Microbiology of an Orchard Soil

David Eissenstat

Penn State University

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Introduction

- Many kinds of microbes, both beneficial, neutral and parasitic
- Trophic levels: saprotrophs, predators, herbivores, parasites.
- Includes fungi, bacteria, arthropods (mites, insects, nematodes

Outline

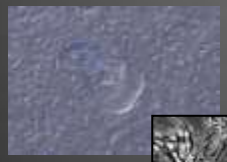
- Microbial communities and cultural practices
- Mycorrhizal and nonmycorrhizal fungal interactions with roots
  - Effects of root age and root growth rate
  - Effects of cropload and soil nutrient availability
- Root herbivores

Functional Roles of Soil Microbiology

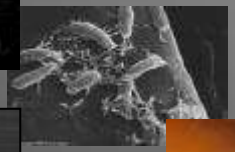
Root development

Nematodes

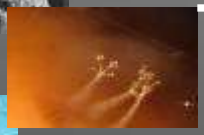
Protozoa



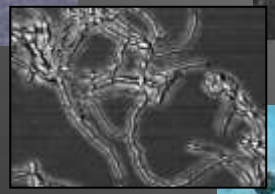
Bacteria



Nutrient cycling



Fungi



Actinomycetes

Oomycetes

Lesion nematode

Phytophthora

Pythium

Suppress plant pathogens

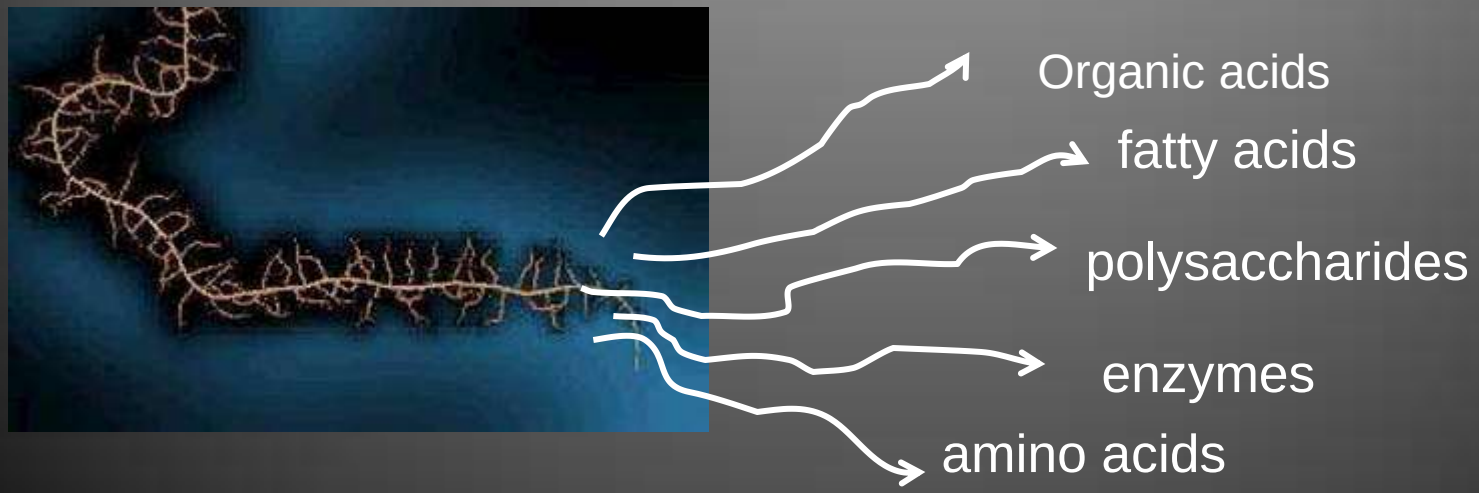
Credit: M. Mazzola

Bulk Soil vs Soil by Root (Rhizosphere)

- Area around root much richer in nutrients that microbes feed upon
- Bulk soil for microbes is like a microbial desert
- Vast majority of microbes located in rhizosphere.
- Microbial community composition of rhizosphere does not resemble that in bulk soil.

Plant-driven selection:

Rhizo-deposition accounts for 30-40% of total OM input to soils



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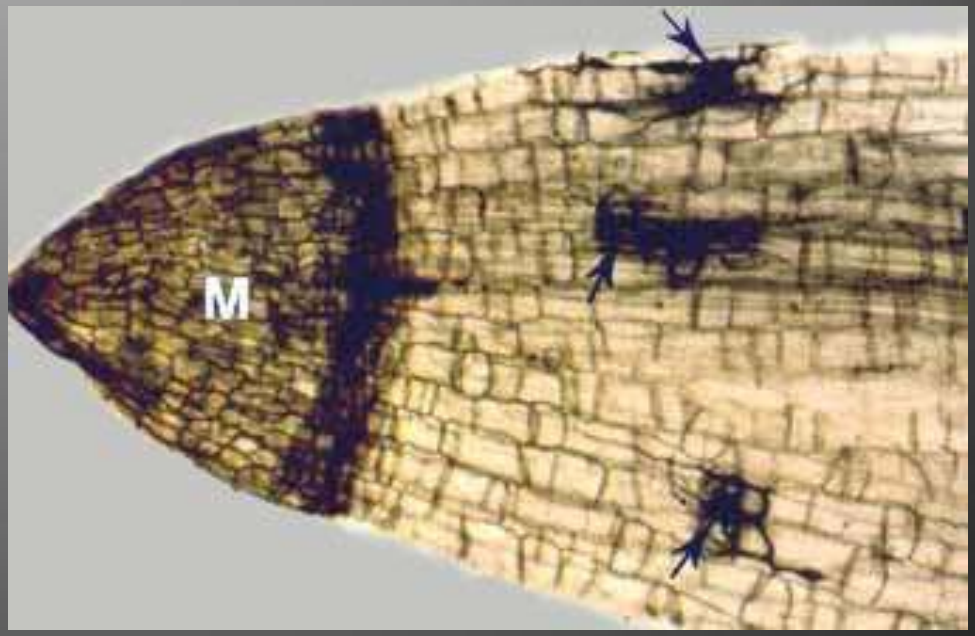
Mycorrhizas

- Arbuscular Mycorrhizal (AM) Fungi
- Fungal taxon Glomeromycota.
- Historically considered to be generalists but now specialization is being observed more frequently with molecular techniques
- Colonize by far the most diverse plant taxa of mycorrhizal fungi

AM
Mycelium Infection Sites

- Hyphae enter the root into the cortex, penetrating the cell walls (but not the cell membrane-endomycorrhizas)



*Smilacina racemosa.*Woodland perennial with metacutnized (M) root cap and AM fungal hyphae (arrow). Mark Brundrett http://www.ffp.csiro.au/research/mycorrhiza/

AM Arbuscule

- Finely branched in intimate contact with plant plasmalemma.
- Probable site for nutrient exchange

Arbuscule of *Glomus mosse. (*Bar = 10um)
Mark Brundrett;
http://www.ffp.csiro.au/research/mycorrhiza/

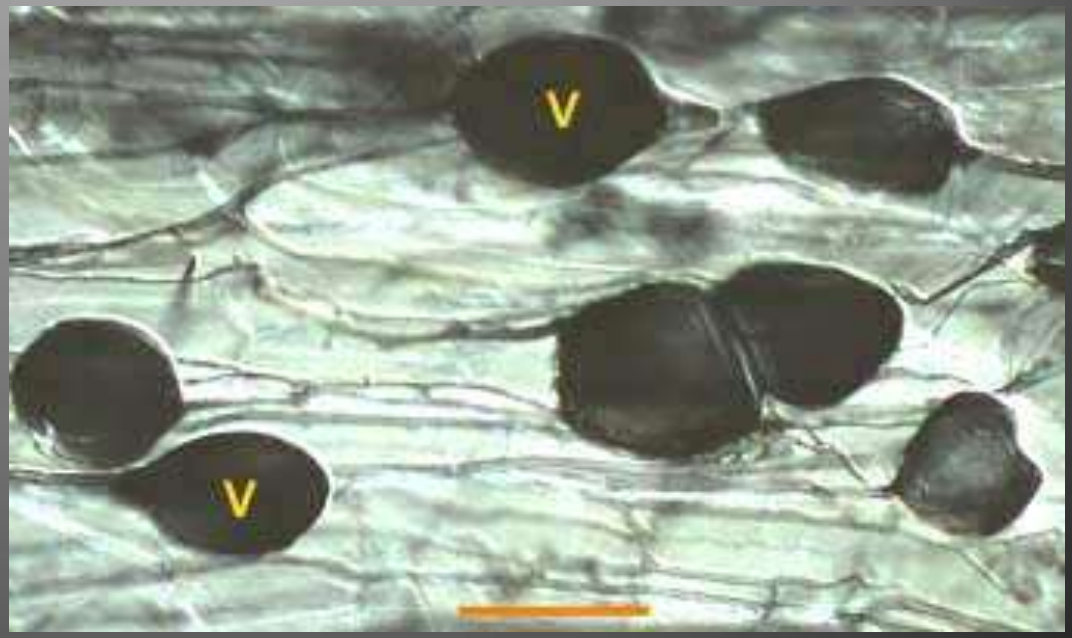
AM Cell Penetration

- Mycorrhiza fungal mass may represent a significant portion of the cell biomass.
- Thus an appreciable fraction of root biomass may be fungal

Glomus virsiforme arbuscule heavily branched in cell (bar 10 um)*;* Mark Brundrett; http://www.ffp.csiro.au/research/mycorrhiza/

AM Vesicles

- Most AM fungi produce vesicles
- Often present in older roots
- Source of nutrient storage (rich in lipids)
- May also serve as propagules



Glomus vesicles (V) and intracellular hyphae in leek root (bar 100 um). Mark Brundrett: http://www.ffp.csiro.au/research/mycorrhiza/

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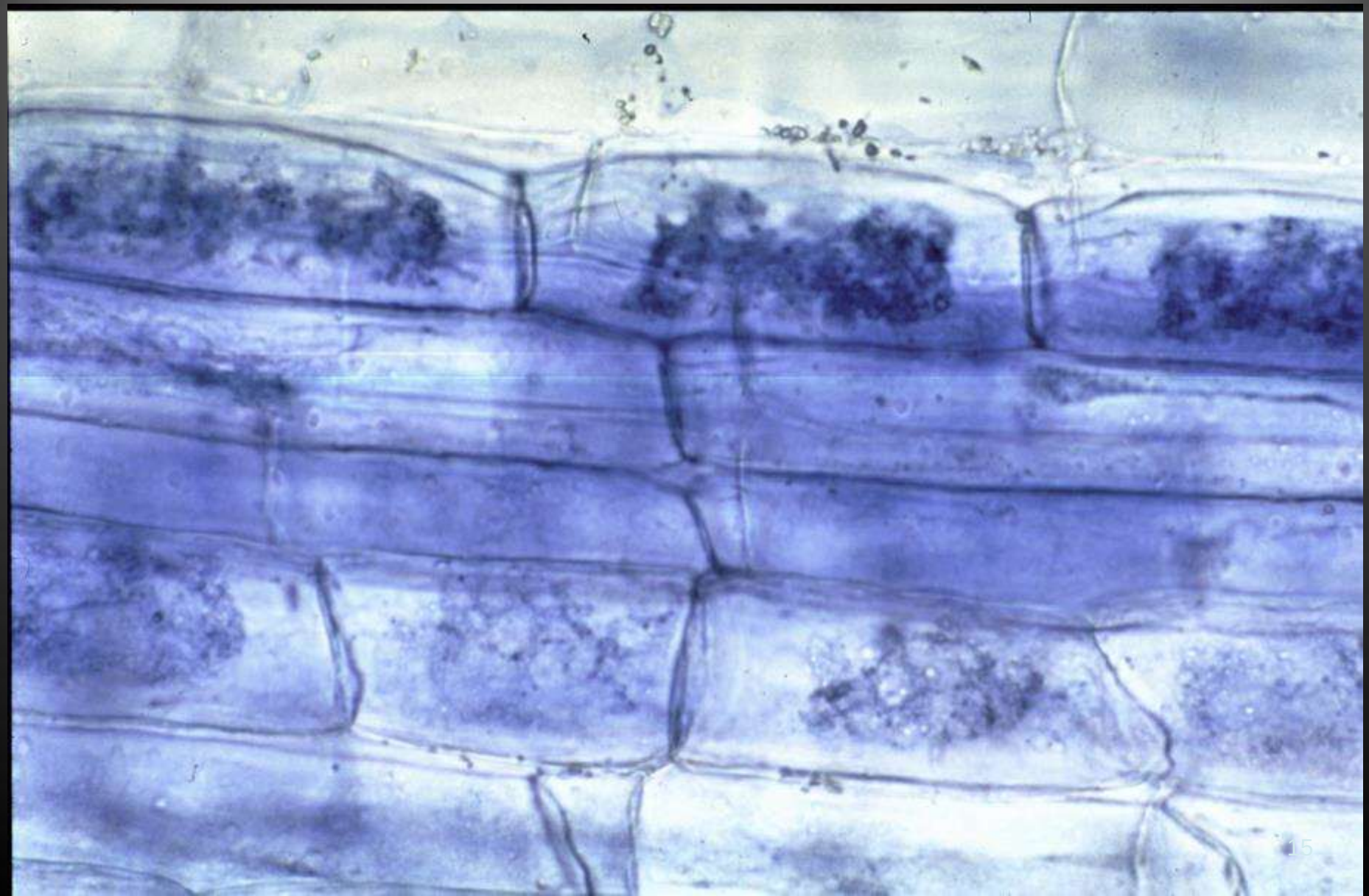
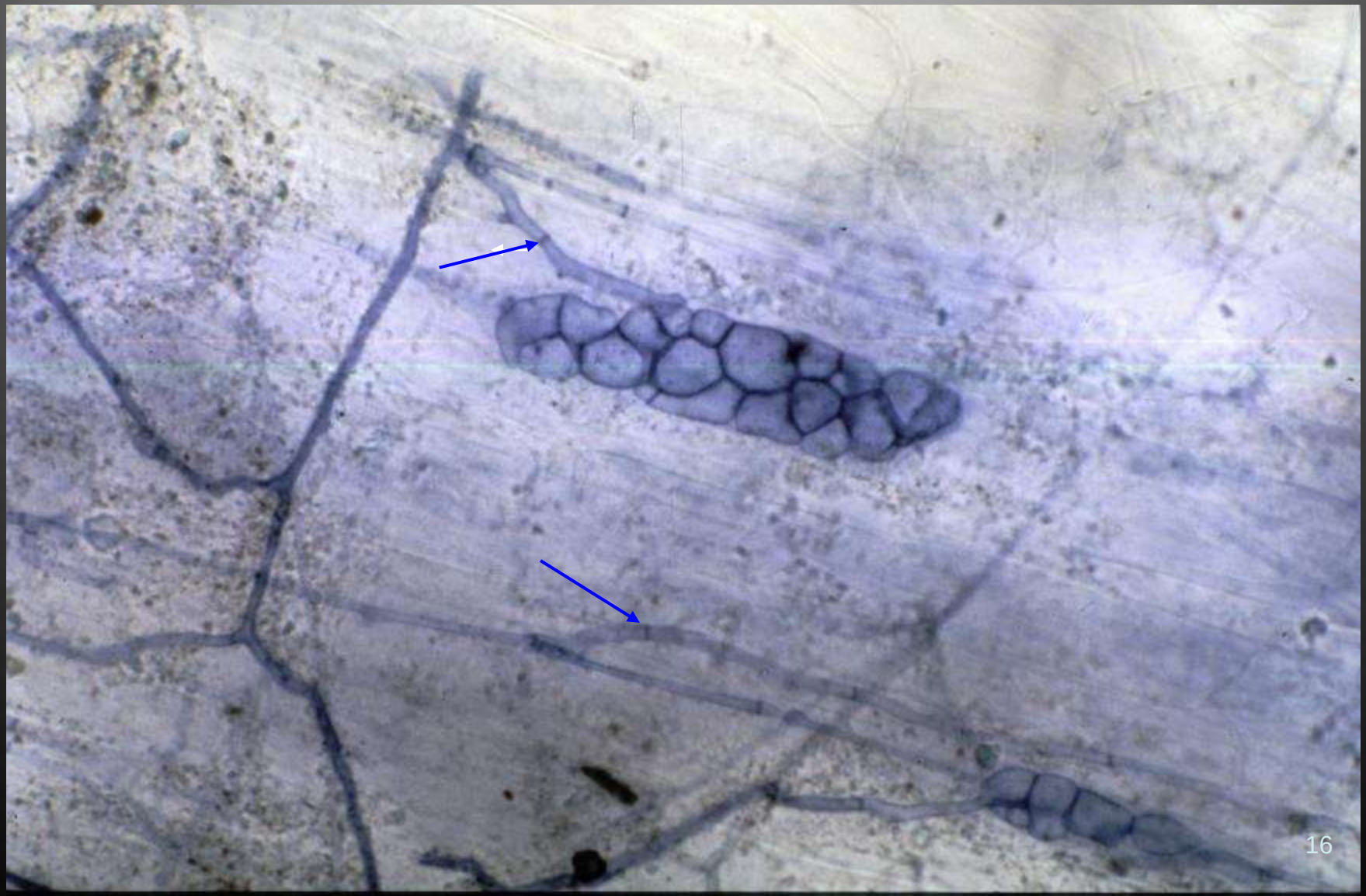
Taking a root-centric view on mycorrhizal and non mycorrhizal fungi

Absorptive Apple Roots with Arbuscules



Nonmycorrhizal Fungi

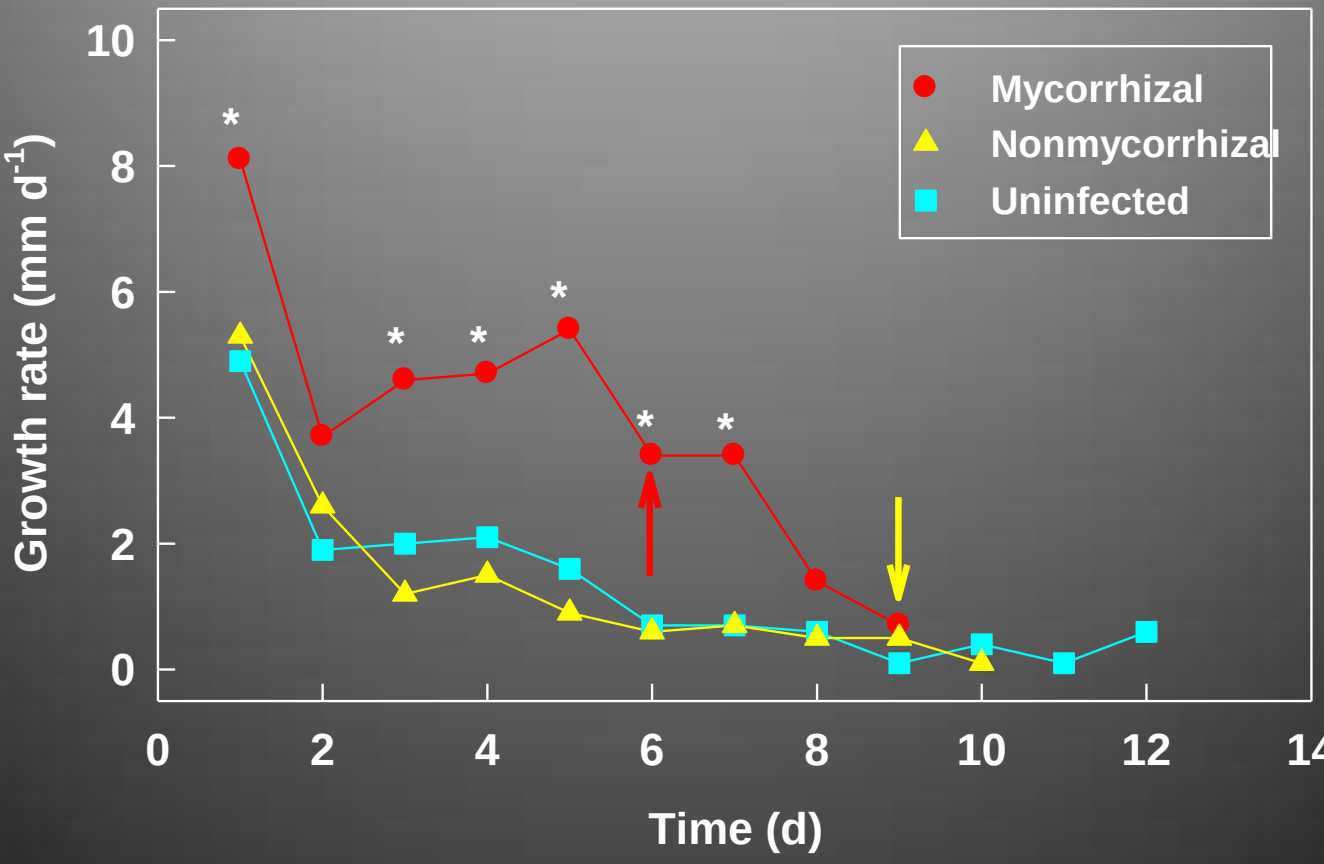


Proportion of Young Roots Either Infected or Uninfected by Mycorrhizal or Nonmycorrhizal Fungi

	Type of root fungi (%)	
	Fall 1997 (*n*=69)	Spring 1998 (*n*=44)
M fungi	28.1	42.3
NM fungi	50.0	11.5
Uninfected	21.9	46.2
M + NM fungi	0	0

Resendes et al. 2008 *Plant and Soil*

Infection During Early Root Development



Resendes et al. 2008 *Plant and Soil*

Summary I

- Small differences in roots at birth might lead to very different microbial colonization
- Understanding variation at the individual root level with regards to traits like age, growth rate, and diameter may provide new insights into root-microbe interactions.

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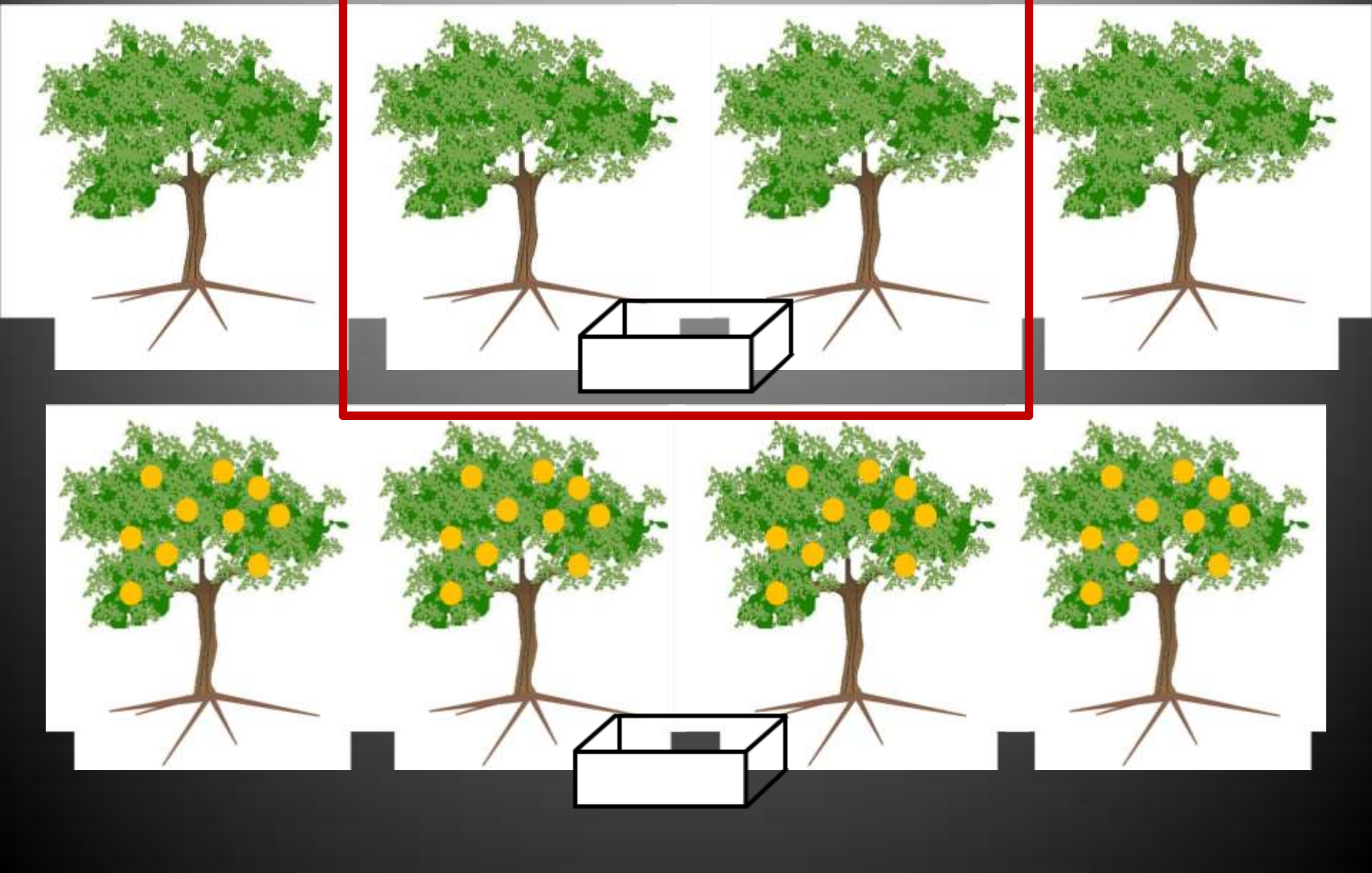
Carbon Supply and Soil Microbes

Manipulation of Carbohydrates



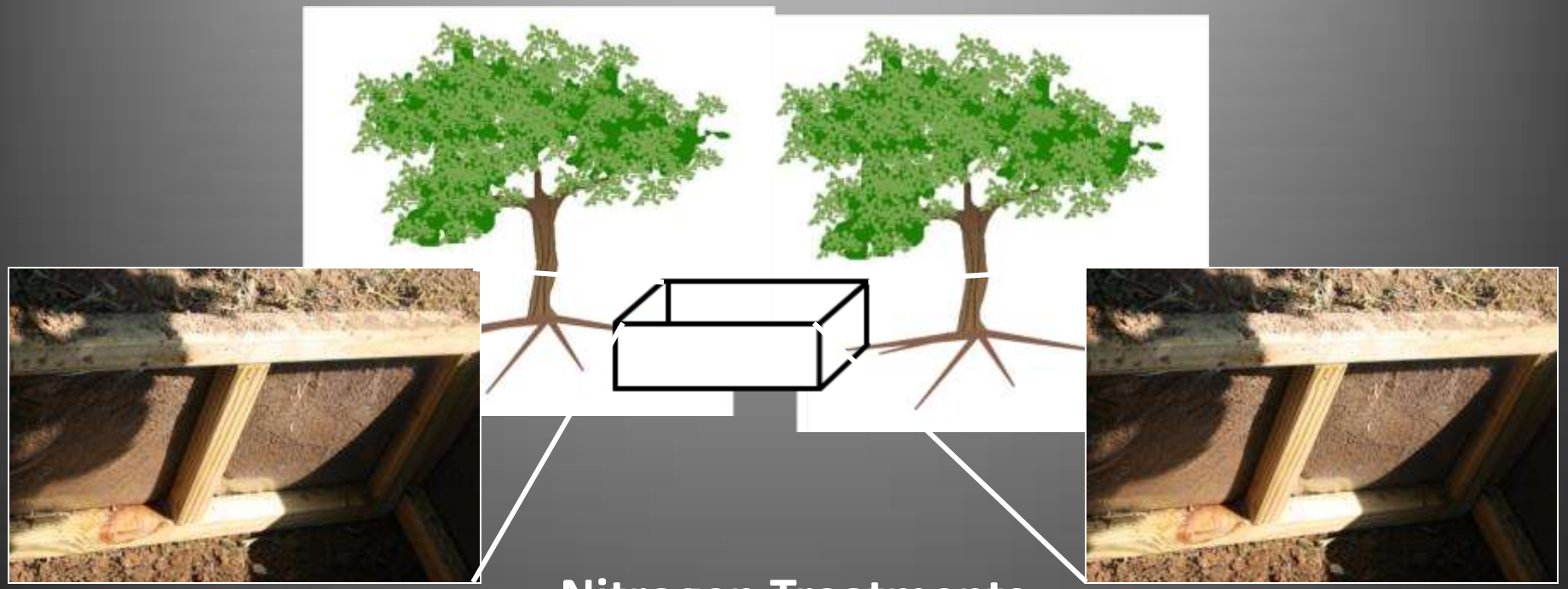
Root Observations in Rhizotrons

- 20 rhizotrons (EUs)
  - Between 2 apple trees
  - Installed in May 2013
  - 4 plastic windows

Application of Nitrogen Patch

- Control: 20 mL de-ionized water
  - –Applied weekly
- Organic: 5 g DW of ground apple leaves
  - –Estimated 5% release of N weekly
  - –Applied once
- Urea: 20 mL of 70 ppm N
  - –Equivalent to organic release
  - –Applied weekly

Addition of Localized Nitrogen Patch



Nitrogen Treatments

- Applied to 3 of 4 windows in each rhizotron
- 1 N treatment applied per window
- Applied at root emergence, May 31, 2013

Belowground Measurements

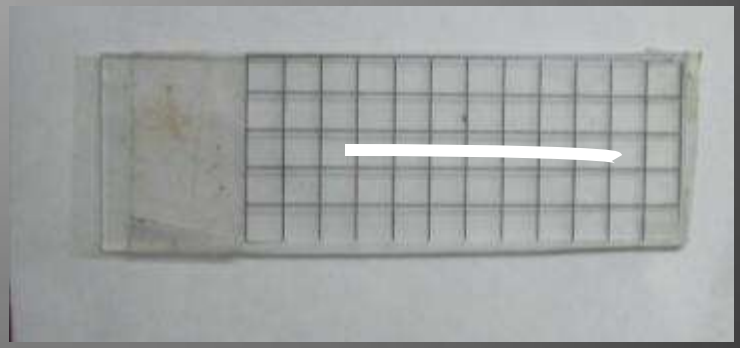
- Traced new root proliferation weekly
- Traced every other day, 3 to 5 days before harvest
- Traced daily, 3 days to harvest
  - May 31 – Aug. 14, 2013
  - Sept. 24 - Oct. 25, 2013

Root Harvest and Data Collection

- For both sampling dates
  - Removed plastic windows to harvest roots
  - Collected roots in tubes and stored at 4˚C for analysis
- Root length and number by color
  - Scanned plastic from windows for image analysis
  - Recorded root length in WinRhizo Pro 2007

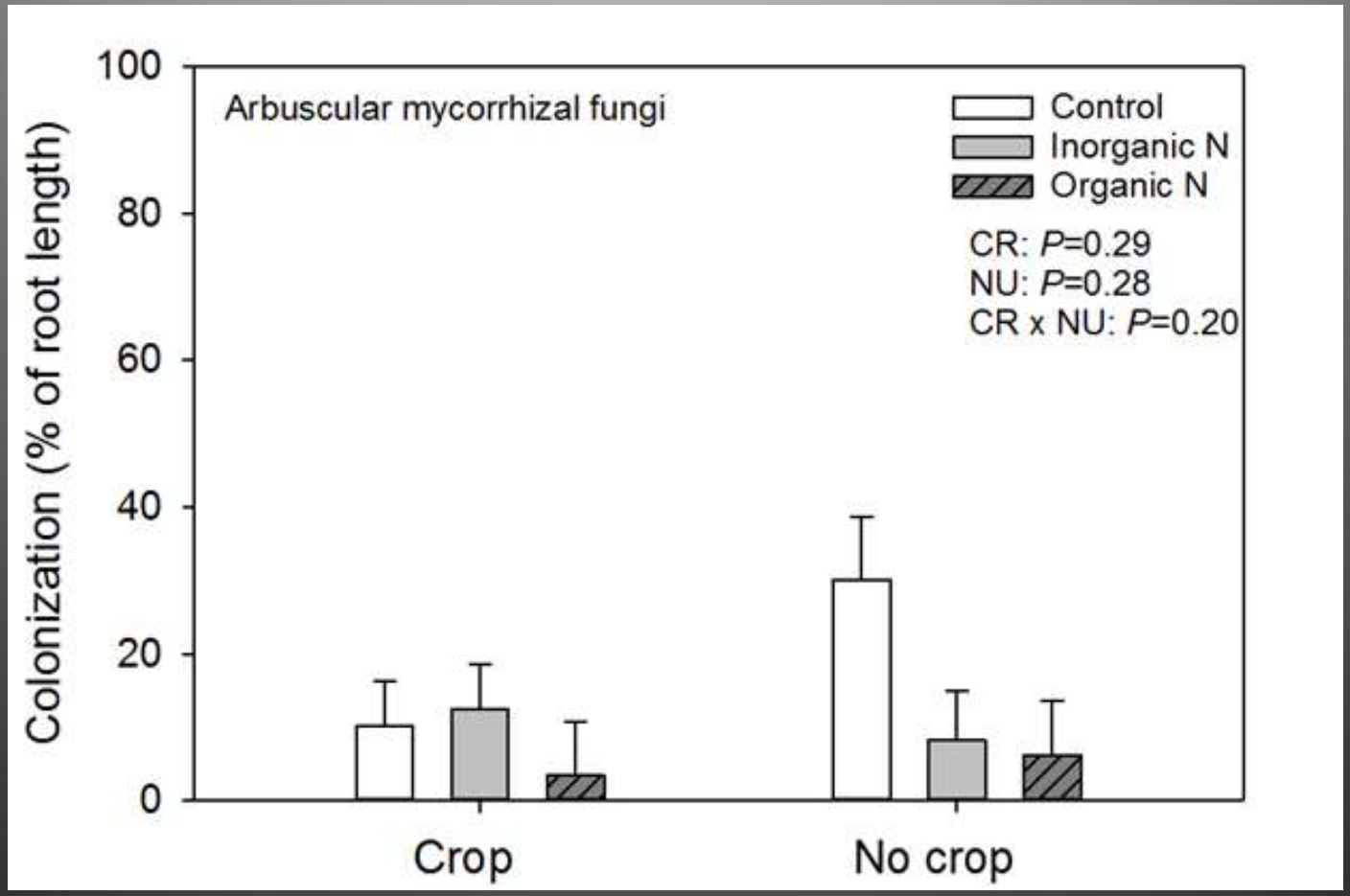
Quantification of AMF

- Microscopic observation
  - Trypan blue
  - Modified line-intercept



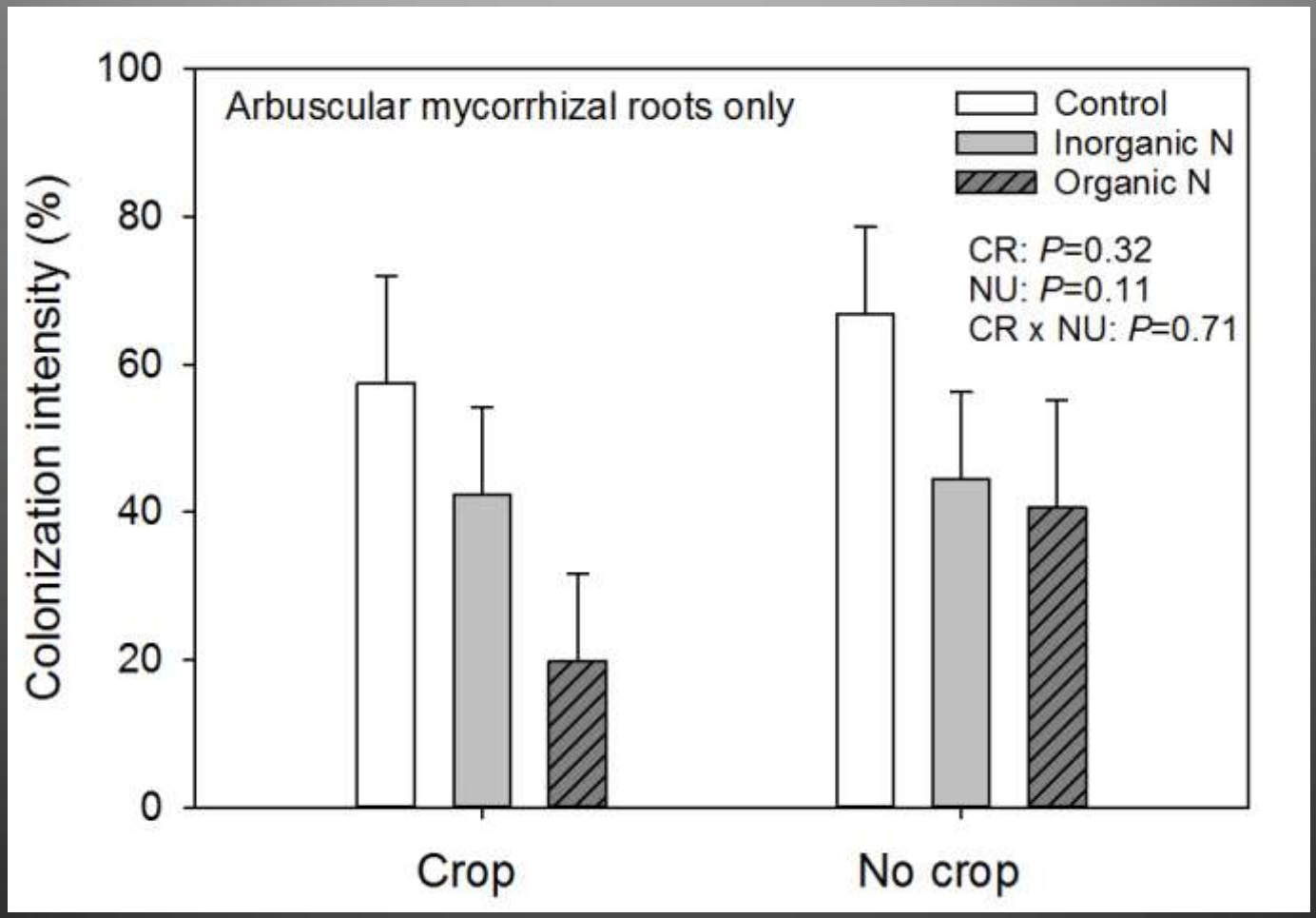
- Hyphal Biomass: Phospholipid fatty acid
  - AMF fatty acid indicator
    - 16:1ω5c
  - Analyzed by Jared DeForest Lab

AMF colonization in apple



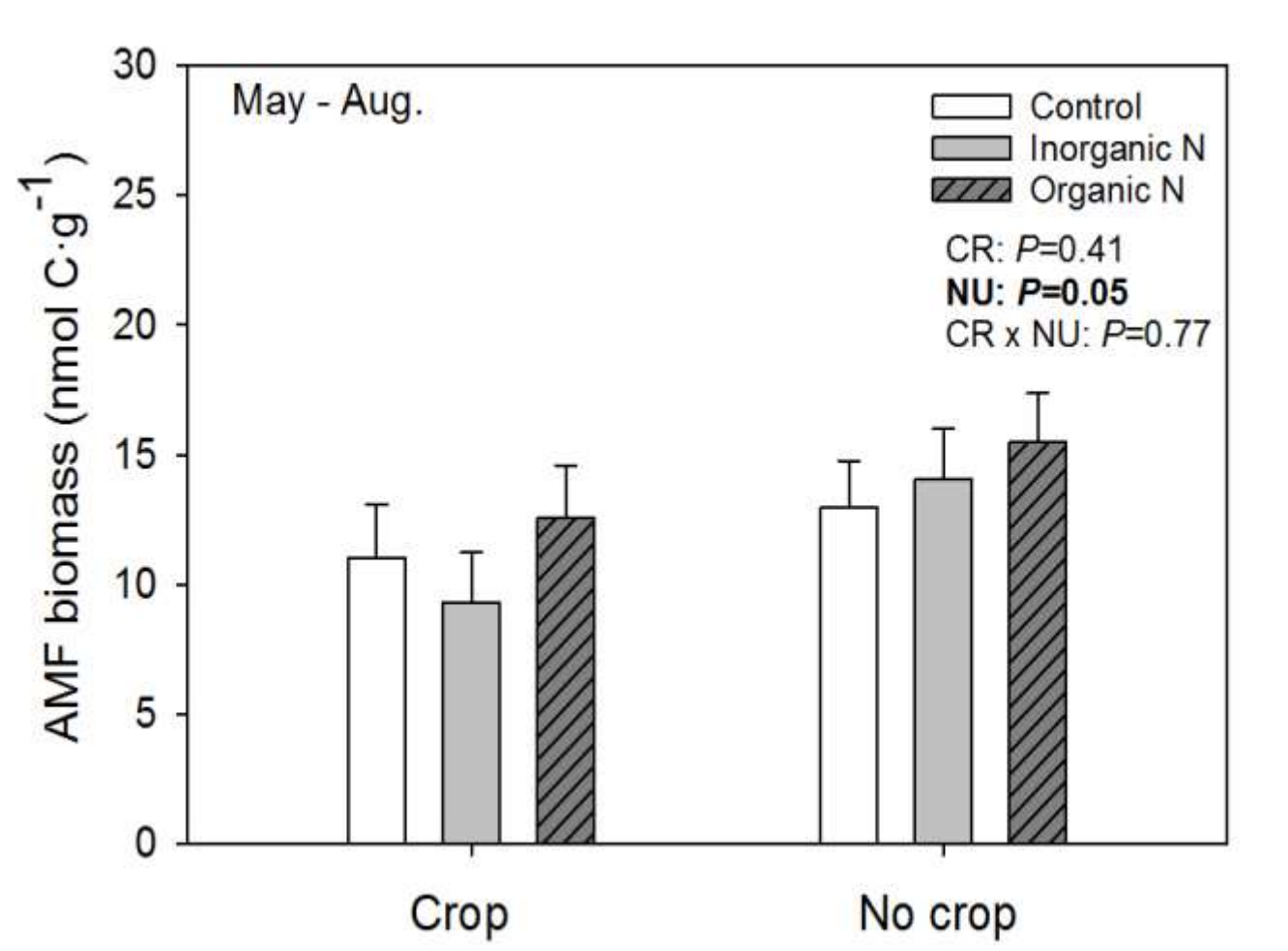
Colonization low and not clearly affected by cropping or fertilization

AMF colonization intensity.



Roots that are colonized are general heavily colonized

AMF Hyphal Biomass Increased Only in the Organic Patch



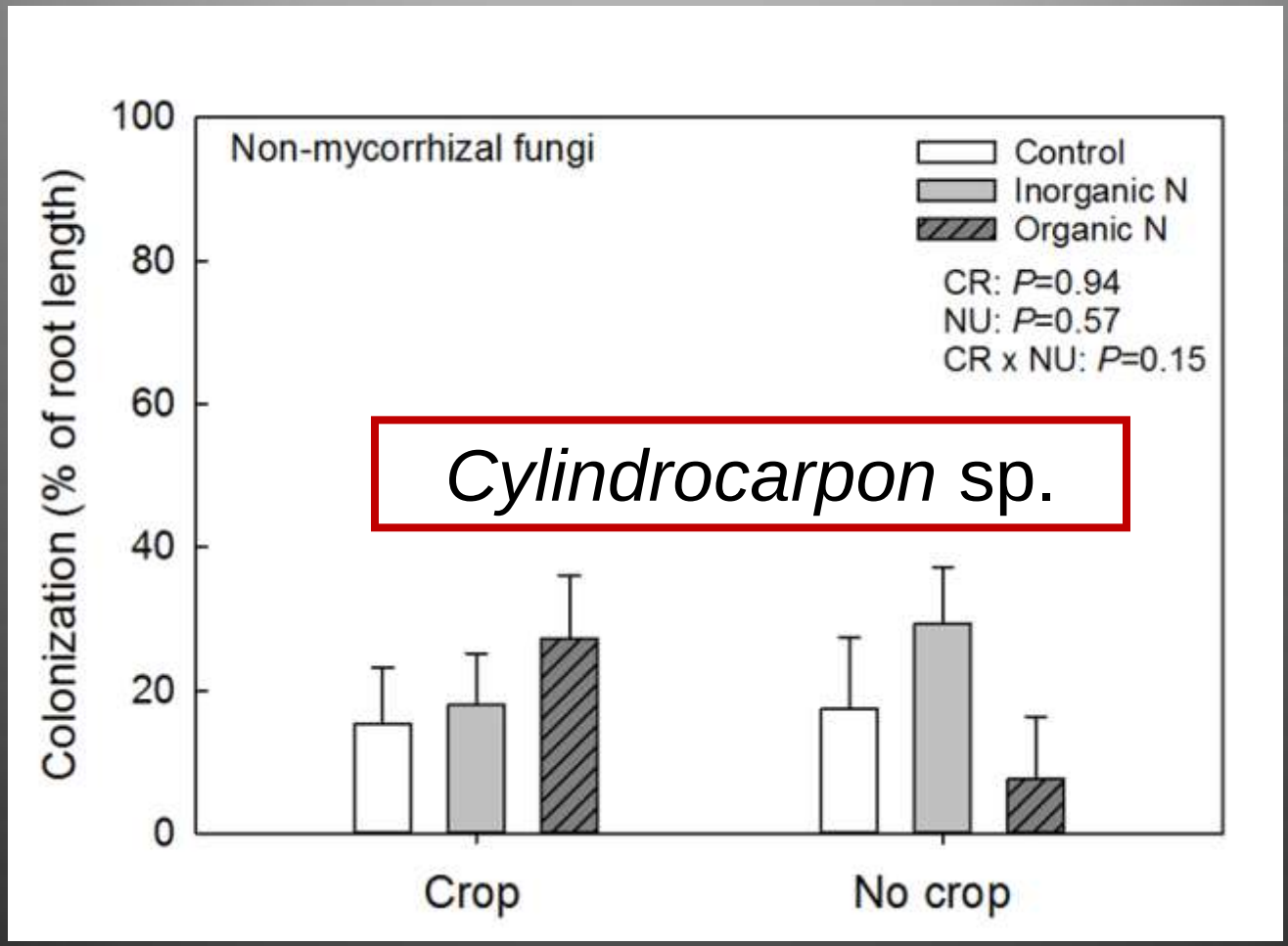
Carbohydrates and Nutrient Patches

- Reduced apple crops can increase overall root production
- No evidence that increased carbohydrates increased mycorrhizal colonization
- Some evidence of preferential extramatrical hyphal growth in organic rich patches

What about non-mycorrhizal fungal (NMF) infection of apple roots

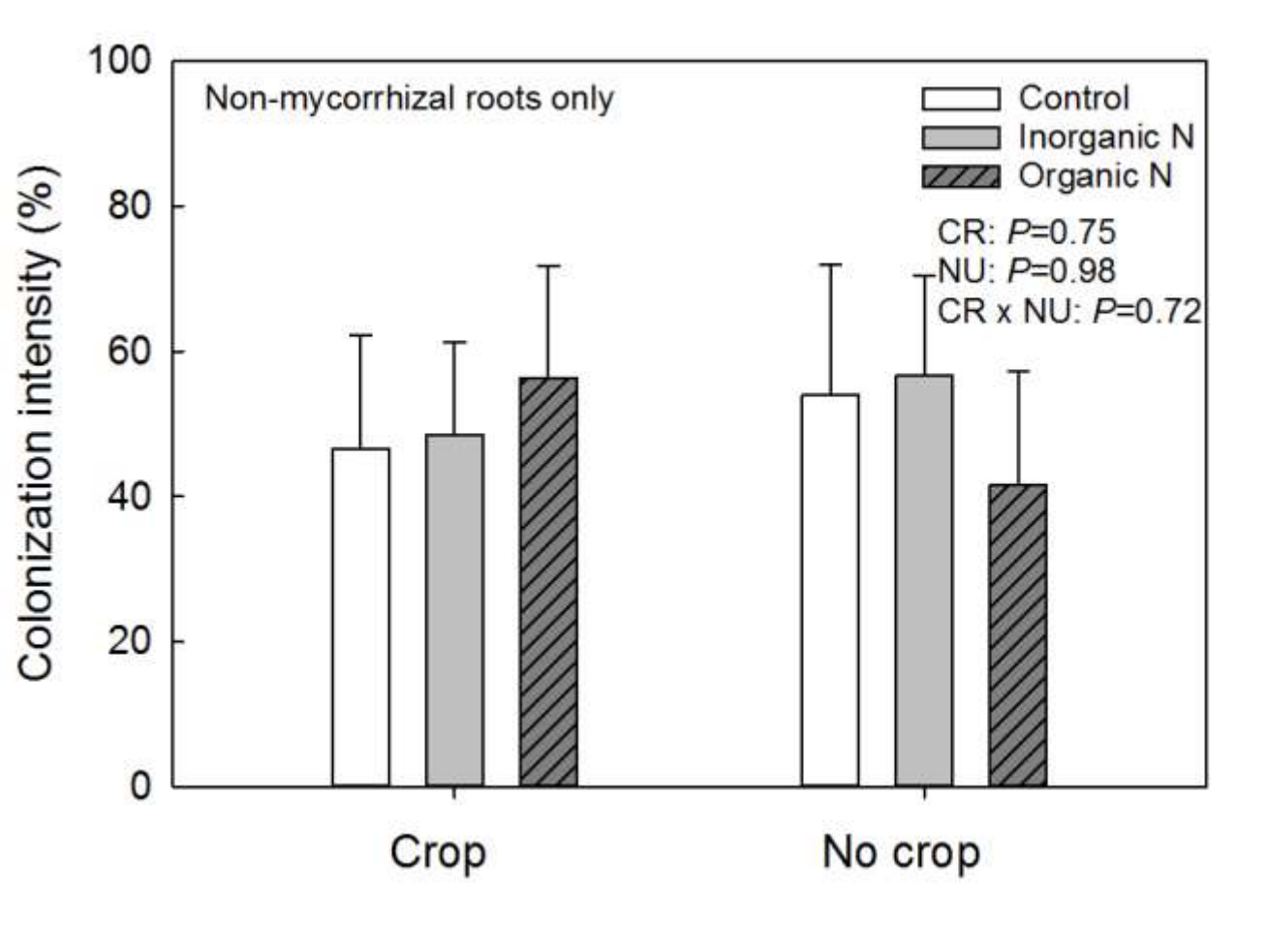
- Do increased root carbohydrates decrease NMF infection?
- Do roots in nutrient-rich patches decrease NMF infection?

NMF infection not affected by cropping



No strong support for the hypothesis that roots in more favorable soil patches or with greater carbohydrate supplies caused by reduced apple crops limit NMF colonization

NMF colonization intensity



If a root is colonized by NMF, it is usually colonized along about 50% of its length

Summary II

- Mixed evidence that mycorrhizal fungi can limit infections by NMF
- Greater carbohydrate allocation belowground more clearly affected root growth than root colonization by microbes
- Organic matter additions may increase mycorrhizal hyphal proliferation

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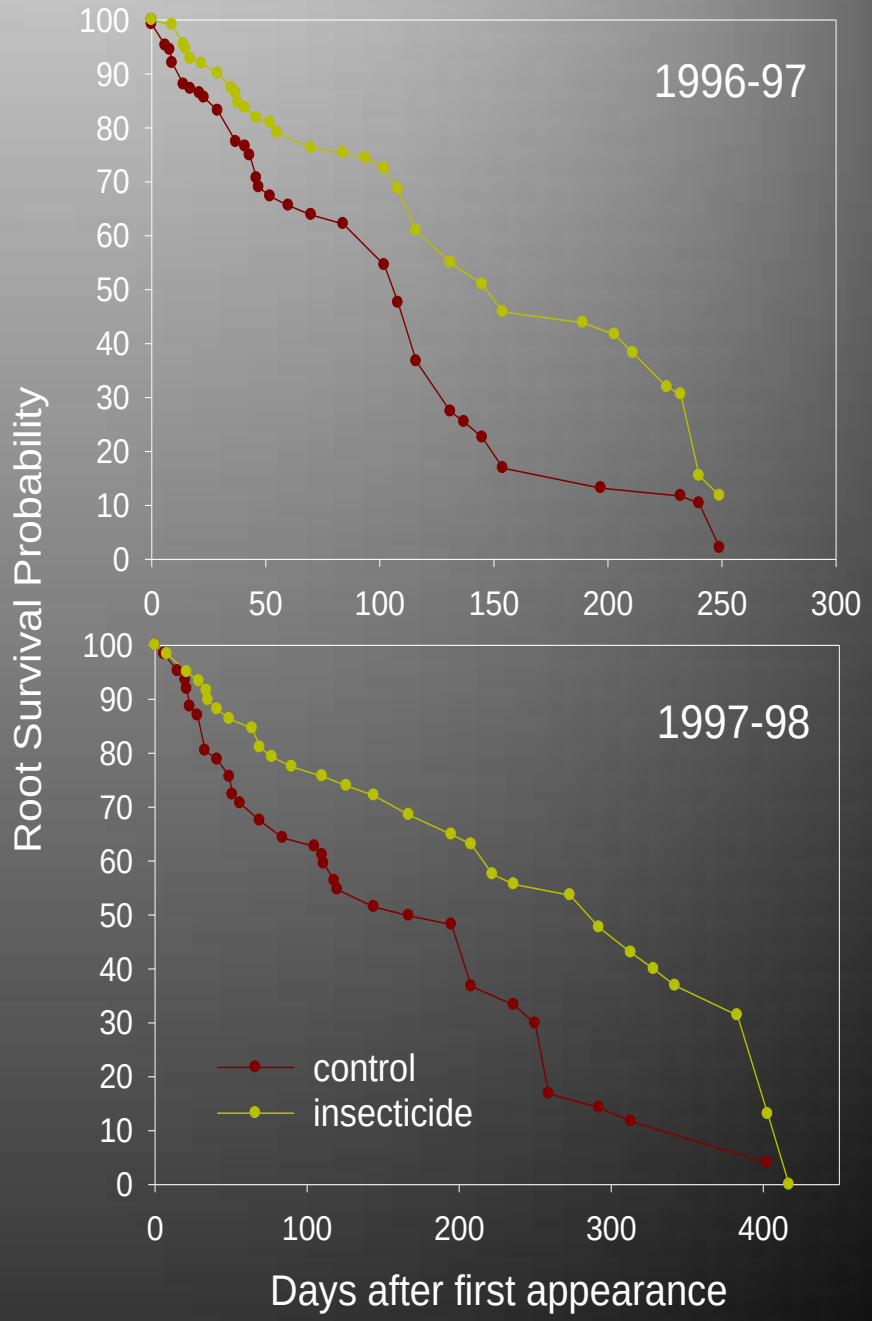
Root herbivory in Peach

- Christina Wells, Michael Glenn
- Kearneysville, West Virginia
- Added Lorsban (wide spectrum insecticide)

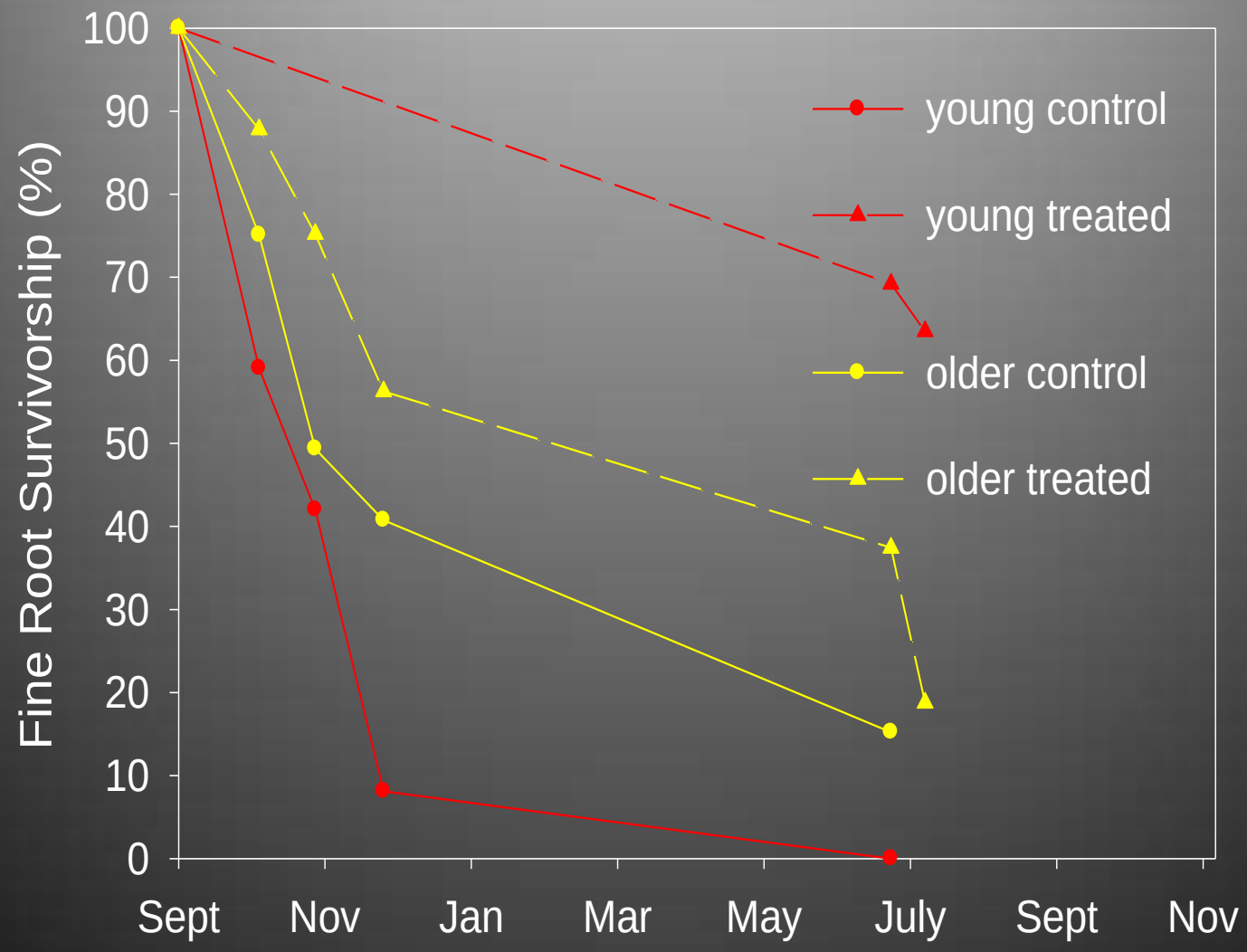
Installing Minirhizotrons in Peach Study in West Virginia

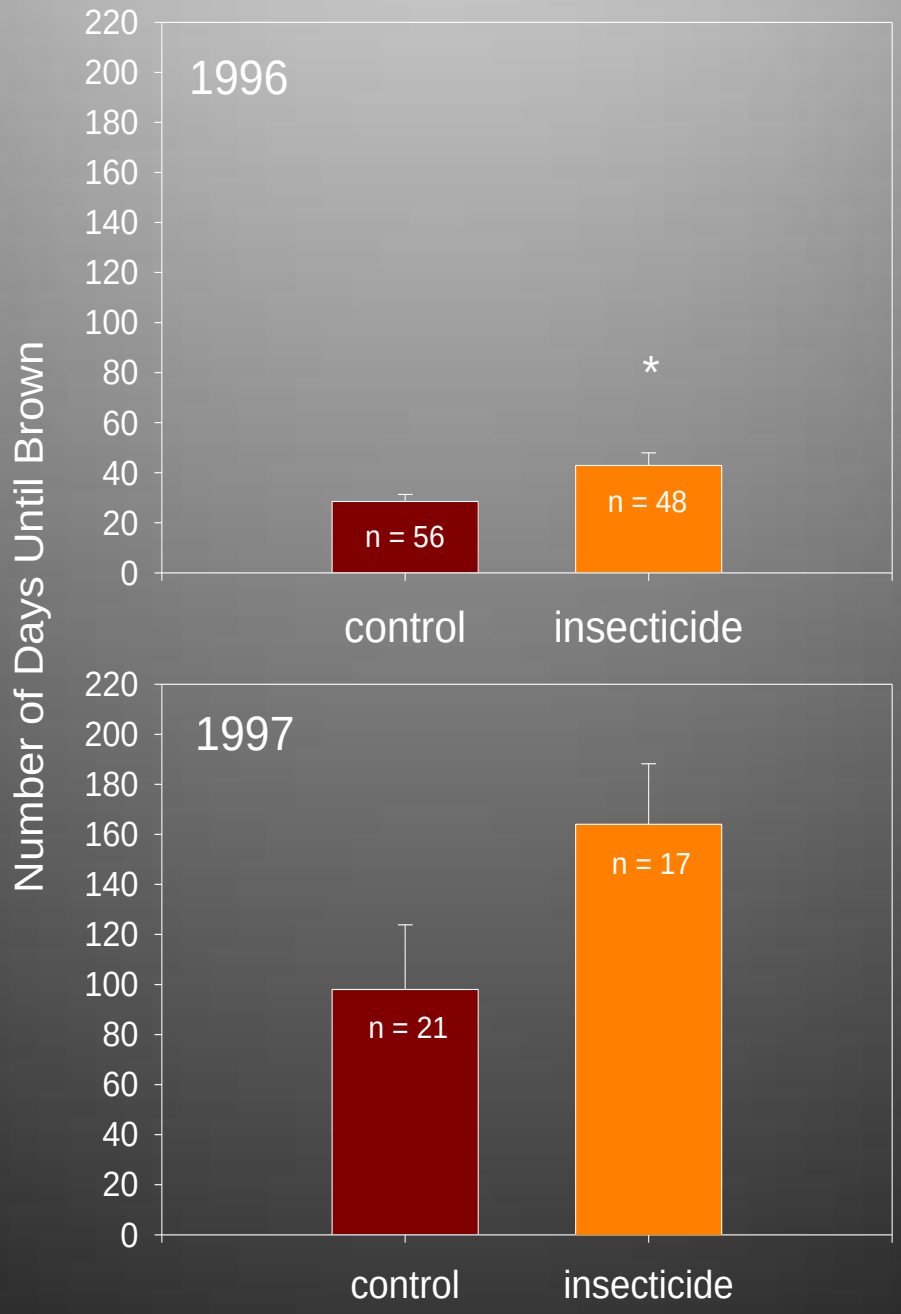
Peach root survival



Wells, C.E., D.M. Glenn, and D.M. Eissenstat. 2002. Plant, Cell & Environment 25: 431-439

The influence of root age on herbivore removal




Number of Days Until Brown
1996
220
200
180
160
140
120
100
80
60
40
20
0
*
n = 56
n = 48
control
insecticide
1997
220
200
180
160
140
120
100
80
60
40
20
0
n = 21
n = 17
control
insecticide

Summary III

- Root herbivory can be an unrecognized factor influencing roots in the orchard
- Herbivory most influential on the young, highly absorptive roots
- Herbivores also can increase root defense production, which reduces their uptake potential

Strategies to direct resident rhizosphere biology

Tillage

Fertility management

Plant-driven selection

Amendment based selection

- Compost
- Green manures
- Bio-based waste products

Well-drained soils

Acknowldegements

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