MARYLAND COOPERATIVE EXTENSION
UNIVERSITY OF MARYLAND
COLLEGE PARK•EASTERN SHORE

Fact Sheet

Fact Sheet 838

Plant-Parasitic Nematode Management on Vegetable Crops in Maryland

What are Nematodes?

Nematodes are minute worm-shaped animals containing most of the body systems found in higher animals such as digestive, nervous and reproductive systems as well as an organized musculature. Nematodes can be divided into two broad groups: free-living and animal or plant parasitic. Plant-parasitic nematodes are nearly microscopic, virtually invisible to the naked eye when in the soil, and range from 1/50 to 1/8 of an inch (0.2 to 4.0 mm) long with a diameter of about 1/1000 of an inch (30 µm) (Fig. 1). Nematodes feed by using a spear-like structure (stylet) located on the head end to puncture the plant cell and withdraw plant cell juices. Root-knot, *Meloidogyne* spp. and lesion, *Pratylenchus* spp. nematodes are the two most common nematodes that cause damage in vegetables in Maryland. Nematodes are basically aquatic animals and require a water film around soil particles before they can move. Nematode eggs will not hatch unless there is sufficient moisture in the soil. Soil moisture conditions that are most favorable for plant growth are also best for the development of nematodes.

Figure 1. Nematodes on glass slide.

Host Range

Many plant-parasitic nematodes have a wide host range while a few are host specific. Root-knot and lesion nematode species have a wide host range consisting of more than 600 to 800 crop and weed species, including weeds common to Maryland such as dande-

Figure 2. Nematode-infested area of field.

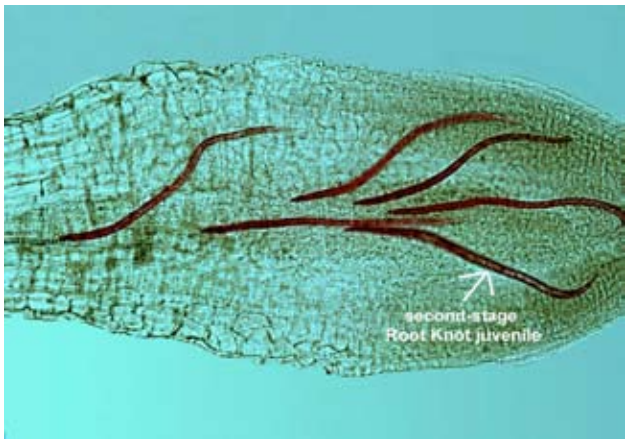

Figure 3. Invasive stage of root knot nematode in root.

Figure 4. Secondary root branching.

lion, purslane, mallow, and plantain. Most plant-parasitic nematodes contain large food reserves enabling them to survive for long periods of time in the absence of a living host. However, a living host is required by these nematodes for growth and reproduction.

Some nematodes are able to survive for at least one year without a host plant in moist soil through the winter—even if the soil is frozen. They can also overwinter in decaying plant material in the soil or in the roots of perennial plants.

Symptoms of Damage

Nematodes do not produce any specific aboveground symptoms, but one of the first indications of a nematode infection is an area in the field where plants wilt in the middle of the day even though there appears to be sufficient soil moisture to prevent wilting. These plants may also look stunted and yellow. Fruit set on infected plants is very poor, and the fruit formed frequently fails to ripen and is of poor quality. These symptoms are most prevalent on hillsides and in very sandy soils and are not uniform in the field, occurring in irregular patches of 5 to >100 feet. Nematode damage is often confused with low nutrient conditions, too little or too much water, improper soil pH, poor soil or other environmental factors or root diseases. However, if nematode feeding is responsible for these symptoms, correcting the "cultural deficiencies" usually fails to improve plant growth.

The most characteristic symptoms of root-knot nematode damage are those occurring on the underground parts of the plant. Infected roots swell at the point of nematode invasion and develop into typical root galls, which are swellings 2 to 3 times as large as a healthy root. Several infections can take place along the same root and the developing galls give the root a rough, clubbed appearance (Fig. 6). Water conduction by roots is also inhibited, so that water and nutrient movement to the top of the plant slows or stops. Rotting of the roots may develop later in the season. Lesion nematodes cause brown dead areas on the root and reduce plant vigor (Fig. 7). When plants are infected in the seedling stage, losses are extremely heavy and may result in early death of the plant.

Root-knot Nematodes

Meloidogyne spp.

Some of the most damaging and most commonly detected vegetable nematodes are the root-knot nematodes: southern root-knot, *Meloidogyne incognita* and northern root-knot, *M. hapla*. New York has found only northern root-knot nematodes in their fields. Maryland, however, is on the border between the two nematodes' host range and can have either, although southern root-knot nematode is much more commonly found than northern root-knot nematode in soil samples. The northern root-knot nematode causes tiny galls on roots of many plants and often is found on strawberries. The southern root-knot nematode causes massive root galls on plants such as soybean, cucurbits, tobacco, tomato, carrots, and many others. Corn is usually not damaged by root-knot nematodes, but can serve as a host to the southern root-knot nematode and increase populations to damaging levels for subsequent vegetable crops.

Life History: In early spring, the infective second stage juvenile, which is the only stage of the nematode capable of infecting a plant,

Figure 5. Egg sacs of RKN on root surface.

Figure 6. RKN-infected roots vs. noninfected roots.

hatches from egg masses and moves through the soil in response to elevated CO_2 concentrations in search of roots of a suitable host. The juveniles usually penetrate host roots just behind the root tip region and establish their special permanent feeding sites called giant cells in the vascular tissues of the root (Fig. 3). The giant cells provide nutrients for the sedentary nematodes, which continue to feed, enlarge, and molt three times. Root cells around the feeding sites are also induced to enlarge and form galls or knots and secondary branching of the main root (Fig. 4). Fifteen to 20 days after juveniles enter the root the females are capable of laying 1,000 or more eggs in an egg sac, which can be observed attached to the posterior end of the female or on the root surface (Fig. 5). This sac protects the eggs from dehydration. Eggs hatch immediately in the summer while those produced in the fall overwinter and do not hatch until the following spring. Root-knot nematodes are found at least 4–12 inches below the soil surface in the spring, but may be present to

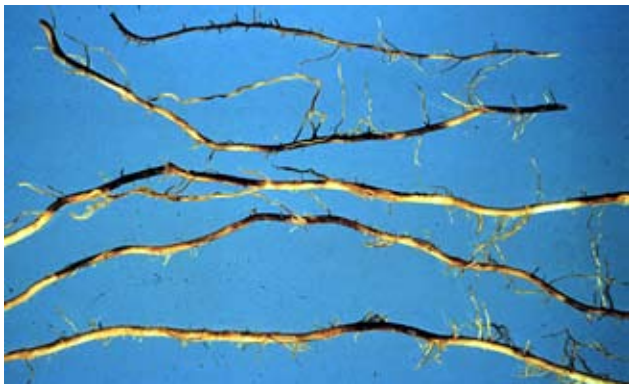

Figure 7. Root lesions caused by *Pratylenchus*.

a depth of 16 feet. The northern root-knot nematode can withstand freezing soil temperatures, whereas the southern root-knot nematode only survives at soil depths where freezing temperatures do not occur. In Maryland, one to three generations of root-knot can be produced in a single growing season and depending upon the host and soil temperature, the entire life cycle may be completed in 17 days or as long as 57 days.

Root Lesion Nematodes

Pratylenchus spp.

Lesion nematodes are endoparasites of plant roots and burrow tunnels through the root cortex. All life stages except the egg stage are motile and can invade roots. Eggs are laid inside root tissues or in the soil where they hatch, and these juveniles then contribute to root injury. Root lesion nematodes are migratory and therefore are capable of repeatedly entering and exiting from root tissue, although several generations can occur inside the roots without the nematodes migrating into the surrounding soil. Large numbers of lesion nematodes in a root frequently cause the root to turn brown and die (Fig. 7). However, roots of some plants are not sensitive and do not turn brown even when infected by nematodes. In addition to the death of root cells caused directly by the nematode feeding, wounds resulting from nematode activity provide opportunity for root-infecting fungi such as *Rhizoctonia*, or *Verticillium dahliae*, which causes verticillium wilt, to cause disease. Studies have shown that *V. dahliae* and root lesion nematodes can interact synergistically, causing significant yield reduction at

Figure 8. Soil sampling for nematodes.

population levels that have little or no effect when each organism is present individually.

Lesion nematodes have a wide host range, which, in addition to most vegetable crops, includes corn, soybean, strawberry, lawn grasses, and many ornamentals and weeds (lambsquarters, redroot pigweed, common purslane, common chickweed, wild mustard, fireweed, wild carrot, common milkweed, field bindweed, common plantain, goldenrod, common ragweed, common groundsel, Canada thistle, Scotch thistle, chicory, and common dandelion). Lesion nematodes commonly occur throughout Maryland. Potatoes and strawberries are favorite hosts and populations tend to increase on them. The most common species encountered in Maryland is *Pratylenchus penetrans*.

Nematode Management

Extracting and identifying nematodes from soil samples or infected plant material is the best means for determining if and which nematode species are responsible for poor growth. The mere presence of nematodes in a sample does not mean they are causing plant damage. The nematodes must be identified and quantified correctly to determine if control measures are needed.

Sampling

Nematode populations are generally highest in the fall. Sampling at this time provides the most accurate information in predicting potential nematode damage to a crop (Fig. 8). Important things to consider when sampling include:

- Samples can be taken anytime the soil is moist and in good working condition.
- During the growing season samples may be taken whenever decline of plant growth is evident.
- One pint of soil is required for each sample submitted.
- Root samples should be submitted with the soil sample.
- Place each sample in a plastic bag, seal tightly and securely attach a sample identification number or symbol OUTSIDE of the bag.
- Keep samples out of direct sunlight to avoid overheating. Samples may also be damaged by heat if they are kept in the trunk of the car. When storing samples, avoid extremes of either hot or cold.

Soil sampling procedure

- In each field to be sampled, take the sample from an area with a common cropping history and/or which will be planted to a single crop.
- If the soil in the area to be sampled is not uniform, such as having clay in one portion and sandy in another, take one sample from each soil type.
- For an area 4 acres or less in size, one sample is sufficient. For larger fields, divide the area into 4-acre blocks and take a sample of each.
- Sample from the plowed layer of soil (6-8 inches) with a soil sampling tube (1 inch bore), trowel, or shovel.
- Take at least 20 cores of soil in a systematic pattern for each area to be sampled and deposit soil in a plastic bag.
- An alternative, but laborious sampling procedure, is to check for root-knot galls at the end of the season, which provides valuable information on the level of nematode infestation and the likelihood of nematode damage in the next year. With a shovel, remove plants from several areas of the field, being sure to recover the fine feeder roots, and observe roots carefully for the presence of galls. The number and size of the galls provides an indication of the degree of root-knot nematode infestation.

To ensure proper collection and handling of samples submitted for nematode analysis,

refer to the Nematode Diagnostic Laboratory "Sampling Procedures." Forms are available at county Maryland Cooperative Extension offices. Deliver samples to your county Extension agent who will forward them to the University of Maryland for diagnosis, or send or take the samples directly to the Nematode Diagnostic Laboratory, Department of Entomology, Room 3169, Plant Sciences Bldg., University of Maryland, College Park, MD 20742.

Control Measures

Whenever root-knot nematode is detected control measures must be applied because of the nematodes' known destructive capability. However, with most other nematodes the soil population levels that make control measures economically practicable are not as well understood. Control measures rarely kill all plant-parasitic nematodes, but rather reduce nematode populations to levels below which economic plant damage occurs. Therefore, when control measures are recommended, it is often necessary to repeat the measures periodically to maintain satisfactory plant growth. There are two ways to reduce nematode damage to plants: cultural methods and chemical control. A combination of both cultural and chemical control methods may be the most practical means of achieving adequate nematode control.

Cultural Control Practices

Sanitation

Cleaning machinery, tools and clothing after working in a nematode-infested field often slows the spread of nematode species into other areas. Since nematodes reproduce on certain weed species, weed control can significantly help slow population increase. Research in Florida found that if weeds are allowed to grow in between rows of plastic,

Figure 9. Radish and rye cover crops.

root-knot nematode populations are 5 to 10 times greater than if all weeds are completely controlled between rows. Vegetable transplants, for example tomato, pepper and crucifers, should be certified by state officials as free of nematodes and disease pathogens. Another sanitation practice is crop destruction. The crop should be ploughed under as soon after crop harvest as possible to avoid additional nematode population increases.

Resistant varieties

Nematode resistant plant material is available for several crops grown in Maryland, including tomato and sweet potato. Resistant varieties are not damaged severely by nematode infection and can reduce nematode populations by literally starving them. Therefore, planting these varieties in problem fields usually is the most effective and least expensive way to avoid losses. However, when resistant varieties are overused, new pathogenic strains or races of nematodes may appear. To prevent new races from developing, rotations should include non-host, resistant and/or susceptible crops when feasible. Using plants resistant or immune to one species of nematode but highly susceptible to another will reduce or negate the overall effectiveness of resistant varieties. Therefore, any plans for using resistant varieties must be designed with the knowledge of the existing nematode population in the field to be planted and the specific crop to be grown. Asparagus, onions, garlic, rye-grain, barley, oats, Sudangrass, tall fescue, and wheat are non- or poor hosts for root-knot nematode. Some common vegetables that have resistant/tolerant cultivars to root-knot nematode include: Bell Pepper: Carolina Wonder and Charleston Bell; Hot Pepper: Carolina Cayenne and Charleston Hot; Cherry Tomato: Small Fry and Sweet Million; Paste Tomato: Classica and Viva Italia; Tomato: Atkinson, Auburn, Better Boy, Early Girl, Park's Whopper, Goliath, Vine Ripe, VFN 8 and Wonderboy VFN; Snap Bean: Excell and Bountiful Heart. With many of the pepper and tomato varieties resistance begins to break down at high (>87°F) field temperatures.

Crop rotation/Cover crops

Crop rotation to a nonhost crop can reduce nematode populations from reaching economically damaging levels. However, it is necessary to positively identify the species of nematode in order to know what plants are nonhosts. Rotations like these will not only help prevent nematode populations from reaching economic levels, they will also help control plant diseases and insect pests. Sudangrass and sorghum contain dhurrin that degrades into hydrogen cyanide, which acts as a potent nematicide. Sesame also may be an effective rotation crop to control southern root-knot nematode.

The incorporation of organic matter into the soil can also reduce populations of plant-parasitic nematodes (Fig. 9). Several plant species are known to produce compounds that kill nematodes. Butyric acid, which is released during the decomposition of ryegrass and timothy, and isothiocyanate released during the decomposition of rapeseed and other plants in the genus *Brassica* are two examples. These plant materials must be incorporated into the soil as green manures to be effective. Plant selection is important because green manure treatments are not equally effective against all plant-parasitic nematodes and therefore it is important to consult with a diagnostic lab or extension educator to make sure the treatment is appropriate for the targeted plant-parasitic nematode. For example, rapeseed is effective against dagger nematodes (*Xiphinema* spp.) and root-knot nematodes but not lesion nematodes. Also, some rapeseed varieties are more effective at suppressing nematode populations than others, and some varieties will not overwinter or they bloom too early in summer to be useful. The rapeseed winter varieties work well for both spring and fall planting dates. A University of Maryland study evaluated crop rotations and other cultural practices to manage southern root-knot and lesion nematodes and found that a summer rotation of sorghum-Sudangrass reduced root-knot nematode populations as effectively as the control treatment (a non-resistant soybean cultivar with one nematicide application). Poultry litter/tillage (Year 1) and fallow (Year 2) were equally as effective in managing the lesion nematode population. To maintain the effect, the rotations had to be included annually.

A fallow system works well in reducing root-knot nematode populations, but is probably not practical for Maryland's erosive soils and for reducing nutrient runoff. If cover crops are used any volunteer crop or weed hosts must be controlled, otherwise the nematode population will not be reduced.

Chemical Control

Fumigant nematicides

Many broad-spectrum fumigants give outstanding control of nematodes in soil. As they turn to gas, the chemical diffuses through the spaces between soil particles contacting and killing nematodes. Fumigants perform best in soils that do not have high levels of organic matter and that are not water saturated but have adequate moisture. Fumigants such as methyl bromide, Telone and Vapam volatilize and move through the soil as gases. The movement of a fumigant through the soil is strongly affected by factors such as temperature, moisture, and soil texture. Fumigants tend to move upward through the soil and are quickly lost to the atmosphere unless the surface is sealed immediately after treatment. This is usually accomplished using plastic mulch. The plastic mulch is then planted into several days to weeks later when all traces of the fumigant are gone.

Nonfumigant nematicides

Several nonfumigant nematicides are available for some vegetable commodities. These nematicides do not volatilize in the soil as do fumigants but are effective over a wider range of soil temperatures and moistures. In general, distribution of these nematicides is less efficient than that of fumigants and results with granular nematicides have sometimes been inconsistent. Chemicals that are registered for use on selected vegetables include Counter (20CR), Mocap (10G and 6EC), Nemacur (15G and 3SC), Temik (15G), and Vydate L. The first two are contact nematicides, and the last two are both contact and systemic nematicides. Most work best at low to moderate nematode population levels. Consult the label before applying any of these chemicals and follow proper personal protection guidelines. Recommendations for the application of nematicides may be found in the University of Maryland's current Extension publication, "Commercial Vegetable Production Recommendations," EB-236.

References

NemaPix. *A Journal of Nematological Images*. 1997. Vol. One. J.D. Eisenback and Ulrich Zunke, eds.

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Figure 7: http://www.plantpath.wisc.edu/PDDCEducation/ScoutSchool/General/Slide66.htm.

Figure 8: http://www.ipm.iastate.edu/ipm/icm/1999/4-5-1999/scninterp.html.

Figure 9: Gerald E. Brust.

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