil sample may underestimate the problem because nematodes are always more concentrated in plant roots while they are widely dispersed in soil. Only use a soil sample to indicate the presence of nematodes and the type of species, not as a reliable estimate of the population density. If the goal is to simply identify nematode presence, then soil samples are sufficient.

- Follow the sampling pattern for bare soil by taking a soil core in a Z pattern, taking a soil core every 10-25 paces and changing direction (**Figure 6a)**. Remove the top 2 cm of soil before sampling. Each soil sample should represent no more than 2.5 ha.

DIAGNOSING NEMATODES POST-PLANT IN YOUNG ORCHARDS

A root sample is always preferred over a soil sample because nematodes live and feed in the roots of trees. Sampling directly from an established crop will give an estimate of the population density of nematodes that feeds on apple tree roots.

- Collect and submit an entire root system and surrounding soil of an infected plant. Collect a separate sample of a healthy tree's roots and surrounding soil, for comparison.

- Do not sample the roots of dead or severely infected plants. Weak plants are a depleted food source for nematodes, so nematodes will vacate the area to feed on neighbouring plants. Sample from trees that show minor symptoms – usually trees at the margin of an affected area.

Alternatively, a soil sample can be used to diagnose the presence of nematodes surrounding a tree. The thresholds are less reliable because nematodes are dispersed in soil and the nematode count can underestimate a problem.

- To determine if nematodes are the cause of tree decline, choose a plant that is mildly infected. Prepare a soil sample using soil cores taken from the sampling pattern for an individual tree **(Figure 6b)**. Sample the soil where feeder roots grow because nematodes are expected in this area. Collect a separate soil sample surrounding a healthy tree, for comparison.

- Each 1 L soil sample is composed of a mixture of 10 or more soil cores. Soil should be sampled to a depth of 20 cm. You may use a soil corer, tube or narrow trowel. Mix the soil and discard any excess back to its origin.

- Collect soil in clean pails using clean shovels or soil probes. Do not cross-contaminate samples from separate sites.

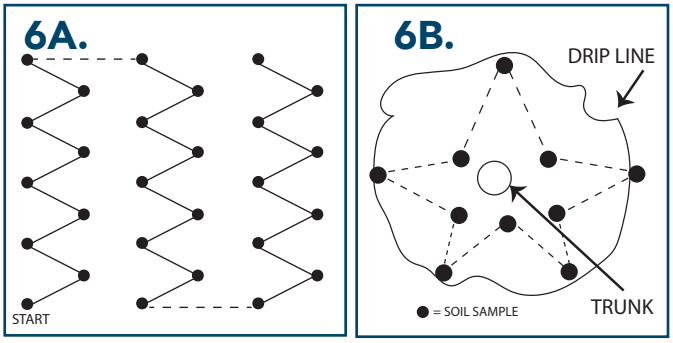

***Figure 6A**. Sampling pattern for soil samples used to diagnose nematodes in an orchard a) pre-plant using a Z pattern, sampling every 10-25 paces throughout a field of bare soil, **Figure 6B.** post-plant using a star pattern around an individual tree within the area where feeder roots grow, from the branch to the tip of the trunk. Soil core=*

For more information, follow the sampling and shipping guidelines provided by the diagnostic lab.

REVIEWING THE RESULTS

The diagnostic lab will report nematode counts but will not usually give an economic threshold. What do the results mean? Table 1 can be used as a guideline, in conjunction with review by your tree fruit specialist. The thresholds are only a guideline because fruit trees can compensate for nematode feeding, depending on their root reserves and environmental conditions. Also, the trees are susceptible to nematode parasitism when they are young and become less susceptible as they age.

*Table 1. Economic thresholds of plant-parasitic nematodes for tree fruit from soil samples.**

TYPE OF NEMATODE	ECONOMIC THRESHOLD BY SOURCE	
	OMAFRA (nematodes/kg soil)	PennState Extension (nematodes/kg soil)
Root-lesion	1000	400-600
Root-knot	1000	n/a
Pin	5000	n/a
Dagger	100	Any
Buld and Stem	100	n/a

**Estimates represented in this table are not local to Nova Scotia. Most are from field experience and observations – not controlled experimental data – with no indication of timing or pattern of sampling. The economic thresholds listed should only be used as a rough guideline.*

FOR MORE INFORMATION ABOUT APPLE REPLANT DISEASE, CONTACT:

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