

Nematodes:

Nice, not naughty



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Funding Support

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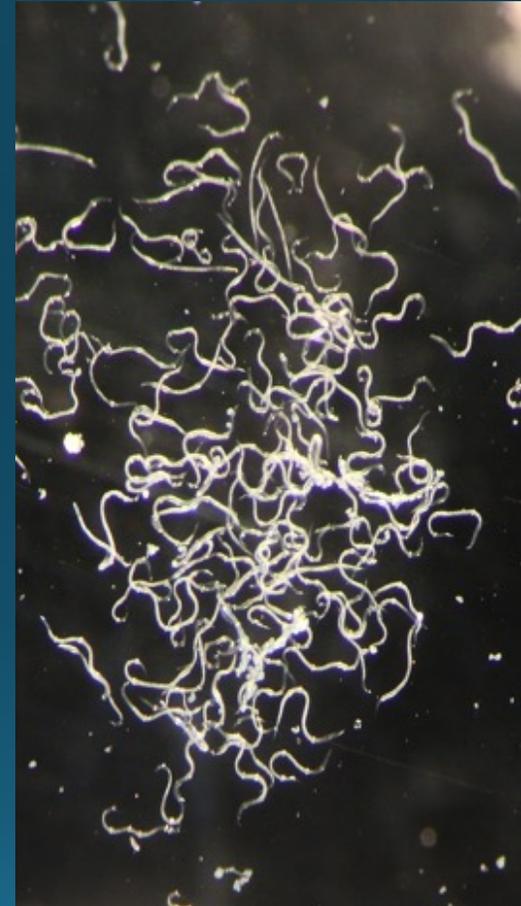


USDA Hatch/Multistate project NE1332



Things to Cover:

- Background
 - Who uses nematodes?
 - What are they?
 - Key pests
- Nematode Applications
 - Available Products
 - Steps & tips
 - Technology
- Ensuring efficacy
 - Potential pitfalls
 - Research in our lab
 - Integrating nematode with other control options



Nematodes in the Greenhouse Industry

Greenhouse Grower Magazine's 2017 State of the Industry:

- 975 respondents
- 63% of growers use biological control
- One of biggest crop protection issues = **Thrips control**
→ *nematodes* as best solution



Nematode use increased because of:

- Increased awareness & understanding
- Better quality and application technology
- Decreasing prices
- Necessity

2017 survey results from NYS greenhouse businesses:

Grower Plans for Fungus Gnats

% Responding	Pest Mgt. Tactic	
40	Insecticides	
35	Biological Control	
8	Biocontrol & Insecticides, on separate crops	
17	Biocontrol & Insecticides, on same crops	
For Biocontrol:	% Using	Biocontrol Agent
	25	Hypoaspis/Stratiolaelaps predatory mites
	42	Nematodes
	28	Gnatrol (Bt var. israelensis bacterium)
	6	Atheta/Dalotia rove beetles

2017 survey results from NYS greenhouse businesses:

Grower Plans for Thrips

% Responding	Pest Mgt. Tactic	
45	Insecticides	
21	Biological Control	
11	Biocontrol & Insecticides, on separate crops	
21	Biocontrol & Insecticides, on same crops	
For Biocontrol:	% Using	Biocontrol Agent
	21	Hypoaspis/Stratiolaelaps predatory mites
	23	Nematodes
	20	Cucumeris/swirskii predatory mites
	9	Orius bugs
	27	BotaniGard/Naturalis/Preferal fungi

Nematodes Basics

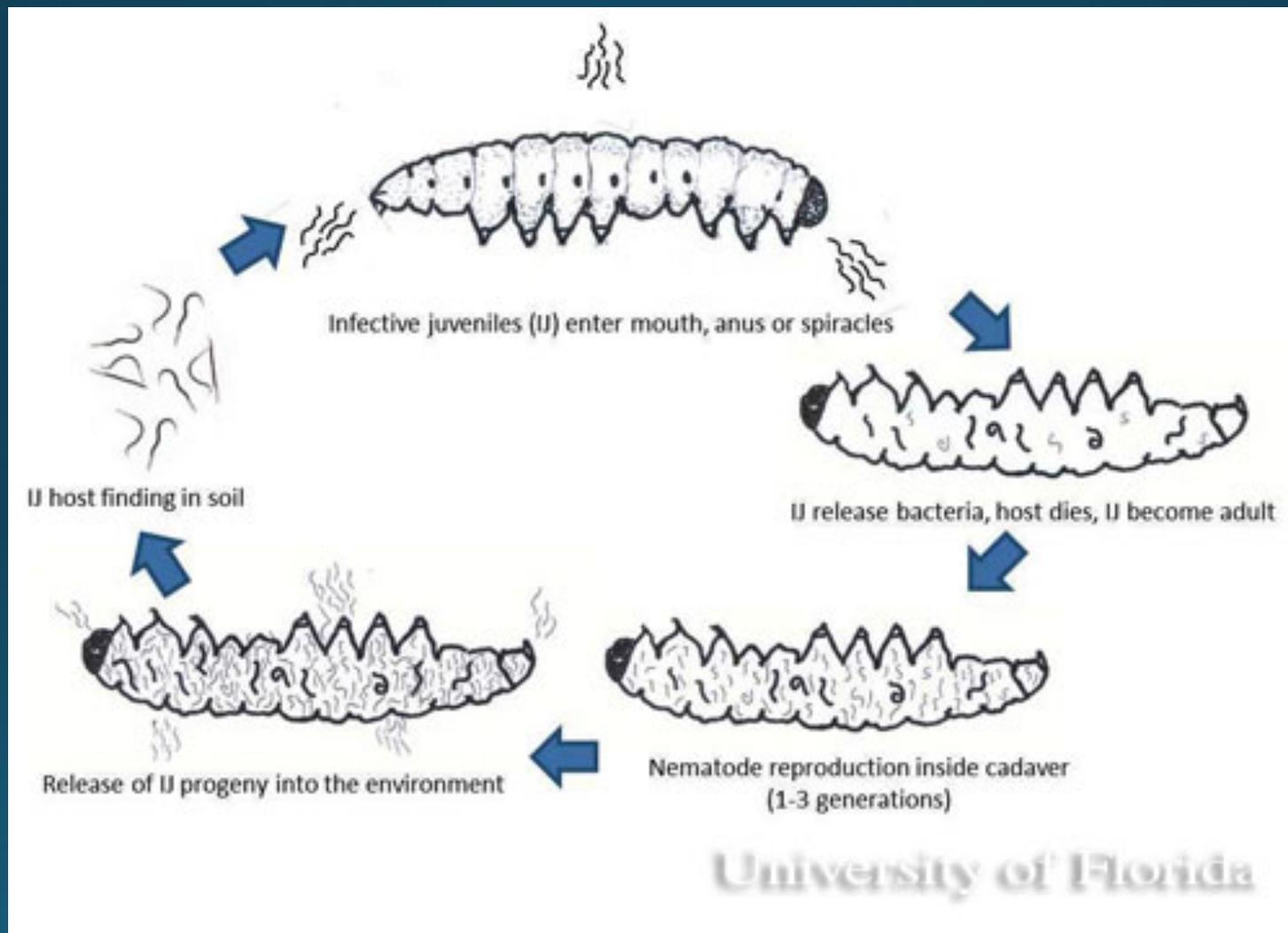
- Most abundant land animal on earth (?)
- Roundworms
 - Phylum Nematoda
 - Harmful *and* helpful species
- For biological control
 - Insect-killing, or “entomopathogenic” nematodes (EPNs)
 - Virtually no risk of resistance
 - No REI or PHI
 - Apply preventatively



Entomopathogenic Nematodes (EPNs)

- Microscopic
- Soil-dwelling
- Need water film to disperse
- Develop inside insect hosts
- Carry *bacteria* responsible for insect death

Generalized Life Cycle of Insect-killing Nematodes:



Fungus Gnats

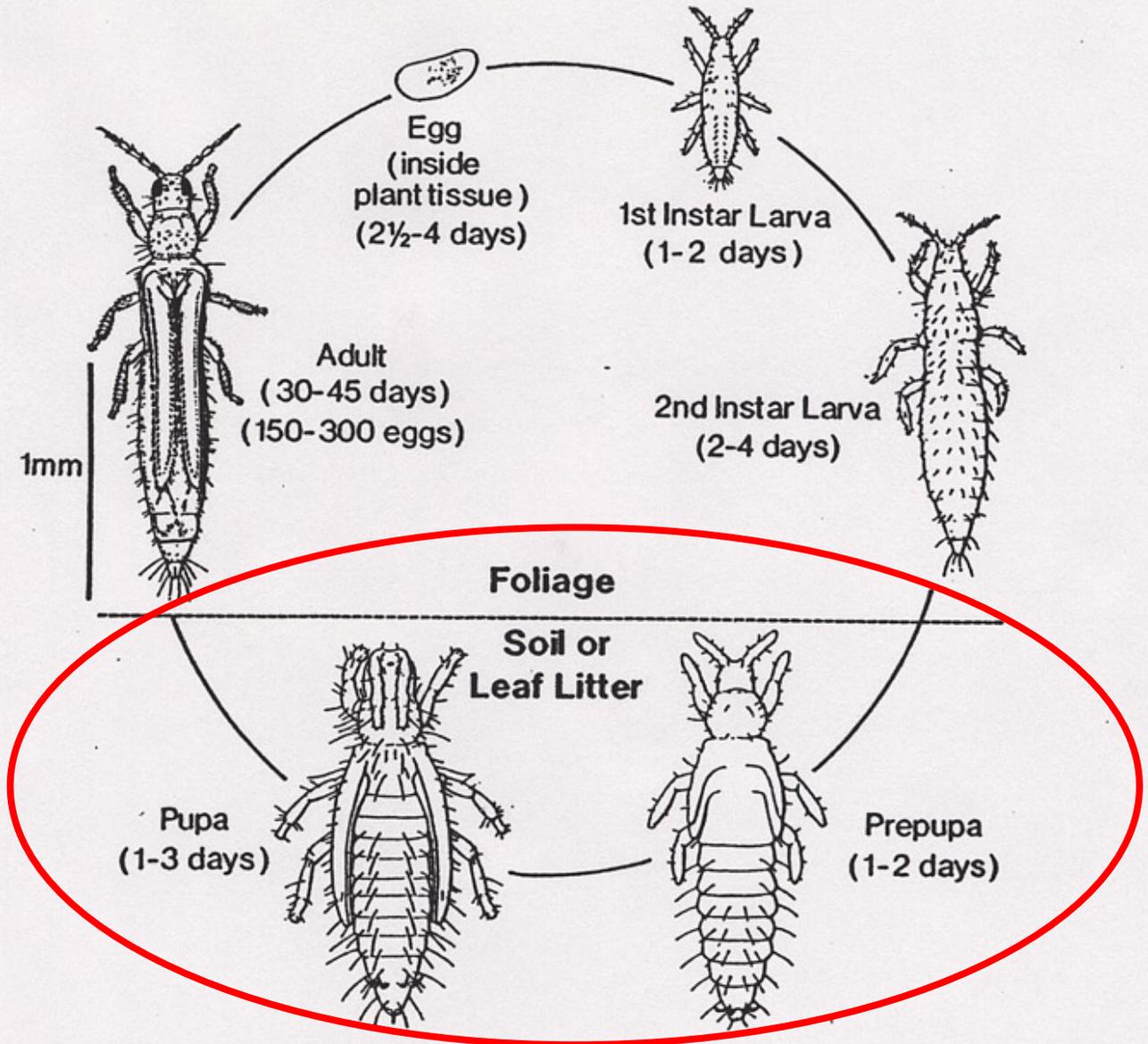


Healthy larva



Infected larva

Western Flower Thrips



Thrips and nematodes

Yes - Western flower thrips



?? - Onion thrips



U. Kentucky

No - Echinothrips ("Poinsettia thrips")



U. Florida

No - Greenhouse thrips



U. Florida

WFT Pupae



Before Infection

After Infection



Shore Flies

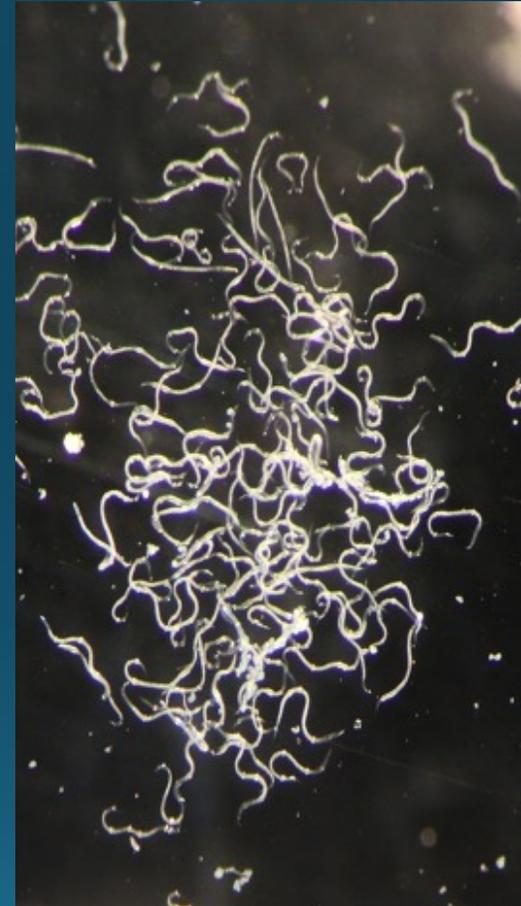


No direct damage, but...
black specks
soil-borne pathogens
nuisance

Reducing algae is best control, but nematodes can help!

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Widely Available Nematodes

Steinernema feltiae

Steinernema carpocapsae

Heterorhabditis bacteriophora

Variations in:

- Host insects attacked
- Environmental tolerance
- Price



EPN-infected thrips pupa

Steinernema feltiae is most commonly used nematode

Steinernema feltiae



Characteristics:

- Controls FG, WFT, (shore fly, black vine weevil, white grubs, etc.)
- Cool-Mid temperature range
- Often lowest-priced nematode products

Available Products:

NemaShield

Nemasys

Scanmask

Entonem

Steinernema-System

Exhibitline SF

E-Nema

and more...

Steinernema carpocapsae



Characteristics:

- Marketed to control shore flies, weevils, grubs, mole crickets, etc.
 - Can also help control FG and WFT
- Mid-High temperature range
- Less commonly used → sometimes higher price

Available Products:

Millenium
Nematac C
Ecomask
Capsanem
Exhibitline Sc
Carpocapsae-System
and more...

Heterorhabditis bacteriophora



Characteristics:

- Marketed to control weevils, white grubs (European chafers, Oriental and Japanese beetles)
 - Can help with FG, WFT, and shore flies (??)
- Mid temperature range
- Less commonly used → sometimes higher price

Available Products:

Nemashield HB
Nemasys G
Heteromask
Larvanem
B-Green
and more...

Nematode Products

- Most common: trays with 50, 150, or 250 million nematodes
- Sponges, granule, and vermiculite mixes exist, but much less common than gels
- Best to use as soon as possible
- May be stored in refrigerator (40°F)
- Check expiration date
- If package is opened, do not store*



Checking Nematode Viability

- Let the package come to room temperature for 30 min
- Place a very small sample on a dark plate or dish
- Add 1 drop of water
- Wait about 5 minutes, then observe with lens or microscope
- Can also take sample from spray solution to check for live nematodes



Application Technology

- Almost any full-volume sprayer can be used
 - Keep pressure below 300 psi
 - Remove filters and screens!
 - Nozzle should have adequate openings
 - Agitation – nematodes drop out of suspension
- Some irrigation systems
 - Better distribution with boom sprayers than drip, sprinkler systems



Avoid mixing with incompatible pesticides





**Aeration/Agitation Bucket-
Battery Operated**



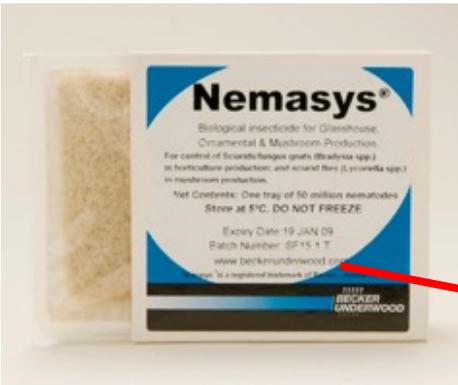
**Ferticart 50 Gallon with
Aeration/Agitation**

Dramm Agitation/Aeration Bucket



Basic Steps for Nematode Application

- Pre-wet soil, if possible
- Remove from fridge, ~30 min to warm up
- Mix into water
 - Less than 100F!!
 - Cold tapwater OK
- Apply, agitating regularly



Nematode Application



Double row of nozzles on boom sprayer:

1st row – nematodes

2nd row – water to flush into soil

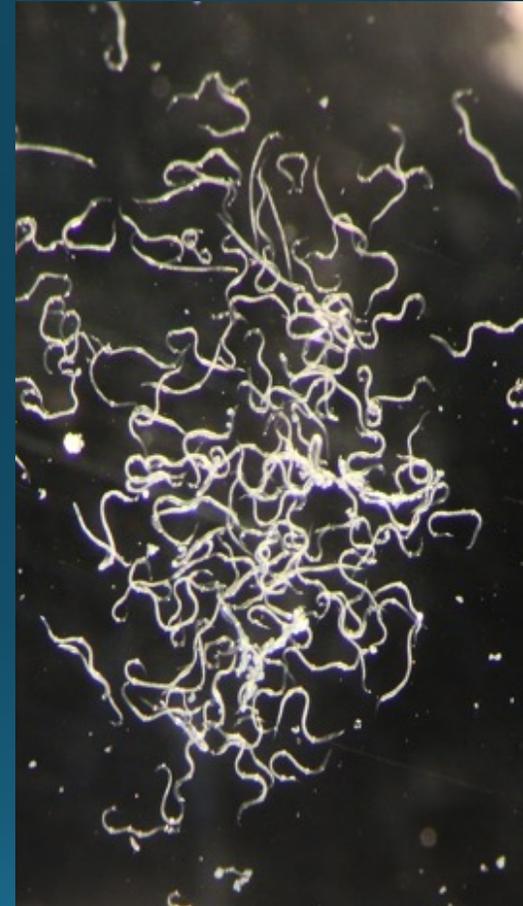


Biocontrol with Nematodes in the Real-World

Great YouTube video at UMass Floriculture:
Using Beneficial Nematodes to Manage Pests in Greenhouses
<https://www.youtube.com/watch?v=Y67yhIIQdLU>

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Ensuring Nematode Efficacy

Risks	Safeguards
Dry growing mix Desiccation Impaired mobility	Make sure media is moist before nematode application.
UV light	Apply early morning or evening
High pressure	Keep spray pressure in equipment below 300 psi
High temperatures	Avoid hot afternoons Avoid hot water for mixing Use heat-tolerant species in summer

Ensuring Nematode Efficacy

Risks	Safeguards
High chlorine in water	Tap water is generally safe
Incompatible pesticides in tank in growing mix	Check side effects lists for EPNs Stay aware of possible effects of whatever you add to the mix

Pesticide compatibility

with insect-killing nematodes

BioBest, Koppert have Side Effects Lists

Compatibility info also available on most biocontrol company websites

BASF Compatibility Chart:

Addresses adjuvants, insecticides, fungicides

Puts active ingredients into following categories:

- Suitable for Tank Mixing
- Apply Separately
- Separately, 7 day Intervals
- Separately, 14 day Intervals

<https://betterplants.basf.us/content/dam/cxm/agriculture/better-plants/united-states/english/products/nemasys-beneficial-nematodes/nemasys-chemical-compatibility-guide.pdf>

Experiment 1:

Nematode Persistence in Growing Media

How long can nematodes remain active and infective after a single application?

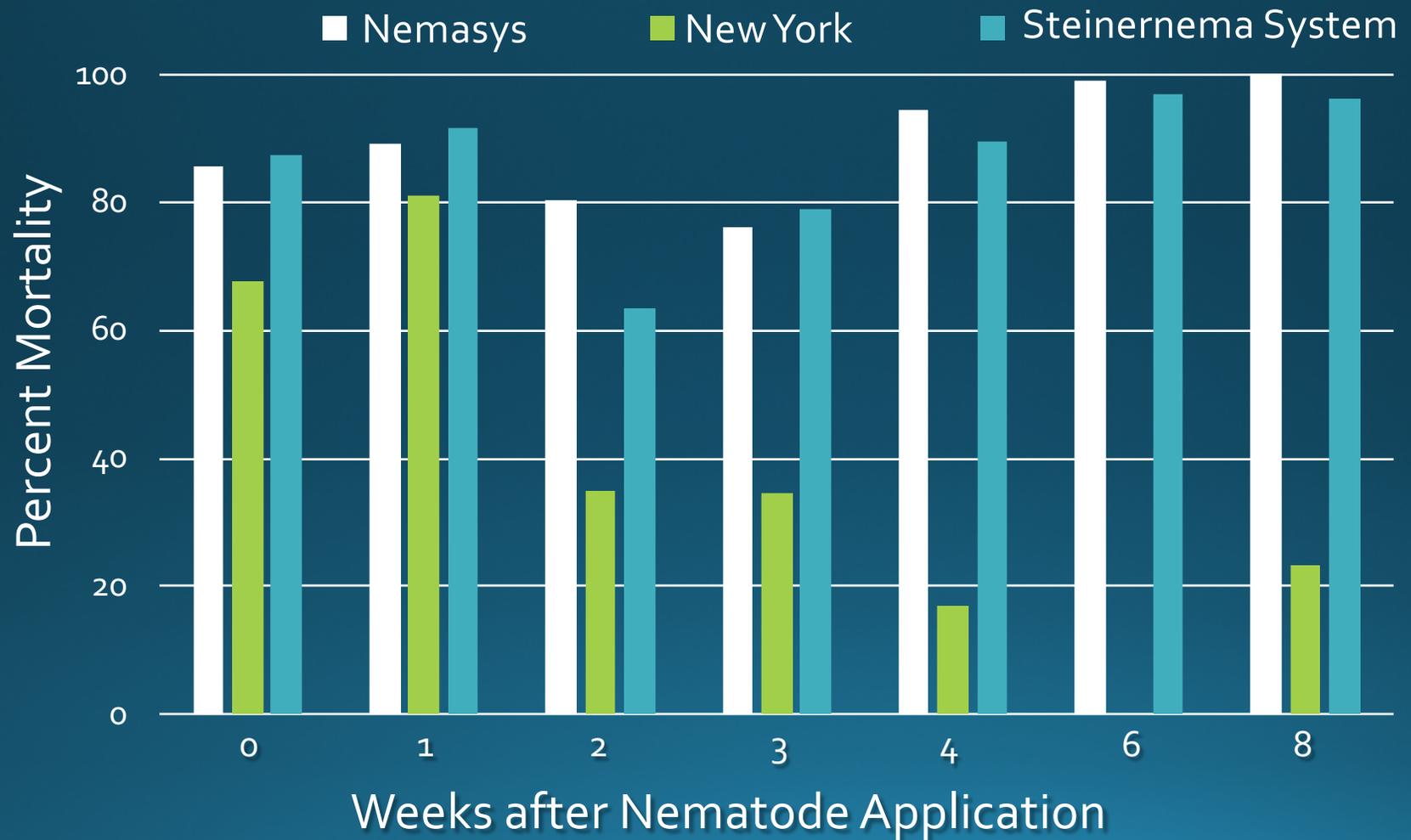
-Commercial recommendation is usually every 2 weeks, but some claim 6 is adequate...

Nematode Persistence in Growing Media

- 3 *S. feltiae* products: Nemasys™, native New York strain, Steinernema-System™
- Single initial drench @ 36,000 IJs per pot
- Then add 30 late-instar FG larvae after 0, 1, 2, 3, 4, 6, or 8 weeks
- 5 pots per treatment per week
- Pots were sub-irrigated in trays
- 2 weeks after introducing FG, count new adults on traps



Percent mortality of fungus gnats after single initial nematode application



Nematode Persistence in Media

Eight weeks control after single drench???

However, the pots were sub-irrigated...

Overhead watering may wash some nematodes out of the pots.



Experiment 2:

Overhead Watering vs. Subirrigation

Mortality is consistently $>80\%$ for 2 weeks after initial application; differs afterwards.

→ Should apply once every 2 weeks for fungus gnats.

Effect of growing substrate

Rockwool



Dwight Sipler via Wikimedia Commons

Peat-based growing mix

Nematodes may wash out of rockwool

Experiment 3: Effects of cool temperatures on nematode control of fungus gnats

Will FG still be a problem at cooler temperatures, and will nematodes be able to infect them?





Experiments carried out in bugdorms within growth chambers

"Warm" chamber = 75F

"Cool" chamber = 55F

Equally infested with FG adults

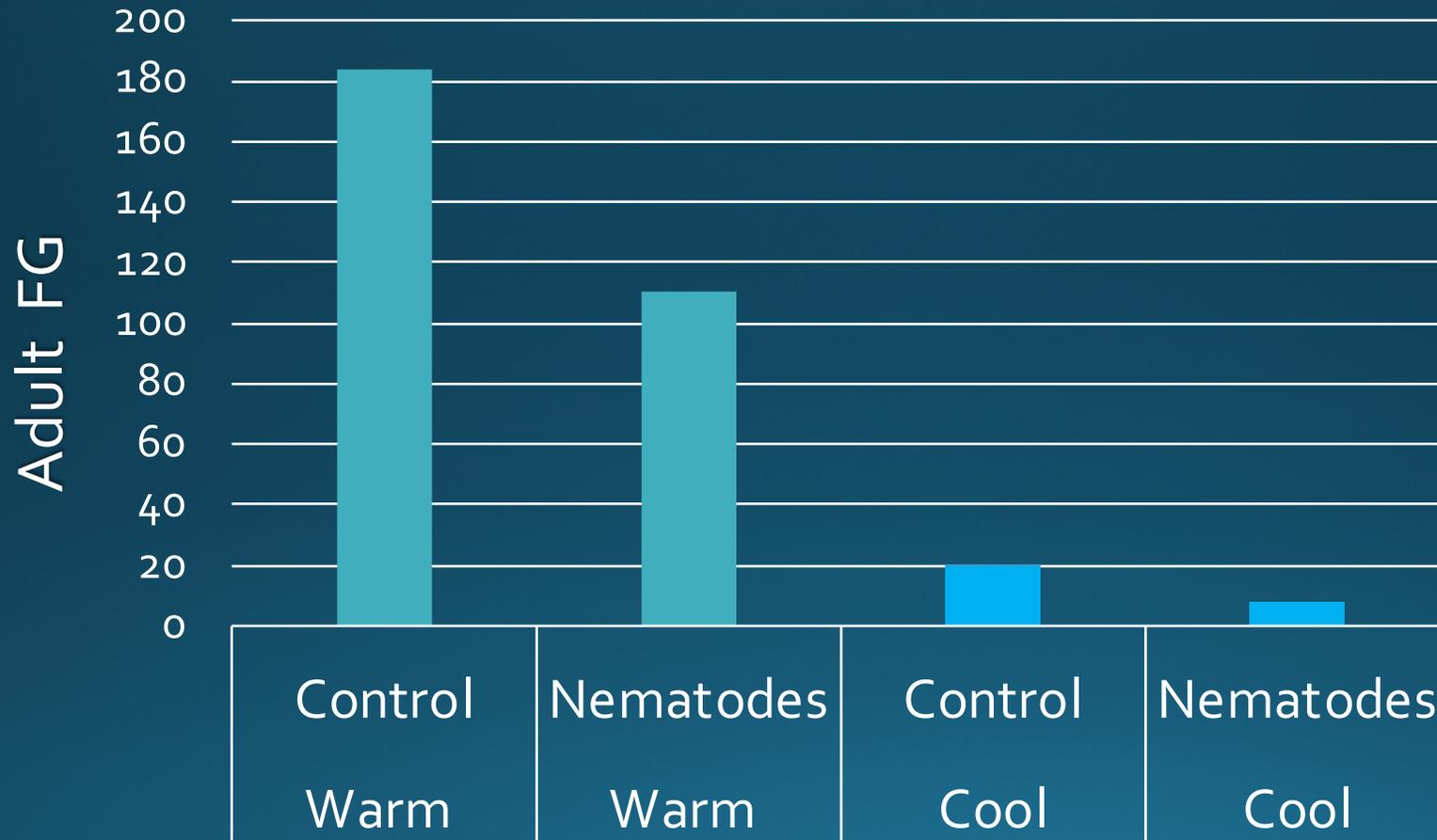
Treatments:

- 2 Nemasys drenches, 2 weeks apart
- Untreated control
- 5 cages of each

Traps added after 15 days



Average adult FG trapped in cages after two nematode drenches, in warm or cool environments



Conclusion from Exp. 3:

With *Nemasys* nematodes against high FG infestation:

Warm temps = 40% control

Cool temps = 60% control

→ *S. feltiae* nematodes work well at low temps!

Ensuring Nematode Efficacy

High temperatures	Avoid hot afternoons Avoid hot water for mixing Use heat-tolerant species in summer
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But how hot is “hot”??

“Experiment 4”
(series of experiments)

M.S. thesis research by Anna Giesmann



“Experiment 4”:

High temperature tolerance for
Heterorhabditis bacteriophora (Hb), Steinernema
carpocapsae (Sc), and Steinernema feltiae (Sf)

- Exposed all 3 species (and 3 strains of each species) to 86, 95, 104, or 113F, and each temperature for 1, 2, 4, 6, 8, or 10 hours.
- Evaluated survival (infectivity tests underway)
- Preliminary results, but fair amount of confidence.

Experiment 4:

Tentative Takehome Messages

Research still underway!

Tolerance to high temps

S. feltiae (NemaShield, Nemasys, Steinernema-System, Entonem, ExhibitLine sf) is most susceptible to high temperatures (lots of mortality ca. 95F)

least

H. bacteriophora (Larvanem, Terranem, B-Green, Exhibitline hb, Nemasys G) had 100% mortality after 4 h at 104F

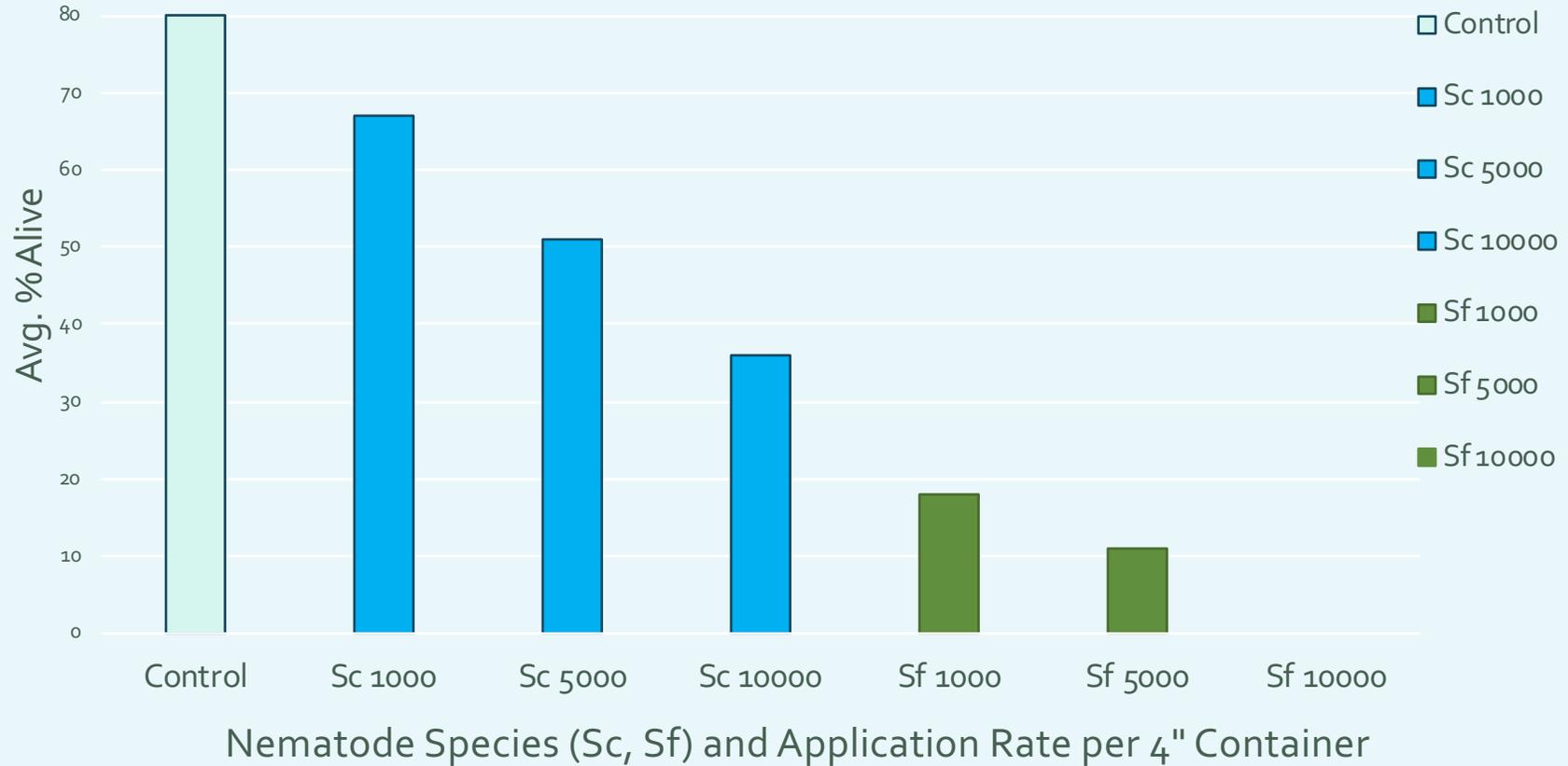


S. carpocapsae (Millenium, Exhibitline sc, Sportnem T, Carpocapsae-System) is least susceptible to high temperatures (only species that survived at all at 113F)

most

→ More research yet to do, but maybe use heat-tolerant species whenever water or substrate temps exceed 95F?

S. carpocapsae vs. *S. feltiae* for Fungus Gnat Control, Room Temperature



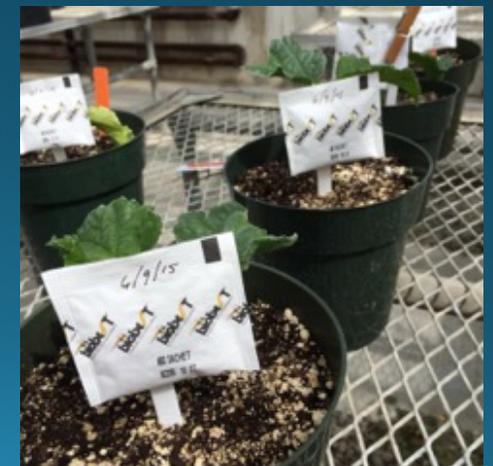
Results may look very different at high temperatures

Integrating nematodes with other beneficial arthropods



Predaceous Mites + Nematodes for Thrips

- Nematodes kill pupal stages in soil
- *A. cucumeris* or *A. swirskii* mites kill first-instar thrips on foliage
 - Applied in broadcast mixtures or sachets
- Compatible biocontrol!



Other Compatible Biocontrol Combinations

For foliar control of thrips, can also use:

- Predatory bugs such as *Orius*

Or

- Entomopathogenic fungi



BotaniGard may not be compatible with Orius!

Biocontrol combinations for fungus gnats

Nematodes plus:

✓ *Strateolaelaps*/*Hypoaspis* mites

✓ Gnatrol

✓ Rove beetles
(*S. feltiae* is OK)

? Hunter Flies



Resources

- Article from U Mass Greenhouse Crops and Floriculture Program. Website also includes demonstration video!

<https://ag.umass.edu/greenhouse-floriculture/fact-sheets/biological-control-using-beneficial-nematodes>

- BASF guide for use of Nemasys

<https://betterplants.basf.us/content/dam/cxm/agriculture/better-plants/united-states/english/products/nemasys-beneficial-nematodes/nemasys-technical-information-bulletin.pdf>

- BASF, Biobest, Koppert guides for compatibility

<https://betterplants.basf.us/content/dam/cxm/agriculture/better-plants/united-states/english/products/nemasys-beneficial-nematodes/nemasys-chemical-compatibility-guide.pdf>

- Email us (jps3@cornell.edu or arg296@cornell.edu)



Thanks for Your Attention!



Questions?

