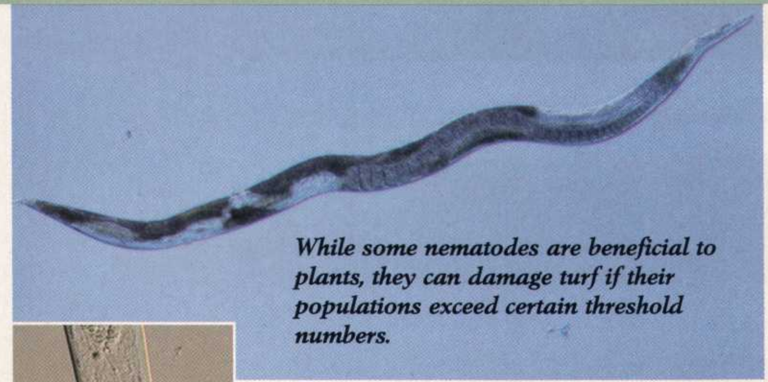
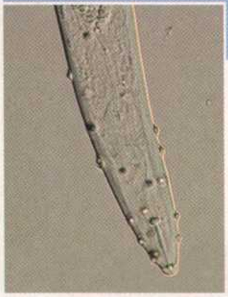
it’s not about
WHO’S TO BLAME





While some nematodes are beneficial to plants, they can damage turf if their populations exceed certain threshold numbers.

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tial is usually low. *Meloidogyne*, however, can be extremely damaging even when population numbers are low.

Host: Grass species is probably the next most important consideration in determining a nematode threshold. Most nematode thresholds are determined on a commercially produced grass species such as creeping bentgrass. Across the United States, however, one is also likely to encounter putting greens comprised of annual bluegrass or mixtures of the two.

It is well-established that plant parasitic nematodes often (but not always) have very discrete host ranges. Even if a nematode species can cross over to another host, it is probable that its virulence on the new host will be different (and likely reduced) from its virulence on the original host.

While pathogenicity is the ability to cause disease (a qualitative character), virulence is often regarded as severity (a quantitative character). Turf parasitic nematodes are exceptional, however, because they often have wide host ranges, affecting creeping bentgrass, velvet bentgrass, annual bluegrass, Kentucky bluegrass and others. As a result, it is often not always necessary to consider the turfgrass species when applying a nematode threshold.

There are a few notable exceptions, however, that do have discrete host ranges including the root-gall nematode, *Subanguina radicicola*. Although this nematode is not frequently observed, it is common in the coastal areas of Rhode Island and New Jersey. Recently, we have observed it from as far north as New Brunswick, Canada (Mitkowski and Jackson, 2003). This nematode has a very discrete host range.

Work by Jatala *et al.* (1973) clearly demonstrated that it could only parasitize annual bluegrass, while bentgrass in mixed stands will be unaffected. Discrete pathogenicity is often the rule in other agronomic crops but exceptions do also exist. Cultivar also plays a role in susceptibility to nematodes, as it does with most plant pathogens. Work by Townshend *et al.* (1973) has demonstrated different levels of varietial resistance within turfgrasses of many different species. A more recent study by Settle *et al.* (2002) showed that Penncross creeping bentgrass supported much higher populations of *Hoplolaimus* than Crenshaw, L93 or Providence. Such relationships can potentially affect the reliability of a nematode threshold.

Soil type: Soil type is another factor that may affect nematode thresholds. Nematodes are aquatic organisms. Even terrestrial nematodes live in films of water. The available water, the size of pores and level of soluble inorganic molecules will all be affected by soil characteristics.

Most turf parasitic nematodes are ectoparasitic; that is, they spend their lives in the soil and only their stylets ever enter into the plant. Even migratory endoparasites (those that move around side of plants) will spend some time in the soil. Soil characteristics are critical to nematode success. Nematode thresholds are determined under precise experimental conditions, including specific soil parameters. If these parameters are changed, as is likely to occur when a threshold is taken into a field situation, nematode viability, reproduction and pathogenicity may be affected. The same number of nematodes may be found in multiple soil types, but the nematodes may be more pathogenic in one soil type than another.

It is difficult to determine exactly which parameter is exerting the most influence on nematode populations because water-holding capacity, bulk density, organic matter and many other factors are inherent characteristics of each soil. Even when thresholds are not directly affected by soil type, whether a nematode population can increase to the threshold level is clearly a function of soil type (Walker & Martin, 2002).

Vigor: Plant health and vigor have a major impact on nematode thresholds. Nematodes are often considered stress-related pathogens. They usually do not cause significant damage but can cause visible disease symptoms when plants are under excessive stress. The same population of nematodes that can kill stressed turf may go unnoticed on a vigorously growing stand. Turf parasitic nematodes feed on plant roots.

When fewer roots are produced, nematode populations are concentrated on less root sur-

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face. This can further stress turf and exacerbate a decline problem. When turf is cut at a lower height, it produces shallower roots and nematode populations are quickly concentrated. As a consequence, nematode problems are most often seen on putting greens.

Rarely do even extremely high numbers of turf-parasitic nematodes have an effect on grasses cut at fairway or lawn heights, although plenty of parasitic nematodes can be found in these systems.

Antagonism: Microbial antagonists surely play a role in limiting nematode populations and may affect threshold values.

Many species of fungi live off plant-parasitic nematodes and can reduce total nematode numbers. While this may not affect a nematode threshold, antagonists like the bacterium *Pasteuria penetrans* certainly do. *Pasteuria* attach to the cuticle of nematodes and slowly invade and reproduce inside the host. During this process, the nematode continues to survive but its pathogenicity, vigor and fecundity will decline.

An uninfected nematode can produce more damage and more offspring than an infected nematode. If half a population of turf parasitic nematodes is infected with *Pasteuria*, the pathogenicity of that population will be greatly diminished and the actual threshold value is likely to rise. Unfortunately, quantifying the degree to which *Pasteuria* affects any one population is difficult to measure and will change as the proportion of infected individuals changes.

Temperature: While climate and temperature are often overlooked, they may dramatically affect a threshold in the context of nematode vigor.

Nematodes are invertebrates, and as such their life cycle is entirely dependent upon the environmental temperature. Nematode reproductive rates and metabolism are directly proportional and respond to fluctuations in temperature. Some nematode species have the ability to become dormant in colder climates and survive in frozen soils while others die. Some become quiescent at high soil temperatures while others thrive.

To a certain point, nematodes that experience warmer temperatures will be more active and cause more damage. Thus, thresholds for the same nematode may vary from Florida to Maine.

In the South, 150 nematodes per 3 cubic inches of soil is considered the threshold for *Hoplolaimus* (Couch, 1995). In the Northeast, *Hoplolaimus* does not start to produce damage symptoms until its population reaches about 400 nematodes per 3 cubic inches of soil. An unanswered question is whether this difference in threshold is attributable to altered nematode metabolism, the presence of different *Hoplolaimus* species in different climates or both.

Population dynamics: Although nematode thresholds are absolute values, thresholds also implicitly take into consideration the population's ability to reproduce and cause additional damage. Thus, sampling timing has an effect on how a threshold is used.

Even though populations of specific nematodes are above a threshold at sampling, there may be no need to control the population, depending upon the climatic location and the time of the year. Indeed, the population may actually be declining. Population dynamics are critical to understanding whether a population is above a threshold. Nematode population levels begin at low levels in the spring and increase throughout the season.

Some nematode populations crash in the summer and rebound in the fall. Others peak in the summer and decline in the fall. Unfortunately for the diagnostician, the dynamics of a population occur throughout time and space. A single absolute number provides only limited information. This highlights the point that appropriate use of nematode thresholds can only occur in context, incorporating a thorough case history.

Synergy: While interactions between nematode species can dramatically increase nematode damage, these interactions are rarely incorporated into predicted nematode damage on turf.

While stunt nematodes have a practical threshold of 800 nematodes per 3 cubic inches of soil, and lance nematodes have a threshold of 400 nematodes per 3 cubic inches of soil in the Northeast, an algorithm does not exist that can predict whether a combination of 600 stunt nematodes and 300 lance nematodes per cubic inches of soil will cause observable damage.

Nematode thresholds currently used for turf systems are extremely simple models. While this makes them easy to use, it ignores much of the inherent complexity of the soil microcosm. Diagnosticians, however, need to be cognizant of these potential interactions.

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Sampling: Sampling location, specifically within a green, has a significant impact on nematode counts and thus the applicability of nematode thresholds.

There are two general philosophies towards nematode sampling in turf. The first philosophy is to take two composite samples, one from affected areas and the other from unaffected areas, a process that we will call spot sampling. The other philosophy is to take a single composite sample from across an entire green, which we will call holistic sampling. While they are both valid, they serve two entirely different purposes and cannot be used interchangeably.

Spot sampling can only be used when there is observable damage. The intent of spot sampling is to determine whether observable damage is caused by high populations of nematodes.

Holistic sampling should not be used to make such a determination because a holistic sample actually dilutes the highest nematode population clusters with areas of low nematode density. While holistic sampling gives an estimation of nematode density across a green, it does not account for hot spots.

The holistic approach is most useful in monitoring population density over multiple seasons or throughout a single season. Sampling methodologies can be complex, and these two methods can be modified in numerous ways but are generally the most useful for superintendents and other turfgrass managers.

Extraction: In order to count nematodes in soil, they must first be extracted from soil, which is an inherently error-prone process.

Nematode extraction is largely performed by people, although some very expensive automatic and semiautomatic elutriators do exist. Technique and equipment vary from lab to lab, and this has a direct impact on the average extraction efficiency of each lab. Additionally, differences between each individual lab employee may have an effect on extraction efficiency.

As a result, two labs that process exactly the same sample may generate different nematode counts. While these counts will often be close enough that they do not affect the final management recommendation, sometimes the management recommendation may vary based on a particular extraction, especially when counts hover close to threshold values.

Superintendents often look at threshold values as absolutes. They treat for nematodes when levels are above the threshold for a particular nematode. In the Northeast, where nematode damage and symptomology is subtle, this approach is ill-conceived. The cost, availability and environmental impact of nematicides should be seriously weighed before making such an application. But assembling the proper information to make an educated decision about control entails a significant amount of work with uncertain results.

Type of nematode, species of grass, soil composition, plant health, time of year and a number of other factors will all influence management decisions. While we often treat preventatively for fungal diseases, it is unclear whether preventative nematicides are warranted in the Northeast.

Courses in the South that deal with sting nematodes certainly do rely on perennial nematicide applications, but this situation is very different from what occurs in Northern states. The best recommendation that can be made to superintendents is to carefully monitor nematode populations annually. When numbers approach thresholds, treatment may be necessary. But populations can sometimes exceed threshold without disease symptoms ever being observed, given the variability discussed previously. Correlating nematode populations with observed damage is critical for making informed decisions about nematode management.

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Rarely do even extremely high numbers of turf-parasitic nematodes have an effect on grasses cut at fairway or lawn heights.

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Silicon Suppresses Leaf Spotting on Bermudagrass

By Lawrence E. Datnoff

Silicon is the second most abundant element after oxygen in the earth's crust, and most soils contain considerable quantities of the element (Savant *et al.*, 1997). However, some soils contain little plant-available silicon in their native state, and repeated cropping can reduce the levels of plant-available silicon to the point that supplemental silicon fertilization is required for maximum production.

Low silicon soils are typically highly weathered, leached, acidic and low in base saturation. Highly organic soils that contain little mineral matter may also contain little silicon, and soils comprised mainly of quartz sand (SiO_2) also may be low in plant-available silicon. Such conditions are presumably prevalent on many sod farms and golf course greens throughout the United States.

Plant nutritionists and plant physiologists generally concentrate on improving the management of 13 essential elements (Savant *et al.*, 1997). These include six macro-elements (nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg) and seven microelements (iron (Fe), manganese (Mn), zinc (Zn), boron (B), molybdenum (Mo), chlorine (Cl) and copper (Cu). These elements are considered essential because deficiency of any one of them adversely affects physiological plant function, resulting in abnormal growth and/or an incomplete life cycle.

Silicon (Si) is considered a plant-nutrient anomaly because it is presumably not essential for plant growth and development. Soluble silicon, however, has enhanced the growth and development of several plant species including rice, sugar cane, most other cereals and several dicotyledons such as cucumber and watermelon.

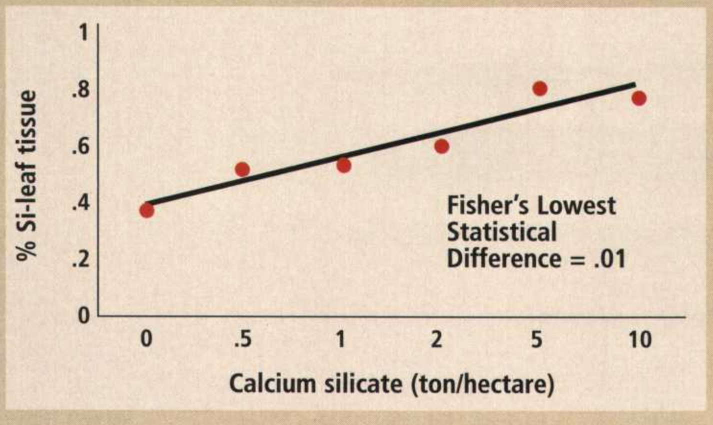
Higher plants vary in their capacity to accumulate silicon (Datnoff *et al.*, 2001b). Wetland gramineae (rice) absorb silicon as monosilicic acid, $Si(OH)_4$, on a dry-matter basis ranging from 4.6 percent to 6.9 percent, dryland gramineae (sugar cane, cereals, St. Augustinegrass) between .5 percent to 1.5 percent and dicotyledons less than .2 percent. Therefore, silicon can be accumulated from soil by plants in amounts that are several folds higher than those of other essential macro- or micronutrients. For example, silicon accumulation may be twice that of N in rice.

Silicon amendments also have proved effective in controlling both soil-borne and foliar fungal diseases in cucumber, rice, sugar cane, turf and several other plant species (Datnoff *et al.*, 2001b). In rice, silicon has been demonstrated to control rice blast, as effectively as a fungicide and even reduce the rate or number of fungicide applications (Datnoff *et al*, 2001a). In addition, partially blast-resistant rice cultivars amended with silicon had their resistance augmented to the same level as those considered completely resistant (Seebold *et al.*, 2000).

Because this element had proven effective for controlling rice blast (Datnoff *et al.*, 2001a; Datnoff *et al.*, 1997; Savant *et al.*, 1997), Datnoff and Nagata (1999) studied the effect of silicon on gray leaf spot development in St. Augustinegrass under greenhouse conditions. They demonstrated that silicon significantly reduced area under the disease progress curves (AUDPC) for gray leaf spot between the 44 percent and 78 percent, final

FIGURE 1

Silicon accumulation in the leaves of bermudagrass (173)



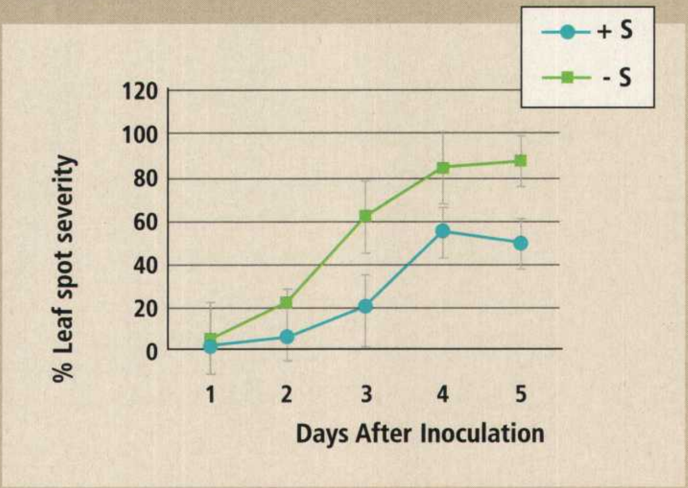
disease severity between 2 percent and 38.8 percent, and final whole-plant infection between 2.5 percent to 50.5 percent. Plant silicon content in Si-amended treatments increased between 2.2 times to 3.5 times more than the nontreated controls.

Similar results were obtained in the field, and silicon appears to be as effective as a fungicide in controlling gray leaf spot development (Brecht *et al.*, 2001). Silicon also has been shown to reduce the incidence of powdery mildew in Kentucky bluegrass (Hamel and Heckman, 2000).

As documented in rice and St. Augustinegrass, silicon may potentially be used as an important component of an integrated management program for controlling diseases in bermudagrass. The objective of this study was to determine if bermudagrass accumulates Si, and if Si could enhance host plant resistance to *Bipolaris cynodontis*, the cause of leaf spotting and melting out of bermudagrass in Florida.

FIGURE 2

Development of bermudagrass leaf spot severity caused by *Bipolaris cynodontis* over a five-day period. (Bars represent standard error)



Materials and methods

Sprigs of bermudagrass were grown in flats filled with Fafard-2 mix and sand (1:1) for four weeks. Afterwards, these sprigs were transplanted into pots containing this mixture with silicon applied as calcium silicate slag (20 percent to 22 percent Si) at several rates ranging from .5 tons to 10 tons per hectare.

After eight weeks, plants were collected and processed for silicon analysis, using the autoclaved-induced digestion method for plant tissue (Elliott and Snyder, 1991). Shoot biomass also was recorded.

No. 51 growing trays (Hummert, 2002) also were filled with Fafard-2 mix and sand (1:1). One tray was amended with calcium silicate slag at a 10 tons per hectare while the other was the nonamended control. Five sprigs of bermudagrass were transplanted into each cell. Trays were fertilized weekly with Peters Professional Fertilizer 20-20-20 for four weeks.

Bipolaris cynodontis was isolated from common bermudagrass exhibiting symptoms of leaf spot and melting out. This isolate was single-spored and grown on Sach's media that contained autoclaved bermudagrass leaves. Plates were placed in an incubator at 68 degrees Fahrenheit with a 12-hour photoperiod. Sporulation on media and leaves occurred in seven days to 14 days.

Leaves colonized by *B. cynodontis* were removed from three plates of Sach's media and placed in a 50 millileters (ml) test tube. In addition, each of the three plates received 5 ml of de-ionized water and was scrapped with a rubber soldier. This was poured into the same test tube that received the colonized leaves. The plates were then rinsed again over the test tube with 5 ml of deionized water. After the contents of the three plates were transferred to the tube, five drops of Tween 20 were added. The tube was then capped and placed on a vortex for one to two minutes. Afterwards, the volume of the tube was adjusted to 50 ml of water and shaken manually for 30 seconds.

Soluble silicon has enhanced the growth and development of several plant species.

The contents of the tube were then poured through two-ply cheesecloth into a 200 ml beaker. Quantification of conidia was achieved with a hemacytometer and light microscope. Inoculum density of 10,000 conidia/ml was prepared.

This inoculum was transferred to a two-part spray tool used for atomizing the plants. Stoloniferous plugs (1.9 inches in diameter) of Tifway bermudagrass were wrapped in moist paper towels and placed within 4-inch azalea

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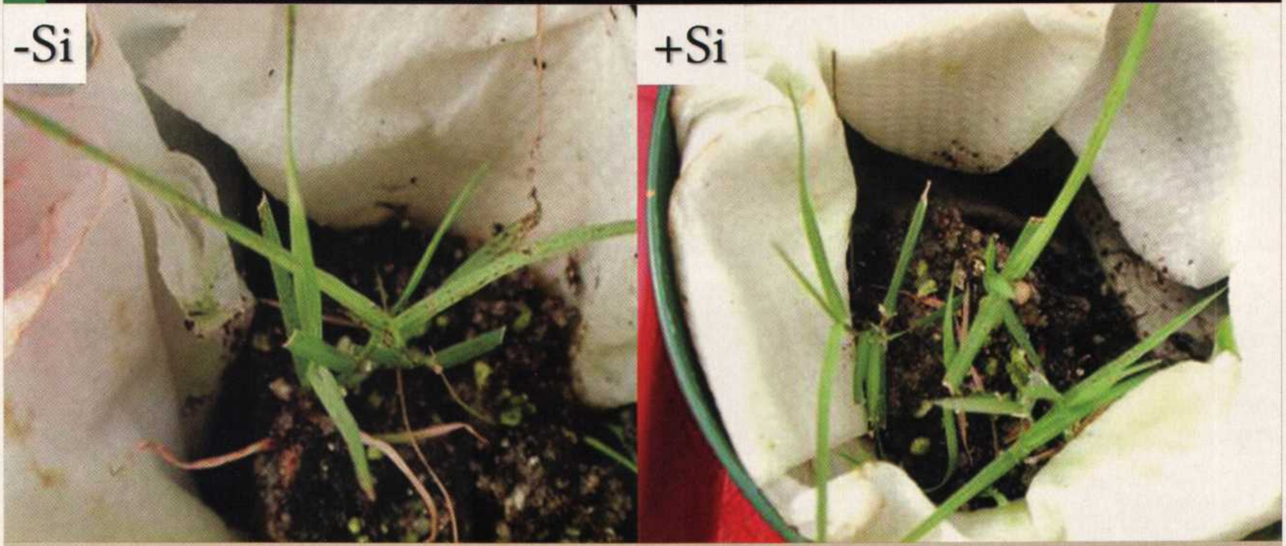
FIGURE 3



Bermudagrass leaf spot symptoms caused by *Bipolaris cynodontis*, four days after inoculation.

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pots. Five plugs amended with silicon and five plugs without silicon were sprayed with the propellant container until run-off.

The pots were then covered with opaque plastic cups afterwards to enhance relative humidity and infection by *B. cynodontis*. The containers were then transferred to the greenhouse.

After 24 hours, the plastic cups were removed and five randomly selected leaves per plant were evaluated for overall leaf spotting (0 = no disease, 10 = 100 percent leaf area infected). The plants were evaluated for five consecutive days, approximately every 24 hours. After the fifth day, plants were collected and processed for silicon analysis as described previously.

The data were then analyzed using the Student's t-test and Fisher's Protected LSD (P) is less than .05). The data sets were also used to generate AUDPC's.

Results and discussion

There was a significant linear increase in percent of silicon that accumulated in the leaves of bermudagrass as the rate of calcium silicate amended to the soil increased (Figure 1).

The percent of silicon in the leaf tissue increased between 38 percent to 105 percent over the control. No linear response was found between increasing silicon rates and leaf dry weight (data not shown). However, these plants were grown under optimum environmental conditions and experienced no abiotic or biotic stresses.

This demonstrates for the first time that bermudagrass can accumulate silicon, especially when the soil is low or limiting in this element. This grass was grown in a peat/sand mixture that would represent many golf course greens found within Florida and throughout the United States. This provides credence to the idea that low silicon conditions are prevalent on many golf course greens throughout the country.

This demonstrates for the first time that bermudagrass can accumulate silicon, especially when the soil is low or limiting in this element.

Silicon also was effective in suppressing leaf spot development on bermudagrass caused by *B. cynodontis* (Figures 2 and 3). Final percent of leaf spot severity was reduced by 38.9 percent.

Plant tissue levels of silicon dramatically increased when soil was amended with calcium silicate slag. There was an 80 percent