

NEMATODE CONTROL
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Plant parasitic nematodes are small, microscopic, thread-like animals that utilize a stylet to puncture and feed from plant cells. In turf, these nematodes are root parasites. Nematodes are important turf pests in SC, particularly in sandy native soils of the Sandhills and coastal regions, but also in artificial, sand-based rootzone mixes on putting greens or athletic fields. Depending on the species of nematode and the numbers in soil, they are capable of contributing heavily to the decline of turf. However, many times weak turf is blamed on nematodes when poor cultural practices, fungi, insects, nutrient problems, soil compaction, poor drainage, or other environmental problems may be the more serious factor leading to the decline. All of these other stresses can also make nematode damage worse. Therefore, correct diagnosis is important to adequately address the problem and determine if the use of a nematicide is warranted. Nematicides vary in restrictions on their use and vary in their effectiveness against different species of nematodes. It is critical to carefully consult the label to be sure a product can be used on a particular site.

ABOVE GROUND SYMPTOMS: yellowing of turf initially, followed by wilting and slow recovery from wilt, poor response of turf to fertilization and eventual thinning in irregular shapes, followed by weed invasion. These symptoms occur over months and years.

ROOT SYMPTOMS: short, stubby roots with few branch roots compared to healthy roots. Roots may have a dark brown color, and sometimes (with sting or stubby root nematodes) exhibit swollen root tips. In sod with severe infestations, the sod strength is low.

SOIL SAMPLING: This is necessary for accurate diagnosis. Quart-size plastic bags can be obtained from the Cooperative Extension Service office in your county, and they will help you submit the samples to the nematode assay laboratory at Clemson University, associated with the Plant Problem Clinic (www.clemson.edu/plantclinic). The number of nematodes recovered from soil can vary greatly, depending on the time of year and the stage of crop or plant development at the time the samples are taken. Many other factors can be involved. Samples taken during the Winter and early Spring are less reliable, and in some situations certain nematodes may be missed entirely. In general, for routine assays, sample during the time of year that the turf is growing. For warm-season turfgrasses, May, June or July is a good time to detect high populations if they exist. For cool season grasses, late spring or early summer should detect damaging populations, if they exist. Diagnostic assays (those taken to determine if nematodes may be a factor) can be taken at any time: if high populations of damaging species are encountered, then certainly nematodes are a factor. However, if nematodes are not found in damaging numbers, it still doesn't preclude their role if the time of year the sample was taken is unfavorable for their survival. If nematode populations are high, determine the best approach to the problem including: improved turf management practices, planting new grass type, or chemical control. Usually a combination or integrated approach leads to the best success. Consult the SC Nematode Guidelines for sampling protocols and damage thresholds (http://www.clemson.edu/public/regulatory/plant_industry/plant_prob_clinic/nematode_assay_lab/nematode_guidelines_for_sc.pdf).

Improve Turf Management Practices. Most grasses can withstand moderate numbers of most kinds of nematodes. Deep, infrequent waterings encourage deeper rooting of the turf, allowing grass to obtain more water and nutrients than a turf having a short root system due to shallow, daily waterings. Avoid excess nitrogen fertilization, as this encourages lush, succulent roots conducive to nematode population buildups. Avoid stresses to turf such as mowing too short. Alleviate compacted soils and correct any nutrient deficiencies.

Nematode Control Considerations

Because crop rotation, varietal resistance, biological control and several other disease management strategies are not always practical or effective for turfgrass nematode control, the use of nematicides is currently the most reliable approach to reducing parasitic nematode levels in turfgrass stands. Nematicides can be applied as preplant fumigants and as post-plant non-fumigant contact chemicals. Fumigants are toxic to plants and are labeled for use only before establishment of the turfgrass stand. In established turfgrass stands contact nematicides come in granular or spray formulations and are always watered in immediately after application. Some may have some insecticidal and even fungicidal activity. Some nematicides are extremely toxic to humans and animals and should be handled with all precautions indicated on the product label. No single product is effective against all nematodes on a given turfgrass species.

Nematodes and the Grasses Most Affected by Each

Turfgrass	Sting ¹	Ring ²	Stubby-Root ³	Lance ⁴	Root-Knot ⁵	Spiral ⁶
Warm-season						
Centipedegrass	✓	✓	✓			✓
St. Augustinegrass	✓		✓	✓	✓	✓
Bermudagrass	✓	?	✓	✓	✓	✓
Zoysiagrass	✓	?	✓	✓	✓	✓
Cool-season						
Creeping bentgrass	✓	✓	✓	✓		✓
Tall fescue	✓		✓			✓
Ryegrasses	✓		✓			✓
Bluegrasses	✓		✓			✓

¹Sting nematodes damage all grasses although bahiagrass is somewhat tolerant; generally found only in very sandy soils.

²Ring nematodes are widely distributed. Found on all turfgrasses but are considered a major pest only on centipedegrass. If populations are high enough, they can damage bermudagrass and zoysiagrass; populations may become high on bentgrass, but damage is usually minor.

³Stubby-root nematodes in the genus *Paratrichodorus* occur in most soil types in South Carolina and cause damage similar to sting nematodes; however they are particularly encountered in bentgrass greens, but populations capable of causing severe damage are much higher than sting nematode populations. Recently *Trichodorus obtusus* was found in limited sites, and research has shown this nematode to be much more virulent to bermudagrass and St. Augustinegrass than *Paratrichodorus*.

⁴Lance nematodes are widely distributed. They attack all turfgrasses in South Carolina, but are especially damaging to and frequently associated with St. Augustinegrass. Lance nematodes also attack bermudagrass and bentgrass and may become a predominant nematode in old greens where sting nematode has been controlled with nematicides.

⁵Root-knot nematodes are widely distributed. Found frequently in St. Augustinegrass, zoysiagrass, and bermudagrass, but can occur in all turfgrasses. The effects of these nematodes on turf are not well known, but they are believed to be injurious at high population densities. *Soil assays for larvae may not accurately reflect true infestations on perennial turfgrasses.*

⁶Spiral nematodes are frequently found on all turfgrasses, but are not believed to cause serious damage in most circumstances.

Soil Fumigation Before Planting

Soil fumigants are chemicals applied as gases or liquids that readily vaporize. They are very toxic to the turfgrass but may be used to treat soil prior to seeding or planting to reduce populations of plant parasitic nematode, weeds, fungal pathogens, and other soil-borne microorganisms. Turfgrasses established in fumigated soil show more uniform and vigorous growth. The fumigants used in turf are the gas methyl bromide, and the liquids 1,3-Dichloropropene (Telone II), 1,3-dichloropropene-chloropicrin (Telone C-17) and metam-sodium (labeled as Vapam, Sectagon or Busan 1020). All three fumigants are Restricted Use pesticides that usually require special equipment and application only by licensed professionals especially when large areas are to be treated. A granular material, Basamid Granular, can be applied with a drop spreader but generates a fumigant, methyl isothiocyanate, that is toxic to nematodes. Basamid Granular carries a 'warning' signal word on the label.

Methyl bromide is a very effective broad-spectrum biocide that has "served" the turf industry well. It is standard practice to fumigate new greens and tees and areas being replanted with methyl bromide.

When fumigants or Basamid are used the best results are usually obtained when the old sod is first stripped from the area to be treated, followed by thorough tilling of the soil at least two weeks prior to the application of the fumigant to allow adequate decomposition of old roots. Tilling loosens the soil and permits more rapid and

uniform diffusion of the fumigant. At the time of application the soil should be moist (not water-saturated). Too much fumigant escapes in dry soil and too little diffuses when pores are filled with water. The temperature of the soil should be about 50 to 80°F (at a depth of 4 inches). Too much fumigant evaporates from hot soil whereas diffusion is too slow in cold soil. For maximum effectiveness, the treated area should be sealed immediately with plastic tarp for several days. It is extremely important that the fumigated area is not recontaminated by accidental introduction of nematodes in soil clinging to tools, equipment, footwear, in run-off water, or in infested soil. Pests introduced into partially sterilized soil usually reproduce rapidly because of the lack of competition from microorganisms.

Nematicides for Established Commercial Turf

Only one of the older chemical nematicides can still be used on established turfgrass stands *if users have it in stock*. It is an organophosphate, namely fenamiphos (Nemacur 10G or 3 EC). However, Nemacur has been withdrawn from the market and only existing stocks may be used. This material can only be used on commercial turf (including golf courses, cemeteries and industrial grounds) where the risks of exposure can be minimized. The active ingredient in the granules or emulsifiable concentrate must be carried into the soil by an adequate amount of irrigation or rain water (enough to reach the root zones and give effective control of nematodes but without product loss through leaching).

Nematicide applications should be made in autumn or spring (before nematode populations peak) during periods when soil temperatures are at or slightly above 60°F. For granular formulations, gravity or “drop-type” granule spreaders are preferred (or required) over centrifugal types for more accurate application and for ensuring the safety of animals, humans and non-target plants. Experiments comparing the effectiveness of broadcast application of granules vs. subsurface injection of granules have shown similar effectiveness. Prior to application, physical soil treatments that aid soil penetration by water (such as core cultivation, vertical mowing and mechanical thatch removal) may aid in effectiveness. Applications should be followed by adequate overhead irrigation in order to wash the active ingredient into the soil and avoid exposure of people, pets and wildlife to the chemical.

The following rules are required for fenamiphos use. These measures are designed to reduce the risk of exposure to birds and aquatic organisms. It is suggested that others consider adopting these guidelines as good stewards of the environment as well as for the product. No more than 10 acres per golf course per day may be treated with Nemacur (3 EC or 10G). There must be a three-day interval before an additional 10 acres could be treated. Do not apply Nemacur closer than 10 feet from bodies of water and surface fairway drains. Total product application must not exceed 200 lb per acre per year.

At this juncture, instructions for the use of Nemacur remain the same as stated on the most current product label for other states in the Southeast. The safest guidelines are always on the product label. The product must be distributed evenly over the area to be treated and it must be washed immediately into the soil with at least 0.5 inches of water (usually up to the point when 1 inch of the top soil has become wet). Total irrigation should not result in puddling and runoff. Do not apply Nemacur where water runoff is likely to occur. The 3 EC formulation is not recommended for use on greens and tees. The purchase and use of **all** formulations of Nemacur are restricted to certified applicators for uses authorized by their certification, or to persons under their direct supervision.

The effects of nematicides are only *temporary*. Fumigants leave behind no residual active ingredients, so nematodes that survived the treatment (i.e., were too deep to be reached by it) or were brought in on the new sod can begin to re-colonize the normal turf root-zone immediately. The non-fumigant nematicides that may be applied to living turf must remain in the root-zone (top 4-10 inches in which most turfgrass roots normally grow) for several weeks to be effective. However, they will eventually dissipate from that region as a result of combined effects of leaching and decomposition. These products do not necessarily kill all nematodes that are exposed to them, but “inactivate” or paralyze many of them. Therefore, when the chemical is gone, there are usually some nematodes ready to resume feeding and reproducing. With either kind of nematicide, the treatment only provides a limited period of relief from nematode stress. The treatment cannot result in the desired improvement in turf health unless other stresses are also controlled and the nutrients (especially potassium) and water that are needed for good root growth are available.

OVER-USE OF NEMATICIDES

No nematicide is equally effective against all nematodes. When one is used frequently, nematodes that are least affected by it will have a distinct advantage over those that are most affected by it. For instance, prolonged frequent use of a product that affects lance nematodes less than other species enables lance nematodes to become dominant in that population.

Enhanced biodegradation is a phenomenon that can reduce the effectiveness of soil-applied pesticides where the same product has been used over a prolonged period

of time. Repeated application of the same chemical to soil encourages build-up of bacteria and other microbes which can metabolize ("digest") that chemical, so they can destroy it much more quickly than was the original case. The net effect is a shorter period of control from a given treatment. Enhanced microbial degradation has been reported for over 200 soil-applied pesticides, including nematicides, which have been used too frequently on a particular site. Enhanced biodegradation of Nematicur has been documented in South Carolina recently on several golf courses experiencing chronic problems with nematode control. Therefore, it is prudent to use all soil pesticides as little as necessary, to reduce chances of developing such soil microbial populations. It also seems wise to rotate or alternate among all products that are legal and effective for a particular problem, to avoid prolonged selection for microbes that can build up on a particular pesticide.

Soil fumigants used pre-plant to control pests such as nematodes and weeds.

Liquid Soil Fumigants	Rate of Product/Broadcast	Comments
Telone II (1,3-dichloropropene, 94%)	9-18 gal/A - mineral soils 24-36 gal/A - muck or peat soils	These fumigants are injected into the soil with tractor-mounted equipment. Maximum effectiveness is achieved when soil is covered with a plastic tarp for one to several days.
Telone C-17 (1,3-dichloropropene 78.3% + chloropicrin 16.5%)	10.8-17.1 gal/A - mineral soils 21.8 gal/A - muck or peat soils	Telone C-17 contains chloropicrin, which is an effective fungicide as well as a nematicide. Restricted Use Pesticides. Check labels for reentry periods
Vapam (metam sodium, 32.7%)	50-100 gal/A	Apply either as a drench in water or inject by chisels. Cover after the treatment with a plastic tarp for maximum benefit. Restricted Use Pesticides.
Vapam HL (metam sodium, 42%)	30-75 gal/A	
Gaseous Soil Fumigants	Rate of Product/Broadcast	Comments
Methyl Bromide Terr-O-Gas	1-2 lb/100 ft ²	Inject by chisels and cover immediately with a plastic tarp. Restricted Use Pesticide.
Brom-O-Gas		Available in small cans (1 lb or 1½ lb per can) for small area treatments. Must be covered with a plastic tarp to be effective. Restricted Use Pesticide
Granular Soil Fumigant	Rate of Product/Broadcast	Comments
Basamid Granular (dazomet 99%)	222-530 lb/A	This material carries a warning signal word, and is not a restricted use pesticide. It generates a gas when exposed to water, which fumigates the soil. It is more effective when tarped, but can be used with a water seal.

Nematicides for commercial turfgrass use.

Nematicide	Rate	Comments
Avid 0.15EC (abamectin 0.15lb/gal))	57 fl oz/A	Special local need label (24C) for SC. Avid 0.15EC is the only abamectin formulation approved for nematode control. For nematode control on golf course greens only. Apply in 2 gallons water/1000 sq.ft. with spray nozzles to deliver coarse droplets; spray onto wet turf and immediately incorporate with 0.1 inch irrigation/A. Addition of a soil wetting agent may improve performance. For sting (<i>Belonolaimus</i> spp.) and ring (<i>Criconebella</i> and related genera) nematodes only. Use 3 to 4 consecutive applications on a 14-21 day interval. Combinations of Avid 0.15EC and Heritage fungicides are recommended to reduce fungal infections and promote healthier turf.
Nortica 5% WP (<i>Bacillus firmus</i> @ e 3 x 10 ⁹ cfu/gram)	30-100 lb/acre	Apply in standard spray equipment to deliver desired rate; reapply on a 3 month interval as needed. Best results have been noted in the spring as bermudagrass turf resumes growth after winter dormancy
Multiguard Protect 90EC (8.68lb/gal furfural)	8 gal/A followed by 5.5 to 8 gal/A; 6 applications per season at 14-28 day intervals	For use on golf course greens, tees, practice greens and sod farms only. Requires appropriate personal protective equipment (PPE) and buffer zones. Golf courses must be closed during application, with a 2 hour re-entry interval to treated zones. See label for details. Apply at 1:9 dilution with water at a rate of 8 gal/acre initially, followed by 5.5 to 8 gal/acre in subsequent treatments. Incorporate with irrigation (1/4-1/2 acre inch water) within 15 minutes of application in sandy soils.
Nemacur 10%; Turf & Ornamental Nematicide (fenamiphos 10%)	2.3 lb/1000 sq.ft. or 100 lb/A	Golf courses, cemeteries, industrial grounds; DO NOT USE on residential lawns or public recreational areas other than golf courses; not for use on turf being grown for sale or other commercial use as sod, or for commercial seed production, or for research purposes. Irrigate immediately with at least 1/2 inch of water; do not allow puddling or run-off to occur. Do not treat newly-seeded areas until plants have developed secondary root systems. Restricted Use Pesticide. See product label for further application restrictions. Not to exceed 200 lbs/acre/year. No longer for sale; existing stocks in possession of manager can be used by label.
Nemacur 3 Turf (fenamiphos 35%)	9.7 fl oz/1000 sq.ft. or 3.3 gal/A	Use on golf courses, cemeteries, and industrial grounds; not recommended for tees or greens. DO NOT USE on residential lawns or public recreational areas other than golf courses; not for use on turf being grown for sale or other commercial use as sod, or for commercial seed production, or for research purposes. Apply dosage in minimum of 1/2 gallon of water per 1000 sq.ft. (min. 20 GPA). Irrigate immediately after treatment with a minimum of 1/2 inch of water. Do not treat newly seeded areas until plants have developed secondary root systems. Do not apply more than twice per year. Restricted Use Pesticide. Do not apply to more than 10 acres per golf course per day; wait 3 days before treating any additional area. See product label for further application restrictions. No longer for sale; existing stocks in possession of manager can be used by label.
Curfew EC Soil Fumigant (1,3-dichloro-propene 97.5%)	3-5 gal/acre broadcast basis	Special local need label. For golf course use only, by certified commercial applicators. Do not re-enter treated areas for 24 hours. Do not apply within 30 feet of any occupied structure, such as a school, hospital, business or residence. Curfew should be placed a minimum of 5 inches deep, with soil moisture adequate to provide good turfgrass growth, and such moisture content maintained for 7 days post-application. Immediately after application, apply 1/4 to 1/2 inch of irrigation.

¹The presence of a nematicide in this list does not constitute a recommendation. Trade names are used with the understanding that neither no endorsement is intended nor is criticism implied of similar products, which are not mentioned. All chemicals should be used in accordance with the manufacturer's label.

Nematicide Registration Sites

Nematicide	Golf Greens	Fairways	Tees	Sod Farms	Sports Fields	Cemeteries	Industrial Grounds	Home Lawns
Avid	YES	NO	NO	NO	NO	NO	NO	NO
Nortica	YES	YES	YES	YES	YES	YES	YES	YES
Multiguard Protect	YES	NO	YES	YES	NO	NO	NO	NO
Nemacur 3	YES	YES	YES	NO	NO	NO	NO	NO
Nemacur 10G	YES	YES	YES	NO	NO	YES	YES	NO
Curfew EC	YES	YES	YES	NO	YES	NO	NO	NO