Alternative Management Tactics for Combating Soilborne Phytophthora Diseases

Jim Downer
University of California Cooperative Extension
Ventura, CA 91003
ajdowner@ucdavis.edu
Avocado Root Rot
Phytophthora: symptoms
Generalized Phytophthora Life History

Diagram showing the life cycle of Phytophthora, including zoospores, sporangium, encystment, germination, chlamydospores, mycelium, and oospores.

- Zoospores
- Sporangium
- Encystment
- Germination
- Chlamydospores
- Mycelium
- Oospores

Types of germination:
- Indirect
- Direct

Types of fusion:
- Homothallic
- Heterothallic

Species:
- A1
- A2
Phytophthora spore stages

- Zoosporangia/spores
- Chlamydospores
- Zoospore cysts
**Phytophthora** Life History: where to attack the organism?

- Mycelium: coenocytic
- Spore walls: thickened, soil longevity
  - chlamydospore
  - oospore
- Cyst wall: High cellulose content
- Zoosporangia: direct germination or…
- Zoospore: naked protoplasts, i.e., no cell wall

Concern:

- +
- ++
- +++
- +++
- ++++
Some methods for control

• Biological Control
  – Mulch
  – Compost/Amendments
    • Tillage
• Calcium based Control
• Silicon
• Cultural Controls
• Phosphorus acids
• Mycorrhizae
Effects of organic mulches

• An attempt to explain the “Ashburner” system for mulching systems in California Avocado orchards

• The system suggests an enzymatic approach to control of the *P. cinnamommi*.

• Various glucanases are now known as defense eliciting proteins.
  
Mulch Transect Studies

Surface of mulch

Mid mulch

Interface

0-7.5 cm

7.5-15 cm
Soil Fungi

Log CFU

<table>
<thead>
<tr>
<th>Depth</th>
<th>Unmulched Soils</th>
<th>Interface</th>
<th>0-7.5 cm</th>
<th>7.5-15cm</th>
<th>10-15 cm</th>
<th>15-20 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>35ab</td>
<td>35ab</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1d</td>
<td>4.1d</td>
<td>45a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27bc</td>
<td>27bc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.9d</td>
<td>2.9d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10cd</td>
<td>10cd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.4d</td>
<td>3.4d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.4d</td>
<td>6.4d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Many mulch fungi are hyperparasites.
• *Trichoderma, Gliocladium, Penicillium* etc.
Roots

- Trees produce abundant roots in mulch layers
- These roots are generally free of *Phytophthora*.
- Mulch layers are where cellulase enzyme systems are most concentrated.
Organisms seen in Mulches

Deutermycotina
abundant spores

Basidiomycotina
abundant biomass

Phanerochaete chrysorhiza

Ceraceomyces tessulatus
Mulch full of fungi
Enzyme activities in transect profile

Sample depth

- surface
- midmulch
- interface
- 7.5
- 15cm

Enzyme activities

- mg reducing sugars/g soil/h

Legend:
- CMCCase-soil
- CMCCase-mulch
- infections
Enzyme meltdown

Cellulase

No enzymes present
Cellulase effects on Zoosporangia/spore production

Obvious difference significant according to Tukey’s HSD $P = .05$
Zoospores $\rightarrow$ Cysts

- Zoospores will encyst on roots in the zone of elongation “en masse”
Cysts germinate and then infect after penetration of the root
$\beta$-1,3 glucanase effects on encystment on excised roots

![Graph showing cysts per square centimeter root surface against enzyme concentration (units/ml)].

- **Y-axis**: Cysts/sq.cm root surface
- **X-axis**: Enzyme Concentration (units/ml)
- **Legend**:
  - Exp 1
  - Exp 2
Zoospore encystment

High glucanase levels prevent zoospore encystment on roots.

Encystment must occur on roots for an infection to occur.
Enzymatic degradation of *P. cinnamomomi*
Mulch effects

• Mulches provide the fungi necessary to create an environment destructive to *Phytophthora*.

• This is due to both biological control via hyperparasites and enzymatic degradation of the pathogen in the mulch layers.
Compost effects on Disease suppression

- Amendments
- Bedding plants as a model system
- Found wherever color plants are planted continuously.
- Fungal and nematode pathogens are predominant.
Bedding Plant diseases in composts

• Treatments
  – No amendment
  – Sand
  – Yardwaste fresh
  – Yardwaste composted
Amendment Plots
compost, fresh yardwaste, sand, and sand unamended.
Mycelium Integrity Rating Scale

5                 4                  3                 2 1

Mycelium integrity rating scale
Degradation of *P. cinnamommi* in amended soils

![Graph showing degradation of *P. cinnamommi* in amended soils. The x-axis represents different treatments: untreated, sand, compost, and yardwaste. The y-axis represents the degree of degradation, with 1 = dissolved and 5 = fresh mycelium. The bars indicate the degradation levels for each treatment: untreated (b), sand (b), compost (bc), and yardwaste (a).]
Degradation of *Phytophthora cinnamomi* mycelium associated with time after rototilling
Mycelial integrity of *P. cinnamomi* in various soil amendments over time

![Graph showing mycelial integrity over time](image)

**Mycelium integrity**:
1 = completely dissolved, no sign of mycelium left in envelope; 2 = mycelium degraded into bits and pieces, you have to scrape it up to pick it up; 3 = mycelium degraded on the edges, discolored, mushy; 4 = minimal degradation, discoloration, firm texture; 5 = no evidence of degradation, mycelium not mushy, no discoloration, firm texture.
Calcium control

• Calcium supplied as gypsum
• Applied to young trees at 15#/tree annually.
• Gypsum applied as a mulch and leached into the soil profile or over organic wood chip mulches.
Zoospore motility

Calcium at 1µM concentrations reduces the ability of the zoospores to swim uni-directionally. Disrupted swimming patterns prevent the spores from finding host roots.

Messenger et al., 1996 Plant Disease
Gypsum Mulches

Provide a slow release Ca\(^{++}\) source

Will not harm avocado roots

Will harm *Phytophthora* propagules.

Provides control equivalent to fungicides in some cases
Silicon

- A phytoalexin elicitor
  - Fawe et al., 1998. Phytopathology 88:396-401

- For root rot control (*Pythium*) seems to require either continuous or multiple applications as a preventative material

- *Trees drenched with soluble Silicon before inoculation with P. cinnamomi had greater root dry weights*

- *Suppression of disease better than with phosphonates*
  - Bekker et al., 2007. Procs of VI World Avo Congress, Vista Del Mar, Chile

- *Silicon amended potting soils led to the production of chitinase and glucanase defense proteins*
Phosphorus Acids

• Phosphorus acids are popular “fertilizers” that also control root rot in many cropping and ornamental plant growing areas
• Are they all alike?
• How do they compare to Aliette for root rot control?
P. Cinnamomi control with phosphorus acids

Uninoculated control

Inoculated control

Fosfite™ drench
Effect of various phosphorus acids on root rot control.
AM Mycorrhizal Effects

That mycorrhizae selectively enrich for bacterial associates from the background soil that contribute to plant growth and health

(antagonistic bacterial associates)

Antagonistic potential

• Capacity of all the bacteria in bulk, rhizosphere or mycorrhizosphere soil to inhibit a specific pathogen

• **Antagonistic Potential Index (API)** is the sum of all the zones of inhibition (mm) by the bacteria tested *in vitro* to inhibit growth of a specific pathogen.
Compost or compost tea effects on diseases: Interpretation

- Adding antagonists that suppress disease
- Stimulating antagonists already present in soil or potting mix
- Adding anti-pathogen chemicals produced during composting (including microbial metabolites)
- Poor correlation between active CFU’s and disease reduction.

- For a review on compost teas see:
Compost Tea

• Advocated for disease suppression
• Many systems and plant types
• Putative foliar and root disease controls
Compost Tea
Summary
(Linderman, 2007)

The Mycorrhizosphere Paradigm-a microbial hierarchy

Plant roots attract
Mycorrhizal fungi attract
Bacterial associates

Result: a “team” system that has worked to support plant growth and health for some 460 million years!!
Integrated Control

• Use all the methods discussed today
  – Mulching
  – Fungicides
  – Cultural controls
  – Resistance
Disease predisposing factors & cultural controls

- Excess moisture → drainage
- Planting too deep
  - Backfill over the crown → correct planting depths
- Salinity → leaching
- Compaction → aeration
Flooding is deadly if *Phytophthora* is present in the soil
Planting Too Deep

- Almost always leads to problems/death of the plant
- Associated with *Phytophthora* collar rots
- “Kiss of death” for native plants
Soil Salinity

Jim MacDonald, UC Davis, effects studied on Chrysanthemum
Soil Structure

- Soil particles combine to form aggregates
Earth transport + compaction
Cultural Controls

Without attention to cultural control all other control methods will fail and the disease will worsen
Conclusions

• Organic mulches probably have varied roles in the suppression of diseases in soil Parasitism, enzymes and soil modification.
• Disturbance (tillage) probably plays a significant role in raising microbial activity of soils and thus the level of antagonists.
• Phosphorus acids are effective but alike
• Calcium ion can be used as therapy
• Mycorrhizae play a role as they increase antagonistic potential of the soil.