ENY-008

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Nematode Management for Golf Courses in Florida[1]

William T. Crow[2]

Golf contributes to the quality of life of many residents and visitors to the state of Florida and generates billions of dollars for our state economy. Some of the criteria that are used to designate a good course are speed and evenness of the playing surface, and green, healthy grass. Each of these quality parameters can be negatively affected by plant-parasitic nematodes (Figure 1). Of all the pests that commonly affect golf course turf in Florida, nematodes are probably the least understood and most difficult to manage. Nematode problems are more common and more severe in Florida than in most other states because our climate and soils provide a perfect habitat for many of the most destructive nematode species.

What Are Plant-Parasitic Nematodes?

Nematodes are unsegmented roundworms. Not all nematodes are bad, in fact most species are beneficial, feeding on bacteria, fungi, or other microscopic organisms. There are even nematodes that can be used as biological control organisms to help manage important turf insect pests. However, there also are genera of nematodes that are pests or pathogens of animals or plants. Nematodes that feed on plants are called plant-parasitic nematodes. Plant-parasitic nematodes are very small, microscopes are required to see them (Figure 2).

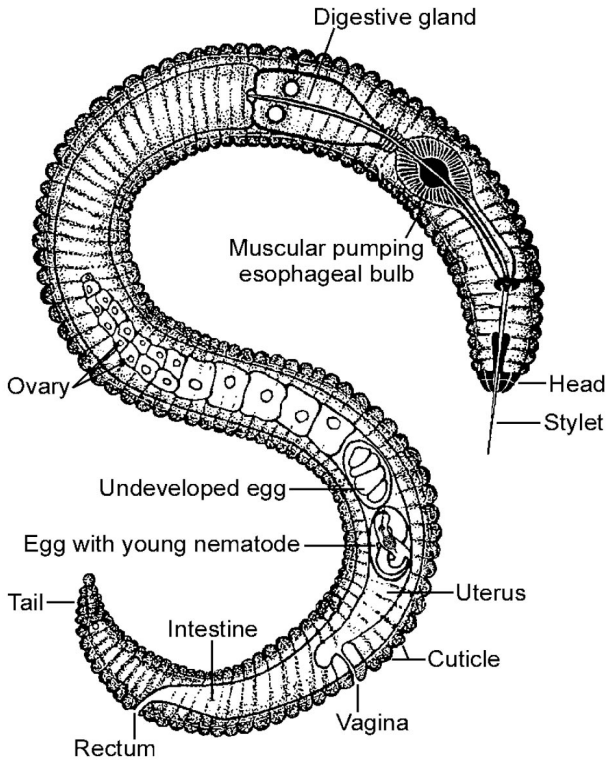

Figure 1. Diagram of a typical plant-parasitic nematode.

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2. William T. Crow, assistant professor, Entomology & Nematology Department, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

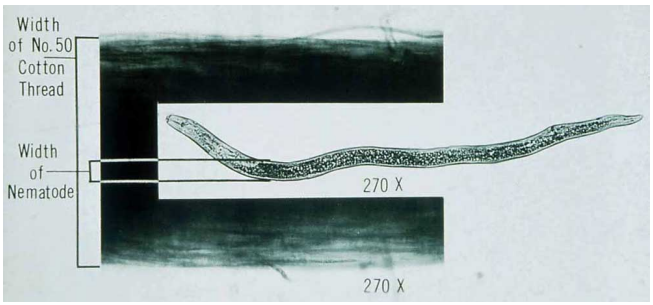

Figure 2. Size comparison of a typical plant-parasitic nematode to a cotton thread.

Plant-parasitic nematodes have a stylet or mouth-spear that is similar in structure and function to a hypodermic needle (Figure 3). The stylet is used to puncture plant cells and then the nematode can inject digestive juices and ingest plant fluids through it. Plant-parasitic nematodes are grouped by how they feed on plants.

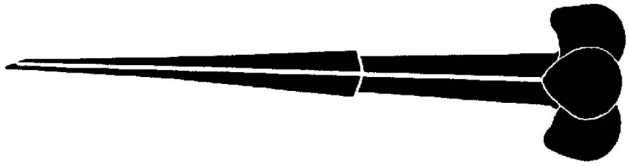

Figure 3. A typical plant-parasitic nematode stylet resembles a hypodermic needle.

Ectoparasites are species that feed by inserting just their stylet into roots while their body remains outside in the soil (Figure 4). Because they spend their entire life in the soil, contact nematicides can work well for these nematodes. Some common genera of ectoparasitic nematodes that damage turf in Florida are sting nematode (Belonolaimus), stubby-root nematodes (Trichodorus and Paratrichodorus), and ring nematodes (*Mesocriconema*).

Migratory endoparasites are nematode species that enter into plant tissue with their body and tunnel around, feeding as they move from cell to cell (Figure 5). As they tunnel through plant roots they disrupt the vascular tissues and prevent roots from functioning properly. These nematodes typically lay their eggs within roots. Because the nematodes and their eggs are largely within roots, systemic nematicides usually work best against migratory endoparasitic nematodes. The most common genera of migratory endoparasites that affect turf in Florida are lance nematodes (Hoplolaimus).

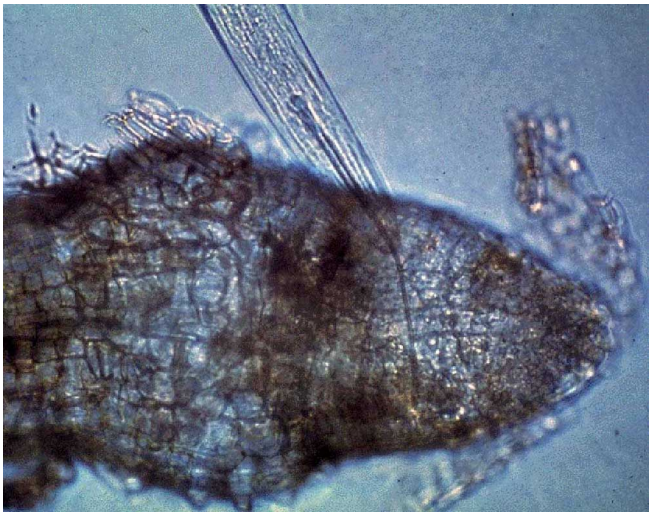

Figure 4. An ectoparasitic nematode feeding by inserting its stylet into a root tip.

Figure 5. Endoparasitic nematodes burrowing within a root.

Sedentary endoparasites are nematodes that enter into roots and then inject hormones that cause specialized feeding sites to develop. After initiating a feeding site these nematodes will no longer move and will lose their typical worm-like shape. Females become round or pear-shaped (Figure 6). Eggs are laid in egg masses that can contain several hundred eggs per egg mass. The egg masses may occur within the root tissue, or be exposed at the root surface. While systemic nematicides typically are more effective for sedentary endoparasites, contact nematicides can affect eggs exposed at the root surface. The most common genera of sedentary endoparasites on turf in Florida are the root-knot nematodes (*Meloidogyne*).

How Do Nematodes Affect Turf?

As plant-parasitic nematodes feed they damage the root system and reduce the ability of the plant to obtain water and nutrients from the soil. Ectoparasites usually cause roots to be short and stubby (Figure 7). Endoparasites often cause roots to be dark and rotten-looking (Figure 8). Both ecto and endoparasites cause a reduction in the fine feeder-roots that are important in water and nutrient uptake by the plant. The root galls or knots associated with certain nematode damage to other crops are usually not evident on grasses, but may occur in some cases.

When nematode population densities get high enough, or when environmental stresses occur, aboveground symptoms may become evident. Symptoms include yellowing, wilting, thinning, or death (Figure 9). Plant-parasitic nematodes usually occur in clumps, so nematode damage usually occurs in irregularly shaped patches that may enlarge slowly over time. Often, as the grass thins out weeds, particularly spurge, may become prominent (Figure 10). This is because the nematode damaged grass is less competitive with the weeds.

Research has shown that nematode-damaged turf roots are less able to get water and nutrients from soil. Nematode-damaged turf typically needs frequent irrigation to avoid wilting and decline. Also, the potential for nutrient leeching is higher from nematode-damaged turf.

Figure 6. Female root-knot nematode laying eggs inside a bermudagrass root. The nematode and eggs are stained red.

Figure 7. Healthy bermudagrass roots (right) and roots that have been cropped off at about 1/2 inches deep by nematodes (left).

Figure 8. Healthy grass roots (left) and dark, rotting grass roots damaged by nematodes.

Figure 9. Severe nematode damage on a bermudagrass putting green.

Figure 10. Turf decline caused by nematodes is often accompanied by proliferation of spurge.

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 time, money, effort, and unnecessary pesticide applications. The only reliable way to determine if plant-parasitic nematodes are involved in a grass problem is by having a nematode assay conducted by a professional nematode diagnostic lab. The University of Florida has such a facility and will assay nematode samples for a cost of $20 each (out-of-state samples cost $25 each). Forms for submitting nematode samples to the Florida Nematode Assay Lab can be downloaded at http://edis.ifas.ufl.edu/sr023.

A nematode assay is a separate procedure and requires different sampling guidelines than those required for soil analysis or disease samples. Be aware that when a disease sample is submitted to most labs a nematode analysis is not normally performed unless you specifically request it. A nematode assay often requires separate payment and may even be sent to a separate address. Familiarize yourself with the procedures required by the lab where you intend to submit the sample. 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 University of Florida lab without using our sample kits, following the guidelines below will help insure an accurate diagnosis:

1) A sample must consist of multiple cores. Nematodes are not evenly distributed in soil, but rather are clumped in distribution. A nematode population density may be high at one spot and low just a few feet way. By collecting multiple cores with a device such as a T type soil probe or similar device an average population density can be measured. A cup-cutter core is often adequate for a disease diagnosis, but not for nematode diagnosis. A good rule of thumb is to collect 16-20 1/2-inch-diameter cores per area (green, fairway, etc.).

2) If damage is evident then sample near the margin of affected areas (Figure 11). Nematode populations will decline in severely damaged areas because they have nothing left to eat. Do not take samples from dead areas. Try and sample turf that is declining, but not dead.

When taking samples from turf that is not yet showing above-ground symptoms, or if sampling before planting, sample in a zig-zag pattern across the area (Figure 12).

3) Put the soil from each sampled area into a plastic bag and seal it. Nematodes require moisture to survive so drying the soil will kill them. This is different than submitting a sample for nutrient analysis where dry soil is preferred. Make sure that each bag is labeled with a permanent marker so that the diagnosis can be assigned to the correct area. If using a ziplock type bag seal it with tape because the zippers often come open in transit.

4) Handle samples carefully. Do not expose samples to direct sunlight or heat. Nematodes are sensitive to high temperatures and UV light. Leaving samples on the dashboard of your car or in the back of a golf cart for periods of time can kill them quickly and negatively affect the accuracy of the diagnosis. Keeping the nematode sample in an air-conditioned room or other cool spot until shipping is best. For shipping and transport pack the samples well so that shifting is minimized.

5) Submit the sample right away. Next day delivery is best. One study found greatest nematode recovery from hand-delivered samples, the next highest from next-day delivery, and the lowest from regular postal delivery. Shipping samples early in the

week is best in order to avoid having them sit in a warehouse or on a truck over the weekend.

The staff at the University of Florida Nematode Assay Lab will make a determination of how much risk of nematode damage the sampled turf is under based on which nematodes are found and how many of them there are. Turf from each sample will be assigned as having low, moderate, or high risk of damage occurring. Not all plant-parasitic nematodes are equal in their ability to harm grass. For example, one sting nematode can cause damage equal to hundreds of individuals of some other types of plant-parasitic nematodes. The current risk thresholds used for golf course turf in Florida are shown in Table 1.

Be aware that different diagnostic labs may use different extraction techniques, use different quantities of soil, or use different thresholds. Because of this, samples submitted to separate labs may report different quantities of nematodes. Do not be alarmed by this, in most cases the different thresholds used are adjusted to account for the differences in methodology and sample size.

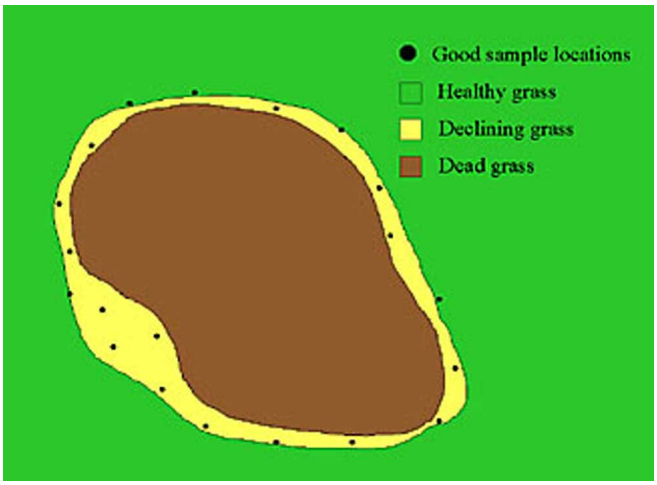

Figure 11. Collect cores for a nematode sample from the edges of declining areas.

How Do I Manage Nematodes?

Before Planting

It is always preferable to avoid a potential problem than to deal with an existing one, so it is best to consider nematodes during course construction or reconstruction. Currently, chemical management of

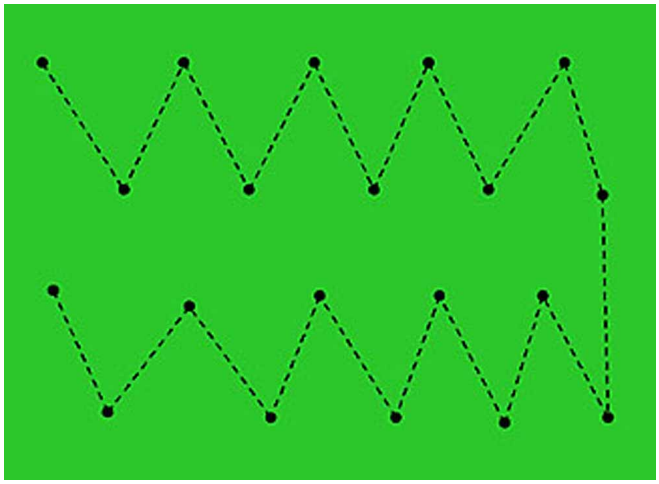

Figure 12. When sampling healthy appearing turf collect cores in a zig-zag pattern across the area.

nematodes before planting is most commonly achieved by soil fumigation. Soil fumigation involves injecting a liquid or incorporating a granular material into the soil. The material then either coverts to a gas or releases a gas that kills nematodes and other organisms. In addition to nematodes, many of the fumigants have activity against weeds and/or soilborne diseases and/or insects. Several soil fumigants are currently available for course construction and reconstruction. Currently the broad-spectrum fumigant methyl bromide (bromomethane) is the most commonly used fumigant in course golf course construction and reconstruction. Because this fumigant has been identified as an ozone-depleting compound it is currently being phased out worldwide. In the United States, existing stocks can still be used but the fumigant will become harder and harder to obtain. Researchers at the University of Florida continue to explore alternative fumigants.

Contaminated planting material (sod or sprigs) are a means whereby nematodes can be spread into new areas. Certified sod is generally not nematode free. Before purchasing sod it is sometimes a good idea to have the sod field sampled prior to purchase to detect the presence of the more damaging nematode species.

A key component of IPM is the use of resistant or tolerant plants. Research at the University is currently underway to evaluate the relative response of bermudagrass and seashore paspalum cultivars to sting nematode. When completed, the results of this

research should allow the recommendation of specific cultivars that will experience fewer nematode problems. Generally speaking, the more vigorously rooting a cultivar, the more nematode tolerant it should be.

Established Turf

Cultural Practices:

Plant-parasitic nematodes are often one of many stress factors affecting the health of turf. The nematodes may be a major contributing factor to turf stress, or a minor one. Often reducing the overall stress level on turf can help the grass to counteract the negative effects of nematodes.

Mowing height: As a rule of thumb, the lower the grass is mowed the greater the stress the grass is under. Research has shown that nematode infested turf declines more readily at lower mowing heights. Often raising mowing height slightly can reduce nematode damage considerably. With increased pressure by certain golfers to have increased ball speed, course superintendents face increased pressure to lower mowing height. Unfortunately, sometimes a choice must be made to sacrifice some ball speed in order to maintain turf on nematode infested greens.

Fertility: Excessive nitrogen fertilization can increase succulent root growth and encourage rapid foliage growth. Succulent root tips are more susceptible to nematode damage, and the proliferation of root tips (nematode food) can cause nematode population densities to rise dramatically. Rapidly growing foliage drains nutrient reserves from the roots that are needed to compensate for the nematode damage. Under-fertilization should also be avoided. Roots damaged by nematodes will already have a reduced capability to extract nutrients from soil. This makes nutrient deficiencies more pronounced on nematode-infested plants.

Watering: Deep, infrequent watering encourages deep root growth. A deep root system is more tolerant of nematodes than a shallow root system resulting from shallow, frequent watering. However, once nematode damage is extensive, frequent light watering may be required to keep the grass from wilting. During times of extended drought this can lead to build up of salts and other problems, so periodic deep irrigation will still be required.

Compaction and aeration: Over-compaction reduces oxygen penetration to the root system and enhances susceptibility to nematode damage. Aeration encourages a healthy root system and thereby enhances tolerance to nematodes. In cases where certain greens are nematode-infested and others are not, aerate the infested greens last to avoid transferring nematodes to the clean ones in soil adhering to aerification equipment.

Soil amendments: Generally anything that promotes healthy root growth can enhance tolerance to nematodes. Incorporation of colloidal phosphate has been shown to enhance bermudagrass tolerance to several nematodes. Some organic amendments such as composted municipal sludge or composted manures may also reduce nematode damage and speed the recovery process after damage has occurred.

***Shade*:** By damaging roots nematodes impair the ability of turf to store energy. Therefore, nematode-damaged turf often is more prone to decline from shade, or prolonged poor weather. If greens are in partial shade trimming or thinning trees to get more light to the turf will greatly enhance the turfs ability to withstand nematode damage.

Bionematicides:

In 2010 a new bionematicide, EcoNem™ was launched in Florida. The active ingredient in EcoNem is a species of *Pasteuria*, a bacteria that parasitizes and kills sting nematode. The *Pasteuria* in EcoNem™ recognizes a sting nematode as it moves past and attaches to the nematodes body. The bacteria then injects itself into the sting nematode, filling its body with bacteria and killing the nematode. EcoNem™ is specific to sting nematode and should not be used for control of other types of nematodes. University of Florida research has found the bacteria in EcoNem™ to be effective at suppressing sting nematodes and protecting turf roots in greenhouse studies. However, field efficacy for EcoNem™ has not been established at this time.

EcoNem™ is labeled for use on turfgrasses in Florida. Currently, the commercial formulation is a

clay granule applied topically to turf. The bacteria are moved off of the clay and into the soil during irrigation or rainfall. Manufacturer recommendations for EcoNem™ are three applications of 2 lb./1000 ft^2 applied at four-week intervals for most turf situations. However, the labeled rate is up to 10 lb./1000 ft^2 which can be applied to "hot-spots" of nematode activity.

Registration of additional bionematicides for use on turf is expected in the near future. Hopefully, we will soon have several options available in this category.

Chemicals:

Even the best managed turf can suffer from nematode injury, requiring chemical intervention. Historically, most nematicides have been toxic at low levels and water soluble in order to move into the soil profile and get to the nematodes. Many of the effective nematicides used in the past have been withdrawn from the market during the last 25 years for environmental and health reasons until only a handful remain. When using any nematicide the product label must be strictly adhered to in order to minimize human and environmental health impacts and to avoid liability. Nematicides labeled for golf course turf in Florida that have shown consistent efficacy in University of Florida research trials are discussed below. This information is not a substitute for the product label. Always follow directions on the product label when applying any pesticide.

Nemacur products: Nemacur was the most commonly used turfgrass nematicide for 30 years. While production of Nemacur in the United States ceased in 2007, stocks of Nemacur still remain in some golf courses pesticide inventory. These supplies may still be used legally if applied according to the product label. The active ingredient in Nemacur products is fenamiphos, an organophoshate pesticide with both contact and systemic activity. Because of its systemic properties it is effective on both ectoparasitic and endoparasitic nematodes.

Because fenamiphos has been so widely used without rotation with other products a condition called enhanced biodegradation of this compound has occurred on some golf courses in Florida. Fenamiphos is a carbon-containing molecule that can be broken down by microbes in the soil. The more often fenamiphos is used at a given location, the greater the number of these microbes will occur. These microbe populations can get so high that they become capable of breaking down the fenamiphos before it has time to work.

If the period of satisfactory control following application of Nemacur is much less than previously experienced, its use on that soil should be ceased and the best alternative methods for dealing with nematodes should be sought.

Curfew Soil Fumigant: Curfew Soil Fumigant™ is different from most other turfgrass pesticides in that it is injected into the soil profile as a liquid that then volatilizes and moves through the soil as a gas (fumigant). The active ingredient in Curfew Soil Fumigant™ is 1,3-dichloropropene (1,3-D). 1,3-D is one of the oldest nematicides and has been used for nematode control on agricultural crops since the 1950s.

Curfew Soil Fumigant™ cannot be applied by golf course staff, but may only be applied by approved custom applicators. Applications are scheduled through certain golf course industry distributors. While application equipment for greens is slightly different from that used on fairways, the application method is similar. Slits are made in the turf by knives that have a metal drip tube welded onto the back. As the knives are pulled through the soil, the fumigant is injected 5-6 inches-deep into the soil profile and the slits are then pressed back together to reduce fumigant lose. The 1,3-D turns into a gas that disperses through the sol profile and kills nematodes on contact.

Curfew Soil Fumigant™ is highly effective against sting nematode and other ectoparasites. It also is effective against mole-crickets. However, because it is a contact nematicide, its efficacy against endoparasitic nematodes such as lance or root-knot nematodes is less consistent. Curfew Soil Fumigant™ does not have residual activity, so nematode populations sometimes may rebound following an application.

Dow AgroSciences instructions for irrigation and turf care following a Curfew Soil Fumigant™ application should be followed closely to avoid problems and maximize the benefits of Curfew. Curfew cannot be applied within 30 ft of buildings and a 24-hour reentry restriction applies. In areas of Florida with certain geologic feature Curfew Soil Fumigant™ cannot be used.

Other Products: In order for University of Florida faculty to recommend a pest management product, data from properly conducted field research trials should indicate that the product works on a consistent basis. There are a several botanical nematicides on the market. For most of these either field efficacy data is lacking, or field trial data has not shown consistent benefit. That does not mean that these products never work, but that there is insufficient evidence to recommend their use.

Faculty at the University of Florida are committed to testing as many of these products for efficacy as possible. Additionally, we network with researchers at other institutions to gather their experience working with these products. While we have data on many of these products, we do not have data on all of them. Feel free to contact us for information on our experience with specific products.

Summary

Nematode management on a golf course can be a daunting task. Expectations for a pristine playing surface are high and nematodes are notoriously difficult to control. The best management practices for golf courses with nematode problems are: 1) avoid other stresses on the grass as much as possible, 2) monitor nematode populations by sampling frequently, and 3) apply nematicides when needed.

The University of Florida is committed to bringing you the most current information possible. Consequently this document will be modified with each breaking development. The most current version of this document may be obtained on-line at the University of Floridas Electronic Document Information System (EDIS) website at http://edis.ifas.ufl.edu/.

For additional information regarding nematodes, nematode management, or help interpreting nematode assay results contact:

William T. (Billy) Crow, Ph.D.

Associate Professor of Nematology

University of Florida

Entomology and Nematology Dept.

P.O. Box 110620

Gainesville, FL 32611

(352) 273-3941

FAX (352) 392-0190

E-mail wtcr@ufl.edu

For information on submitting samples to the University of Florida Nematode Assay Lab or to check on the status of a sample you submitted contact:

Nematode Assay Lab

P.O. Box 110820

Gainesville, FL 32611

(352) 392-1994

FAX (352) 392-3438

E-mail nemalab@ifas.ufl.edu

Table 1. Risk Thresholds for Golf Course Turfgrasses in Florida.

Nematode Species	Bermuda		Zoysia		Seashore paspalum	
	M	**H**	**M**	**H**	**M**	**H**
Root-knot (*Meloidogyne*)	80	300	80	300	80	300
Sting (*Belonolaimus*)	10	25	10	25	10	25
Lance (*Hoplolaimus*)	40	120	40	120	40	120
Stubby-root (*Paratrichodorus*)	150	300	150	300	150	300
Stubby-root (*Trichodorus*)	40	120	40	120	40	120
Spiral (*Helicotylendhus*)	700	1500	700	1500	300	700
Spiral (*Peltamigratus*)	150	300	150	300	150	300
Ring (*Mesocriconema*)	500	1000	500	1000	500	1000
Sheath (*Hemicycliophora*)	150	300	150	300	150	300
Sheathoid (*Hemicriconemoides*)	500	1000	500	1000	500	1000
Awl (*Dolichodorus*)	10	25	10	25	10	25

Key:
M = Turf is considered at moderate risk of damage. Damage may become evident if the turf is placed under stress conditions.
H = Turf is considered at high risk of damage. Root systems are likely damaged and turf quality may be declining.

* These rnematodes are based upon numbers per 100 cc of soil extracted using a sugar-flotation with centrifugation method.
** Other nematodes may damage turf in Florida, but damage from these is very rare so thresholds are not listed.
*** These thresholds are based upon nematodes, grasses, and conditions in Florida only. They may not apply in other states.