A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

Volume 10, Issue 5 • May 2001

5 ✓

TURFGRASS PEST MANAGEMENT

Using Entomopathogenic Nematodes for Turfgrass Pest Management

By Parwinder Grewal

Entomopathogenic nematodes (Steinernema and Heterorhabditis) are microscopic roundworms that parasitize and kill insects in the soil. These nematodes have demonstrated potential for biological control of insect pests.

The entomopathogenic nematodes occur naturally in almost all soils and reproduce in dead hosts (see Fig. 1). The nematodes cause widespread mortality of insects in the soil and are often seen as crashes in insect populations or conspicuous epizootics. More than 30 of these nematode species have been discovered worldwide. Due to the ease in nematode mass production, several nematode-based products have been developed for use as biological insecticides. Entomopathogenic nematodes are well suited for pest control in turfgrass because they attack a broad range of pests and can be easily mass-produced and applied using conventional spray equipment.

Tests on home lawn turf have shown that S. carpocapsae is the most effective nematode species for the control of armyworms.

Life cycle

Under suitable environmental conditions, the infective juvenile nematodes seek insect larvae and pupae in soil. They penetrate host insects through natural body openings (mouth, anus, and spiracles) and release a bacterium that kills the insects within a day or two. Insects killed by the nematodes are flaccid, do not give off foul smell, and have conspicuous colors. For example, insects killed by Steinernema carpocapsae are yellow and those killed by Heterorhabditis bacteriophora are reddish brown.

After the death of the host, nematodes feed on the bacteria, and insect body contents, and reproduce. Within two to three weeks, hundreds of infective juveniles are released into the environment to seek out new insect hosts and continue their life cycle. For commercial uses, they are mass-produced either in live insects or in fermenters.

Species, strains and searching behavior

Nematode species and strains differ in their activity against different insect pests. These differences are due to the different search behaviors of nematodes, and also the type and number of bacteria carried by the infective juveniles. Steinernema carpocapsae will kill more mobile insects that live in the upper soil or thatch layer, such as billbugs, sod webworms,

AN ADVANSTAR ★ PUBLICATION

IN THIS ISSUE

TURFGRASS TRENDS

Executive Editor
Sue Gibson
440/891-2729; 440/891-2675 (fax)
sgibson@advanstar.com

Managing Editor
Curt Harler
440/238-4556; 440/238-4116
curt@curt-harler.com

On Line Editor
Lynn Brakeman

Senior Science Editor
Dr. Karl Danneberger

Group Editor
Vern Henry

Production Manager
Rene' Fall
218/723-9352; 218/723-9223 (fax)
rfall@advanstar.com

Senior Graphic designer
Jeff Landis
440/891-2702; 440/891-2675 (fax)
jlandis@advanstar.com

Circulation Manager
Cheryl Beeman
218/723-9271

Group Publisher
John D. Payne
440/891-2786; 440/891-2675 (fax)
jpayne@advanstar.com

Corporate & Editorial Office
7500 Old Oak Blvd.
Cleveland, OH 44130-3369

New Subscriptions
888/527-7008

Abstracts: 800/466-8443
Reprint: 440/891-2744
Permission: 440/891-2742
Single copy or back issues:
Subscription/Customer Service
888/527-7008; (fax) 218/723-9437
Web site address:
www.landscapemanagement.net

ADVANSTAR
COMMUNICATIONS

Chairman and Chief Executive Officer
Robert L. Krakoff

Vice Chairman
James M. Alic

VP-Finance, CFO & Secretary
David W. Montgomery

Executive Vice Presidents
William J. Cooke
Alexander S. DeBarr
Morris R. Levitt
Daniel M. Phillips

Vice President & General Counsel
Eric I. Lisman

Treasurer and Controller
Adele D. Hartwick

cutworms, and armyworms. This nematode species uses an ambush approach to find insect hosts.

The infective juvenile nematodes stand on their tails and wait for long periods for insect to come into range. Steinernema glaseri and H. bacteriophora on the other hand use a more active search strategy called cruising, to find insect hosts. These nematodes are therefore, more effective against less mobile hosts such as white grubs. This distinction should be used as an overall guide for matching the right nematode species with the target pest. Turfgrass pests that can be successfully controlled by the nematodes are listed in Table 1.

Pests controlled

Armyworms

The common armyworm, fall armyworm, and yellowstriped armyworm most commonly damage home lawns, and only occasionally are pests on golfcourse turf. Armyworms are also very susceptible to nematodes, as all larval stages and the pupae may be infected. Tests on home lawn turf have shown that S. carpocapsae is the most effective nematode species for the control of armyworms.

Cutworms

The black cutworm is found throughout North America and is a perennial problem on bentgrass turf of golf course greens, tees, and fairways, but rarely damages lawns. The bronzed, variegated, and glassy cutworms are pests of home lawn turf. Cutworms are semi-subterranean pests and usually dig a burrow into the ground or thatch and emerge at night to clip off grass blades and shoots. S. carpocapsae can be used effectively to manage all cutworm species. Black cutworm larvae can be controlled on golf course greens by applying nematodes at a rate of 1.0 billion per acre.

Sod webworms

The bluegrass, larger, western, striped, elegant, and vagabond sod webworms, along with the closely related cranberry girdler sometimes damage cool season grasses. The tropical sod webworm is the most damaging pest of warm-season grasses. Both S. carpocapsae and H. bacteriophora are effective against sod webworms in turfgrass.

Weevils

The annual bluegrass weevil or Hyperodes weevil is an important pest of Poa annua and annual bluegrass on golfcourses in the northeastern United States. S. carpocapsae, H. bacteriophora, and H. megidis have shown good results for the control of weevil larvae in golfcourse turf.

Two species of billbugs are most important in turfgrass. The bluegrass billbug damages most cool-season grasses, but mainly Kentucky bluegrass and perennial ryegrass. The hunting billbug causes damage to warm-season turfgrasses including bermudagrass and Zoysiagrass. Nematodes infect both adult and larval billbugs, but treatments against larvae are generally more effective. Trials often show nematodes to be more effective than standard insecticides when larval stages are treated. In fact nematodes are the most effective control method for the hunting billbug on golfcourses in Japan. Both S. carpocapsae and H. bacteriophora are equally effective.

Soil temperatures between 50° F to 85° F are favorable for application of most nematode species. If soil temperature is above 85° F, pre-application irrigation is usually recommended to reduce soil temperature prior to nematode application.

Fleas

Larvae of the cat flea are highly susceptible to nematodes The cat flea is a cosmopolitan parasite on dogs and cats, and has also been reported feeding on humans. Flea adults spend most of their time feeding on mammal hosts where mating and egg laying also occur. The eggs eventually drop off the animal and the emerging larvae feed on organic debris in pet beddings on lawns, carpeting, or upholstered furniture.

Nematodes have been extremely effective at controlling flea larvae and pupae in home lawns. In tests performed in North Carolina, S. carpocapsae applied at 1 billion per acre caused more than 90% mortality of flea larvae within 24 h. Steinernema carpocapsae also caused 91 to 97% mortality of flea pupae in cocoons in a test in Louisiana. Nematodes are most effective against flea larvae in turf and soil when the outdoor temperatures are above 14° C and the soil is moist. S. carpocapsae-based products Interrupt and bio Flea Halt became extremely popular in 1994 and 1995.

CRANE FLIES OR LEATHER JACKETS

European crane fly is considered a pest of turfgrass in British Columbia, Nova Scotia, Oregon, and Washington. Substantial research conducted in Europe shows that the crane fly larva is highly susceptible to heterorhabditid nematodes.

MOLE CRICKETS

The tawny mole cricket and the southern mole cricket are the two most destructive crickets and are distributed throughout the coastal plain region of the southeast United States. Mole crickets are considered the most serious pests of turf and pasture grasses. Adult and nymphal mole crickets cause damage by feeding on grass roots and shoots, and by tunneling through the ground. A single mole cricket can create 10 to 20 feet of tunnel in just one night, drying out the soil and causing serious damage to plant roots. Annual costs of controlling mole crickets are estimated to exceed 50 million in Florida alone.

Nematodes have been successful in reducing damage to turfgrass by mole crickets. S. scapterisci, which was originally isolated from infected mole crickets in Uruguay, showed 75 to 100% infection of adult mole crickets under laboratory conditions. In an inoculative release effort, S. scapterisci was introduced into pastures during the summer of 1985. Based on the evaluation of field-collected mole crickets over a five-year period, the nematodes were found to be established at all the sites, with the mean number of adults infected being 11% for the entire period.

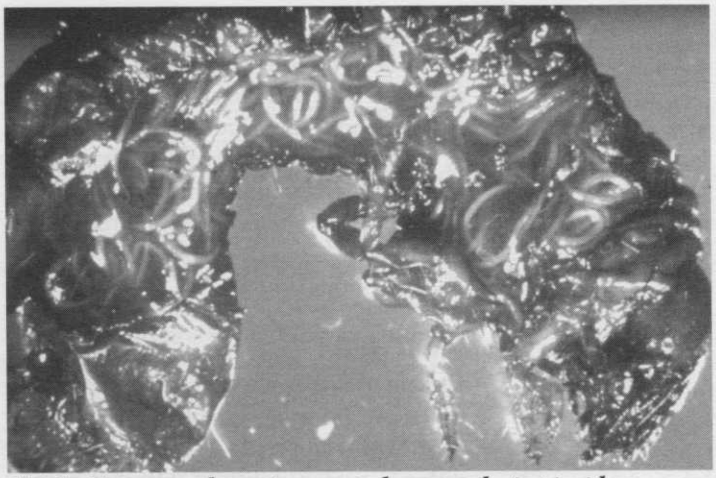

Fig. 1. Entomopathogenic nematodes reproducing inside a recently killed white grub.

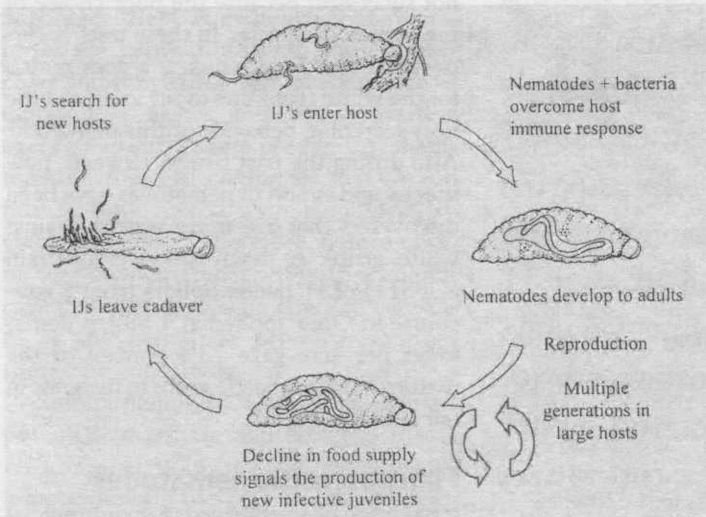

Fig. 2. Generalized life cycle of Steinernema and Heterorhabditis nematodes.

A British company has recently acquired a license for this nematode from the University of Florida and plans to develop a product in the near future.

Another nematode species, S. riobrave, has shown exceptional potential as a biological insecticide for mole crickets. S. riobrave, which was originally isolated from soil in the Rio Grand Valley in Texas. In one test, 66-86% reduction in turf injury was observed with a single application of 1 billion S. riobrave per acre in South Carolina. A commercial product called Vector MC was marketed by Lesco, Inc. for the control of mole crickets in turf. ThermoTrilogy corporation is currently considering reintroduction of this product.

White grubs

Certain strains of entomopathogenic nematodes can be quite effective for curative control of white grubs. White grub species differ in susceptibility to different nematode species. For example, the Japanese beetle is more susceptible to H. bacteriophora and H. zealandica nematodes than the European chafer. It also appears that young instars are more susceptible to nematodes than the fully grown grubs.

Earlier tests against white grubs were not successful because the poor choice of the nematode species. In these tests, S. carpocapsae was used which is a poor match for the white grubs due to the ambush type host searching behavior of this nematode. Also during the past five to 10 years, new species and strains of nematodes have been discovered that are more potent against white grubs. A newly discovered strain (GPS11) of H. bacteriophora from a golf-course in Ohio applied at 1 billion nematodes per acre gave 73% control of the mature Japanese beetle grubs in turfgrass in fall of 2000 (Fig. 3).

Plant-parasitic nematodes

It has often been observed that commercial applications of entomopathogenic nematodes also result in unexpected improvements in plant growth. Analysis of soil samples from the nematode-treated plots of turfgrass and citrus revealed fewer plant-parasitic nematodes than the untreated plots. Systematic evaluations in the field have provided support for the above observations.

In one trial, S. riobrave applied at 6 billion nematodes per acre provided 95 to 100% control of the root-knot nematode, sting nematode, and the ring nematode at a golf course in South Carolina. In another test, both S. riobrave and S. carpocapsae applied at one billion nematodes per acre provided 86 to 100% control of the root-knot, sting, and ring nematodes on golf-course fairways in Georgia. In a recent study conducted in Medina, Ohio, we found that heterorhabditid nematodes effectively controlled plant-parasitic nematodes in golf course roughs.

Where to buy

Entomopathogenic nematodes can be obtained directly from producers or retailers. The nematodes can also be purchased through gardening mail-order catalogs and at some agricultural and nursery supply stores. Below is a guide to lists of commercial suppliers of nematodes:

Commercial sources of insect-parasitic nematodes, 2000. Compiled by P. Grewal & K. Power. Ohio State University. http://www2.oardc.ohio-state.edu/nematodes/nematode_suppliers.htm

Retail suppliers of beneficial nematodes, 1994. Compiled by Robert Wright. Nebraska Cooperative Extension. http://www.ianr.unl.edu/pubs/insects/nf182.htm

Suppliers of beneficial organisms in North America, 1997. State of California, Department of Pesticide Regulation, Environment Monitoring & Pest Management. Mailing address: 830 K Street, Sacramento, CA 95814-3510

Phone 916/324-4100

http://www.cdpr.gov/docs/ipminov/bscover.htm or/bensuppl.htm

Quality

The quality of commercially produced nematodes aimed at a mail-order market in the USA was assessed in 1999 by three different university laboratories in New Jersey, California, and Ohio. They found that most companies were accessible, reliably shipped pure populations of the correct species on time, in sturdy containers, and often with superb accompanying instructions.

Nematodes were received in satisfactory condition with acceptable levels of viability.

Figure 3. Rove beetles have been reported to be predators of various white grub species.

How and when to apply

Nematodes can be easily applied using conventional liquid pesticide, fertilizer, and irrigation equipment with pressures of up to 300 PSI. Electrostatic, fan, mist, and pressurized sprayers can be used. If the tanks are agitated through excessive sparging (recirculation of the spray mix), or if the temperature in the tank rises above 86 F, the nematodes will be damaged. Irrigation systems may also be used for applying most species; however, high pressure, recycling pumping systems are not good delivery systems. Screens smaller than 50 mesh should be removed from spray or irrigation equipment to allow nematodes to pass through the system.

Volumes of two to six gallons of water per 1,000 square feet (86 to 260 gallons per acre) are recommended on most labels. A broadcast application rate of 1 billion nematodes per acre is generally recommended to control most soil insects. For smaller areas, the recommended application rate is 250,000 nematodes per square meter.

Nematodes require moist soil for optimum activity and will not kill insects if soil temperatures are below 50° F. They are also extremely sensitive to heat and sunlight, and will perish in a matter of minutes when exposed to full sun. Therefore, nematodes should be applied in early morning or late in the day to prevent exposure to sunlight. Also turf may need to be irrigated before treatment if the soil is too dry, and irrigated again with at least 1/2 inch of water immediately after application to rinse off nematodes from the foliage and move them into the soil and thatch.

Nematodes require a thin film of water for movement, but are not capable of movement under flooded conditions. Maintenance of optimum soil moisture after application usually enhances nematode activity and efficacy. In general, nematode activity and survival is lower in heavy clay soils than in sandy-loam soils. Soil temperature during and after application can also affect nematode efficacy. Warmer temperatures usually reduce nematode survival while cooler temperatures reduce activity and infectivity.

Soil temperatures between 50° F to 85° F are considered favorable for application of most nematode species. If soil temperature is above 85 F, a pre-application irrigation is usually recommended to reduce soil temperature prior to nematode application.

Compatibility

Although there is evidence that nematodes are compatible with most herbicides and fungicides, they are sensitive to certain insecticides, nematicides, wetting agents, and surfactants used in turf maintenance. A list of chemicals that should not be tank mixed with nematodes in given in Table 2. Therefore, before tank-mixing the nematodes with other chemicals, the label should be checked carefully or the nematode producer/supplier should be consulted.

Entomopathogenic nematodes have the potential to recycle and establish in the environment following use as biological insecticides or if used in inoculative releases as in the case of parasites and predators. However, studies documenting the long-term persistence of nematodes are limited. Steinernema glaseri was reported to have maintained itself in the field for 14 years in New Jersey with a Japanese beetle larval densities of less than five per square foot. Steinernema scapterisci has been shown to maintain its population in mole crickets in Florida for 5 years.

Other studies have reported that a single application of nematodes can impact more than a single generation of white grubs.

The annual bluegrass weevil or Hyperodes weevil is an important pest of Poa annua and annual bluegrass on golf courses in the northeastern United States. S. carpocapsae, H. bacteriophora and H. megidis have shown good results for the control of weevil larvae in golf course turf.

TABLE 1. TARGET PESTS OF COMMERCIALLY AVAILABLE ENTOMOPATHOGENIC NEMATODES

Target pest	Target life stage	Best nematode species
Armyworms (Noctuidae: Lepidoptera)		
Armyworm	Larva/pupa	S. carpocapsae
Fall armyworm	Larva/pupa	S. carpocapsae
Yellowstriped armyworm	Larva/pupa	S. carpocapsae
Lawn armyworm	Larva/pupa	S. carpocapsae
Cutworms (Noctuidae: Lepidoptera)		
Black cutworm	Larva/pupa	S. carpocapsae
Bronze cutworm	Larva/pupa	S. carpocapsae
Variegated cutworm	Larva/pupa	S. carpocapsae
Glassy cutworm	Larva/pupa	S. carpocapsae
Sod webworms (Pyralidae: Lepidoptera)		
Bluegrass webworm	Larva/pupa	S. carpocapsae, H. bacteriophora
Larger sod webworm	Larva/pupa	S. carpocapsae, H. bacteriophora
Western lawn moth	Larva/pupa	S. carpocapsae, H. bacteriophora
Striped sod webworm	Larva/pupa	S. carpocapsae, H. bacteriophora
Elegant sod webworm	Larva/pupa	S. carpocapsae, H. bacteriophora
Vagabond sod webworm	Larva/pupa	S. carpocapsae, H. bacteriophora
Cranberry girdler	Larva/pupa	S. carpocapsae, H. bacteriophora
Tropical sod webworm	Larva/pupa	S. carpocapsae, H. bacteriophora
Burrowing sod webworm	Larva/pupa	S. carpocapsae, H. bacteriophora
Fleas (Policidae: Siphonaptera)		
Dog flea larvae	Larva/pupa	S. carpocapsae
Cat flea larvae	Larva/pupa	S. carpocapsae
Mole crickets (Gryllotaplidae: Orthoptera)		
Tawny mole cricket	Nymph/adult	S. scapterisci, S. riobrave
Southern molecricket	Nymph/adult	S. scapterisci, S. riobrave
Short winged mole cricket	Nymph/adult	S. scapterisci, S. riobrave
Native mole cricket	Nymph/adult	S. scapterisci, S. riobrave
Crane flies or leather jackets (Tipulidae: Diptera)		
European crane fly	Larva/adult	H. bacteriophora, H. megidis
Weevils (Curculionidae: Coleoptera)		
Annual bluegrass weevil	Larva/adult	H. bacteriophora, S. carpocapsae
Bluegrass billbug	Larva/adult	S. carpocapsae, H. bacteriophora
Hunting billbug	Larva/adult	S. carpocapsae, H. bacteriophora
Phoenician billbug	Larva/adult	S. carpocapsae, H. bacteriophora
Denver billbug	Larva/adult	S. carpocapsae, H. bacteriophora
White grubs (Scarabaeidae: Coleoptera)		
Asiatic garden beetle	Larva	H. bacteriophora, H. zealandica
Black turfgrass ataenius	Larva	H. bacteriophora
Green June beetle	Larva	H. bacteriophora
Japanese beetle	Larva	H. bacteriophora, H. zealandica, S. glaseri
May or June beetles	Larva	H. bacteriophora
Oriental beetle	Larva	H. bacteriophora, H. zealandica
European chafer	Larva	Steinernema sp.
Northern masked chafer	Larva	H. bacteriophora, H. zealandica
Southern masked chafer	Larva	H. bacteriophora
Southwestern masked chafer	Larva	H. bacteriophora, S. glaseri
Plant-parasitic nematodes (Nematoda)		
Sting nematodes	Juvenile/Adult	S. carpocapsae, S. riobrave
Ring nematodes	Juvenile/Adult7	S. carpocapsae, S. riobrave
Root-knot nematodes	Juvenile/Adult	S. carpocapsae, S. riobrave, S. feltiae
Lance nematodes	Juvenile/Adult	H. bacteriophora
Lesion nematodes	Juvenile/Adult	H. bacteriophora
Stunt nematodes	Juvenile/Adult	H. bacteriophora
Spiral nematodes	Juvenile/Adult	H. bacteriophora
Pin nematodes	Juvenile/Adult	H. bacteriophora

Conservation

Whether they are applied or occur naturally, conservation of entomopathogenic nematodes in the turf should be a goal. There are several factors that influence nematode persistence in the soil. Extremely dry soil conditions, absence of host insects for extended periods, and the application of toxic chemicals may reduce nematode numbers in soil. Studies are continuing to shed light on the complex ecology of entomopathogenic nematodes to develop practical approaches to effectively conserve and augment their populations in turfgrass.

Nematodes are safe to apply and are exempt from government registration. They do not harm the environment, plants, animals, pets or wildlife, or non-target invertebrates. They are found naturally in various soil types, in turfgrass lawns, cultivated sites, and in undisturbed natural areas. No worker protection measures are necessary for nematode applications and turf can be used immediately after treatment.

Parwinder Grewal is assistant professor in the Department of Entomology, OARDC, Ohio State University, Wooster, Ohio. He invites everyone to visit the insect-parasitic nematode Web site at www.oardc.ohio-state.edu/nematodes .

TABLE 2

CHEMICALS THAT SHOULD NOT BE TANK MIXED WITH ENTOMOPATHOGENIC NEMATODES.

Chemical Trade Name:

- Anilazine Dyrene
- Azadirachtin Azatin
- Azinphosmethyl Guthion
- Bendiocarb Turcam
- Carbofuran Furadon
- Carbaryl Sevin
- Chlorpyriphos Dursban
- Ethoprop Mocap
- Fenamiphos Nemacur
- Fipronil Chipco Choice
- Insecticidal Soap Various
- Isazophos Triumph Methomyl Lannate
- Oxamyl Vydate
- 2-4-D Various
- Trichlorfon Dylox
- Triclorpyr Turflon
- Confront

FURTHER READING

Gaugler, R., Grewal, P. S., Kaya, H. K. and Smith-Fiola, D. (2000). Quality assessment of commercially produced entomopathogenic nematodes. Biological Control 17, 100-109.

Georgis, R. and Poinar, G. O. Jr. (1989). Field effectiveness of entomophilic nematodes Neoaplectana and Heterorhabditis. In: Leslie A. R. and Metcalf, R. L. (eds.) Integrated Pest Management for Turfgrass and Ornamentals. Environmental Protection Agency, Washington, DC, pp. 213-224.

Niemczyk, H. D. and Shetlar, D. J. (2000). Destructive Turf Insects. Second Edition, HDN Books, Wooster, OH.

Grewal, P. S. (1997). Using nematodes for turfgrass pest management. Insect-parasitic nematode website at www2.oardc.ohio-state.edu/nematodes.

Grewal, P. S. and Georgis, R. (1998). Entomopathogenic nematodes. In: Hall, F.R. and Menn, J. (eds.) Methods in Biotechnology: Biopesticides: Use and Delivery. Humana Press Inc., Totowa, New Jersey, pp. 271-299.

Grewal, P. S., Martin, W. R., Miller, R. W. and Lewis, E. E. (1997). Suppression of plant-parasitic nematodes in turfgrass by entomopathogenic nematodes. Biocontrol Science and Technology 7, 393-399.