Entomopathogenic Nematodes

This is another installment in our ongoing series of articles on pest control measures that are alternatives to the more common chemical methods. This month we discuss entomopathogenic nematodes (EPNs) – microscopic worms that eat insects. Entomopathogenic nematodes are soft bodied, non-segmented roundworms that are obligate or sometimes facultative parasites of insects. Entomopathogenic nematodes occur naturally in soil environments and locate their host in response to carbon dioxide, vibration and other chemical cues. Entomopathogenic nematodes are an appropriate measure for integrated pest management (IPM) programs because they are considered non-toxic to humans, relatively specific to their target pests, and can be applied using normal pesticide application equipment. Entomopathogenic nematodes are exempted from the U.S. Environmental Protection Agency (EPA) pesticide registration, there is no personal protective equipment (PPE) requirements or re-entry restrictions and resistance development is unlikely.

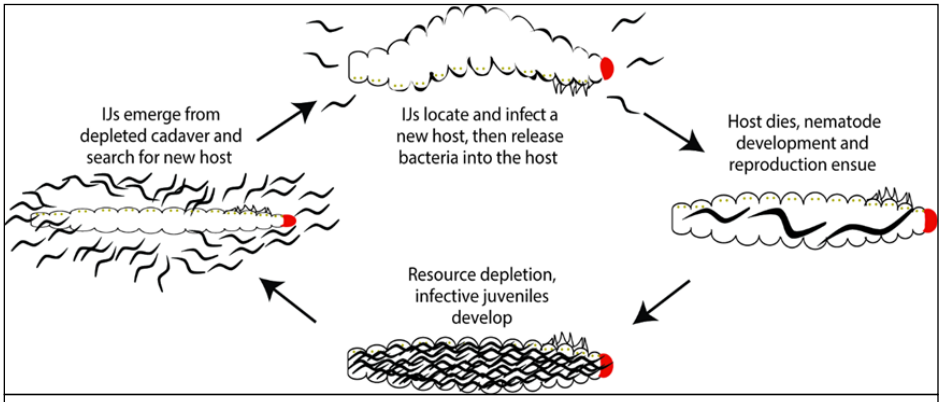

Figure 1: Life cycle of a typical entomopathogenic nematode.

The only free-living stage of entomopathogenic nematodes is the infective juvenile stage. The nematode infects the host insect through natural openings or in some species through the soft membranes between body segments, and then enters into the body cavity containing the insect blood (hemocoel). Two common entomopathogenic nematode genera are *Heterorhabditis* and *Steinernema*. Both have a mutualistically association with bacteria of the genera *Photorhabdus* and *Xenorhabdus*, respectively. Upon entering the insect, the nematode releases some of their bacteria from their intestines into the insect's hemocoel. The bacteria feed and multiply within the insect host which usually dies within 24 to 48 hours. The bacteria are known to produce a toxic cocktail of secondary metabolites created are lethal to the insect hosts, and also prevent other opportunistic bacteria and fungi from infesting the dead host, thus preserving the resources for themselves and their nematode partners. The nematodes continue to feed on the dead host tissue, mature and reproduce. The insect cadaver becomes red if the insects are killed by heterorhabditids and brown or tan if killed by steinernematids due to pigments produced by the associated bacteria growing inside the host. Depending on the available resources, one or more generations may occur within the dead host and many infective juveniles are eventually released into the environment to infect other hosts and repeat the cycle.

Depending on the species, infective juveniles either lie-in-wait to attack mobile insects or move significant distances in search of prey. Some nematode species use both approaches to find their host.

Entomopathogenic nematodes are living organisms, and both biotic and abiotic factors can be detrimental during applications. Entomopathogenic nematodes work best in sandy soil with a pH between 4 and 8. Entomopathogenic nematodes are susceptible to freezing, hot temperatures, desiccation, and UV light. The nematode efficacy can be enhanced in many ways; 1)by matching the most appropriate species to the target pest, 2) using the correct rate of a viable nematode product, 3) keeping the treated area wet for at least 8 hours post application and 4) applying

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during early morning or evening hours to minimize UV exposure and drying conditions. It is also important to inspect entomopathogenic nematodes after receiving them and prior to application to ensure that they are viable (wiggling movement of healthy juvenile stages can be observed with a 20× hand lens).

Entomopathogenic nematodes can be applied with most horticultural equipment including pressurized sprayers, mist blowers, and electrostatic sprayers. Filters, screens and swirl plates should be removed from spray equipment lines to prevent clogging by infective juveniles. Regular agitation during application is essential because entomopathogenic nematodes quickly settle out of suspension. Studies have shown that entomopathogenic nematodes are compatible with many insecticides, fungicides and herbicides. Entomopathogenic nematodes come in a variety of formulations: water-dispersible granules, nematodes on gel, micronized vermiculite, nematode wool, and an aqueous suspension of nematodes. Follow label directions for best results. There are currently several products available – you can even buy them on Amazon. ~Dr. Joe Willis

EPN species	**Major pest target as recommended by commercial producer**
Steinernema glaseri	White grubs, banana root borers
Steinernema kraussei	Black vine weevil, *Otiorhynchus sulcatus*
Steinernema carpocapsae	Armyworm (*Pseudaletia unipuncta*), Artichoke Plume Moth, Bagworm, Beet Armyworm (*Spodoptera exigua (Hubner)*), Black Cutworm (*Agrotis ipsilon (Hufnagel)*), Black Vine Weevil (*Otiorhynchus sulcatus*), Bluegrass Weevil, Caterpillars, Cockroaches (American, Asian, German), Codling Moth (*Cydia pomonella*), Corn Earworm, Cotton Bollworm, Cranberry Girdler, Cucumber Beetle, Cutworm (*Agrotis, Amathes, Peridroma, Prodenia spp*), Fall Armyworm (*Spodoptera frugiperda*), Flea Larvae, Fly Larvae, Fruit Flies (*Drasophylla*), Greater Peach Tree Borer (*Synanthedon exitiosa*), Lesser Peach Tree Borer (*Synanthedon pictipes*), Large Pine Weevil, Leafminers, Mint Flea Beetle, Mint Root Borer, Mole Crickets, Navel Orangeworm, Strawberry Root Weevil (*Otiorhynchus ovatus*), Tobacco Budworm, Webworms, Wireworm, Wood Borers
Steinernema feltiae	Beet Armyworm, Black Cutworm, Cabbage Maggot, Codling Moth, Corn Earworm, Cucumber Beetle, Fruit Flies (*Drasophylla*), Fungus Gnats (*Bradysia impatiens*), Onion Maggots, Pill Worm, Raspberry Crown Borer, Root Maggots, Sclarids, Shore Flies, Subterranean Termites, Sweet Potato Weevil, Thrips (*Franklinothrips sp*), Ticks, Tobacco Cutworm
Steinernema scapterisci	Mole crickets (*Scapteriscus* spp.)
Steinernema riobrave	Citrus root weevils (*Diaprepes* spp.), mole crickets
Heterorhabditis bacteriophora	Ants (Queen), Asparagus Beetle (*Crioceris asparagi; Crioceris duodecimpunctata*), Bagworm, Banana Moth, Banana Weevil, Berry Root Weevil, Billbug, Black Vine Weevil, Borers (Iris, Tree, Vine), Carrot Weevil (*Listronotus oregonensis*), Chafers (European, Masked), Citrus Root Weevil, Colorado Potato Beetle (*Leptinotarsa decemlineata*), Corn Rootworm, Cranberry Root Weevil, Cucumber Beetle (Spotted) (*Diabrotica undecimpunctata howardi*), Flea Beetles, Fleas (Adults), Gall Midges, Grape Root Borer, Grubs, Humpbacked Flies, Japanese Beetle (*Popillia japonica Newman*), Leafminers, May/June Bugs (*Phyllophaga sp.*), Root Weevils, Scarabs, Sugarcane Stalk Borer, Sweet Potato Weevil, Ticks, Webworms
Heterorhabditis megidis	Weevils
Heterorhabditis indica	Fungus gnats, root mealybugs, grubs
Heterorhabditis marelatus	White grubs (scarabs), cutworms, black vine weevils
Heterorhabditis zealandica	Scarab grubs

There are several entomopathogenic nematodes commercially available for control of various insects as indicated by the table above.