SOIL BORNE DISEASES OF PISTACHIO

F. P. Trouillas
Department of Plant Pathology,
University of California, Davis, CA
Kearney Agricultural Research and
Extension Center, Parlier, CA

Soil-borne diseases:
The relative importance of soil-borne diseases has changed over time with changes in choice of rootstocks.

Historically:
- Verticillium wilt
- Armillaria root rot
- Rhizoctonia seedling blight

New soil-borne diseases:
- Phytophthora root and crown rots
- Macrophomina charcoal rot
- Fusarium crown rot

Verticillium wilt:
- Historically, the most destructive disease of pistachio in California
- The development of resistant rootstocks (PGI and UCB-1) has solved the Verticillium wilt problem of pistachio in California
- Still observed sporadically in the southern half of the San Joaquin Valley
Verticillium wilt:

- Soilborne fungus: *Verticillium dahliae*
- Wide host range: over 300 plant species
- Common crops affected in CA include: cotton, tomato, pepper, potato, strawberry
- Non-cultivated plants, weeds also serve as hosts

Verticillium wilt: Almond

- All rootstock cultivars susceptible
- Flagging, shepherd hook, vascular streaking
- Trees over 5 years old are rarely affected by the disease

Verticillium wilt:

- Symptom development on portion of the tree
- Dead leaves remain attached to the tree
- The whole tree may die
- *Pistacia atlantica* is highly susceptible
Verticillium wilt:

- In locations where highly susceptible crops were grown previously (cotton, pepper, tomato, strawberries, etc.)
- Cool spring weather, mild summer and most soils favor the disease
- Hot San Joaquin Valley summer temperatures apparently slow or inhibit Verticillium
- Over irrigation when temperatures are cool will increase Verticillium wilt
- Stressed trees are more vulnerable
- Trees of all ages are susceptible to the disease

Verticillium thin leaf:

- Symptoms develop slowly over several years and are characterized by a slow loss of vigor and a reduction in growth and yield.
- A gradual thinning of the leaf canopy occurs: “see-through” symptom
- Diagnosis is more difficult
Verticillium wilt:
- Survive in the soil as microsclerotia
- Microsclerotium: hard dark resting body of certain fungi, consisting of a mass of hyphal threads
- Persist in soil for long periods.
- Survive on weed hosts

Disease cycle:
- Microsclerotia germinate in the presence of root exudates
- The pathogen invades the cortical cells of young roots, then the current year’s xylem vessels
- It produces conidia that are transported into the tree trunk
- Colonization of the xylem results in disruption of water and nutrient transport

Management:
- Use of resistant/tolerant rootstocks (PGI, UCB-1)
- Avoid planting in soils with history of susceptible crops
- Avoid inter-cropping your pistachios with a susceptible host crop
- Submit soil samples to commercial lab for analysis: # microsclerotia/g soil
- For almond/pistachio, three microsclerotia per gram of soil is considered high risk
- Reduce inoculum: flooding fallow field, solarization, fumigation, growing grass crops for several seasons
- Minimizing tree stress through maintenance of soil fertility and soil moisture will help trees tolerate the disease and encourage their recovery, but do not over-irrigate
- Potassium deficiency increases tree loss due to Verticillium at low inoculum levels

Armillaria root rot:
- Soil borne pathogen
- Armillaria mellea or the oak root fungus
- Basidiomycetes (mushroom)
- Orchards planted where oak trees once grew can be severely damaged
- Plants along streams and river get more affected
- Rare in pistachio
**Armillaria root rot:**
- The presence of mycelial plaques is sufficient to confirm the disease
- Plaques are white, fan-shaped sheets of fungal mycelium and occur between the bark and wood
- Symptoms are reduced growth, yellowing of leaves, defoliation
- The disease progresses to adjacent trees
- The fungus survives on dead roots
- Control is difficult and consists of removing infected roots from soil before new planting

**Rhyzoctonia seedling blight:**
- 1995: found in a nursery in CA where it resulted in the death of over 10,000 rootstock seedlings
- Leaves turn brown, wilted, and hanged to shoots
- Brown cortical lesions develop on roots
- Seedlings are stunted, blighted, and die
- *P. atlantica, P. integerrima,* and UCB-1 were all similarly infected
- The disease has not been observed on planted trees in an orchard

**Phytophthora root and crown rots:** Symptoms
Phytophthora root and crown rot:
- Can affect old trees as well

Phytophthora crown rot: Symptoms
- Affects the tree trunk at or near the ground level; girdling of trees; relatively fast decline
Phytophthora crown rot: Symptoms

- Girdling of trees causing a relatively fast decline

Phytophthora crown rot: Symptoms

- Occurrence of concentric growth rings below the bark
Aerial Phytophthora or trunk canker:

- Mainly a problem in sprinkler-irrigated pistachio orchards

Phytophthora root rot: Symptoms

- Affects small roots, kill feeder roots and reduces the uptake of water and nutrients causing trees to slowly decline

Phytophthora disease cycle:
Phytophthora root and crown rot:
- Little knowledge about Phytophthora diseases in Pistachio.
- Early reports of Phytophthora spp. as causal agents of branch and trunk cankers in the scion (MacDonald et al., 1992).
- Phytophthora root and crown rot generally was considered a minor disease in California pistachio, occurring sporadically in saturated soil conditions.
- *Phytophthora* *parisiensis*, *Phytophthora helicoides* were recently found in potted pistachio plants in research plots (E. Fichtner et al. 2015, 2016).

Phytophthora diseases: Generalities
- Soil borne pathogens
- Fungus-like organisms
- Oomycetes: water molds
- Water spores: zoospores – they can swim
- Favored by standing water in the orchard

Phytophthora diseases: Generalities
- Many *Phytophthora* spp. are present in canal and river water
- Generally introduced to orchards irrigated from these sources
- To date, *Phytophthora* has not been found in well water
- Historically not so common on pistachio trees in California
- Increasing cases in the last few years
**Phytophthora diseases:**

Favored by:

- Prolonged periods of high soil moisture
- 24 hours soil saturation period
- Low spots in the orchard
- Soil with poor water infiltration/drainage (heavy soil, hardpan)
- Irrigation from surface water
- Flood irrigation systems
- Alternating cycles of wet and dry soil also exacerbate Phytophthora root rots

---

**Phytophthora root and crown rot:**

Diversity of Phytophthora species in CA pistachios:

- Phytophthora niederhauserii
- Phytophthora cinnamomi
- Phytophthora taxon walnut

---

**2015-2017 Disease surveys of pistachio orchards**

- Phytophthora niederhauserii
- Phytophthora cinnamomi
- Phytophthora taxon walnut
Root inoculation of UCB1 and Platinum rootstocks:

- Root and crown rots
- Using rootstocks plantlets
- Zoospore inoculum

Root inoculations with Phytophthora spp.:

After 3 weeks (UCB1 rootstocks)  After 3 weeks (Platinum rootstocks)

<table>
<thead>
<tr>
<th>Phytophthora species:</th>
<th>Wilted/dead plants (%) UCB-1 clone</th>
<th>Wilted/dead plants (%) Platinum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytophthora cinnamomi</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Phytophthora taxon walnut</td>
<td>100</td>
<td>34</td>
</tr>
<tr>
<td>Phytophthora niederhauseri</td>
<td>58</td>
<td>50</td>
</tr>
<tr>
<td>Control</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Rootstock inoculations: UCB1 and Platinum

- 21 days after inoculation: 12 plants for each treatment (4 reps x 3 isolates)

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>Phytophthora species:</th>
<th>Wilted/dead plants (%) UCB-1 clone</th>
<th>Wilted/dead plants (%) Platinum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytophthora cinnamomi</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Phytophthora taxon walnut</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Phytophthora niederhauseri</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>12.5</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 2</th>
<th>Phytophthora species:</th>
<th>Wilted/dead plants (%) UCB-1 clone</th>
<th>Wilted/dead plants (%) Platinum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytophthora cinnamomi</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Phytophthora taxon walnut</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Phytophthora niederhauseri</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>12.5</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Pathogenicity studies using mycelium plugs

- Inoculation into UCBI rootstocks
- Three to four months incubation period

Phytophthora: Disease management

- Water management is the basis for control of Phytophthora root and crown rot
- Avoid puddling forming around the crown
- Avoid to wet soil longer than 24 hours at a time
- Do not apply water if adequate soil moisture is present
- Improving water penetration, drainage, infiltration rates (soil amendments)
- Planting on berms
- Phosphites: 2-3 foliar spray applications starting when trees are fully leafed out (May/June) + 1 fall (late September/early October) foliar application
- Best used as preventive treatments
- Trade issues with MRL requirements
- Mefenoxam (Ridomil Gold) is not currently registered for pistachio in California

Phytophthora: Disease Management

- Avoid placing drip hoses at the base of a tree
Macrophomina charcoal rot:
- Declining of recently planted UCB rootstocks
- Heavy soils (clay)
- West side

2015-2017 Disease surveys

Macrophomina phaseolina

Macrophomina charcoal rot:
- Caused by Macrophomina phaseolina
**Macrophomina phaseolina:**

- Causal agent of Charcoal rot in many plant species (row crops)
- Little information about *Macrophomina phaseolina* affecting perennial woody crops
- We have isolated *Macrophomina phaseolina* from declining table grapes and cherry rootstocks
- Produce microsclerotia, which is enhanced under low water potentials that occurs during drought

**Root inoculations with *Macrophomina phaseolina***:

<table>
<thead>
<tr>
<th>Macrophomina isolates</th>
<th>Wilted/dead plants (%)</th>
<th>Wilted/dead plants (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Macrophomina phaseolina</em> KARE1400</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><em>Macrophomina phaseolina</em> KARE1411</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><em>Macrophomina phaseolina</em> KARE1350</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Control</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

UCB1 clonal rootstocks and Platinum
Three isolates of *Macrophomina phaseolina*
5 repetitions per isolate
Using microsclerotia
Incubation period 22 days
Pathogenicity studies using mycelium plugs

- Complete Koch's postulates
- UCB1 rootstocks (clonal and seedlings)
- Using mycelium plugs (crown rots)

Fusarium crown rots:

- Unusual symptoms
- Mainly cambium and phloem tissues affected
- Gumming
Fusarium taxonomy:
- 5 species isolated from symptomatic pistachio rootstocks

Fusarium as secondary pathogens:
- Plant stresses including old Phytophthora infections may allow Fusarium species to become virulent in pistachio

Pathogenicity studies using mycelium plugs
- Complete Koch's postulates
- UCB1 rootstocks (clonal and seedlings)
- Using mycelium plugs (crown rots)
Pathogenicity studies using mycelium plugs

- 3 to 10 months incubation period

Disease management: Rootstock susceptibility study

- UCRL, PGI and Platinum rootstocks were inoculated with *P. niederhauserii*, *P. cinnamomi*, *P. taxon walnut*, *Fusarium* spp. and *Macrophomina phaseolina*
- Inoculation of stems with mycelium plugs
- 10-month incubation period

Rootstock susceptibility study: all isolates combined

- Phytophthora
**Rootstock susceptibility study: all isolates combined**

- **Fusarium**

![Bar graph showing Fusarium susceptibility among different rootstocks.]

- **Macrophomina**

![Bar graph showing Macrophomina susceptibility among different rootstocks.]

**Rootstock susceptibility study: Macrophomina**

<table>
<thead>
<tr>
<th>Control</th>
<th>M. phaeolina</th>
<th>Control</th>
<th>M. phaeolina</th>
<th>Control</th>
<th>M. phaeolina</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCIII Rootstocks</td>
<td>![Image of UCIII rootstock sample]</td>
<td>PGII Rootstocks</td>
<td>![Image of PGII rootstock sample]</td>
<td>Platimum Rootstocks</td>
<td>![Image of Platimum rootstock sample]</td>
</tr>
</tbody>
</table>

---

18
Rootstock susceptibility study:
- All pathogens combined

Root asphyxiation: “Wet feet”
- Frequently misdiagnosed as Phytophthora root or crown rot

Root asphyxiation: “Wet feet”
- Overall symptoms similar to Phytophthora diseases.
- More common issue in the field than Phytophthora
- Pistachio trees are drought tolerant: deep-rooted, can survive in extremely dry conditions
- Less tolerant to soils with high moisture
Root asphyxiation: “Wet feet”

- Roots need oxygen to grow and to absorb nutrients.
- Too much water eliminates air space in soil and around roots.
- In water-saturated soil, the oxygen content is low; without oxygen, roots cannot respire properly and cannot take up water and nutrients.
- Anaerobic conditions: bad smell.
- Trees declining slowly and may die.

Root asphyxiation: “Wet feet”

- Low spots, heavy loam or clay, soil overly wet, etc...
- End of the row
- Fields with poor water infiltration/drainage.

Thank you!