New and Expanding Plant Diseases: Hull Rot and Ganoderma
Session Speakers

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New and Expanding Plant Diseases: Hull Rot and Ganoderma

Barat Bisabri, Shiraz Ranch, Chair, ABC Pest Management Workgroup.
INCREASE ADOPTION OF ENVIRONMENTALLY FRIENDLY PEST MANAGEMENT TOOLS BY 25%
New and Expanding Plant Diseases: Hull Rot and Ganoderma

- Mohammad Yaghmour, Farm Advisor, UC-ANR
- Patrick Brown, Professor, UC Davis
- David Rizzo, Professor, UC Davis
- Bob Johnson, PhD, UC Davis
Questions to be addressed during this session

Hull Rot:

- Where are we with the current research in this area, the water management recommendations and the chemical recommendations?
- What is the nitrogen recommendation to avoid/reduce hull rot susceptibility?

Ganoderma:

- What have we learned about this disease so far?
  - Causes, symptoms and cultural manage
New and Expanding Plant Diseases: Hull Rot

Mohammad Yaghmour, Farm Advisor, UC-ANR
Patrick Brown, Professor, UC Davis
Causal Agents

**Monilinia spp.**
Infected almond and stone fruit twigs, fruits, mummies, etc

**Rhizopus stolonifer**

**Aspergillus niger**
Soil
Symptoms and Signs of Hull Rot

- When the hull is infected and disease progress, leaves near the infected fruit starts to dry and shrivel.

- *Monilinia*: Infected hull has a brown area on the outside and either tan fungal growth in the brown area on the inside or outside of the hull.

- *Rhizopus*: Black fungal growth on the inside of the hull between the hull and the shell.

- *Aspergillus niger*: Flat jet-black spores between the hull and the shell.
Fruit susceptibility to Hull Rot Pathogen *Rhizopus stolonifer*

(b1) Initial separation-50% or more of a thin separation line visible

(b2) Deep V, is the most susceptible stage  
(source: Adaskaveg. 2010. Almond Board of California Research Proceedings # 09-PATH4-Adaskaveg)

(b3) Deep V, split-a deep "V" in the suture, which is not yet visibly separated, but which can be squeezed open by pressing both ends of the hull

(c) Split, less than 3/8 inch
Field Fruit inoculation at different fruit development stages and fruit susceptibility with *A. niger*

![Graph showing percentage of symptomatic spurs inoculated on different fruit development stages in 2018 and 2019.](image)

- **Inoculated 7/10/2018**
  - Unsplit: 10%
  - V: 20%
  - Split (less than 1 cm): 80%

- **Inoculated 7/17/2018**
  - Unsplit: 10%
  - V: 20%
  - Split (less than 1 cm): 90%

- **2019**
  - Unsplit: 10%
  - V: 30%
  - Split (less than 1 cm): 70%
Aspergillus niger spore population on almond fruit

**Aspergillus niger**

- **Northern plot**
  - 7/6/2018: 10.5
  - 7/11/2018: 13.4
  - 7/16/2018: 14.1
  - 7/27/2018: 860.6

- **Southern plot**
  - 7/6/2018: 15.4
  - 7/11/2018: 14.5
  - 7/16/2018: 13.3
  - 7/27/2018: 213.0

**Rhizopus Stolonifer**

- **Northern plot**
  - 7/6/2018: 0.0
  - 7/11/2018: 1.0
  - 7/16/2018: 2.0
  - 7/27/2018: 3.0

- **Southern plot**
  - 7/6/2018: 0.0
  - 7/11/2018: 1.0
  - 7/16/2018: 2.0
  - 7/27/2018: 3.0
Irrigation Management and Hull Rot

Deficit irrigation decreased incidence of hull rot, and regulated deficit irrigation was more effective than sustained deficit irrigation.

<table>
<thead>
<tr>
<th>Irrigation treatment</th>
<th>1994 (no. per tree)</th>
<th>1995 (no. per tree)</th>
<th>1994 (cm per tree)</th>
<th>1995 (cm per tree)</th>
<th>1994 (%)</th>
<th>1995 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 (control)</td>
<td>20.1</td>
<td>23.1</td>
<td>28.4</td>
<td>49.2</td>
<td>26.5</td>
<td>24.2</td>
</tr>
<tr>
<td>85 sustained</td>
<td>18.0</td>
<td>35.2</td>
<td>32.8</td>
<td>66.6</td>
<td>35.0</td>
<td>24.5</td>
</tr>
<tr>
<td>85 regulated</td>
<td>6.1</td>
<td>13.5</td>
<td>8.2</td>
<td>22.1</td>
<td>24.2</td>
<td>14.5</td>
</tr>
<tr>
<td>70 sustained</td>
<td>7.1</td>
<td>15.5</td>
<td>8.4</td>
<td>17.2</td>
<td>21.5</td>
<td>14.2</td>
</tr>
<tr>
<td>70 regulated</td>
<td>4.7</td>
<td>5.4</td>
<td>2.2</td>
<td>2.2</td>
<td>35.8</td>
<td>18.8</td>
</tr>
</tbody>
</table>

Significance of F, P = 0.032

Orthogonal contrasts

100 versus deficits | 0.005 | 0.022 | 0.006 | 0.068 |
100 versus 85 sustained | NS | NS | NS | 0.072 |
85 versus 70 | 0.030 | 0.007 | 0.003 | 0.003 |
Sustained versus regulated | 0.027 | 0.002 | 0.003 | 0.009 |

Publication 8515 has important information regarding irrigation management: Understanding deficit irrigation (DI), and the use of strategic deficit irrigation (SDI).

**Drought Management for California Almonds**

*Impacts of Stress on Almond Growth and Yield*

Almond trees are tolerant to drought conditions and respond to water availability with increasing yields. Research has shown that trees are able to survive on as little as 7.6 inches of water (Shackel et al. 2011), but they produce maximally with 54 to 58 inches in many areas of California (Sandén 2007). Minimizing water stress increases growth and yield due to increased rates of photosynthesis and respiration.

Water and carbon dioxide are required by plants for photosynthesis. Water is provided through the root system of the tree, while stomata, or “windows,” on the lower leaf surface are responsible for allowing carbon dioxide to enter the leaf and oxygen to leave. As this gas exchange occurs, substantial amounts of water vapor is also lost through the stomata via transpiration. When the water loss potential from transpiration exceeds the amount of soil water the roots can easily absorb, the plant will begin to appear stressed. If water applications through either irrigation or rainfall are not adequate to alleviate this stress, stomatal closure will be initiated, reducing gas exchange, rate of photosynthesis, and production of carbohydrates. This limits the amount of energy available for the many processes, negatively impacting vegetative growth and potentially fruit and kernel development.

The severity of stress determines its effect on the tree. Low to moderate levels of plant stress often occur within orchards and may be beneficial. Research has shown that an application of moderate stress at the onset of hull split helps to reduce the fungal disease hull rot and synchronize hull split (Tevishade et al. 2001). Mild to moderate stress levels, if monitored, are useful for irrigation scheduling, as plant stress levels indicate the current soil-water status (Fulton et al.)
Deficit Irrigation and Hull Rot

• Moderate stress at the onset of hull split will
  – Increase hull split uniformity
  – Reduce hull rot

• Water reduction of 10-20% at beginning of hull split.

• When trees 2-3 bars below baseline, resume normal irrigation.

• When hullsplit starts 1% (-15 bars)

• Maintain Deficit irrigation for 2 weeks and then return to normal irrigation until harvest dry-down.
Chemical Control of Hull Rot

- Dr. Adaskaveg worked extensively on chemical control.
- Several fungicides have a “good and reliable” rating to control hull rot.
- Use of alkaline fertilizers were as effective in controlling hull rot.

### ALMOND: FUNGICIDE EFFICACY

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate(A</th>
<th>7-18</th>
<th>8-3</th>
<th>Hull rot strikes/tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>di-K-PO4</td>
<td>48 oz</td>
<td>---</td>
<td>@</td>
<td>b</td>
</tr>
<tr>
<td>di-K-PO4</td>
<td>48 oz</td>
<td>---</td>
<td>@</td>
<td>b</td>
</tr>
<tr>
<td>di-K-PO4 + Ca(OH)2</td>
<td>48 + 320 oz</td>
<td>---</td>
<td>---</td>
<td>b</td>
</tr>
<tr>
<td>Ca(OH)2</td>
<td>320 oz</td>
<td>---</td>
<td>@</td>
<td>b</td>
</tr>
<tr>
<td>Cincasis</td>
<td>24 fl oz</td>
<td>@</td>
<td>@</td>
<td>b</td>
</tr>
<tr>
<td>Cincasis</td>
<td>24 fl oz</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Fontelis + Tebucon</td>
<td>20 fl oz + 8 oz</td>
<td>---</td>
<td>@</td>
<td>b</td>
</tr>
<tr>
<td>Fontelis + Inspire</td>
<td>20 + 7 fl oz</td>
<td>---</td>
<td>@</td>
<td>b</td>
</tr>
<tr>
<td>Fontelis + Abound</td>
<td>20 + 15.5 fl oz</td>
<td>---</td>
<td>@</td>
<td>b</td>
</tr>
<tr>
<td>Fontelis + Ph-D</td>
<td>20 fl oz + 6.2 oz</td>
<td>---</td>
<td>@</td>
<td>b</td>
</tr>
</tbody>
</table>

7-18-17: early suture opening, 8-3-17: 5% hull split. 0 4 8 12 16 20
Timing of Chemical Control of Hull Rot

- Hull rot caused by *R. stolonifer* can be managed by a single application at hullsplit (1-5% hullsplit), timed with the navel orangeworm insecticide treatment.
- Hull rot caused by *Monilinia* spp. is best managed with fungicide applications 3 to 4 weeks before hull split (early June).
In vitro sensitivity of *A. niger* to different fungicides

**Aspergillus niger** colony diameter (mm):
- Quash
- Tebuconazole
- Meriven
- Luna Sensation
- Tilt
- Fontelis
- Pyraziflumid
- Luna Experience
- Quadris Top
- Abound
- Control

**Aspergillus niger** percent germination:
- Quash
- Tebuconazole
- Meriven
- Luna Sensation
- Tilt
- Quadris Top
- Luna Experience
- Fontelis
- Pyraziflumid
- Abound
- Control
Chemical control of Hull Rot 2019

Number of symptomatic spurs

Control: 36.3
Abound: 22.2
Quash: 23.7
Merivon: 16.8
Thank You!

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Influence of Nitrogen Management on Hull Rot

Patrick H. Brown
Influence of N Rate on Hull Rot in Almond

Hull Rot Incidence increased as N increased.

- Excess N increases hull susceptibility
- Excess N increases canopy humidity favoring fungus
- Excess N changes fruit ripening and infection window
- Deficit irrigation reduces canopy humidity
Seasonal Almond Nitrogen Uptake
(2008-2012 Belridge Excavations)

Ideal Fertilization: Multiple Applications in season timed with demand

Common Fertilization: 3-4 applications 80-90% complete by June 1 (added complexity in wet years)

Potential for loss of N -Nitrate in soil/irrigation

Potential for excess canopy vigor -N uptake in excess of fruit demand

Nonpareil Western Kern 275lbs. N
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Nonpareil
Western Kern
275lbs. N
Impact of Harvest Date on Hull Rot in extreme year (2012)

80% B-D  
High N: Harvest 15 days prior to ‘normal’ harvest = 0 Hull Rot

100% D-F  
High N: Harvest at 100% Hull Split = 50% Hull Rot

100% F  
Early harvest removes fruit before HR can develop

Early harvest reduces NOW infestation

Early harvest reduces insecticide cost
Hull Rot and Plant Nutrition

- Nitrogen added in excess of tree demand can result in enhanced tree vigor and enhanced Hull Rot, inefficient use of added fertilizer and the potential for nitrate loss to groundwater.

- Attempting to apply the majority of the years N demand prior to June has the potential to increase nitrogen loss and to result in an overly vegetative shoot growth which encourage hull rot.

- Eliminating nitrogen applications from June through September risks limiting nitrogen availability to developing flower buds (June-October).

- The most effective control for hull rot (and NOW) is early harvest.
New and Expanding Plant Diseases: Ganoderma

David Rizzo, Professor, UC Davis
Bob Johnson, PhD, UC Davis
Ganoderma root and butt rot
Heart rot

- Infects canopy and trunk
- Decays heartwood and sapwood reducing structural stability
- Results in trunk and limb breakage
- Spread via airborne spores
- Requires wounding for infection
Armillaria root rot

- Decays cambium and sapwood eventually girdling tree
- Kills tree standing
- Primarily spreads via root contact
- Wounding not necessary
- Characteristic disease center
Ganoderma Root and butt rot

- Decays heartwood and sapwood reducing structural stability
- Tree killed by decay related breakage
- Primarily spreads via airborne spores
- Requires wounding
Ganoderma spp. in orchards

**G. brownii (G. australe complex)**
- Isolates from non-agricultural host and regions in California
- Genbank accessions from Brazil, Korea, Australia, California
- Previously reported

**G. adspersum**
- Genbank accessions from India, Italy, Finland, Belgium
- Previously unreported

**G. polychromum**
- Isolates from non-agricultural host and regions in California
- Genbank accessions from California and Oregon
- Previously reported
Ganoderma adspersum – cause for concern?

**Experience in Europe**
- Very common
- Can overcome tree defense
  - CODIT model
    - Reaction wood
    - Formed in response to injury or infection
  - *G. adspersum* “Preferentially” consumes reaction wood (Schwarze and Ferner 2003)
- Wide host range, hardwoods and conifers
- Considered destructive

**In California almond orchards**
- More destructive than *G. brownii* and *G. polychromum*
- Killing young trees
  - 4 years youngest
  - Average of 14
- Resulting in removal of orchards at less than half their life-span.
Ganoderma spp. distribution

Legend
- Almond acreage
- Ganoderma species
  - G. adspersum
  - G. applanatum
  - G. brownii
  - G. polychromum
Ganoderma adspersum

Symptoms
– General decline
– Trees break at ground level
– Flat strip on trunk
– Clefting at graft union
– Shallow rooting

Signs
– Conks
– White rot
– Mycelia
Inoculum – spores

Many infected orchards first generation

High incidence of trees with conks
  – Ganoderma produces “astronomical” number of spores
    12-40 million (day⁻¹ cm⁻² pore surface area) (Kadowaki et. al, 2010)

Somatic incompatibility groupings

Multiple individuals and species in same tree

DOES NOT rule out infection from root contact
Harvest and cultural practices probably drives infection and spread

Shaking
- Wounds to lower trunk and roots at or below soil line

Sweeping Pickup
- Spore dispersal

Irrigation and winter rains
- Spore percolation into soil
- Spore germination

Dormant Shaking
- Winter Sanitation for NOW
- Additional wounding
New and Expanding Plant Diseases: Hull Rot and Ganoderma
Upcoming Sessions at 10:45 a.m.

• Almond Food Safety: Past, Present and Future (Room 1)
• Europe: Playing a Pivotal Role in Almonds’ Future (Room 2)
• Alternatives for Managing Replant Pests and Problematic Weeds (Room 3)
Visit the Exhibit Halls and Participate in the Passport Game

- 3P Partners #2206
- ABC Booth #526
- AC Horn #421
- Ag Spray Equipment #2203
- Bayer CropScience #127
- Best Drayage #2112
- Bird Gard, LLC #1812
- Borrell USA #327
- Cablevey Conveyors #217
- Central Life Sciences #917
- JAX, Inc. #413
- JKB Energy #635
- K. Coe Isom #707
- Lincoln Agribusiness Services #733
- Napasol #2205
- NETZSCH Premier Technologies #218
- Satake #521
- Suterra, LLC #1638
- TOMRA Sorting Solutions #335
- Trécé, Inc #516
- Valent U.S.A. #621
- Westbridge Agricultural Products #1534
- Wilkey Industries #320
- Yara North America #627

The first 500 attendees to turn in a completed passport card to the ABC booth (#526) will receive a hat and will be entered to win one of seven amazing prizes!
Lunch: Pushing Your Personal Limits
Featuring John Stenderup

Doors open at 12:15 p.m. in Building C
You must have already purchased a ticket to attend luncheon

Sponsored by: Farm Credit
Food Truck Village

Food Truck Village is located next to Building D

Open on Tuesday and Wednesday from 11:00 a.m. – 2:30 p.m.

Cash and credit cards are accepted
Almond Food Truck

Wednesday, December 12
- 9 am to Noon
- Donation-Only (all proceeds to benefit California FFA)
- Outside the Registration Tent

California FFA
California FFA members will be on-site selling CalAg License Plates

Valent U.S.A. is proud to partner with the California FFA Foundation and support the CalAgPlate program.