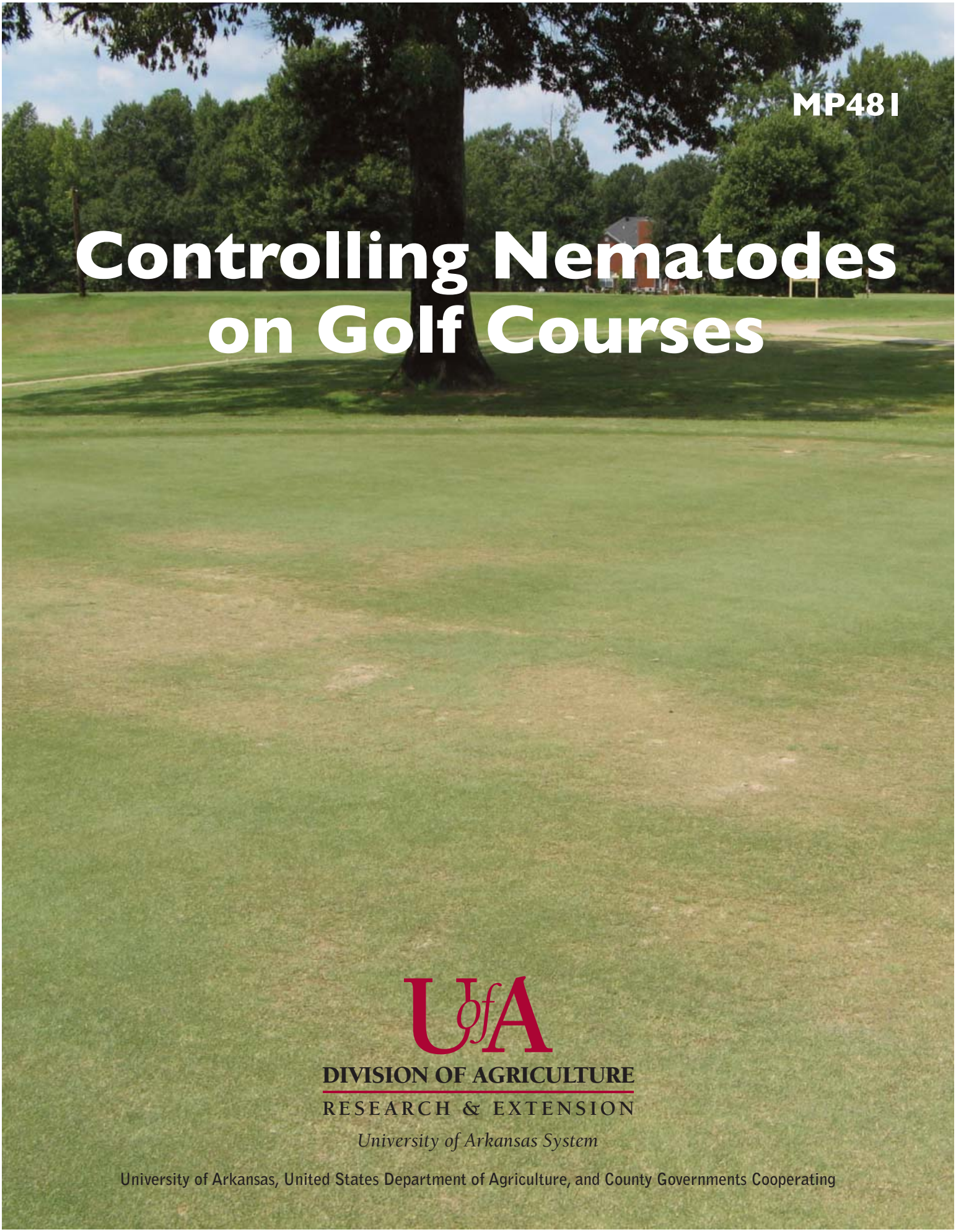

MP481

Controlling Nematodes on Golf Courses

DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

University of Arkansas, United States Department of Agriculture, and County Governments Cooperating

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Controlling Nematodes on Golf Courses

Nematodes are important economic pests of golf courses in Arkansas. These pests are particularly problematic in golf course putting greens. Nematodes are microscopic, unsegmented roundworms, 1/300 to 1/3 inch in length (10) (Figure 1), which live in the soil and can parasitize many crops including turfgrasses.

Although most nematodes are actually beneficial and feed on fungi, bacteria and insects or help in breaking down organic matter, there are a few species that parasitize turfgrasses and cause damage, especially in sandy soils. All plant-parasitic nematodes have a stylet (Figure 1), which is a protruding, needle-like mouthpart used to feed on plant cells. Nematodes feed on turfgrass roots and are most abundant when the turfgrass is actively growing (spring and fall for cool-season grasses and the summer months for warm-season grasses). In addition to direct damage, nematodes may also enhance turf damage by fungal pathogens and increase the level of damage that is caused. Soil fungal pathogens that are known to form disease complexes with nematodes include *Fusarium* and *Rhizoctonia* and oomycetes in the genus *Pythium*. Control methods for nematodes, including preventative and curative measures, are discussed later in this publication. Diseases caused by fungi and oomycetes may be managed with fungicide applications.

There are two general classes of nematodes differentiated primarily by the shape of their stylets. The most common class has a stomatostyle, which is a hollow spear with distinct knobs at the base (Figure 2). Sting (*Belonolaimus* spp.), lesion (*Pratylenchus* spp.) and root-knot (*Meloidogyne* spp.) nematodes, all damaging turf nematodes, belong to this class.

A second class of parasitic nematodes has an odontostyle rather than a stomatostyle type stylet (Figure 3). The odontostyle stylet has flanges at the base rather than knobs and a larger lumen (opening). Needle and dagger nematodes belong to this class. This larger lumen is significant because it is large enough to allow viruses such as the St. Augustine Decline virus to be ingested by the nematode and transmitted from infected plants to healthy plants.

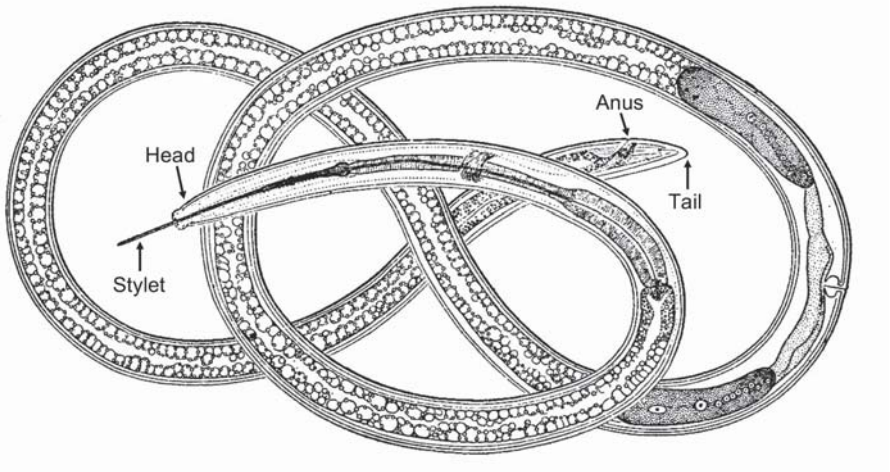

Figure 1. Schematic drawing of a plant-parasitic nematode.
Adapted from N. A. Cobb, Nemapix Vol. 2

Figure 2. Stomatostyle type stylet of a lesion nematode.
Photo by C. Högger, Nemapix Vol. 2

Figure 3. Odontostyle type stylet of a dagger nematode.
Photo by T. Vrain, Nemapix Vol. 2

Life Cycle

There are six stages in the nematode life cycle including an egg stage, four immature (juvenile) stages and the adult. The four juvenile stages allow the nematode to increase in size (in some species to change shape) and are similar to the larval stages found in insects. Nematodes are aquatic animals and require water to survive. They live and move in the soil water film that surrounds soil particles. Soil type, particularly sand content, has a major impact on the ability of nematodes to move, infect roots and reproduce. For most nematodes that are a problem in turf, well-drained sandy soils with soil moisture at or near field capacity are optimum for nematodes to flourish. For this reason, nematodes are most problematic on highly maintained putting greens and sand-capped tees and fairways.

Feeding Habits

Nematodes feed as either ectoparasites or endoparasites. Ectoparasitic nematodes spend their entire life cycle outside the host roots, feeding and reproducing in the soil surrounding the root system. Many ectoparasites cause only limited damage to roots by their feeding, thus a relatively high population density of these nematodes is required to cause appreciable turf damage. An exception, however, is the sting nematode (*Belonolaimus*), which is the most economically damaging nematode pest of turf. Sting nematodes are large and have a long, slender stylet. Feeding by only a few sting nematodes can result in root systems that have a stubby appearance and in the absence of root hairs. With severe infestations, plants may show little or no new root development during spring and summer. Because sting nematodes require soil with an 80 percent or greater sand content, putting greens, particularly those established according to USGA specifications, are ideal environments for nematode damage.

Endoparasites actually enter roots to feed and reproduce. There are two types of endoparasitic nematodes – migratory and sedentary. Migratory endoparasitic nematodes, such as the lesion nematode *Pratylenchus* spp., can enter and move through roots, feeding as they go, and can leave and reenter the root at will. Sedentary endoparasitic nematodes enter the root either partially (semi-endoparasitic) or fully as juveniles and create a permanent feeding site, where they remain for the rest of their life cycle. Root-knot nematodes (*Meloidogyne* spp.) are sedentary endoparasites. Lance nematodes (*Hoplolaimus* spp.) are semi-endoparasitic in turf (Figure 4).

Figure 4. Semi-endoparasitic lance nematode feeding on a plant root.
Photo by U. Zunke, Nemapix Vol. 2

Symptoms and Signs

In turfgrasses, there are few definitive symptoms or signs for consistent diagnosis of a nematode problem. Generally, symptoms of nematode damage are similar to those of other pest problems, nutritional deficiencies or environmental stresses (Figures 5 and 6). However, greens or fairways where there

Figure 5. Typical nematode damage: irregular-shaped areas without distinct border including yellow, stunted turf that is thin and not responsive to fertilizer or irrigation.
Photo courtesy of N. Walker

Figure 6. Mild symptoms from nematode infection can appear similar to many other plant stresses including drought, nutrient deficiencies, pH problems and other common symptoms seen in damaged turf.

are irregular areas in the turf without distinct borders, areas of yellow, stunted plants, areas of wilting and thin, weedy turf could indicate a nematode problem. Actual signs of nematode infection such as root galls due to root-knot nematodes or the presence of cysts attached to roots may sometimes be evident, but a soil sample assayed by a nematology laboratory will generally be required for an accurate diagnosis of a nematode problem.

An additional symptom of nematode damage is a lack of response to irrigation, fungicides, insecticides and fertilizers. Aboveground symptoms do not typically occur until injury to the turfgrass root system is well advanced (10), and since the root system is damaged by nematode feeding causing a reduction in root hairs, turfgrasses may not readily respond to applications of fertilizer or irrigation. Additionally, turf may be unresponsive to applications of fungicides and insecticides since these products will not control nematodes. Once nematode populations reach a critical threshold, turfgrass death can occur (Figure 7).

Important Nematodes in Turfgrass

Sting Nematodes

Sting nematodes are more damaging to turfgrass than any other nematode species (6). Sting nematodes can grow to 3 millimeters long and can complete their life cycle in 18 to 24 days. In Arkansas, sting nematodes are found in golf courses, particularly in putting greens and sand-capped tees or fairways. Sting nematodes generally feed at the root tip causing roots to cease growing and the turf to exhibit symptoms of nutrient and water deficiencies. As a result, these areas could be overirrigated and overfertilized in an attempt to get a response from the turf (11, 13). Symptoms of sting nematode damage can include wilt, stunted growth, nutrient deficiency, irregular patches and added growth of weeds such as prostrate spurge (Figure 8). Turf areas with heavy sting nematode infestations can be completely killed.

Figure 7. Once nematode populations reach a critical threshold, turfgrass death can occur, as seen in this zoysiagrass lawn.

Figure 8. TifEagle putting green showing symptoms of sting nematode damage.

Lance Nematodes

Lance nematodes are migratory semi-endoparasites (Figure 9). Adults can grow to 1 mm long. Lance nematodes are the most common nematode problem nationwide because they are adapted to many soil environments. Generally, damage thresholds are higher than for sting nematodes, but since lance nematodes can feed and reproduce on a wider variety of soil types, damage can be found extensively in native soil fairways and tees in addition to older putting greens with higher organic matter. Lance nematodes generally affect warm-season grasses. Since they are semi-endoparasitic, lance nematodes are harder to control with chemical nematicides (5). Since they feed inside the root, damage throughout the root system may occur. Root tips can also appear dead, and small feeder roots may be limited.

Aboveground symptoms of lance nematode damage to turfgrasses include patches of yellowing, dying and poorly rooted turf (Figures 10 and 11). It is difficult to diagnose lance nematode damage by observing symptoms since the symptoms are similar to other stresses, including insect damage, disease, drought and nutrient deficiency.

Figure 9. Female lance nematode (*Hoplolaimus* spp.).
Photo by J. D. Eisenbac, Nemapix Vol. 2

Root-Knot Nematodes

Root-knot nematodes are sedentary endoparasites. They penetrate the root with their entire body and then form a permanent feeding site where they remain for life. Root-knot nematodes are the most well known and most economically important nematode in many agronomic and horticultural crops. Several species of root-knot nematodes are damaging to turfgrass. A sign of root-knot nematodes is root gall formation in response to their infection (Figure 12). Although galls can be easily observed on the roots of most crops, they can be difficult to see on turfgrass roots. Roots may look normal on the outside, but galls can be seen if the root is dissected longitudinally. Symptoms of root-knot nematodes can include darkened, rotted roots, chlorotic areas of turf and limited response to fertilizer, fungicide or irrigation.

Figure 12. Root-knot nematode, *Meloidogyne* spp., feeding on barley.
Photo by G. Caubel, Nemapix Vol. 2

Figure 10. Lance nematode damage to bermudagrass rough.
Photo courtesy of N. Walker

Figure 11. Decrease in bermudagrass rooting (right) caused by lance nematodes.
Photo courtesy of N. Walker

Other Ectoparasites

Other ectoparasites known to parasitize turfgrasses in Arkansas include spiral (*Helicotylenchus* spp.), stunt (*Tylenchorhynchus* spp.), pin (*Paratylenchus* spp.), dagger (*Xiphinema* spp.), awl (*Dolichodorus* spp.), ring (*Criconemoides* spp.), sheath (*Hemicycliophora* spp.) and stubby-root (*Trichodorus* and *Paratrichodorus*).

Spiral, Stunt, Sheath and Pin Nematodes – Feeding by spiral, stunt, sheath and pin nematodes causes roots to appear shriveled, which results in a short, poor root system. Spiral nematodes, named for the shape of the inactive nematodes, are not economically damaging on most turfgrasses in the southeast, with the exception of seashore paspalum, which can be severely damaged (7). At high population densities or in situations where turf is already stressed from other causes, sheath, stunt and pin nematodes can be damaging to several turfgrass species.

Dagger and Awl Nematodes – Dagger nematodes may damage roots of many turf species. Symptoms include sparse, discolored roots systems that lack feeder roots. Dagger nematodes also belong to the class of nematodes that are known vectors of plant viruses, although viruses in turfgrasses in Arkansas are not a significant problem. Generally, dagger nematodes are not considered a significant threat to golf course turf in Arkansas.

Awl nematodes can cause severe damage to turfgrasses and are similar to sting nematodes in their damage potential. Fortunately, awl nematodes are rarely found in Arkansas.

Ring and Stubby-Root Nematodes – Both ring and stubby-root nematodes can cause significant damage to turf if population densities are high. With both nematode species, feeding results in tiny lesions on the roots, and under high nematode pressure, roots can become discolored and stubby. Centipedegrass is highly susceptible to ring nematodes, while bermudagrass, bentgrass and St. Augustinegrass are less susceptible.

Two species of stubby-root nematodes, *Paratrichodorus minor* and *Trichodoridae obtusus*, are known to damage turfgrasses. Although both species can be damaging to a number of turfgrasses, *T. obtusus* causes more damage to bermudagrass and St. Augustinegrass (7).

Other Endoparasites

Other endoparasites known to parasitize turfgrasses are lesion (*Pratylenchus* spp.) and cyst (*Heterodera leuceilyma*) nematodes. Lesion nematodes can cause roots to have black spots (lesions) or even severe root rot. Although not well studied, lesion nematodes are not thought to be very damaging (9).

As with root-knot, cyst nematodes form a permanent feeding site. These nematodes are semi-endoparasitic, with the females partially embedded in the root. The eggs are formed inside the body of the mature female (the cyst), where they remain even after she has died and dropped off into the soil. Cyst nematodes are very resilient because eggs can remain viable inside the cyst for years, if necessary, until a suitable host is near. In addition, the cyst provides partial protection to the eggs and/or juveniles when nematicides are applied (7). Fortunately, cyst nematodes are not known to cause major damage in Arkansas turfgrasses.

Diagnosing Nematode Problems

Nematode problems in turf are often misdiagnosed as being the result of poor cultural practices, diseases, insect damage, soil compaction, nutrient deficiencies, poor drainage, drought or other environmental stresses. To diagnose a nematode problem accurately, a soil sample must be collected from the affected area and be assayed by a nematology laboratory where trained professionals can determine if there are parasitic nematodes present at levels that could cause the observed damage.

The process of taking a soil sample for nematode assay includes collecting random subsamples in a zigzag pattern (Figure 13) from the area in question, similar to the procedure that would be used for a soil sample for nutrient analysis. Soil samples for nematode analysis should be taken to a depth of 4 inches – since this is where the majority of the roots are located – with several subsamples making up a representative sample of the area. It is important to submit

separate samples of both healthy and unhealthy turf to reflect the population density of the area accurately. Never sample only dead or severely damaged areas (dead turf), as these samples may not contain many nematodes since there are few roots available for nematode feeding. Collect samples in areas bordering the damaged area and from healthy-looking areas as well as from severely affected areas. Sample putting greens or fairways separately, because it is important to know specifically where nematode infestations are and where they are not. This information will help in implementing sanitary maintenance practices as well as the control options that are discussed further in the "Control" sections.

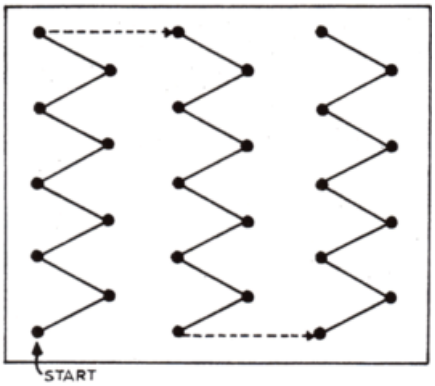

Figure 13. Sampling pattern for turfgrass area with suspected nematode problems. In a similar pattern, also collect a sample from a healthy-looking area.

Combine the subsamples for a particular sample as they are collected. A convenient method is to use a small bucket or other container that is easy to carry. When 8 to 12 subsamples are collected, mix the soil thoroughly and place approximately 1 pint into a quart-sized plastic bag. Bags should be sealed to retain soil moisture and kept out of direct sunlight – placing samples into a small, insulated cooler (without ice) is a safe and convenient method for protecting the sample until it can be sent to the nematology laboratory. Label each sample on the outside of the plastic bag with your name, address, putting green number (or other short sample identifier) and county. Ziploc® storage bags are ideal for this use because they generally have a labeling space on the outside.

Deliver the sample to your county Extension agent as soon after it is collected as possible. If samples must be stored for a few days (up to one week), keep them in an insulated cooler at cool (air-conditioned) room temperature. NEVER store the samples in the refrigerator or store them on ice in an insulated cooler. The county agent will help you submit your samples online through the DDDI sample submission system. A $10 cost-recovery fee is charged for each sample that is assayed. The samples should be mailed first class or shipped by courier to:

Arkansas Nematode Diagnostic Laboratory, University of Arkansas
Southwest Research and Extension Center
362 Highway 174 North
Hope, AR 71801
Phone: 870-777-9702

Results are generally available within a few days of receipt by the laboratory. Results can be sent by e-mail, fax or U.S. postal service. More information about nematodes and the diagnostic lab can be found at the University of Arkansas System Division of Agriculture Cooperative Extension Service website (https://www.uaex.edu/farm-ranch/pest-management/plant-disease/nematodes.aspx).

Interpreting the Results

Once assay results are complete, the next step is to interpret the results. The assay report will include information on the individuals who collected and submitted the sample, the sample identifiers and tabular results of all plant-parasitic nematodes that were found. Note that the results are reported in a standardized fashion as nematodes per 100 cm^3 (cubic centimeters) of soil. Table 1 lists the most common parasitic nematodes for turfgrass and their estimated threshold levels needed to cause moderate or high levels of damage. While these threshold values may be used as a general guide, it is important to remember that damage due to nematodes is strongly related to overall turf health and turf species (Table 2).

Healthy turf can withstand higher nematode levels than stressed turf. Control methods may be warranted if any one nematode species surpasses the medium threshold limit. If multiple nematode species are present at levels less than the medium threshold limit, it is more difficult to determine if control is warranted. The nematode and turf species, overall turf health, site history and other factors must be considered. Although nematode damage is

TABLE 1. Nematode common name and genus, threshold level, damage potential, feeding habit and root symptoms. Modified from Tables 1 and 2 from Anonymous (1), Table 1 from Crow (3) and from Davis et al. (8).

Common Name (Genus Name)	Threshold[a]		Damage Potential[b]	Feeding Habit	Root Symptoms
	Medium	High			
	- - Number/100 cm^3 - -				
Sting (*Belonolaimus*)	10 (25[c])	25 (50[c])	1	Ectoparasite	Cropped, stubby roots. Large lesions.
Lance (*Hoplolaimus*)	40	120	1	Endoparasite (migratory)	Roots sloughing away. Slight swellings and brown lesions.
Root-knot (*Meloidogyne*)	80	300	1	Endoparasite (sedentary)	General swellings and galls. No reaction to applications of irrigation, fertilizer or pesticides.
Spiral (*Helicotylenchus*)	700	1500	2	Ectoparasite	Roots wilted, cropped off, discolored.
(*Peltamigratus*)	150	300	2	Ectoparasite	Roots wilted, cropped off, discolored.
Stunt (*Tylenchorhynchus*)	100[+]		2	Ectoparasite	Roots wilted, cropped off, discolored.
Dagger (*Xiphinema*)	51[+]		2	Ectoparasite	Roots wilted, cropped off, discolored.
Stubby-root (*Paratrichodorus*)	150	300	2	Ectoparasite	Stubby roots, attacks root tips, lesions may be present.
(*Trichodorus*)	40[c,d]	120[c,d]	2	Ectoparasite	Stubby roots, attacks root tips, lesions may be present.
Lesion (*Pratylenchus*)	51[+]		2	Endoparasite (migratory)	Black spots, root rot.
Sheath (*Hemicycliophora*)	200	400	2	Ectoparasite	Stubby roots, attacks root tips, lesions may be present.
Cyst (*Punctodera heterodera*)	10[c]	40[c]	2	Endoparasite	Swollen, white females or brown cyst on roots.
Ring (*Mesocriconema*)	500 (150[e])	1000 (300[e])	3	Ectoparasite	Discolored roots, tiny lesions.
Pin (*Paratylenchus*)	500[+]		3	Ectoparasite	Roots wilted, thin.

[a]These thresholds were developed based on observations in other states and may be adjusted occasionally as more data is collected in Arkansas on nematode pathogenicity to turfgrasses. If nematode assays indicate that you have more than the medium threshold for a given nematode species, damage may become evident if turf incurs additional environmental stress. If nematode assays indicate that you have more than the high threshold for a given nematode species, root systems are likely damaged and turf quality is likely declining. Threshold levels are determined under otherwise normal conditions. It should be noted that in the presence of other stresses (drought, disease, insects), the threshold is effectively lowered.

[b]Damage potential: 1 = very damaging or moderately damaging to turf and very common or common occurrence in Arkansas
2 = moderately damaging to turf and uncommon in Arkansas
3 = damaging to turf only at high populations and uncommon or rare in Arkansas

[c]Indicates threshold numbers for St. Augustinegrass.

[d]Indicates numbers for genus *Trichodorus*.

[e]Indicates threshold level for ring nematode in centipedegrass.

[+]Indicates baseline threshold number based on counts per 100 cm^3 soil.

not absolutely additive, control measures may be warranted if nematode counts are slightly below the threshold limit for multiple nematode species. In these situations, it is highly recommended that a nematologist or turf specialist be consulted concerning a control strategy.

For example, let's say you have 30 lance nematodes (75 percent of the medium threshold) and 60 root-knot nematodes (75 percent of the medium threshold). Both nematode species are present at population densities less than the threshold, but combined they total 150 percent of the medium damage threshold. Nematode damage is not absolutely additive, so you cannot simply add up the relative percentages for all species that are present (8), but if two or more nematode species each reached 90 percent of the medium threshold, chemical control may be warranted. On the other hand, if several nematodes are found at 30 percent of the medium threshold, a combined total of 100 percent likely will not require chemical control (8). As indicated, the overall health of the turf, the environment, past experience and other factors will influence control decisions. The assistance of a nematologist or turf specialist is strongly recommended.

Control Options Before Planting

Very little nematode resistance or tolerance is known in turfgrasses, but there are key differences between species in their susceptibility to certain nematodes (Table 2). Notably, cyst nematode only parasitizes St. Augustinegrass, and bahiagrass is generally more tolerant to nematodes than other turf species (7). Bermudagrass is typically more tolerant to nematode feeding than zoysiagrass because of the deeper root system of bermudagrass (Figure 14). Susceptibility is known to differ among cultivars within certain species, but there are few definitive reports on these differences.

Nematodes are often found as problems in established turf. In some situations, nematodes may already be present in the native soil at the time greens or tees are established, while in some cases, the nematodes are transported to the site in the sand or soil used in forming the greens or in sod. In either case, it is best to avoid or eliminate the problem during golf course construction or renovation. There are two proactive approaches to help avoid nematode problems: fumigation and sanitation.

TABLE 2. Nematodes and the turfgrasses most affected by each (9, 12).

Turfgrass	Sting	Lance	Root-knot	Spiral	Stunt	Dagger	Stubby-root	Lesion	Cyst	Ring	Pin
Warm-season grasses											
Bahiagrass	X	X		X							
Centipedegrass	X			X			X			X	
St. Augustinegrass	X	X	X	X			X		X		X
Bermudagrass	X	X	X	X			X				
Zoysiagrass	X	X	X				X				
Seashore paspalum	X	X	X	X			X				
Cool-season grasses											
Creeping bentgrass	X	X	X	X	X	X	X	X		X	
Kentucky bluegrass	X			X			X				
Perennial ryegrass	X			X			X				
Tall fescue	X			X			X				

Figure 14. A large patch of bermudagrass appears (right of mailbox next to curb) symptom free in this Meyer zoysiagrass lawn weakened by nematodes.

Soil Fumigation

Pre-plant soil fumigation can be helpful in preventing infestations on new putting greens and tees. Soil fumigants are products that volatilize in the soil and control a wide range of soil-borne pests including nematodes. Two compounds are available for soil fumigation – metam-sodium and dazomet (Table 3). Methyl bromide, which was historically used quite often for pre-plant fumigation, is no longer manufactured or legal to use. Curfew, 1,3-dichloropropene, is another fumigant no longer labeled for use in turf in the state of Arkansas.

Metam-sodium, sold under several trade names including Metam-Sodium®, Vapam® and Turfcure®, is a liquid that breaks down to form the highly toxic and volatile chemical methyl isothiocyanate upon contact with moist soil. Metam-sodium should be applied to moist soil when temperature exceeds 60 degrees F. Areas treated with metam-sodium should be either covered with plastic for several days after application or sealed into the soil by irrigation. Because of the risk of phytotoxicity, treated areas should not be planted for 21 days after application.

Dazomet, sold under the trade name Basamid®, is a granular formulation that must be applied accurately (see Table 3) and uniformly and then incorporated into the soil by tilling. An alternative option is to apply dazomet to a scalped area (sod removed) and aerify or verticut followed by irrigation of no more than 1/8 inch of water. Depending on soil temperature, areas should be ready to replant within one to two weeks following application. The effectiveness of dazomet is very similar to metam-sodium.

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NOTE: Federal and state regulations and restrictions on the use of soil fumigants are extensive and restrictive. Soil fumigants should only be applied by experienced professionals according to product label specifications.

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Sanitation

Sanitation practices are extremely important in preventing the spread of nematodes, and it is of utmost importance that an accurate and current picture of where nematodes occur throughout the course is maintained. Nematodes are limited in the distance they can travel through the soil on their own, but they can be easily introduced into new sites or spread with contaminated equipment, new sod, sand or soil. For example, when building a tee box or a putting green, the new sod or soil should be tested for nematodes prior to planting. Similarly, when repairing weak or dead areas of turf by bringing sod or plugs from one area of the golf course to another, do not to transplant nematode-infested turf into areas without nematodes.

Another potential problem may occur when changing cups on putting greens. Do not spread nematodes from one green to another. Keep cultivation equipment clean since nematodes can be spread by any equipment that can transport even a small amount of infested soil. For example, aerifying, spiking or verticutting should be done first in areas **without** a nematode problem and last on areas that have or are suspected to have nematodes. Wash equipment thoroughly after use in nematode-infested areas.

TABLE 3. Pre- and post-planting chemical control options.

Chemical	Rate per 1,000 square feet	Comments
Pre-plant fumigants		
Vapam HL (42 percent metam-sodium)	0.86 to 1.7 gallon (37.5 to 75 gallons per acre)	For best results, Vapam should be applied to moist soil with a temperature between 60 and 90 degrees F. and the area covered with plastic after application. The treated area may be planted 21 days after application.
Basamid (Dazomet)	5 to 12 pounds (220 to 530 pounds per acre)	Basamid is applied as a granular formulation. Basamid is typically incorporated into the soil by tilling. An alternative option is to surface apply Basamid to a scalped area (or sod removed) and aerified and/or verticut followed by 1/8 inch or less of irrigation. Depending on soil temperature, areas typically should be ready to replant within 1 to 2 weeks following application. Basamid is typically applied by custom applicators.
Post-plant nematicides		
Multiguard Protect (Furfural)	0.126 to 0.184 gallons (5.5 to 8.0 gallons per acre)	Apply up to 6 applications per year at 14- to 28-day intervals. Irrigate into the soil to a depth of 6 inches using overhead sprinklers. Labeled to control root-infesting, plant-parasitic nematodes.
Indemnify (Fluopyram)	0.195 to 0.39 fluid ounces (8.49 to 16.98 ounces per acre)	Do not apply more than 17.1 fluid ounces per acre per year. Irrigate to depth of the root zone. Minimum time between applications is 14 days. Labeled to control cyst, dagger, pin, root-knot, sheath, sting, stubby-root and stunt plant-parasitic nematodes.
Nimitz Pro G (Fluensulfone)	60 to 120 pounds per acre	Do not apply more than 240 pounds of product per acre per calendar year. Labeled to control lance, lesion, root-knot and sting plant-parasitic nematodes.

Control Options in Established Turf

Cultural Practices

Cultural practices are fundamental in the prevention of severe nematode damage, and appropriate cultural practices are vital since chemical control options are limited. Well-managed turf can withstand some nematode infection with little noticeable damage. Generally, cultural practices that promote root health and vigorous growth will aid in damage prevention. A few notable cultural practices include increasing the mowing height, use of lightweight mowing and rolling equipment to minimize compaction, proper balance in fertility and pest management practices and core or deep tine aerification.

Irrigate deeply and less frequently in combination with afternoon syringing – wetting the leaf blades and not the soil surface – to promote deep rooting. This practice may help by encouraging the nematodes to move deeper into the soil in search of moisture and away from the majority of the root system (9). If nematode population densities are high and the turf root system is severely damaged, foliar applications of nitrogen will be more readily available to the plant than granular applications. Avoid applying more than 1.0 pound

nitrogen per 1,000 square feet in any one application, as this will promote shoot growth while promoting little root growth. Under-fertilization should also be avoided since damaged plants need some fertility to encourage recovery and new root growth (4). When granular fertilizers are applied, there is limited research suggesting that organic fertilizers may help reduce nematode population densities in sandy areas by increasing soil organic matter, which may encourage nematode-antagonistic microorganisms. Although deep and infrequent irrigation is ideal for enhancing root growth, light and frequent irrigations applied to the depth of rooting may be necessary on nematode-infested putting greens to keep these areas from wilting.

Biological Control

Certain biological and organic products can help minimize nematode damage, but limited efficacy is generally reported under severe infestations (2). Many of these products are known nematode, bacterial and fungal antagonists or naturally occurring plant compounds that are nematicidal. A few examples include Clandosan, Neo-Tec, DiTera, mustard seed meal and mustard bran. Mustard bran, as well as extracts from *Euphorbia* spp., has been reported to work in the laboratory. However, acceptable levels of control in the field have not been consistently demonstrated.

Chemical Control

In some situations, nematode severity is sufficiently high that chemical control is the only effective option (Table 3). Recently labeled products such as Multi-Guard Protect®, Nimitz Pro G® and Indemnify® have shown promise in field testing for control of important plant-pathogenic nematodes. These products can be applied in broadcast applications and offer flexibility in application timing due to relatively low human toxicity. In situations of severe nematode pressure and turfgrass damage, these products may require repeated applications during the season, a significant annual expense.

Conclusions

Managing nematodes on golf courses effectively and economically requires an integrated approach that includes proper sanitation and cultural management and, in some cases, application of nematicides. Nematode management strategies can only be devised, however, if the infestation level and types of nematodes present are monitored on a regular basis, particularly on greens. Greens should be sampled for nematodes at least every third year, more frequently if symptoms are present. As indicated earlier, nematodes generally do not move more than a few feet during their entire life, but they can be moved long distances on equipment, turf or soil. Consequently, sanitation practices are vital to ensuring nematode-free turf.

Cultural practices are also extremely important in controlling nematodes and the damage they cause. Preventing other turf stresses through good management practices for fertility, irrigation and pest management will promote turf health in general. Additionally, it is beneficial to monitor nematode populations in putting greens, tees and fairways to anticipate potential problems. If nematodes become severe, it may be necessary to utilize chemical nematicides to maintain turf health.

Additional Information

- Additional publications are available at http://www.uaex.edu/.
- Additional information about turfgrass management is available at http://turf.uark.edu/.
- Additional information about nematodes is available at https://www.uaex.edu/farm-ranch/pest-management/plant-disease/nematodes.aspx.

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Printed by University of Arkansas Cooperative Extension Service Printing Services.

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MP481-PD-6-2017RV