



FLORIDA  
**MASTER**  
**GARDENER**

# Basic Nematology

# Learning Objectives:



- Define what plant parasitic nematodes (PPN) are and how they damage plants.
- Recognize plant symptoms resulting from PPN damage.
- Know PPN management strategies for various crops.
- Describe how to solarize soil to reduce PPN.
- Be familiar with nematode sampling diagnostic capabilities provided through UF/IFAS.

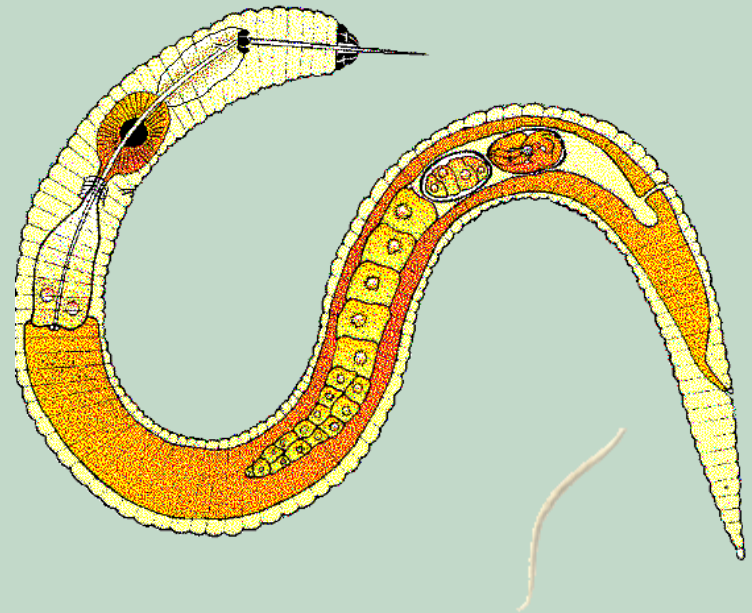


Part I:

**INTRODUCTION TO PLANT  
PARASITIC NEMATODES (PPN)**

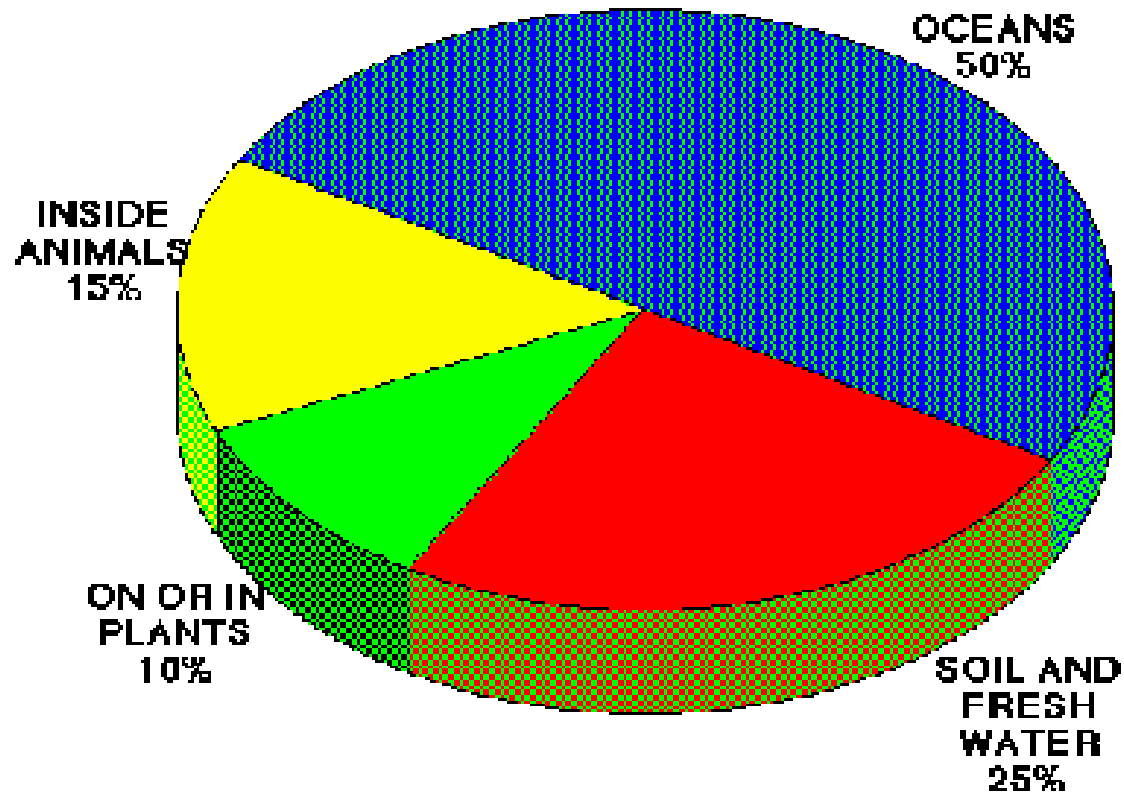
# What Are PPN (Plant-Parasitic Nematodes)?

- Unsegmented roundworms
  - Different from earthworms and other common worms
- Microscopic
- Live in a film of water surrounding soil particles
- Use a spear-like mouthpart (stylet) to feed on plants
- Inhibit root growth and plant performance



# Where are Nematodes Found?

## WHERE NEMATODES LIVE

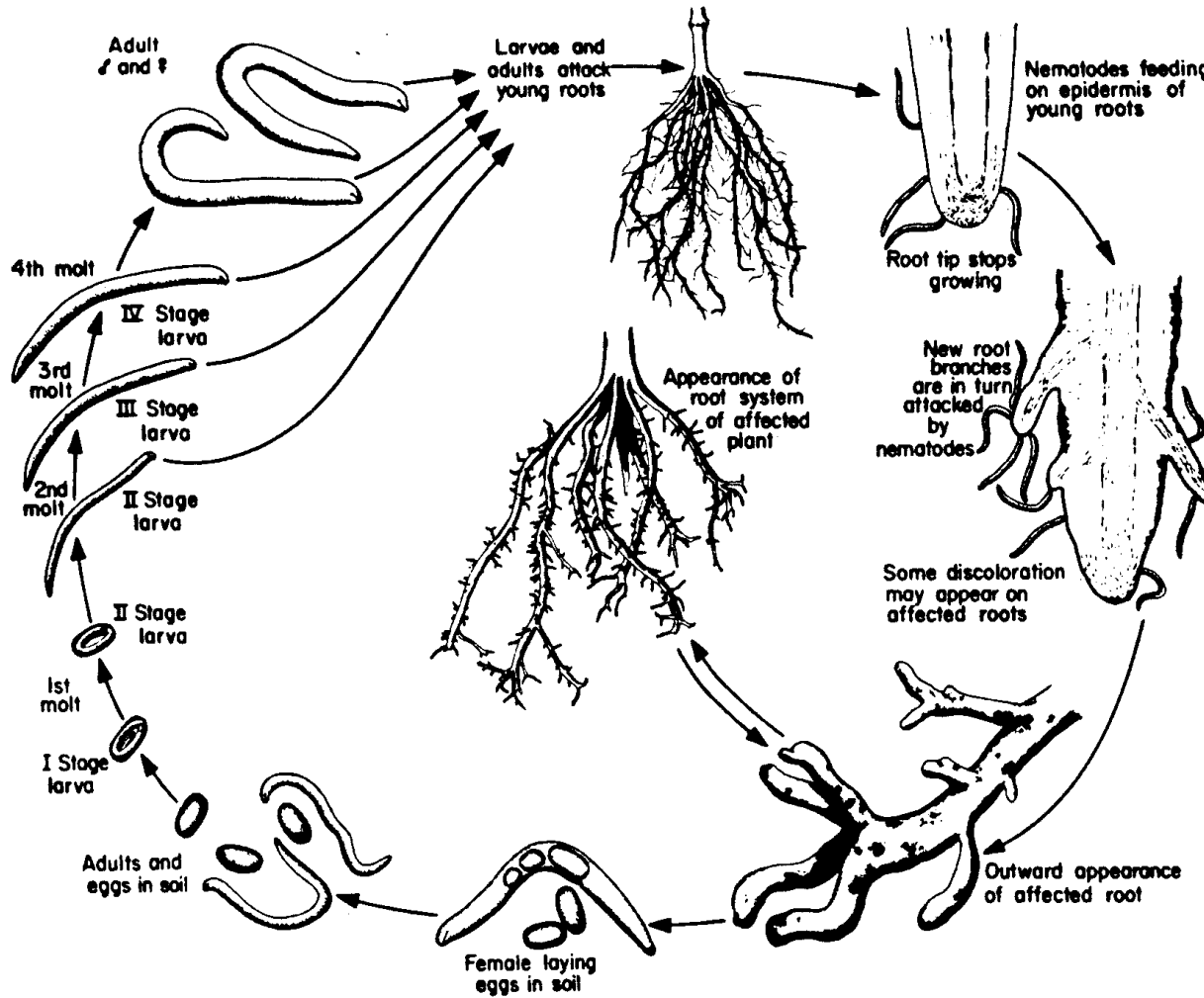


# “Good” versus “Bad” nematodes



- Bacterial feeders
  - Fungal feeders
  - Predators
  - Animal-parasites
  - Plant-parasites
- Harmless or Helpful
- Harmful

# General Life Cycle of PPN



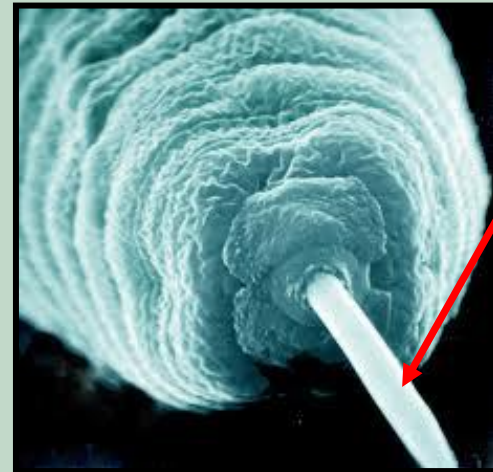
Nematode reproduction increases with increasing soil temperatures;  
decreases as soils cool

# How do PPN Feed?



- Mouth part (stylet) resembles a hypodermic needle
- Stylet inserted into plant cells
- Digestive juices injected into cell
- Plant juices ingested through stylet

Stylet of a spiral nematode



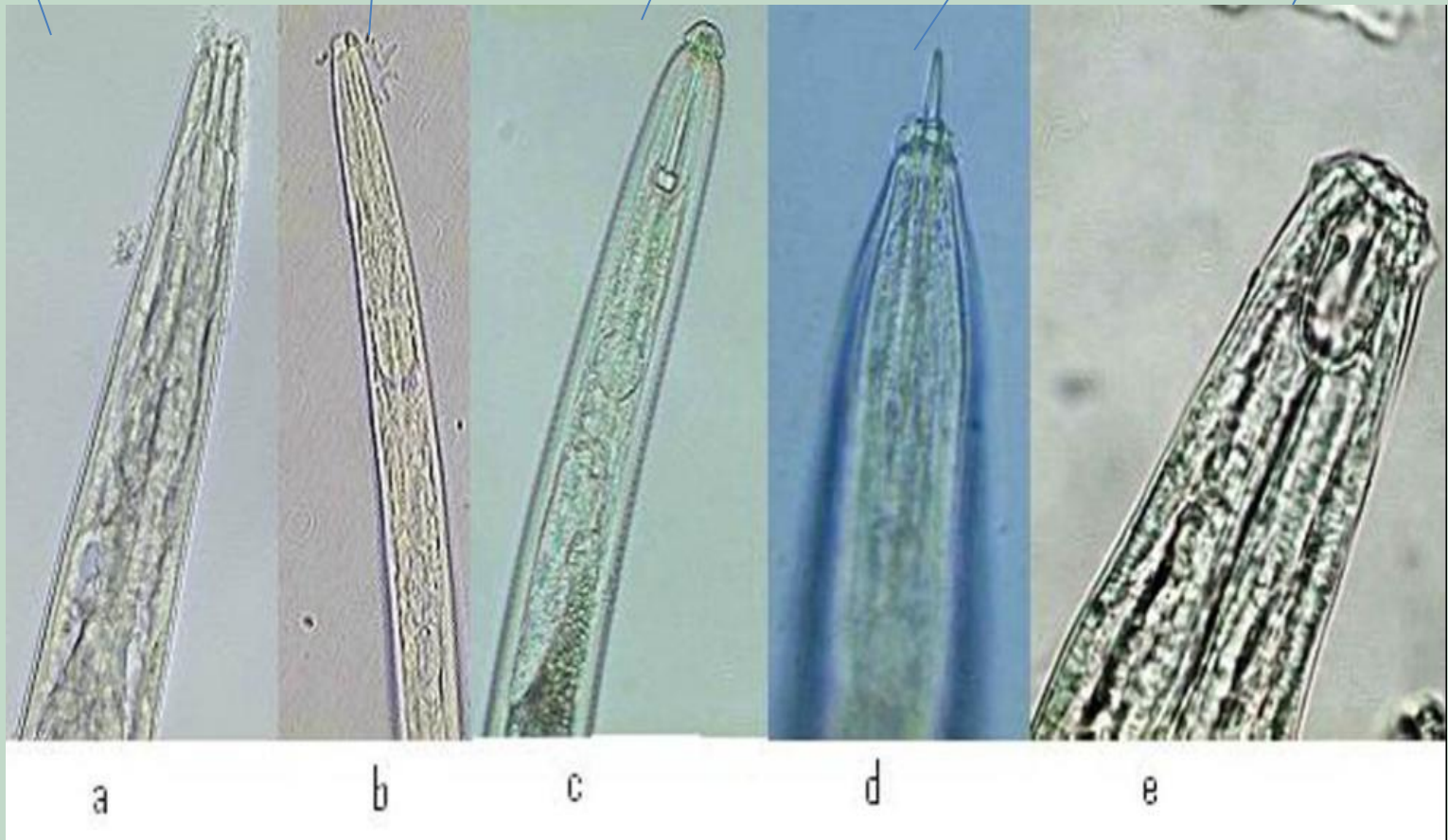



Steinernema scapterisci nematodes  
emerging from an adult mole cricket in the  
laboratory.



# Different nematodes:

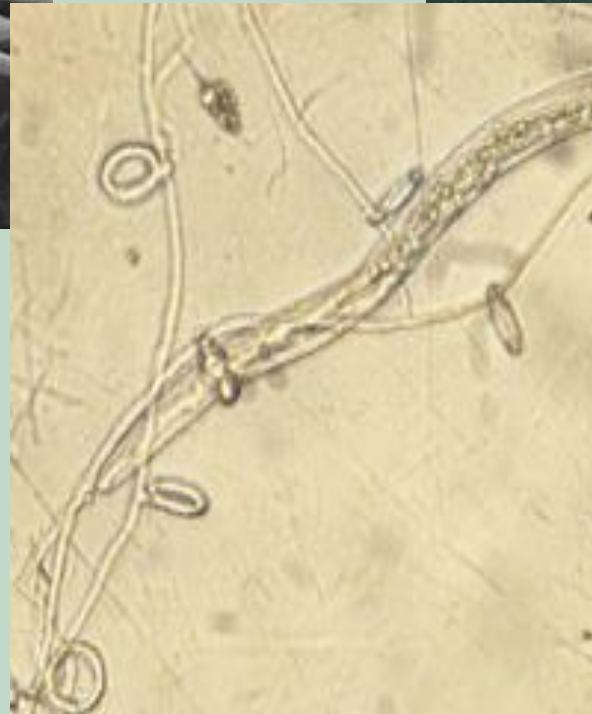
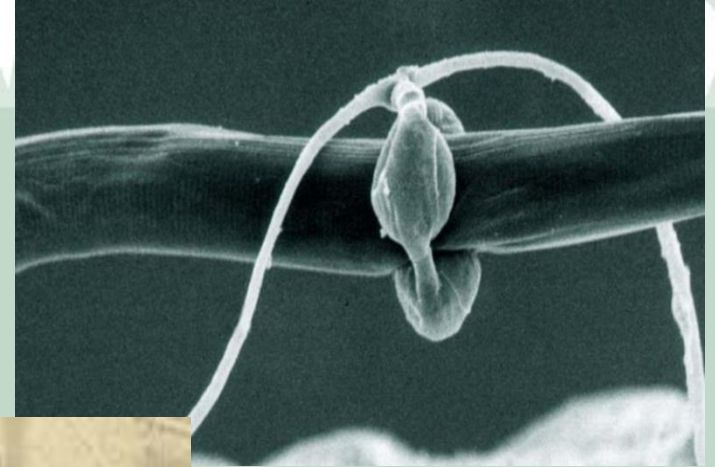
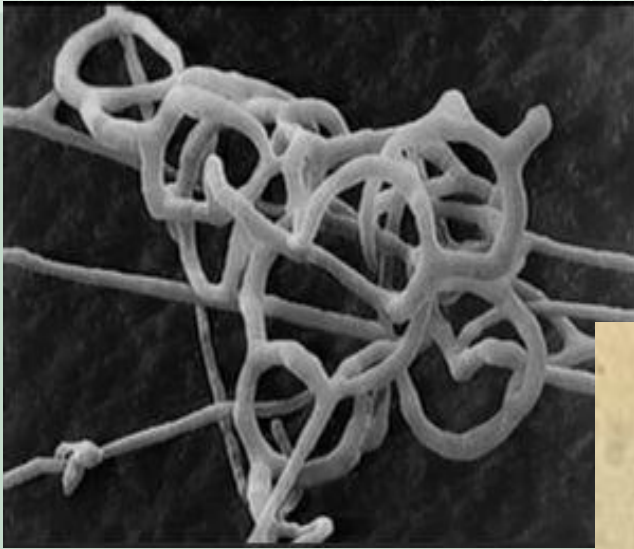
a) Bacterivore, b) Fungivore, c) Herbivore, d) Omnivore, e) Predator



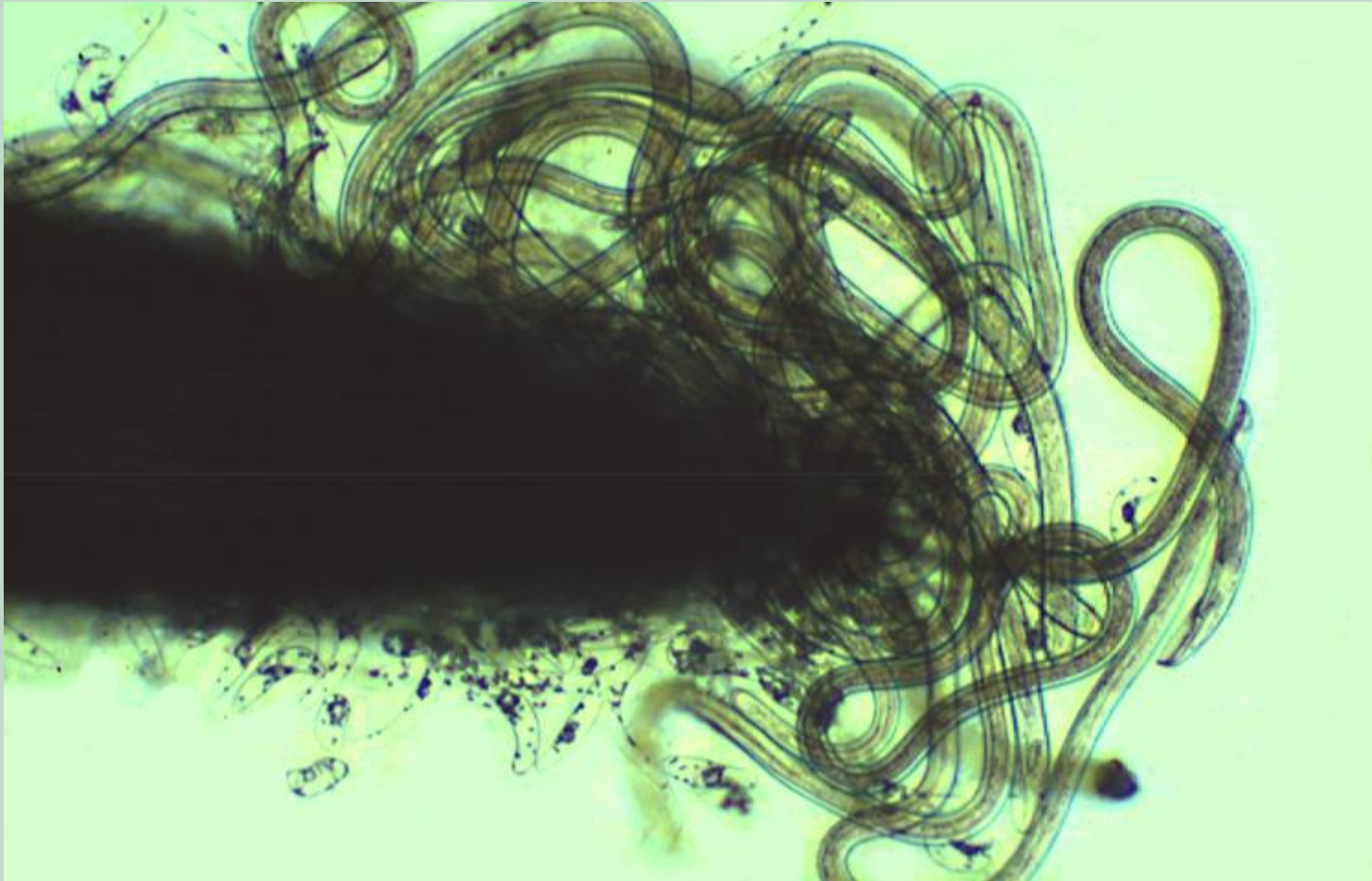
A microscopic image of a nematode worm, likely a C. elegans, shown in a curved, head-to-tail orientation. The worm's body is transparent, revealing internal structures such as the gut and muscle layers. A speech bubble is superimposed on the image, containing the text "Mmmm Tastes like chicken!!". The background is a light blue, slightly textured surface.

Mmmm  
Tastes like  
chicken!!

# Nematophagous Fungi



# Ectoparasites- feeding



# Where do PPN Feed?

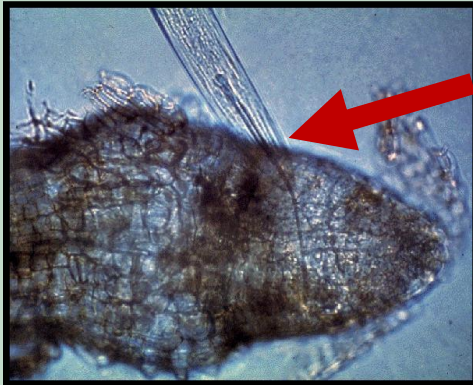
- Most PPN feed on plant roots
  - Exception is *Aphelenchoides* spp. which feed on foliage
  - Foliar nematodes are economically important in some nursery crops:
    - Chrysanthemum
    - Certain Ferns
    - Anthurium
    - Azalea



# Where do PPN Feed?

## Ectoparasitic:

feed on outside of root



Stylet inserted into  
root tip

## Endoparasitic:

feed inside root

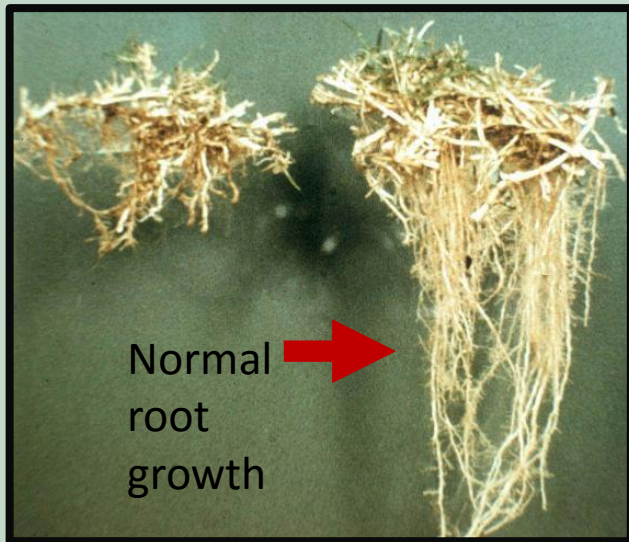


## Important PPN in Florida

- Ectoparasites
  - Sting
  - Stubby-root
  - Spiral
  - Ring
- Migratory endoparasites
  - Lesion
  - Lance
  - Burrowing
  - Foliar
- Sedentary endoparasites
  - Root-knot
  - Citrus

# How do PPN Damage Plants?

- Feeding reduces plant's ability to absorb water & nutrients.
- Damage exposes plant roots to infection by diseases.





# Symptoms of Decline

## Above-ground

- Yellowing; nutrient deficiencies
- Stunting; slow decline
- Premature wilting & slow recovery
- Thinning
- Death

Note similarities to:

- Drought
- Disease symptoms
- General stress



# Symptoms of Decline

## Below-ground

- Symptoms vary with type of nematode and plant.
- General root symptoms:
  - Stunted, short
  - Deformed
  - Dark or rotted
  - Lesions, galls
  - Reduced root proliferation



Healthy roots

Damaged Roots



# Rate of Decline

Depends on:

- Nematode species
- Population density
- Susceptibility of plant/variety
- Soil - temperature & texture
- Presence of other stresses





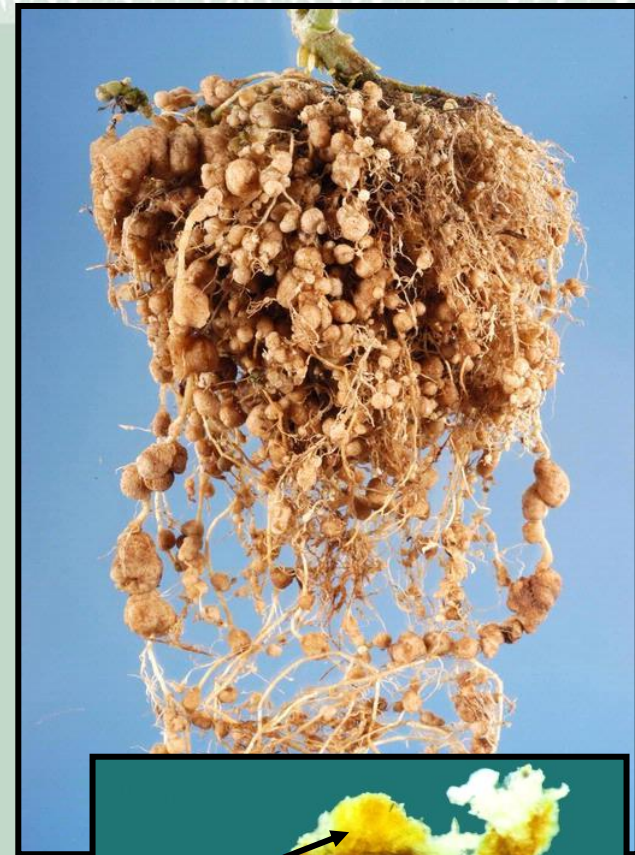
Part II:

## **PPN IN THE VEGETABLE GARDEN**

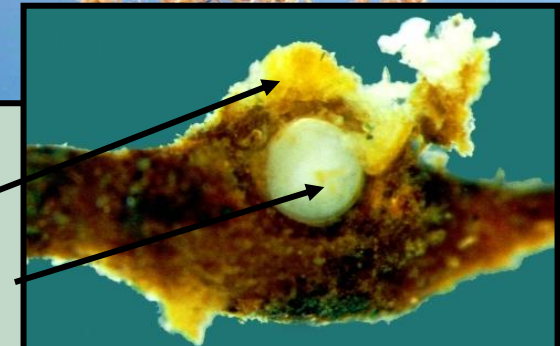
# Are Nematodes the Problem? Symptoms May Be Obvious...

## Root-Knot Nematodes

- Three common RN species in FL
- Recognized by *galls* on fibrous roots
- Galls may be very small
- Small galls enlarge and may merge
- Susceptible: tomatoes (solanaceae), potatoes, okra, beans (legumes), squash (cucurbits), carrots



Egg mass  
Adult female

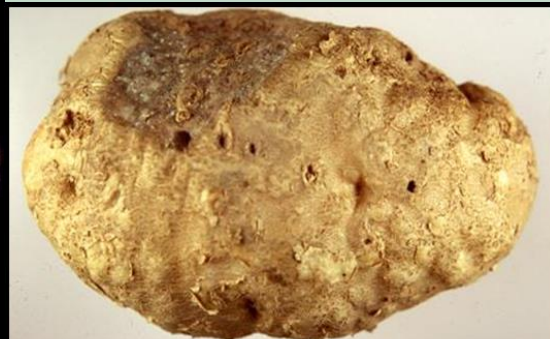


# Are Nematodes the Problem?

## Not So Obvious Symptoms

### Root-Knot Nematodes (*Meloidogyne* spp.)

- In (taproots), galls may not be as visible; roots get knobby.
- In onions, galls are barely noticeable; bulbs may be discolored and smaller.
- In potatoes, appearance is marred; cross-section reveals speckling (feeding sites).



# Galls versus Nodules



**Root-knot galls**



**Rhizobium nodules**

# Numerous PPN Attack Vegetables

Nematode	Bean and Pea	Carrot	Celery	Crucifer	Cucurbit	Egg-plant	Leaf Crop	Okra	Onion	Pepper	Potato	Sweet Corn	Sweet Pot	Tomato
Root Knot	X	X	X	X	X	X	X	X	X	X	X		X	X
Sting	X	X	X	X	X	X	X	X	X	X	X	X		X
Stubby Root	X		X	X		X	X		X	X	X	X		X
Root Lesion												X		
Cyst				X										
Awl	X		X									X		
Stunt												X		
Lance												X		
Reniform	X												X	

Source: EDIS - ENY-012 Nematode Management in the Vegetable Garden



# PPN Management Strategies

**No *one* management option will resolve a nematode problem.**

- Chemical nematicides – none
- Bio-nematicides – suppress only (MeloCon)
- Sanitation
  - Don't introduce contaminated plants or soil.
  - Remove plants and roots after harvest.
  - Keep garden weed-free.
- Soil solarization
- Cover crops
- Organic amendments/ Soil replacement
- Crop rotation & resistant varieties



# Sanitation and Prevention

- Nematodes move very slowly on their own; moved by soil, water, plants, and/or tools.
- Power wash or disinfect tools with a 10% bleach solution.
- Remove nematode-infected roots after harvest & do not compost.

## What spreads nematodes?

Shovels, Hoes, Rakes, Shoes, Boots, Wheelbarrows,  
Vehicle Tires, Neighbors, Family members, Pets,  
Improperly or partially decomposed compost



# Soil Solarization

- Work and moisten soil.
  - Activates pathogens/weeds
  - Increases heat conductivity
- Cover soil with **clear** plastic (minimum 1.5) or thermal-infrared retentive film.
- Seal edges with soil to prevent heat loss.
- Soil temps should reach **95°-140°F (135°F ideal)** to a depth of **4-12 inches**.
- Leave plastic on for at least **6 weeks** – the longer the better.



# Soil Solarization

- Works best in summer.
- Does not work well in shaded areas.
- Affects all living organisms in upper 6-8 inches of soil (weeds, disease pathogens, insects, nematodes).
- Beneficial organisms are also negatively affected – but recolonize quickly.
- No significant impact on organic matter decomposition.
- Do not mix or till soil after solarization.



# Soil Solarization



## Research results:

- Root-knot nematode eggs and juveniles are highly susceptible to heat over short time period.
  - Meloidogyne incognita* Ex: 390 hours required at 100°F; 15 hours at 108°F.
  - M. javanica* juveniles killed instantly at 122°F; eggs died after 2-3 weeks at average temp of 109°F
- Most PPN species recolonize soil to damaging population numbers by the end of the crop cycle following solarization.
- Solarization followed by a cowpea cover crop suppressed root-knot nematode population to a level equivalent to methyl bromide treatment.



# Organic Amendments



- Add as compost, manure, green manure, etc.
- Enhance soil microbes & beneficial nematodes.
- Release chemicals toxic to nematodes as they decompose (Ex: Brassica).
- Benefit the soil and plant health.



# Cover Crops

- Grown between vegetable growing seasons.
- Improve soil fertility and structure.
- Decrease erosion.
- Suppress weeds, insects, nematodes, disease.
- May be incorporated as “green manure.”
- Enhance many beneficial organisms.
- Legume cover crops supply nitrogen to subsequent crops.



Cowpea  
Cover Crop

# More “Nematicidal” Cover Crops

Cover Crop	Nematodes	
	Root-knot*	Sting*
Hairy Indigo, <i>Indigofera hirsuta</i>	G	G
Pangola digitgrass, <i>Digitaria decumbens</i>	G	P
Transvala digitgrass, <i>Digitaria decumbens</i>	F	G
Showy crotalaria, <i>Crotalaria spectabilis</i>	G	G

\* G = good control of the most common species of this nematode; P = poor or no control of this nematode; F = fair control

\*\* Effectiveness differs among varieties of marigolds; one report stated yellow or gold "Petite French" types are most effective against the greatest number of root-knot nematode species.

Excerpted from: EDIS – ENY-012, *Nematode Management in the Vegetable Garden*;  
See also: EDIS – ENY-063, *Cover Crops for Managing Root-Knot Nematodes*



# “Nematicidal” Cover Crops



Cover Crop	Root-knot ( <i>Meloidogyne</i> spp.)	Sting ( <i>Belonolaimus longicaudus</i> )	For more detailed information see:
Cowpea ( <i>Vigna unguiculata</i> )	Depends	No	<a href="#">IN516</a>
Sunn Hemp ( <i>Crotolaria juncea</i> )	Yes	Yes	<a href="#">NG043</a>
Sorghum ( <i>Sorghum</i> spp.)	Yes	No	<a href="#">IN531</a>
Marigold ( <i>Tagetes</i> spp.)	Depends	No	<a href="#">NG045</a>
Velvetbean ( <i>Mucuna deeringiana</i> )	Depends	Yes	<a href="#">IN483</a>
Rye ( <i>Secale cereale</i> )	Yes	No	
Bahiagrass ( <i>Paspalum notatum</i> )	Yes	No	

Yes = should reduce nematode populations. No = might increase nematode populations. Depends = some varieties are resistant, others are susceptible, see "more detailed information" for variety-specific information. From: EDIS-ENY-059 *Soil Organic Matter, Green Manures, and Cover Crops for Nematode Mgt.*

# “Nematicidal” Cover Crops



***This:*** Marigold Planted as  
Cover Crop



***Not this:***  
Marigold Inter-planted  
with Crop

See EDIS pub: *Marigolds for Nematode Management* (ENY-056)

# Use Resistant Varieties

- Use vegetable varieties that are resistant or tolerant.
- Look for VFN designation on seed pack or tag.\*
- Use fruits / ornamentals grafted on nematode resistant rootstock.



## Root-Knot Resistant Tomatoes

- Better Boy
- Celebrity
- Beefmaster
- Sugar Snack

\*Resistant: refers to only one or two species of root-knot nematodes. May still be damaged by other species of root-knot nematodes or other types of nematodes.

# Root Destruction



- Destroy nematode-infected roots and root fragments, which serve as nematode reservoirs.
- Tilling non-infested roots into the soil will improve soil health.

Root-knot nematode infested cucumber



# If All Else Fails – Try Container Gardening

- Containers should not be in contact nematode-infested soil.
- Use pest-free growing media.
- Use disinfected tools (or keep them separate.)
- If possible, isolate containers with screen, cages, etc. – wild animals can move soil around.



# Activity 1



## Crop Rotation and Resistant Varieties

- Many types of PPN damage vegetables – particularly Root-Knot nematodes.
- One method of reducing damage is to rotate crops in the garden and to plant more nematode resistant vegetable varieties.
- Refer to Activity 1 worksheet in your MG Handbook.



Part III:

**MANAGEMENT OF PPN  
IN TURFGRASSES**

# Symptoms of Decline in Turfgrass

## Above-ground symptoms

- Irregularly-shaped patches
- Yellowing, wilting, and browning
- Thinning-grass dies; weeds thrive
- Death of areas

Note similarities to:

- Drought
- Insect damage
- Disease
- General stress





# Symptoms of Decline in Turfgrass

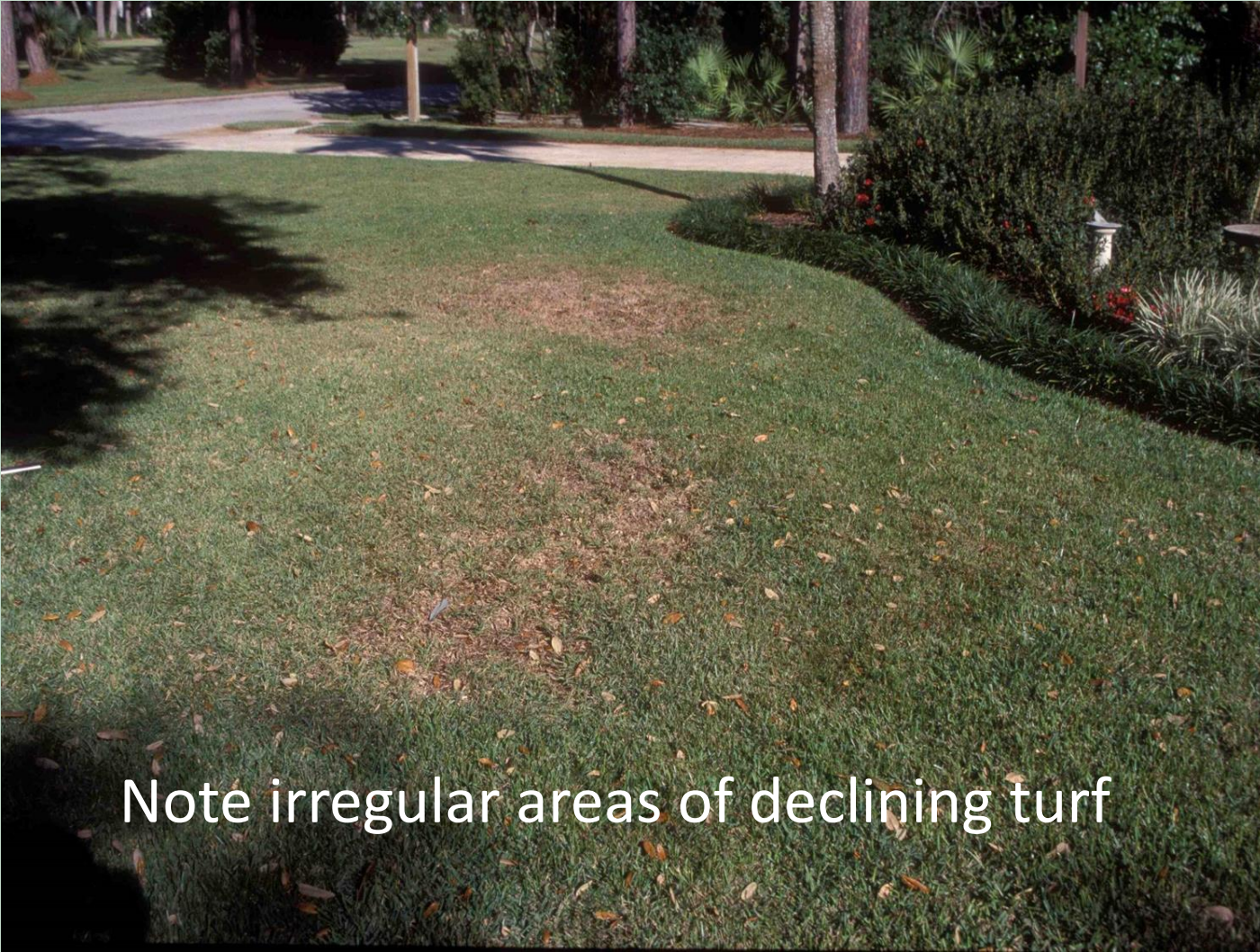
## Below-ground symptoms

### Roots are:

- Abnormally short and stubby;
- Darkened or rotten;
- Appear “cropped off” just below soil surface;
- Root galls or knots usually not evident.



# Symptoms of Decline in Turfgrass



Note irregular areas of declining turf



Drought/water restrictions can cause damage to  
become more severe



Sod farm.

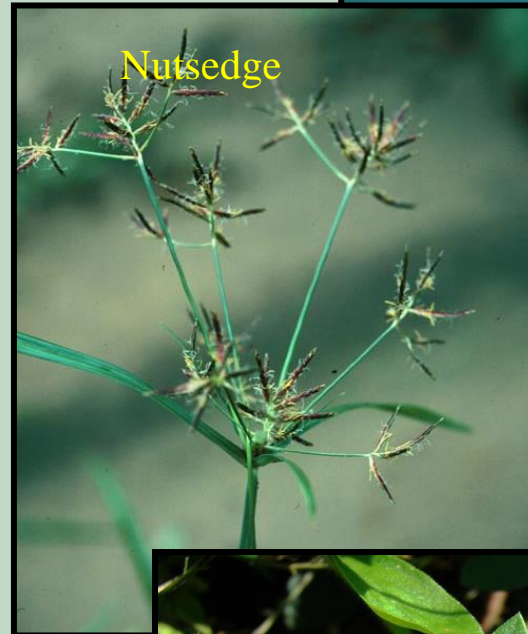
PPN may be introduced into landscapes in new sod.

# Turfgrass Susceptibility to PPN

Grass Species	Susceptibility	Nematode Species	Notes
Bahiagrass	Rarely damaged		Most tolerant turfgrass to PPN
St. Augustinegrass	Commonly damaged	Lance, stubby-root, root-knot	'Floritam' tolerant of sting nematodes
Zoysiagrass	Commonly damaged	Sting, root-knot, stubby-root, lance	No difference among cultivars
Bermudagrass	Commonly damaged	Sting, root-knot, stubby-root, lance	'Celebration' and 'Princess 77' more tolerant to sting than 'Tifway'
Centipedegrass	Commonly damaged	Ring, sting, root-knot, stubby-root, lance	Very susceptible to ring
Seashore Paspalum	Depends	Spiral, sting, lance	Tolerant to most; very susceptible to spiral; occasionally damaged by lance

# Nematodes and Weeds

- Certain weeds tolerate nematodes and proliferate as grass thins.
- Weeds can serve as PPN reservoirs as grass declines.



# Management of Nematodes in Turfgrass

- Choose PPN tolerant grasses.
- Right turf/right place (sun/shade)
- Don't overseed in winter if nematodes are a problem.
- Organic Soil Amendments:
  - Composted municipal sludge or composted manures;
  - Increase soil water & nutrient holding capacity;
  - May increase plant tolerance to PPN;
  - May stimulate natural enemies of PPN
- Proper maintenance (mowing, irrigation, and fertilization) reduces stress and promotes root vigor.



# Management of Nematodes in Turfgrass

**As of 2017, three products are labeled for residential turfgrass:**

## Nortica

- Root-knot, Sting, & Lance
- Protectant
- Long-lived
- 8-months of activity
- Caution
- Not RUP

## Indemnify

- Root-knot & Sting
- Contact
- Long-lived
- 8-months of activity
- Caution
- Not RUP

## Nimitz Pro G

- Sting, Lance, Root-knot
- Contact & Systemic
- Not long-lived
- 4-months of activity
- Caution
- Not RUP

RUP – Restricted Use Pesticide





Part IV:

**MANAGEMENT OF PPN  
IN ORNAMENTAL PLANTS**

# Symptoms of Decline

## Above-ground

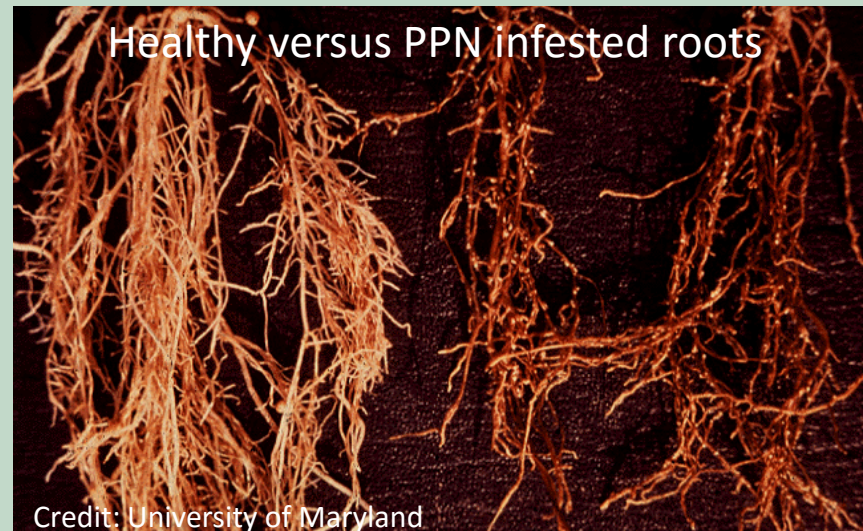
- Yellowing; nutrient deficiencies
- Stunting
- Premature wilting/slow recovery
- Thinning
- Slow decline; death



Credit: N.C. State

## Below-ground (varies with PPN)

- Stunted, short, deformed roots
- Dark or rotted
- Lesions, galls
- Reduced root proliferation



Credit: University of Maryland

# Landscape Plants Damaged by Root-Knot



- Butterfly bush
- Hibiscus
- Boxwood
- Pittosporum
- Lantana
- Ixora
- Japanese holly
- Rose\*
- Gardenia\*

\*Use plants that are grafted unto  
nematode-resistant rootstock

# Some Landscape Plants Resistant to 3 or more species of Root-Knot\*

- Walter Viburnum / Blackhaw
- Sweet Pepper Bush
- Firespike
- 'Gold Dust' Croton
- Oakleaf Hydrangea



\*Results from UF/IFAS research

# Bedding Plants Very Susceptible to Root-Knot Nematodes



- Coleus
- Celosia
- Pansy
- Snapdragon
- Petunia
- Nasturtium
- Calendula
- Sunflower
- Zinnia
- Others\*

\*SEE EDIS: IN470 and INY681

# Management of Nematodes in Ornamental Plants

- No chemical nematicides exist.
- Bionematicides – (Ex: Melocon WG)
- Don't plant susceptible or infested plants  
“Right Plant/Right Place”
- Rotate bedding plants; alternate with resistant or tolerant species/varieties.
- Solarize annual plant beds.
- Add organic amendments
- Remove infested roots/soil
- Grow in containers.





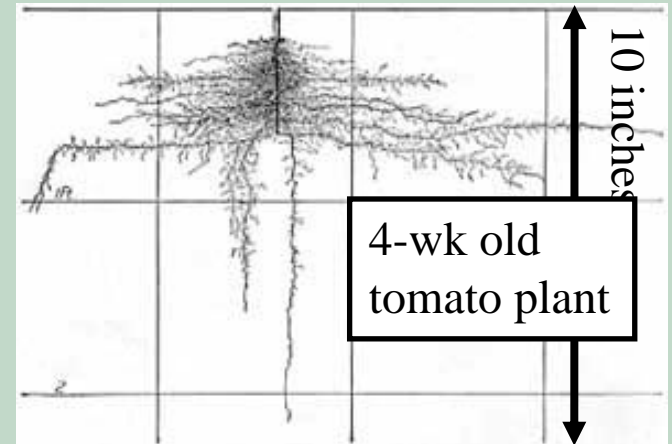
Part V:

# **SAMPLING FOR PPN**

# Sampling for PPN in the Vegetable Garden

- Sample at end of crop.
- Both soil & roots are needed.
- Collect from around the dripline of each plant.
- Soil sampling depth should be 8-10 inches
- Do not include the first 1 inch of soil
- Only include roots from the plant being sampled.
- Place soil and roots in the same plastic bag.
- Minimum 2 cups of soil & 1-2 cups of roots
- Follow sample care and shipping instructions.

Note: The accuracy of the diagnosis depends on the quality of the sample!



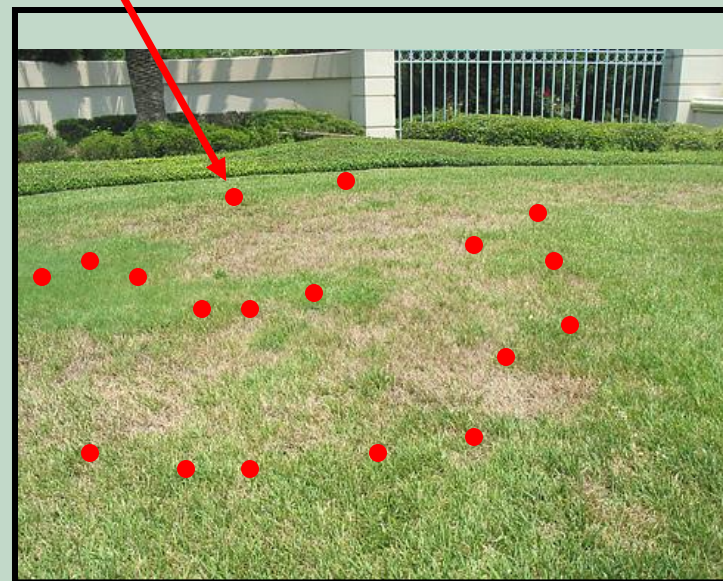


# Sampling for PPN in Turfgrass

## *With Existing Damage*

- Collect sample as instructed by diagnostic lab.
- Don't sample inside dead/damaged areas; these areas don't sustain PPNs.
- Collect sample from declining (still green) areas.
- Using a shovel, trowel, or core sampler, collect soil from ~20 locations.
- Combine soil into a bucket, gently mix, and remove ~one pint for analysis.
- Place sample in plastic bag, seal securely, and label the bag with a permanent marker.
- Store in a cool place, preferably a cooler or fridge, until shipping.
- Ship ASAP, preferably overnight, for analysis.

Note: The accuracy of the diagnosis depends on the quality of the sample!

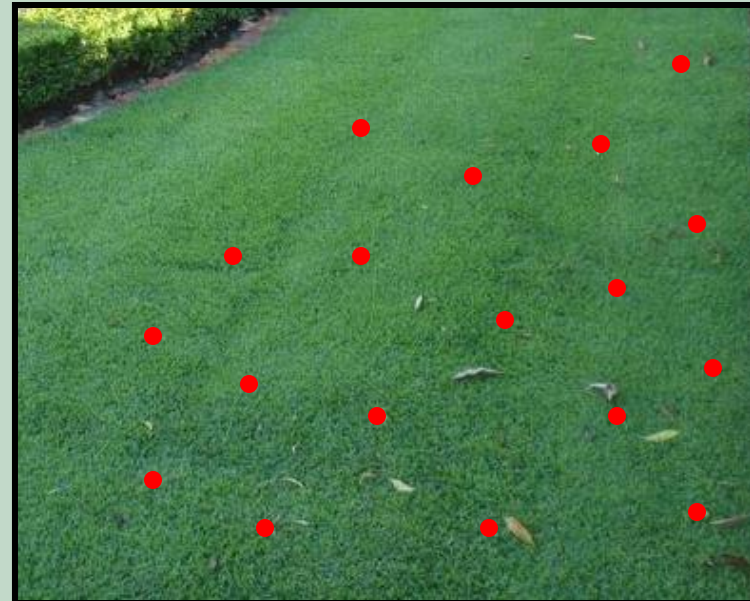
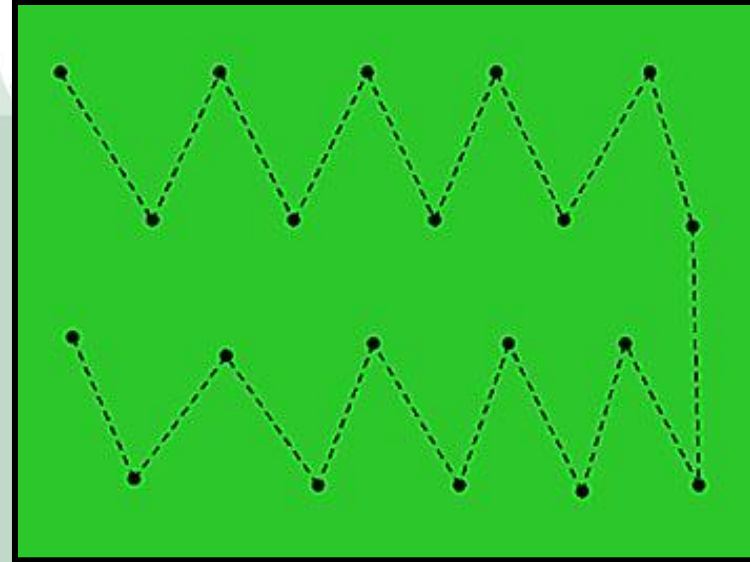


# Sampling for PPN in Turfgrass

## *No Symptoms / Pre-Plant*

- Collect sample as instructed by lab.
- Sample in a “zig-zag” pattern.
- Using a shovel, trowel, or core sampler, collect from approx. 20 locations.
- Combine soil into a bucket, gently mix thoroughly, and remove ~one pint for analysis.
- Place sample in plastic bag, seal securely, and label the bag with a permanent marker.
- Store in a cool place, preferably a cooler or fridge, until shipping.
- Ship ASAP, preferably overnight, for analysis.

Note: The accuracy of the diagnosis depends on the quality of the sample.



# Sampling for PPN in Turfgrass

- Proper sampling is critical to ascertain if PPN are a problem.
- PPN are not distributed evenly
- Take approximately 20 cores per area
- Sample 3-4 inches deep
- *Again*, the accuracy of the diagnosis depends on the quality of the sample

171	31	9	135	280	143
266	214	19	7	197	32
710	470	107	4	149	8
88	23	50	25	427	26
331	162	29	439	64	59
105	53	11	44	52	34
33	28	158	4	264	4

PPN count from 4' x 4' squares.  
Note variability of PPN population across area

# Sampling Depth

The slide features a decorative header with a light green background. At the top right, there are silhouettes of several spiky plants, possibly sunflowers or similar, in a darker shade of green. Below this, a horizontal band of stylized grass blades spans the width of the slide. The main content area has a solid light green background.

- Pre-plant samples - normally taken 8-10 inches deep.
- Post-plant samples - Depends on the crop; think about how deep the root system is.
  - Annual Crops (vegetables & annual bedding plants: 6-8 inches deep
  - Trees and Shrubs: 8 to 10 inches deep
  - Turf: 3 to 4 inches deep

# Sample at the Right Time



- Nematode populations fluctuate throughout the year.
  - May be undetectable during winter/early spring
  - Often increase to very high populations by early fall

# Sample Processing at U of FL Nematode Assay Lab

## Soil

100 cc Subsample



Wash through several sieves  
to remove debris



Centrifuge to compact



Re-centrifuge w/ sugar suspension



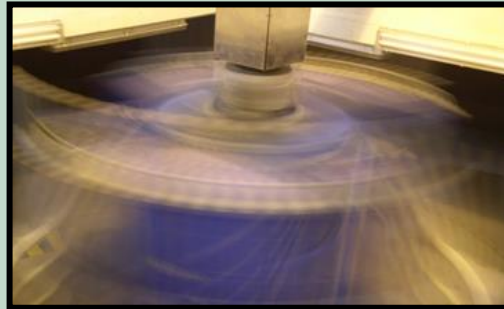
Wash into fine sieve



Remove sugar w/ fresh water



Count nematodes under  
stereomicroscope



## Roots / Corms / Etc.

10 g roots



Coffee Filter



Screen



Mist Chamber



72 hrs



Count nematodes under  
stereomicroscope



# Ten Ways to Destroy a Nematode Sample (Don't Do These...)

- Dry the soil before bagging it.
- Put the sample in a large box so it can rattle around during shipping.
- If taking multiple samples, don't label the bags – let the lab figure it out.
- If shipping in a zip-lock bag, don't put tape over the zipper. Hopefully it won't open up in transit.
- Send grass clippings instead of soil.
- Collect less than a pint of soil.
- Sample in areas of the grass that are dead.
- Keep the sample on your dashboard to bake in the sun.
- Send the sample without a filled-out form and payment.
- Send the sample out on Friday or just before a holiday.

# Nematode Assay Results



Results provide:

- Number of nematodes/100 cc soil
- Number of nematodes in 10 g roots
- Risk level measured against known thresholds for specific host.

Examples of current risk thresholds in St. Augustinegrass:

<u>PPN</u>	<u>Moderate</u>	<u>High</u>
Sting	25	50
Lance	40	120
Spiral	700	1500
Stubby Root	40	120

**NEMATODE ASSAY FORM**

Nematode Assay Laboratory  
 P.O. Box 119122  
 Building 970 Natural Area Drive  
 University of Florida  
 Gainesville, FL 32611-0620  
 Phone: (352) 392-1994  
 E-mail: nematlab@ifas.ufl.edu

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**GROWER/OWNER NAME AND ADDRESS**

Name

Address

City/State  Zip

Phone (  )  Fax (  )

E-mail

COUNTY  EXT AGENT

DATE COLLECTED

**CONSULTANT, PEST CONTROL COMPANY, etc:**

Name

Address

City/State  Zip

Phone (  )  Fax (  )

E-mail

Send Results To:  Grower  Pest Control/Consultant

By:  Mail  E-mail  FAX

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**Information Needed for Correct Interpretation of Assay Results:**

**IS THIS SAMPLE FOR:**

Diagnosis of problem of existing crop/plant

Advice for a future planting

Experimental data

**PLANT/CROP - species and variety if known:**

Present  Age

Previous  Future

**SYMPTOMS:** (✓) terms which describe the crop

Plant -  wilted  stunted  yellow  decline  dead

Root -  galls  stunted roots  root rot  pod rot

**SITUATION** (✓):  Commercial  Residential  Public

(✓) **ONE OF THE FOLLOWING:**

Field  Grove  Nursery  Golf Course  Lawn  Garden  Park  Playing Field  Landscaping

Containerized/Interior Ornamental  Other

**MAIN SOIL TYPE** (✓):  Sand  Clay  Muck  Artificial Mix  Marl

Size of crop area

Recent nematicide use, prior history of nematodes, other pertinent information

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Lab Sample No.  Date Received

Sample Status:  Paid  IFAS Service  Other (explain)



# Activity 2



## Nematode Sampling

- Many types of plant parasitic nematodes can be found in Florida soils. Symptoms of nematode damage resemble disease, improper cultural practices, and/or harsh environmental conditions. Laboratory analysis of the soil and plant roots is necessary to determine if nematodes are causing a problem.
- Refer to Activity 2 in your MG Handbook

# Acknowledgements



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