Jumping Worm Biology

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Why this talk to Vegetable and Berry Growers?

- Currently, this mostly affects ornamental horticulture and forestry
- But this is the second talk in a year that I have given to vegetable growers (NJ Vegetable Growers Association Convention)
- But, some reports out of Massachusetts have them in agricultural fields.
- Some fruit and berry operations are not all that different from horticultural places like tree nurseries

Are you at risk?

- High risk
  - Mulched, semi-permanent, untilled beds
  - Irrigation of such beds
  - Bring in commercial compost (more on that later)
  - Bring in leaf mulch
  - Bring in woody mulch
- Lower risk
  - Tillage?
- pH does not make a difference

But, what are these curious creatures?

How many are there? How did they get here?

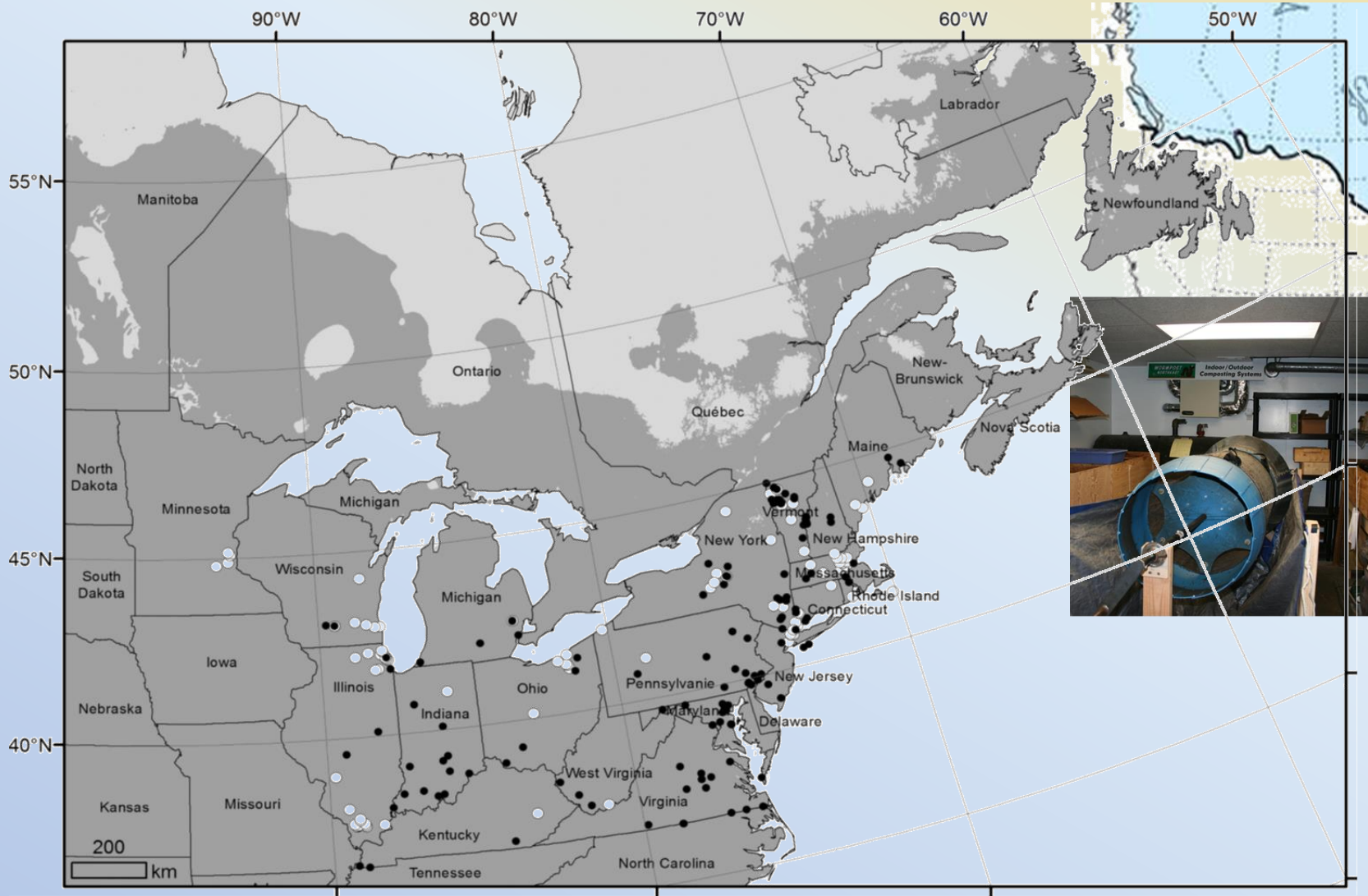
How many species?

- 3 in Vermont
- 16 in North America
- Over 1000 Megascolecidae in the world, not all are jumping worms

East Coast: Anecdotally through the gift of cherry blossoms

West Coast as early as 1860ties: Commodore Perry, opening of trade with Japan 1850ties?

Where in the Northeast? Georeferenced Sites



Moore et al., 2017

Great Lakes Worm Watch

Dark grey: area with greater than 90 days frost free period, the length it takes the worms to become reproductively mature. This is where they can live.

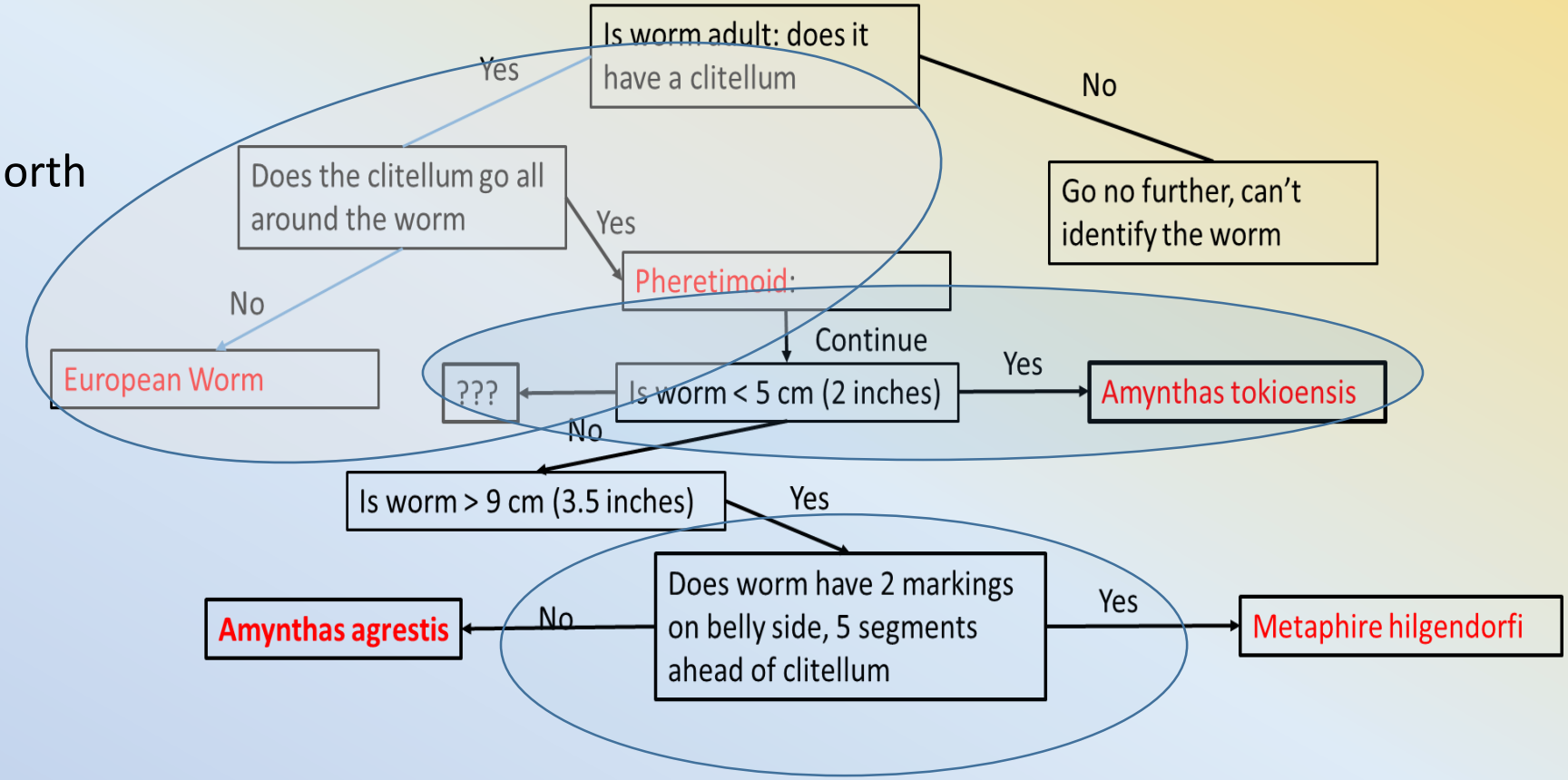
Identification of jumping worms

Proper way

Find a key here:

Chang, C.H., Snyder, B.A. and Szlavecz, K., 2016. Asian pheretimoid earthworms in North America north of Mexico: an illustrated key to the genera Amynthas. *Zootaxa*, *4179*(3), pp.495-529.

Simplified way



Genetic Diversity

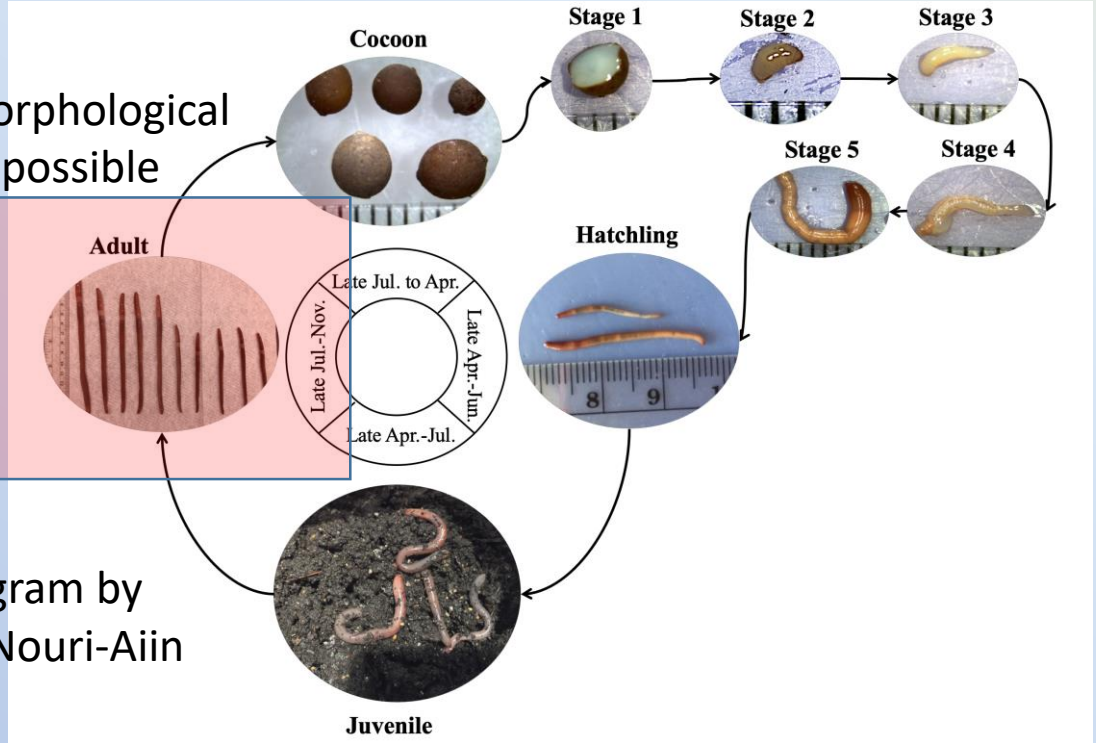
Site	Sample N	Genotype N	Private genotypes	Ploidy		Nei's genetic diversity corrected	Evenness	Sh inc cor
				Diploid	Triploid			
Panel A								
A. tokioensis								
CRN	37	6	2	0	37	0.52	0.34	0.4
AU	33	4	2	0	33	0.57	0.56	0.4
CW	5	2	0	0	5	0.60	0.96	0.2
MTF	29	3	1	0	29	0.58	0.76	0.4
HG	27	1	0	0	27	0.00	1.00	0.0
HF	85	7	5	0	85	0.54	0.32	0.4
Panel B								
A. agrestis								
CRN	26	23	23	0	26	0.98	0.77	1.3
AU	14	11	9	7	7	0.96	0.81	1.0
CW	45	1	0	0	45	0.00	1.00	0.0
MTF	25	2	1	0	25	0.45	0.89	0.2
HG	22	6	5	0	22	0.71	0.45	0.6
HF	64	15	12	51	13	0.73	0.23	0.7

Ploidy levels: A. tokioensis all triploid – no recombination possible; A agrestis about 25% diploids – recombination possible

Diversity: A. tokioensis – 10 genotypes out of 216, 1 site with one genotype HG, most likely clonal; A. agrestis 50 genotypes our of 198 (1 site with one genotype, CW); (1 site with 88% different genotypes CRN); maybe sexual reproduction.

Their Life Cycle

Life History Events

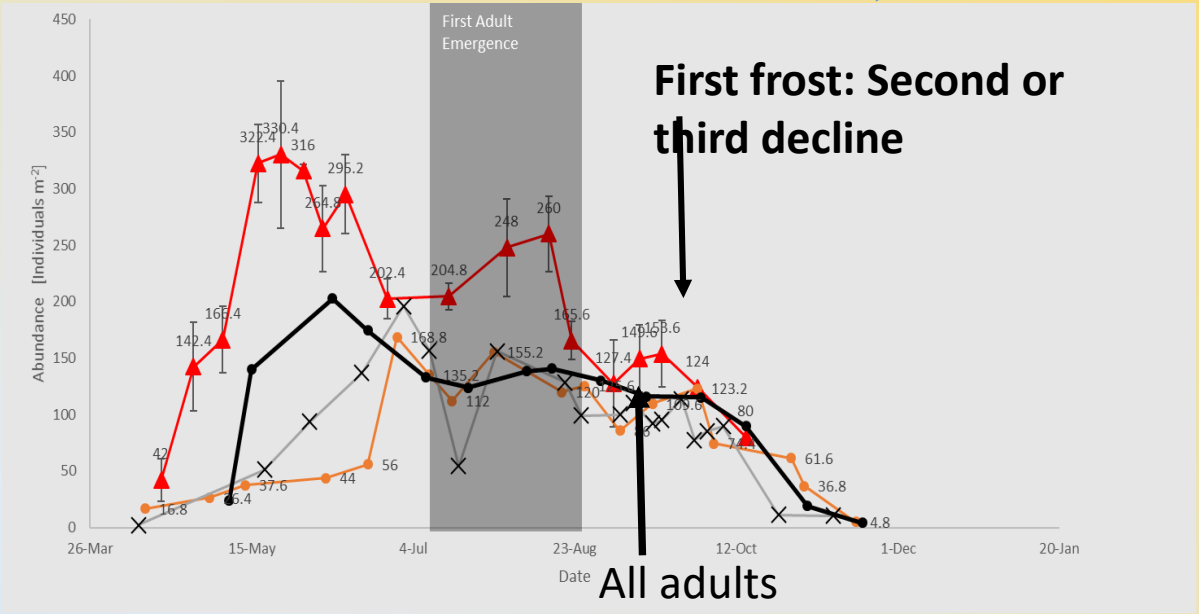


Morphological ID possible

Diagram by M. Nouri-Aiin

Abundance through the year

Production of cocoons



First frost: Second or third decline

All adults

Cocoons

Drought and Winter: cocoons dehydrate

Warmer and moister soils: rehydrate

Photo credit: Maryam Nouri-Aiin

Effects on other organisms

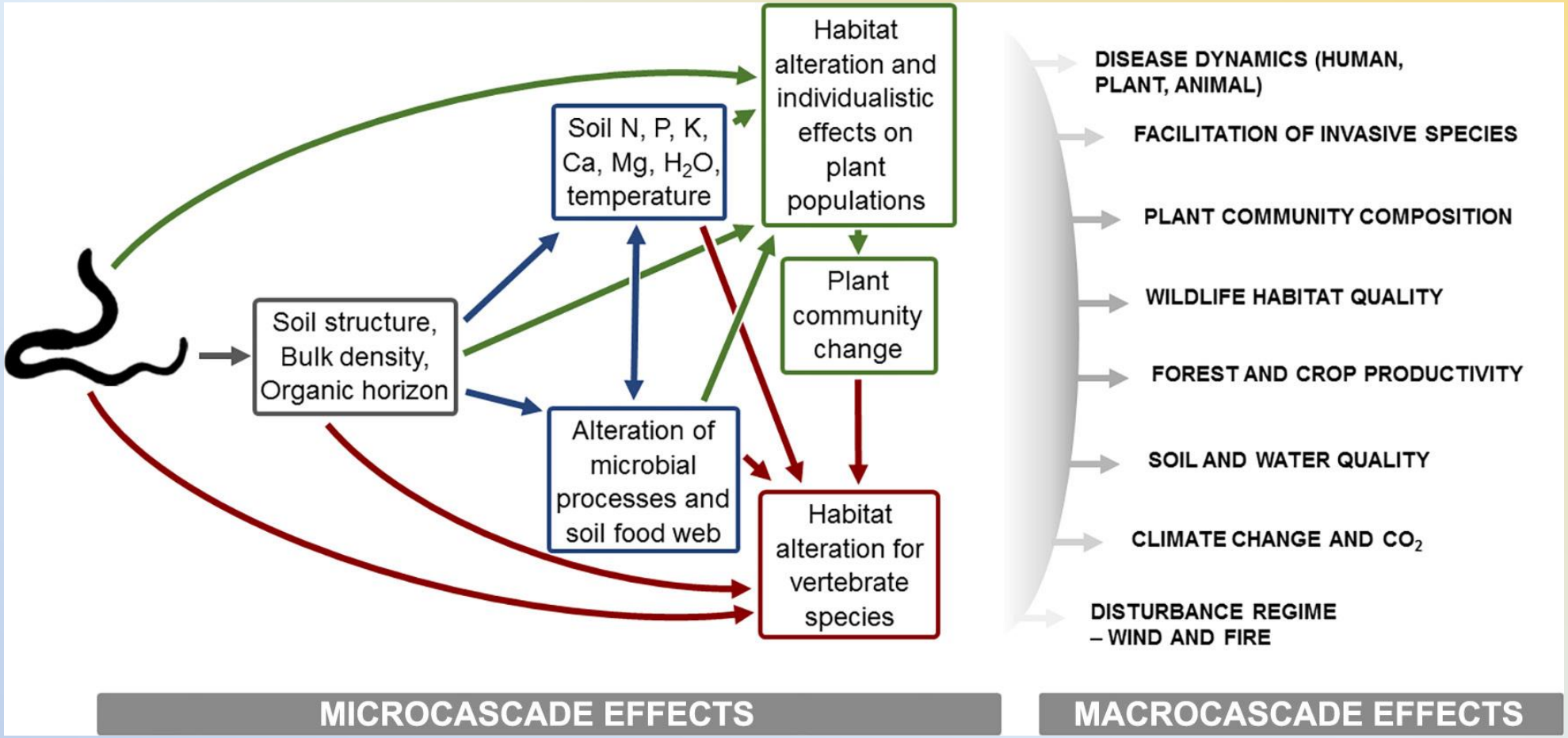
Human evolution

From Homo sapiens sapiens

to

Homo sapiens tristessicus

Effect on other organisms: ecological cascades



Frelich, L.E., Blossey, B., Cameron, E.K., Dávalos, A., Eisenhauer, N., Fahey, T., Ferlian, O., Groffman, P.M., Larson, E., Loss, S.R. and Maerz, J.C., 2019. Side-swiped: ecological cascades emanating from earthworm invasions. *Frontiers in Ecology and the Environment*, *17*(9), pp.502-510.

Net Effect on Vegetation: maple syrup, foliage etc.?

No earthworms, Camels Hump, VT

Forest invaded by *Amynthas agrestis* South Burlington

http://2.bp.blogspot.com/_27y_ETmoUBU/SYSqdKxvPHI/AAAAAAAAAjc/n48-1GUZZfQ/s400/deer-vermont.jpg

Effect on potential predators

Bioaccumulation of Tracemetals

- Jumping worms can accumulate high amounts of toxic trace metals

- For some metals held in the soil bioaccumulation makes up as much as 80%.

Poor Hawk

Photographer: LuAnn Uszakiewicz
Location: Connecticut

How about *my* plants?

Maine Department of Agriculture, Conservation and Forestry/ Cornell Cooperative extension

- In nurseries and greenhouses, Amynthas worms reduce the functionality of soils and planting media and cause severe drought symptoms. After irrigating or rains, you may find these worms under pots. These worms may be inadvertently moved to new areas with nursery stock, or in soil, mulch, or compost.

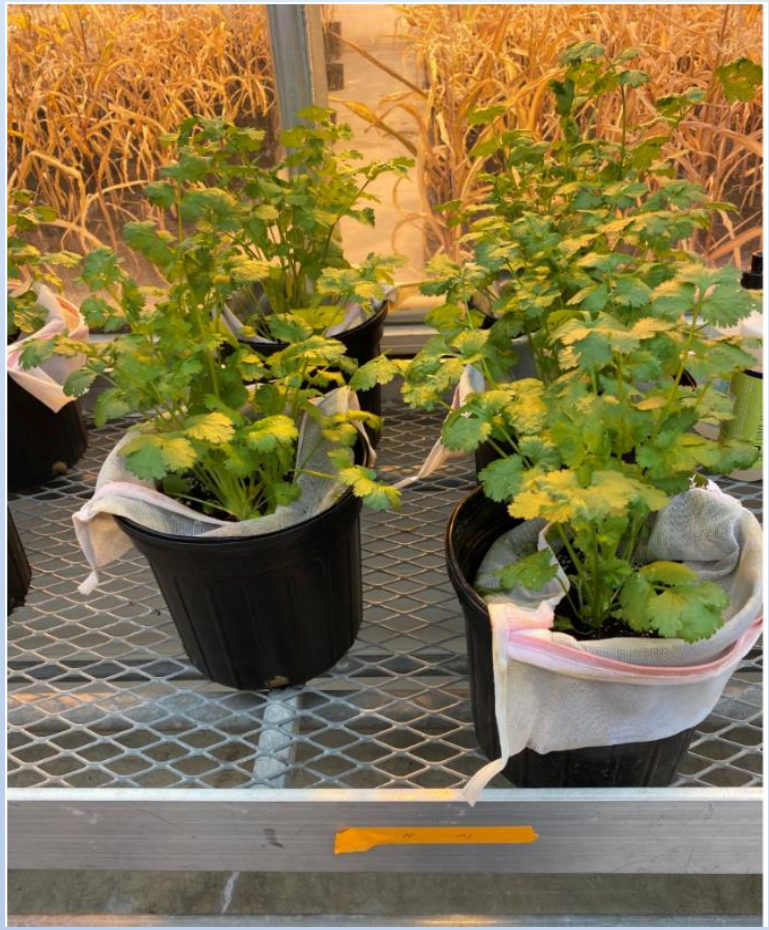
https://www.maine.gov/dacf/php/horticulture/crazyworms.shtml

- Jumping worms can severely damage roots of plants in nurseries, gardens, forests and turf. They, along with other invasive worms, can also help spread invasive plant species by disturbing the soil.

http://ccecolumbiagreene.org/resources/jumping-worm-fact-sheet

Our cilantro experiment: We see multiple symptoms when snake worms are presents

Cilantro plugs into potting medium (ProGro) with no Amynthas



Cilantro plugs into potting medium two weeks after addition of Amynthas. So there are plenty of castings: stunted growth

Photo-credits: Maryam Nouri-Aiin

Cilantro Experiment: Symptoms

Plugs into potting medium two weeks after addition of Amynthas

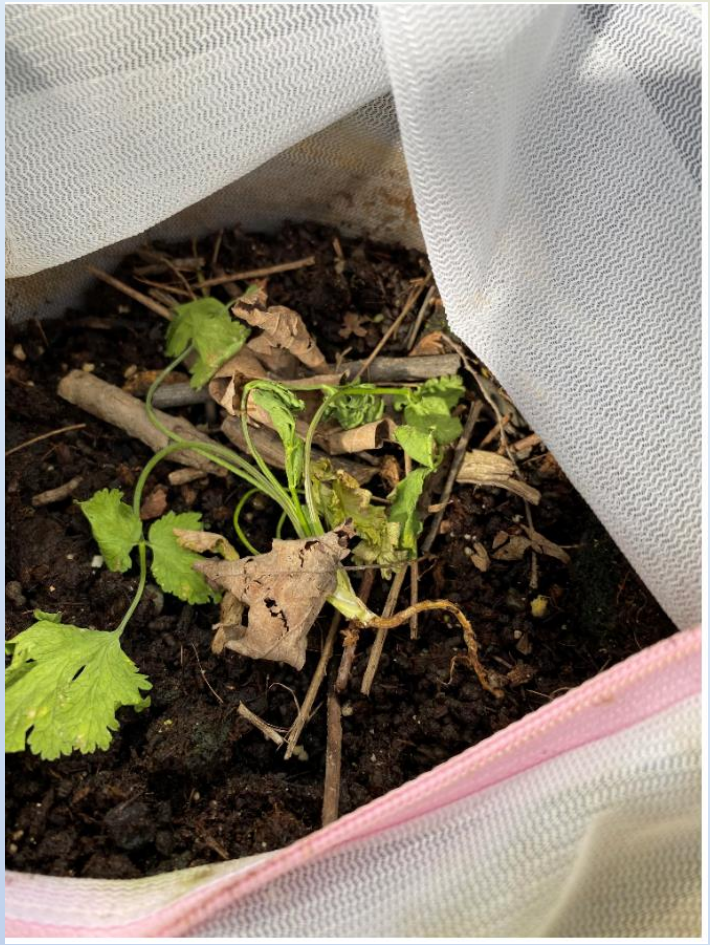
Close up:

Wilt,

Yellowing,

Necrosis,

Spindly stem



Drought stress causes **cilantro leaves to curl inward and, if not fixed quickly, can lead to yellowing, wilting and foliage loss**.

Plugs and worms added at same time

Variable damage, close up next slide

Photo-credits: Maryam Nouri-Aiin

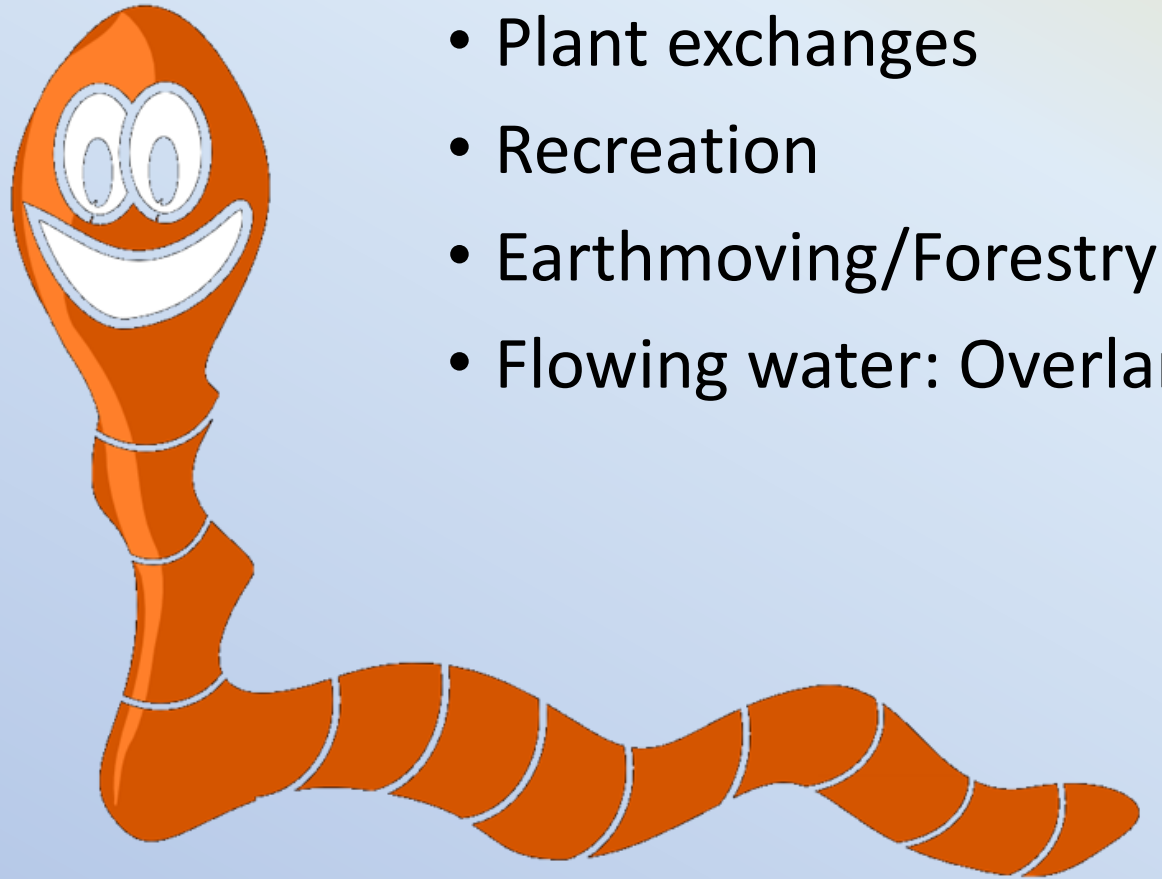
Blackening of leaf margins, leaves distorted

Drought, bacterial leaf spot?

Photo-credits: Maryam Nouri-Aiin

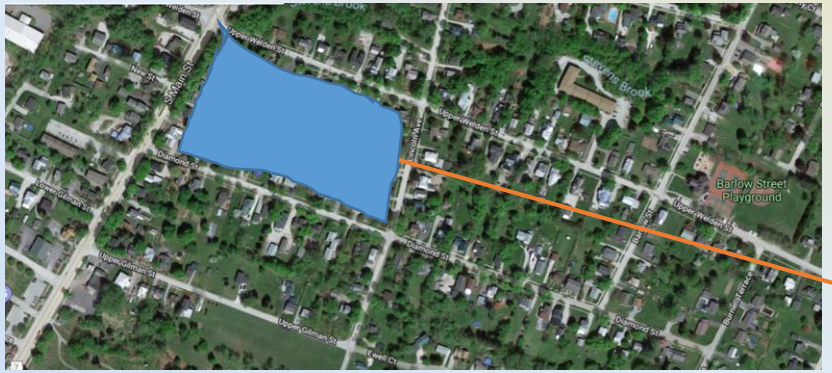
How do they move around?

- Horticulture
- Compost
- Plant exchanges
- Recreation
- Earthmoving/Forestry
- Flowing water: Overland flow/ streams etc..



Spotlight on compost

Somewhere near my neighborhood

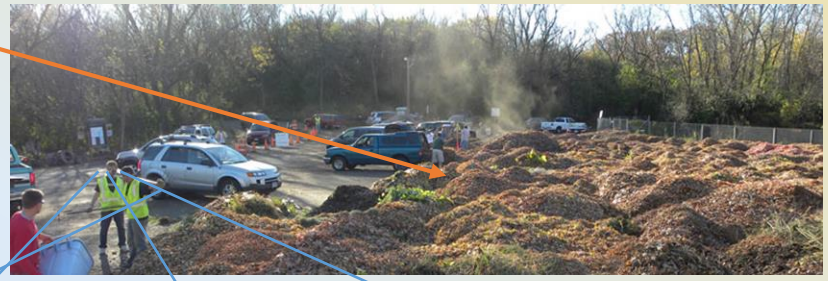


Composts

Free Leaf Mulch

Wood Mulches

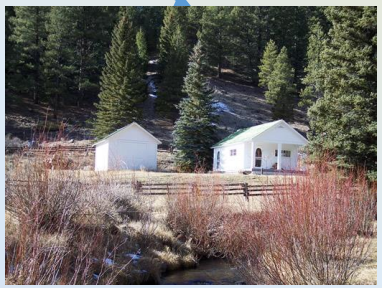
Transfer stations



Many Gardens

Raised beds

Forest edge…



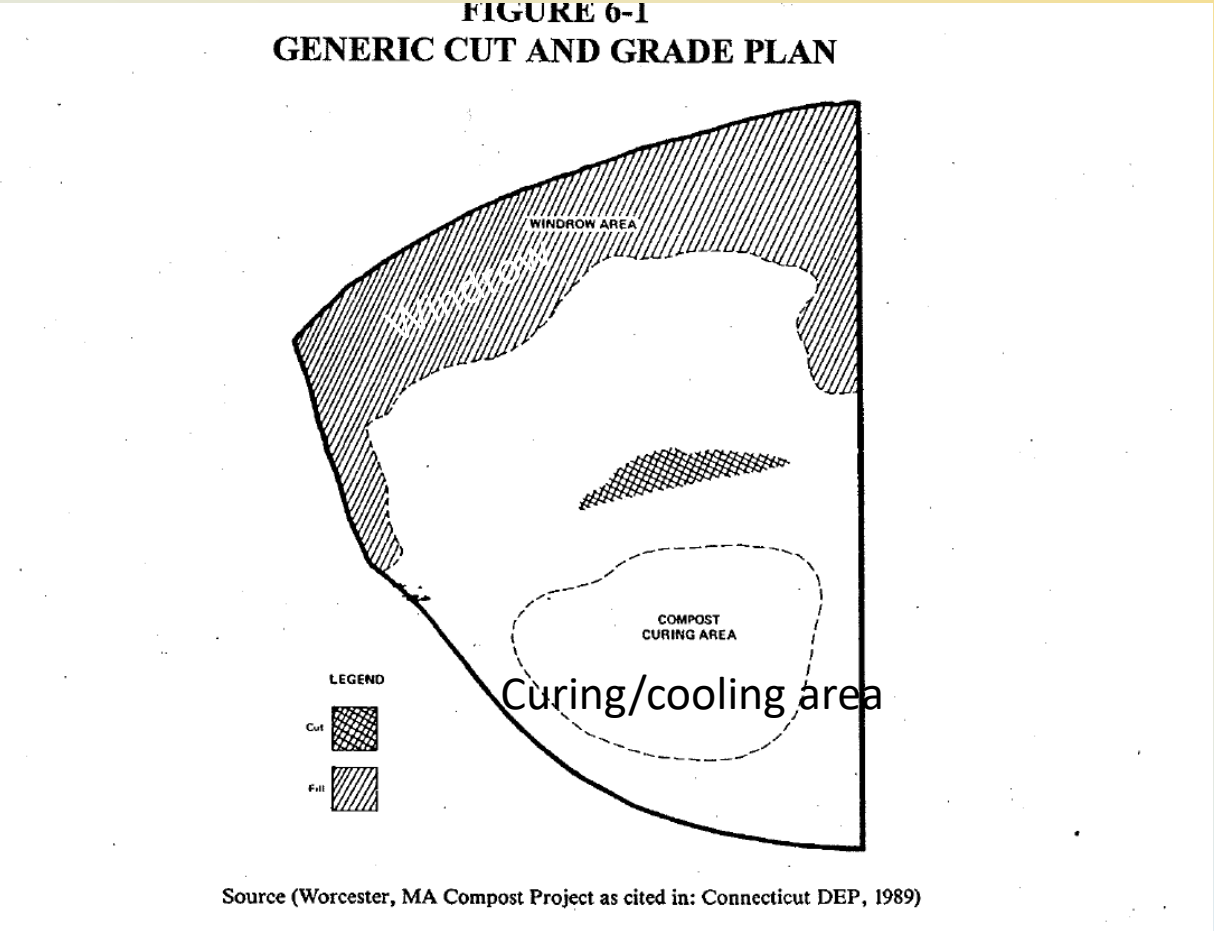
https://www.fs.usda.gov/detailfull/r4/fire-aviation/?cid=fseprd526615&width=full

Can they survive the hot temperatures of composting

Tolerances

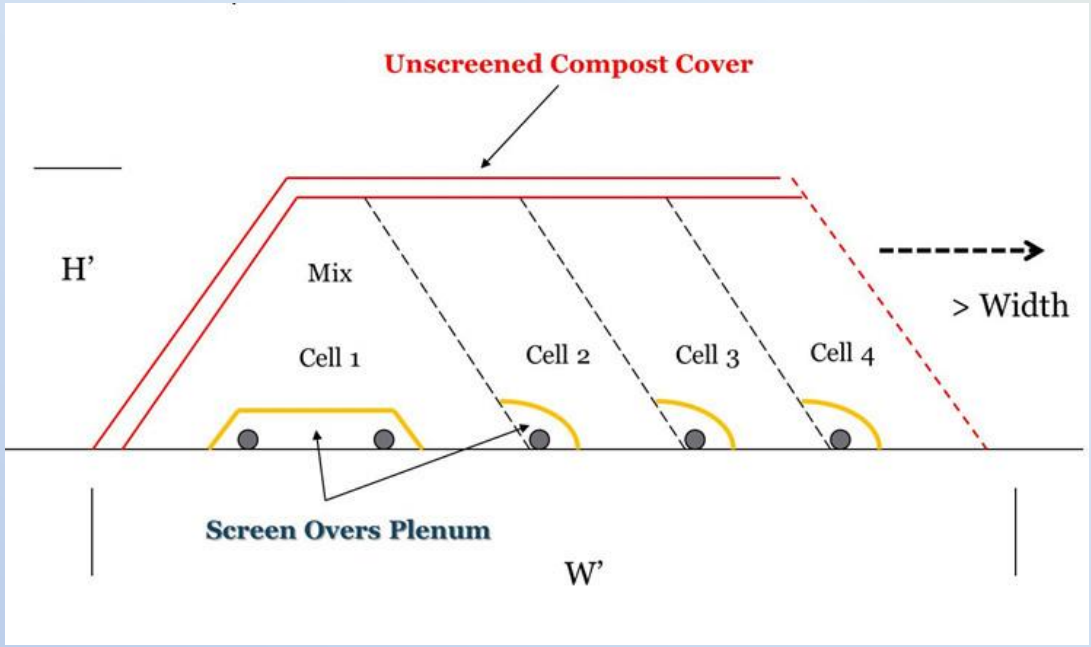
- Worms and cocoons die at > 38 C (105 F)

- Johnston, M.R. and Herrick, B.M., 2019. Cocoon heat tolerance of pheretimoid earthworms Amynthas tokioensis and Amynthas agrestis. *The American Midland Naturalist*, *181*(2), pp.299-309.



Is the compost from windrow or aerated static pile?

Aerated pile with compost blanket

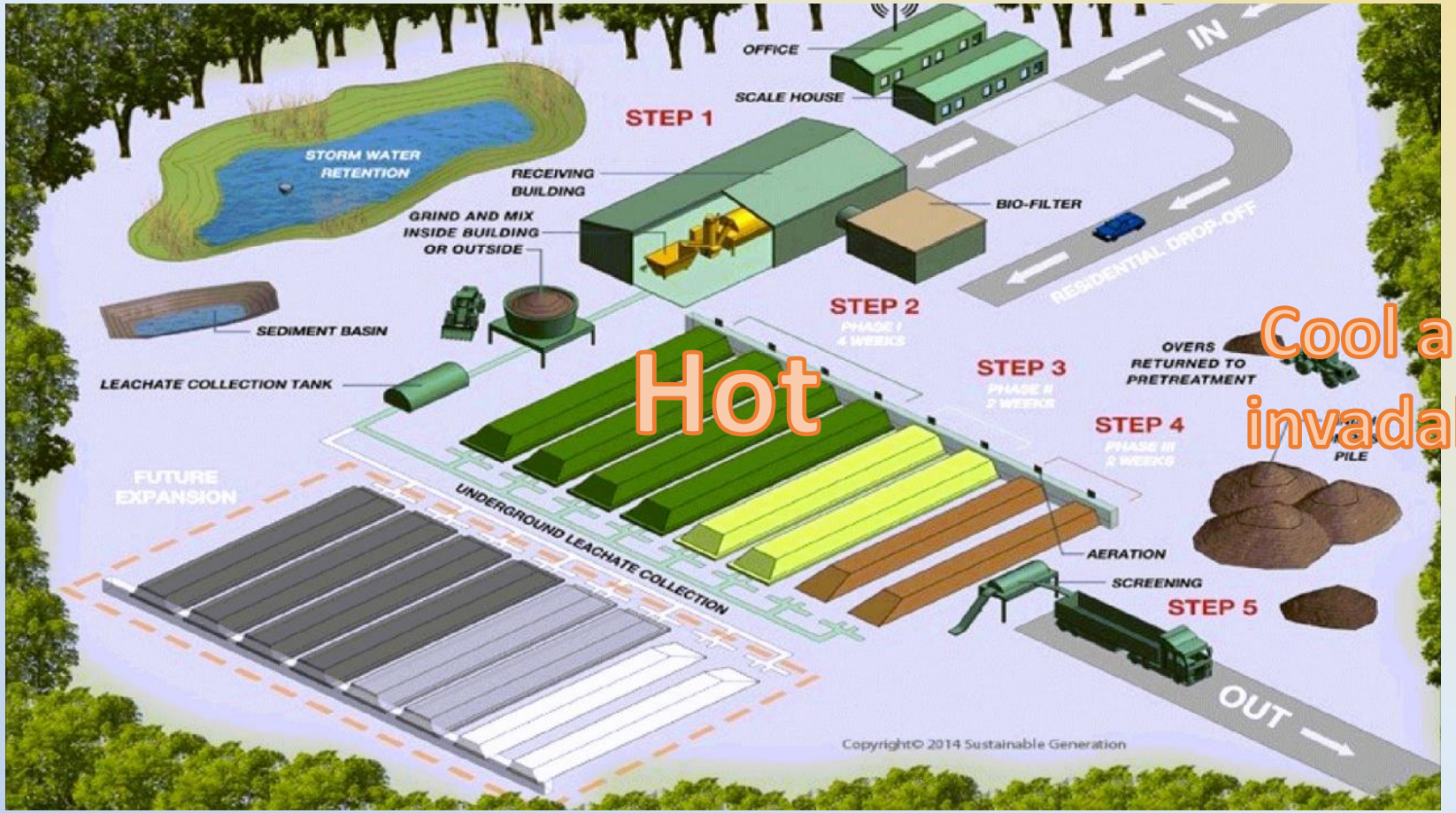


Temperature distribution

- Aerated pile will more likely reach high temperatures throughout, especially with blanket (which may contain cocoons, btw)
- Maybe add a filter blanket on top of the compost blanket so the blanket also reaches sterilizing temperatures

https://www.o2compost.com/asp-composting-webinar-pt2.aspx

The problem is …



https://www.bigislandvideonews.com/2018/11/23/video-east-hawaii-organics-facility-update/

Can they be controlled?
What do we tell panicked callers?

If you haven’t gotten them yet avoid getting them:

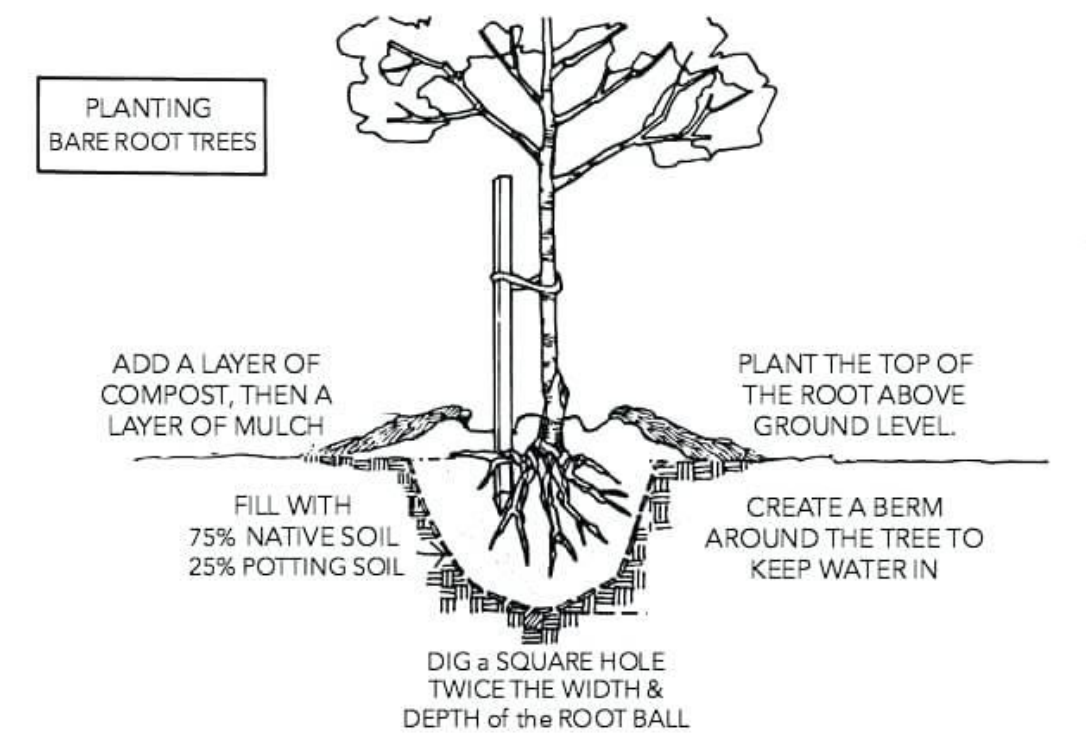
propagate from seed and cuttings

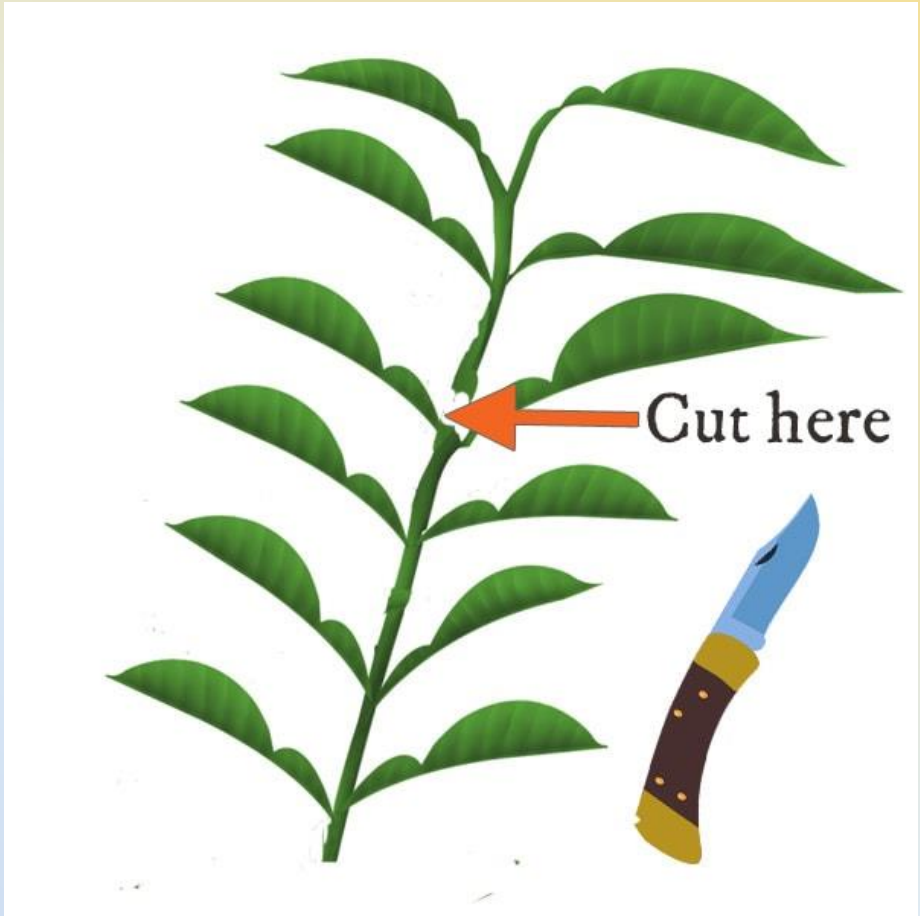
exchange bare root plants

solarize soils and soil materials you buy in

put prairie vegetation buffers and covers in?

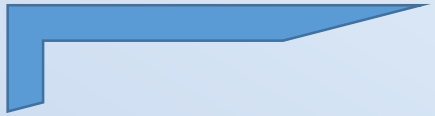
Use bare root shrubs, grow from seed, propagate plants yourself





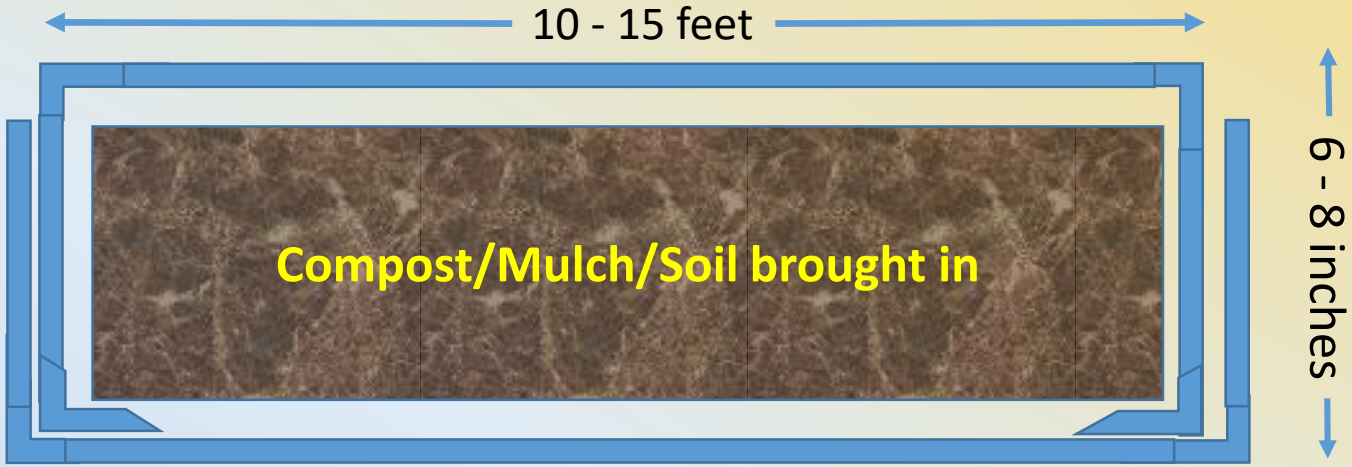
Solarize everything: Prevent Invasion.

Worms and cocoons don't survive temperatures above 105 F



Cheap translucent painter's plastic drop cloth

The solarization package



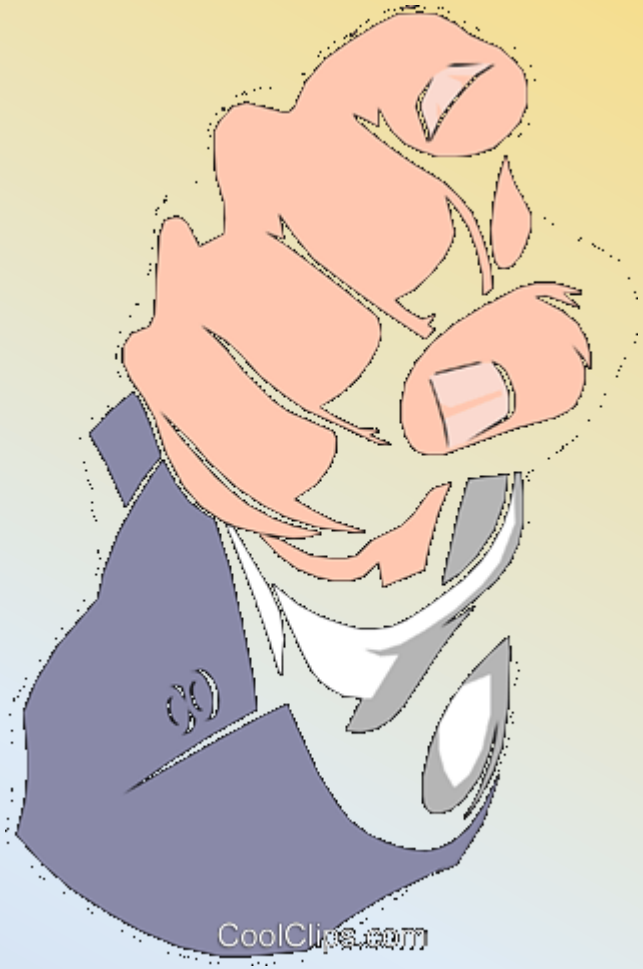
Nice sunny day in May will increase the temperatures in the solarization package **to > 150 F,** killing both cocoons and worms.

Downside, may also kill some of the microorganisms, but they should recover pretty quickly.

You buy compost in plastic bags. Put the bags in the sun ...

If you got them already

Don’t let them worm shame you!

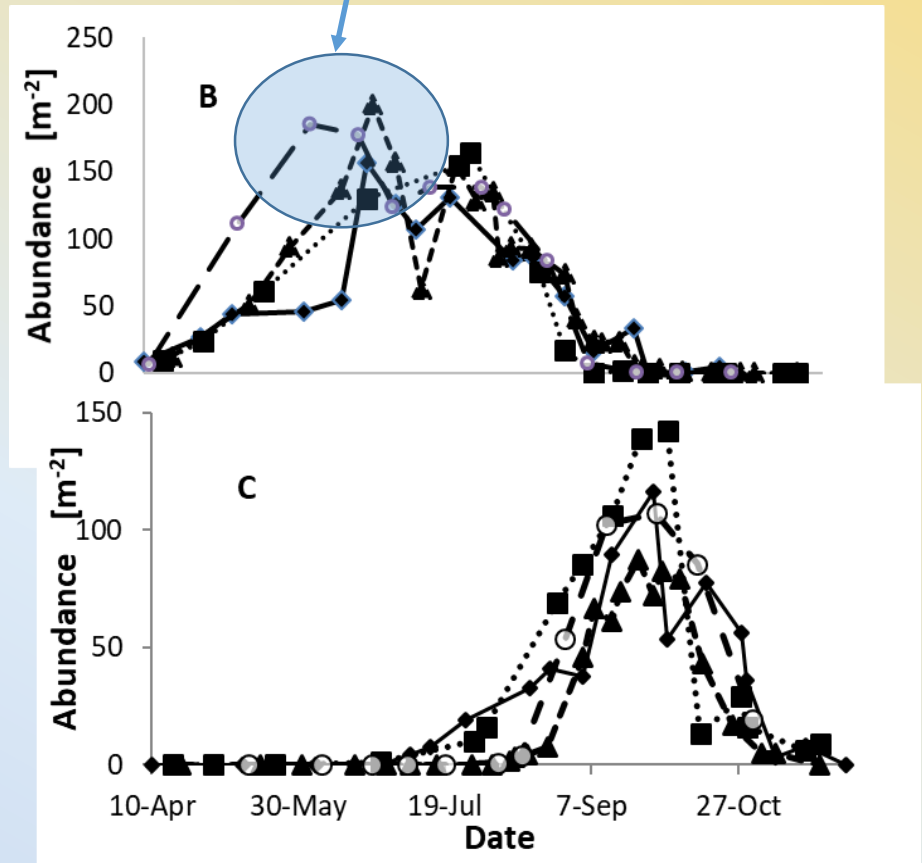


https://www.seekpng.com/ima/u2e6w7y3y3r5o0y3/

1. Cultural Practices

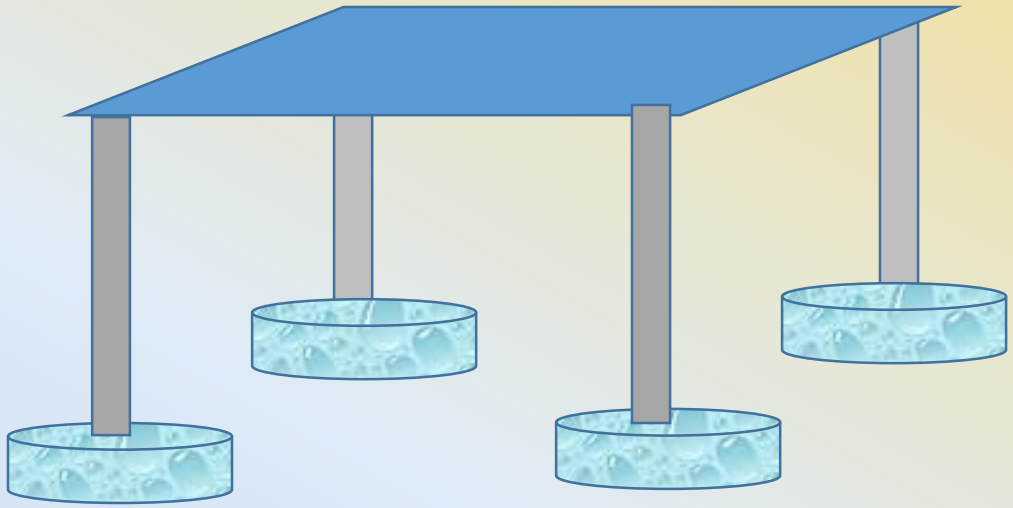
- Most likely to discourage these worms:
  - Tillage (Rototilling) probably kills the worms as they live mostly in the top 2 inches)
- However, it depends on when you till
  - Tillage up to mid May (in Vermont) may not matter because mostly cocoons present
  - **Till around peak worms (still juvenile, mid June, but depends on your location, weather)**
  - Tillage after mid-October (in Vermont) may not matter cause most cocoons have been produced
  - Seed bed preparation? In spring should not matter to their survival ... Mostly cocoons
- This will likely reduce numbers, but not completely eliminate them.

Peak worm season: Mid may to mid June, most years



Put potted plants on benches

- Prevent the worms from climbing up the bench legs
- Put the legs into a small, tough container with soap solution (Anise Dobson suggestion)
- They won't like the soap.



Soapy water containers

2. Biocontrol – entomopathogenic fungi *Beauvaria bassiana, Metarhizium brunneum*

- Commercial product (BotaniGard) that are already certified as biopesticides in horticulture .
  - Still needs to be certified for use on earthworms

- First experiments: Greenhouse pot experiment

Beauvaria bassiana (Botanigard ™)

Juvenile worms
No plants

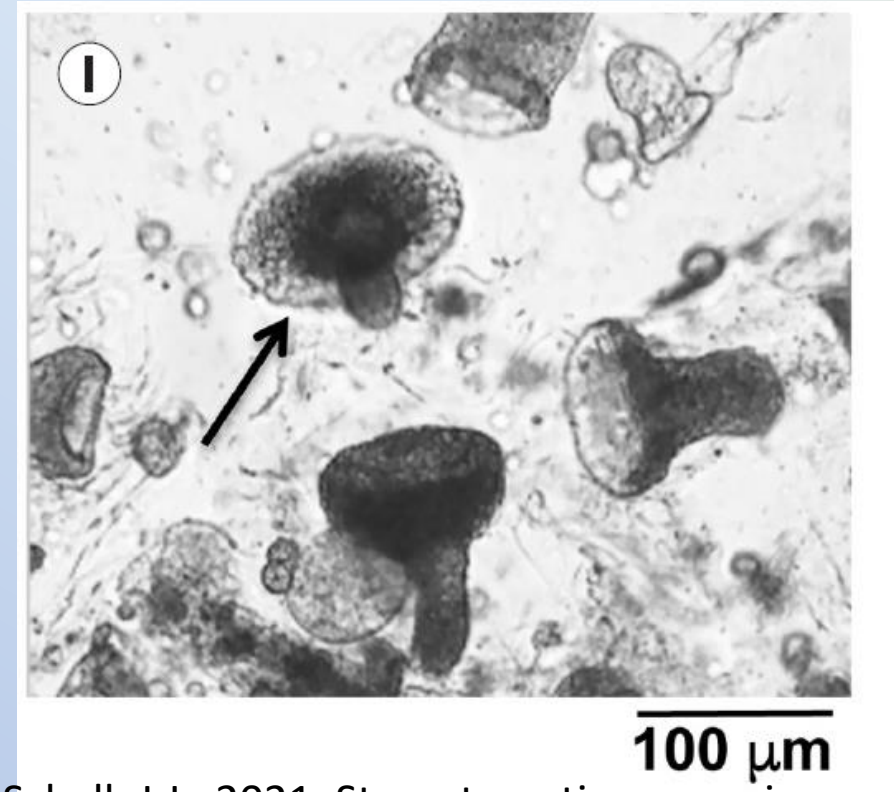
Figure 1 **Millet grains fully mycotized by *B. bassiana* conidia.** Photo credit: Maryam Nouri-Aiin.
Full-size DOI: 10.7717/peerj.11101/fig-1

Nouri-Aiin, M & J.H. Gorres. 2021

https://peerj.com/articles/11101/

Unlikely solutions: parasites

Gregarine Parasites (e.g. funnel mouth)



We call some of them "pearl parasites"

Schall, J.J., 2021. Stomatocystis goerresi, a new species of gregarine parasite (Apicomplexa, Monocystidae) from the invasive Japanese earthworm Amynthas tokioensis (Megascolecidae), with a description of the parasite's life cycle. *Folia Parasitologica*, *68*, pp.1-7.

More interventions

Naturally occurring microbial pathogens

- Maryam Nouri-Aiin has isolated some agents from dead cocoons and worms.
- Need to replicate those bio-assays
  - Were effective on juveniles
  - Not so much on adults
- Need to better characterize the pathogens

[Arun T.P., Bugwood.org, www.invasive.org/browse/detail.cfm?&imgnum=5379895]

Unpublished data: Isolates from dead worms

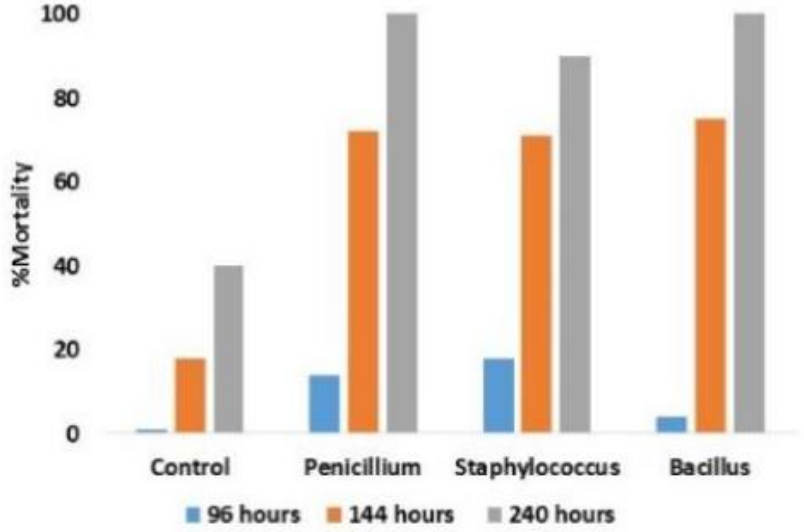


Figure 4: Vermicidal efficacy of different microbial isolates. Mortality of pheretimoids is similar in populations treated with three groups of microorganisms

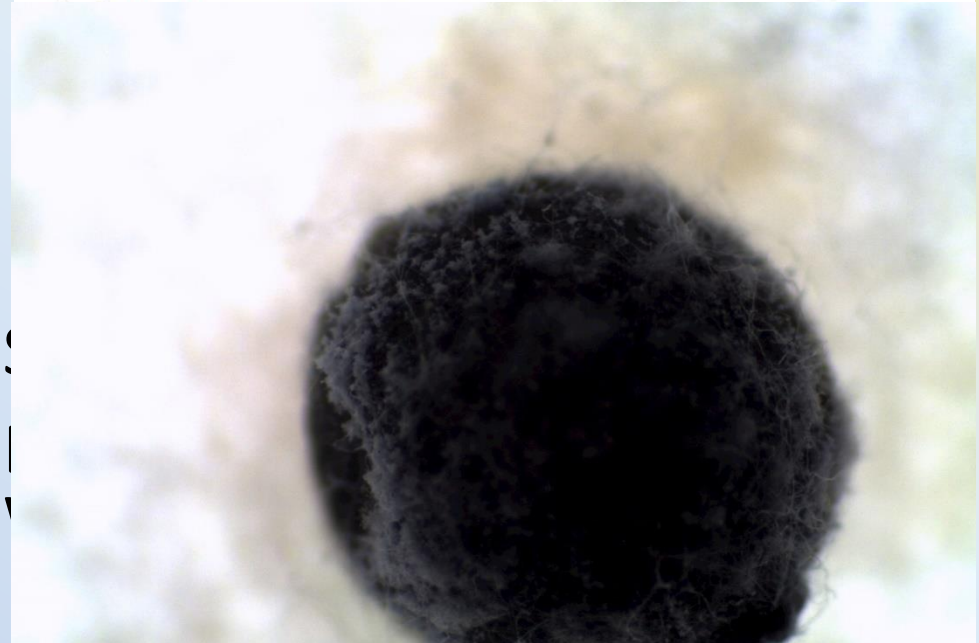
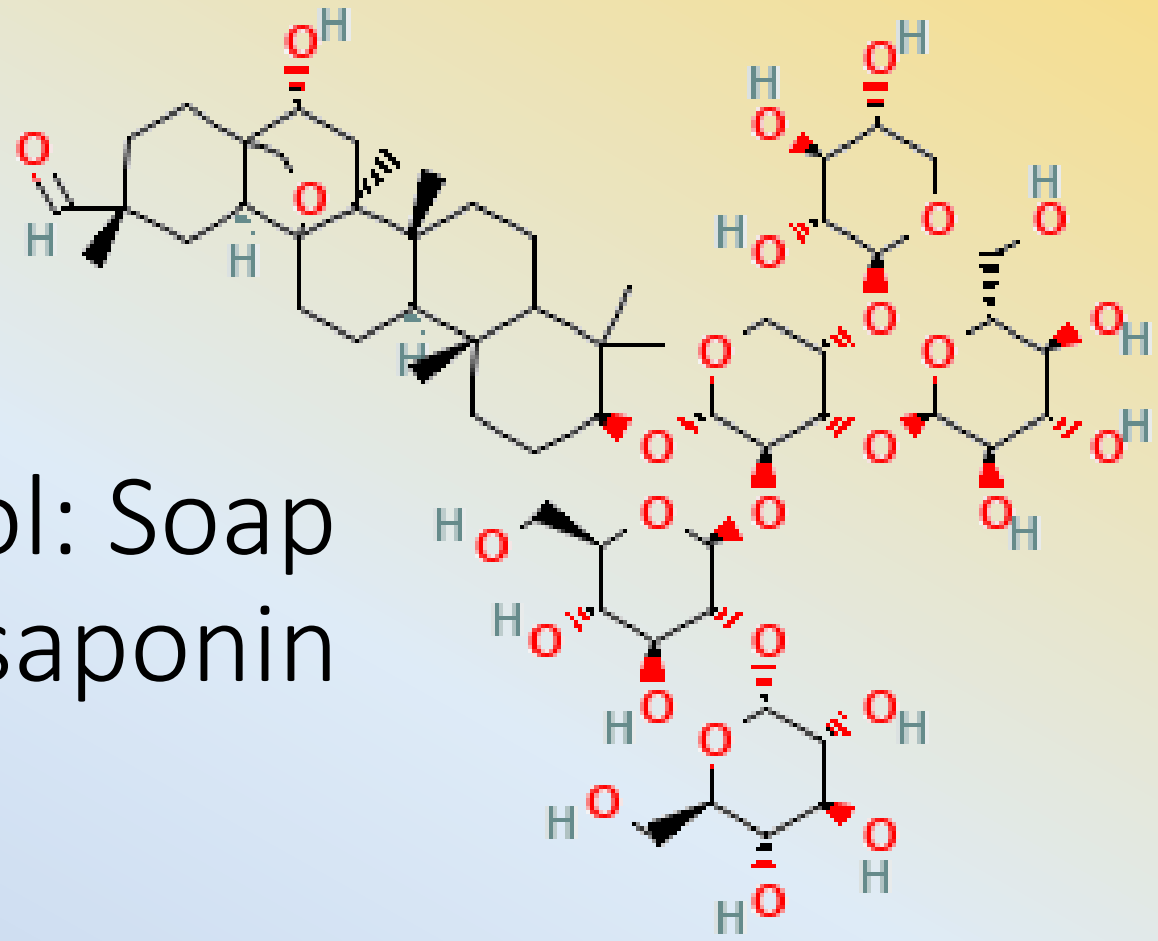


Image of the two organisms from previous slide

Planarian

Ants

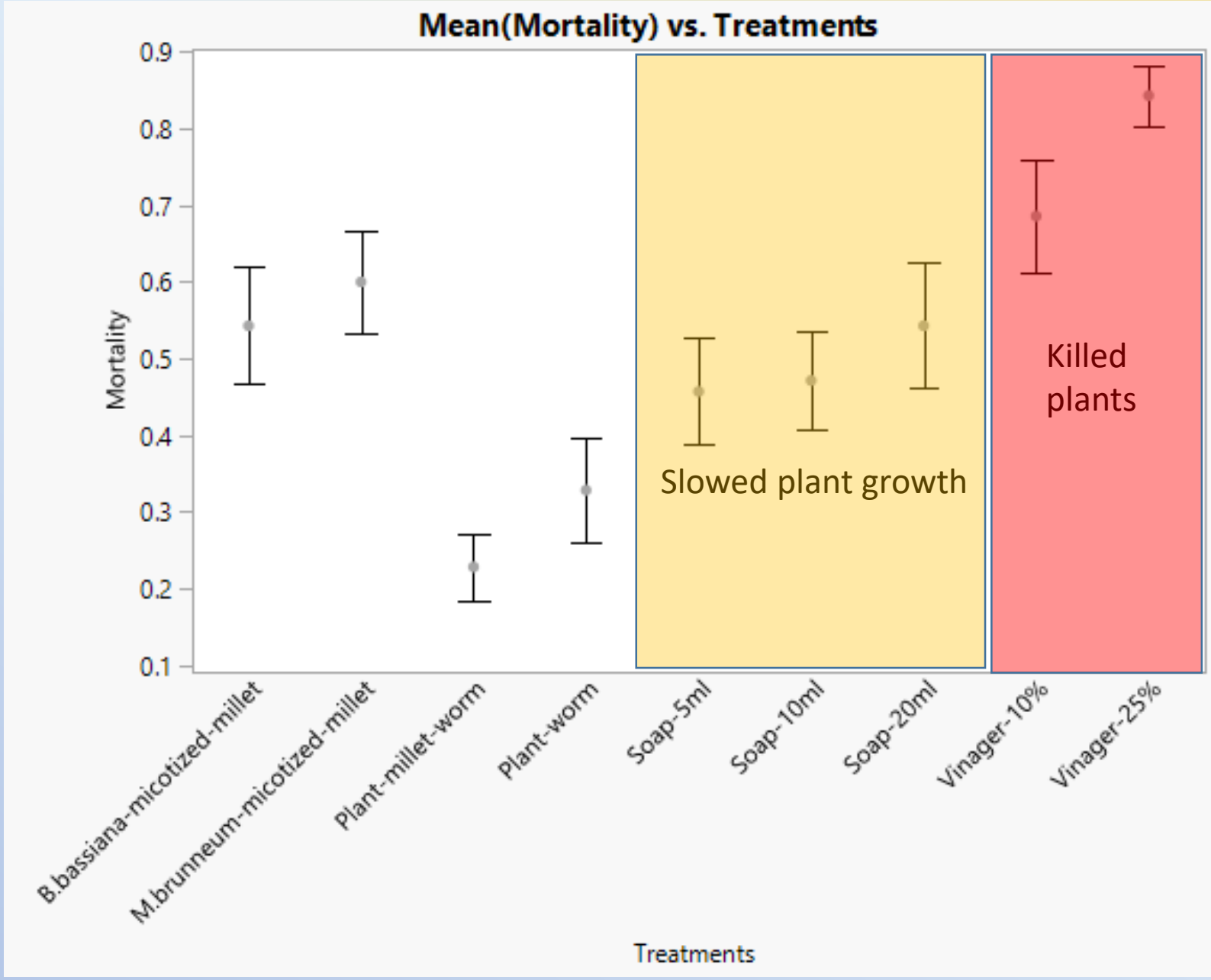
3. Chemical control: Soap
Active ingredient saponin



Bioassays with plants Experiments with Plants

Maryam Nouri-Aiin maintaining a bioassay

Photo credit Jessica Rubin



Nasturtium

Adult worms

Chemical Control Summary

- **There are no chemicals or biopesticides that are currently certified as vermicides**
- **Some chemicals are clearly effective but can also harm plants and other organisms (we trialed Cosmos, Nasturtium and Geranium)**
- **Vinegar kills the worms even at low concentrations 1:10 or 1 :20, but it also kills plants Dish soap (low concentrations: one or two spritzers in 5 gallons) kills them but slows the growth of plants as well with some leaf necrosis.**
- **Horticultural soaps don't kill the worms, but damage the plants when applied to the soil.**
- **Tea tree seed extract works really well.**

Acknowledgements

- Maryam Nouri-Aiin for her hard work

- Funders: Vermont Agency of Agriculture Specialty Crop Block Grant, two anonymous funders, The Eppley Foundation for Research, Northeast Greenhouse Conference Grant