

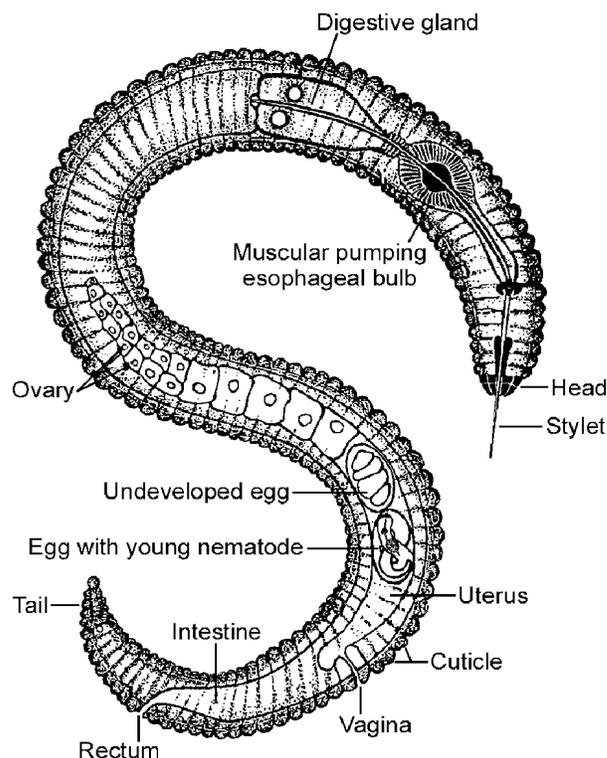
## Managing Nematodes for the Non-Commercial Vegetable Garden <sup>1</sup>

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Vegetable gardening is a popular pastime for many people in Florida. In addition to being fun, the vegetables just seem to taste better when they are homegrown. Unfortunately, we are not the only ones who like these vegetables. Every gardener has had the experience of putting hours of hard work into a garden expecting a bountiful harvest only to have it die. Who are the culprits? They may be things we can see like rabbits, birds, or insects. Other times they may be invisible, too small to be seen. Due to our warm temperatures, sandy soil, and humidity Florida has more than it's fair share of these pests and pathogens. Plant-parasitic nematodes (Figure 1) can be among the most damaging and hard-to-control of these organisms.

### What Are Nematodes?

Nematodes are unsegmented roundworms, different from earthworms and other familiar worms that are segmented (annelids) or in some cases flattened and slimy (flatworms). Nematodes living in soil are very small and most can only be seen using a microscope (Figure 2). There are many kinds of nematodes found in the soil of any garden. Most are beneficial, feeding on bacteria, fungi, or other

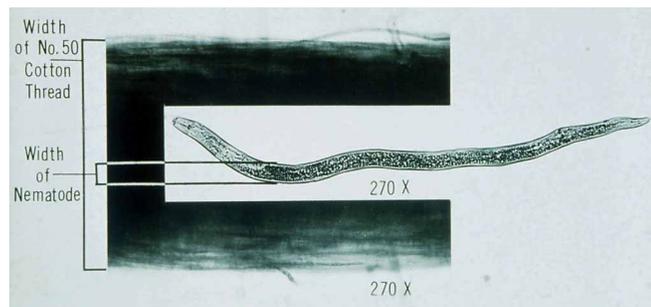


**Figure 1.** Diagram of a typical plant-parasitic nematode.

microscopic organisms and some may be used as biological control organisms to help manage

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important insect pests. Unfortunately, there are also a group of nematodes that feed on plants, these are called plant-parasitic nematodes.



**Figure 2.** Size comparison of a typical plant-parasitic nematode to a cotton thread.

All plant-parasitic nematodes have a stylet or mouth-spear that is similar in structure and function to a hypodermic needle (Figure 3). The nematode uses its stylet to puncture plant cells and then inject digestive juices and ingest plant fluids through it. All of the plant-parasitic nematodes that are important on vegetables in Florida feed on roots and other belowground parts. Some plant-parasitic nematodes remain in the soil and feed by inserting only their stylet into the root, these are called ectoparasitic nematodes (Figure 4). Some endoparasites continually burrow around inside the root, these are called migratory endoparasites (Figure 5). Other endoparasites establish permanent feeding sites inside the root. Once a feeding site is established the nematode no longer moves. These are called sedentary endoparasites. The sedentary endoparasite's body changes shape and is usually swollen (Figure 6).



**Figure 3.** A typical plant-parasitic nematode stylet resembles a hypodermic needle.

## How Do Nematodes Damage Plants?

As plant-parasitic nematodes feed they damage the root system and reduce the ability of the plant to



**Figure 4.** An ectoparasitic nematode feeding by inserting its stylet into a root tip.



**Figure 5.** Migratory endoparasitic nematodes tunnel within root tissue. Credits:



**Figure 6.** Root tissue pulled-back to reveal a swollen root-knot nematode within.

obtain water and nutrients from the soil. When nematode population densities get high, and/or when

environmental stresses occur, aboveground symptoms may become evident. Aboveground nematode symptoms often resemble nutrient deficiencies or drought stress. Symptoms include yellowing (Figure 7), wilting (Figure 8), stunting (Figure 9), or dying (Figure 10). Nematode damage usually occurs in irregularly shaped patches that may enlarge slowly over time. Be aware that similar conditions may be caused by other factors such as localized soil conditions, fungal diseases, or insects.



**Figure 7.** Yellowing of pepper plants resulting from nematode damage to roots.



**Figure 8.** Wilting bean plants resulting from nematode damage to roots.

### Root-knot Nematodes

Root-knot nematodes are the most well-known of the plant-parasitic nematodes. These are sedentary endoparasites. There are three species that are common in Florida, *Meloidogyne incognita*, *M. arenaria*, and *M. javanica*. The nematodes inject hormones into the roots that cause knots or galls to form (Figure 11). These galls are the only nematode symptoms that are easily recognized. Root-knot

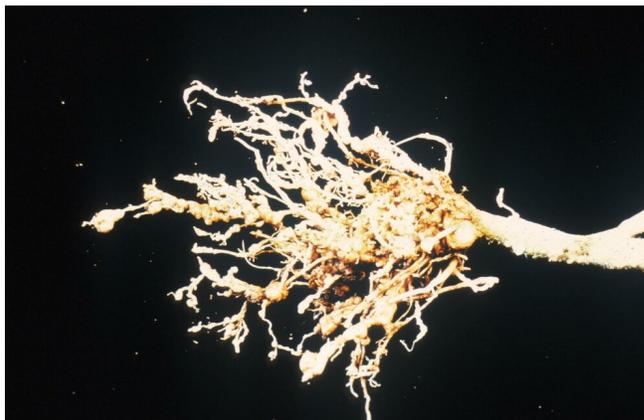


**Figure 9.** Healthy lettuce (left) and stunted lettuce that has been damaged by nematodes.



**Figure 10.** Tomato plants that are sickening (left) and dead (right) resulting from nematode damage.

nematodes cause extensive damage and changes in the root system. These changes allow fungi and bacteria to get into the plant. Some of these secondary organisms cause rotting of the root systems, others cause vascular wilts. Sometimes the damage caused by the nematodes and the other organisms together is worse than that caused by both organisms separately.



**Figure 11.** Tomato roots with root-knot galls.

Root-knot nematodes are one of the most destructive plant-parasites. High infestations can kill many types of vegetables. Garden vegetables that are commonly damaged by root-knot nematodes are tomato, potato, okra, beans, pepper, eggplant, peas, cucumber, carrot, field peas, squash, and melons. Sweet corn is tolerant to root-knot nematodes and is not normally damaged by them.

### Ectoparasites

There are several ectoparasitic nematodes capable of causing severe damage to vegetables in Florida. There is no type of vegetable that is not attacked by one or more species of ectoparasitic nematodes. The most destructive of these are the sting, awl, and stubby-root nematodes. Feeding by these nematodes usually cause a stunted or stubby looking root system (Figure 12). Sting nematodes are found in sandy soil and are common throughout much of Florida. Awl nematodes are usually found in wet habitats such as near ditches, ponds, or poorly drained areas. Several stubby-root species are found in Florida, one or more can usually be found in most Florida habitats. Other ectoparasitic nematodes that parasitize some vegetables are spiral, stunt, and lance nematodes.



**Figure 12.** Abbreviated "stubby root" symptoms resulting from damage caused by ectoparasitic nematodes.

### Other Nematodes

Reniform and cyst nematodes are sedentary endoparasites that occasionally damage vegetables in Florida. These nematodes do not cause galls like root-knot nematodes. Root symptoms are generally unthrifty root systems (Figure 13). Reniform nematodes are limited to soils with a high silt content.

In Florida they are found most often in the Homestead area and parts of the panhandle. Reniform nematodes are damaging to many garden crops such as beans, field peas, tomato, pineapple, and sweet potato. Cyst nematodes are not widespread on vegetables in Florida. They are occasionally found damaging crucifers (greens, broccoli, cabbage, etc.).



**Figure 13.** (Left) Healthy root system. (Right) Unhealthy root system, damaged by reniform nematodes.

Lesion nematodes are migratory endoparasites that are common in Florida soils. These nematodes usually cause dark sunken areas called lesions on roots (Figure 14). Lesion nematodes by themselves are usually not considered highly damaging to most vegetables in Florida. An exception is corn which can be damaged by a species of lesion nematode *Pratylenchus zaeae*. However, feeding by lesion nematodes can make many vegetables susceptible to root-rot and vascular wilt diseases.



**Figure 14.** Some nematodes cause root-lesions.

### How Do I Know if Nematodes are a Problem?

With any plant problem, having an accurate diagnosis is important to address the problem and to avoid wasting effort and unnecessary pesticide applications. Generally, nematode symptoms are identical to other disorders so visual inspection is not

enough. The only reliable way to determine if plant-parasitic nematodes are involved in a plant problem is by having a nematode assay conducted by a professional nematode diagnostic lab. The Florida Nematode Assay Lab is such a facility and will assay nematode samples for a cost that is currently \$20.00 for each sample from Florida and \$25 for each sample from outside of Florida. Nematode sample kits containing everything needed to collect and submit a sample, along with instructions, are available at your local county Cooperative Extension office.

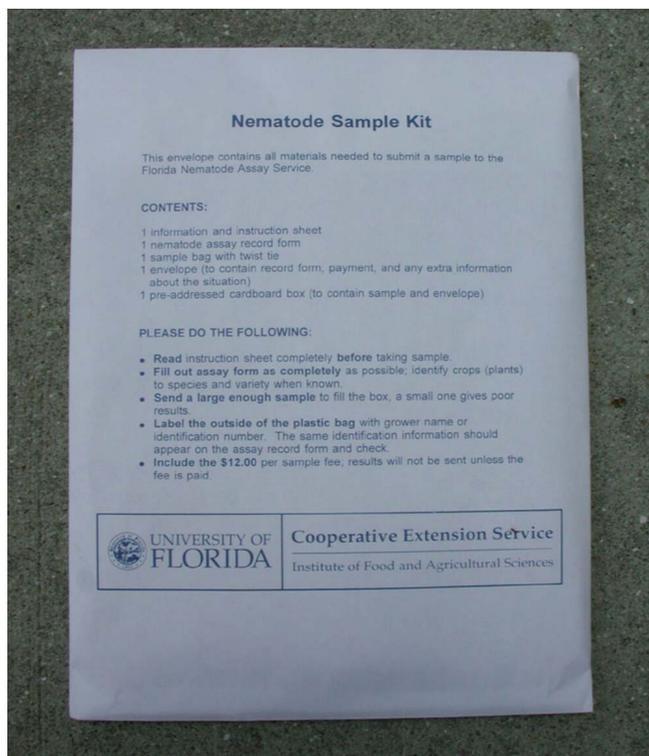


Figure 15. Nematode Sample Kit.

Nematode analysis is a separate procedure and requires different sampling guidelines than those required for soil analysis or plant disease samples. Do not send samples in soil test bags! The addresses are different and, more importantly, the soil testing bags are designed to dry soil out. Drying invalidates the results of a nematode assay. The accuracy of the diagnosis depends on the quality of the sample that you submit. If you are taking a sample for submission to another lab, or if you are submitting a sample to the Florida lab without using our sample kits, following the guidelines below will help insure an accurate diagnosis.

## Sampling

**Before planting:** It is best to take nematode samples well before planting. This allows you to implement management practices, or decide if your garden is in a good spot. Collect soil from 8 to 12 locations in the garden. Samples should be taken 8 to 10 inches deep. About a handful of soil from each location is adequate. Combine all the soil into a single plastic bag. The total volume of soil from the samples should be between 1 pint and a half gallon. Samples may be taken with a shovel, trowel or other device. If using a shovel you can put part of the soil from 8 to 12 shovel fulls into a bucket. Thoroughly mix the soil in the bucket then take out a pint for analysis.

**After planting:** Often a nematode assay is needed to determine if nematodes are causing a plant to get sick. For this type of sample both **soil and roots** are required! Dig soil and roots from around the plant. For most vegetables samples should be taken 8 to 10 inches deep. For very small plants the samples do not need to be that deep. Do not include the top 1 inch of soil. If multiple plants are affected collect some soil and roots from several plants. Place the soil and roots together in the same plastic bag. A minimum of 1 pint of soil and 1 to 2 cups of roots are required.

## Handling

1. If submitting more than one sample make sure that the outside of each bag is labeled with a permanent marker. You can also write on masking tape stuck to the bag. Do not put paper labels inside of bags, they will decompose and be illegible. If submitting several samples together wrap each in newspaper so that the labeling doesn't wear off.
2. Seal plastic bags to keep sample moist. Dried out samples are no good for nematode diagnosis. Self-sealing bags often come open in the mail. If using a self-sealing bag tape the seal shut.
3. Keep samples out of direct sunlight or heat. Heat and ultraviolet light kill nematodes. Even a few minutes on the dashboard or in the back of a pickup can invalidate assay results. If you are storing the sample for more than a day it is best to keep it refrigerated, but not frozen.

4. Handle the sample gently and pack it well. Nematodes are between soil particles. So, the more the soil gets banged around the more the nematodes may get destroyed.
5. Fill out the information on the nematode assay form. In order to make a diagnosis we need to know as much as possible about the plant or plants in question. Make sure that the identification on the form matches the identification on the sample bag.

### Submitting The Sample

1. There is a \$20 fee for each sample from Florida and \$25 fee for each sample from outside of Florida. Place a check or money order payable to the "University of Florida" into an envelope. Do not send cash.
2. Put the sample, assay form, and payment envelope into box. Seal the box with gummed tape.
3. Mail, ship, or deliver the samples to the Nematode Assay Lab as soon as possible. The mailing address is: Nematode Assay Lab, PO Box 110820, Building 78 Mowry Rd., Gainesville, FL 32611.

## What Can I Do About Nematodes?

### Chemicals

There are no nematicides labeled for use in home gardens.

### Resistance and Tolerance

Plants that a particular nematode cannot reproduce on are termed **resistant** to that nematode. Plants that can be reproduced on by the nematode but are not damaged are termed **tolerant**. Table 1 lists some of the more popular vegetables grown in Florida and the nematodes that damage each one. If a nematode assay indicates a certain type of nematode present it is possible to plant another crop that will not be damaged by it.

Some vegetable varieties are marketed as "nematode resistant." Usually this resistance is

only to 1 or 2 of the root-knot species. These plants may still be damaged by other species of root-knot nematodes or other types of nematodes. Still, it is best to use these varieties when root-knot is present.

### Solarization

Solarization is a process of using heat from the sun to kill nematodes and other pests. The soil should be worked with a hoe or rototiller to break up clods. Remove all sticks, roots, and clumps. The soil should be moist, but not wet. Cover the soil with a **clear** plastic tarp and bury the edges of the plastic (Figure 16). Leave the plastic on the soil for at least 4 to 6 weeks. Do not remove the plastic until you are ready to plant.



**Figure 16.** Soil solarization being conducted in a residential landscape.

Sunlight goes through the clear plastic and heats the soil underneath. The plastic then holds in the heat so it penetrates the soil. Long-term exposure to high temperature kills nematodes, as well as many weeds, fungi, and insect pests. The disinfested zone is usually 6 to 8 inches deep. Because it depends on sunlight and heat, solarization works best during the summer months. This fits well into the Florida growing season where vegetables are grown in the cooler seasons.

The benefits of solarization may be enhanced by using a second layer of plastic suspended by wire hoops. An air gap is created between the two layers of plastic giving extra insulation. Also, weeds that penetrate the first layer may then be killed by heat trapped between the plastic layers.

## Flooding

In some areas of Florida flooding may be used to disinfest soil from plant-parasitic nematodes. This needs to be done in areas with a hard-pan or clay layer below the soil surface. High areas with deep sand are not conducive to flooding as the water simply sinks down to the water table. The area should be flooded three times in two week cycles with two weeks flooded and two weeks dry.

## Cover Crops

A cover crop is a crop that is not harvested. Instead it is planted in the season between harvestable crops. Because most vegetables in Florida are grown in the Spring or Fall cover crops are usually grown in the Summer. Cover crops have many benefits including improving the soil, preventing erosion, and increasing fertility. Cover crops may also be used to decrease soil pests.

Plant cover crops that the more important nematode species in an area cannot feed on. Because the nematodes cannot feed on the cover crop, their population densities will decline over time. Nematode damage to the vegetables will be less severe due to the lower population densities.

This approach requires that you know which nematodes are potential problems in order to choose the correct cover crop. Not all cover crops are equally effective on all plant-parasitic nematodes. See Table 2 for a list of cover crops and their relative ability to control root-knot and sting nematodes. It is very important that weeds be kept from growing along with the cover crop. The weeds can feed the nematodes and negate the cover crop's benefits. Detailed information on the use of specific cover crops to control plant-parasitic nematodes is available at <http://edis.ifas.ufl.edu/IN516>, <http://edis.ifas.ufl.edu/IN531>, <http://edis.ifas.ufl.edu/NG043>, and <http://edis.ifas.ufl.edu/IN483>.

## Organic Amendments

Organic amendments can be added to soil as compost, manure, green manure, or other materials. Organic matter can help prevent nematode damage in

several ways. The organic matter increases the ability of the soil to hold water and nutrients, and improve soil structure. This makes a better environment for most plants and can help the plants survive in spite of the nematodes. Organic amendments can also increase natural enemies of nematodes that suppress the nematode populations. Some organic amendments can release chemicals or gasses that are toxic to the nematodes.

There are several "organic" nematode management products for sale. Researchers with the University of Florida have worked with a number of these, but probably not all of them. In the majority of cases these products work no better than adding any other, less expensive, organic material.

For more detailed information on these topics see "Soil organic matter, green manures, and cover crops for nematode management" online at <http://edis.ifas.ufl.edu/VH037> or at your County Cooperative Extension Service office.

## Planting

Nematode activity slows as soil temperatures drop. Therefore, vegetables grown in cooler months are not as damaged by nematodes as those grown in warmer months. Become familiar with the temperature requirements of the plant and grow as early as possible in the Spring or as late as possible in the Fall.

Older transplants are generally more resistant to nematodes than younger transplants. So older transplants should be used in nematode infested soil. Inspect the roots of transplants for root-knot galls. Occasionally nematodes can be introduced with contaminated transplants.

## Soil Tillage and Root Destruction

Roots left in the soil can continue to live and support nematode reproduction. Endoparasitic nematode eggs are attached to roots and will continue to hatch. Therefore, as soon as the crop is harvested pull up all plants and get rid of them. Till the soil with a rototiller or hoe and remove all roots that might harbor nematodes. Exposure to sunlight and drying kills nematodes so working the soil several times can help reduce nematode populations.

## **Container Growing**

Growing vegetables in containers off of the ground can avoid having to deal with nematode problems. Make sure you inspect transplant roots for root-knot galls. You don't want to introduce a problem. Also use clean potting media. Do not mix potting media with native soil or you might contaminate it.

## **Summary**

Following the recommendations listed in this document can help avoid or reduce problems with plant-parasitic nematodes in the garden. However, there are no guarantees of success. County and state faculty with the University of Florida are continually exploring new nematode management options. This document will be updated yearly to make the most recent data available to you. If you are reading an older version of this document you are encouraged to look at the current version on-line at <http://edis.ifas.ufl.edu/> or at your County Cooperative Extension Service office.



**Table 2.** Effects of some cover crops on nematodes important as plant pests in Florida.

Plant Species	Nematodes	
	Root-knot*	Sting*
Bermudagrass, <i>Cynodon dactylon</i>	G	P
French marigold, <i>Tagetes patula</i>	G**	P
Hairy Indigo, <i>Indigofera hirsuta</i>	G	G
Pangola digitgrass, <i>Digitaria decumbens</i>	G	P
Transvala digitgrass, <i>Digitaria decumbens</i>	F	G
Showy crotalaria, <i>Crotalaria spectabilis</i>	G	G
Sunn hemp, <i>Crotalaria juncea</i>	G	G
Velvetbean, <i>Mucuna pruriens</i>	G	G

\* G = good control of the most common species of this nematode; P = poor or no control of this nematode; F = fair control

\*\* Effectiveness differs among varieties of marigolds; one report stated yellow or gold "Petite French" types to be most effective against the greatest number of root-knot nematode species.