

# CHAPTER 8

## NEMATODE MANAGEMENT

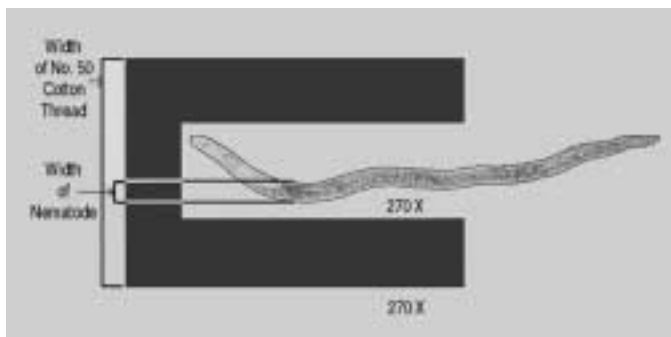
### LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand the basic biology of plant-parasitic nematodes.
- Be familiar with nematodes of importance in vegetable production.
- Know the importance of monitoring nematode population densities.
- Understand the strategies and tactics used to manage plant-parasitic nematodes.

### INTRODUCTION

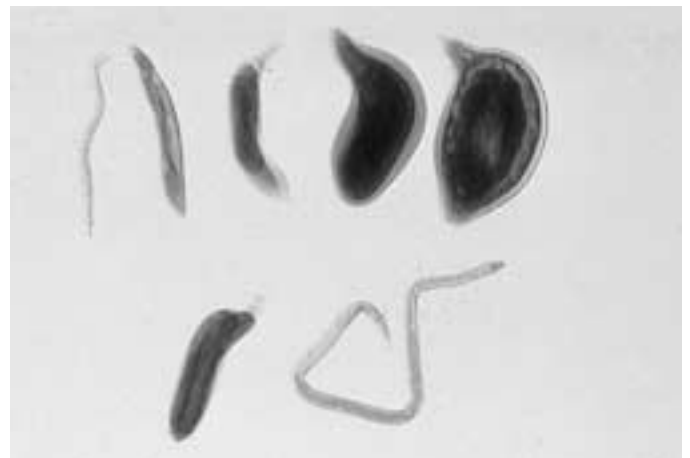
Nematodes are animals. More specifically, nematodes are non-segmented roundworms, which separates them from their close relatives the segmented roundworms, more commonly known as earthworms. Adult nematodes can vary in length from 1/30 inch to nearly 9 feet. Nematodes are commonly found in soil or water, including oceans. They may be the most numerous multicellular



Nematodes are extremely small. Here a nematode is laid on top of a cotton thread to compare size.

organisms on earth. A shovelfull of garden soil typically includes more than 1 million nematodes.

The majority of nematode species are regarded as beneficial. They feed on bacteria, fungi, and other soil-inhabiting or aquatic animals. Some are quite specific in the types of foods they feed on; others are considered omnivores and potentially feed on a wide range of foods.



The life stages of a female (top) and male (bottom) cyst nematode.

Some species of nematodes are parasites of plants and animals. The focus of this chapter will be plant-parasitic nematodes. Plant-parasitic nematodes share three common characteristics. First, they are all microscopic, with adults ranging in length from about 1/30 to 1/4 inch in length. Secondly, they are obligate parasites of plants, meaning they must have living plant tissue to feed on to grow and reproduce. Finally, they all possess stylets, which are structures similar to hypodermic needles that nematodes use to puncture plant cells and obtain the cell's contents. All plant-parasitic nematodes spend at least part of their life cycles in soil, though many are principally found in root or leaf tissue.

## PLANT-PARASITIC NEMATODES

Plant-parasitic nematodes are microscopic animals that attack plants. Every species of plant has at least one species of nematode that parasitizes it. The majority of plant-parasitic nematodes (about 95 percent of the described species) feed on roots, either within the root tissue as endoparasites or outside as ectoparasites. Some nematodes feed within leaves. Plant-parasitic nematodes must have living host tissue to feed on to grow and reproduce. If the host dies, nematodes will disperse and search for other plants to invade.

Feeding by plant-parasitic nematodes, in general, does not result in the development of characteristic symptoms. For this reason, nematode problems often go undiagnosed. Typical aboveground symptoms of nematode infections include stunting, yellowing, wilting, and, most importantly from an economic standpoint, reduced yields. A few types of nematodes do produce characteristic symptoms or signs; these will be discussed when specific nematodes are described.

Nematodes are similar to insects in that they possess an exoskeleton. This skin must be shed or molted for a nematode to grow. A typical plant-parasitic nematode life cycle consists of an egg, four preadult stages (referred to as juveniles) and an adult. Females are often more destructive; males typically do not feed. In many species of plant-parasitic nematodes, males are rare or not known to exist. The life cycle of a plant-parasitic nematode may be completed in as little as two weeks or as long as two years, depending on the species and the temperature.

Because of their size, plant-parasitic nematodes do not move long distances on their own. They are usually transported over long distances on machinery, in nursery stock, on transplants or seed, or by animals. Anything that moves soil moves nematodes, including water and wind. Some nematodes are known to move a few feet vertically in the soil during a growing season when environmental conditions are adverse.

## NEMATODES OF IMPORTANCE IN VEGETABLE PRODUCTION

### Northern Root-Knot Nematode (*Meloidogyne hapla*)

**HOST PLANTS:** Very wide host range, including virtually all vegetables.

**BIOLOGY:** The northern root-knot nematode overwinters in the soil as eggs. As soil temperatures increase in the spring, second-stage juveniles emerge, migrate through the soil, and penetrate the roots of host plants. The nematodes establish feeding sites behind the root cap. As the infected root continues to grow, the vascular tissue slips in the area where the nematodes have fed.

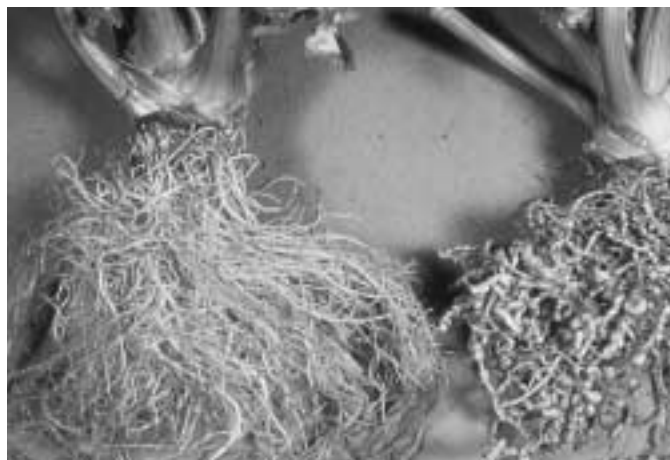
Shortly after successfully establishing a feeding site, the second-stage juvenile begins to swell and soon molts to a third-stage juvenile. Eventually, following two more

molts, it matures to become an adult female or male nematode. Females are round and incapable of movement. Males are worm-like and generally exit the root because they do not feed. Female NRKN produce large numbers of eggs, up to 3,000, in a gelatinous matrix secreted by the anus.

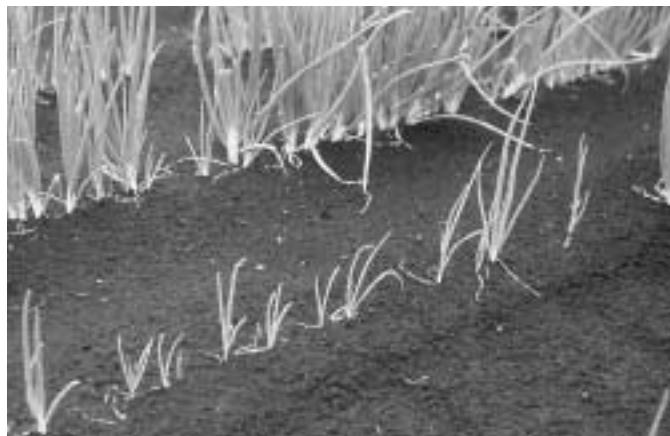
The northern root-knot nematode can complete its life cycle in a month at optimal soil temperatures. Therefore, the nematode can complete multiple generations per growing season.

**SYMPTOMS:** The northern root-knot nematode, like many other nematode species that feed on vegetables, does not cause characteristic foliage symptoms. Typical symptoms are stunting, yellowing, and reduced yields. Severely infested plants usually wilt during periods of hot, dry weather because the nematodes disrupt the plant tissue.

Invasion of roots by northern root-knot nematode will result in the production of small swellings on the roots called **galls**. Galls will vary in size, depending on the numbers of nematodes feeding within them. Carrots are highly susceptible to the northern root-knot nematode, which causes losses due to forking or stubbing of the tap-roots.



A healthy (left) and a northern root-knot nematode-damaged (right) celery root.



Northern root-knot nematode damage on onion.

## MANAGEMENT

**Avoidance:** Once established, root-knot nematodes are virtually impossible to eradicate. Therefore, attempts should be made to keep sites clean of northern root-knot nematode for as long as possible. This is accomplished primarily by using nematode-free transplants and by not contaminating fields with northern root-knot nematode-infested soil.

### Population Reduction

**CULTURAL CONTROLS:** Sites with histories of root-knot nematode problems should be kept out of vegetable production for a period of two to four years. NRKN non-host crops such as corn or small grains should be grown to reduce population densities. Weed control is important because many weeds serve as hosts for the northern root-knot nematode.

**GENETIC CONTROLS:** Some varieties of vegetables are reported to be resistant or tolerant to root-knot nematodes.

**CHEMICAL CONTROLS:** Sites should be routinely sampled for plant-parasitic nematodes before vegetables are planted, especially those extremely susceptible to NRKN. If nematode population densities are recovered at damage threshold levels, use of a nematicide may be advised.

## Lesion Nematode (*Pratylenchus penetrans*)

**HOST PLANTS:** Virtually all species of cultivated plants.

**BIOLOGY:** Lesion nematodes overwinter as juveniles and adults within roots or in soil. These nematodes penetrate young roots. Once inside the root, they migrate between and through cells, often killing them.

Lesion nematode females lay eggs singly in root tissue or in soil. Females typically produce fewer than 100 eggs. Life cycles can be completed in three to four weeks, depending on soil temperatures. They can complete multiple generations per growing season.

**SYMPTOMS:** Aboveground symptoms are virtually the same as those produced by the NRKN. Penetration of roots by lesion nematodes results in very small lesions. These wounds create a point of entry for other soil pathogens, such as the fungi *Verticillium*, *Cylindrocarpon*, *Rhizoctonia*, *Colletotrichum*, and possibly others.

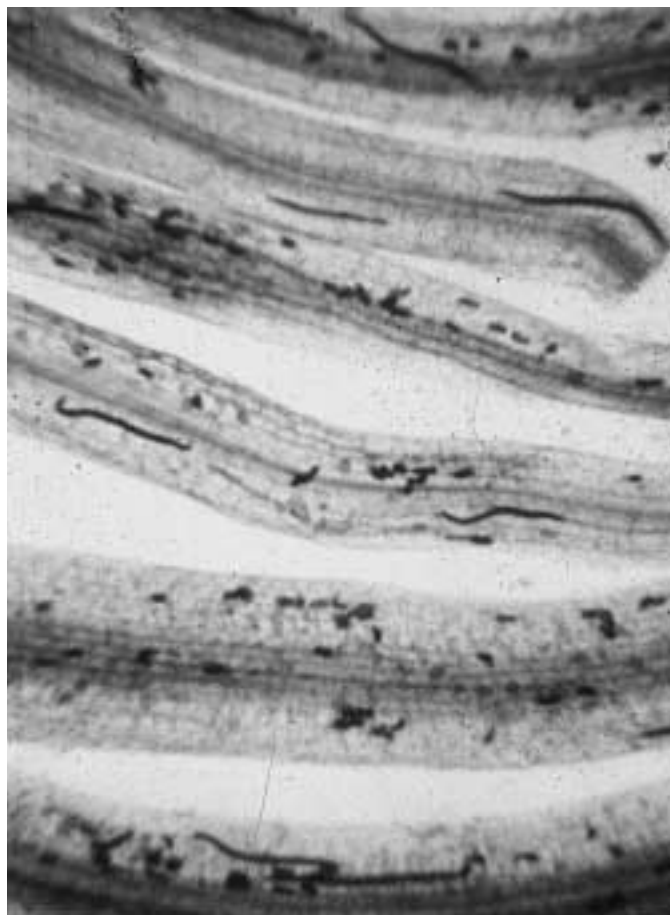
Lesion nematode-infected plants typically have reduced root volumes and weights. Feeding and migration by these organisms kills cells. Feeder roots are usually destroyed.

## MANAGEMENT

**Avoidance:** Plant lesion nematode-free transplants.

### Population Reduction

**CULTURAL CONTROLS:** Lesion nematodes feed on virtually all species of cultivated plants, so they are difficult to manage with rotation. Asparagus is a very poor host. Fields with histories of lesion nematode problems should



Lesion nematodes in roots.

be kept fallow before planting. Maintaining a clean fallow is important because many weeds serve as hosts. Utilizing sorghum or sudax as a rotational crop may help to reduce population densities of lesion nematode.

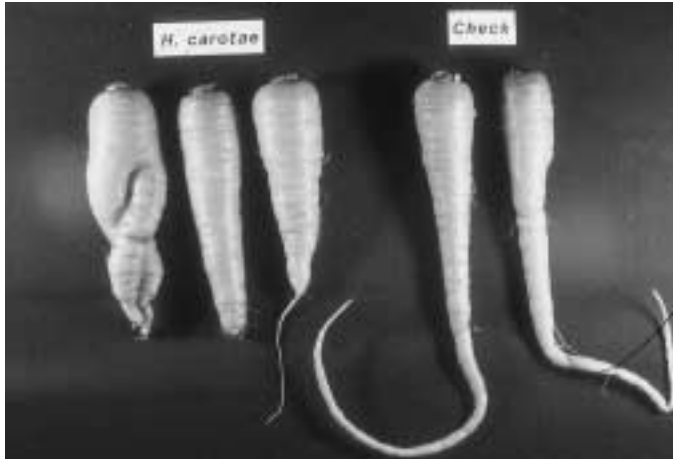
**CHEMICAL CONTROLS:** See the section on nematicides.

## Cyst Nematode (*Heterodera* spp.)

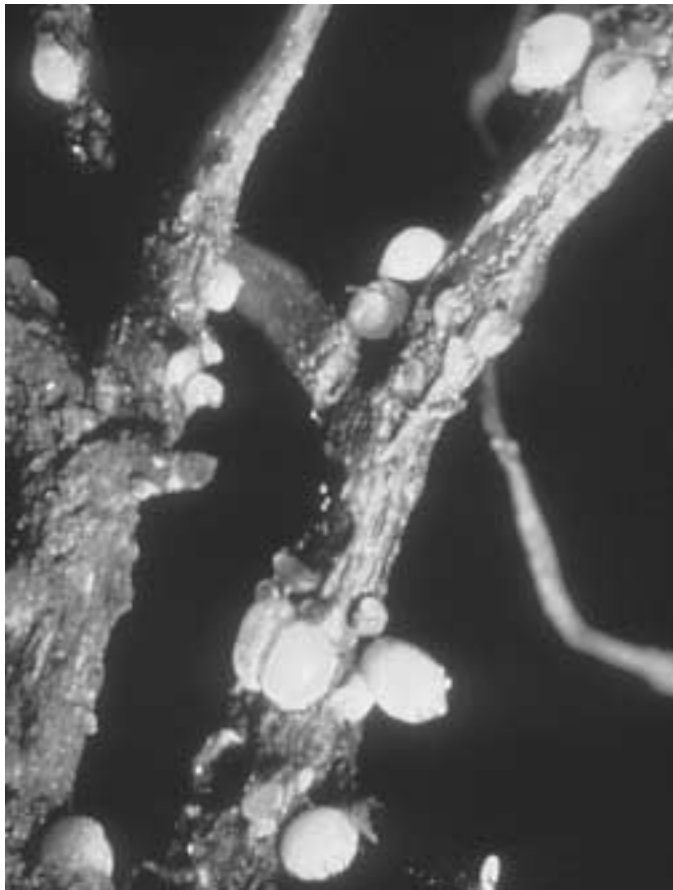
**HOST PLANTS:** Four species of cyst nematodes feed on vegetable crops in Michigan. The carrot cyst nematode, *Heterodera carotae*, has carrot as its only host. The soybean cyst nematode, *H. glycines*, feeds on green beans and peas. The sugar beet cyst nematode, *H. schachtii*, feeds on a variety of vegetables, including beets, broccoli, cauliflower, cabbage, Brussels sprouts, turnips and spinach. The clover cyst nematode, *H. trifolii*, is reported to feed on some vegetables but is not regarded as a serious pest of these crops in Michigan.

**BIOLOGY:** Cyst nematodes overwinter as eggs within cysts in the soil. Cysts are the dead remains of female nematodes. They are lemon-shaped and about the size of a pinhead. Eggs hatch and second-stage juveniles emerge from the cysts, migrate through the soil, and enter roots to feed. They swell as they grow, eventually becoming large enough that they rupture the root and are exposed to the soil. If cyst nematode-infected roots are examined closely after gently removing the soil, these females can be seen with the naked eye. They are white or yellow,

depending on age. Males are worm-like and usually exit the root to mate with females.



Carrot damage by the carrot cyst nematode, *Heterodera carotae*.



Female cyst nematodes are visible without a microscope on plant roots.

Female cyst nematodes produce approximately 50 to 100 eggs in a gelatinous matrix outside their bodies, and many more eggs remain within their bodies. The eggs produced in the matrices typically hatch soon after production, whereas the ones contained within the females may not hatch for 10 years or more. The numbers of eggs produced by cyst nematodes vary by species.

**SYMPTOMS:** Feeding by cyst nematodes results in areas of stunted and yellow plants. Yields can also be significantly reduced. The severity of the symptoms varies according to host and the population densities of the cyst nematodes.

Female cyst nematodes can be observed with an unaided eye on infected plants during the growing season. Females are white or yellow and roughly the size of the period at the end of this sentence. Cyst nematode-infected plants often have reduced root systems.



Aerial view of damage caused by cyst nematodes.



Cyst nematode damage causes plants to wilt.

## MANAGEMENT

**Avoidance:** Cyst nematodes can survive in the soil for 10 to 15 years in the absence of host crops. Do not contaminate fields with cyst nematode-infected soil. Growing host plants in long rotations with non-host crops also minimizes the risks of severe cyst nematode problems developing in the future. If cyst nematodes become established in a field, growers must learn to optimize yields in the presence of these nematodes.

## Population Reduction

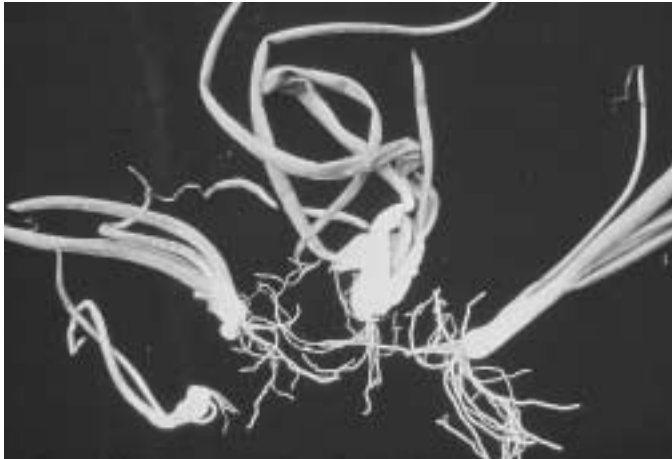
**CULTURAL CONTROLS:** Sites with histories of cyst nematode problems should be kept free from host plants for two or more years. Crop rotation is the most effective tactic to reduce population densities of cyst nematodes. Most of these nematodes have narrow enough host

ranges that at least one or more non-host crops could be rotated into the cropping system.

**CHEMICAL CONTROLS:** Cyst nematodes are difficult to control with nematicides, though use of these materials can result in declines in cyst nematode population densities.

## Stem and Bulb Nematode (*Ditylenchus dipsaci*)

**HOST PLANTS:** Many, including onion, beet, carrot, celery, cucumber and tomato.



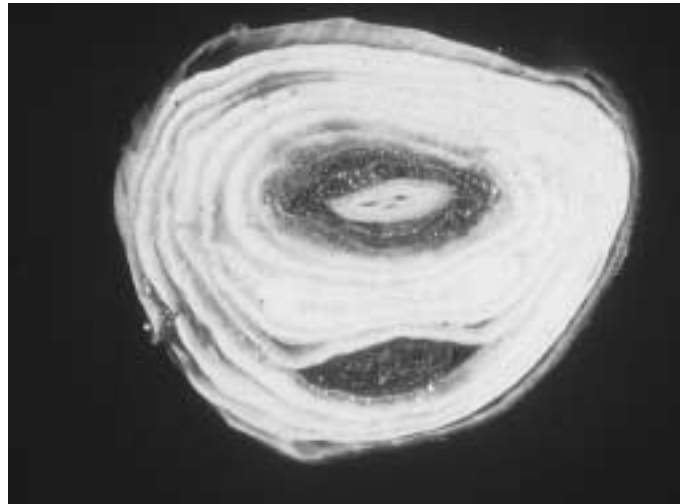
Stem and bulb nematode damage on onions.

**BIOLOGY:** Stem and bulb nematodes overwinter as fourth-stage juveniles and adults. They spend the winter in plant tissue or soil. When moisture is adequate, the nematodes migrate from their overwintering sites onto the leaves and stems of young plants. Females will produce up to 500 eggs and can survive 10 weeks or longer. The life cycle can be completed in about three weeks in optimal conditions. They are active very early in the spring, and egg laying can occur at temperatures below 40 degrees F. Vegetables produced in hot, dry summer conditions are less likely to suffer severe damage from stem and bulb nematodes.

Stem and bulb nematodes can persist for long periods. They are quite resistant to drought and cold temperatures. These nematodes will often form aggregates of large numbers of individuals (sometimes called “eelworm wool”) to survive during adverse conditions. Population densities often decline rapidly in the absence of host plants in fields.

**SYMPTOMS:** Deformed leaves and bulbs are the most common symptoms of stem and bulb infestations in onions. Leaves yellow and develop blisters. Young plants often are deformed or may be killed by high infestations. Older infected bulbs show swelling of the scales. These bulbs are often soft and, when cut open, reveal concentric rings of brown leaf scales. Infected bulbs often rot in storage because they are invaded by soft rot bacteria.

Other plants infested with stem and bulb nematodes are stunted and distorted. In beets, the growing point of the plant is often killed and multiple crowns may develop. For many vegetables infested with stem and bulb nematodes, severe crown rot may develop late in the growing season.



Stem and bulb nematode damage creates entry points for secondary pathogen infections that can cause bulbs to rot.

## MANAGEMENT

**Avoidance:** Do not plant stem and bulb nematode-infested bulbs or seeds.

### Population Reduction

**CULTURAL CONTROLS:** Crop rotation or the use of fallow can reduce population densities of stem and bulb nematodes. A few weeds are host plants, so good weed control is essential.

Disinfecting onion sets and bulbs in hot water dips kills nematodes. The temperature and time of dipping must be carefully controlled. Often temperatures of 110 to 115 degrees F for one to two hours are required to kill cyst nematodes.

These nematodes typically move on the surfaces of plants in water. Therefore, attempts should be made to minimize leaf wetness.

## Common Needle Nematode (*Longidorus elongatus*)

**HOST PLANTS:** Celery, onion, mint, and other vegetables.

**BIOLOGY:** Needle nematodes overwinter as juveniles and adults in the soil. Eggs are laid in the spring and early summer when soil temperatures are cool and new roots are being produced. Females produce relatively few eggs—20 per year. Needle nematode adults live for several years and may require more than a year to complete a generation.

As temperatures rise and soil moisture levels decrease in the summer, needle nematodes move deep into the soil. They often rest 2 to 4 feet below the soil surface. During the fall, they move up to return to the root zones. It is best to sample for needle nematodes in the spring or fall when they are near the soil surface.

**SYMPTOMS:** The most characteristic symptom of feeding by needle nematodes is root swelling, especially of younger roots. Often these roots are killed and stunted root systems develop.

Needle nematode feeding can result in serious stunting or death of young plants. The damage is often very evident early in the growing season, and stunted plants remain in this condition throughout the year.



Needle nematode feeding can stunt plants.

## MANAGEMENT

**Avoidance:** Do not plant stem and bulb nematode-infested bulbs or seeds.

### Population Reduction

**CULTURAL CONTROLS:** Rotation to non-host crops is recommended to reduce population densities of common needle nematodes. Because these nematodes are often present in fairly low numbers and produce few eggs, a year without a host plant may be sufficient to adequately reduce their numbers.

**CHEMICAL CONTROLS:** Soil fumigation is effective for control of needle nematodes. Nonfumigant nematicides are generally not effective.

## Pin Nematode

### (*Paratylenchus hamatus* and *P. projectus*)

**HOST PLANTS:** Carrot and celery are susceptible to pin nematodes. Other vegetables serve as hosts but appear quite tolerant to pin nematodes.

**BIOLOGY:** Pin nematodes typically feed on roots but do not enter the root. We know little about their biology and life cycles.

**SYMPTOMS:** Feeding by pin nematodes can result in stunted, unthrifty plants. In carrots, taproots are stunted and discolored.

## MANAGEMENT

### Population Reduction

**CULTURAL CONTROLS:** Pin nematodes can be managed with rotation, though these nematodes do feed on a wide range of plants. Small grains are often used as covers in the fall to minimize soil erosion in fields where vegetables are

produced. These cover crops can serve as hosts for pin nematodes. However, pin nematodes are not regarded as serious pest of most plants.

## SAMPLING NEMATODE POPULATIONS

Plant-parasitic nematodes are microscopic organisms with concentrated distributions in a field. They tend to occur in clumps, so symptoms occur in circular or elliptical patterns. If aboveground symptoms are uniformly distributed in any given field, the cause of the problem is typically not nematodes.

Points to remember when sampling for nematodes:

- Because of their microscopic size, the only way to diagnose a plant-parasitic nematode problem is to collect soil and/or plant tissue samples and send them to a nematode diagnostic lab for analysis.
- It is impossible to provide specific recommendations for the management of plant-parasitic nematodes unless they are properly identified.
- When collecting soil samples for plant-parasitic nematodes, the more soil cores gathered, the better the sample. However, it is necessary to submit only a pint to a quart of soil to a lab.
- For more complete instructions on sampling for nematodes, please refer to MSU bulletin E-2199, *Detecting and Avoiding Nematode Problems*.

## MANAGEMENT OF PLANT-PARASITIC NEMATODES

The best defense against nematodes is to avoid them. Once fields or plant tissues are infected with nematodes, eradication is usually possible. Nematodes are usually transported over long distances by machinery, in plant material, on animals, or by water or wind. Natural disasters such as floods are uncontrollable, but the patterns in which machinery is moved and the sanitation of this equipment can be controlled. These tactics should be considered when trying to avoid nematodes. The bottom line is that anything that moves soil moves nematodes.

Often, fields do become infested with nematodes. If samples indicate the presence of pest nematodes at damage threshold levels, then steps should be taken to reduce the nematode population. Many tactics can be utilized to accomplish this.

**Biological controls:** The majority of nematodes present in the soil are considered beneficial. They typically feed on bacteria, fungi, or small animals, including other nematodes. Research results indicate that as the abundance of beneficial nematodes increases, the numbers of plant-parasitic nematodes decrease. Steps can be taken to increase the diversity and numbers of beneficial nematodes in fields. This type of approach is outlined in other MSU bulletins on crop ecology.

Many organisms are parasites or pathogens of nematodes. Most of these occur naturally in soils but often do not provide sufficient control of plant-parasitic nematodes.

Some biological nematicides products are available, but their use has not resulted in consistent control of nematodes in Michigan.

**Biotechnological controls:** Plants have not been genetically modified at this time to control plant-parasitic nematodes.

**Chemical controls:** Nematicides are compounds that kill nematodes. Nematicides are either **fumigants** or non-fumigants. Fumigants are typically compounds sold as liquids that react with water in the soil to produce gases that kill a wide variety of organisms, including plants. They are usually applied to the soil in the fall or spring when soil temperatures are adequate. Fumigant nematicides are labeled for use in vegetable production in Michigan. Please consult MSU bulletin E-312, *Insect, Disease and Nematode Control for Commercial Vegetables*, for specific recommendations.

Non-fumigant nematicides are also labeled for use in Michigan vegetable production. Unlike fumigants, they do not volatilize in soil water. They can be applied before, at, or even after planting in some situations. These compounds are not as broad spectrum as killing agents as fumigant types. They will control problem nematodes, but their


use will often result in decreases in numbers of beneficial as well as parasitic nematodes. See MSU bulletin E-312 for information on use of these materials.

**Cultural controls:** Tactics that affect nematode populations include the species of plants grown, planting dates, presence or absence of companion crops, etc. Most of these tactics have been covered in detail in the sections on specific nematodes.

**Genetic controls:** Very few cultivars of vegetables are resistant to plant-parasitic nematodes, though many varieties of tomato have resistance to root-knot nematodes. Varieties of vegetables will differ in their susceptibility to nematodes, but this information is not always readily available. These data can be obtained with on-farm testing or screening of selected vegetable varieties.

**Physical controls:** These include the use of heat, steam or water (flooding) to reduce population densities of nematodes. In field situations, these types of controls are limited. In glasshouse or poly-house production of plants, heat or steam is typically used to sterilize growing media.

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## Review Questions

### Chapter 8: Nematode Management

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Write the answers to the following questions and then check your answers with those in the back of the manual.

1. Nematodes are best described as:
  - A. Aliens.
  - B. Animals.
  - C. Bacteria.
  - D. Earthworms.
  - E. Fungi.
2. 1. Plant-parasitic nematodes typically range in length from approximately:
  - A. 1/3000 to 1/300 inch.
  - B. 1/30 to 1/4 inch.
  - C. 1/4 to 4 inches.
  - D. 4 inches to 4 feet.
  - E. None of the above.
3. Which of the following is not a characteristic shared by all plant-parasitic nematodes?
  - A. Complete their life cycles in usually 7 days
  - B. Microscopic
  - C. Obligate parasites of plants
  - D. Stylet-bearing
4. How are nematodes similar to insects?
  - A. They have compound eyes.
  - B. They have three primary body segments.
  - C. They possess an exoskeleton.
  - D. They have legs and wings.
5. To reduce population densities of northern root-knot nematodes, you should:
  - A. Grow carrots year after year.
  - B. Rotate onions with celery.
  - C. Grow corn or small grains.
  - D. Fertilize crops with nitrogen.
6. Cyst nematodes spend the winter:
  - A. In condominiums in Florida
  - B. In cysts in the soil.
  - C. As second-stage juveniles within leaf tissue.
  - D. None of the above

7. Which female nematodes, of those listed below, would potentially produce the largest number of eggs?
- A. Common needle
  - B. Lesion
  - C. Northern root-knot
  - D. Stem and bulb
8. Which of the nematodes listed below is not a pathogen of onion?
- A. Common needle
  - B. Lesion
  - C. Northern root-knot
  - D. Soybean cyst
9. To diagnose a nematode problem, you should:
- A. Collect a soil sample and place the soil in a paper cup on the windowsill and count the nematodes as they migrate to the top.
  - B. Collect soil and plant tissue samples and send them to a nematode diagnostic lab for analysis.
  - C. Ask an expert.
  - D. Consult with a fortune teller.
10. Lesion nematodes would not be transported over long distances in which of these situations?
- A. By moving machinery from field to field.
  - B. By planting vegetable transplants started in contaminated soil.
  - C. By applying leaf mulch.
  - D. By soil erosion caused by flooding of the local river.