Nematodes and turfgrass health

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Bottom line: Plant parasitic nematodes are some of the most devastating and difficult to control pests in agriculture. There are at least ten different nematode genera that can cause severe damage to turf as well. Keeping turf healthy is the first line of defense against nematodes; healthy turf can frequently tolerate high densities of parasitic nematodes without sustaining damage. But sometimes populations are too high, or the nematode (especially if the nematode is either sting nematode or leaf gall nematode) is too damaging, and pesticide applications are required. Avoiding nematode damage on golf course turf is made difficult by the lack of effective products, and by the complicated interaction between the nematode and plant. For this reason, the assistance of a trained turf diagnostician is usually required to insure accurate diagnoses and appropriate remedial measures.

Plant parasitic nematodes feeding on a plant root tip, viewed at high magnification.

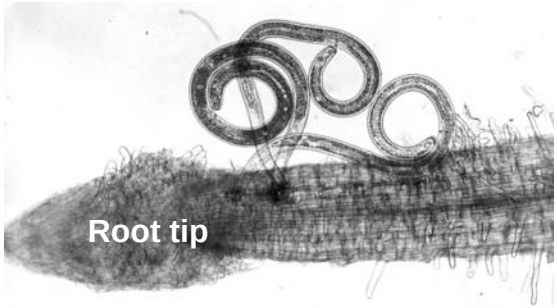

Photo by Dr. M. McClure, University of Arizona

Nematodes, the versatile roundworms that can be found swimming in fresh and salt water, writhing in soil, or parasitizing the tissues and organs of animals and plants, are one of the most contradictory animals that we deal with in turf management. For example, while most nematodes are microscopic sized worm-like animals (0.5 – 2 mm, or 2/100 – 8/100 of an inch in length) that are impossible to see with the naked eye, some nematodes (though luckily none that live near turfgrass!) can reach lengths of 27 feet. While most of the known nematode species are either harmless or even beneficial organisms – a handful of fertile soil will contain thousands of harmless, free-living nematodes – the most famous of them are devastating parasites of animals and humans (causing trichinosis, elephantiasis and heartworm to name a few) and of crop plants, where it is estimated that they cause yield reductions of 5 – 25% each year.

It seems as though the more we study nematodes, the more questions we have. Why is it that we sometimes find more pest nematodes on healthy plants than on damaged plants? Why can't researchers agree on the number of nematodes it takes to cause serious damage to turf, or the number of nematodes it takes to trigger a nematicide application?

In this issue of *PACE Insights*, we will decode some of the mystery that surrounds these squirmy creatures, and will provide some guidance for managing them on your golf course.

What makes it a nematode?

There are many, some would say too many, small worm-like animals that can be found in Nature. So what features separate nematodes from their other slithery brethren?

- Nematodes have eel shaped, cylindrical, unsegmented bodies that are round in cross section, and do not have any legs. In fact, they are missing most of the features that we consider animal-like – for example, eyes, ears or any other comparable sensory organs.
- Nematodes are covered with a transparent, thin, flexible, but protective skin known as the cuticle, which is made up of primarily of proteins and fats. As nematodes grow, they shed (molt) the entire cuticle, in a manner very similar to that performed by insects. A new cuticle is immediately deposited, but in a folded and wrinkled pattern that allows for additional growth. Most nematodes molt four times before they reach adulthood (i.e. sexual maturity).
- Nematodes also don't have a backbone, or an internal skeleton of any kind. Instead, they rely on hydrostatic pressure to maintain their body arrangement. They have no circulatory system to speak of either.
- In many ways, their extremely simple body plan makes it is easier to define nematodes by the structures and organs that they don't have, rather than by those they do. Yet despite all of the things they lack, all nematodes have mouths, which allows them to consume plant materials (among other things), as well as reproductive systems which allow them to reproduce at incredibly high rates.

Do nematodes have lips?

You may be surprised to know that the answer is yes – although Kim Basinger probably shouldn't feel too threatened. The structures known as "lips" occur at the anterior (head) end of the nematode, as illustrated in Figures 1 and 2. In plant parasitic nematodes, the lips surround their most important feature – the **stylet**. It is this rigid, hollow, spear-like structure, which the nematode uses to inject toxins (such as digestive enzymes) into plant cells as well as to suck the nutrients

from plant cells, that makes parasitic nematodes so dangerous to plants. Nematodes that don't possess a stylet are non-parasitic, or free-living, and are not considered to be plant pests.

Figure 1. Line drawing of the anterior (head) region of a plant parasitic nematode (illustration by C.S. Papp, from Ayoub, 1977)

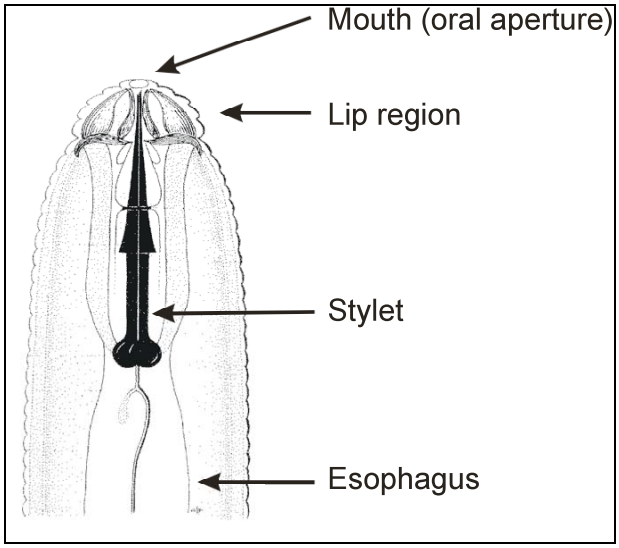

Figure 2. This high magnification micrograph illustrates the anterior (head) region of the plant parasitic nematode *Heterodera*. Note that the stylet is partially extended, perhaps in preparation for feeding.

Photo by Dr. M. McClure, University of Arizona

When a parasitic nematode is not feeding, the stylet is retracted inside the head, as in Figure 1. When the nematode begins to feed, however, the nematode lips are flattened against the plant surface, and the stylet is extended beyond the mouth area, as in Figure 2. The stylet is then thrust, using rapid back and forth motions, into the plant cell.

The majority of nematodes that parasitize turf are classified as **ectoparasites** (see Table 1) because they spend their lifetime outside of the plant ("ecto" means "outside"). They damage the plant by feeding on the root system, thus making it difficult for the turf to get the nutrients and water that it needs to survive. Various toxins secreted through the nematode stylet can further damage roots. A few turf nematodes, such as the root knot nematode (Figure 3) and the leaf gall nematode (Figure 4) spend a portion of their life inside (= "endo") the plant and are therefore called **endoparasites**. Feeding by endoparasites results in damage similar to that caused by ectoparasites. In addition, endoparasites can also inject plant growth regulator-like materials into the root that causes the plant to produce new tissues, in the form of **galls** (see Figures 3 and 4). The galls provide food and shelter for developing nematodes. Besides diverting energy from the plant, the galls can also physically interfere with the movement of water and nutrients.

Nematode presence vs. nematode damage: an important distinction

Once you begin to look for nematodes in turf, you run the risk of seeing them everywhere. Using a 10X or higher magnification, you will see many, small worm-like organisms, especially in the soil. But remember – the majority of nematodes in most turf samples are harmless, free-living types. Unfortunately, it will take a good microscope, with magnifications of 400X, to distinguish between free-living nematodes, which don't have a stylet and are therefore no threat to turf, and parasitic nematodes, which have a stylet and therefore represent a potential threat.

Figure 3. Root knot nematode galls on bermudagrass roots. The round, swollen galls result when the nematode uses its stylet to secrete plant growth regulator-like materials into root cells. This causes the plant to produce new tissues, which form into galls, and serve as a food source for developing nematodes.

But even if parasitic, stylet-bearing nematodes are identified in your sample, it doesn't necessarily mean that they are causing significant damage to turf. In fact, a small handful of soil (100 cc worth) can contain almost 2,000 root knot or spiral nematodes, with no obvious damage occurring to turf. This is why it is so puzzling when, in other turf samples, fewer than 100 of these same nematodes per 100 cc of soil can cause significant damage (Table 1).

Damage thresholds: NOT!!!

How, you may ask, can 100 root knot nematodes be damaging to one turf sample, while 2,000 root knot

nematodes have no effect on another sample? Turf manager's jobs would certainly be much easier if there were consistent **damage thresholds** – the number of nematodes that it takes to cause damage to a plant and should therefore trigger control measures – for each of the pest nematodes of turf. But, as illustrated in Table 1, this is unfortunately not the case for most turf nematodes. The most important reason for this inconsistency can be reduced down to one word – stress.

Table 1. Published damage thresholds for some key turfgrass nematodes. For any given nematode, note the very different threshold values proposed by each institution. The highest number of nematodes/100 cc seen on healthy greens in 1992 and 1996 PACE research trials were 96 (pin), 770 (ring), 1997 (root knot), 1920 (spiral), 64 (stubby root) and 736 (stunt). Table revised July, 2009.

Common Name	Scientific Name	Auburn	Clemson bent/bermuda	Virginia Tech	Rutgers bent/bermuda	Couch, 1995
Lance	*Hoplolaimus*	60	150/50	80-98	150/40	50 - 150
Ring	*Mesocriconema*	500	---/1,000	200-298	1,500/1,000	300 – 1,500
Root knot	*Meloidogyne*	80	80/300	---	100/300	80 - 300
Spiral	*Helicotylenchus*	300	600/1,000	---	600/1000	600 – 1,000
Sting*	*Belonolaimus*	10	20/17	6-12	20/20	12-20
Stubby root	*Paratrichidorus*	100	100/100	20-38	100/100	150
Stunt	*Tylenchorhynchus*	1,000	150/	---	300/100	100 - 400

*recent (12/08) information indicates that healthy bentgrass greens can tolerate up to 600 sting nematodes/100 cc soil, although plant roots are severely thinned and shortened. Bermudagrass thresholds still remain low, at 10 – 20/100cc.

Plants that are stressed by heat, low mowing heights, drought, disease, high salts, or any of the other hurdles that are thrown in the way of healthy plant growth, will not recover well from the additional damage that parasitic nematodes exert. Under these conditions, nematodes can be the straw that breaks the camels' back, and they can result in severe damage. In contrast, a healthy plant can rapidly put out new roots to replace those damaged by nematodes, and thus survive fairly high levels of nematode feeding without any obvious decline. In fact, plants with healthy root systems sometimes have higher nematode densities than stressed plants. This seems like reverse logic, until you realize that the much more extensive root systems of healthy plants is in some way overkill – it can support the plant itself, as well as plenty of nematodes with no trouble. But the stunted, damaged roots of stressed plants are struggling just to keep the plant alive – there is no room for error.

This is why nematode counts can be mis-leading. With the exception of sting nematode and leaf gall nematode (see below), the mere presence of high numbers of parasitic nematodes does not necessarily mean that they are hurting the turf. Many stressors can cause similar damage to plant roots – disease, root feeding insects, excess soil nitrogen, high salts and compaction, to name a few. For this reason, it usually takes a trained diagnostician and/or agronomist to determine which factors are most responsible – and it's usually not a black and white situation.

Sting and leaf gall nematodes: exceptions to the rule

Of the many pest nematodes associated with turf, there are only two that consistently strike fear into the hearts of nematologists -- the sting nematode (*Belonolaimus*) and the leaf gall nematode (*Anguina*). The mere presence of these pests is enough to cause severe damage and even plant death.

The sting nematode is the most damaging of all nematodes for bermudagrass. This root ectoparasite, which is a serious pest of many other crops as well, occurs in the warm, coastal plains climates of the southeastern U.S., and has also been introduced onto a few golf courses near Palm Springs, CA. The nematodes feed on the lateral roots turf plants, which causes root damage, pruning and decreased water and nutrient uptake. Damage to plants, which first appears as a wilted, slightly malnourished look, rapidly progresses, especially during warm weather, with the formation of large, irregularly shaped patches of dead turf, several feet in diameter. Although fenamiphos (Nemacur) provides good control for up to one year in many locations, residual control of as little as 4 weeks has been reported in Florida and South Carolina, and is believed to be due to enhanced biodegradation (see below).

The leaf gall nematode is the most threatening disease of poa greens that we have encountered. Luckily, it is currently restricted to the coastal areas of Central and Northern California.

Figure 4. Poa annua plants with stem galls caused by the leaf gall nematode. The galls, which typically appear as swollen areas near the crown of the plant, can contain hundreds of nematodes each. The leaf gall nematode is one of the few turf nematodes that infects above-ground portions of the plant.

This nematode appears to spend the majority of its short life within the plant, inside nematode-induced galls that form at the base of the stem. The galling gives poa plants the appearance of small scallions or onions, with a bulb-like structure (the gall) near the crown of the plant (Figure 4). With hundreds of nematodes feeding in each small stem gall, the plants are damaged and eventually killed through a combination of nutrient deprivation, as well as the possible interference of the gall with transport of water and nutrients throughout the plant. As for sting nematode, control of the leaf gall nematode is difficult. Fenamiphos (Nemacur) is the best product available, but is only partially effective against this troublesome pest.

Control

Because they are hidden under the soil, or within the galls of plants, killing nematodes is a difficult task. Several approaches are currently used with some success, but each approach is hampered by some serious limitations. **Fumigation** relies on nematicidal chemicals that are volatile (they form a gas easily at low temperatures) as a way to deliver the product into the dense soil. Methyl bromide, Vapam and Basamid (both convert to methyl isothiocyanate), and Telone (1,3-dichloropropene) are fumigants. All are difficult to handle, are highly toxic to most living organisms (including humans) and in most application methods they also kill plants. For this reason, fumigants are typically used in a pre-plant situation, which limits their utility. And despite their high levels of toxicity, some nematodes are able to survive encounters with even the deadliest fumigants.

For post-planting applications, the most commonly used product is Nemacur (fenamiphos). This product is less volatile than the fumigants above and can be used on living plants without killing the turf. Unfortunately, it is also highly toxic to humans. To make matters worse, repeated use of fenamiphos has resulted in selection of soil bacteria that are capable of using the fenamiphos molecule as a nutrient source. In these soils, the microbes gobble up the fenamiphos before it can effectively control the nematodes, in a process known as **enhanced biodegradation**. This decreases the effectiveness of the product significantly.

Biological control techniques include the use of fungi and bacteria that attack nematodes. Unfortunately, none of the organisms researched to date are effective for control of turfgrass nematodes.

The ultimate control strategy to manage plant parasitic nematodes is the use of plant resistance. Unfortunately, there are currently no turfgrass varieties available that have nematode resistance, though this is a possibility for the future. In the agricultural arena, plant resistance to nematodes has been a valuable tool for tomato growers. If nematode problems increase in the future, turfgrass breeders will surely focus on this important pest to provide a genetic solution to the problem.

Some pointers

- Avoid nematode damage by keeping turf healthy with adequate fertility, aeration, traffic management, light, and water.
- If parasitic nematodes are present in damaged turf, don't automatically assume that they're responsible.
- Get input from a trained diagnostician or agronomist to determine which factors are responsible for the observed damage.
- If you are still uncertain whether nematodes are the culprit or just innocent bystanders, you may want to consider a quick test – treat a small strip (about 10 feet long) of damaged turf with the nematicide fenamiphos (Nemacur), following label instructions. If the turf doesn't begin to recover within 7 - 14 days, nematodes are probably not the source of the damage.
- If either sting or leaf gall nematodes are identified on damaged turf, control procedures should be implemented immediately. These are the only two turf nematodes whose presence – even at low numbers – is consistently equated with damage.

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