Management of Plant-Parasitic Nematodes in Florida Cotton Production¹

Zane J. Grabau²

Nematodes in Cotton Production

Nematodes are non-segmented roundworms that are generally microscopic. They live in animal hosts, soil/plant roots, or water. Nematodes in agricultural systems usually live in soil and can be divided into three categories: (1) entomopathogenic nematodes that infect insects; (2) free-living nematodes that feed on bacteria, fungi, or other nematodes and may be beneficial for crop production; and (3) plant-parasitic nematodes that feed only on plants and may drastically suppress crop yield.

Plant-parasitic nematodes of cotton reduce yield by decreasing root size and efficiency, leading to shorter shoots. Infected plants are generally smaller and show varying degrees of yellowing, called chlorosis. They may produce fewer or smaller bolls, and, in severe cases, they die. Nematode infection can also increase the incidence of fungal root diseases, particularly Fusarium wilt. The amount of damage nematode cause is related to their population densities. The greater the density, the greater the damage.

Most plant-parasitic nematodes of cotton complete their life cycles (egg, four pre-adult juvenile stages, egg-producing adult) in two to four weeks depending on the nematode species and environmental conditions, so nematodes may go through six or more generations in a single growing season. A mature female nematode can produce upwards of hundreds of eggs, depending on the nematode species and environmental conditions, so nematode populations can increase rapidly.

Plant-parasitic nematodes of cotton spend their entire life in soil or roots and can be classified by where they reside when feeding, something that is important when sampling for nematodes. Ectoparasites (ecto means outside) spend their entire lives outside the roots. Only the head end or stylet of an ectoparasite enters the roots when it feeds (Figure 1). A stylet is a needle-like mouthpart that all plant-parasitic nematodes possess. Endoparasites (endo means inside) enter the root as a juvenile or adult and remain in the root to feed. Some endoparasites are mobile while feeding (migratory endoparasite) while others do not move once they begin feeding (sedentary endoparasite). A portion of the population of endoparasitic nematodes can be found in the soil at any given time because eggs generally hatch in the soil and mobile nematode stages may move freely in soil or from root to root.

In Florida, southern root-knot nematode (Meloidogyne incognita), reniform nematode (Rotylenchulus reniformis), and sting nematode (Belonolaimus longicaudatus) cause major damage to cotton (Figures 2, 3, 4, 5, and 6). Southern root-knot nematode (a sedentary endoparasite) is probably the most common among these nematodes. It occurs in a variety of soil types and textures although it favors sandy

¹ This document is ENY-004, one of a series of the Department of Entomology and Nematology, UF/IFAS Extension. Original publication date December 2005. Revised January 2017. Visit the EDIS website at http://edis.ifas.ufl.edu. This publication replaces Cotton Nematode Management, written by Jimmy R. Rich, professor emeritus, Department of Entomology and Nematology, UF/IFAS North Florida REC; and Robert A. Kinloch, associate professor (Retired), Department of Entomology and Nematology, UF/IFAS West Florida REC.

² Zane J. Grabau, assistant professor; Department of Entomology and Nematology, UF/IFAS Extension, Gainesville, FL 32611.
soils. There are many species or types of root-knot nematodes, and it is important to distinguish between these types because different types infect different crops. Some species are also divided into different races based on the hosts they infect. Races 3 and 4 of southern root-knot nematode infect cotton, but races 1 and 2 do not.

Reniform nematode (a sedentary endoparasite) prefers fine-textured soils (around 70 percent sand or less), which probably restricts its distribution somewhat, but it is relatively common in cotton-growing regions of Florida. Root-knot and reniform nematode have moderate to high damage potential, and are a major concern because they can increase rapidly in a field, particularly reniform nematode. Sting nematode (an ectoparasite) can be very damaging but is restricted to very sandy soils (80 percent or greater sand and 10 percent or less clay) with minimal organic matter, which limits its range. See the UF EDIS publications on sting nematode and reniform nematode for more information about these nematodes. Columbia lance nematode (*Hoplolaimus columbus*) can be damaging to cotton, but it is apparently not common in Florida. Lesion nematodes (*Pratylenchus* spp.) are common and some species may parasitize cotton, but probably do not cause major damage.

Figure 1. An ectoparasitic nematode (sting nematode) feeding from outside roots. Credits: Ole Becker, University of California, Riverside. Used with permission

Figure 2. Mature female root-knot nematode removed from root. Credits: Charles Overstreet, Louisiana State University. Used with permission

Reniform nematode (a sedentary endoparasite) prefers fine-textured soils (around 70 percent sand or less), which probably restricts its distribution somewhat, but it is relatively common in cotton-growing regions of Florida. Root-knot and reniform nematode have moderate to high damage potential, and are a major concern because they can increase rapidly in a field, particularly reniform nematode. Sting nematode (an ectoparasite) can be very damaging but is restricted to very sandy soils (80 percent or greater sand and 10 percent or less clay) with minimal organic matter, which limits its range. See the UF EDIS publications on sting nematode and reniform nematode for more information about these nematodes. Columbia lance nematode (*Hoplolaimus columbus*) can be damaging to cotton, but it is apparently not common in Florida. Lesion nematodes (*Pratylenchus* spp.) are common and some species may parasitize cotton, but probably do not cause major damage.

Figure 3. Second-stage juvenile (J2) root-knot nematode at 400x magnification. This is the stage that emerges from an egg and enters the root to establish a feeding site. Credits: Zane Grabau, UF/IFAS

Figure 4. Swollen female reniform nematodes, in white, and light brown egg masses produced by reniform nematode on cotton roots. Credits: Charles Overstreet, Louisiana State University. Used with permission
Management of Plant-Parasitic Nematodes in Florida Cotton Production

Sampling for Nematodes

Determining what nematodes are present in a field and at what densities is helpful for developing a plan for managing nematodes. This can be accomplished by submitting soil or root samples to a professional nematology diagnostic lab such as the UF/IFAS Nematode Assay Laboratory. These samples may be submitted to aid with the diagnosis of disease problems or for advisory service to predict whether or not a potential nematode problem may exist for a future crop. This information allows growers the opportunity to implement management practices to reduce the damage that nematodes may cause.

Detailed information about sampling for nematodes can be found in EDIS Publication ENY-027, Sampling Instructions for Nematode Assays. When submitting samples for testing for nematodes, either soil or soil and plant root samples should be included. It is suggested to always collect soil because ectoparasitic nematodes can only be recovered from the soil and at least one stage of all endoparasites can be found in soil. It can be useful to collect plant roots in addition to soil when diagnosing crop damage. If the problem is caused by an endoparasitic nematode, then some nematodes will be found inside the roots.

Soil samples for nematodes should be taken to about 12 inches deep. If plants or remnants of plants are still in the field, soil samples should be taken within a few inches of plant stems and intersect plant roots if possible. Because nematode densities vary considerably across a field, about 20 soil cores of about an inch in diameter should be taken from an area of 10 acres or less. Thoroughly mix cores within a single area and submit a 1-pint portion of this mixture for analysis. For larger areas, take multiple, separate samples, making sure to properly label samples. Do not take samples when soil is excessively wet or dry. Store soil samples in closed plastic bags to protect them from drying and keep them cool but not frozen until shipment. When digging root samples, be sure to retain the soil surrounding the roots to slow decay by microbes. Root samples should be collected and stored in a similar manner to soil samples. If samples are intended to diagnose a current crop problem, it may be useful to collect separate samples from the diseased area and a healthy area for comparison.

While samples can be taken at any time of the year, nematode populations fluctuate throughout the year, so timing can be important. In most cases, nematode population densities peak around harvest while plant roots are still in the ground, so that is an ideal time to take routine or predictive samples. When diagnosing crop damage, take samples as soon as you see damage and again around harvest. For questions about sampling for nematodes, contact your local UF/IFAS Extension agent, personnel of the Nematode Assay Lab, or the author of this paper.

Foliar Symptoms

Symptoms of nematode infection in cotton are often indistinct and difficult to detect, so routine sampling for nematodes is especially important. Foliar symptoms of nematode infection are often similar to symptoms of nutrient deficiency or diseases and include stunted plants, sometimes with red or yellow hue. These symptoms often occur in oval or irregular patches in the field, corresponding to areas of greater plant-parasitic nematode densities. These patches may surround the initial entry point for the nematodes or correspond to uneven environmental conditions, such as soil type.
Plants infected with root-knot nematode also tend to wilt during the day in hot, dry conditions. Plants recover in the evening when temperatures cool. Sting nematode infection can cause severe stunting leading to reduced plant stand, symptoms that tend to appear early in the year (Figure 7). In fields infested with sting nematode, there may be sharp boundaries between healthy and diseased plants with apparently healthy plants next to severely stunted ones. Fields recently infected by reniform nematode may exhibit patchy stunting, but this aggressive nematode is often evenly distributed throughout a field after a few years, which leads to uniform stunting that is difficult to detect.

**Belowground Symptoms**

Stunted root systems and reduced yield are common, generalized symptoms of plant-parasitic nematode infection. Specific belowground symptoms vary by nematode. Root-knot nematode infection is characterized by irregular swellings of the roots called galls (Figure 8). These galls are caused by an increase in the size and number of cells triggered by root-knot nematode feeding. Galls contain one or more sedentary adult female root-knot nematodes. These nematodes are contained in the roots and small, about 1 mm in diameter, so it is very difficult to view them in the field. However, with some practice, or the aid of a nematologist, it is possible to excise these pearly white females from the roots and look at them—a hand lens will make the examination much easier. Galls caused by root-knot nematode are often smaller on cotton than other crops. Gall size will vary based on the severity of the infection; galls may coalesce across the root surface if nematode densities are very great. Galls sometimes rot because they become entry points for secondary infection by other pathogens.

Soil may cling more easily to roots infected by root-knot or reniform nematode than uninfected roots. This is because female root-knot and reniform nematodes exude gelatinous egg masses—sac-shaped structures containing hundreds of nematode eggs. Reniform nematode produces these egg masses at the root surface while root-knot nematode may produce them inside or on the surface of the root. Soil adheres to the roots coated with moist egg masses. Egg masses are brown and about 1 mm or smaller, so they are not readily visible with the naked eye.

Reniform nematode does not induce root galling or any other distinct below-ground symptoms. Because aboveground symptoms of reniform nematode infection are also indistinct, it is especially important to soil sample regularly for this nematode. Sting nematode causes dark lesions of necrotic root tissue, often near the root tip where this nematode tends to infect. Lateral roots may proliferate...
above this point, resulting in severely stunted roots with a hairy or bearded appearance.

Management
Once plant-parasitic nematodes infest a field, it is not possible to eradicate them completely. Rather, the goals are to minimize crop damage by nematodes and keep nematode densities low, ideally at a level where no crop loss occurs. The best way to manage a nematode problem is to use a combination of the most effective and economical practices for the given production situation based on nematode infestation level, other pest problems, available equipment, economics, and other considerations.

Exclusion
Exclusion is taking steps to stop or slow the spread of one or more plant-parasitic nematodes from infested to non-infested fields. Nematodes do not actively migrate from field to field; rather they are transported in infected soil, water, or plants. Wind and rain move these materials naturally, but they are also carried on field equipment. Besides avoiding intentionally moving soil or plant material, cleaning these materials from field equipment can slow nematode movement. This is particularly important when working both infested and non-infested areas. Nematodes can also be brought in on infected planting material. In general, this is not a large concern for row crops because cotton nematodes do not infect seeds, but closely monitor any crops that are started as transplants and rotated with cotton.

Crop Rotation
Producers can use crop rotation to reduce nematode densities by growing a crop that the particular nematode cannot reproduce on (a non-host crop) or that the nematode does not reproduce well on (poor host). As a guide for choosing rotation crops for nematode management, the host statuses, based on current information, of selected cash and cover crops for the three major plant-parasitic nematodes of Florida cotton are listed in Table 1.

Root-knot and reniform nematodes have wide host ranges, but for each nematode there are a few agronomic or forage crops that can help with management. Cotton and peanut are good rotation partners for managing root-knot and reniform nematodes. Neither southern root-knot nor reniform nematode infects peanut, while the root-knot nematodes that infect peanut, *Meloidogyne arenaria* and *Meloidogyne javanica* (peanut and Javanese root-knot nematodes) do not infect cotton. Corn will help manage reniform nematode but is a host for most root-knot nematodes. Soybeans are good hosts for both root-knot and reniform nematodes.

Sting nematodes have a very wide host range, including cotton, peanut, and soybeans, so there are few rotations that will help manage these nematodes. Grasses are especially good hosts for sting nematodes and should be avoided where these nematodes are a concern. Weed management is an important supplement to crop rotation because plant-parasitic nematodes can be maintained or increased on weedy hosts, including volunteer cotton, growing in a non-host crop.

Fallow and Cover Cropping
Offseason periods when a cash crop is not grown should also be considered as part of a crop rotation strategy. These periods are opportunities to either reduce or worsen a nematode problem. Fallowing fields in the offseason can help reduce nematode densities, but only if weeds, including volunteer cotton, are controlled because many of them serve as hosts for nematodes. Growing an appropriate cover crop is usually best because erosion can be a major problem when fallowing fields, particularly on sandy soils.

If cover crops are grown, choosing a non-host for the nematodes present in a given field is critical for nematode management. Table 1 includes a summary of the host status of selected cover crops for root-knot and sting nematodes. Small-grain cover crops, such as wheat, rye, and oats, are poor or non-hosts for reniform nematode but good hosts of sting nematode. Susceptibility of these cover crops to southern root-knot nematode tends to vary by cultivar.

Some cover crops—such as Brassicas (radish, mustards, etc.)—may have nematicidal properties, directly reducing densities of nematodes. However, most cover crops with nematicidal properties are not suitable or have not been tested as a winter cover crop in Florida. Susceptibility to nematodes should always be considered when selecting a cover crop, even one with nematicidal properties, because these cover crops can also be good hosts for some plant-parasitic nematodes, such as most Brassicas for root-knot nematodes. For further information on cover cropping for root-knot nematode management, see (http://edis.ifas.ufl.edu/in892).

Resistant Cultivars
Resistant cultivars prevent or reduce reproduction by one or more specific types or genera of plant-parasitic...
nematodes. Resistant cultivars can be categorized by their
efficacy, which ranges from immune (no individuals of
the target nematode can reproduce on the cultivar) to
moderately resistant (some individuals can reproduce on
the cultivar). Resistance is a trait that is selected for or bred
in a cultivar; the given nematode can infect most cultivars
of the crop to which the resistant cultivar belongs. Resistant
cultivars sustain little or no damage from the target nema-
tode, and growing resistant cultivars reduces field nematode
population densities in a similar manner to non-host crops.

Some cotton cultivars with moderate resistance to root-
knot nematode are commercially available. There are no
commercially available cotton cultivars that are resistant
to reniform or sting nematodes. Using cotton varieties
resistant to Fusarium wilt may curb yield loss from nema-
todes because nematode infection increases Fusarium wilt
incidence.

Nematicides and Other Commercial Products

Nematicides are chemical products intended to reduce
nematode densities. To protect workers, consumers, and
the environment, nematicides must be used in a legal
manner, as specified on the label, including on specified
crops only. Cotton nematicides may be fumigants, broad-
spectrum pesticides that move through soil as a gas, or
non-fumigants, liquid or granular products that affect only
nematodes and, for some products, insects or fungi. Ideally,
nematicides reduce crop damage and nematode popula-
tions. However, nematicide application sometimes provides
only early-season nematode control, protecting crops from
some damage, but not preventing nematode populations
from rebounding to high population densities later in the
season.

Because nematicide application, particularly fumigation,
is a relatively high-cost practice and agronomic crops such
as cotton are relatively low-value, growers should test the
level of nematode infestation in their fields before choosing
to apply nematicides. Because nematode distribution is
often patchy, applying nematicides only to the regions of a
field with high nematode infestation can be a cost-efficient
strategy.

1,3-dichloropropene is a fumigant product available for
use on cotton and can be effective for managing nematode
problems. This product is applied as a liquid that volatilizes
once in soil, moving through the soil profile. 1,3-D is often
applied in the row at less than the full label rate to provide
an economic return. To ensure maximum efficacy, apply
1,3-D in a manner that maximizes fumigant movement
through the soil profile and improves chances for contact
with nematodes. This means injecting the fumigant to at
least a 10- to 12-inch depth using a shank or other equip-
ment, then sealing and compacting the soil.

Metam sodium and metam potassium are broad-spectrum
products that are also labeled for nematode management
in cotton. At the lower-than-label rates typically used in
cotton production, they are not very effective for nematode
management. They are formulated and applied as a liquid
but they do not consistently volatilize once in soil, therefore
they depend on water to transport them through the
upper soil. They must be sprayed over the soil surface and
incorporated with a tillage instrument or injected with
closely-space chisels (e.g., 7 inches apart).

There are two non-fumigant nematicides currently labelled
for Florida cotton. Oxamyl is a soil or foliar spray, but is
not currently available although it is expected to return
to production in the future. Fluopyram is a new active
ingredient introduced in the last few years, and the current
product (Velum Total) is combined with the insecticide
imidacloprid. For nematode control, fluopyram would
be applied as an in-furrow spray, but it has not yet been
tested extensively in University trials. Fluopyram has
fungicidal activity and is the active ingredient in other
products labelled as fungicides. Velum Total is not labelled
as a fungicide but is considered a group 7 fungicide for
resistance management.

A couple of biologically based products are also available
but have not been tested extensively on cotton in Florida.
Majestene is a biological nematicide composed of dead
Burkholderia bacteria. It can be injected into the soil or
applied as an in-furrow or banded spray. Meloco WG
contains live spores of the fungus Paecilomyces lilacinus.
Because the product contains live organisms, it must be
stored in a cool (70°F or less) location, not mixed with or
exposed to other chemicals, and applied to moist soil.

In addition to nematicides applied to soil or plants, several
seed treatments (Aeris, Avicta, VOTIVO, and others) are
labeled for use against nematodes. Most of these products
are pre-coated on seeds and may be exclusive to a particular
seed brand. Because seed treatments contain small amounts
of product that are not distributed widely in the soil, they
may protect from some early-season nematode damage,
but can only provide modest nematode control and yield
increase. Seed treatments are usually relatively low cost,
though, so a modest yield increase would provide a return
on investment.
Other Practices

Practices that promote plant health may help plants better tolerate nematode infection even if they do not reduce nematode populations. This includes practices such as maintaining soil fertility and tilth, providing adequate water, and managing insects and diseases (see EDIS publication AGR-194 Cotton Cultural Practices and Fertility Management (http://edis.ifas.ufl.edu/ag200). Good knowledge of environmental and biological properties of one’s soil can also aid in making good nematode management decisions. As mentioned above, soil type and texture influence where nematode damage is likely to occur.

Some soils keep plant-parasitic nematode densities low despite a susceptible crop. This suppression often develops gradually over a period of time. Practical and tested methods for developing suppressive soils have not been established, but natural predators and pests of nematodes are one cause of nematode-suppressive soils. Recognizing suppressive soil by monitoring nematode densities and cropping history can help cut costs by eliminating unnecessary management practices.

Selected References


Table 1. Host status of selected cash and cover crops for management of specific plant-parasitic nematodes of cotton.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Southern root-knot nematode(^1)</th>
<th>Reniform nematode</th>
<th>Sting nematode(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agronomic or forage crops</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bahia grass</td>
<td>Poor/non-host</td>
<td>Poor/non-host</td>
<td>Good host</td>
</tr>
<tr>
<td>Carinata</td>
<td>Good host</td>
<td>Unknown(^2)</td>
<td>Unknown</td>
</tr>
<tr>
<td>Corn</td>
<td>Good host</td>
<td>Poor/non-host</td>
<td>Good host</td>
</tr>
<tr>
<td>Millet</td>
<td>Poor/non-host</td>
<td>Poor/non-host</td>
<td>Good host</td>
</tr>
<tr>
<td>Peanut</td>
<td>Poor/non-host</td>
<td>Poor/non-host</td>
<td>Good host</td>
</tr>
<tr>
<td>Potato</td>
<td>Good host</td>
<td>Good host</td>
<td>Good host</td>
</tr>
<tr>
<td>Sesame</td>
<td>Varies by cultivar</td>
<td>Varies by cultivar</td>
<td>Unknown</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Varies by cultivar</td>
<td>Poor/non-host</td>
<td>Good host</td>
</tr>
<tr>
<td>Soybean</td>
<td>Varies by cultivar</td>
<td>Varies by cultivar</td>
<td>Good host</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Good host</td>
<td>Poor or non-host</td>
<td>Good host</td>
</tr>
<tr>
<td>Tobacco</td>
<td>Varies by cultivar</td>
<td>Good host</td>
<td>Poor/non-host</td>
</tr>
<tr>
<td><strong>Fruit or vegetable crops</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field pea</td>
<td>Good host</td>
<td>Good host</td>
<td>Good host</td>
</tr>
<tr>
<td>Melon (specialty)</td>
<td>Varies by cultivar</td>
<td>Good host</td>
<td>Good host</td>
</tr>
<tr>
<td>Snap bean</td>
<td>Varies by cultivar</td>
<td>Good host</td>
<td>Good host</td>
</tr>
<tr>
<td>Tomato</td>
<td>Varies by cultivar</td>
<td>Good host</td>
<td>Good host</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Good host</td>
<td>Good host</td>
<td>Poor/non-host</td>
</tr>
<tr>
<td><strong>Selected cover crops</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sudan grass</td>
<td>Poor/non-host</td>
<td>Poor/non-host</td>
<td>Good host</td>
</tr>
<tr>
<td>Winter oats</td>
<td>Varies by cultivar</td>
<td>Poor/non-host</td>
<td>Good host</td>
</tr>
<tr>
<td>Winter rye</td>
<td>Varies by cultivar</td>
<td>Poor/non-host</td>
<td>Good host</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>Varies by cultivar</td>
<td>Poor/non-host</td>
<td>Good host</td>
</tr>
</tbody>
</table>

\(^1\) Host range of southern root-knot nematode varies by race or population. There is evidence that physiological or geographic races of sting nematode also exist, but these are not well-established.

\(^2\) Most mustards are non-hosts or poor hosts of reniform nematode, but carinata has not been tested.