Management of Brown Rot of Stone Fruit Crops in California

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"Brown rot is a major fungal disease of all commercially grown Prunus *species in most regions of the world and can result in extensive crop losses".* (Batra, 1991)

"It is the primary disease for which fungicides are applied to stone fruits." (D. Ritchie, North Carolina State University)

Brown rot of peach

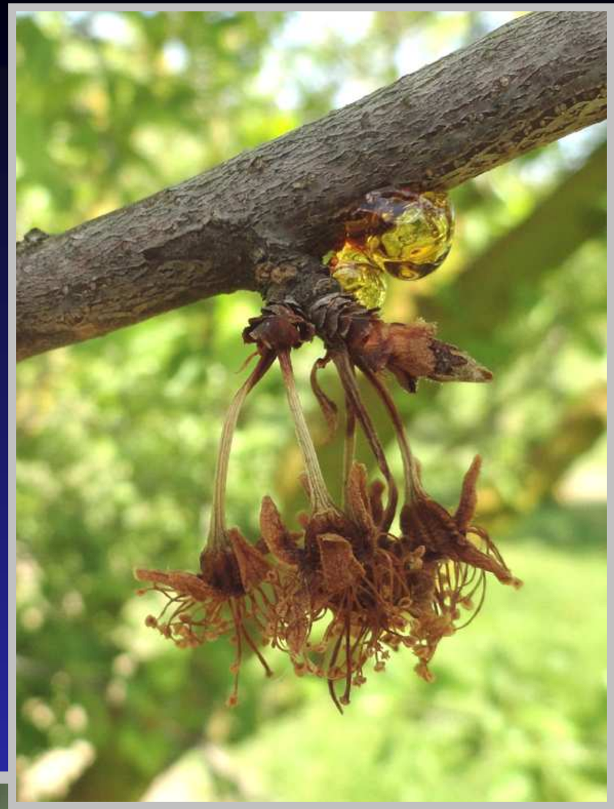
Preharvest fruit decay

Blossom blight and twig cankers

Postharvest fruit decay

Brown rot of prune and apricot

Blossom blight



Preharvest fruit decay

Brown rot of sweet cherry

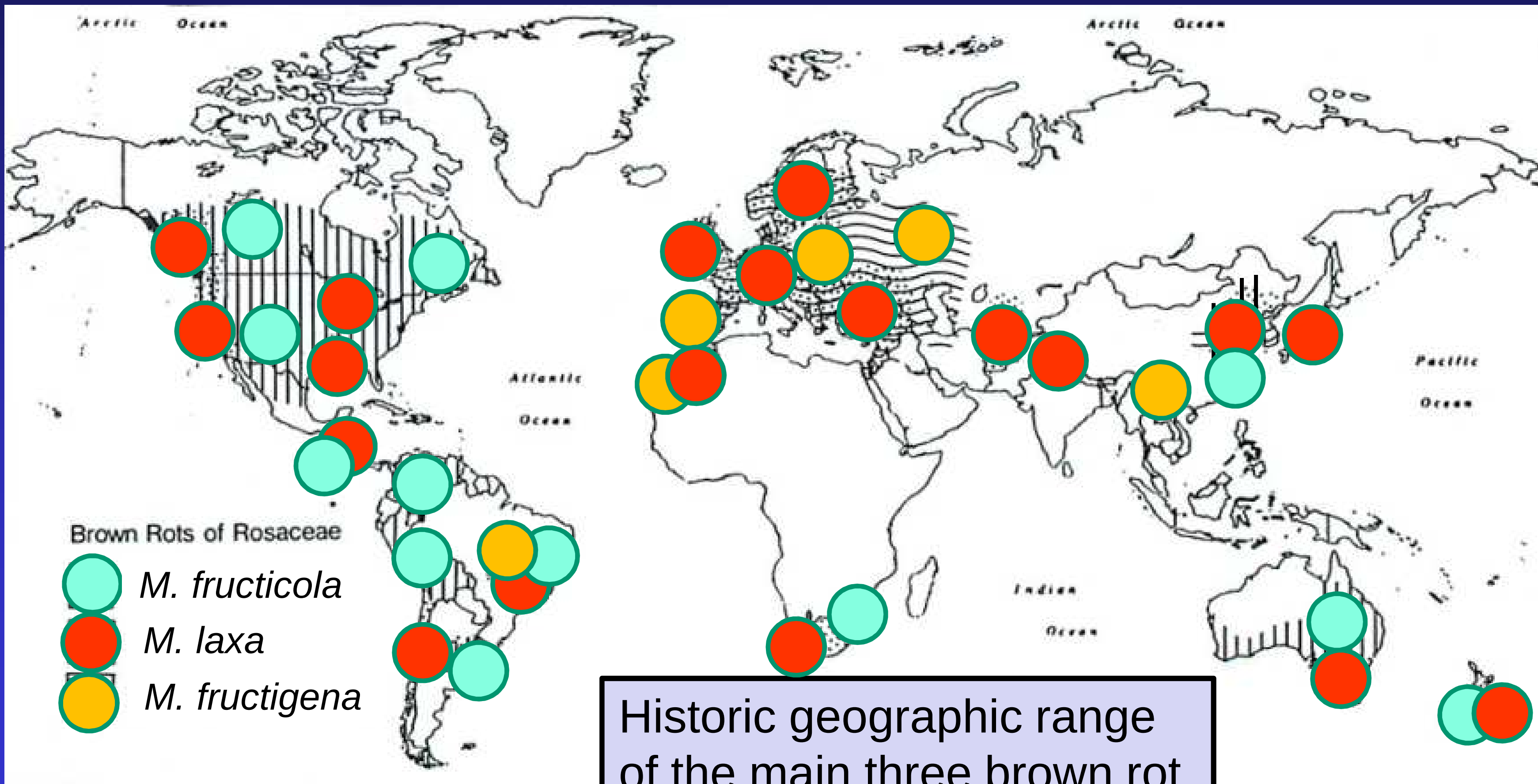
Blossom blight

Preharvest fruit decay

Postharvest fruit decay

Brown rot of stone fruits - Pathogens

- Main pathogens: ***Monilinia fructicola, M. laxa, M. fructigena***
- *M. fructicola* and *M. laxa* are the most destructive on stone fruit
- **New species** reported from China in 2010/11: *M. polystroma, M. mumecola, M. yunnanensis.*



Historic geographic range of the main three brown rot pathogens (Batra, 1991)

Brown rot of stone fruits - Pathogens

- Main pathogens: ***Monilinia fructicola, M. laxa, M. fructigena***
- Cultural identification on PDA:

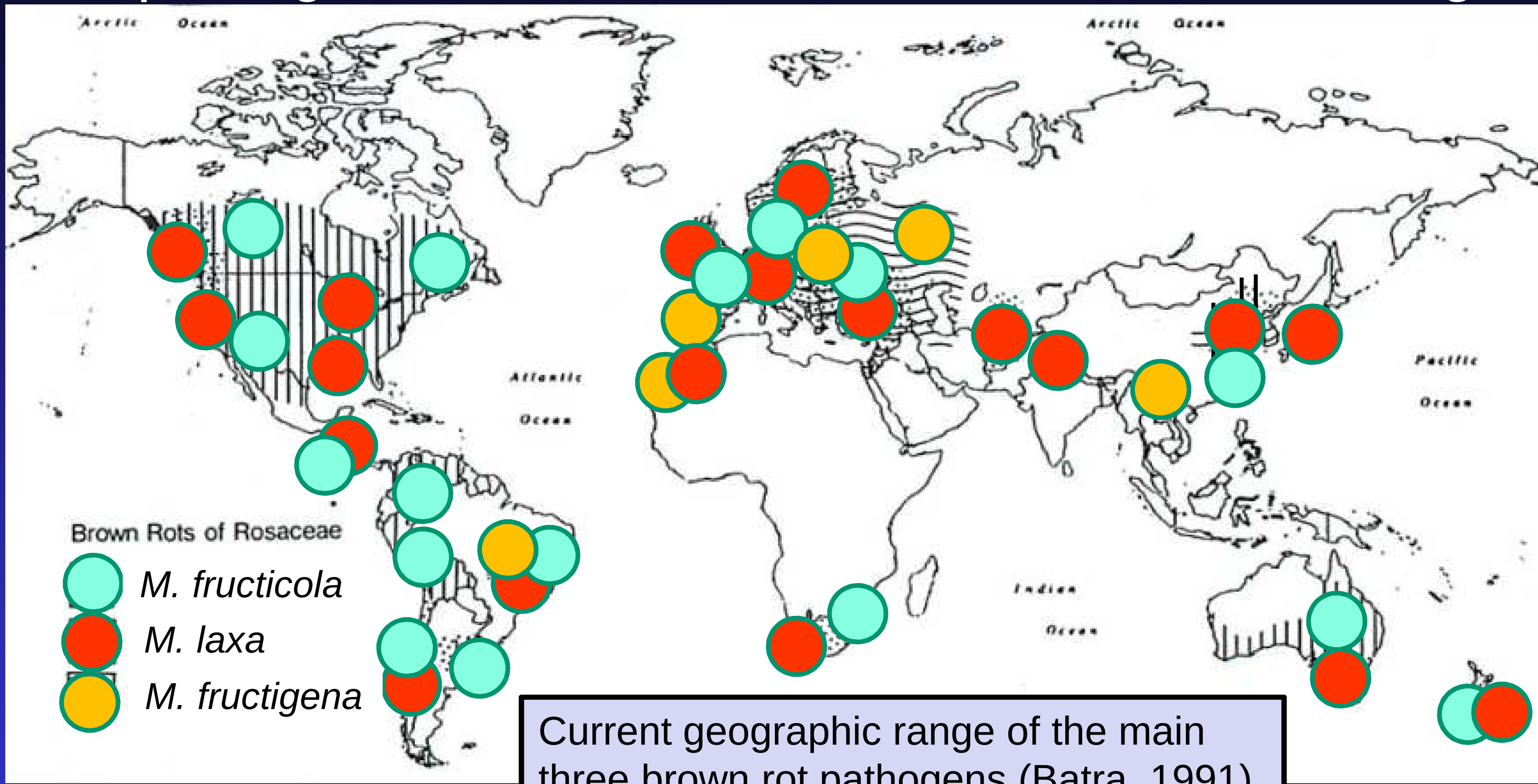
M. laxa

M. fructicola

M. fructigena

Brown rot of stone fruits - Pathogens

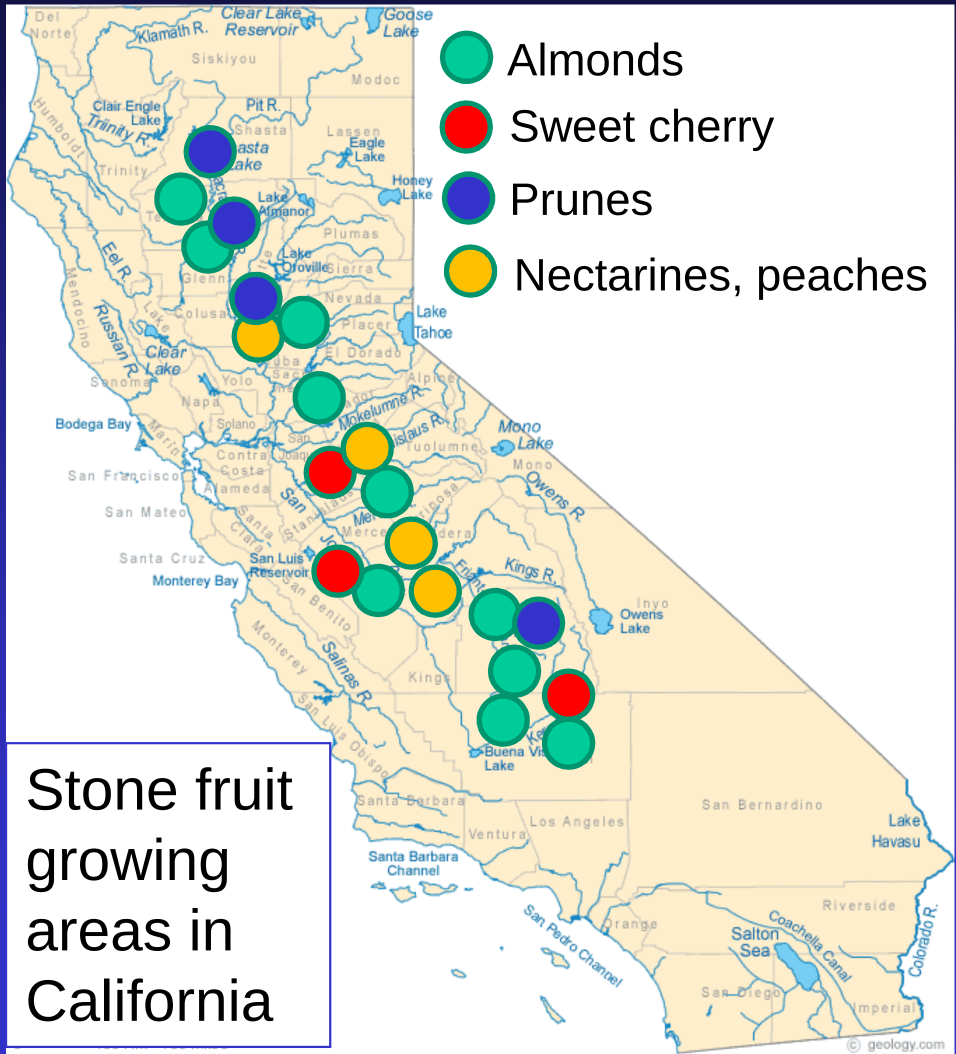
Main pathogens: *Monilinia fructicola, M. laxa, M. fructigena*



Current geographic range of the main three brown rot pathogens (Batra, 1991)

- *M. fructicola* has been a quarantine pest in **Europe**, but since 2001 has been found at locations in France, Austria, Spain, the Czech Republic, Italy, Germany, and Switzerland, presumably by way of imported fruit.
- *M. fructicola* is also a new occurrence in **Chile**.

Brown rot pathogens of stone fruits in California



Stone fruit growing areas in California

- **Blossom blight**

  Northern growing areas
  - Prunes, almonds: mostly *M. laxa*
  - Peaches: *M. fructicola/M. laxa*

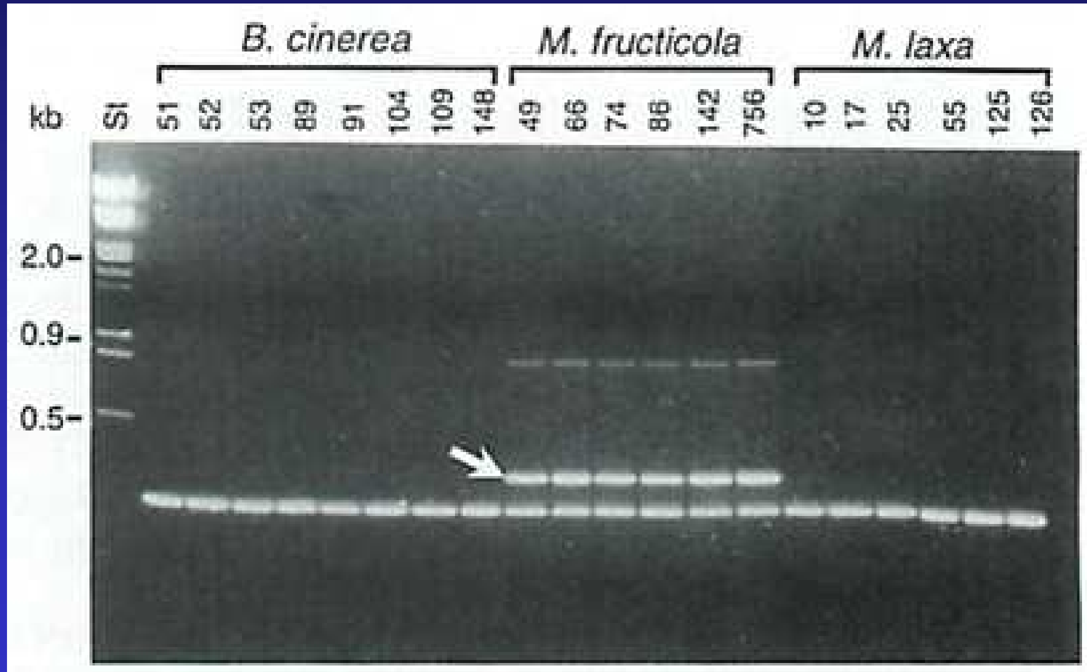
  Southern growing areas
  - Peaches, nectarines, plums, sweet cherry: mostly *M. fructicola*
  - Almonds: *M. fructicola, M. laxa*

- **Fruit rot**
  - All crops (except almond): mostly *M. fructicola*

Brown rot of stone fruits – Identification of pathogens

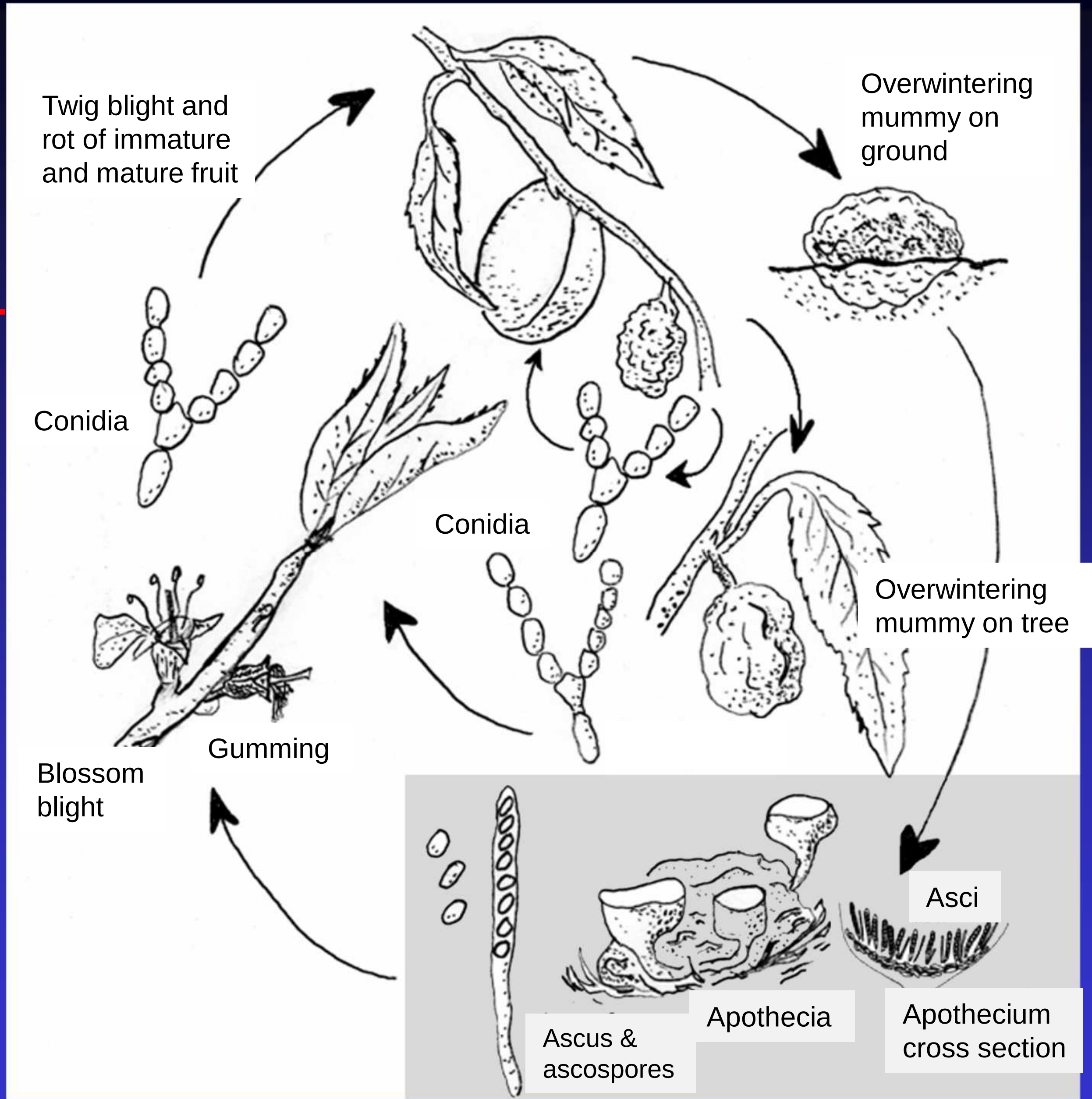
Main pathogens: *Monilinia fructicola, M. laxa, M. fructigena*

- The 3 species are often difficult to differentiate morphologically, but several species-specific primers have been published that can be used in identification and detection of the pathogen.



Specificity of primers developed from ribosomal DNA sequences. A non-specific DNA band is present in all isolates and serves as an internal standard. (Forster and Adaskaveg, 1999).

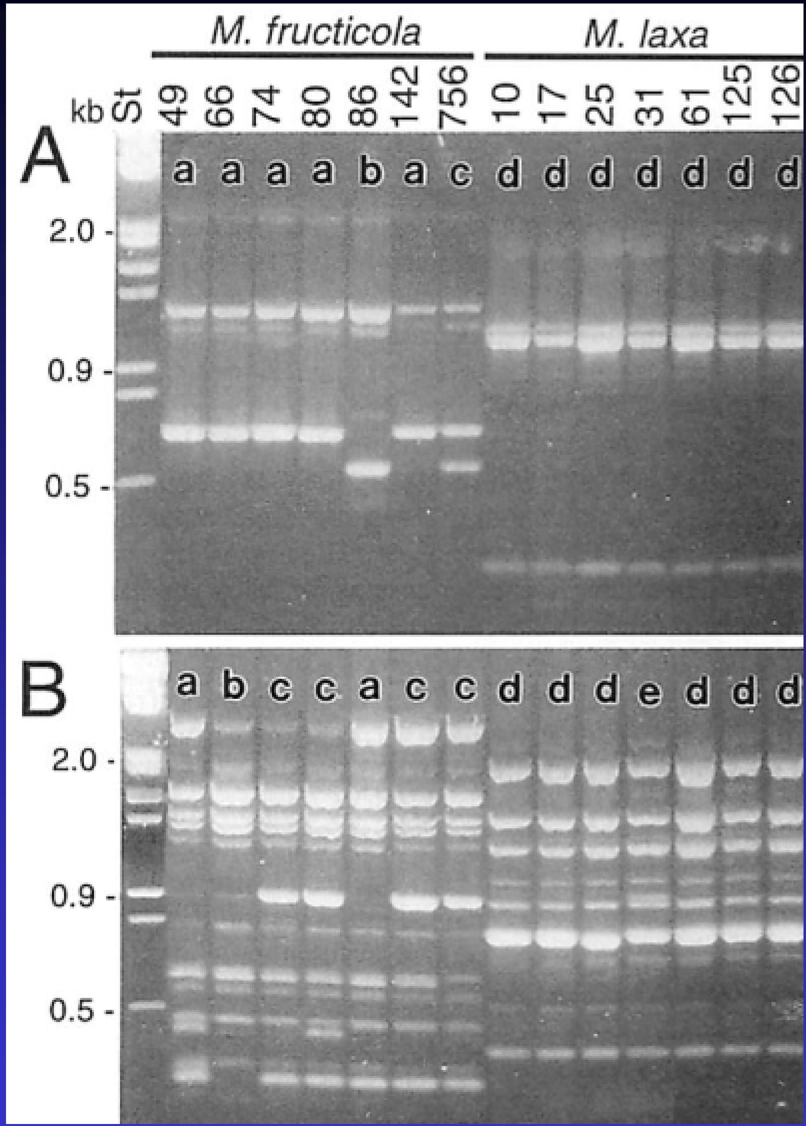
Disease cycle of *Monilinia* species on peach



Sexual cycle *M. fructicola* only

M. fructicola and *M. laxa*
- Reproductive modes -

- Evidence of sexual reproduction in *M. fructicola*, but not in *M. laxa* – molecular diversity among isolates based on RAPD analysis
- Sexual reproduction creates new gene combinations that may be more adapted to new environments and that are propagated by asexual reproduction.
- Sexual reproduction adds to another survival mechanism.



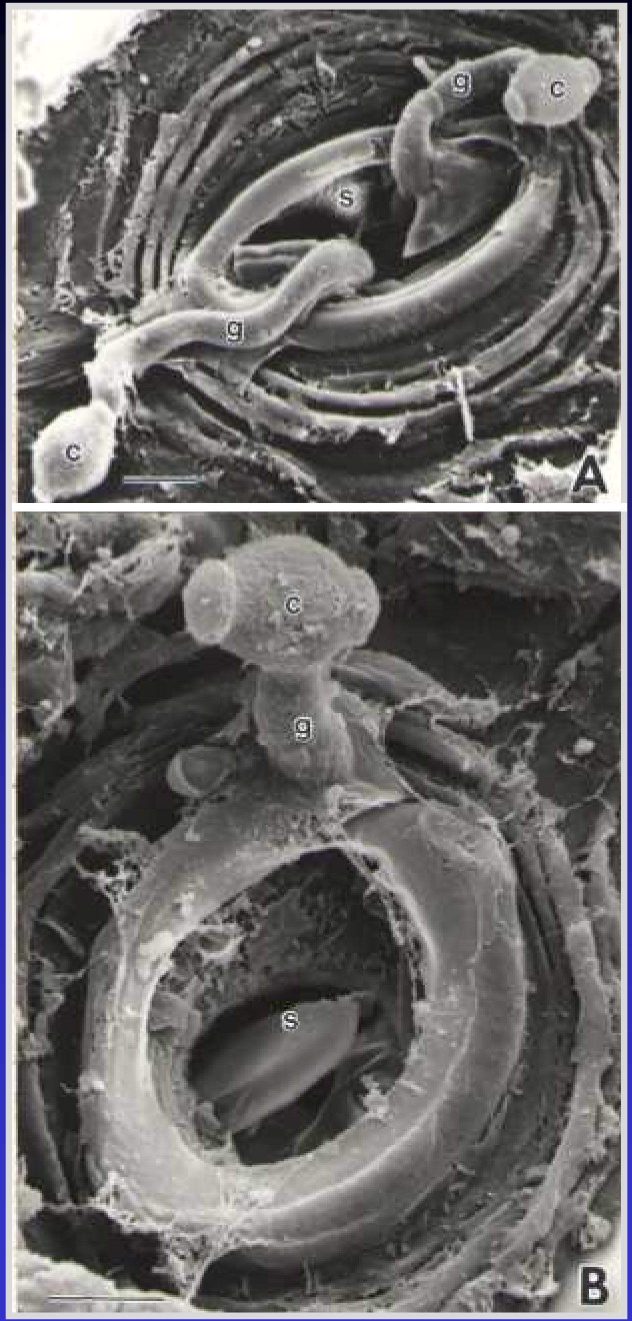
RAPD analysis of California isolates of *M. fructicola* and *M. laxa* (Forster and Adaskaveg, 1999).

Brown rot of stone fruits
- Infection -

Infection

- Direct penetration through the host cuticle
- Indirect penetration through injuries or natural openings (stomata)

J. E. Adaskaveg



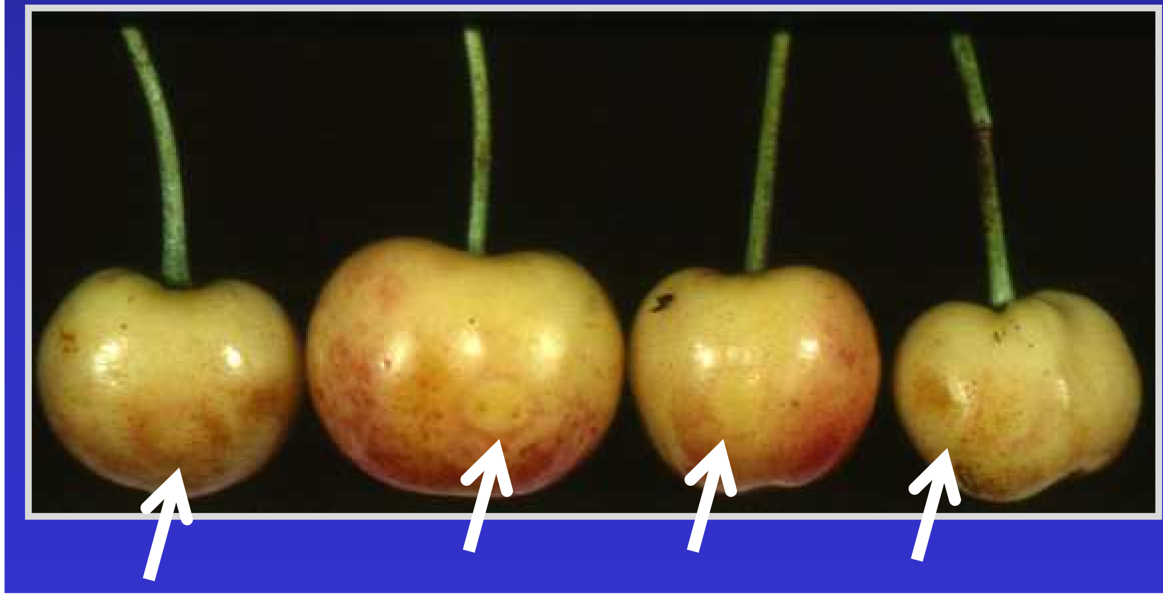
Indirect penetration through stoma of peach fruit

Direct penetration through cuticle of peach fruit

Brown rot of stone fruits - Infection

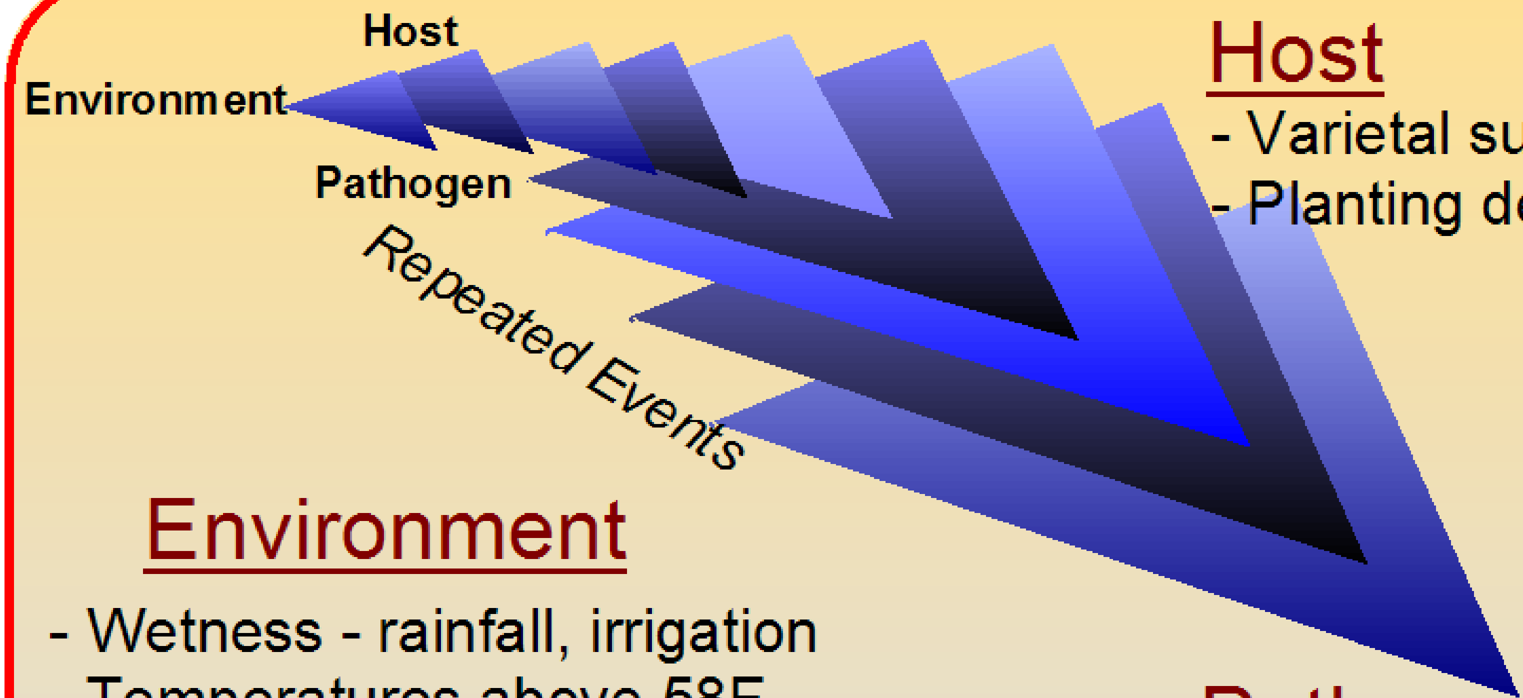
Quiescent infections

- Infections may remain quiescent (latent) and be activated when fruit mature or when environmental conditions become more favorable.
- Quiescent infection may be visible (see image below) or non-visible.
- The presence of quiescent infections can explain sudden increases in fruit decay just before harvest.



Visible quiescent infections on Rainier cherry after inoculation with *M. fructicola* with a 6-h wetness period (Adaskaveg and Forster 1999)

- The Disease Triangle of Plant Pathology -



Host

- Varietal susceptiblity,
- Planting design

Environment

- Wetness - rainfall, irrigation
- Temperatures above 58F

Pathogen

- *M. fructicola, M. laxa*
- Inoculum potential (overwintering mummies, twig cankers)

The interactions between the components effect the amount of disease.

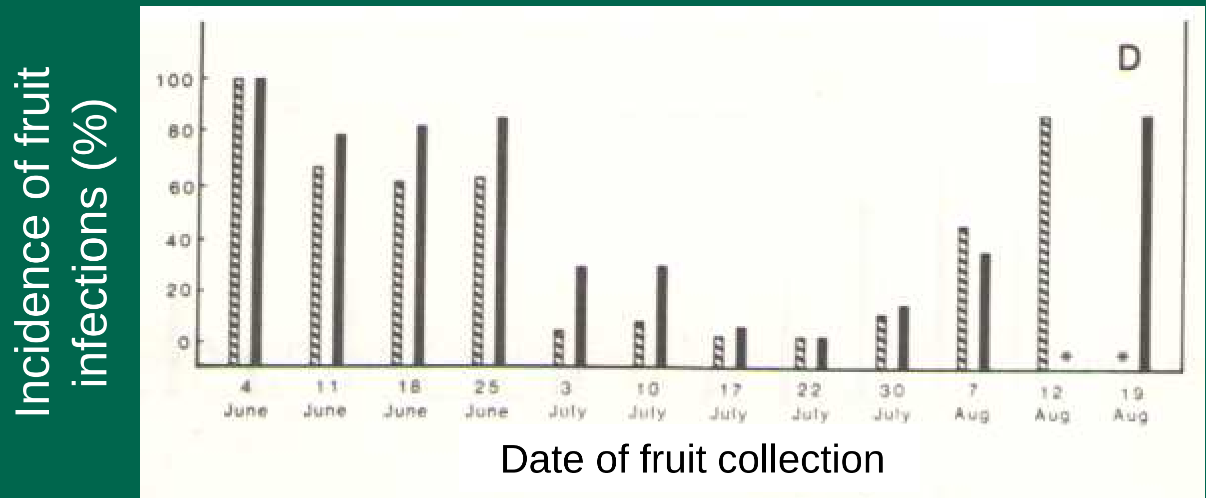
Brown rot of stone fruits - Epidemiology

Host

Host phenology

- Susceptibility to infection is high during early fruit development, decreases during green fruit stages, and increases again as fruit mature and ripen.

Seasonal susceptibility of peach fruit to brown rot infection (Biggs et al., 1988)

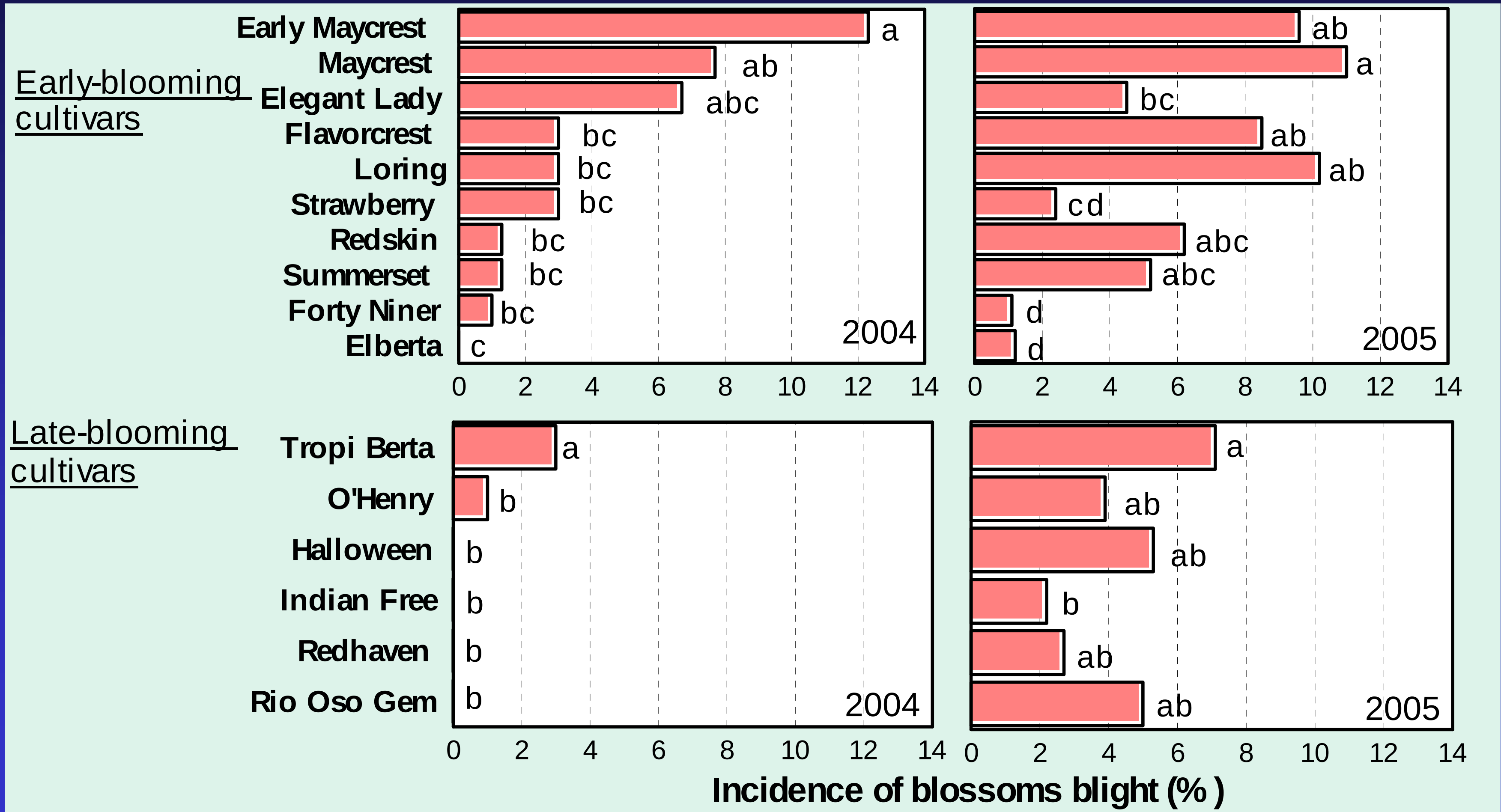


Great differences in **varietal susceptibility**

Green fruit rot

Brown rot of stone fruits

Natural host resistance to brown rot blossom blight - peaches



Simulated rain was applied on 2-10, 2-24, and 2-28-2005. Blossom blight was evaluated on 4-8-04 and on 3-31-05. There were three single-tree replications for each cultivar.

Brown rot susceptibility of peach cultivars within the three-week ripening period before harvest

Majority of peach cultivars are susceptible to brown rot.

Fungicides need to be applied:

High Pressure	Moderate Pressure	Low Pressure	Very Low pressure
Baby Gold 5	Catherina	Allstar	Hale Harrison
Early Red Haven	Redhaven	Blazingstar	Halehaven
Elberta	Vinegold	Blushingstar	Maybelle
Garnet Beauty	Virgil	Bounty	Mayflower
Glohaven	Vivid	Brighton	Redbird
Harbrite	Vulcan	Coralstar	Southhaven
Harken		Cresthaven	Summercrest
Harrow Beauty		Dixired	
Harson		Glowingstar	
		Redstar	
		Rising star	

Modified from Biggs et al. 1995

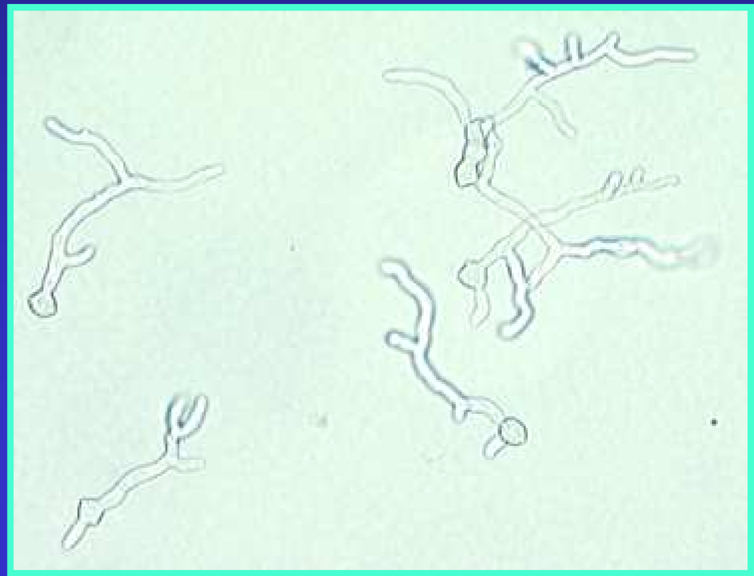
Brown rot of stone fruits - Epidemiology

Environment

Temperature requirements:

- Conidial germination occurs over a wide temperature range from 0-30° C
    - Optimum: 20-25° C
- Infections can occur over a wide range
    - Optimum: 22.5-25° C
    - Range: 4-32° C

Conidia production of *M. fructicola*



Germinating conidia of *M. fructicola*

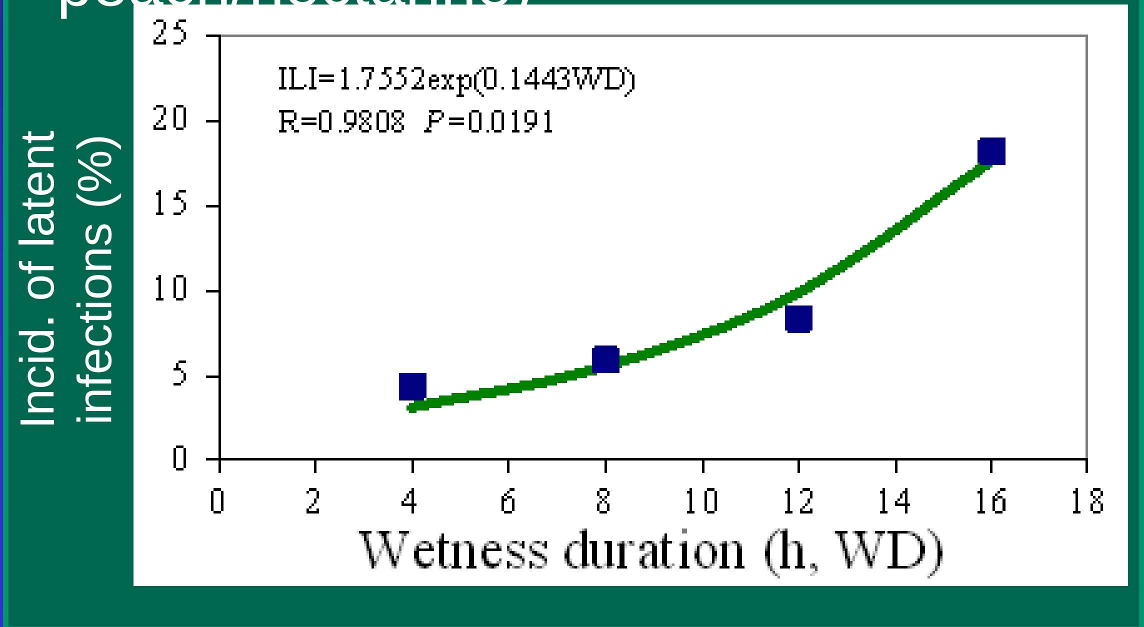
Brown rot of stone fruits - Epidemiology

Environment

Wetness requirements

- *Conidial germination* - 4 h of wetness at 20° C (68° F)
- *Blossom and fruit infection*

  - 7 h of wetness at 20° C (68° F) to 18 h of wetness at 10° C (50° F) (cherry & peach/nectarine)



Effect of wetness duration on incidence of latent infections on prune fruit under field conditions (Michailides et al., 2007)

Brown rot of stone fruits - Epidemiology

Environment

- **Areas with high rainfall**:
  - Severe epidemics may occur in most years.
- **More arid locations:**
  - Favorable environmental conditions commonly occur in the spring for development of blossom blight.
  - During the season orchard irrigation contributes to sufficient wetness. Occasional rains can be highly destructive.

Brown rot of stone fruits - Epidemiology

Blossom blight and twig cankers

↓

Inoculum production for fruit infections

Preharvest fruit decay

↓

Inoculum production for infection of other fruit

Increase of inoculum over the growing season if the disease is not managed

↓

Late-season fruit is usually more affected than early-season fruit

Brown rot of stone fruits - Epidemiology

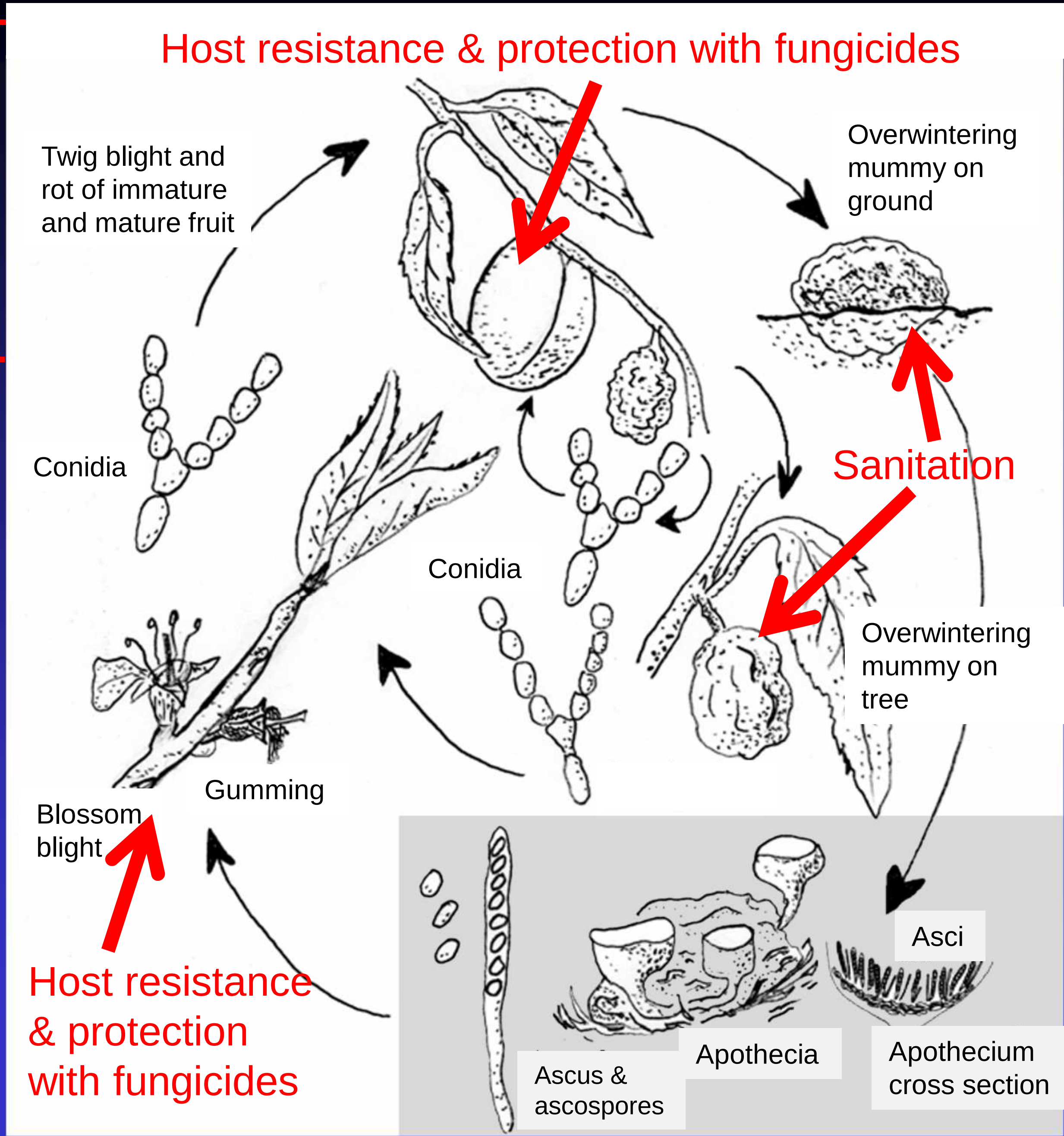
Stromatized mummies in partial contact with soil produce apothecia:

a) 2C for 8 weeks at >97%RH;
b) 12-20C for 2 weeks, under a 12 h photoperiod

Components of an integrated disease management program for brown rot of stone fruit

- Early disease detection
- Planting
  - Variety selection (host resistance)
  - Plant spacing (greater air movement, shorter drying period)
  - Row orientation – direction of prevailing winds
- Cultural practices
  - Avoid high-angle sprinkler irrigation
  - Provide a balanced nutrition
  - Pruning practices (improved microclimate, removal of diseased tissue)
- Sanitation
  - At harvest remove all fruit from trees
  - Remove overwintering mummies from trees and cultivate mummies into soil
- Chemical control and pest management
  - Fungicides and insect management (SWD, OFM, PTB, etc.)

Disease cycle of *Monilinia* species on peach



Sexual cycle *M. fructicola* only

Orchard sanitation: Removal of overwintering fruit mummies and soil cultivation

Mummies are primary inoculum sources in the spring.
A) On the tree, asexual conidia; B) On the ground, sexual ascospores

Complete harvests and mummy removal from tree

Destroy mummies on the ground by mowing or disking

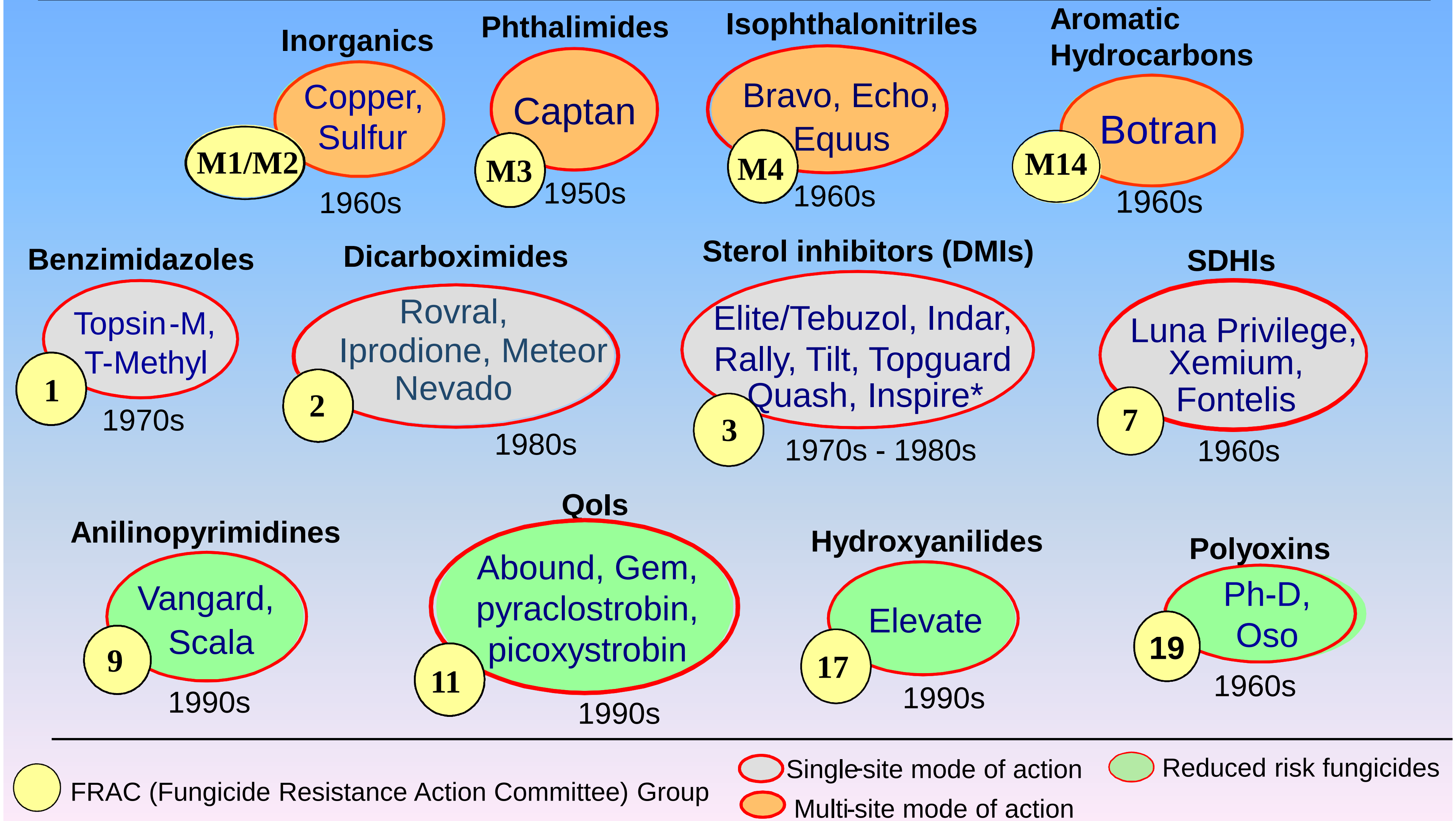
Brown rot management with fungicides

- Protective fungicide **field treatments** that are properly applied and timed provide the best control for
    - *Blossom blight*
    - *Fruit rot*

- **Postharvest treatments** can protect fruit from infections that occur at harvest and during transport and may prevent the activation of quiescent infections and the establishment of new infections.

Fungicides Registered and in Development for Managing Stone Fruit Diseases in the United States

Single-fungicides - Inorganics and Conventional Synthetics



Fungicides for Management of Brown Rot of Stone Fruits in the field in the US

Single-fungicides - Inorganics and Conventional Synthetics

Benzimidazoles
1 — Topsin-M, T-Methyl — 1970s

Dicarboximides
2 — Rovral, Iprodione, Nevado — 1980s

Sterol inhibitors (DMIs)
3 — Elite, Indar, Inspire, Tilt, Procure, Quash, Rally, Rubigan, Topguard — 1970s – 1980s

SDHIs
7 — Endura, Luna Privilege, Xemium, Fontelis — 1960s

QoIs
11 — Abound, Gem, picoxystrobin, Cabrio — 1990s

Hydroxyanilides
17 — Elevate — 1990s

Polyoxins
19 — Ph-D, Oso — 1960s

(Yellow circle) FRAC group (mode of action class) – all have a single-site mode of action

(Green oval) Reduced risk fungicides

Information available at: Statewide IPM Program - *www.ipm.ucdavis.edu*

Fungicides for Management of Brown Rot of Stone Fruits in the Field in the United States

Conventional Synthetic Fungicides – Pre-mixtures

- 3+9 **Inspire Super**
- 3+7 Luna Experience
- 3+11 **Quadris Top, Quilt Xcel**
- 7+11 **Pristine, Luna Sensation,** Merivon, Q8Y78

3	DMIs
7	SDHIs
9	Anilinopyrimidines
11	QoIs

Natural Products and Biocontrols for Managing Stone Fruit Diseases

Actinovate, Regalia, polyoxin-D, BotryZen, Serenate Optimum, Fracture

Natural products and biocontrols for organic production

Polyoxin-D recently received an exempt status in the United States

EFFICACY AND TIMING OF FUNGICIDES, BACTERICIDES, AND BIOLOGICALS FOR DECIDUOUS TREE FRUIT, NUT, STRAWBERRY, AND VINE CROPS 2013

ALMOND	*PEACH*
APPLE AND PEAR	*PISTACHIO*
APRICOT	*PLUM*
CHERRY	*PRUNE*
GRAPE	*STRAWBERRY*
KIWIFRUIT	*WALNUT*

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www.plpnem.ucdavis.edu

UC Kearney Agricultural Center
www.uckac.edu/plantpath

Statewide IPM Program
www.ipm.ucdavis.edu

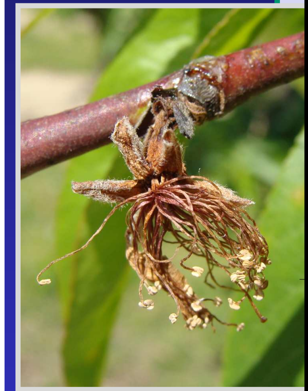
Efficacy tables are updated annually

Chemical disease control

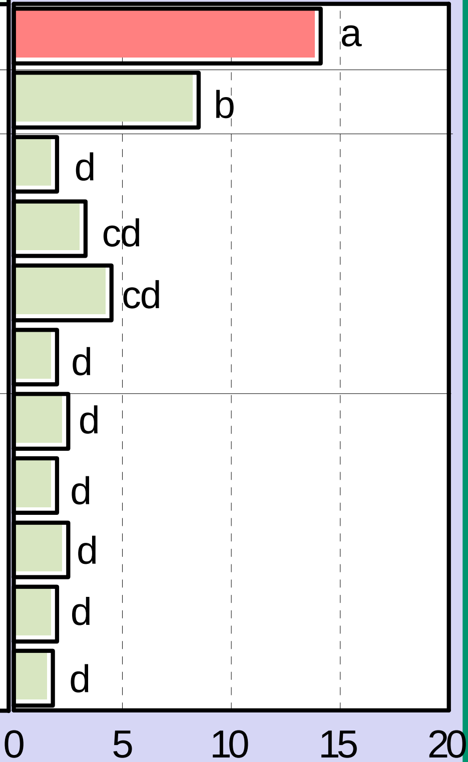
- There is an increasing arsenal of fungicides being introduced.
- Using the proper material is becoming more difficult and requires an increasing knowledge on the modes of action (fungicide classes), spectrum of activity, efficacy, and best usage strategies.
- Generic compounds can lower the cost.
- Selecting the best materials with the broadest spectrum and timing the application at a critical stage can lower costs.
- Rate and formulation are critical -
  - Use middle to high label rate
  - Forumulation rating: AQ < WG < WP < SC < EC

Management of Brown Rot
Blossom Blight

Management of brown rot blossom blight in field trials



Program	Treatment	Rate/A	60-70% bloom	Number of infections/tree
---	Control	---	---	a
Biological	Fracture	36.6 fl oz	@	b
Single	Quash 50WG	3.0 oz	@	d
	Mettle	8 fl oz	@	cd
	TopGuard	7 fl oz	@	cd
	Fontelis + NIS	14 fl oz	@	d
Pre-mixtures	Luna Sensation	5 fl oz	@	d
	Inspire Super + NIS	20 fl oz	@	d
	Quadris Top	14 fl oz	@	d
	Pristine 38WG	14.5 oz	@	d
	Merivon	6.5 fl oz	@	d



Treatments were applied using an air-blast sprayer at a rate of 100 gal/A. Evaluation was done on 5-16-12.

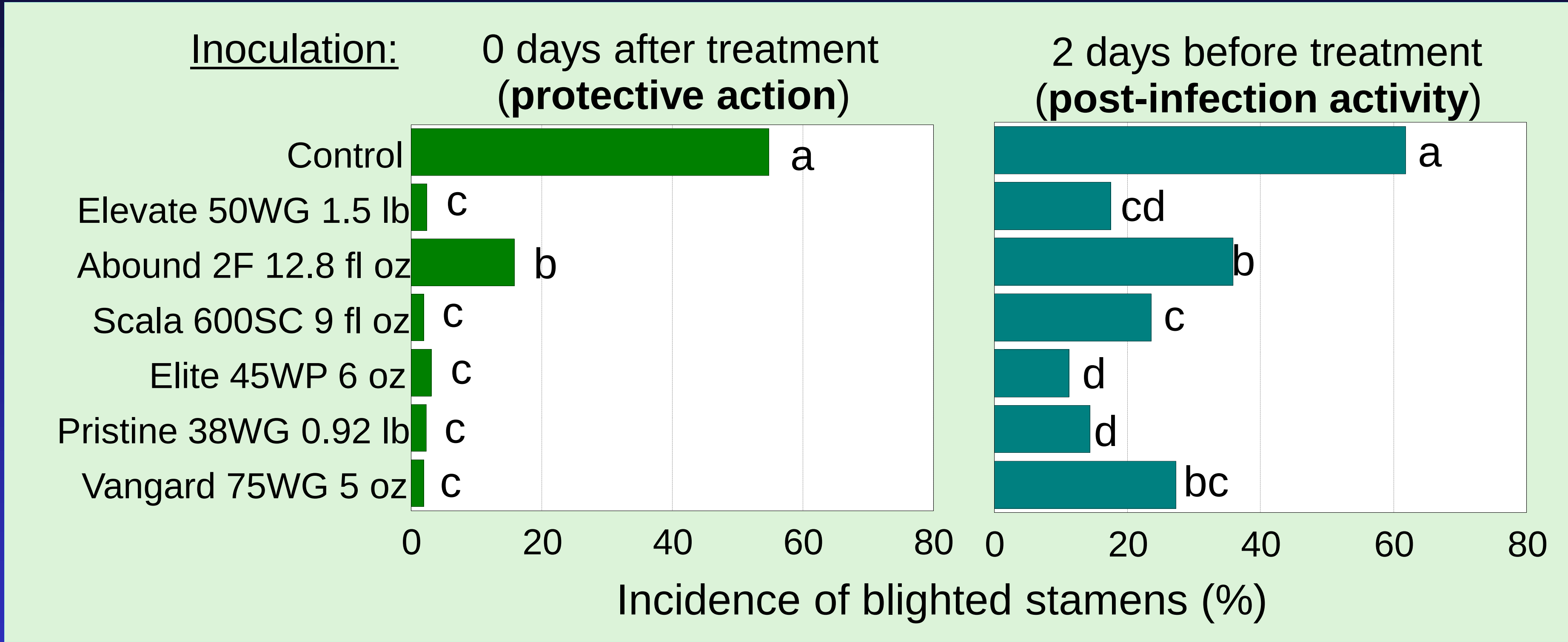
Post-infection activity laboratory tests for fungicides against brown rot blossom blight of sweet cherry

Control | Merivon | Luna Sensation

Full bloom treatment 1 day after inoculation with *M. fructicola*

Test is done under highly favorable disease conditions (high inoculum, wetness).

Pre- and post-infection activity of fungicides against of brown rot blossom blight of peach



Protective action: One application of each treatment was made in the field at full boom using an air-blast sprayer (100 gal/A). Blossoms were collected the same day and inoculated in the laboratory with *M. fructicola.*

Postinfection activity: blossoms were inoculated in the laboratory and then treated after 2 days. Blossoms were evaluated after 4 to 5 days at 20C.

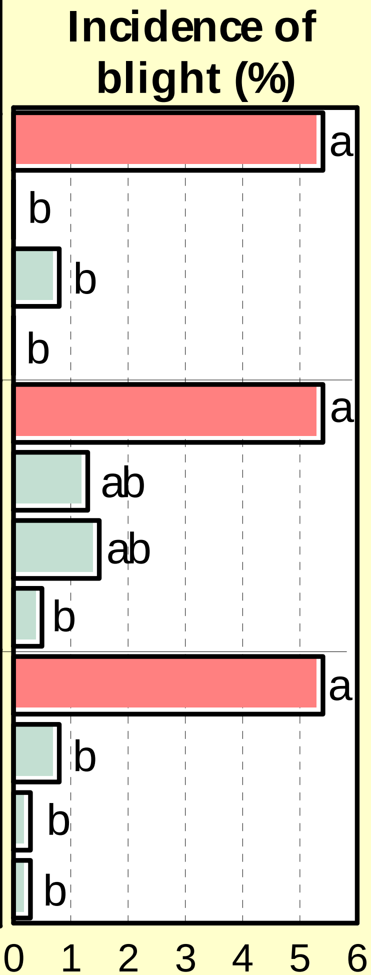
Timing of fungicide treatments for management of brown rot blossom blight

cv. Summer Fire nectarine –

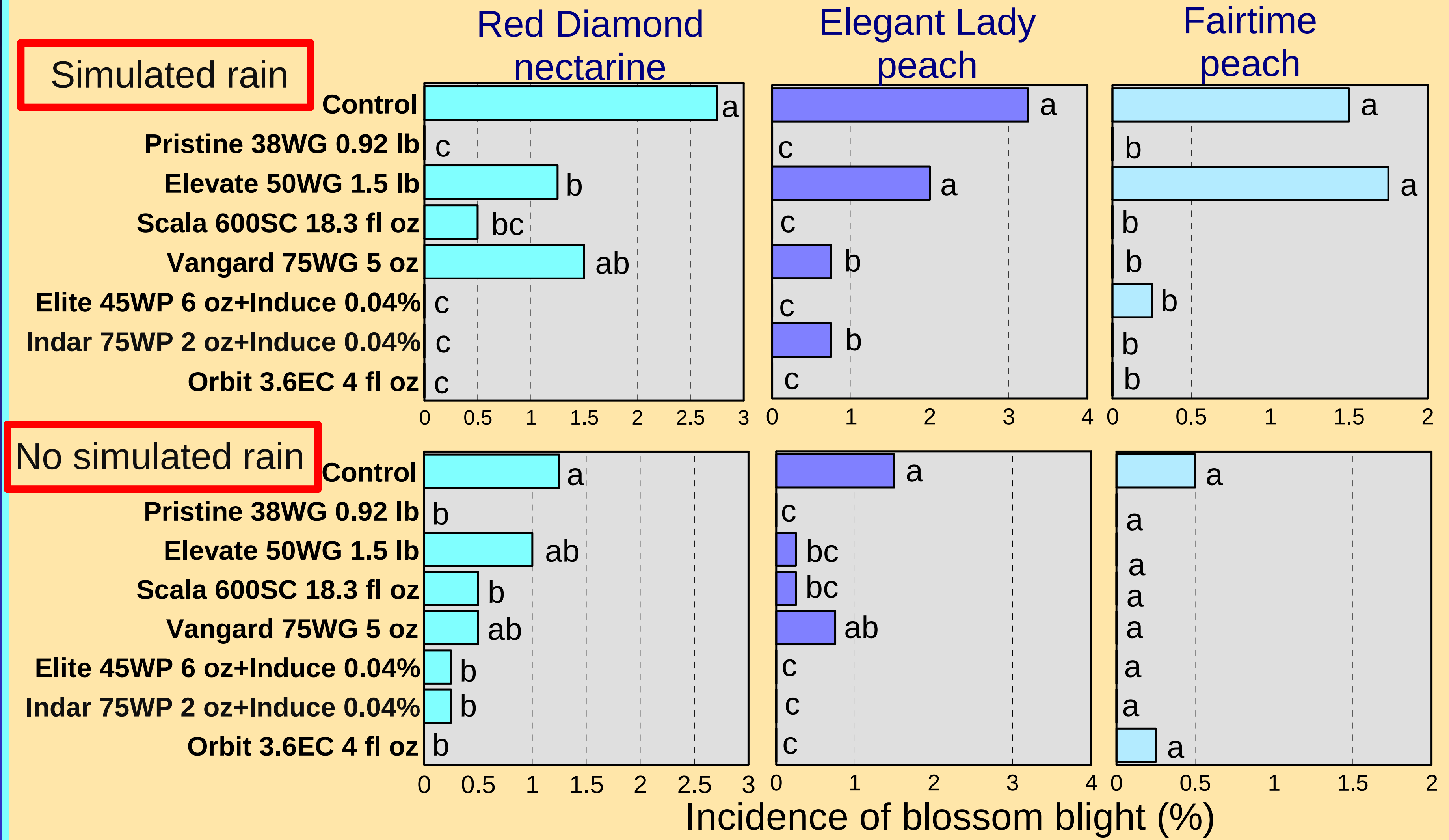
High rainfall conditions.

All fungicides used have some systemic activity.

Fungicide	3-3-11 30% bloom	3-9-11 50-60% bloom
Control	---	---
Quash 50WG 3.5 oz	@	---
	---	@
	@	@
Control	---	---
Vangard 75WG 5 oz	@	---
	---	@
	@	@
Control	---	---
Tilt (Orbit) 4 fl oz	@	---
	---	@
	@	@



Blossom blight control with fungicides under conducive and less conducive conditions for disease



One application of each treatment was made on 3/4/04 using an air-blast sprayer (100 gal/A) to Red Diamond nectarines (35% bloom), Elegant Lady peach (20% bloom), and to Fairtime peach (1-5% bloom). Simulated rain treatments (8 h each) were done on 3/5 and 3/8. Blossoms were evaluated for blossom blight after 5 weeks.

Considerations for timing of bloom applications

Environmental conditions and properties of fungicide used

Determining factors	WT <u>or</u> FB <u>or</u> **DB**	WT <u>and</u> FB application	WT, FB, &PF application
Environmental conditions (rain)	Less favorable	Favorable	Highly Favorable
Fungicide properties	Locally systemic action	Contact or locally systemic action	Contact or locally systemic action

WT = White tip (5% bloom)
FB = Full bloom (80% bloom)
Delayed bloom (DB) = 20-40% bloom

Blossom blight control with fungicides

Univ. of California guidelines 2 applications during bloom	**Delayed bloom application** 1 application at 30-50% bloom
Use when environmental conditions are highly favorable (rain)	Use when environmental conditions are less favorable

Models that have been developed to predict the need of a fungicide application are considered not economical due to the low cost of a fungicide spray and the high risk for crop losses.

Brown rot management using preharvest fungicide applications

Preharvest treatments for management of brown rot

Control

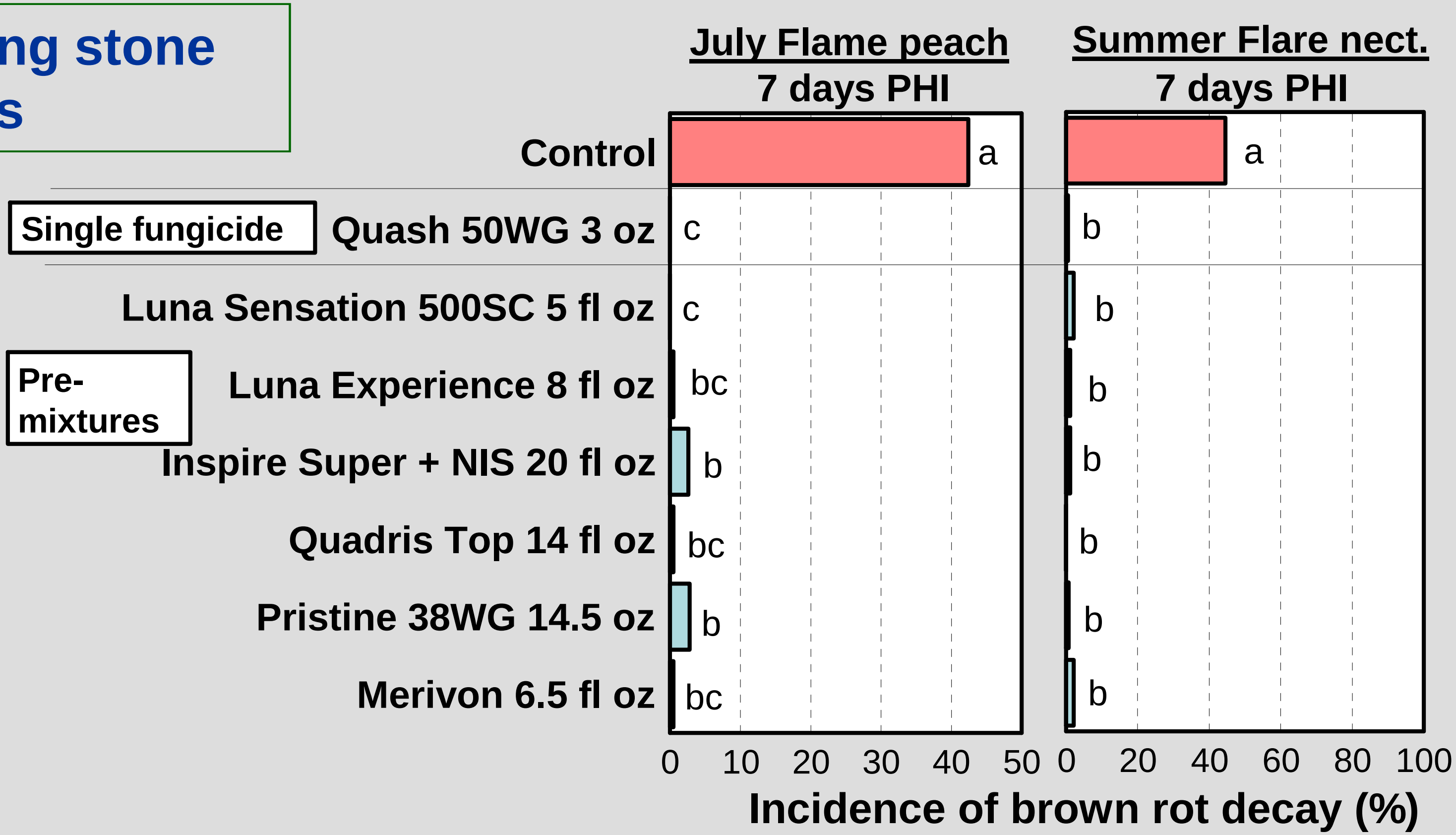
Elevate + Elite

Elevate

1 preharvest application 1 – 10 days before harvest

Preharvest fungicide treatments for managing brown rot fruit decay in field trials - 2012

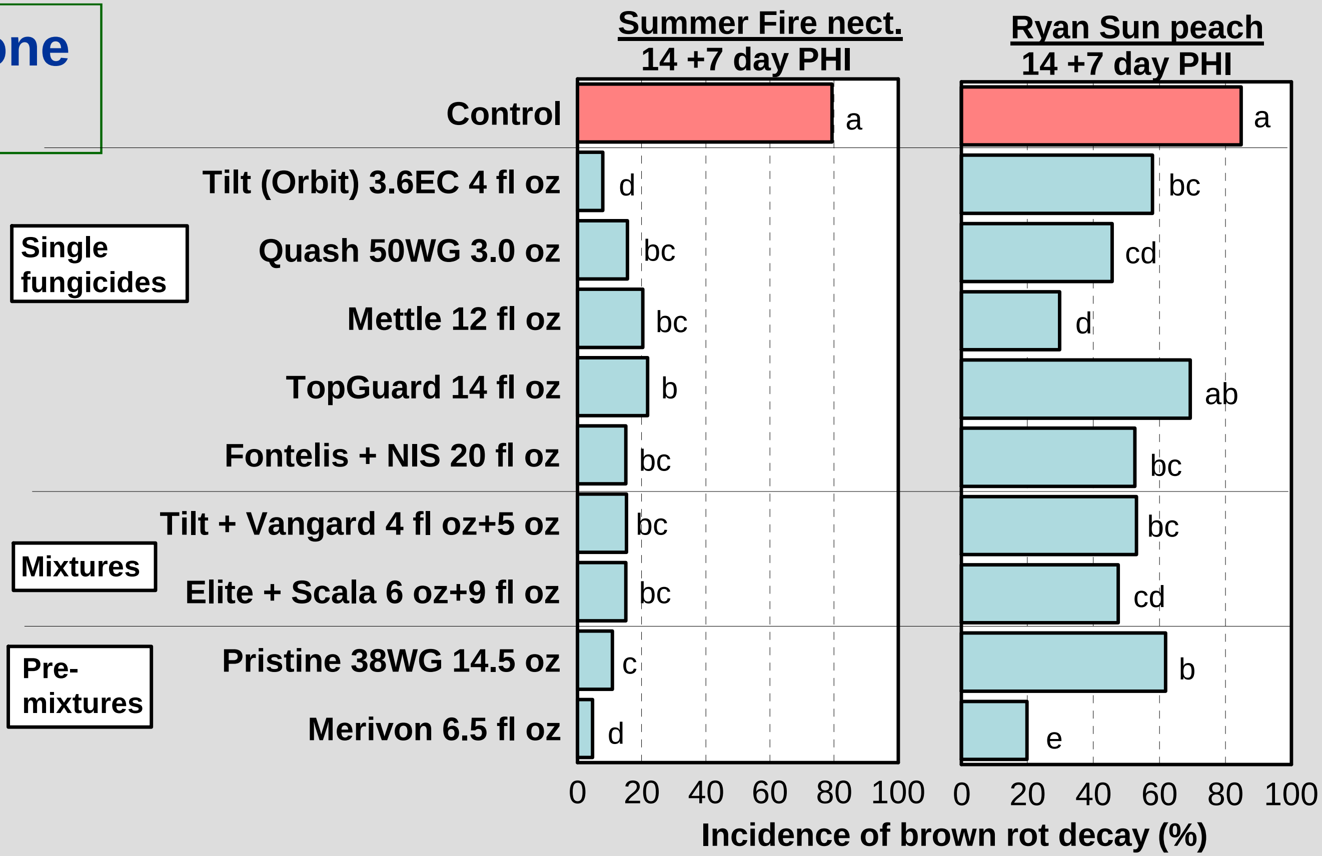
Early maturing stone fruit cultivars



- Numerous highly effective fungicides are available
- **Single applications** are best applied within 8 days of harvest, whereas treatments in a **two-spray program** should be done at a 7- to 10-day interval within two weeks of harvest.

Preharvest fungicide treatments for managing brown rot fruit decay in field trials - 2012

Late maturing stone fruit cultivars



- Late-maturing varieties benefit from two preharvest applications due to an increased inoculum level in the orchard and higher decay potential.

Efficacy of selected fungicides for control of common in-season diseases of stonefruit*

Fungicide	Common Name	Brown Rot	Gray Mold	Powdery Mildew	Rust
Rovral 50WP	Iprodione	+++ (BB)	+++	-	-
Elite 45WP	Tebuconazole	++++	+	+++	+++
Orbit 3.6EC	Propiconazole	++++	-	+++	+++
Indar 75WSP	Fenbuconazole	++++	-	++	?
Rally 40WP	Myclobutanil	+++	-	+++	-
Elevate 50WDG	Fenhexamid	+++	+++	++	-
Vangard 75WG	Cyprodinil	+++	+++	-	?
Scala 600SC	Pyrimethanil	+++	+++	-	?
Abound 4F	Azoxystrobin	++	-	++	+++
Flint 50WDG	Trifloxystrobin	++	-	++	+++
Pristine 38WG	Pyraclostrobin boscalid	++++	+++	+++	?
Quintec 2L	Quinoxyfen	-	-	++++	-

* - Data shown from 'www.ipm.ucdavis.edu'.

Summary of management of brown rot with preharvest fungicide treatments

- Numerous highly effective treatments are available
- Current trend in fungicide registrations are pre-mixture products
  - Highly effective
  - Consistent
  - Built-in resistance management
- Pre-harvest treatments
  - 14 <u>or</u> 7 PHI very effective but rate dependent; 14 <u>and</u> 7 PHI more consistent with lower labeled rates
  - Fungicide characteristics are important in their performance – AP fungicides appear to be heat/humidity unstable with rapid decline of residues, DMIs have some locally systemic activity – persistent if rainfall
  - Biologicals/natural products sometimes effective (inconsistent)

Treatment timing for peach diseases

Disease	Dormant	Delayed Dormant	Bloom		3-6 weeks postbloom	Preharvest [a]	
			Early (5-20%)	Late (40-80%)		3 weeks	1 week
Brown rot	----	----	++	+++	+	++	+++
Powdery mildew	----/ND	----	++	+++	+++[e]	----	----
Leaf curl[b]	+++	+++	+	----	----	----	----
Rust	+[c]	----	----	----	+++	++	----
Scab	----	----	+	++	+++	----	----
Shot hole[d]	+++	----	+	+	++	----	----

[a] - Rating: +++ = most, ++ = moderately, + = least effective, and ND = no data.

[b]- Treatment should be made before bud break and preferably before bud swell.

Disease	Dormant	Bloom		3-6 weeks postbloom	Preharvest	
		20-40%	80-100%		3 weeks	1 week
Brown rot	----	1, 2 (+oil) 3, 3/11 9, 9/11	1, 2 (+oil) 3, 3/11, 7/11 9, 9/11,17	3, 3/11 7/11, 9/11, 17	3, 3/11 7/11, 9/11 17	3, 3/11 7/11, 9/11, 17
Powdery mildew	----/M2	1, 2+oil, 3	1, 3, 7/11	3, 7/11, 11 M2, NP/BC	----	----

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EFFICACY AND TIMING OF FUNGICIDES, BACTERICIDES, AND BIOLOGICALS FOR DECIDUOUS TREE FRUIT, NUT CROPS, AND GRAPEVINES

2013

ALMOND	***PEACH***
APPLE AND PEAR	***PISTACHIO***
APRICOT	***PLUM***
CHERRY	***PRUNE***
GRAPE	***WALNUT***

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Web Site Addresses

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www.plpnem.ucdavis.edu

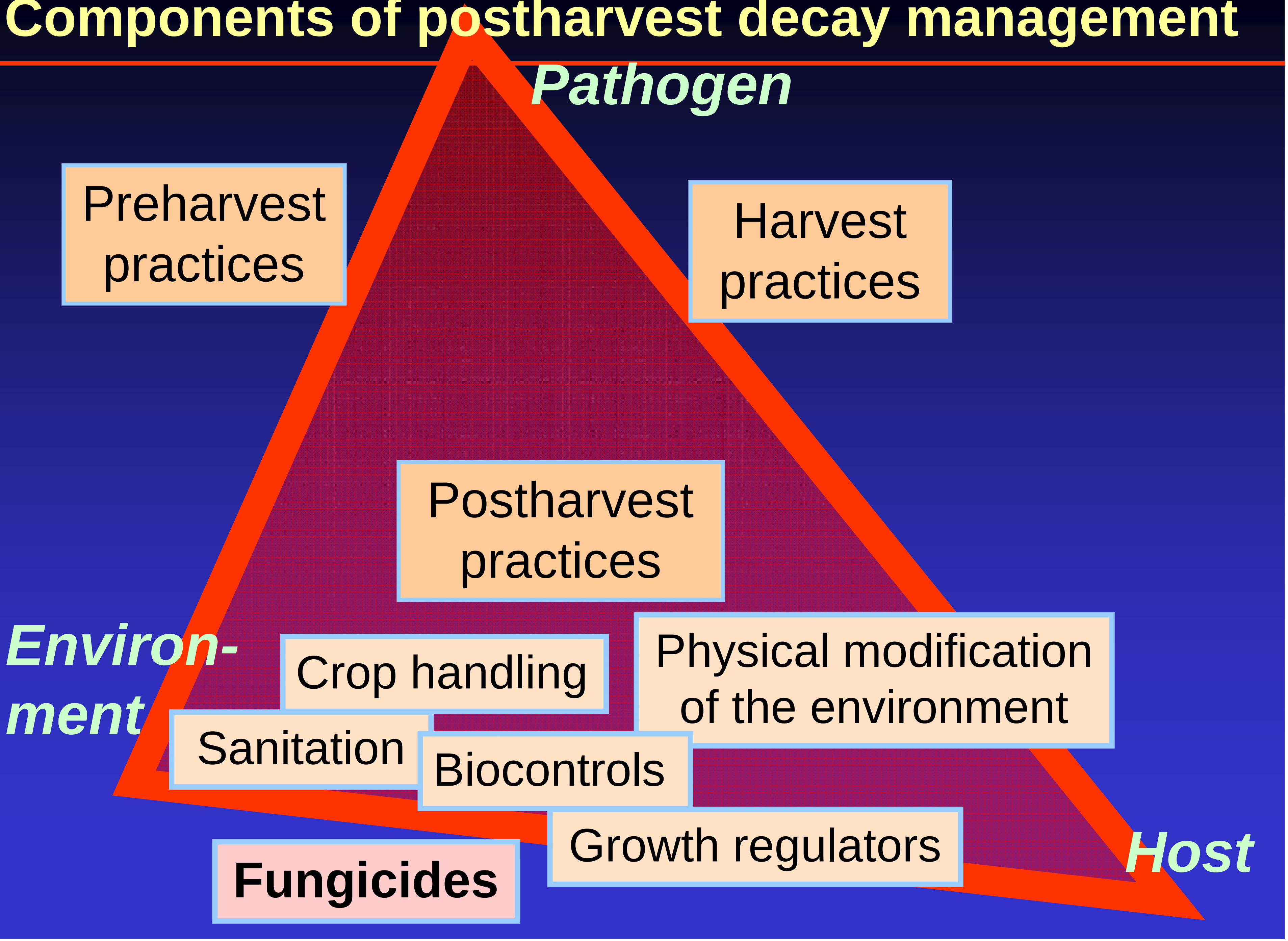
UC Kearney Agricultural Center
www.uckac.edu/plantpath

www.ipm.ucdavis.edu

Summary of management of brown rot by crop

- Apricot, prune, and sweet cherry
  - Highly susceptible to blossom blight and fruit rot (fruit clusters)
  - All flower parts are susceptible – Start early (1-3 sprays)
  - Fruit – Cover sprays starting after shuck split and then preharvest (3 weeks before harvest)
- Peaches and nectarines
  - Moderately susceptible to blossom blight and highly suscept. to fruit rot
  - Pistal and stamen infections lead to blossom blight (1-2 sprays)
  - Fruit – Cover sprays starting after shuck split and then preharvest (3 weeks before harvest)
- Plums
  - Less susceptible to blossom blight (0-1 spray)
  - Blossom sprays are needed when large number of mummies present
  - Cover sprays starting after shuck split and then preharvest (3 weeks before harvest)

Components of postharvest decay management



Strategies for integrated management of postharvest decays

Crop handling – reduce crop injuries, minimize process time

Temperature management -

Cold - slow physiological processes of pathogen and host

Hot – eradicate the pathogen

Atmosphere management – MA, CA

Sanitation – (oxidizers)

- reduce pathogen levels in wash water
- prevent inoculation

Biological controls – competition, antibiosis, site exclusion

Chemical control – fungicides to inhibit fungal growth

Advantages and dis-advantages of management methods of postharvest decays

Method	Pros	Cons
Crop Handling	Minimizes injuries	Pre- and postharvest infection
Temperature	Slows development	Does not eradicate
Atmosphere	Slows development	Does not eradicate
Sanitation	Water Disinfestation	Does not disinfect wounds
Biological control	Protectant	Inconsistent
Chemical	Systemic &Protective - Consistent	Residues (MRL)

Postharvest decay management

Infections occurring before harvest → Active fruit decay in the orchard

Infections occurring before harvest → ● Quiescent infections → Postharvest fruit decay in storage and during transport and marketing

● Infections occurring during and after harvest (injuries!) → Postharvest fruit decay in storage and during transport and marketing

● Target of postharvest fungicide treatments

Newer postharvest fungicides for temperate and sub-tropical crops – 5 FRAC groups

1997
DMI - 3
Tebuconazole
(Elite,Tebuzol)

1997
Phenylpyrrole - 12
Fludioxonil
(Scholar, Graduate)

2003
Hydroxyanilide - 17
Fenhexamid
(Judge)

2006
DMI - 3
Propiconazole
(Mentor)

2005
Anilinopyrimidine - 9
Pyrimethanil
(Penbotec)

2014-pending
DMI - 3
Difenoconazole

2008
QoI - 11
Azoxystrobin

DMI = Demethylation inhibitor (SBI), QoI = quinone outside inhibitor

Postharvest fungicide pre-mixtures

DMI Imazalil + **Anilinopyrimidine** Pyrimethanil = **Philabuster citrus - registered**

Phenylpyrrole Fludioxonil + **QoI** Azoxystrobin = **Graduate A+ Citrus - registered**

Fludioxonil + Azoxy-strobin + **DMI** Propiconazole = **Citrus –** in development

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Phenylpyrrole Fludioxonil + **MBC** TBZ = **Scholar Max MP Pome fruit - registered**

Phenylpyrrole Fludioxonil + **DMI** Difenoconazole = **Pome fruit -** in development

\+ **DMI** Propiconazole = **Stone fruit -** in development

and others ….

Toxicity data for new 'reduced-risk' postharvest fungicides and "permitted" preservatives

	Fungicide /Preservative	Class	LD_{50} rat
Fungicides	Fludioxonil	Phenylpyrrole	>5,050 mg/kg
	Azoxystrobin	QoI	>5,000 mg/kg
	Fenhexamid	Hydroxyanilide	>2,000 mg/kg
	Pyrimethanil	Anilinopyrimidine	>5,000 mg/kg
Preservatives	Benzoic acid	Organic acid	1700 mg/kg
	Sorbic acid	Organic acid	>4000 mg/kg
	Natamycin	Macrolide polyene	>5000 mg/kg

Multiple active ingredients are/will be registered on many fruit crops in the US

- The group of new-generation postharvest fungicides has an overlapping spectrum of activity and several compounds are/will be registered for most crops.

➢ Increased spectrum of activity

➢ Different markets have different MRLs (export limitations)

➢ Application of mixtures of different classes to reduce pressure for resistance selection: Resistance management and fungicide stewardship

Efficacy of fungicides against postharvest decays

Fungicide	FRAC Group	Brown rot	Gray mold	Rhizopus rot	Sour rot
Tebuconazole (cherry and plum)	3	++++	++	++	+++
Propiconazole	3	++++	+/-	++	++++
Penbotec	9	+++	+++	---	---
Fludioxonil	12	++++	++++	++++	+
Fenhexamid	17	+++	++++	---	---
Iprodione with oil	2	++++	++++	+++	---

Rating: +++ = excellent; ++ = very good; + = some activity; - not active.

= reduced risk

Common application methods for postharvest fungicides

- Drenches
- High volume sprayers
- Low volume sprayers (CDA)



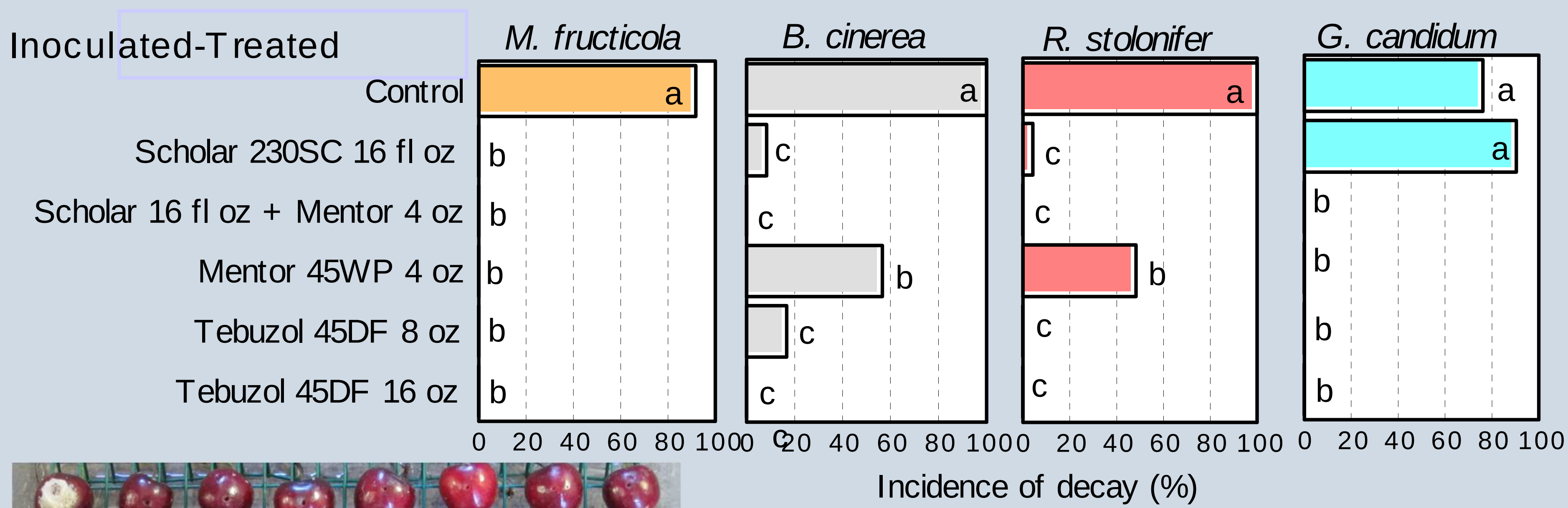



Evaluation of new and registered postharvest treatments for postharvest decay management

Experimental conditions that closely mimic commercial conditions

- Experimental packingline studies
- Use of commercial application systems
- Use of fruit coatings
- Evaluation of pre-infection activity simulating conditions when fruit are infected after fungicide treatment
- Evaluation of post-infection activity simulating when fruit is treated up to 20 h after initiation of infection (e.g., harvest)

Evaluation of new and registered postharvest treatments for postharvest decay management of sweet cherry

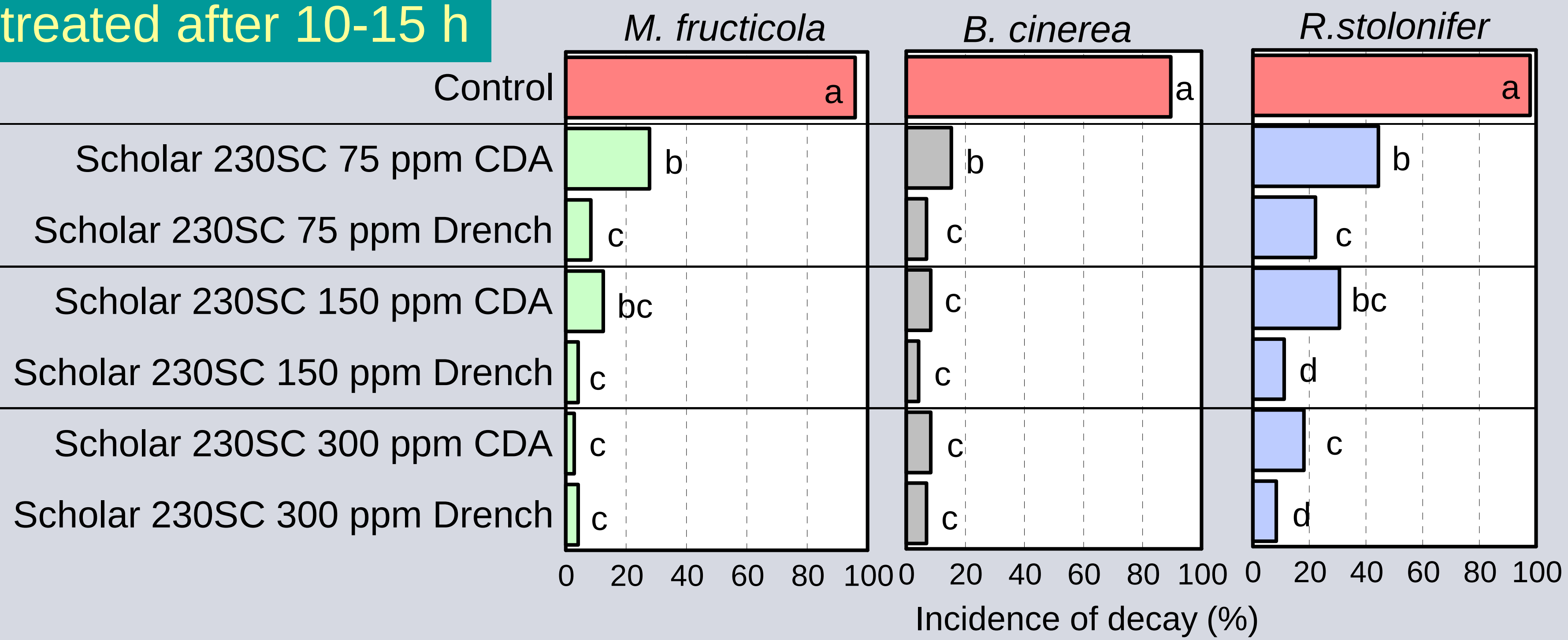


Evaluation of treatments for brown rot

- Brown rot is effectively controlled by all three fungicides.
- Scholar-Mentor mixtures and Tebuzol at high rates is highly effective against all four decays.

Low-volume spray vs. in-line drench applications of Scholar to Spring Flame peaches in an experimental packingline study

Fruit inoculated, treated after 10-15 h

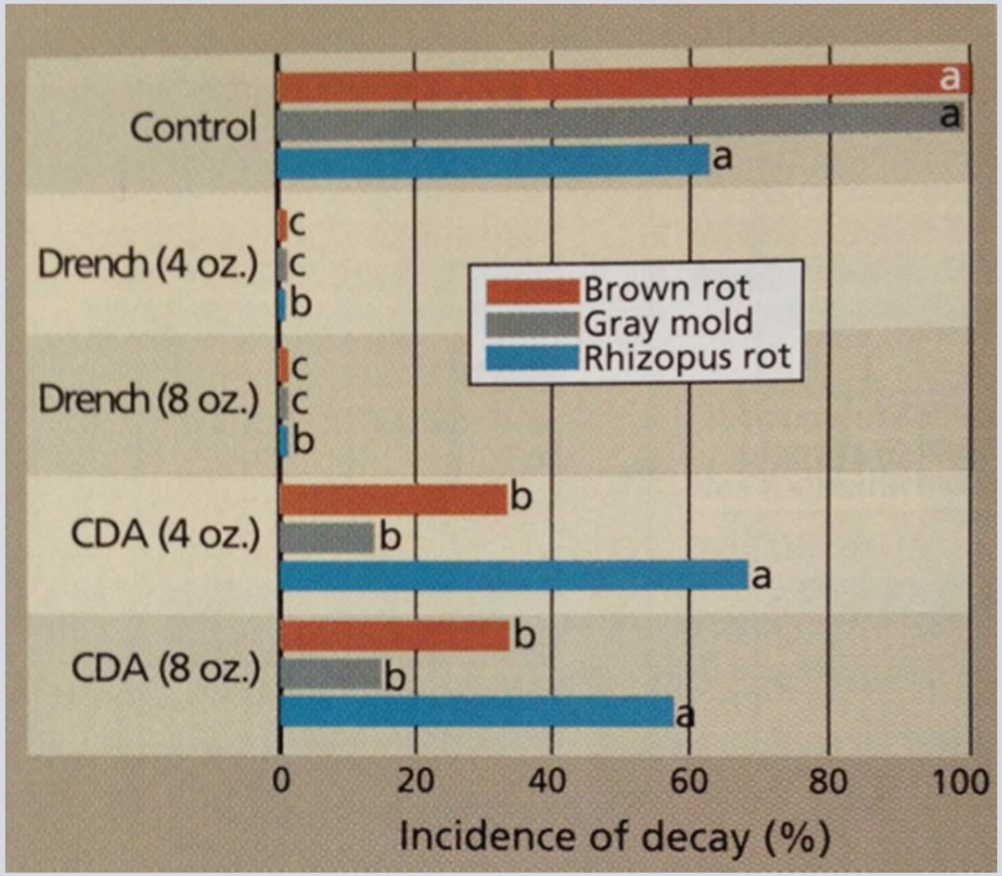


Aqueous in-line drenches over a roller bed followed by CDA wax or CDA application in wax.

Lower rates of Scholar can be used in in-line drench applications with equal efficacy to CDA applications.

Low-volume spray vs. in-line drench applications of Scholar to Casselman Plums in an experimental packingline study

Fruit inoculated, treated after 14-16 h



Aqueous in-line drenches over a roller bed followed by CDA wax or CDA application in wax (10 gal/200k lb).

Lower rates of Scholar can be used in in-line drench applications with greater efficacy than CDA applications.

Postharvest brown rot management

- Several highly effective fungicides are registered in the United States on specific crops: Fludioxonil, pyrimethanil, propiconazole, tebuconazole, fenhexamid.
    - Broad spectrum
    - Low rates
    - High food safety
- Different modes of action minimize the selection of resistance if treatments are properly applied.
- Treatments are effective as protectants and sometimes as eradicants (post-infection activity up to 24 h)
- MRLs established for some of these fungicides worldwide.

Fungicide resistance - Definitions

- **Resistance** is the reduction in sensitivity beyond natural variation.
- Natural variation is described as the **baseline sensitivity**. Baseline sensitivities are based on a sample of pathogen individuals that were never exposed to the fungicide.
  - Baseline sensitivities have been established for the most important pathogen-fungicide systems.
- **Field-resistance (practical resistance)** is the reduction in sensitivity in the pathogen that is accompanied by crop losses.

Anti-resistance strategies

Resistance management is a game of numbers and survivorship

- *"Minimize pathogen survivors" - Do not compromise control by minimizing rates or coverage*
- *Rotation between different classes and MOAs*
- *Limit the number of applications of any MOA (Enough different classes of materials are or will be registered to limit each MOA to one/season)*

Anti-resistance strategies for fungicides

- Fungicides within the same chemical class have the same mode of action. Thus, knowledge on the class of a particular fungicide being used is important.

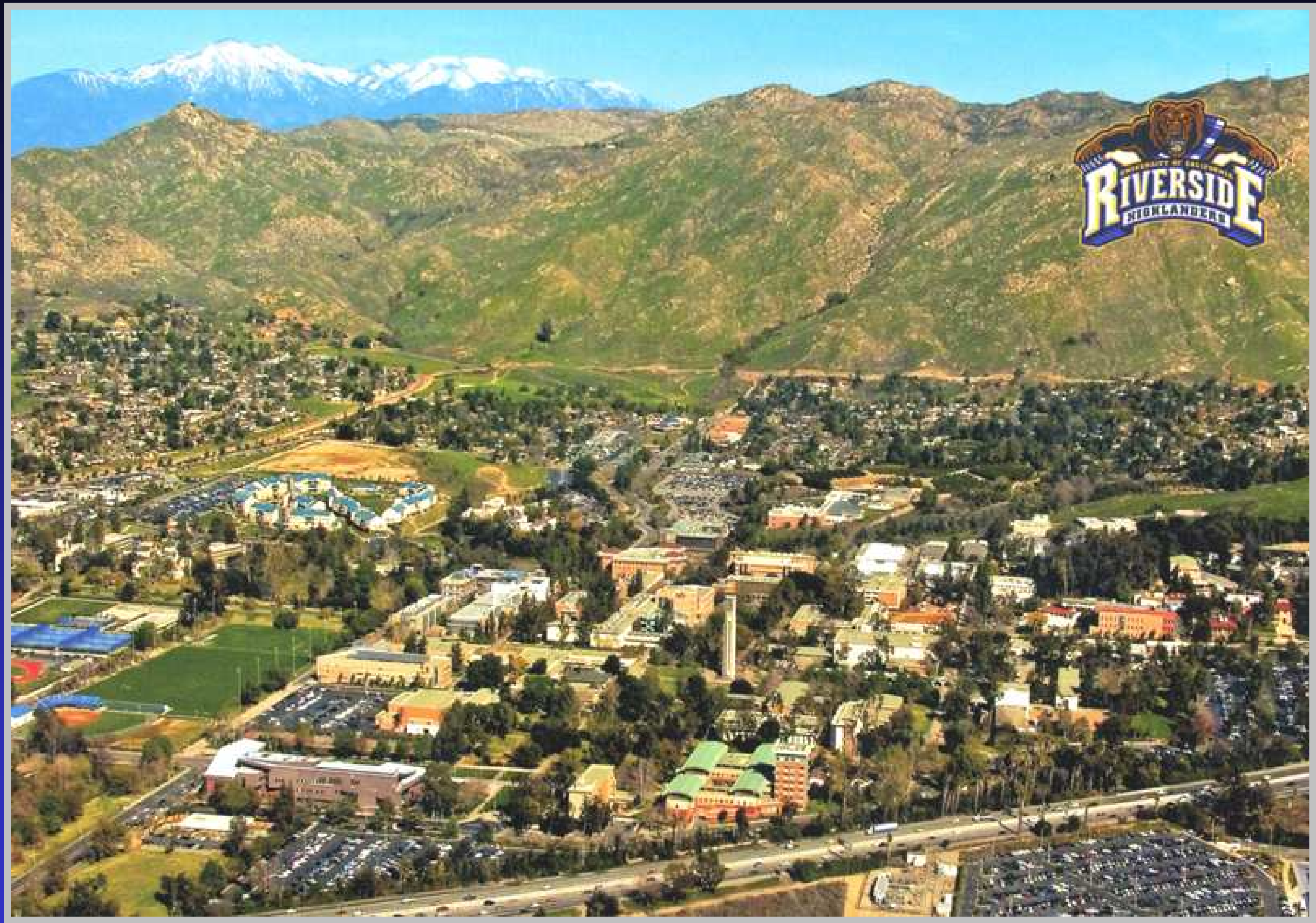
> *Unlike insecticide-resistance, with fungicides cross-resistance patterns generally follow modes-of-action, presumably reflecting target site alterations rather than uptake and detoxification changes.*
>
> *Kendall and Hollomon, 1998*

Anti-Resistance Strategies for Postharvest Fungicides

- Post-Registration Strategies -

- Follow the RULES of Fungicides Stewardship -

- ***R***otate between different classes of fungicides or use pre-mixtures *prior* to the development of resistance.
- ***U***se labeled rates and optimize application.
- ***L***imit total number of fungicide applications of any one class to 1 per fruit lot.
- ***E***ducate yourself about fungicide activity, mode of action, and class.
- ***S***tart a fungicide management program with the use of sanitizers to reduce the amount of inoculum on fruit and equipment.



UC Riverside

Thank you


Quesions!

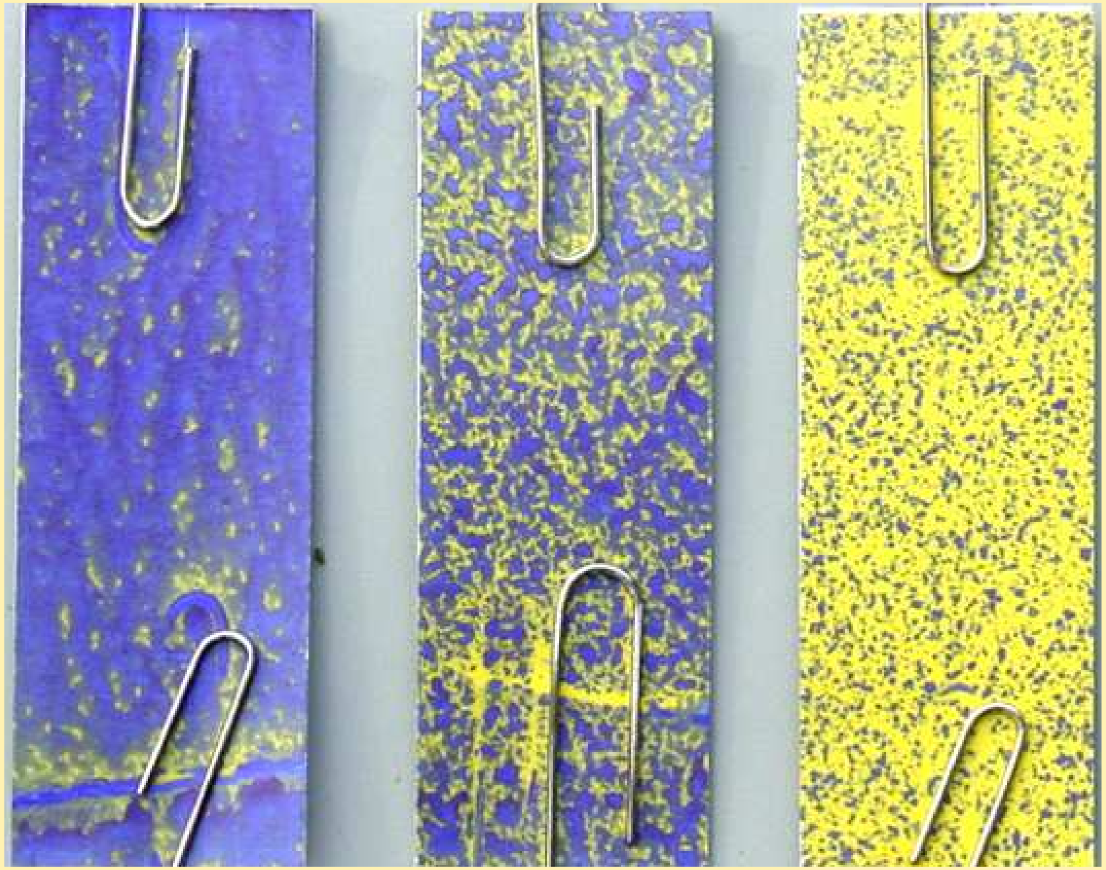
Additional information

Alternate-row spraying for control of blossom diseases

- A method that is being increasingly used in California orchards for control of blossom diseases
  - Savings in cost for labor and fungicides

Methods: Trees were sprayed with Vangard (cyprodinil) or Laredo (myclobutanil) from only one side. Blossoms were collected from the sprayer-facing and the -opposite sides of the tree for inoculation and fungicide residue analysis.

Spray coverage on near, middle, and far sides of tree



Near side Middle Far side

Spray cards that were attached to the tree at application time were used as indicators of fungicide coverage.

Disease evaluations of Laredo-treated blossoms after inoculation with *M. laxa* 2002

Butte – Treated at 80% Bloom

Anther infection (%)/Residue

Control
98.5%/ND

Near side
10.8%/10.3 ppm

Far side
57%/3.1 ppm

Detached blossoms were spray-inoculated with conidia of *M. laxa.*

Conclusions of studies on alternate-row spray programs

Alternate row spraying reduces fungicide efficacy and fungicide residues on the ‘far-side’ of the trees.

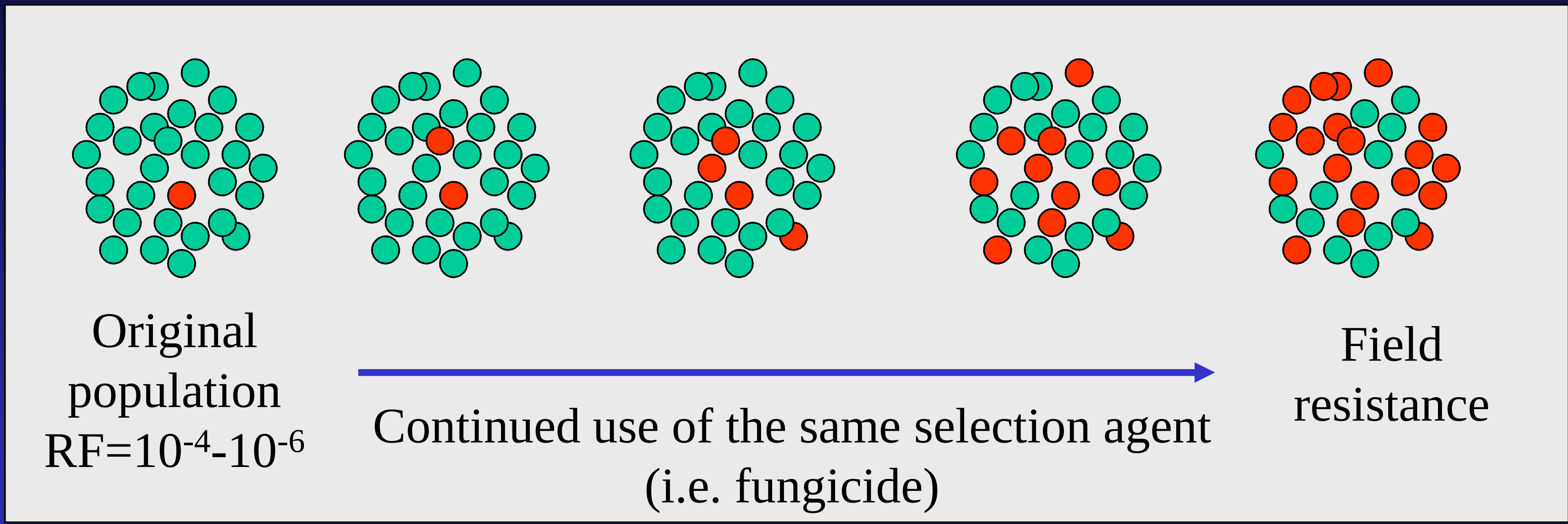
Exposure of the pathogen to lower fungicide concentrations may favor the selection of resistant pathogens by increasing population size.

Alternate-row application programs may reduce disease management costs, but may be a high-risk practice that potentially leads to fungicide resistance in the field.

If alternate-row spraying is done, it should only be conducted at the pink bud stage of bloom (5%) of susceptible varieties to allow adequate fungicide coverage.

How does resistance develop?

- The pathogen component of resistance development -



The inherent resistance frequency in a population depends on the type of pathogen and on the type of fungicide. It can range from ca. 1 individual/10^4 individuals to 1 individual/10^6 individuals.

Resistance development in pathogen populations

Recipe for resistance development

Lab

Large amount of pathogen propagules + Low fungicide concentration + Repeated exposure to the fungicide = Resistance development is optimal

Field

Conducive environment, susceptible varieties, improper timing + Alternate row, Air application, Off-Label use + Repeated usage of fungicide class = Resistance development is optimal