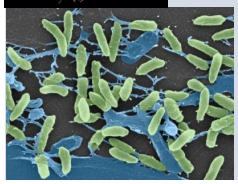
Soil Health and Biological Control

NEM204 – Spring 2024

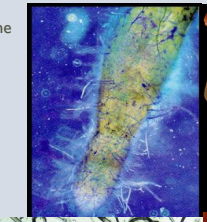
Amanda Hodson, Ph.D.
Assistant Professor
Department of Entomology and Nematology
University of California Davis
akhodson@ucdavis.edu

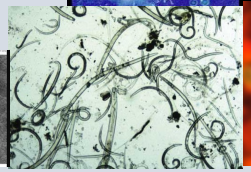
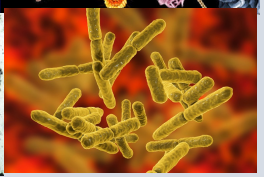



Human vs. Root microbiome

Soil biodiversity is the ground underneath us:

- Self-existing
- Responsive
- Alive

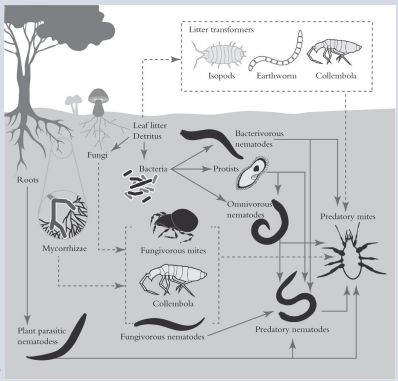


World Soil Day 2023:
"Soils: where food begins"

Soil Health = synergy of agronomic and ecological functioning.

Relationships create ecosystem processes like carbon and nutrient cycling.



Nielsen, U. (2019). Soil and Its Fauna.

Soil is alive!

In 100- 200 g soil:

Bacteria	50 billion
Protozoa	50 million
Fungus	100 million
Nematodes	10,000
Arthropods	1000
Earthworms	0 to 2

Size range of soil organisms

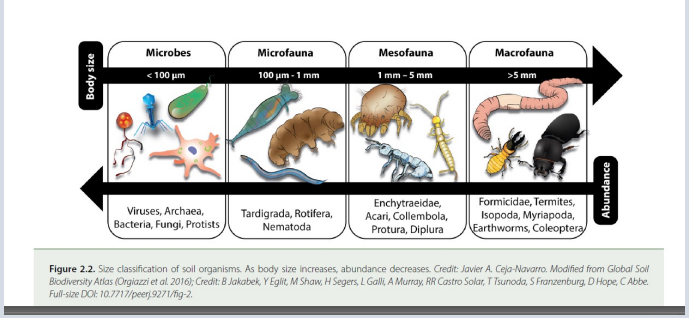


Figure 2.2. Size classification of soil organisms. As body size increases, abundance decreases. *Credit: Javier A. Ceja-Navarro. Modified from Global Soil Biodiversity Atlas (Orgiazzi et al. 2016); Credit: B Jakabek, Y Eglit, M Shaw, H Segers, L Galli, A Murray, RR Castro Solar, T Tsunoda, S Franzenburg, D Hope, C Abbe. Full-size DOI: 10.7717/peerj.9271/fig-2.*

What does soil biology do?

Microorganisms

- Mineralize most C and N
- Binding of soil aggregates
- Detoxification
- Symbionts/disease
- **Potential nematode control agents**

"Larger" Soil Fauna

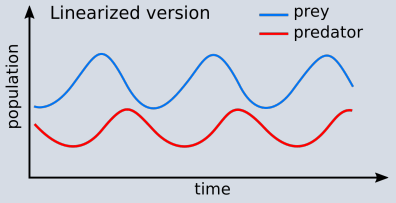
- Eat/fragment detritus
- Feces stimulate bacteria and fungi
- Increase soil porosity (burrows)
- Increase aggregate stability (casts)
- **Potential nematode predators**

Biological Control

- Biological control = the control of a pest by the introduction of a natural enemy or predator.
- Usually involves insects.
- Potential use of predatory nematodes as biological control agents.
- Suggested for use against plant parasitic nematodes by Cobb 1917.

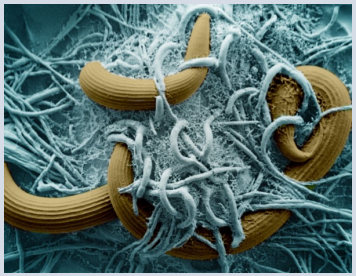
Biological Control vs Natural Control

- Natural control – occurres when "beneficial" natural enemies control pests.
- Happens regardless of whether humans are aware of it or not.
- Biological control – purposeful manipulation populations of "beneficial" groups to manage "undesirables".



Mechanisms of Biological Control

- Predation/Parasitism
- Competition for food/space –consortia?
- Antibiosis/toxic compounds
- Bio-nematicides
  - Ditera—fungal toxin
  - Melocon—fungus
  - Nema-Q—plant extract
- Not as effective as traditional fumigant.
- **Need for integrated strategies**.



Types of Biological Control: #1 Classic

- Both pest and natural enemy species of foreign origin.
- Exotic invasive pest that has escaped natural enemy used to control it.
- Long, rigorous, and costly process of finding, testing, quarantining, and rearing these natural enemies.
- Typically conducted by large governmental agencies or universities with public funding.
- Extensive testing of the natural enemy host ranges before introduction to reduce non-target effects.
- Scale = national/regional

Example: Phorid flies released as biological control agents to control invasive red imported fire ant

Types of Biological Control: #2 Augmentative

- Natural enemies released into area where they are either not present or populations too low to suppress pests.
- Scale - often practiced in greenhouses, nurseries, and some fruit and vegetable fields.
- Mass-produced biological control agents purchased and released.
- *Inoculative release:* released in small numbers to establish population providing long-term control.
- *Inundative release:* released in large numbers to quickly overwhelm pest population. No expectation of continued establishment or control.

Types of Biological Control: #3 Conservation

- Manipulating habitat, plant diversity or production practices to increase population of existing natural enemies.
- Scale – farm level.
- Diverse plant communities generally have a greater diversity of natural enemies and lower abundance of pests.

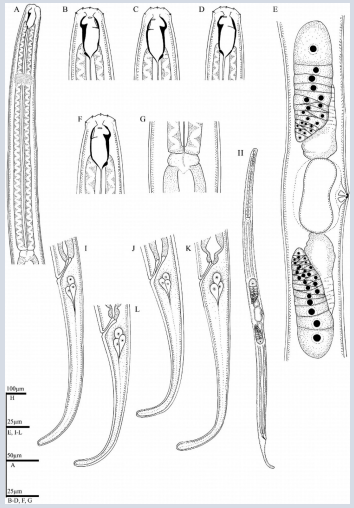
Restored remnant tallgrass prairie vs corn monoculture. Which will likely have more natural enemies above and belowground?

Soil predators of nematodes

- Tardigrades
- Collembola
- Insects
- Mites
- Other Nematodes

Mononchid Predatory Nematodes

- Microbivorous as juveniles.
- Predators as adults
- Strongly sclerotized buccal cavity.
- Armed with teeth – diagnostic for genera.
- Long muscular tubular espophagus.
- Long life cycles (15 – 45 days).
- Cannabilistic.



- May completely swallow preys if it is of smaller size, or may cut into pieces

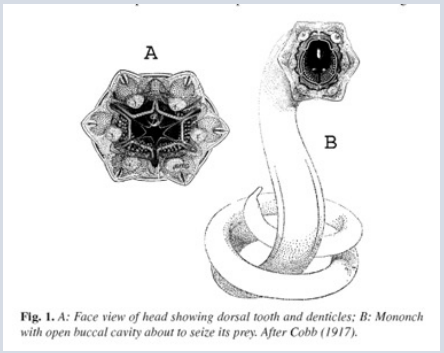


Fig. 1. *A: Face view of head showing dorsal tooth and denticles; B: Mononch with open buccal cavity about to seize its prey. After Cobb (1917).*

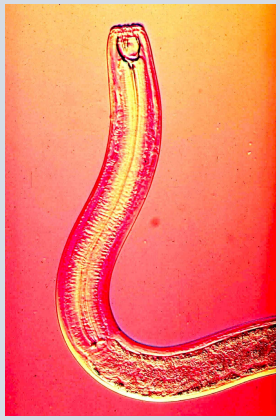
Illustration by William Chambers in Cobb (1917)

- Pot studies and field studies show reductions in plant parasitic nematodes.

Mononchids and biological control

<u>Drawbacks</u>

- Populations variable and difficult to control.
- Not possible to grow up in larger cultures – cannibalistic.
- Reproduction too slow.
- Susceptible to environmental conditions.
- Non specific predators.



Mononchids and biological control

- Can provide natural control of plant parasitic nematodes in soil.
- Can't culture in mass.
- But..if their population can be manipulated in the field then they can be used as successful biocontrol agents.
- Which type of biological control would be best suited to them?

- Conservation
  - Reduce chemical disturbance (pesticides).
  - Reduce physical disturbance (tillage).
  - Large body size of these nematodes means they can be easily damaged.

Predatory nematodes: Diplogasterids

- Specific predators of other soil nematodes.
- But also eat bacteria.
- Switch feeding preferences depending on availability.
- Characterized by movable teeth in stoma
- Very muscular metacorpus (upper part of esophagus).
- Individuals may connect with others at tail tip in water to form a ball of nematodes.
- Abundant in decomposing organic matter.

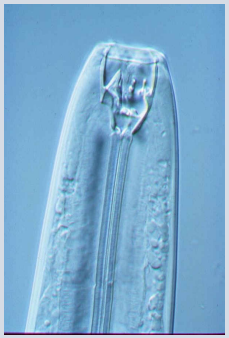


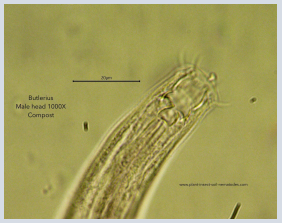
Photo by J. Chitamber

Diplogasterids and biological control

<u>Advantages</u>

- Easy to culture
- High productive rate.
- High predation rate
- Short life cycle (8-15 days).
- Cannibalism rare.
- Tolerant to environmental conditions.
- Able to switch food resources bacterial/predator.
- Formation of dauer larvae under adverse conditions.

- Which type of biological control would be best suited to them?
  - Augmentative – Inundative release.



Potential for Conservation Biological Control

- Organic Amendment application such as compost, leaves or mulch can sometimes increase predatory nematodes.
- Supports bacterial and fungal growth → bacterial and fungal feeding nematodes → more predatory nematodes.
- Improved soil texture makes it easier for large bodied predators to move.
- Potential effects of cover cropping and continuous feeding of soil food web.

Why are predatory nematodes not commonly used for biological control?

- Need to know more about what best to feed them to rear commercially.
- Huge population of predators is required to execute biocontrol programs successfully.
- Adult *Clarkus papillatus* (Family Mononchidae) easily maintained in vitro with nematode prey but juveniles in culture couldn't survive on bacteria or agar alone.
- Juveniles only able to moult into adulthood in culture plates that contained adults (Salinas and Kotcon, 2005).
- Possibly juveniles require combination of both dead or wounded prey that were previously attacked by adults as well as bacterial food to survive.

Innundative release of entomopathogenic nematodes – case study in natural biological control

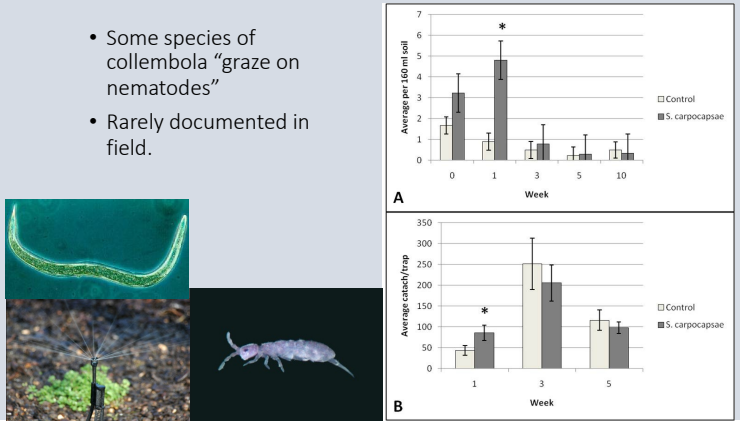
- Entomopathogenic nematodes applied to control insect pests.
- Adding large numbers through the irrigation system to control a pest of pistachios showed some unexpected food web effects.
- Highlights groups that could control plant parasitic nematodes*

Collemebola

http://www.geocities.com/~fransjanssens/taxa/hypogast.htm

Collembola – *Isotoma* spp.

- Some species of collembola "graze on nematodes"
- Rarely documented in field.



Predatory Mites

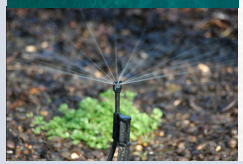
Predatory mites

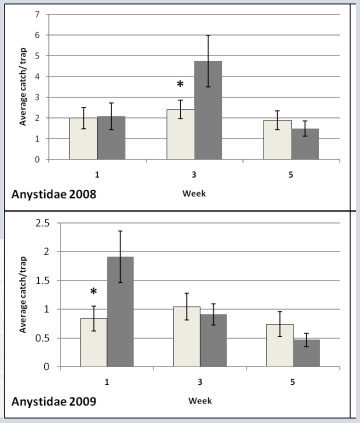
- Front legs modified for grabbing prey.
- Specialized chelicera

https://www.chaosofdelight.org/mites

Predatory Mites –*Anysitis agilis*

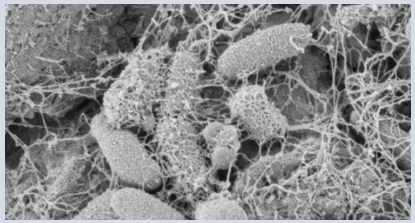
- Increased after nematode application in field plots.



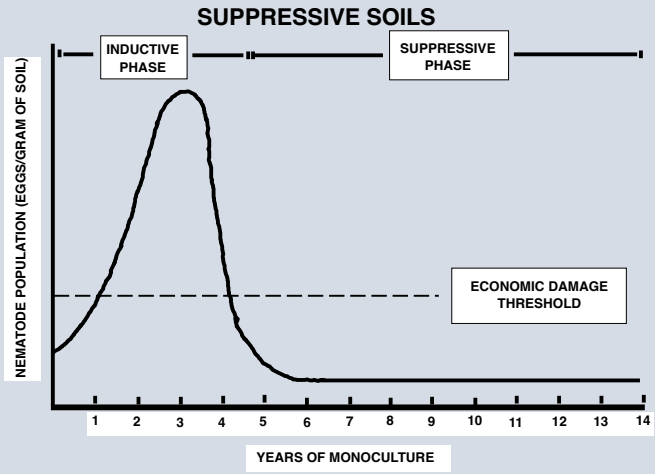


Managing for pest suppressive soils

- General suppression – protective community
- Specific suppression—targeted
- Inoculation—natural enemies are released directly via soil, seeds or planting materials

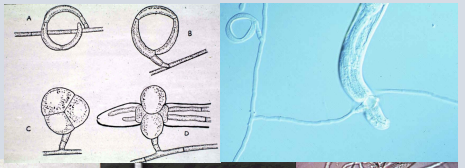


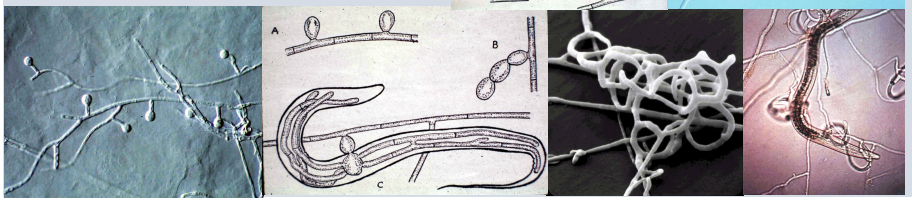
Bacillus as a bacterial antagonist of root-knot nematodes (picture: Deisy Amora, Chr. Hansen (DK))



Fungal antagonists of nematodes

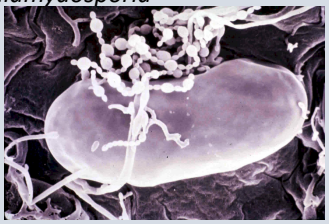
- Constricting ring traps
  Arthrobotrys dactyloides
- Sticky nets
  Arthrobotrys oligospora
- Adhesive knobs

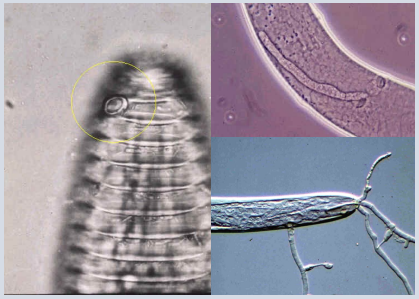




Fungal antagonists of nematodes

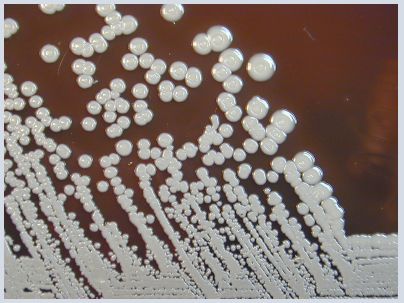
- Sticky spores - *Hirsutella rhossiliensis*
- Egg parasites - *Paecilomyces lilacinous (Product - MeloCon), Pochonia chlamydosporia*





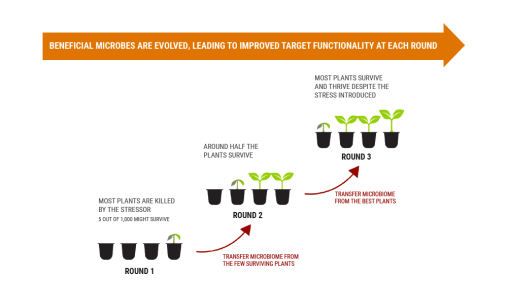
Other microbial products

- DiTera -Myrothecium verrucaria (Valent)
  - Fungus fermented in liquid nutrient media and spray-dried.
  - Drying process kills fungus but retains fermentation products – nutrients and fungal metabolites
  - Fertilizer effect, nematode mortality and reduced foraging.
- Majestene – Burkholderia spp., (Maronne Bio Innovations)
  - Heat killed bacteria
  - Produces nematicidal compounds
  - Inhibits egg hatch and development.



Modifying the root microbiome

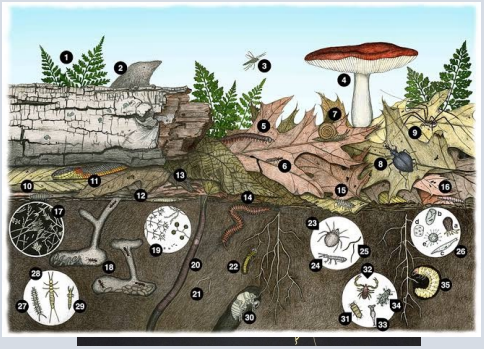
- Microbial selection to evolve communities resistant to nematodes.



Bioconsortia - Advanced Microbial Selection™ (AMS)

Inoculation Challenges

- Microbes often do not survive when introduced
- Unknowns:
  - how plants and microbes communicate
  - how key beneficial organisms function to influence plant health and/or repel pathogens



BioAg Alliance-Monsanto/SARE – our living soil