PLANT-PARASITIC NEMATODES ON GOLF COURSE TURF

William T. Crow, Nematologist, University of Florida, PO Box 110620, Gainesville. FL 32611, USA; (wtcr@ifas.ufl.edu) describes the problems associated with different genera of nematodes on golf courses and offers solutions to the damage that they cause

Keywords
Nematode, Pest Management, plant-nematode interactions, turf, turfgrass, golf course turf

Introduction

In recent years, golf has been increasing in popularity around the world. In many regions, golf and its related industries are a major component in the local economy. For example, in 2000 golf course revenues were $4.44 billion in the state of Florida, USA (Haydu and Hodges, 2002). Two of the key features of a successful golf course are beautiful turfgrass and a smooth, "fast" playing surface. This is especially true on putting greens, where the turf is intensively managed and is typically mowed to be between 3 and 4 mm high. Even using modern, highly adapted turfgrass cultivars it is extremely difficult to maintain a healthy root system under these conditions. Therefore, plant-parasitic nematodes that feed on and damage turfgrass roots are of great concern to golf course superintendents and others who manage golf course turf.

Nematode damage

Turfgrass roots suffering from nematode damage have impaired ability to take up water and nutrients from soil, thereby requiring more frequent irrigation and fertilizer applications. This may lead to waste of precious fresh water resources, increase the risk of groundwater contamination with nitrates (Luc and Crow, 2004), and necessitate increased fungicide use by creating conditions ideal to outbreaks of fungal diseases (Smiley *et al*., 1992). Nematode affected turf is also less competitive with weeds and may require increased herbicide use (Busey, 2003). Of even greater direct concern to turfgrass managers, the turf may become chlorotic, wilt, thin out, and die.

Most turfgrass on golf courses is grown as a perennial crop. Because of this, even putting greens that are fumigated with methyl bromide during construction may suffer from reinfestation as, over time, nematode populations build up from non-detectible to damaging numbers. Furthermore, many turfgrasses are produced via vegetative propagation and planting is done using sod or sprigs. This planting material can be a source of inoculum for plant-parasitic nematodes inside the roots or adhering to soil. Some of the worst nematode infestations occur on putting greens within a year of construction following fumigation with methyl bromide. Methyl bromide may kill most of the antagonists that naturally inhibit nematode populations and, if nematodes are then inoculated on planting material, their numbers can increase unchecked.

Effects of environmental factors on nematodes and nematode damage

Soil temperature can have a great effect on nematode activity (Robbins and Barker, 1974; Van Gundy, 1985). While individual nematode species will have different optima, nematode reproduction and activity is generally favored by long periods of moderate soil temperatures. Therefore, nematode damage on turf is less common in areas with long periods of freezing temperatures. High temperatures can make nematode damage worse by decreasing plant tolerance. As temperature increases, the transpiration requirement of turf also increases, but nematode-damaged root systems cannot supply enough water to meet these demands. Therefore, nematode damage is most noticeable during seasons of high temperature.

Soil texture also has a major role on nematode activity (Mashela *et al*., 1991; Robbins and Barker, 1974; Van Gundy, 1985). Most of the plant-parasitic nematodes that damage turfgrasses favor sandy soil. Additionally, tolerance to nematode damage decreases as sand content increases as a function of low water holding capacity and high rate of nutrient leaching. Many putting greens are constructed of >90% sand content, an ideal habitat for most plant-parasitic nematodes. Other areas of most golf courses (fairways, tees, roughs) are usually constructed of native soil, so soil texture is much more variable. Therefore, nematodes problems are most common on putting greens but can occur in other areas where conditions are favorable.

Nematodes affecting turfgrasses

Plant parasitic nematodes that reproduce and feed on plants while their bodies remain in the soil are termed ectoparasites. Nematodes that enter into plant tissue to feed and reproduce are endoparasites. Turfgrasses can be damaged by both ectoparasitic and endoparasitic nematode species. Because ectoparasitic nematodes remain in the soil, contact nematicides often have greater success on these species than on endoparasites that may be protected by root tissue. Usually, systemic nematicides work much better on endoparasites than do contact nematicides. Also, the potential for

 DOI: 10.1564/16feb04

disinfesting planting material by washing, or by use of hot water or chemical treatments, is greater for ectoparasitic than endoparasitic species.

Ectoparasites

Sting nematode

The sting nematode (*Belonolaimus longicaudatus*) is considered the most damaging plant-parasitic nematode on turfgrasses. This is a large ectoparasitic nematode, adults commonly are >3 mm in length. Sting nematode feeds primarily on root tips, which then cease growth. This results in an abbreviated or "stubby" appearing root system (Figure 1). Often the root system appears cropped off just below the soil surface. Severe infestations can cause complete destruction of the turf root system, leading to wilting, thinning, and death of the turf (Figure 2).

Figure 1 **Bermudagrass roots damaged by sting nematode (left) and healthy roots (right)**

Figure 2 **Bermudagrass putting green suffering severe damage from sting nematode**

Sting nematode is native to the coastal plains of the southeastern United States, but it has been spread in contaminated planting material as far west as California within the USA (Mundo-Ocampo *et al*., 1994), and also to several island nations in the Caribbean, Costa Rica, and Bermuda (Perry and Rhoades, 1982). There also are unconfirmed reports of sting nematode damaging turf on golf courses in Australia. Sting nematode is very sensitive to soil texture, being limited to soils with >80% sand content (Robbins and Barker, 1974). In sandy areas it can be damaging on fairways, tees, and roughs, as well as on putting greens. In areas with heavier soils, it is normally a problem only on putting greens.

Stubby-root nematodes

Two species of stubby-root nematodes (*Paratrichodorus minor* and *Trichodorus obtusus*) are known to damage turfgrasses in the USA. These nematodes cause symptoms very similar to those caused by sting nematode. *Paratrichodorus minor* is widely distributed and is common on golf course turf worldwide. *Trichodorus obtusus* is more damaging to bermudagrass (*Cynodon* spp.) than *P. minor* (Crow and Welch, 2004), but appears to be confined to the USA. Other stubby-root nematode species may affect turfgrasses in other regions of the world.

Stunt nematodes

Several species of stunt nematodes in the genus *Tylenchorhynchus* are known to parasitize turfgrasses on golf courses. They cause reductions in turf root systems and can lead to chlorosis and thinning of turf, particularly on putting greens. In the USA, stunt nematodes appear to be more problematic in temperate than in subtropical regions.

Ring nematodes and their relatives

Ring nematodes (*Criconemoides* spp., *Mesocriconema* spp., etc.) are commonly found infesting golf course turf throughout the USA. High numbers of ring nematodes can cause visual chlorosis and decline of turfgrasses, particularly on putting greens. Pin (*Paratylenchus* spp.), sheath (*Hemicycliophora* spp.) and sheathoid (*Hemicriconemoides* spp.) nematodes are relatives of ring nematodes that are reported as parasites of turfgrasses, but they cause noticeable damage on golf courses less frequently.

Spiral nematodes

Several genera of spiral nematodes (*Helicotylenchus* spp., *Peltamigratus christiei*, *Scutellonema* spp.) are parasites of turfgrasses on golf courses. While common, these nematodes cause visual symptoms only when populations reach extremely high numbers.

Other ectoparasites

Awl nematodes (*Dolichodorus* spp.) and dagger nematodes (*Xiphinema* spp.) are known to be very damaging to turfgrasses, but damage to golf course turf caused by these ectoparasites is rare.

Endoparasites

Lance nematodes

Several species of lance nematodes (*Hoplolaimus* spp.) are known to be parasites of turfgrasses. In the USA, lance nematodes are the most common nematode problem on putting greens nation-wide. On turfgrasses, lance nematodes feed as migratory endoparasites, meaning that they tunnel

Figure 3 **Turfgrass roots showing lance nematodes (stained red) tunnelling inside them. Courtesy A.C. Hixson**

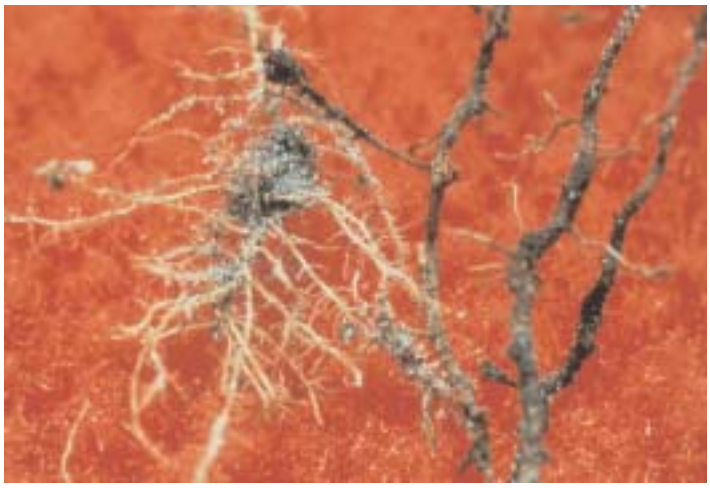

Figure 4 **Healthy turfgrass roots (left) and turfgrass roots infested by lance nematode (right).**

within the roots as they feed and lay eggs (Figure 3). Lance nematodes are usually associated with discolored or rotting roots, lack of feeder root development, and areas of declining turfgrass (Settle, 2002) (Figure 4).

Root-knot nematodes

Several species of root-knot nematodes are known to cause damage to turfgrasses, including *Meloidogyne graminis, M. naasi*, and *M. incognita*. A new species (*M. minor)* has been identified recently as causing visual symptoms on golf courses in the UK (Karssen *et al*., 2004). Juvenile root-knot nematodes enter into turfgrass roots and establish permanent feeding sites from specialized cells that develop in response to enzymes that the nematodes inject into them. After it establishes a feeding site, a root-knot nematode becomes swollen and is no longer able to move (Figure 5). Female root-knot nematodes lay several hundred eggs in an egg mass either on the root surface or within root tissue.

While root-knot nematodes are common parasites on most turfgrasses, on golf courses they are mostly a problem on putting greens, particularly those planted to bentgrass (*Agrostis palustris*). On bentgrass, root-knot nematodes typically cause yellow patches to develop, particularly during times of high temperatures (Figure 6). Some root-knot nematode species cause galls or swellings on turfgrass roots, while others do not. Affected roots may be unthrifty, brown, or rotten and lack feeder roots.

Root and stem gall nematodes

The root gall nematode (*Subanguina radicicola*) causes galls to develop on the roots of annual bluegrass (*Poa annua*) on golf courses in temperate regions and can lead to chlorotic patches on putting greens (Mitkowski and Jackson, 2003). The stem gall nematode (*Anguina pacificae*) is an endoparasite that infests stem tissue of annual bluegrass and bentgrass (Cid del Prado *et al*., 1984). The stem gall nematode causes galls to develop on stem and crown tissue and leads to turf decline (Figure 7). In the United States, the stem gall nematode appears to be a problem only on golf courses in coastal California.

Other endoparasites

Several other endoparasitic nematodes are found parasitizing turf on golf courses, but it is unknown how much

Figure 5 **Turfgrass root with tissue pulled back to reveal a swollen root-knot nematode inside. Courtesy of Theresa Friday.**

Figure 6 **Yellow patches on a bentgrass putting green caused by root-knot nematodes. Courtesy of Mark Hunt.**

Figure 7 **A bermudagrass putting green infested by the stem gall nematode. Courtesy of Pat Gross.**

damage they cause. The cyst nematode (*Heterodera iri*) is found in northern regions of Europe and North America parasitizing bentgrass. The lesion nematode (*Pratylenchus zeae*) is distributed around the world and is often found parasitizing golf course turf in the USA.

Management

Cultural practices

It is always preferable to avoid a problem than to deal with an existing one, so using planting material that is free of the more damaging plant-parasitic nematodes is advised. Sod certification is used to guarantee that sod is genetically pure and free of noxious weeds, but does not generally imply that the sod is free of plant-parasitic nematodes. Therefore, it may be advisable to have a nematode assay conducted on sod to be purchased for use on golf courses. While it is extremely unlikely that any sod will be free of all plant-parasitic nematodes, sod infested with some of the more damaging species should be avoided.

Most plant-parasitic nematodes affect turf by reducing the efficiency of the root system, thereby making the turf more susceptible to environmental stresses. Therefore, alleviating stresses on turf can sometimes mask the effects of nematode damage. Raising the height of cut by two millimeters can greatly improve tolerance to nematodes. Unfortunately, golf course turf superintendents are consistently under pressure from club members, greens committees and general managers to lower mowing height on putting greens as height of cut is inversely related to ball "speed".

Chemicals

Fenamiphos, the active ingredient in Nemacur products, has been the most widely used nematicide on golf course in the United States for the past 30 years. Fenamiphos has both contact and systemic modes-of-action and is useful against both endo- and ectoparsitic nematode species. However, the manufacturer (Bayer CropScience) will cease production of all Nemacur products in May, 2007 (Anonymous, 2002). Additionally, enhanced microbial degradation of fenamiphos has reduced its efficacy in many places where it is used frequently (Ou *et al.*, 1994).

1,3-Dichloropropene (1,3-D) is the active ingredient in Curfew Soil Fumigant, a new nematicide labeled for golf course use in portions of the USA. Curfew is injected in a liquid state 13 to 15 cm-deep using specialized slit-injection equipment (Figure 8). The 1,3-D then disperses upward through the soil profile, killing nematodes by blocking respiration. 1,3-Dichloropropene is very effective against sting nematode, and other plant-parasitic nematodes on golf courses in the southeastern USA (Crow *et al.*, 2002, 2005).

Figure 8 **Application equipment injecting 1,3-dichloropropene into a putting green**

Plant-derived materials

Numerous plant-derived materials are currently being marketed for nematode management on golf course turf. Some of these such as sesame and mustard are processed or formulated plant dry material. Others are oils derived from plants such as sesame or thyme. Finally, some are extracts from plants such as neem, black walnut, sugarcane, oak, or pine. Some (but not all) of these have been evaluated in objective field research trials. Of those evaluated, certain ones have shown some benefit, at least in some studies, while others have not. Mustard bran releases allyl-isothiocyanate, a biochemical nematicide. In Florida, recent research using formulated mustard bran to manage nematodes on golf course turf has shown promise, but we are still trying to improve the formulation and application method to enhance efficacy and consistency. The mustard material has been submitted to the US Environmental Protection Agency for approval as a biopesticide and is under consideration at this time.

Organic amendments

Organic amendments such as processed municipal waste, ground crab or shrimp shells, or composted animal manures can help reduce nematode damage to turf (Giblin-Davis *et al.*, 1988; White and Dickens, 1984). Organic amendments help increase cation exchange capacity and water adsorption in sandy soils, thereby enhancing tolerance to nematodes. They can also stimulate microbial antagonists or directly

affect nematode mobility (Hunt *et al.*, 1973). However, care should be taken with their use as they can cause excessive turf growth or phytotoxicity.

Biological controls and biorationals

Several studies have shown that the use of beneficial nematodes can suppress plant-parasitic nematodes on turf in some regions of the USA (Grewal *et al.*, 1997). However, in numerous field experiments conducted in Florida this approach has not worked. The reasons for these regional differences are not known at this time, so testing in specific areas may be necessary to be able to predict how well they will work locally.

Nematodes have numerous bacterial and fungal antagonists. *Pasteuria usgae* and *P. penetrans* are obligate bacterial parasites of sting and root-knot nematodes, respectively. When a putting green infested with sting nematode was inoculated with *P. usgae*, populations of sting nematode declined and turf quality improved over time (Giblin-Davis, 2000). While these bacteria may be effective in suppressing populations of certain plant-parasitic nematodes, they are extremely difficult to grow outside of their host. Efforts to culture large quantities of these bacteria in artificial media are currently underway. Many other bacteria and fungi are facultative parasites that may feed on nematodes and nematode eggs, in addition to other organic matter. Efforts to inoculate with large numbers of these microbes or to build up natural populations with organic amendments have had mixed results.

Conclusions

Problems with plant-parasitic nematodes can be expected to increase in coming years due to several factors. With modern globalization, the spread of damaging nematode species to new regions by means of contaminated soil and plant material is liable to continue. Also, current worldwide trends toward decreasing mowing heights and the use of sand-based putting greens tend to reduce tolerance to plant-parasitic nematodes. Finally, there is a lag between the removal of the historically used turfgrass nematicides and the identification and implementation of new nematode management strategies that are practical, environmentally safe, and effective.

However, all is not bad news. Great strides are being made in regard to biological control of nematodes and the use of biorational compounds. Companies are attempting to develop new nematicides that are nematode-specific and therefore pose less risk to non-target organisms. Research seeking to find ways to adapt existing nematicides to use on golf courses continues. Some of these efforts are beginning to bear fruit (Figure 9), and in the next few years golf courses should have new weapons in their arsenal to use against plant-parasitic nematodes.

Acknowledgement

This paper was supported by the Florida Agricultural Experiment Station and was approved as Journal Series No. R-10502

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Figure 9 **Plot on a putting green infested with sting nematode that was treated with an experimental nematicide.**

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Recent articles in *Outlooks on Pest Management* (*Pesticide Outlook*) that featured nematode control include 1999 **10(3)** 107; 2004 **15(4)** 172

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