New and Expanding Plant Diseases: Hull Rot and Ganoderma

the Almond CONFERENCE 2019

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Session Speakers

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Bob Johnson, UC Davis

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

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New and Expanding Plant Diseases: Hull Rot

Mohammad Yaghmour, Farm Advisor, UC-ANR

Patrick Brown, Professor, UC Davis

Causal Agents

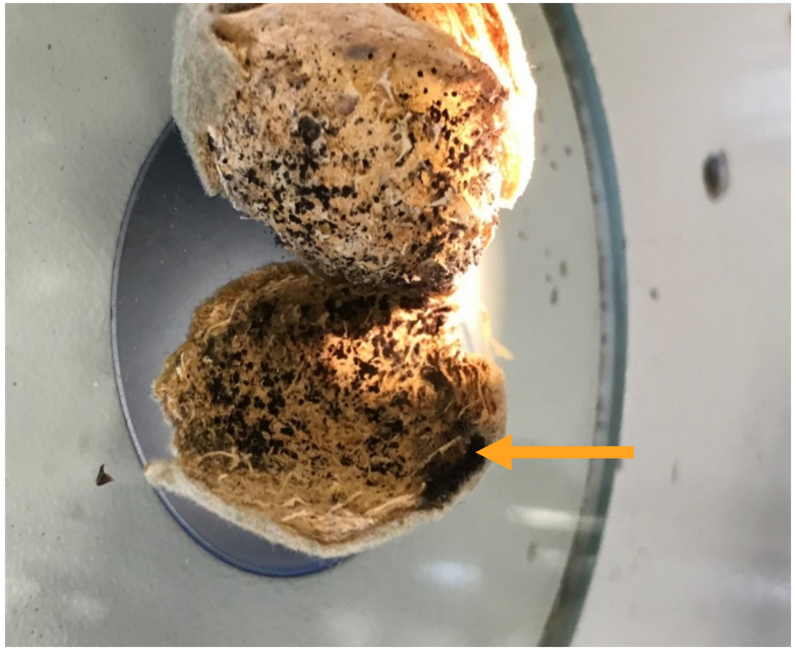
***Monilinia* spp.**

Infected almond and stone fruit twigs, fruits, mummies, etc

Rhizopus stolonifer

Soil

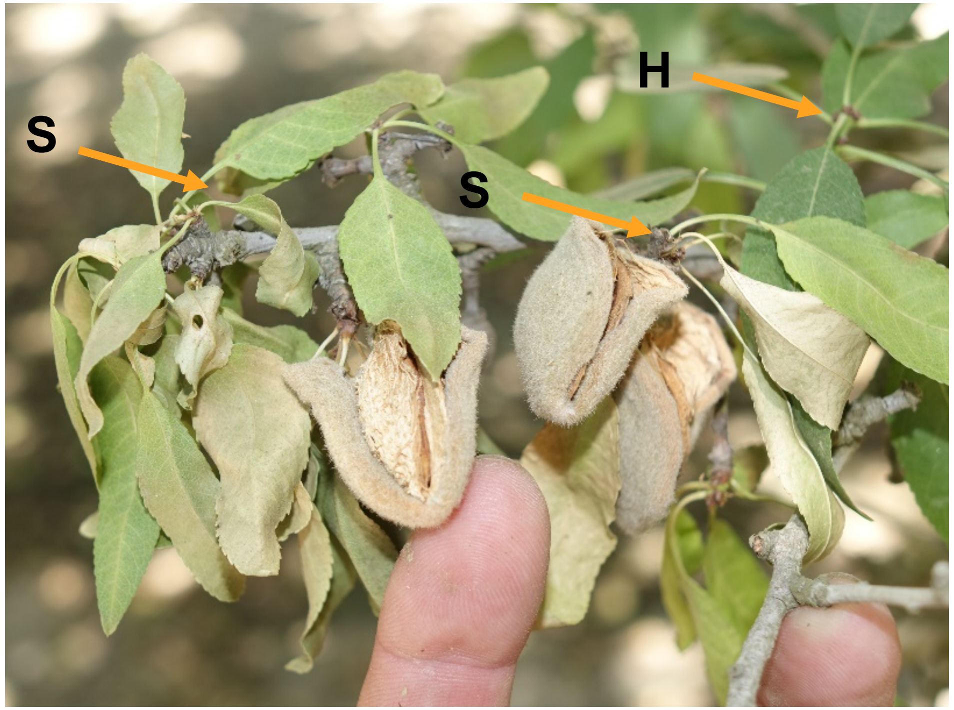
Aspergillus niger

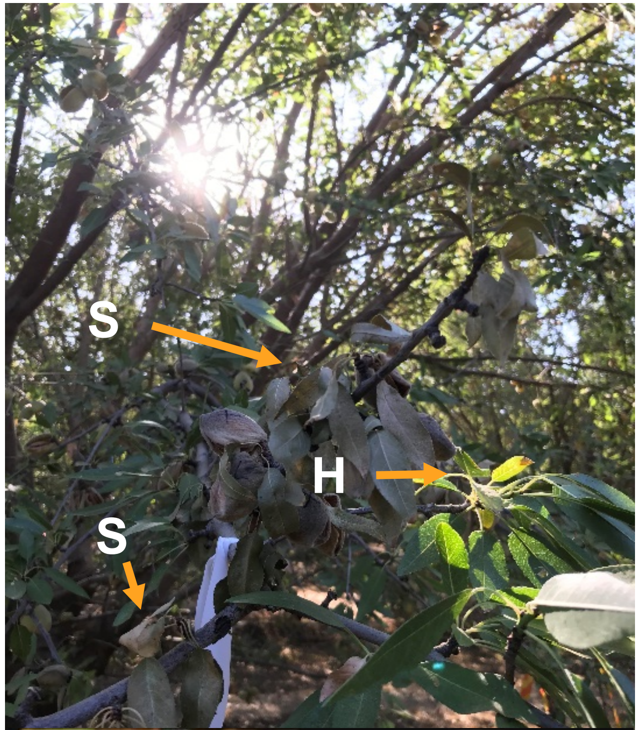


Soil

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.





Rhizopus

Aspergillus niger

Monilinia

Fruit susceptibility to Hull Rot Pathogen *Rhizopus stolonifer*

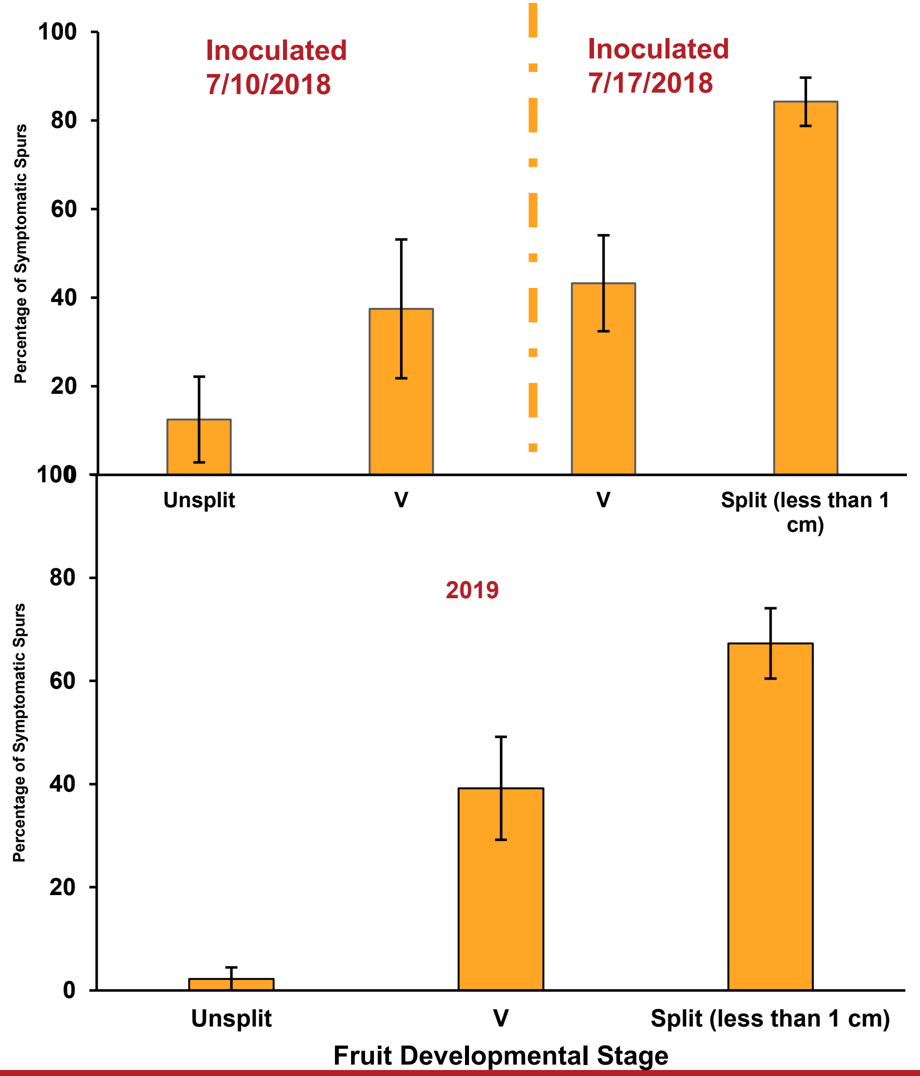
(b1) Initial separation-50% or more of a thin separation line visible

(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*



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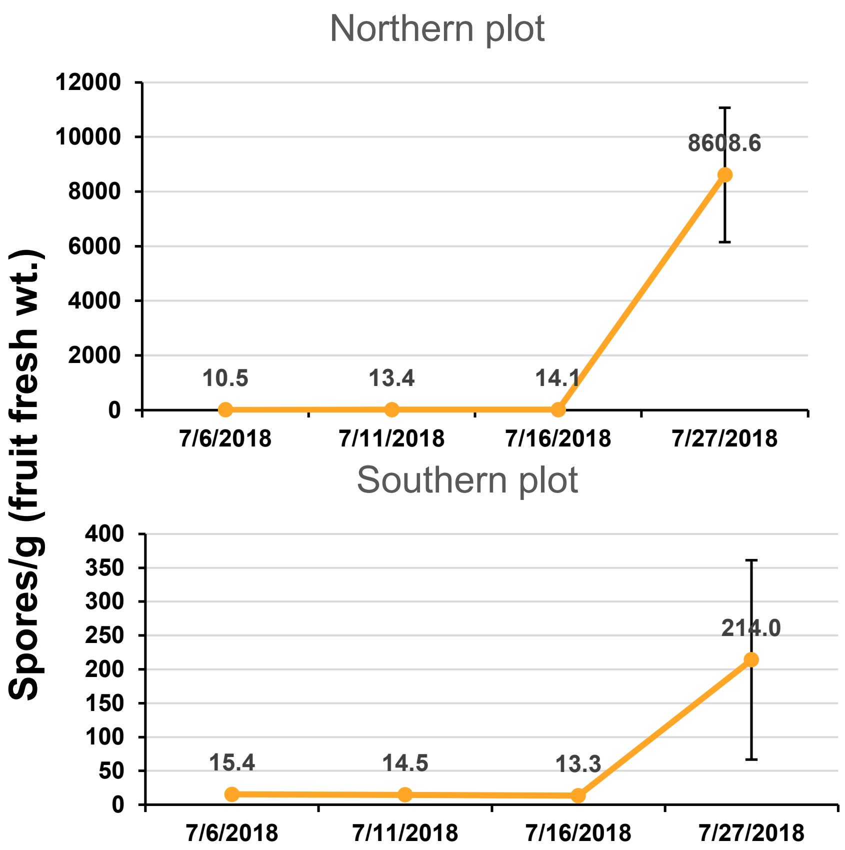
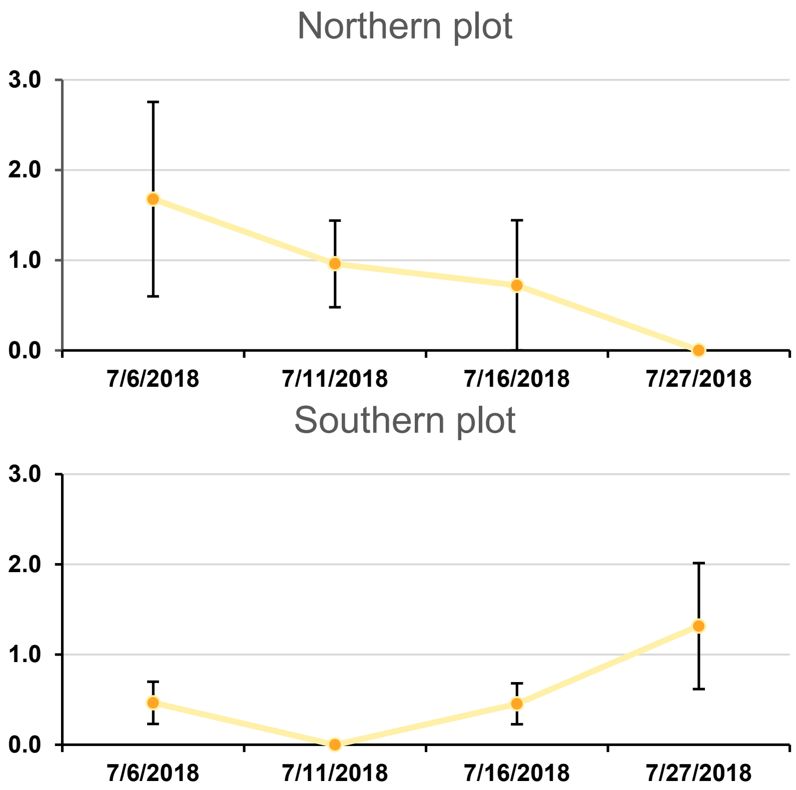
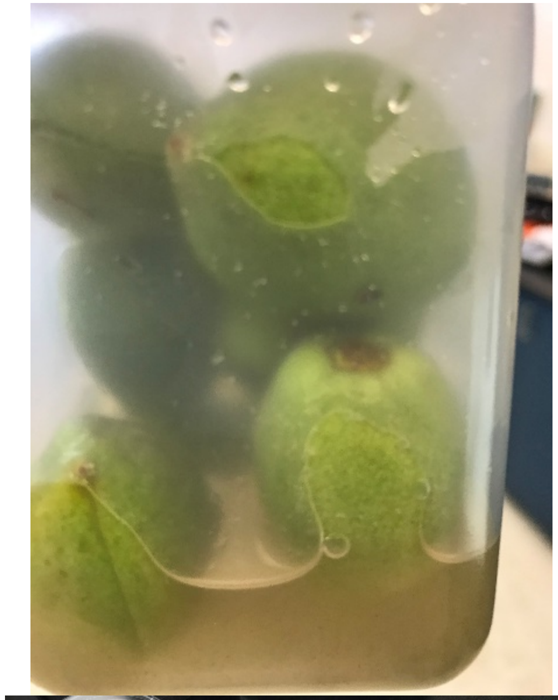
A. niger spore population on almond fruit

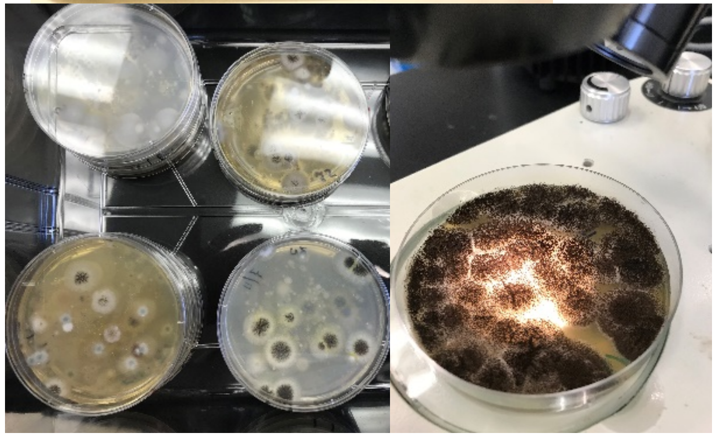
Aspergillus niger



Rhizopus Stolonifer







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Irrigation Management and Hull Rot

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

Table 2. Effects of deficit irrigation on natural incidence of hull rot disease caused by *Rhizopus stolonifer* in almond trees cultivar Nonpareil, Kern County, CA

	Dead leaf clusters[y] (no. per tree)		Dead wood[y] (cm per tree)		Infected hulls[y] (%)	
Irrigation treatment[x]	**1994**	**1995**	**1994**	**1995**	**1994**	**1995**
100 (control)	20.1	23.1	28.4	49.2	26.5	24.2
85 sustained	18.0	35.2	32.8	66.6	35.0	24.5
85 regulated	6.1	13.5	8.2	22.1	24.2	14.5
70 sustained	7.1	15.5	8.4	17.2	21.5	14.2
70 regulated	4.7	5.4	2.2	2.2	35.8	18.8
Significance of F, P = [z]	0.032	0.001	0.001	0.002	0.010	0.036
Orthogonal contrasts						
100 versus deficits	0.005	0.022	0.006	0.068	NS	0.063
100 versus 85 sustained	NS	NS	NS	NS	0.072	NS
85 versus 70	0.030	0.007	0.003	0.003	NS	NS
Sustained versus regulated	0.027	0.002	0.003	0.009	NS	NS

[x] Irrigation deficits of 70 and 85% of potential evapotranspiration (ETc) were imposed at every irrigation (70 and 85 sustained) or by one preharvest reduction to 50% of ETc from 1 June to 31 July (70 regulated) or 1 to 15 July (85 regulated).

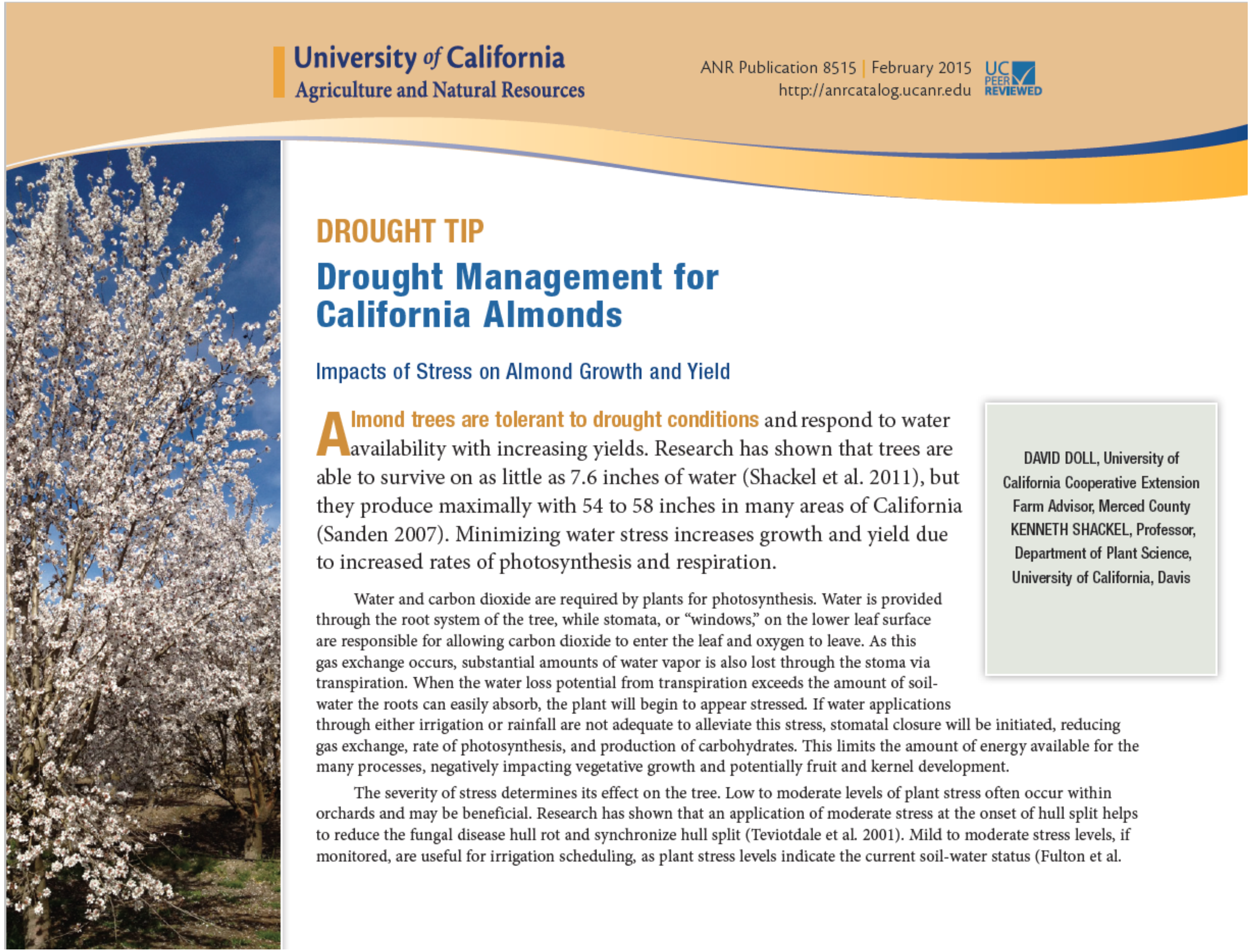
[y] Average of 12 trees per replication. Dead wood consisted of spurs, twigs, and small branches and was visually estimated. Data collected 11 and 18 August 1994 and 1995, respectively, 2 days after trees were shaken for harvest.

[z] Irrigation treatments were replicated six times and arranged in a randomized complete block design. NS = not significant, $P > 0.1000$. Means were separated by orthogonal contrasts.

Source: Teviotdale et al. 2001. Effects of deficit irrigation on hull rot disease of almond trees caused by *Monilinia fructicola* and *Rhizopus stolonifer.* Plant Dis. 85:399-403

Irrigation Management and Hull Rot

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



University of California
Agriculture and Natural Resources

ANR Publication 8515 | February 2015
http://anrcatalog.ucanr.edu
UC PEER REVIEWED

DROUGHT TIP

Drought Management for California Almonds

Impacts of Stress on Almond Growth and Yield

DAVID DOLL, University of California Cooperative Extension Farm Advisor, Merced County
KENNETH SHACKEL, Professor, Department of Plant Science, University of California, Davis

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 (Sanden 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 stoma 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 (Teviotdale 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.

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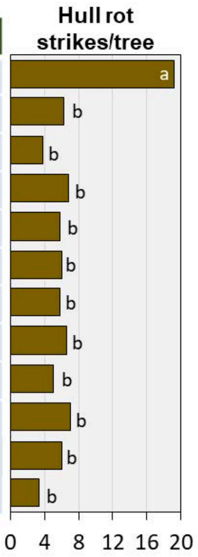
Chemical Control of Hull Rot

- 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.

Treatment	Rate(/A)	7-18	8-3
Control	---	---	---
di-K-PO4	48 oz	---	@
di-K-PO4	48 oz	@	@
di-K-PO4 + Ca(OH)2	48+ 320 oz	---	@
di-K-PO4 + Ca(OH)2	48 + 320 oz	@	@
Ca(OH)2	320 oz	---	@
Cinetis	24 fl oz	@	@
Cinetis	24 fl oz	---	@
Fontelis + Tebucon	20 fl oz + 8 oz	---	@
Fontelis + Inspire	20 + 7 fl oz	---	@
Fontelis + Abound	20 + 15.5 fl oz	---	@
Fontelis + Ph-D	20 fl oz + 6.2 oz	---	@



7-18-17: early suture opening, 8-3-17: 5% hull split.

ALMOND: FUNGICIDE EFFICACY

Fungicide	Resistance risk (FRAC)[1]	Brown rot	Jacket rot	Anthrac -nose	Shot hole	Scab[3]	Rust[3]	Leaf blight	Alternaria leaf spot[3]	PM-like[5]	Hull rot[16]
Bumper,Tilt,Propicure, Propiconazole[4]	high (3)	++++	+/-	++++	++	++	+++	ND	++	+++	++
Fontelis[4]	high (7)	++++	++++	++	++++	+++	+++	ND	+++	ND	----
Kenja[4]	high (7)	++++	++++	++	++++	+++	+++	ND	+++	ND	----
Indar	high (3)	++++	+/-	+++	++	++	NL	ND	+	ND	----
Inspire	high (3)	++++	+	+++	++	+++	+++	ND	+++	ND	+++
Inspire Super[4]	medium (3/9)	++++	++++	ND	+++	+++	+++	ND	+++	ND	+++
Luna Experience[3]	medium (3/7)	++++	+++	++++	+++	++++	++++	ND	++++	+++	+++
Luna Sensation[3,7]	medium (7/11)	++++	++++	++++	++++	++++	++++	ND	++++	+++	+++
Merivon[3,7]	medium (7/11)	++++	++++	++++	++++	++++	+++	ND	++++	++++	+++
Pristine[3,7]	medium (7/11)	++++	++++	++++	++++	++++	+++	ND	+++	+++	+++
Quadris Top[3]	medium (3/11)	++++	NL	++++	+++	++++	++++	ND	+++	+++	+++
Quilt Xcel,Avaris 2XS[3]	medium (3/11)	++++	+++	++++	+++	++++	++++	ND	+++	+++	+++
Quash[4]	high (3)	++++	++	++++	+++	+++	++++	ND	++++	+++	+++
Rovral + oil[8, 9]	low (2)	++++	++++	----	+++	+/-	++	ND	+++	ND	----
Scala[3, 7]	high (9)	++++	++++	ND	++	----	ND	ND	+	----	----
Tebucon,Toledo (Elite**,Tebuzol**)	high (3)	++++	+/-	+++	++	++	+++	ND	+	ND	++
Topsin-M,T-Methyl, Incognito,Cercobin[2,6,7,8]	high (1)	++++	++++	----	----	+++	+	+++	----	++	----
Vangard[3, 7,9]	high (9)	++++	++++	ND	++	----	ND	ND	+	----	----
Viathon	medium (3/33)	++++	+/-	+++	++	++	+++	ND	+	ND	++
Abound[3,4,7,10]	high (11)	+++	----	++++	+++	++++	++++	+++	+++	+++	+++
CaptEvate*	low (M4/17)	+++	+++	+++	+++	+++	----	+++	+	----	----
Elevate[7]	high (17)	+++	++++	----	+	ND	ND	ND	ND	ND	----
Gem[3,4, 7, 10]	high (11)	+++	----	++++	+++	++++	++++	+++	+++	+++	+++
Laredo	high (3)	+++	----	++	++	----	+	+++	----	+++	----
Luna Privilege	high (7)	+++	++	++	++	+++	+++	ND	+++	++	++
Rovral,Iprodione, Nevado[9]	low (2)	+++	+++	----	+++	----	----	ND	++	----	----
Rally[13]	high (3)	+++	----	++	+/-	----	+	+++	----	+++	----
Rhyme	high (3)	+++	+/-	ND	+	++	ND	ND	++	ND	ND
Bravo,Chloro- thalonil,Echo,Equus[11, 12, 15]	low (M5)	++	NL	+++	+++	+++	++++	NL	NL	----	----
Captan[4, 6, 12]	low (M4)	++	++	+++	+++	++	----	+++	+	----	----
Fracture	low	++	+	----	----	----	----	----	----	----	----
Mancozeb	low (M3)	++	++	+++	+++	++	+++	+++	+	----	----
Ph-D	medium (19)	++	+++	----	++	+++	+++	ND	++++	ND	+++
Ziram	low (M3)	++	+	+++	+++	+++	----	++	+	----	----
Syllit	medium (U12)	+	----	ND	+++	++++	ND	ND	+	ND	----
Copper[14,15]	low (M1)	+/-	+/-	----	+	+	----	----	ND	----	----
Lime sulfur[12,15]	low (M2)	+/-	NL	----	+/-	++	++	NL	NL	----	----
Sulfur[4,12]	low (M2)	+/-	+/-	----	----	++	++	----	----	+++	----
PlantShield[17]	low	----	----	----	----	----	----	----	----	----	----
Copper + oil[14,15]	low (M1)	ND	ND	----	+	+++	----	----	ND	----	----

Rating: ++++ = excellent and consistent, +++ = good and reliable, ++ = moderate and variable, + = limited and/or erratic, +/- = minimal and often ineffective, ---- = ineffective, NL = not on label, and ND = no data

* Registration pending in California.

**Not registered, label withdrawn or inactive in California.

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).

ALMOND: TREATMENT TIMING

Note: Not all indicated timings may be necessary for disease control.

Disease	Dormant	Bloom			Spring[1]		Summer	
		Pink bud	Full bloom	Petal fall	2 weeks	5 weeks	May	June
Alternaria leaf spot	—	—	—	—	—	++	+++	+++
Anthracnose[2]	—	++	+++	+++	+++	+++	+++	++
Bacterial spot	+	—	++	+++	+++	++	+	—
Brown rot blossom blight	—	++	+++	+	—	—	—	—
Green fruit rot	—	—	+++	++	—	—	—	—
Hull rot[7]	—	—	—	—	—	—	—	+++
Leaf blight	—	—	+++	++	+	—	—	—
Rust	—	—	—	—	—	+++	+++	+[6]
Scab[3]	++	—	—	++	+++	+++	+	—
Shot hole[4]	+[5]	+	++	+++	+++	++	—	—

Rating: +++ = most effective, ++ = moderately effective, + = least effective, and — = ineffective

1 Two and five weeks after petal fall are general timings to represent early postbloom and the latest time that most fungicides can be applied. The exact timing is not critical but depends on the occurrence of rainfall.

2 If anthracnose was damaging in previous years and temperatures are moderate (63°F or higher) during bloom, make the first application at pink bud. Otherwise treatment can begin at or shortly after petal fall. In all cases, application should be repeated at 7- to 10-day intervals when rains occur during periods of moderate temperatures. Treatment should, if possible, precede any late spring and early summer rains. Rotate fungicides, using different fungicide classes, as a resistance management strategy.

3 Early treatments (during bloom) have minimal effect on scab; the 5-week treatment usually is most effective. Treatments after 5 weeks are useful in northern areas where late spring and early summer rains occur. Dormant treatment with liquid lime sulfur improves efficacy of spring control programs.

4 If pathogen spores were found during fall leaf monitoring, apply a shot hole fungicide during bloom, preferably at petal fall or when young leaves first appear. Reapply when spores are found on new leaves, or if heavy, persistent spring rains occur. If pathogen spores were not present the previous fall, shot hole control may be delayed until spores are seen on new leaves in spring.

5 Dormant copper treatment seldom reduces shot hole infection but may be useful in severely affected orchards and must be followed by a good spring program.

6 Treatment in June is important only if late spring and early summer rains occur.

7 Make application at 1-5% hull split to manage hull rot caused by *Rhizopus stolonifer*.

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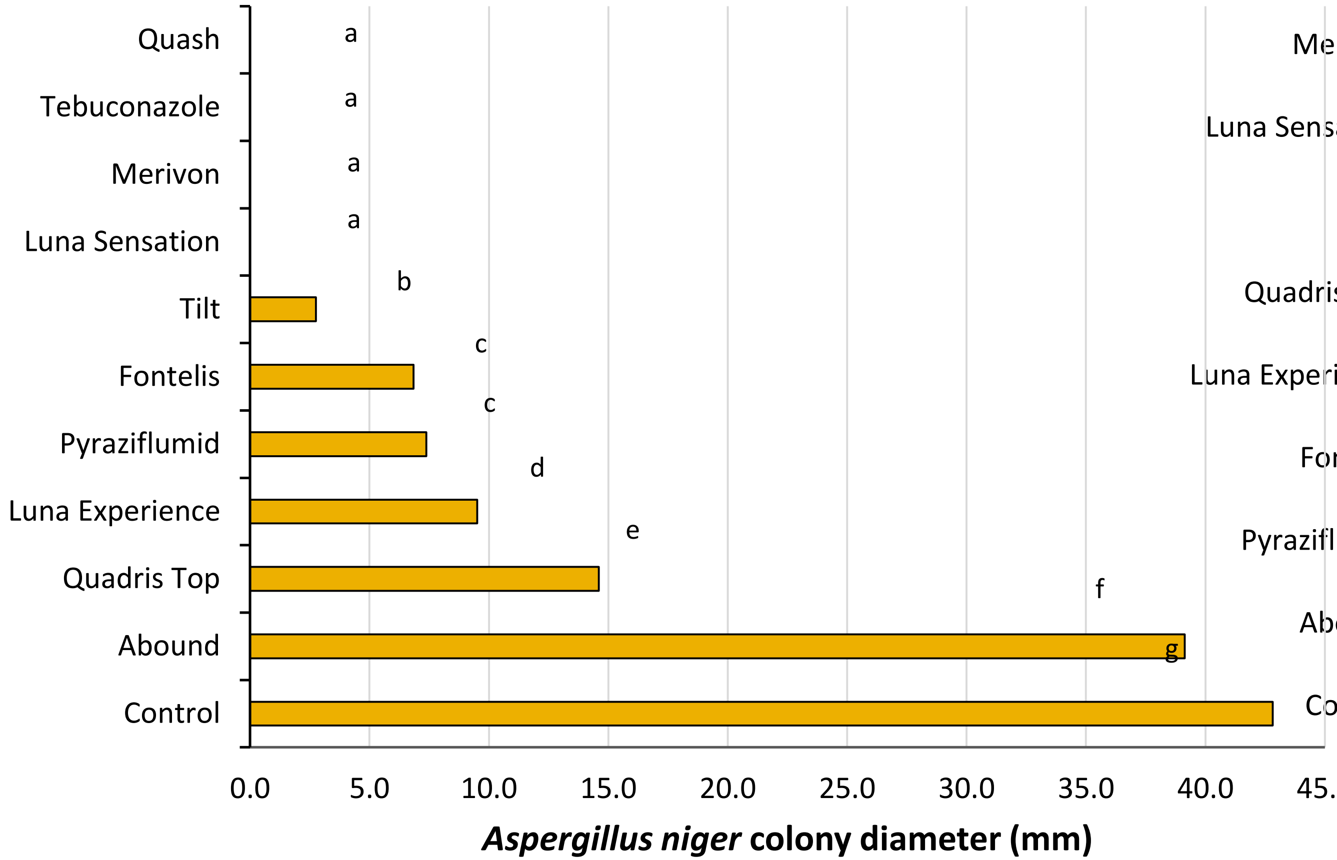
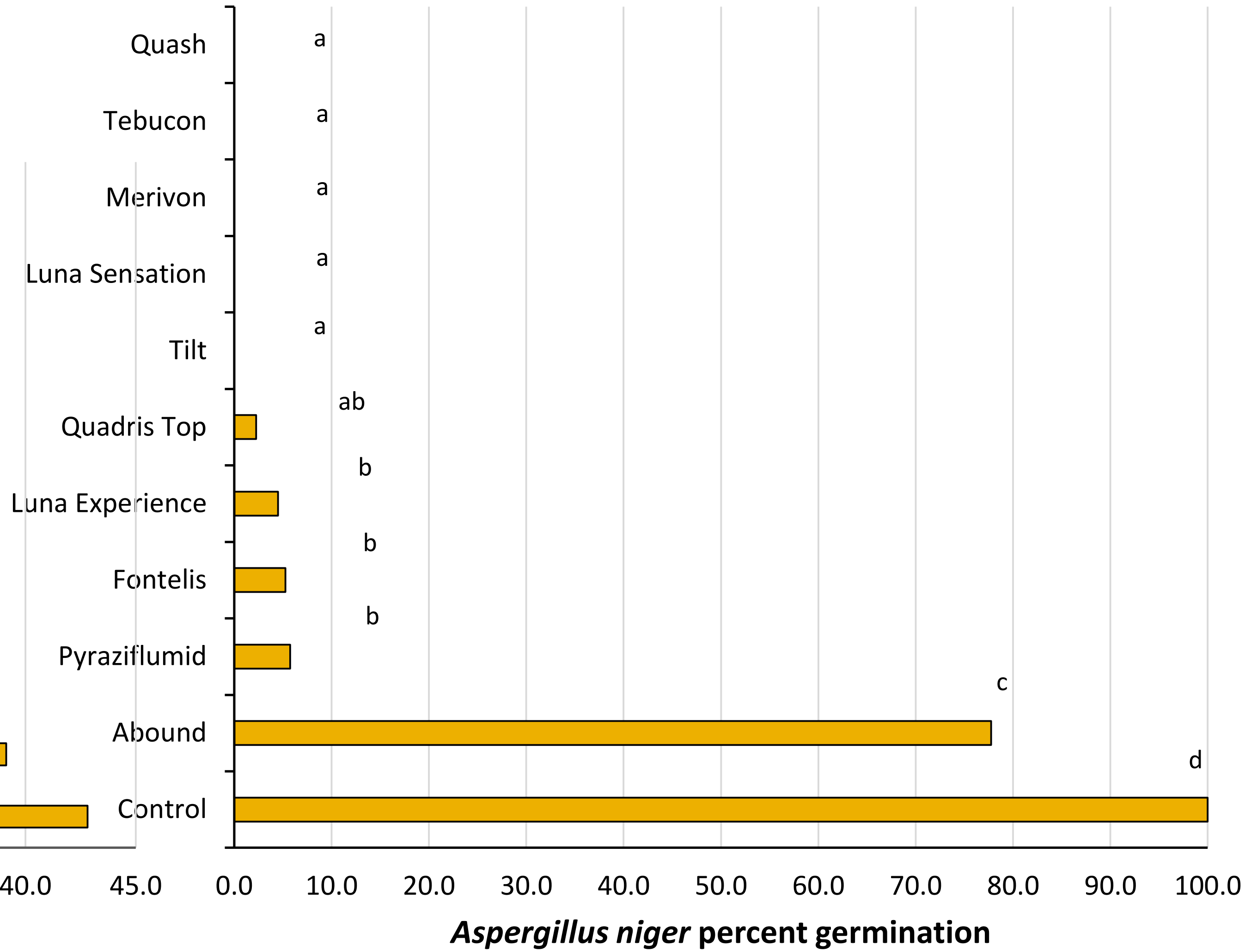
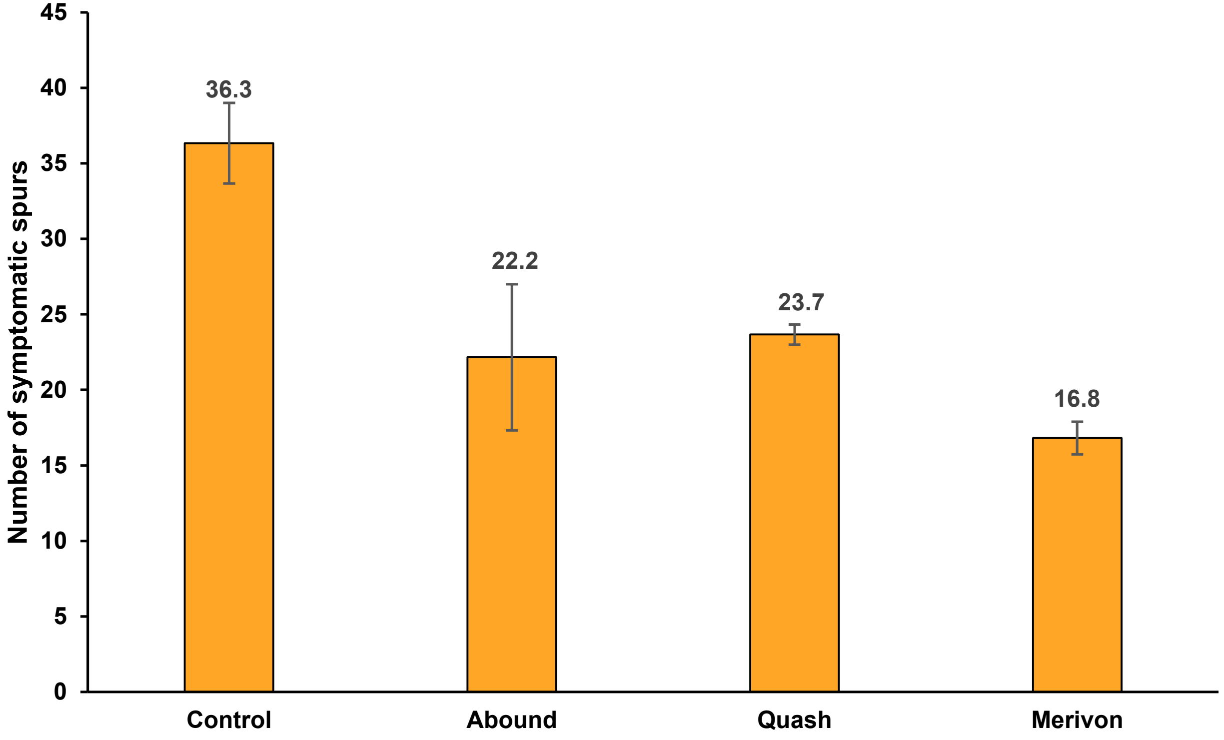
In vitro sensitivity of *A. niger* to different fungicides





Chemical control of Hull Rot 2019



Thank You!

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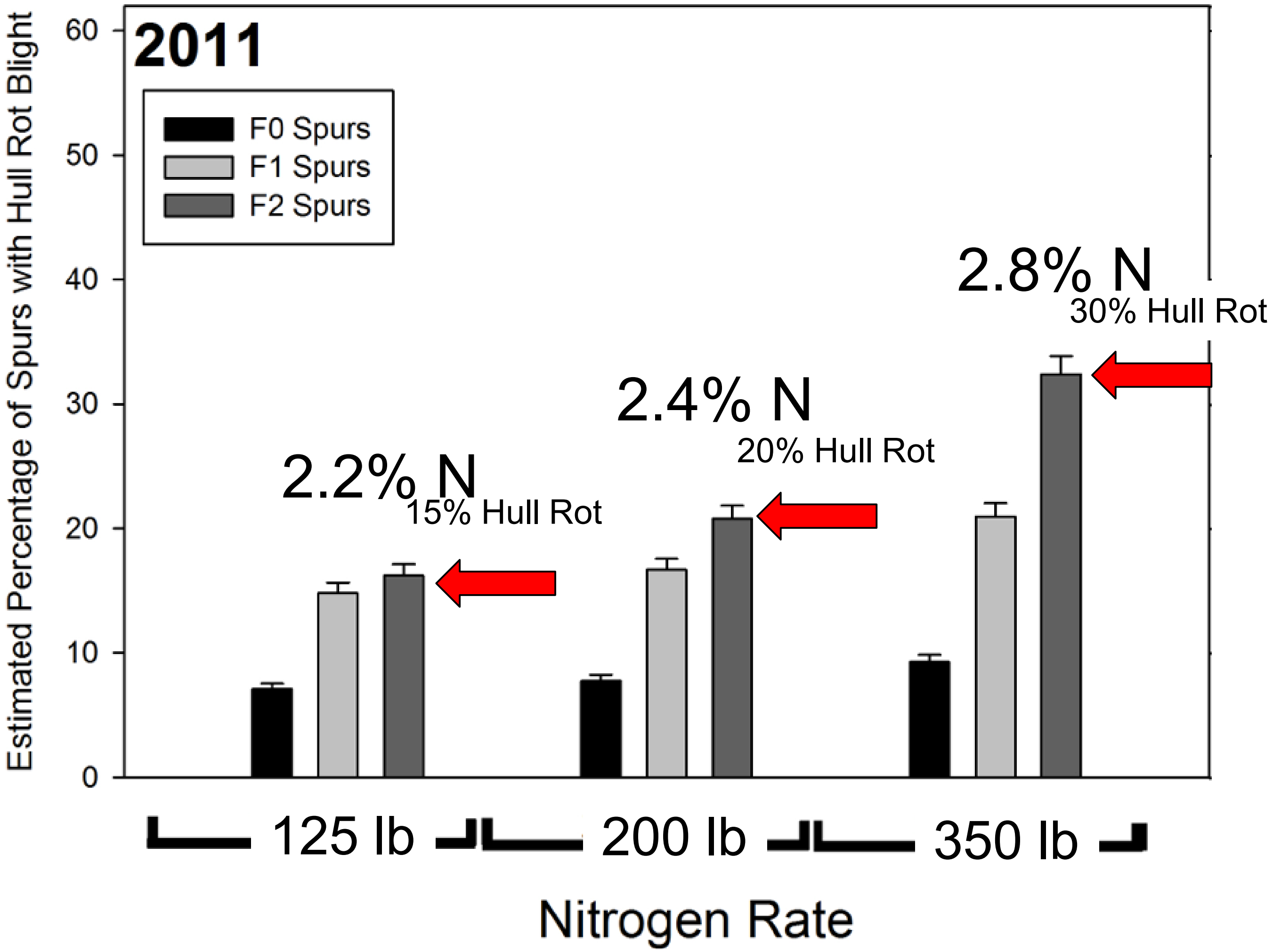
Influence of Nitrogen Management on Hull Rot

Patrick H. Brown

Almond Board of California

Influence of N Rate on Hull Rot in Almond

Hull Rot Incidence increased as N increased.

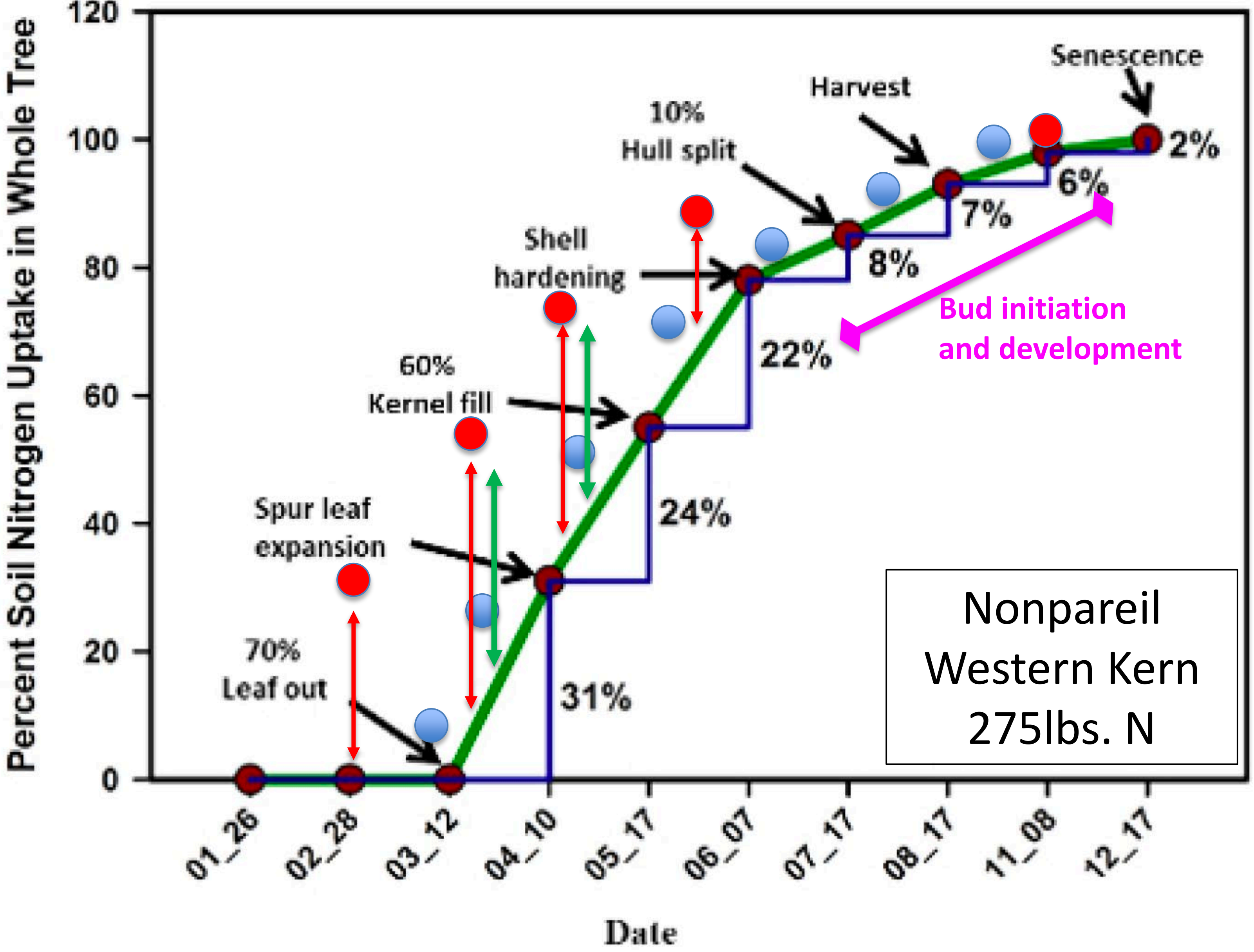


- Excess N increases hull susceptibility
- Excess N increases canopy humidity favoring fungus
- Excess N changes fruit ripening and infection window

- Deficit irrigation reduces canopy humidity

Elana Peach-Fine, MSc. 2013

Seasonal Almond Nitrogen Uptake
(2008-2012 Belridge Excavations)



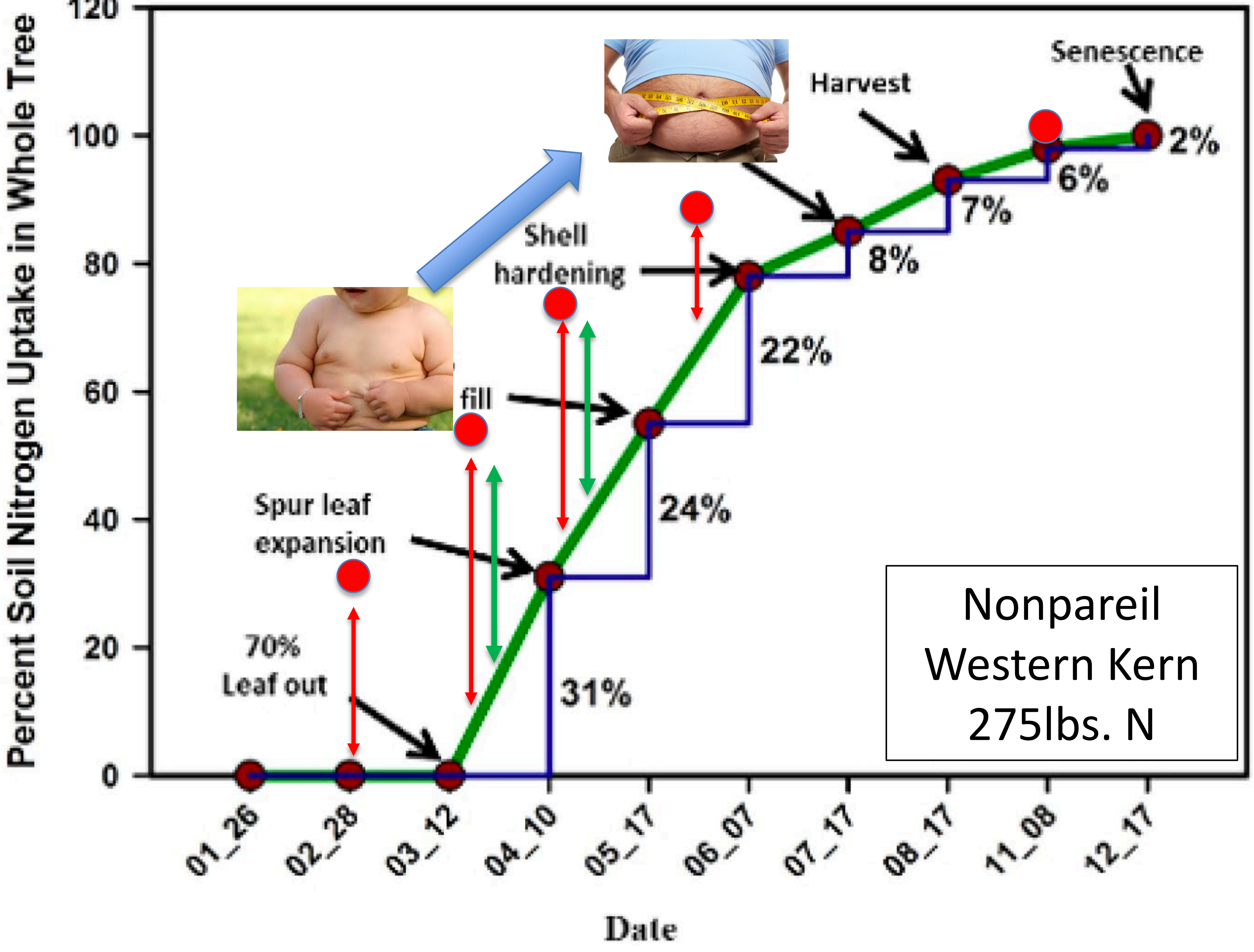
Ideal Fertilization: Multiple Applications in season timed with demand

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

Seasonal Almond Nitrogen Uptake
(2008-2012 Belridge Excavations)



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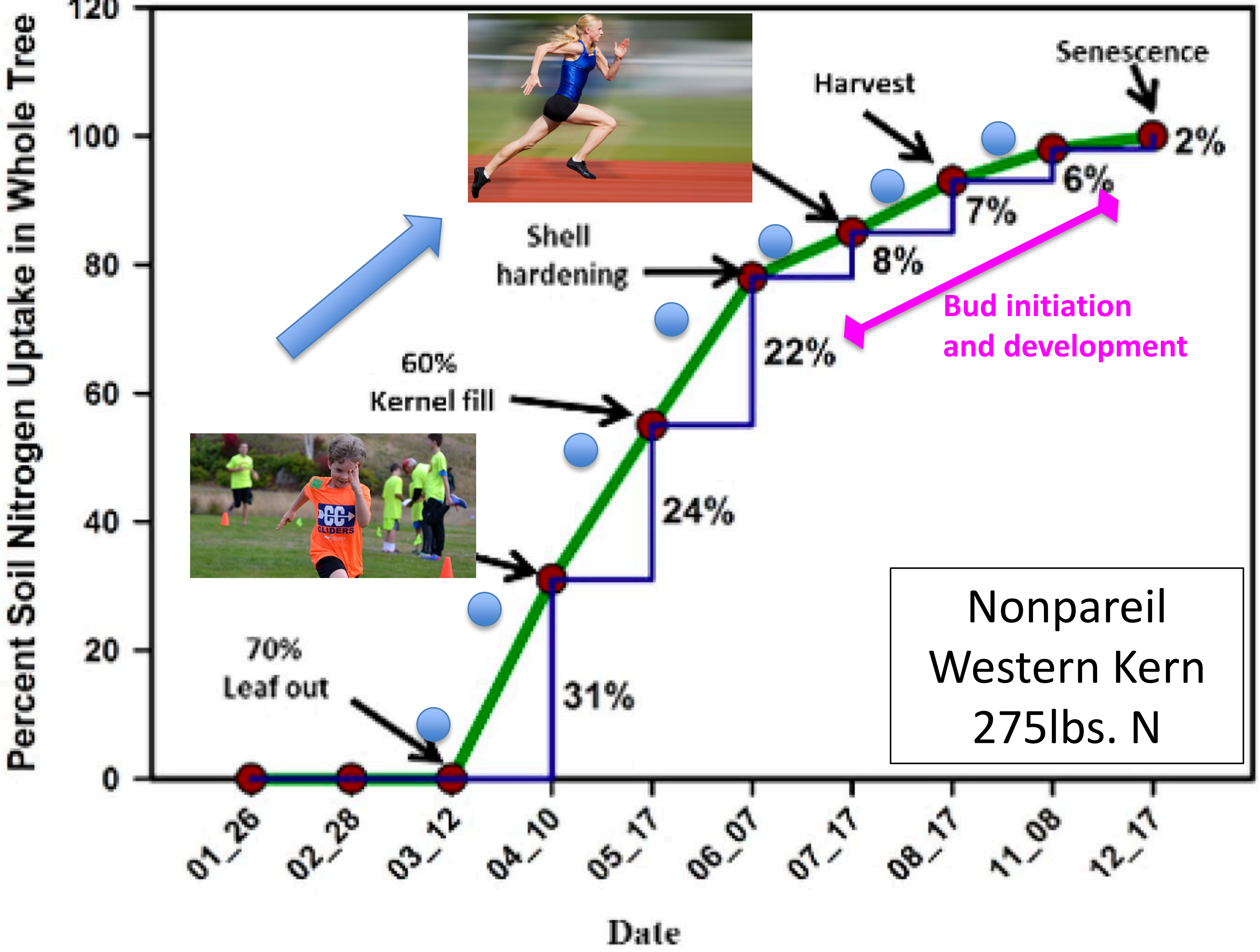


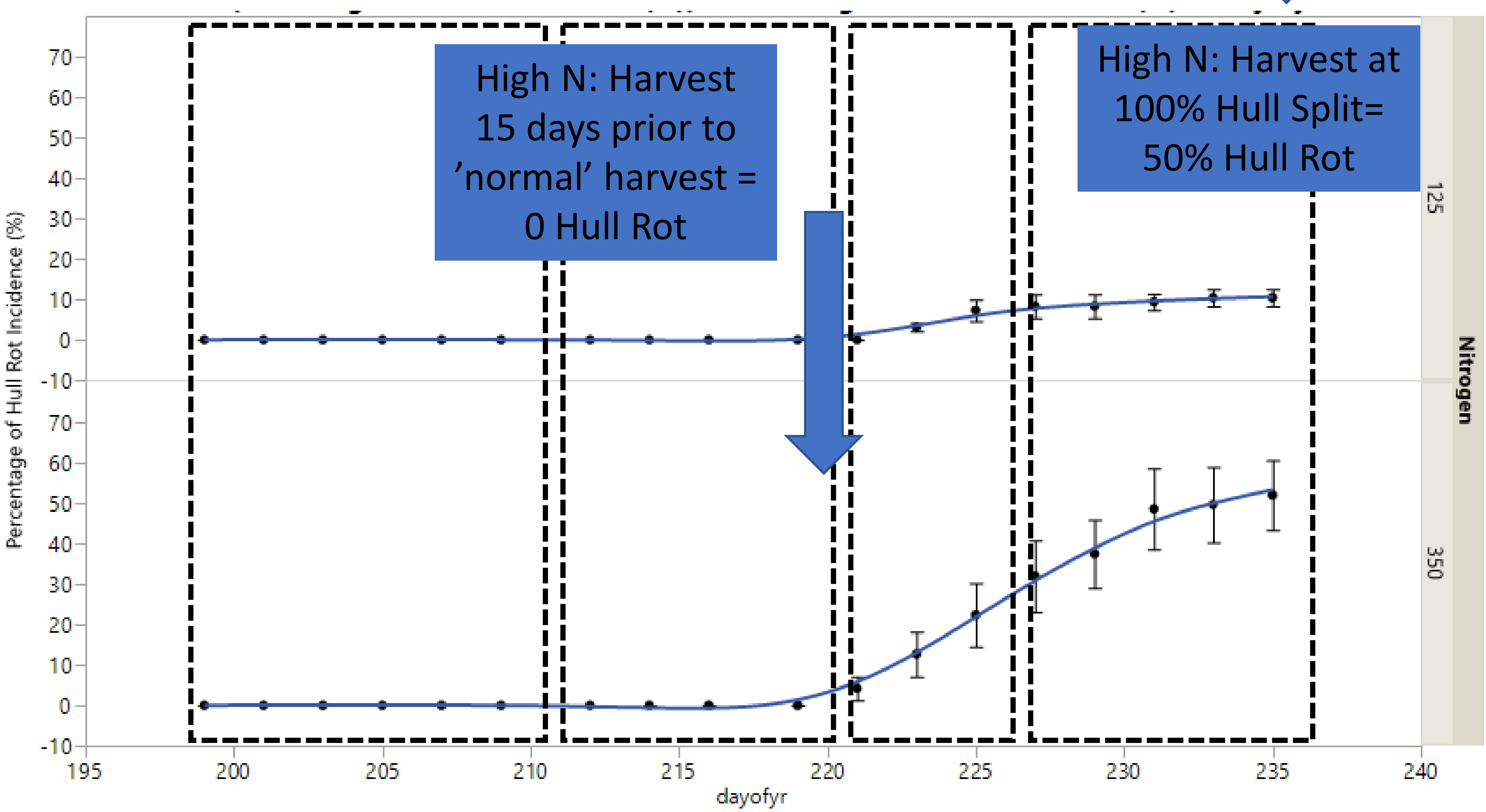
Ideal Fertilization: Multiple Applications in season timed with demand

Impact of Harvest Date on Hull Rot in extreme year (2012)

80% B-D

100% D-F

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

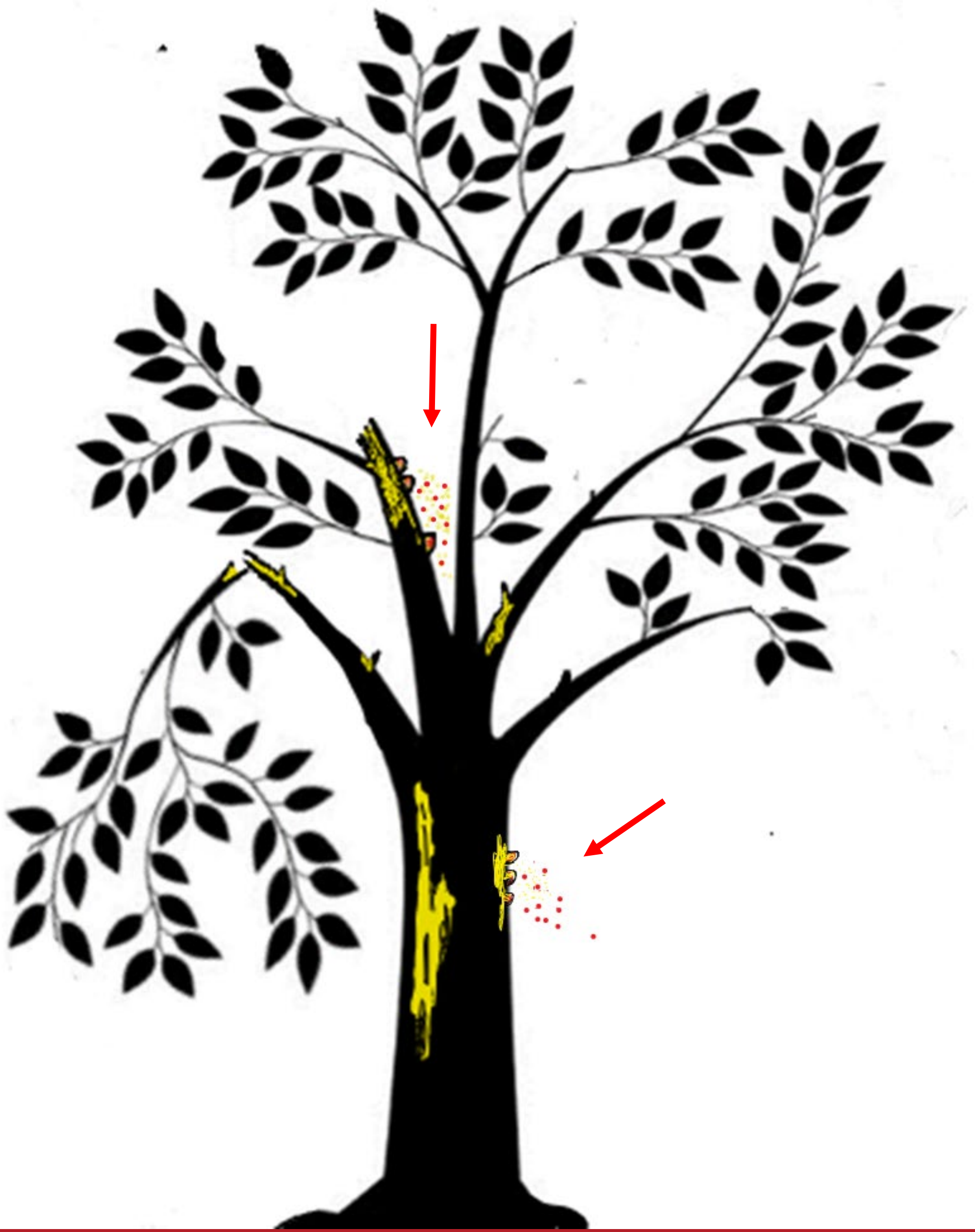
David Rizzo, Professor, UC Davis

Bob Johnson, PhD, UC Davis

Ganoderma root and butt rot

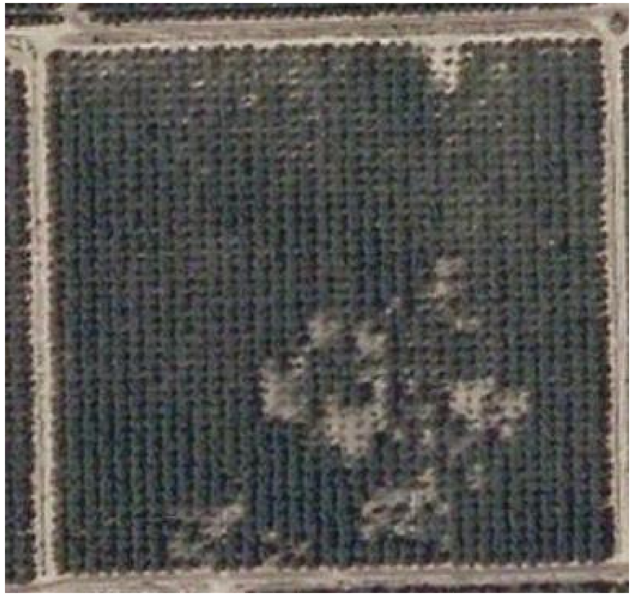
Heart rot

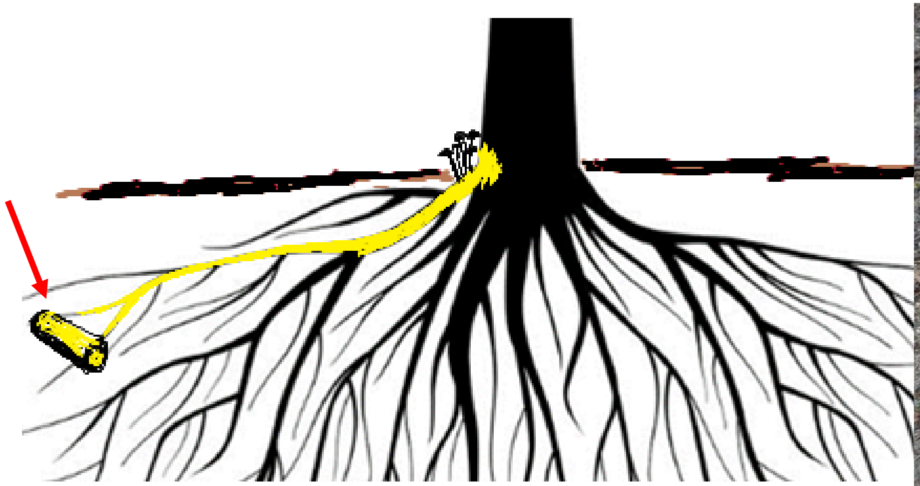
- Infects canopy and trunk
- Decays heartwood and sapwood reducing structural stability
- Results in trunk and limb breakage
- Spread via airborne spores
- Requires wounding for infection



Armillaria root rot

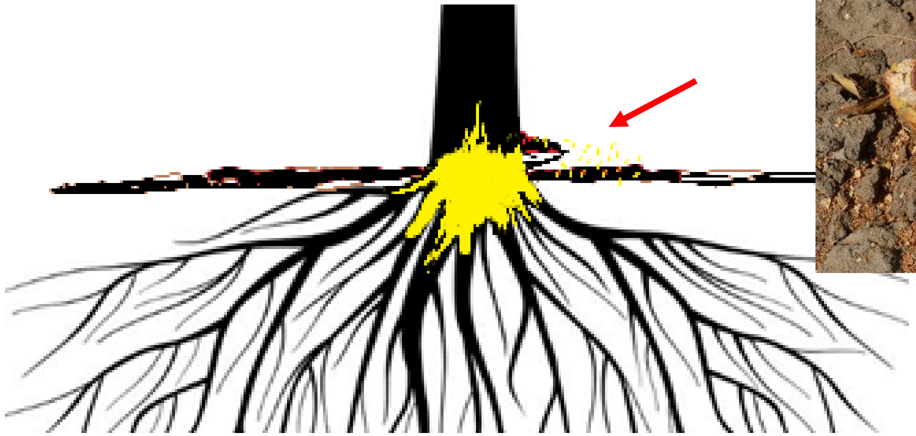
- Decays cambium and sapwood eventually girdling tree
- Kills tree standing
- Primarily spreads via root contact
- Wounding not necessary
- Characteristic disease center



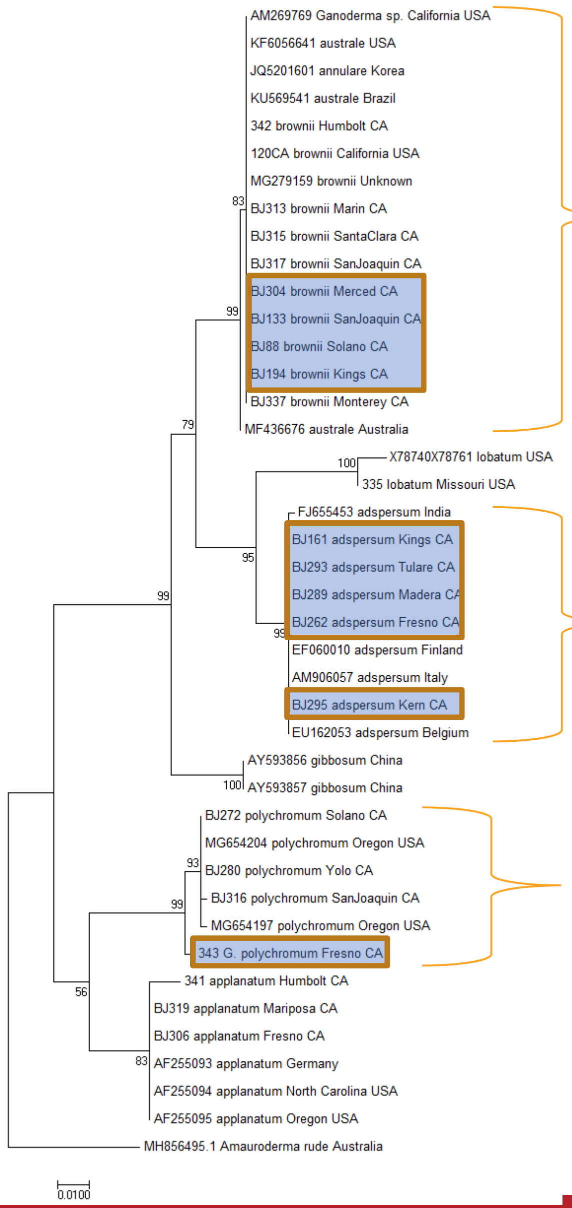


Ganoderma Root and butt rot

- 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

7%

G. adspersum

- Genbank accessions from India, Italy, Finland, Belgium
- Previously unreported

94%

G. polychromum

- Isolates from non-agricultural host and regions in California
- Genbank accessions from California and Oregon
- Previously reported

2%

Ganoderma adspersum – cause for concern?

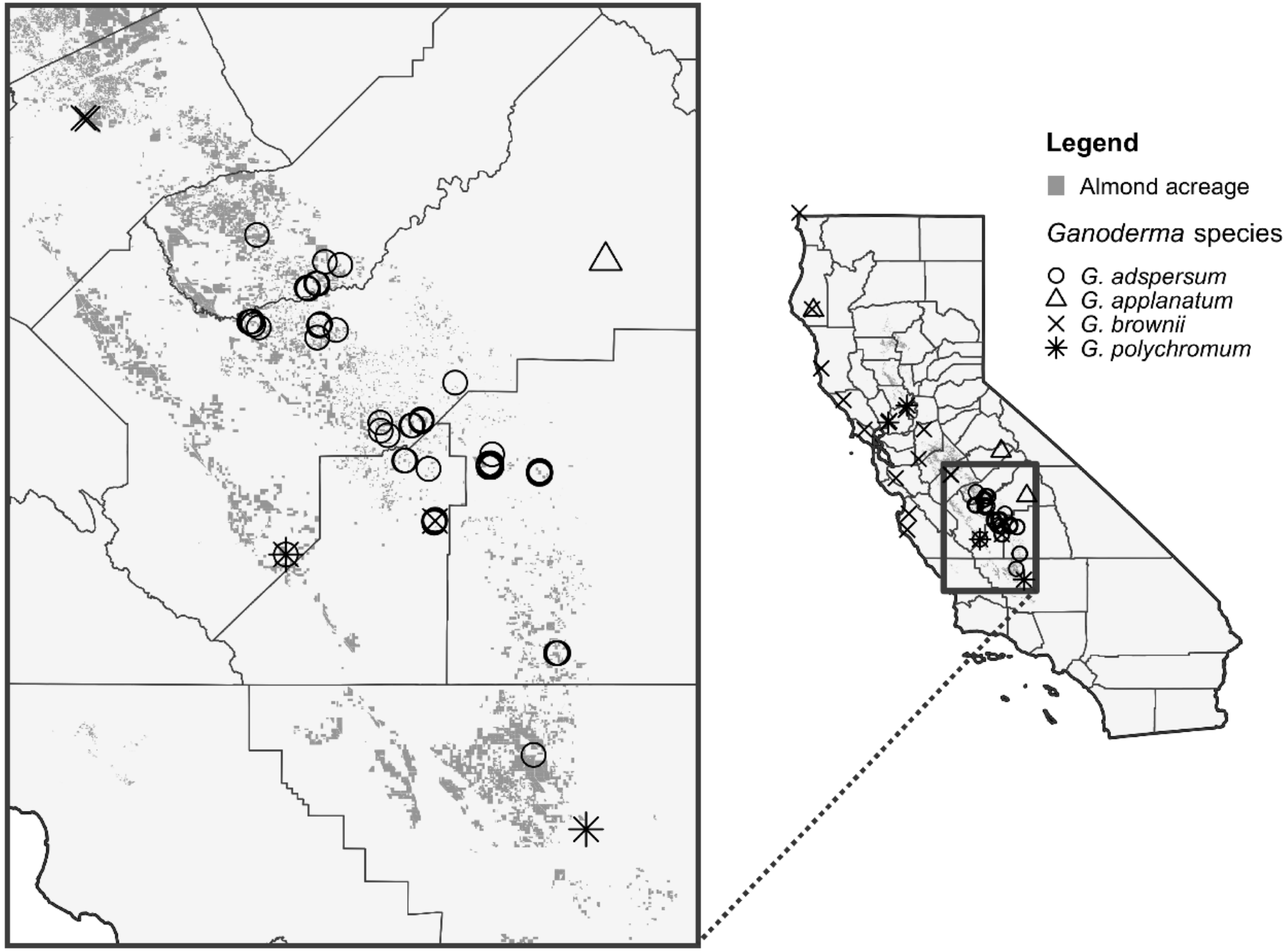
Experience in Europe

- 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



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

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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

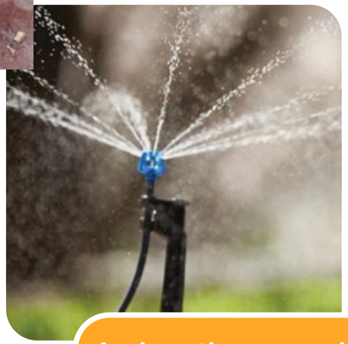
Harvest and cultural practices probably drives infection and spread

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

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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

Sponsored by:

FARM CREDIT

Doors open at 12:15 p.m. in Building C

You must have already purchased a ticket to attend luncheon

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.