The HLB Era:

"manageable problems have become intolerable"

Larry Duncan
CREC

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"manageable problems have become intolerable"

Salinity
pH
Citrus blight
Phytophthora
Root weevils
Nematodes

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This morning

Root weevils & burrowing nematodes

Biology/Ecology
Management

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This morning

Root weevils & burrowing nematodes

Transgenic Rootstocks

(An overlooked aspect of GMOs for HLB control)

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The Post-HLB Era:

"longstanding problems have been solved"

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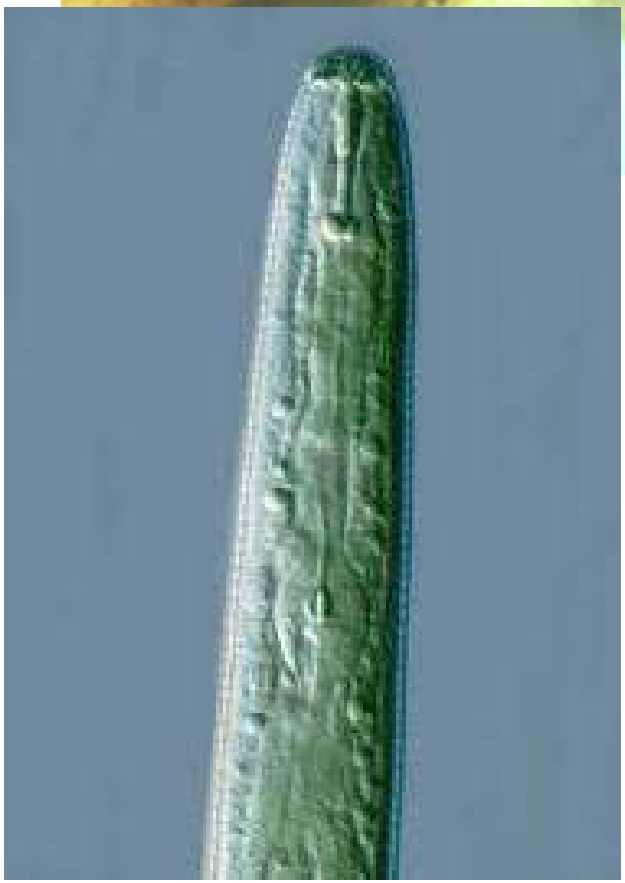
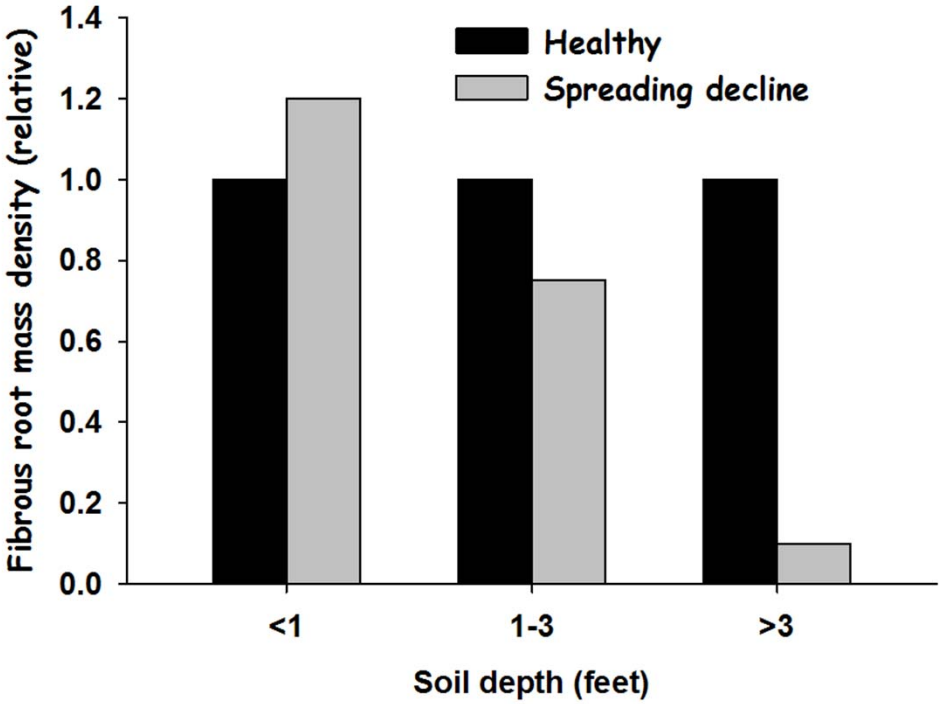


Spreading decline caused by *Radopholus similis* the burrowing nematode

Spreading decline caused by *Radopholus similis* the burrowing nematode



95 pounds of fibrous roots on 20-year-old healthy tree vs 35 pounds of roots on tree infected by burrowing nematode.

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Certified trees

Resistant rootstocks
- Kuharski Carrizo
- Milam lemon
- Ridge pineapple

Protect shallow roots
- Supplemental irrigation
- Fertigation
- No disking

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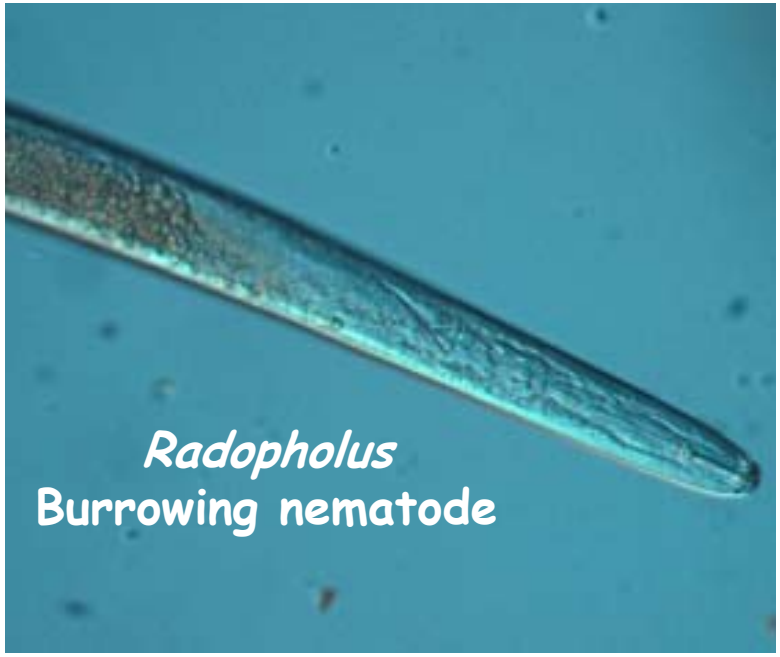
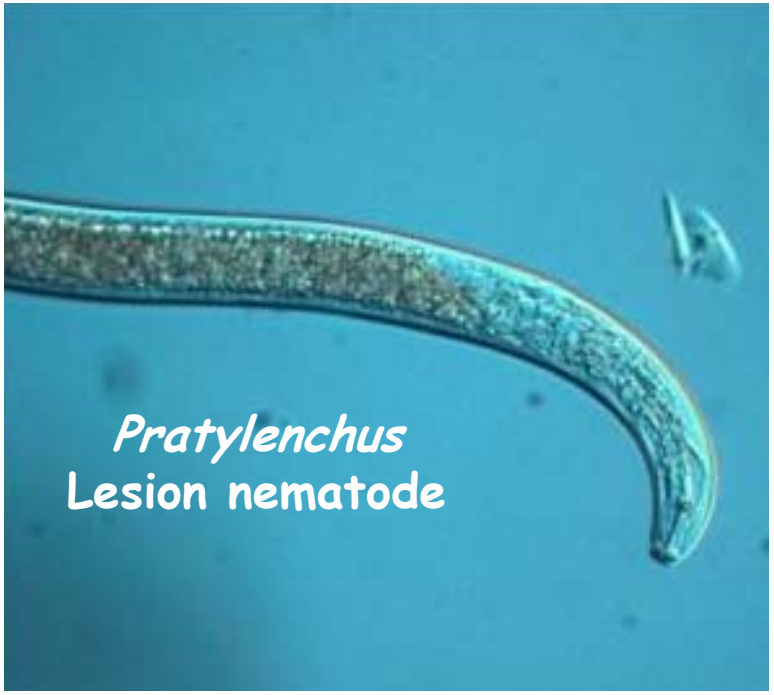
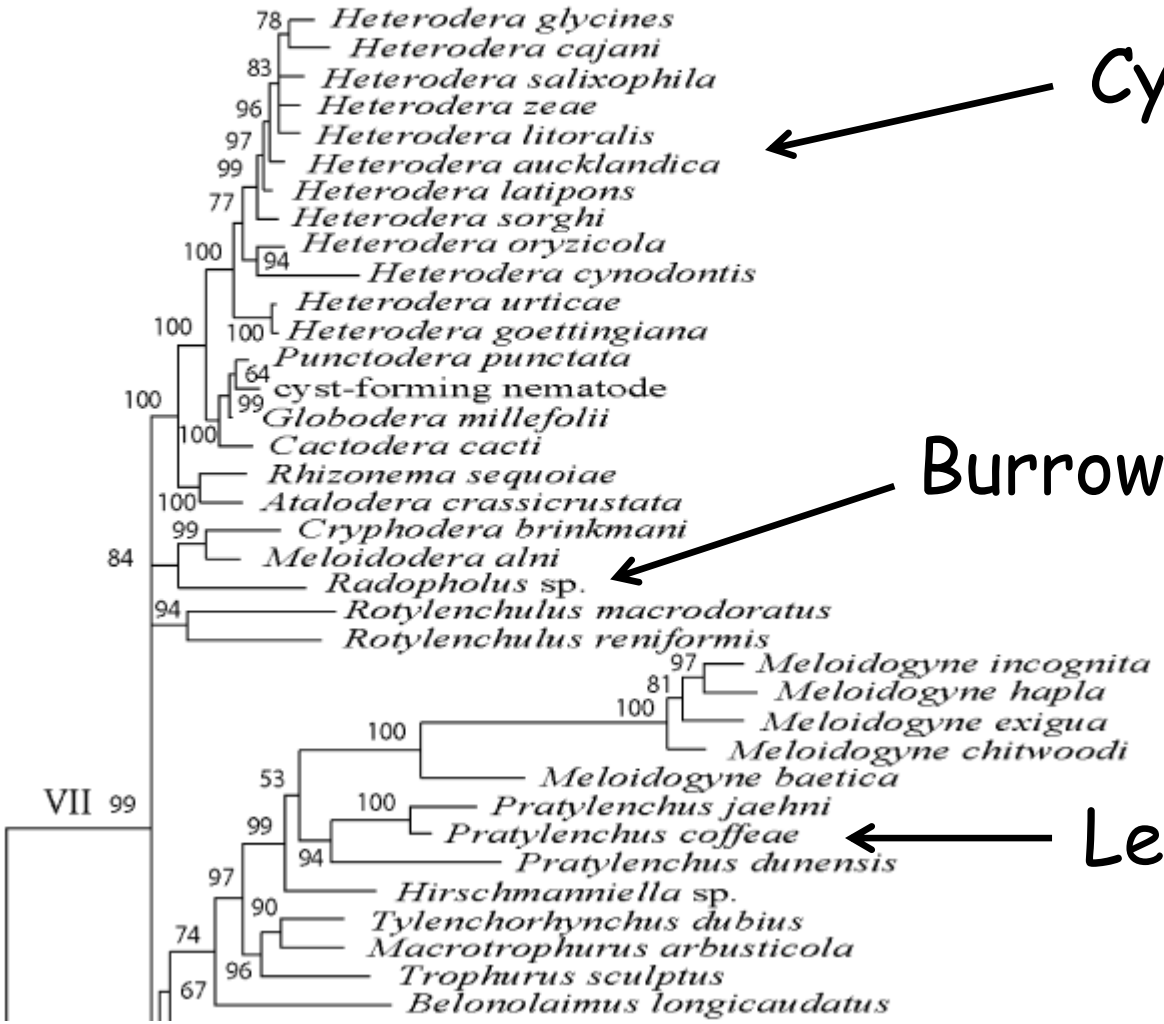




Which 2 are cousins?



Cyst nematodes

Burrowing nematode

Lesion nematodes

Subbotin et al., 2006, Nematology 8: 455-474

Journal of Applied Ecology 2002
39, 915–923

The effect of transgenic nematode resistance on non-target organisms in the potato rhizosphere

SUE E. COWGILL, RICHARD D. BARDGETT*, DAAN T. KIEZEBRINK and HOWARD J. ATKINSON

Transformed potato in 2002 to express a cystatin that disrupts digestion of certain proteins and also a peptide that interferes with sensory function of cyst nematodes.

Molecular Plant Pathology

MOLECULAR PLANT PATHOLOGY (2012) 13(8), 842–851 DOI: 10.1111/J.1364-3703.2012.00792.X

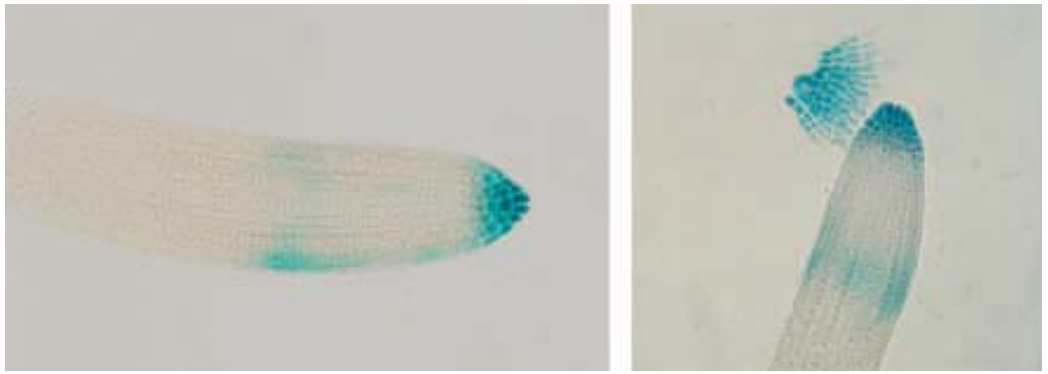
Generation of transgenic plantain (*Musa* spp.) with resistance to plant pathogenic nematodes

HUGH RODERICK[1], LEENA TRIPATHI[2], ANNET BABIRYE[2], DONG WANG[1,†], JAINDRA TRIPATHI[2], PETER E. URWIN[1,*] AND HOWARD J. ATKINSON[1]

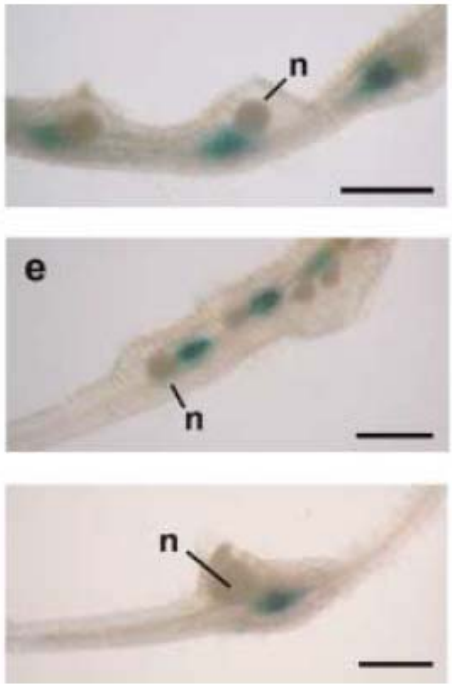
In 2012 transformed banana with these genes to confer resistance to burrowing nematode. Heavy use of nematicides currently required to grow banana.

Lilley et al. 2004 & 2011.
Plant Biotechnology Journal 2: 3-12
Plant Biotechnology Journal 9:151–161

AtMDK-20 (root cap promoter)



Tub-1 promoter



RB-7 promoter

Next generation transgenic rootstocks

- Inexpensive
- Durable resistance (multigenic targets)
- No environmental/safety risk

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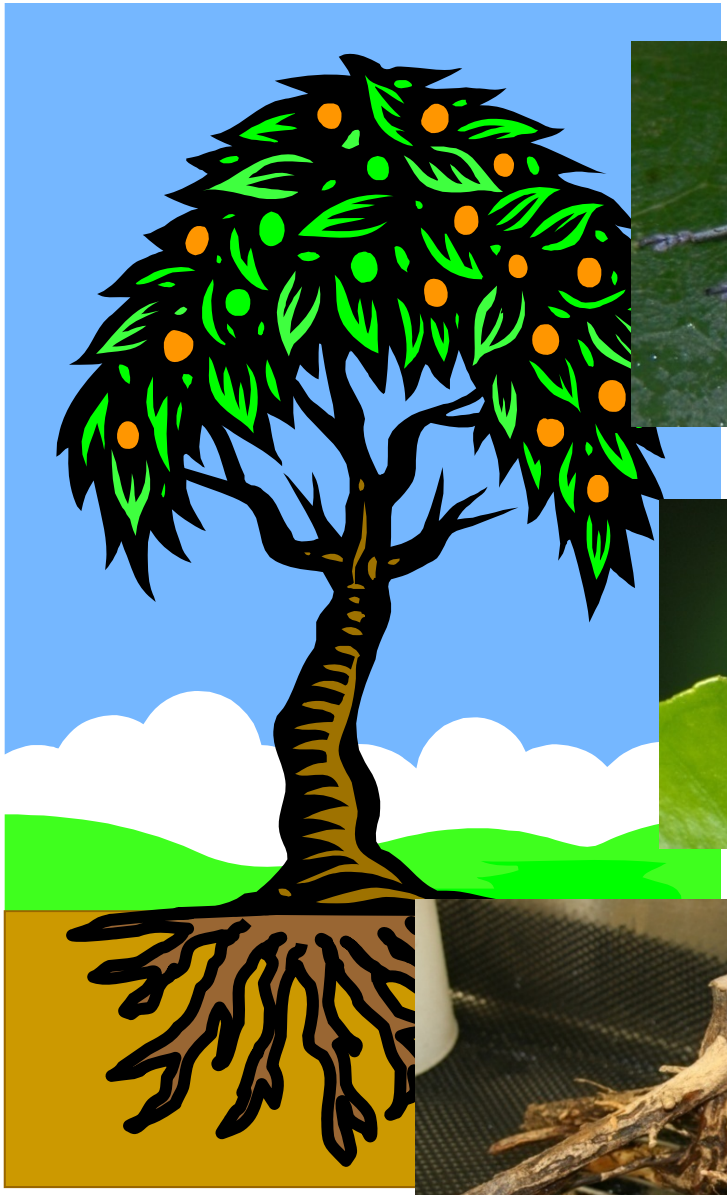

Citrus root weevils

Why so hard to manage?

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Basically…

Modern pesticides have little residual activity

Different weevil stages live in both the tree canopy and the soil. They serve as source of new individuals to replace those killed by management practices

Damage to roots is cumulative. Yearly damage by just a few larvae eventually kills trees.

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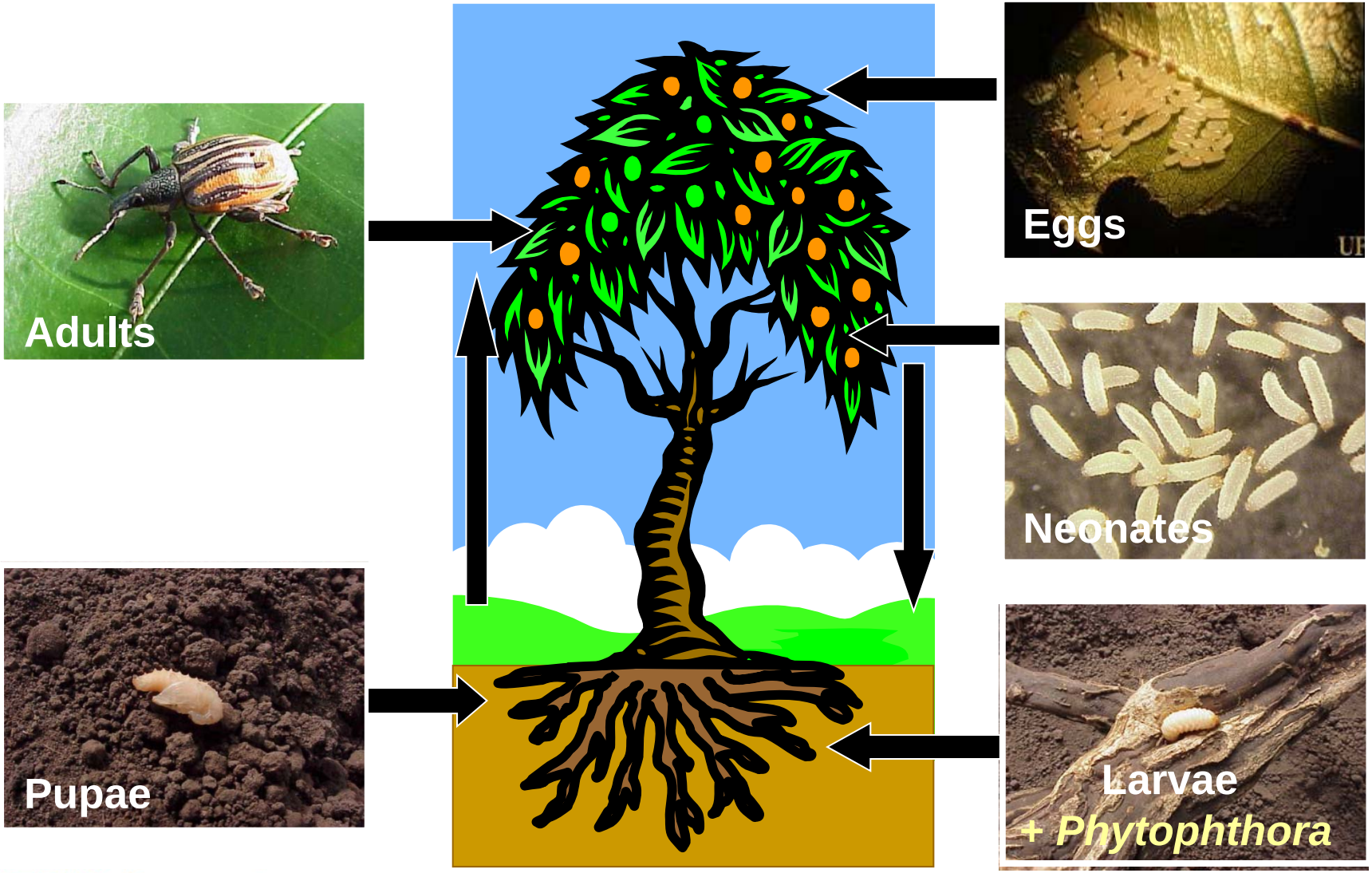
Diaprepes abbreviatus life cycle



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The fact that weevils comprise part of a pest-disease complex is the basis for an important management tactic…

While there are currently no rootstocks that are resistant or tolerant to weevils, they do exist for *Phytophthora* control.

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Diaprepes-Phytophthora complex evident on the sour orange trees, but not the Swingle citrumelo resets, in this DeSoto County grove.

Symptoms of the pest-disease complex on roots of sour orange

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Rootstocks for central ridge (*Phytophthora nicotianae*)

- Swingle citrumello
- Carrizo citrange
- C-35
- C-32

Rootstocks for flatwoods (*Phytophthora palmivora*)

- Cleopatra mandarin
- US-802
- US-897

Weevil management

- Rootstocks
- Regional considerations
- Cultural practices
  - Soil drainage
  - pH
  - Physical barriers
- Insecticides (monitoring weevil abundance)
- EPNs

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The Diaprepes Root Weevil

(Diaprepes abbreviatus) is a major pest of crops and ornamental plants in Florida and the Caribbean Basin. The Diaprepes Task Force was organized in 1993 to coordinate and facilitate research, education and regulatory efforts to manage this pest more efficiently.

Diaprepes Task Force members include growers as well as scientists and administrators from Florida Department of Agriculture and Consumer Services - Division of Plant Industry, the University of Florida - Institute of Food and Agriculture Sciences, and the United States Department of Agriculture - Agriculture Research Service.

Battling the Evil Weevil: Recent Advances in the War on Diaprepes abbreviatus

Robin J. Stuart and Michael E. Rogers
This article appeared in Citrus Industry 87: 7-11 (2006).

The Diaprepes root weevil, *Diaprepes abbreviatus*, was first detected in Florida over 40 years ago and continues to be a major cause of tree decline and death in certain citrus

Diaprepes Task Force website has biliography of all research papers, general information and dichotomous management key for 8 common grove situations

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Scenario 2

Diaprepes weevils are sometimes less damaging to citrus growing on the Central Ridge than in other parts of Florida. The numbers of these insects are often lower on the Central Ridge (Futch et al. 2005), possibly because conditions there favor the natural enemies of the weevil larvae in the soil (Duncan et al., 2005). The incidence of *Phytophthora*-induced foot rot and feeder root rot is also lower in the well drained, sandy soils on the Central Ridge than in finer textured, poorly drained soils in the flatwoods (Graham and Timmer, 2007) The greatest threat from Diaprepes on the Central Ridge is that feeding by the insect allows *Phytophthora nicotianae* to cause damage similar to that done in the flatwoods (higher incidence of foot rot). Citrus rootstocks that resist or tolerate feeding damage by Diaprepes are unknown. Therefore, the primary consideration on the Central Ridge is selecting a rootstock best suited to resist infection by the species of *Phytophthora* (*Phytophtora nicotianae*) that occurs there. Swingle citrumelo, Carrizo citrange, C-32, and C-35 are trifoliate orange hybrid rootstocks that are well adapted to the soils of the Central Ridge and that resist damage by this fungus better than other available rootstocks.

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Each of 8 common scenarios provides links to resources from which recommendations were derived

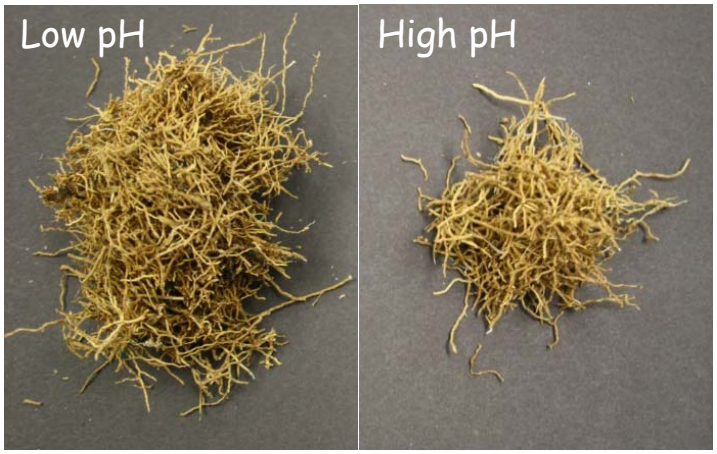
Cultural practices

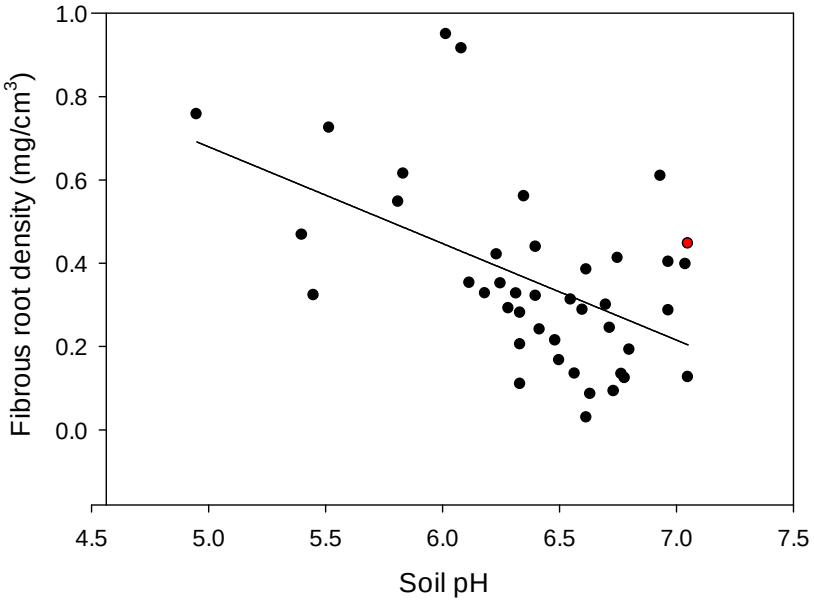
Soil drainage is critically important because weevil abundance and therefore root damage is greatest in wet soil. Trees stressed by wet soil are less tolerant of weevil damage. Some natural enemies of weevils are less abundant in wet soil.

Campos-Herrera et al., 2013 Soil Biology and Biochemistry

Cultural practices

Soil pH is critically important because many rootstocks are less tolerant of stress in high pH soil (>6.5) and because some important natural enemies of weevils are intolerant of high pH soil.

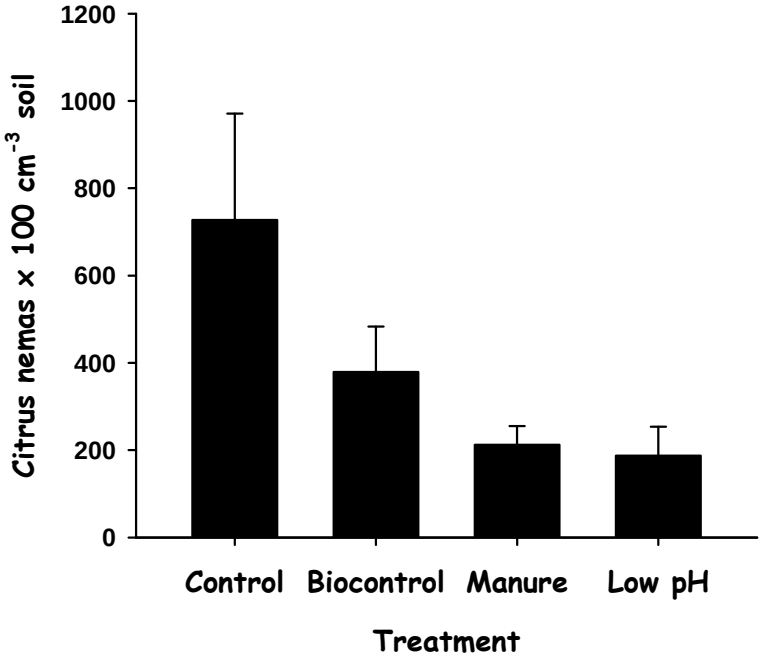


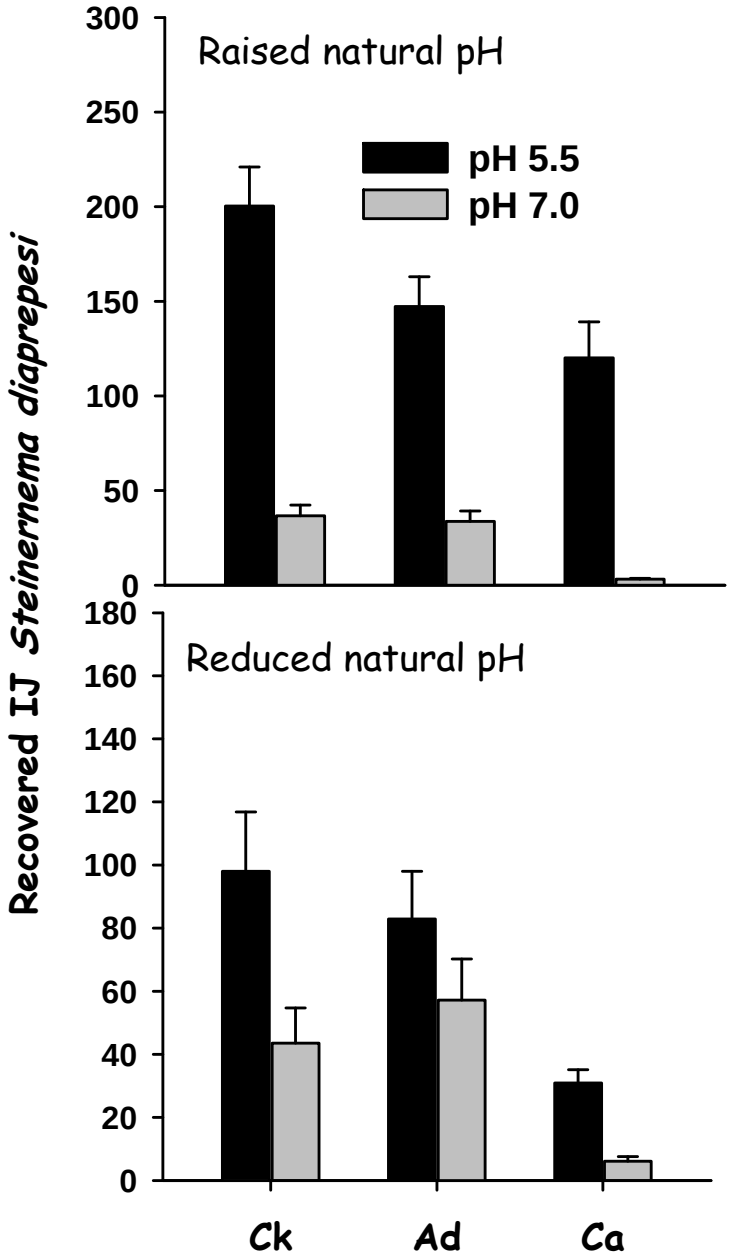


Graham et al., 2013. Plant Disease

Cultural practices

Soil pH is critically important because some entomopathogenic nematodes are intolerant of high pH soil, whereas some plant parasitic nematodes are favored by high pH.





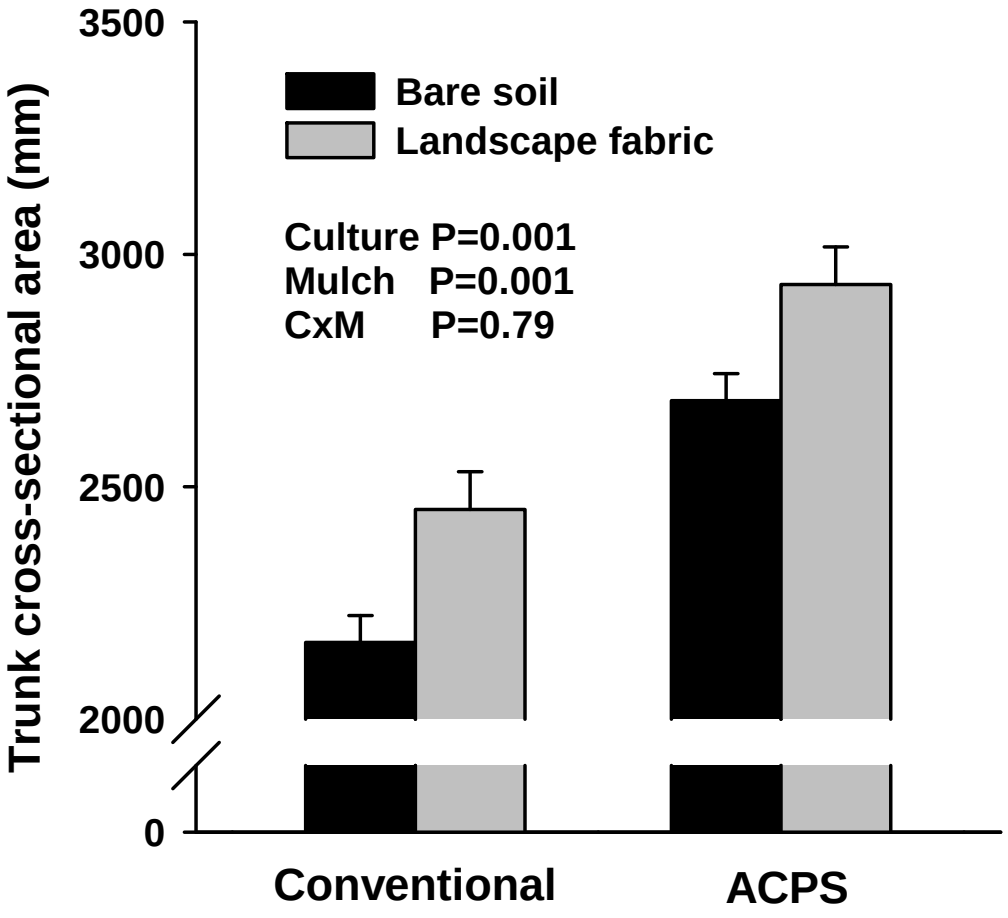
Cultural Practices

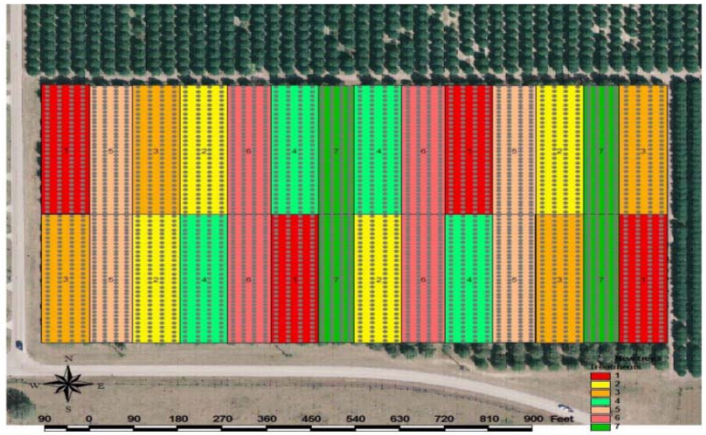
Landscape fabric can be installed as a barrier to prevent larvae from entering soil and adults from exiting soil

McKenzie et al. 2001
Duncan et al 2008

The integrity of these barriers was maintained for 5-6 years. Herbicide savings equaled the fabric cost.

Typical effect of landscape fabric mulch on tree growth





In an experiment measuring effects of Advanced Citrus Production System (ACPS) versus conventional citriculture (CC), we also installed landscape fabric under some trees.

ACPS trees were 25% larger than CC trees, but only 9% larger than mulched CC trees.

Mulched ACPS trees were 35% larger than conventional trees.

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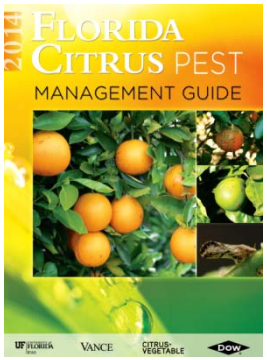


Chemical management of aboveground weevil stages

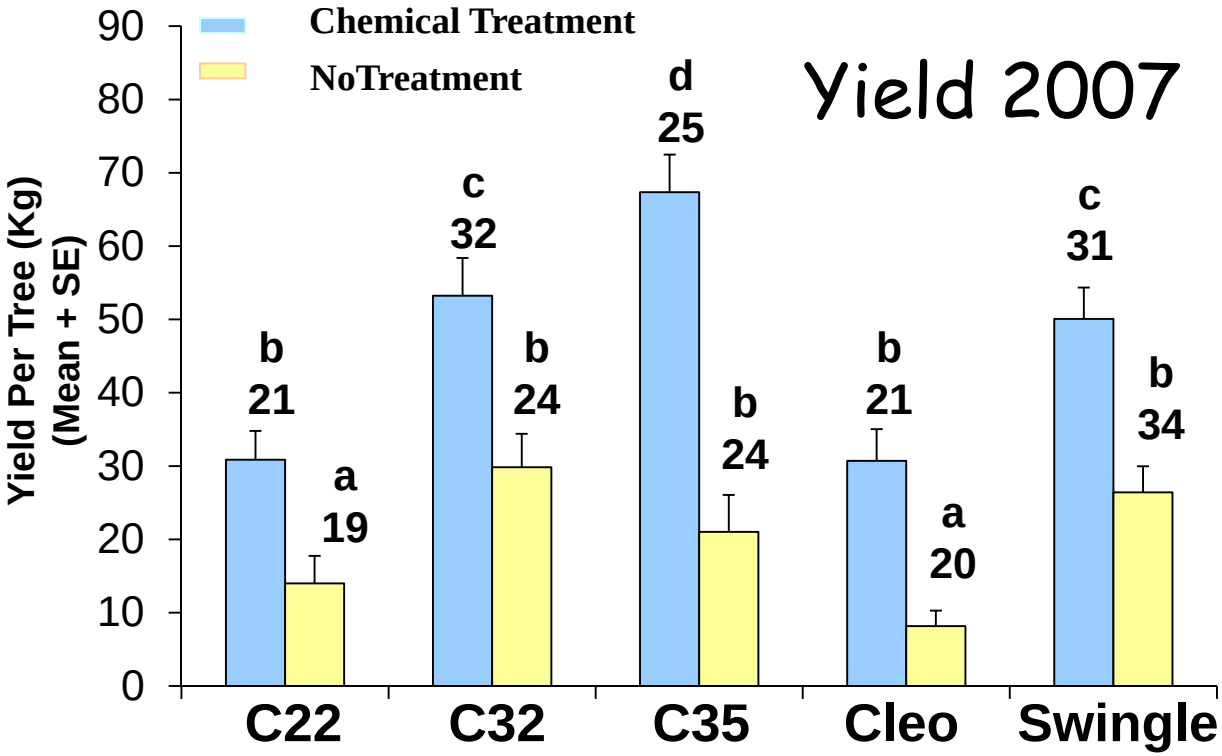
Monitoring peak abundance is important for timing pesticide application

Adulticide combined with ovicide is most effective

Egg laying begins 7-10 days post emergence of adult from soil

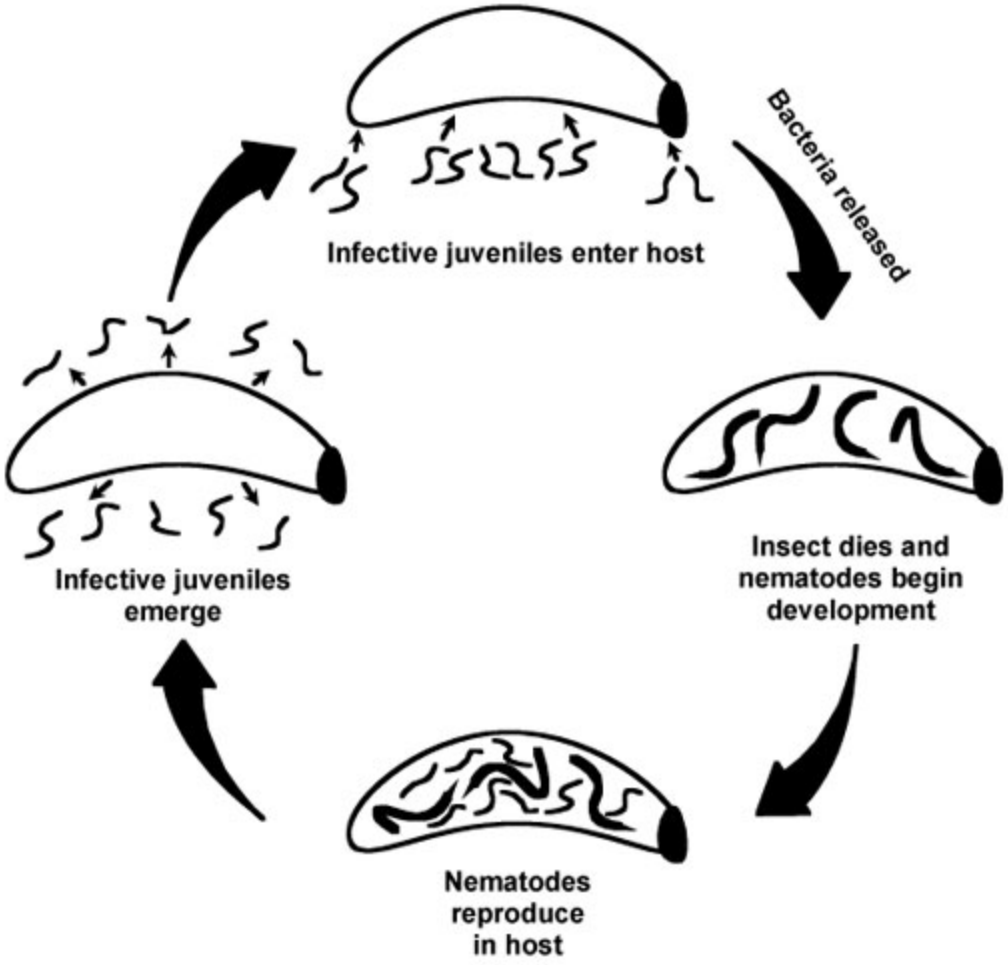
Choice of adulticide should be integrated with rotation schedule for psyllid resistence management

Chemical management of aboveground weevil stages



Remember, rootstock is also critical and choice is based on *Phytophthora* species present at site.

EPNs function in association with entomopathogenic bacterial symbionts that provide nutrients and protection from competitors



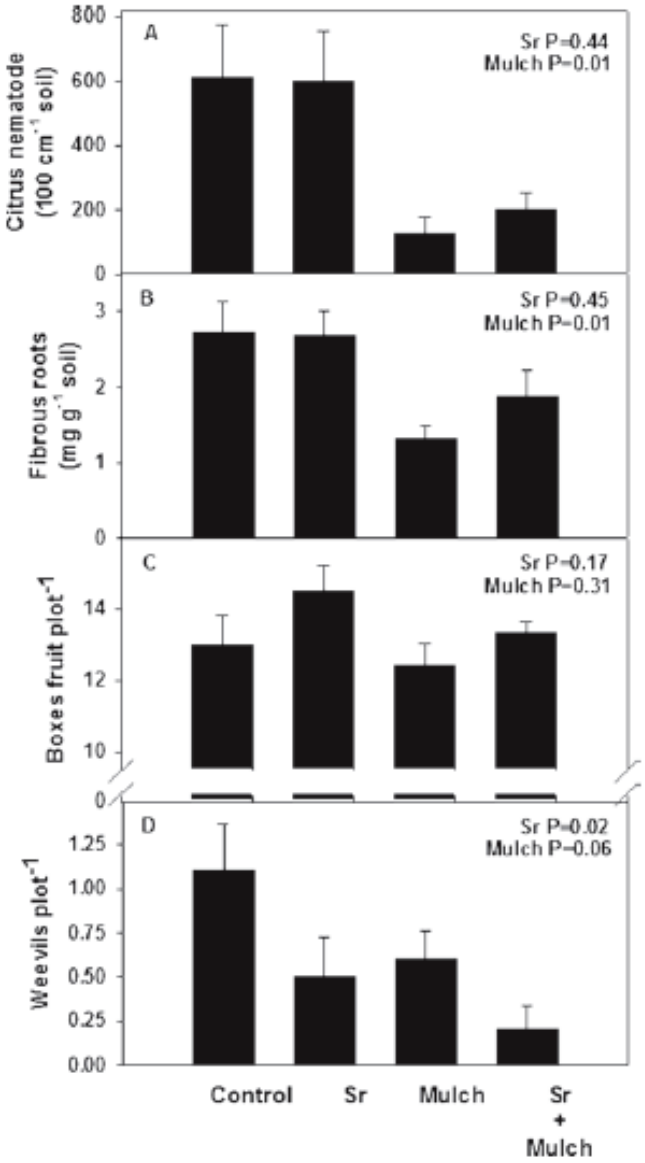
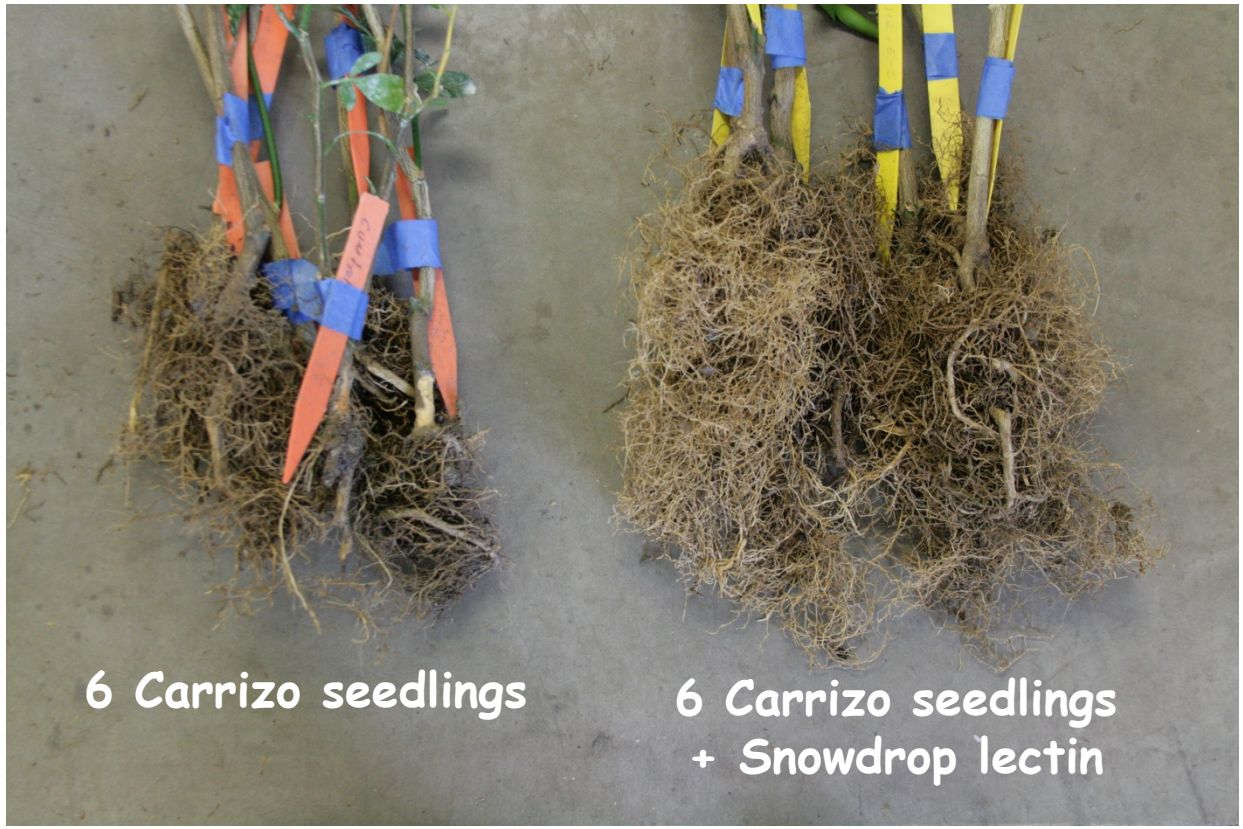


FIG. 9. The effects of *Steinernema riobrave* and composted animal manure mulches on the numbers of *Tylenchulus semipenetrans* in soil (A) and the mass density of citrus fibrous roots (B) on 2 February 2006, the numbers of 41-kg boxes of citrus fruit per plot on 2 June 2006 (C) and the numbers of adult citrus root weevils emerging from soil during one year beginning in October 2005 (D).

EPNs @ 25 IJs / cm^2 reduced adult weevils by >50%

Duncan et al. 2007 J. Nematology

Transgenic sources of resistance/tolerance



Promising resistance genes from plants such as *Galanthus nivalis* (snowdrop) have been introduced into Carrizo citrange and are being evaluated for weevil management

Conclusions

Synergism between HLB and other causes of stress to the citrus root system creates urgency in the need to manage all root stressors and to find ways to improve available IPM tactics.

Research supported in part by:

Citrus Research and Development Foundation
Marie Curie Foundataion (EU)
Ministry of Science and Innovation (Spain)

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