

Getting the Most Out of Beneficial Nematodes in Organic Production

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Native Persistent Nematodes: <http://www.alfalfasnoutbeetle.org/index.php/resources-contacts/>

IPMLabs: <https://www.ipmlabs.com/>

Application Methods

Can entomopathogenic nematodes (EPNs) be applied through drip? You *can* apply EPNs via drip irrigation but it may take some experimentation on your farm. Nematodes are heavier than water and will settle out of suspension if the water is not flowing quickly or if there are low spots. Test your system before investing heavily in this and make sure that the nematodes are reaching the furthest emitter. I would also be concerned about lack of oxygen in the drip system. How fast does the water move through the system? Is the water aerated in any way after the nematodes are added and before they enter the system?

Can EPNs be applied under black plastic mulch or does the increased heat kill them?

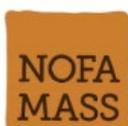
If using black plastic mulch, the soil can get very hot under there and temperatures over 85F can kill EPNs. *Heterorhabditis bacteriophora* is more tolerant to high temperatures than the *Steinernema* species. Other mulches like straw or bark mulch would cool the soil and those should cause no problem for them nematodes and will help prevent soil drying. In high tunnels, the soil temperature should not be too high for EPNs—soil has a tremendous insulating ability and does not fluctuate that much below 2 inches depth. A recent MS student studying the heat tolerance of the commercial *Steinernema* and *Heterorhabditis* found *Heterorhabditis bacteriophora* and *Steinernema carpocapsae* can tolerate 100 F for a couple of hours without death and can still infect. *S. feltiae* is much more sensitive to heat and can tolerate 90 F for a couple of hours

Can EPNs be sprayed onto wet mulch, or must they be applied directly to exposed soil?

The best way to apply them is directly to the soil in as much water as is needed to move them down into the soil profile where you want them. If the EPNs are sprayed onto mulch, they will be susceptible to desiccation and UV-radiation. You would want to really soak them in to wash the nematodes off the mulch and down into the soil, or apply before rain.

When applying EPNs with a sprayer, what are some tips to remember? Do you know if a backpack mist blower creates pressures too high for beneficial nematodes?

Nematodes should be stored in the refrigerator (*S. feltiae* can be active and will thereby deplete its energy reserves above 50F) and will be killed at temperatures over 85F. They need oxygen to survive and can be killed within a couple of hours if left in non-aerated water. Ultraviolet light in sunlight is also harmful to nematodes and can kill them in a half hour. When spraying, keep the pressure below 300 psi and remove any mesh screens. Apply with enough water that the nematodes will be flushed down into the soil. Not sure about mist blowers, the volume of water would be very small and so



that might not be the best way to apply them—Carol is not aware of growers who apply them with a mist-blower. If you are worried about your application method, check the survival of sprayed EPNs by spraying some nematodes through the mister, collecting the sprayed solution in a cup. Then, check to see if the nematodes are still moving by holding a flashlight on the bottom of the cup and looking down into the cup with a hand lens.

Do you recommend adding a surfactant to an EPN spray mix when making a foliar application or soil application?

A surfactant should be used when applying EPNs to foliage for pests like thrips, which are walking around on the plant and/or hanging out in the flowers. Otherwise, EPNs are applied to soil and should be applied with enough water to get the material down into the soil around the roots where you want the EPNs to be. A surfactant is not necessary for soil applications.

How often do commercial EPNs need to be applied?

Usually, a single application will be sufficient if timed properly to target the susceptible stage. Weekly treatments are only recommended for thrips control in greenhouses.

Can you over apply EPNs?

While there may be no ecological or crop harm to applying more EPNs than necessary, it may not be a good economic choice. In general, we are not applying very many nematodes to the soil; the soil is a huge reservoir, anything we add is really a drop in the bucket. It can also be very expensive to apply EPNs at a high rate. In some cases, applying a lot of EPNs has been shown to attract nematode-parasitic fungi which come in and kept the EPN populations in check, while also reducing numbers of plant-parasitic nematodes. With native, persistent nematodes, they seem to come into balance on their own. The nematodes require a baseline level of susceptible insects to maintain their population, so the pest and nematode populations maintain a balance. There is no dose response with nematodes, meaning that if we apply 4 times the rate of EPNs, we do not get 4 times better insect pest control, so it doesn't "pay" to overapply

What level of control can I expect to get with either commercial or persistent nematodes?

This is an example of biological control, in which the nematodes need the insect host to complete their life cycle and so would not benefit from wiping the insect host out entirely. Control will therefore never be 100%, but can be quite high. In the case of persistent nematodes, full activity requires a full growing season and they are fully active in season 2. In the case of commercial nematodes, the efficacy depends a lot on getting the right application timing and getting the material where you need it. In the field, efficacy using commercial products is variable, but in more controlled environments (like using EPNs for fungus gnat control in greenhouses) control can be very high.

Use of EPNs for Specific Pests

Is there a nematode that is effective against slugs?

No. There is a nematode product that is being developed in the EU and a new one is being developed in the US but is not on the market currently.

Is there a nematode that is effective against onion maggot?

No, EPNs are not recommended for onion maggot control. Onion maggot eggs are laid in such a way that the larvae enter the onion very quickly and the nematodes do not have a chance to intercept and kill the larvae. Interestingly, onion thrips can be managed effectively indoors using EPNs, but this method hasn't been tested outdoors. There is currently an active research project investigating the efficacy of persistent EPNs against onion maggot on muck soils.

Is there a nematode that is effective against flea beetles?

Since flea beetles are coming into your fields from other areas (nearby fields, farms or weedy areas), it is not effective to use EPNs to protect your brassicas. That said, EPNs do have an effect on flea beetle larvae in the soil, so you may be able to pull off some kind of trap crop/EPN approach, but it would not directly impact flea beetles attacking your brassica crop in a meaningful way. Elson presented some data on reduction in damage to harvested daikon roots after applying the native/persistent nematodes—this damage may have been caused by wireworms and/or flea beetles larvae. So that may be a benefit of using EPNs for flea beetle control, but again would not reduce damage to foliage cause by adult beetle feeding.

Elson: Since alternate hosts to flea beetle are throughout the non-crop areas of a farm and the major damage is the adults moving into the field in the spring from outside the field, the best strategy would be to treat a significant area surrounding the fields with persistent EPNs to reduce the flea beetle population moving into the field in the spring. In addition, treating the field would reduce the larval population which matures and moves to the field margins for overwintering.

Is there a nematode that is effective against striped cucumber beetles?

Like with the flea beetles, striped cucumber beetles come in to your field or greenhouse from other fields, farms, and weedy areas, and so applying EPNs to the soil in your cucumber plot may cause some mortality to cuke beetle larvae in the soil but it will do nothing to reduce damage to foliage or prevent spread of bacterial wilt. If you were producing cukes in a screened in greenhouse or tunnel and beetles were not coming in from outside then you may be able to effectively use EPNs for control.

Is there a nematode that is effective against broad mites?

A: Not that we are aware of. We do not have any nematodes commercially available for mite control.

Is there a nematode that is effective against Japanese beetles/grubs?

A: Native white grubs are very susceptible to EPNs. Annual white grubs are less so. Japanese beetle larvae are most sensitive when small in the late summer and early fall. Asiatic garden beetle is less susceptible and European chafer is almost immune to EPNs. *Heterothabditis bacteriophora* can be used effectively in August or *Steinernema feltiae* in May before the JB grubs pupate, since the grubs are more susceptible to nematodes than the pupae are. Rates of 25 million per 1000 sq ft are recommended as a knock down dose, but if you just want to inoculate the soil, you can use 25 to 50 million per acre.

Is there a nematode that is effective against squash vine borer? Would applying EPNs to last year's squash field the following spring be effective?

Effectiveness has everything to do with how long the insect has a direct interface with soil, especially in the immature stage. Squash vine borer overwinters in crop residues (stems and fruit) as a pupa and so may not be very susceptible over the winter period because it is protected within the crop tissue. In spring, the vine borers hatch into adult moths and fly away. Growers have used nematodes to control SVB when injected into stems to kill the vine borer larvae but this would be very labor intensive and you may be better off just poking the larva with a knife at that point and not wasting the money on pesticide and/or nematodes.

Is there a nematode that is effective against grain moth in storage?

A: Nematode applications require water, something that you do not want to add to grain storage! *Trichogramma* are used in grain storage. That is a tiny wasp that kills grain moth eggs.

Impact of Crop Production Practices on EPNs

What are the chances that a particular farm already has native nematodes? You almost certainly have some native EPNs on your farm already! EPNs have been isolated from every inhabited continent and from virtually every type of soil habitat where they have been looked for. Elson and collaborators have found the main three species of nematode with efficacy against pest insects all over the Northeast. These species are *Steinernema feltiae*, *Steinernema carpocapsae* and *Heterorhabditis bacteriophora*. They occur at low densities and are not adapted to agricultural systems or pests, which is why Elson has started re-inoculating agricultural fields using a species mix depending on soil type to have nematodes which cover the entire root zone of the plants.

Does tillage or other farming practices effect native nematode populations?

Tillage does not kill EPNs, but does help spread them through the soil. Moldboard plowing buries EPNs but they can move up to shallower depths where they are happier. Plowing just once will move native nematodes about 100 yards. Grazing livestock can also spread the nematodes through soil, helping get more even and widespread distribution.

Are EPNs effective in a community garden where plots may be separated by 3 ft paths?

Commercial or persistent nematodes could be used effectively in a community garden system like this, you would just want to apply the nematodes in each plot where you anticipate a pest species may be present. The grassy strips between plots could help to maintain the native/persistent nematodes over time and to help them spread.

Can I inoculate my compost, vermicompost, and/or compost tea with EPNs? Will they have any effect on the rest of the soil biology we are trying to improve?

EPNs can't be grown in liquid culture, but you could add them to your compost tea before you apply it to soil, as long as you keep the solution well aerated—nematodes will die quickly (30 minutes!) without oxygen in the water, but if you keep the solution aerated they can survive for hours. Don't add the nematodes to the compost tea during the long fermentation process, they will drown and die. If you can apply it quickly this works well and is a commonly used practice in NY (using liquid

dairy manure). EPNs are generalist insect predators and could affect beneficial insects you are trying to cultivate through reduced till practices, but they usually are kept in balance, and some beneficial insects have evolved defenses against EPN attack—see question 1 in the “EPN in the larger environment” section.

I use *Steinernema feltiae* nematodes for fungus gnat control in vermicompost which stays moist and 55-70F. How often do I need to apply the nematodes to control the fungus gnats throughout their lifecycle?

EPNs (and rove beetles) are used commonly in compost facilities to control little flies present in the compost. Nematodes may perpetuate after a single application, a lot of times a single application can do the trick, but with flies where you may have overlapping generations a few applications may be needed. You can use some leftover compost from the previous bin to “inoculate” the next bin of compost.

What pesticides are okay to use along with EPNs?

Most organic pesticides should not have any effect on EPNs unless they are specifically listed as nematicides. EPNs are commonly mixed with *Beauvaria bassiana* products as a dip treatment for small plants or seedlings, though *Beauvaria* may be able to infect EPNs.

Can I use nematodes and milky spore together?

A: Milky spore is a bacterium used against Japanese beetles which would not harm EPNs but Carol does not recommend its use because EPNs are much more effective than the bacterium is.

The black vine weevil case study - were the EPNs only applied in fall and they overwinter in the field?

A: Yes the native EPNs Elson described were applied once and are surviving over the winter and providing several years of control of the weevils.

EPNs in the Larger Environment

Do the commercially available nematode species have any negative effect on native insect or nematode populations in the field?

Nematodes are generalists and will affect any insect species present. These EPN species have evolved in the region and occur naturally in balance with insects good and bad. Commercially available nematodes are short-lived. Native/persistent nematode populations ebb and flow with insect pest populations. Rigorous research on impacts on beneficial soil insects has not been done, but we don't expect to see a lot of these in intensive agricultural soils anyway, or below the top two inches of the soil profile. Some soil-dwelling insects like rove beetles have evolved resistance to EPNs and developed a thick skin that can't be penetrated. So many beneficial insects have naturally evolved resistance to EPNs and would not be affected. In low-till systems you may have more beneficial insects like carabid beetles in soil and these could be effected, though many beneficial insects have evolved some resistance to EPNs. But it does become a conscience decision, agricultural systems are not natural systems and we are trying to manipulate an artificial condition with the least impact.

Is there any difference between the natural distribution of nematodes in Vermont compared to New York?

No, we see the same species and similar distribution across the Northeast, and they do persist even in the cold north! The nematodes in your soil are the same species that Elson is rearing and inoculating, what he provides is a blend of the three species that are effective at different soil depths/niches that you can use to inoculate your fields.

What is known about the general nematode ecosystem, outside of biocontrol nematodes?

Lots of other nematodes exist in soils naturally that do not impact other insects (entomopathogenic). Some are plant pathogens or human/animal pathogens, like root-knot nematode or the species that cause elephantiasis or heart worm. Some are barely visible to the naked eye when they have been extracted from the soil and are floating in the water; you cannot see any when looking at soil directly with the naked eye.

How to Obtain EPNs

Elson - Do you have a publication available that outlines how to produce native, persistent EPNs on farm; like a step-by-step procedure?

Yes, to get native persistent nematodes check out the resources on Dr. Shields site, including [manuals](#) and videos on rearing your own EPNs:

<http://www.alfalfasnoutbeetle.org/index.php/resources-contacts/>. To get “starter cups” of EPNs, contact Mary DeBeer at 518-812-8565 or email md12957@aol.com or from Elson’s lab.

Where can I buy EPNs or materials on rearing my own EPNs?

Several biocontrol companies sell commercially raised EPNs including Carol’s company [IPMLabs](#) and others like [BioBest](#), and [Koppert](#). These should be applied as Carol described, to target a specific pest at the time in its life cycle that is most susceptible (usually the immature stage) and where the pest is located. To get native persistent nematodes check out the resources on Dr. Shields site, including [manuals](#) and videos on rearing your own EPNs:

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