Management of postharvest fungal decays in California citrus production

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Overview

- Citrus production in California
- Important pre- and postharvest diseases of citrus in California
- Overview of postharvest decay management
- Currently registered and new postharvest fungicides
- Challenges in postharvest decay management
  - Optimizing efficacy and perfomance
  - Resistance management: Prevent resistance development against new fungicides – find use strategies for the ‘old’ fungicides.

California citrus production



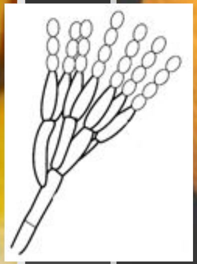
- Over 108,000 ha:
  - 70% is oranges, 17% is lemons
- Ranking:
  - **Oranges**: 80% of US fresh market production
  - **Lemons**: 90% of US production
  - **Tangerines, mandarins, clementines**: 70% of US production, increasing acreage
- Major export markets:
  - Canada, Mexico
  - Asia (Japan, China, Korea, India)

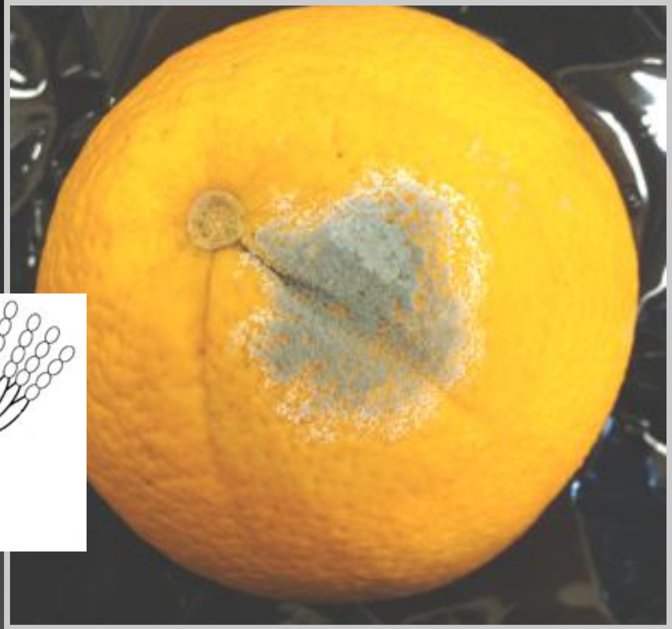
Important pre- and postharvest fungal diseases and disorders of citrus fruit in California

Disease	Cause	Pre-	Post-
Penicillium decays	*Penicillium digitatum, P. italicum, (P. ulaiense)*	*	***
Sour rot	*Galactomyces (Geotrichum) citri-aurantii*	*	**
Brown rot	*Phytophthora* spp.	**	**
Septoria spot	*Septoria citri*	*	*
Anthracnose	*Colletotrichum gloeosporioides*	*	*
Alternaria rot	*Alternaria* sp.	*	*
Gray mold	*Botrytis cinerea*	*	*
Mandarin rind breakdown	Environmental conditions (rain) Fungi: *Alternaria* spp., others?	**	-

Pre-harvest diseases are mostly high-rainfall diseases – incidence in most years is relatively low. Citrus canker, CBS, CVC, etc. absent. HLB not detected in commercial fields.

Postharvest decays of citrus:





Penicillium decays – wound pathogens

Blue mold caused by *Penicillium italicum*

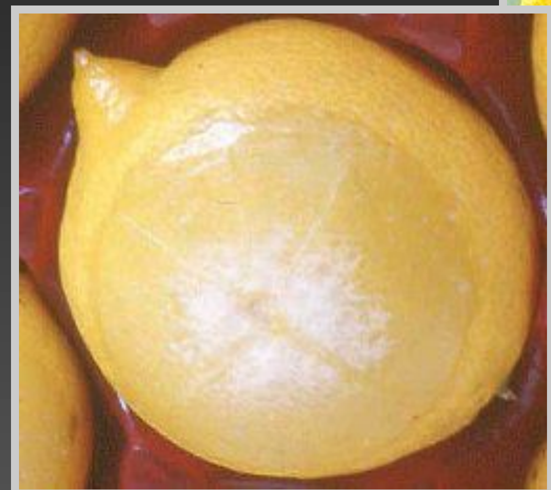
Green mold caused by *Penicillium digitatum* (most important)

Penicillium soilage

Decay of stored fruit

Postharvest decays of citrus:
Sour rot caused by *Geotrichum citri-aurantii*

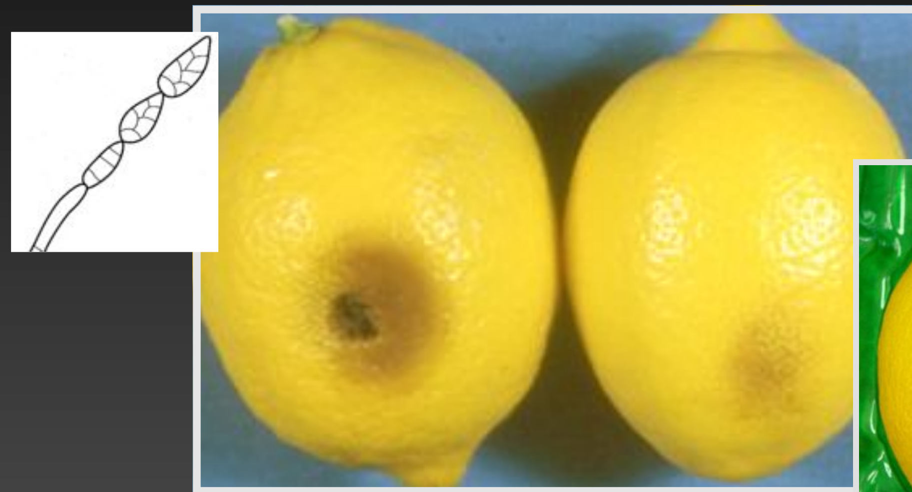
- Second most important postharvest disease of citrus in California
- Pathogenic on ‘weak’, wounded, bruised, and split fruit
- Infects all citrus species but due to long-term storage is especially prevalent in lemons and grapefruit.
- Chilling stimulates infection



Decay in a stored fruit lot

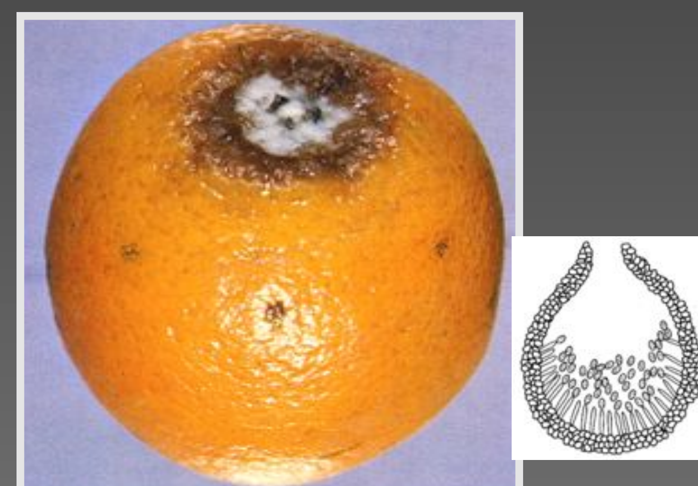
Postharvest decays of citrus

Brown rot caused by *Phytophthora* spp. Infection through intact tissue.



Alternaria decay caused by *Alternaria* sp.

Tear stain and anthracnose caused by *Colletotrichum gloeosporioides*



Stem end rot caused by *Botryodiplodia theobromae*

Botrytis infection of citrus fruit

Occasionally a problem on lemons in California

Infection during early fruit development may cause deformation of fruit.

Postharvest decay in storage. Nesting of gray mold in a crate of stored lemons.

Postharvest decay organisms

Penetration through wounds – Wound pathogens:

- Most common
- Only minor wounds required (micro-wounds).
- Wounds commonly occur before harvest (insect injuries, wind damage, etc.) or more frequently during and after harvest during handling, transport, packaging.
- **Goal in postharvest handling: Minimize fruit injuries.**

Penetration of intact fruit:

- Through surface of mature fruit.
- Quiescent infections that are established early during fruit growth but remain inactive until the fruit matures.
- Colonization of flower parts, invasion of maturing fruit

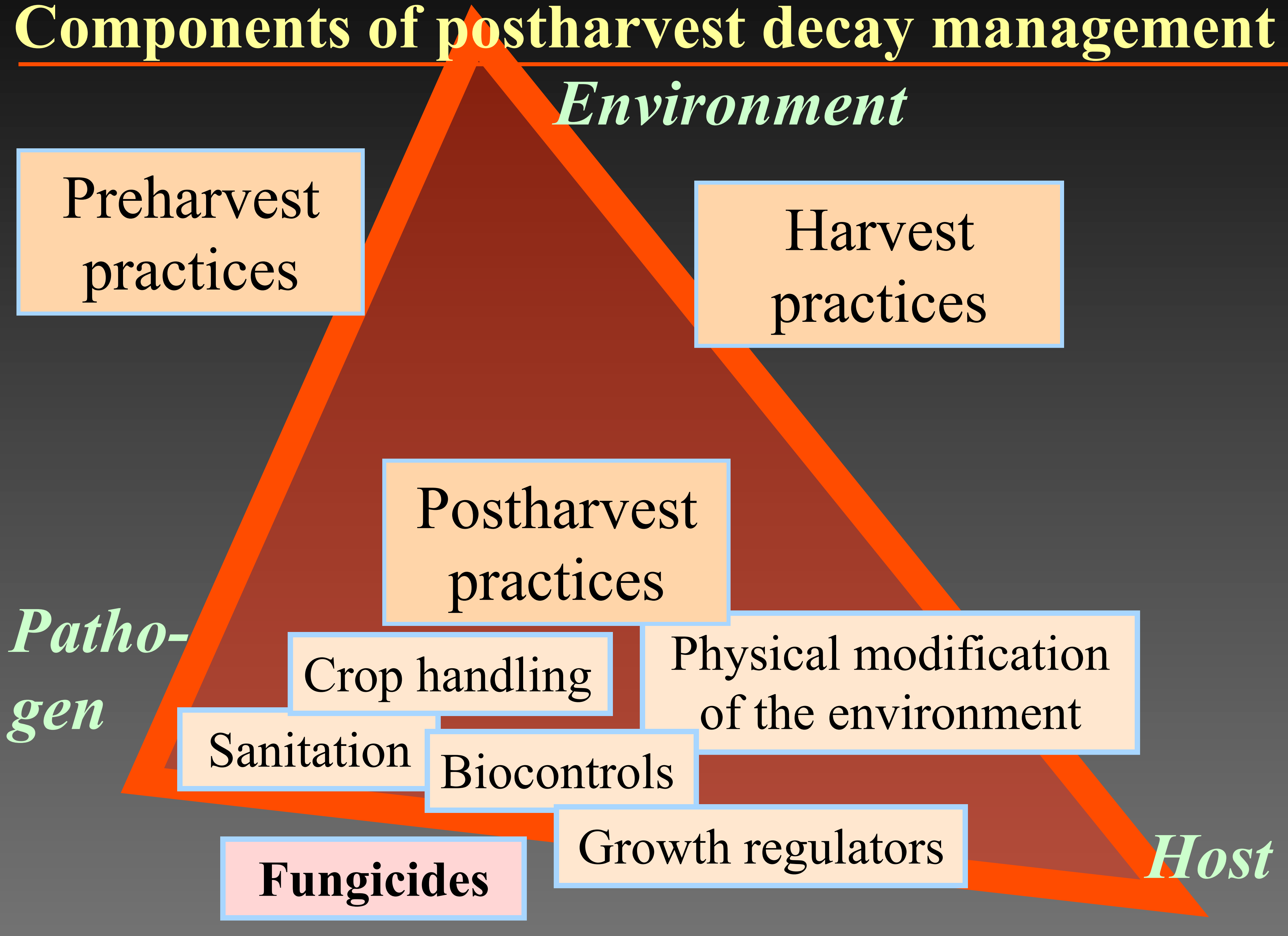
Postharvest decay management of edible fruit crops

- <u>Consumer demands:</u>
  Healthy, wholesome fruit

- <u>Competitive market:</u>
  Global market
  Zero decay tolerance

- <u>Worldwide marketing:</u>
  Long-distance transport

Components of postharvest decay management



Postharvest fungicide treatments as a component of postharvest handling
Example: Lemons in California

Fruit arrival

→ Sorting

↓

Chlorine wash, soda ash treatment, water rinse

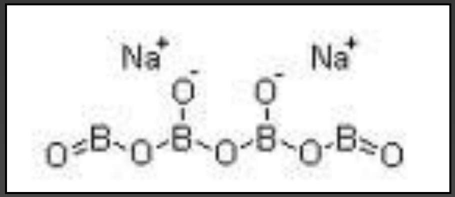
↓

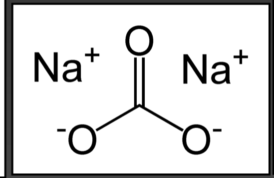
Application of fungicide and fruit coating

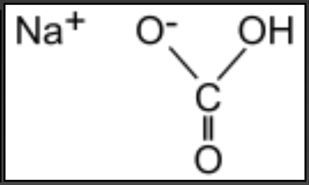
Usage of borax, sodium carbonate (soda ash), and sodium bicarbonate in postharvest treatments of lemons

Usage of borax, sodium carbonate (soda ash), and sodium bicarbonate in postharvest treatments of lemons

Treatment with heated soda ash







Water rinse after soda ash treatment

Use of inorganic salts for decay control

- **Borax, sodium carbonate (soda ash), and sodium bicarbonate** are standard treatments in many California packinghouses.
- These salts provide partial control of Penicillium decays by alkalization of infection sites, but are not stand-alone treatments.
- They can also inactivate spore inoculum and thus, reduce the amount of inoculum and the potential of resistance development.
- **Potassium sorbate** is less effective than the carbonate salts. It is rarely used in the US, but more commonly in Europe.

Postharvest handling of lemon fruit after harvest

Storage wax application & bulk packing bins after grading

↓

Storage for up to 3 months

Postharvest handling of lemon fruit after storage

Chlorine wash after storage

Sorting

Fungicide and pack wax application

Boxing and marketing

Postharvest fungicides for citrus in the US

Phenols
Sodium ortho-phenyl phenate (SOPP)
1930s

Benzimidazoles
Thiabendazole
(TBZ)
1970s

DMI-imidazoles
Imazalil
1980s

Phenylpyrroles
Fludioxonil
(Graduate)
2006

Strobilurins (QoIs)
Azoxystrobin
(Diploma)
2010

DMI-triazoles
Propiconazole
(Mentor)
2013

Anilinopyrimidines
2006-2010
Pyrimethanil
(Penbotec)

Phosphonates
Potassium Phosphite
(Prophyt, Kphos)
2012

New
EXP-13

Reduced risk fungicides

Exempt from tolerance

Fungicide with resistance in *Penicillium* spp. packinghouse populations

- Goal is to prevent resistance to fludioxonil and azoxystrobin and to define usage pattern for fungicides with resistance.
- New mixture partner for fludioxonil and azoxystrobin – EXP-13

Efficacy of new fungicides against Penicillium decays

Use of synthetic postharvest fungicides is the most effective method to reduce the incidence of decays

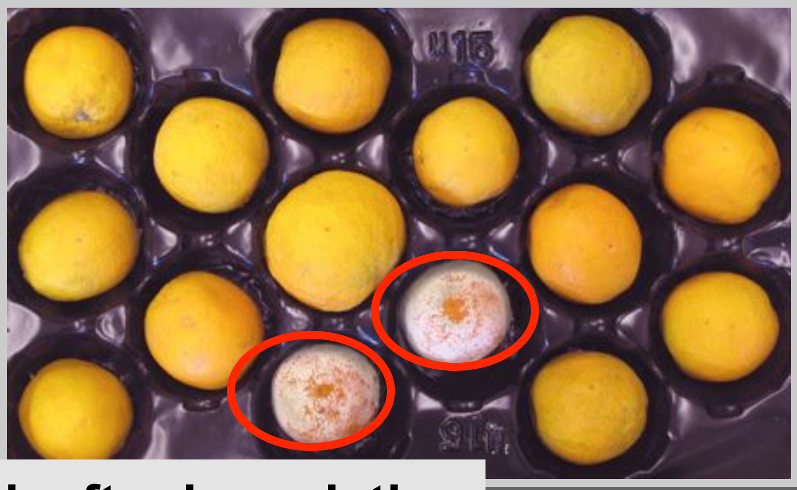
Understanding performance:
Contact vs. systemic determines the best application timing.

Timing of post-inoculation treatments with Graduate

Control

9 h after inoculation

12 h after inoculation

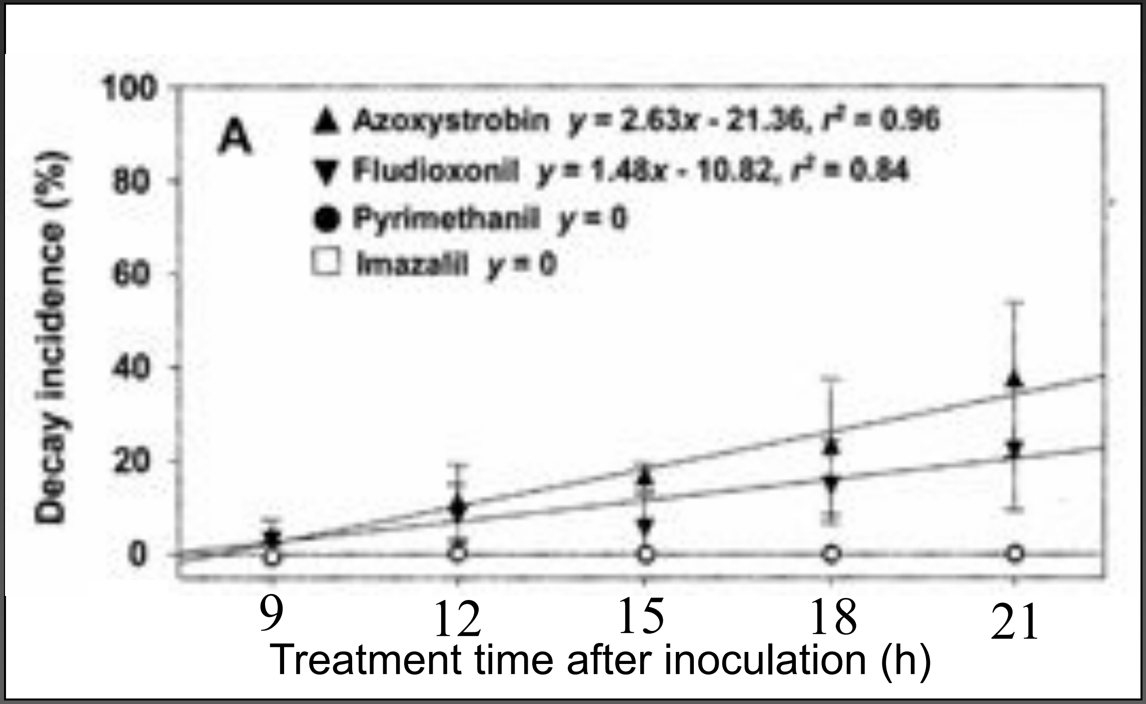


15 h after inoculation

Treatments with aqueous solutions of 1,000 ppm Graduate (fludioxonil)

Time effect in controlling citrus green mold

- Treatments selected times after inoculation -



Studies with inoculated fruit -

- Inoculation with a *P. digitatum* isolate sensitive to imazalil and TBZ
- Spray treatments selected times after inoculation
- Fungicides: each at 1,000 ppm

Incidence of decay in the controls was >90%

Fungicides with systemic activity (azoxystrobin, imazalil, TBZ, pyrimethanil) have a longer post-infection activity than fludioxonil.

Efficacy of new fungicides against Penicillium decays

Understanding performance:
Contact vs. systemic compounds

Contact

- **Graduate (fludioxonil) is a contact fungicide**
- **Fruit should be treated within 12 h of harvest**

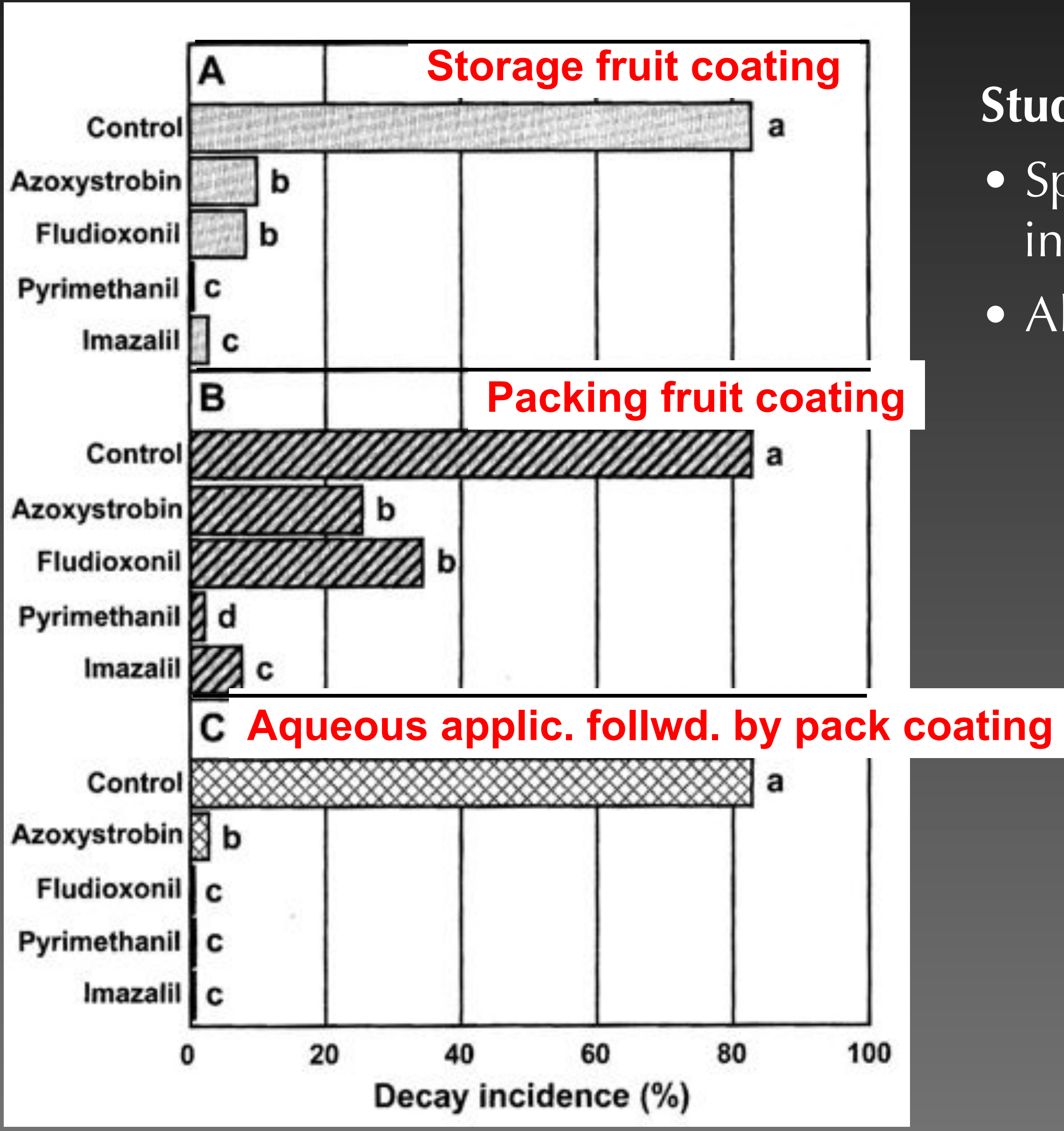
Systemic

- **Penbotec (pyrimethanil) and Diploma (azoxystrobin) are locally systemic fungicides**
- **Fruit should be treated within 24 h of harvest**

Optimizing treatment efficacy

- Compatibility with fruit coatings
- Efficacy for controlling decay and sporulation of infected fruit

Effect of fruit coatings on the efficacy of postharvest fungicides for decay control



Studies with inoculated fruit -

- Spray application 13-15 h after inoculation
- All fungicides at 1,000 ppm

- Efficacy of fludioxonil and azoxystrobin for decay control is *decreased* when applied in storage or packing fruit coatings.
- A staged application – aqueous application followed by fruit coating prevents the negative effect of fruit coatings.

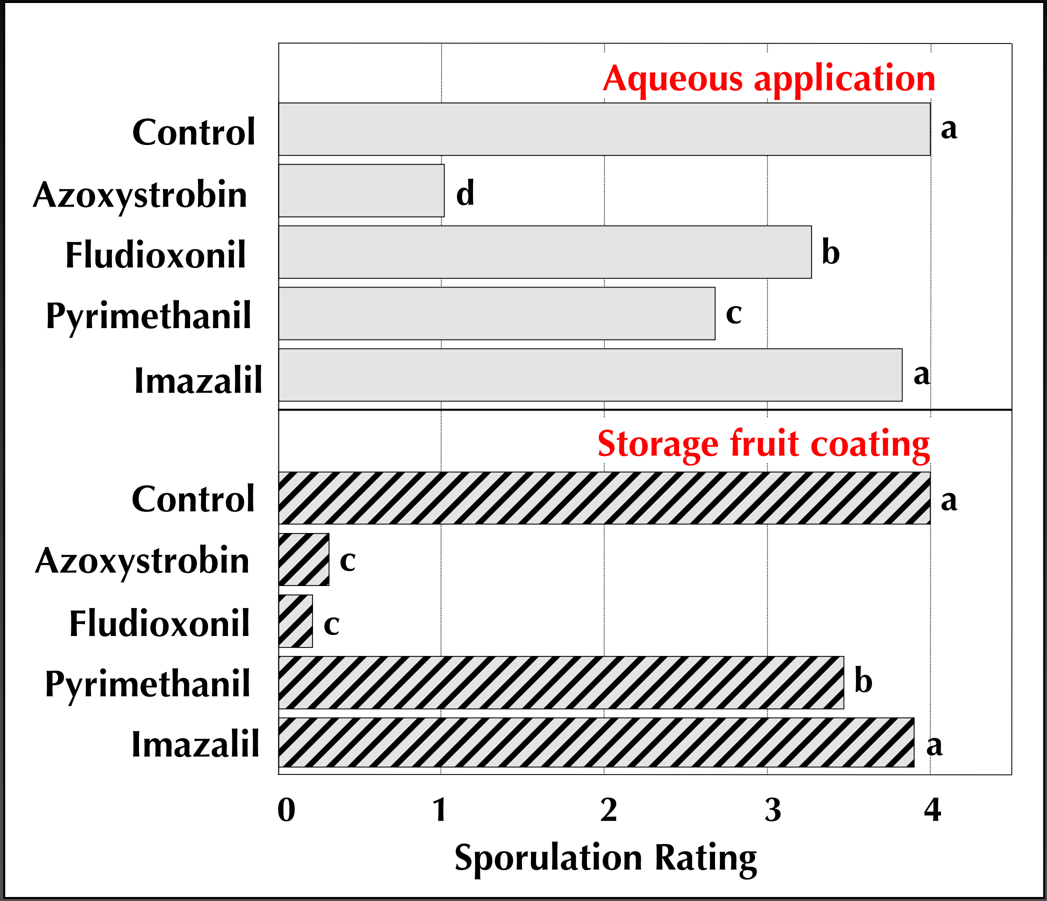
Penicillium soilage

Postharvest treatments that reduce sporulation of infected fruit, reduce soilage of healthy fruit.

Effect of fruit coatings on the efficacy of postharvest fungicides for sporulation control

Studies with inoculated fruit -

- Inoculation with *P. digitatum* resistant to imazalil and TBZ
- 30-sec dip treatment
- Fungicides: each at 500 ppm



- Efficacy of fludioxonil and azoxystrobin for sporulation control is *increased* when applied in storage fruit coating.
- Pyrimethanil has little effect on sporulation.

Control

Fludioxonil in storage coating

Optimizing treatment efficacy

Compatibility with fruit coatings

Highest efficacy in *decay* control:

- Fludioxonil (Graduate) and fludioxonil/azoxystrobin (Graduate A+) - Application as aqueous solutions followed by a fruit coating.
- Pyrimethanil (Penbotec) - Effective with or without waxes

Highest anti-sporulation activity:

- Fludioxonil/Azoxystrobin – In storage fruit coating
- Pyrimethanil - Mix with anti-sporulation fungicides

Staged postharvest application – get the best of both:

- Aqueous application of fludioxonil followed by an application of fludioxonil in a fruit coating.

Efficacy of old and new 'reduced-risk' fungicides against postharvest decays of citrus

Fungicide	Trade Name	Green Mold*	Blue Mold	Sporulation Control	Sour Rot
Imazalil	Imazalil	$+++^{S}/+^{R}$	+++	+++	-
Thiabendazole	TBZ	$+++^{S}/+^{R}$	+++	+	-
SOPP	SOPP	$++^{S}/+^{R}$	++	-	+
Pyrimethanil	Penbotec	$+++^{S}/+^{R}$	+++	+	-
Fludioxonil	Graduate/ Scholar	+++	+++	+++	-
Azoxystrobin	Diploma	+++	-	+	-
Propiconazole	----	+++	+++?	++	++

*- Azoxystrobin, fludioxonil, and pyrimethanil are effective against decay caused by TBZ- or imazalil-resistant *Penicillium* populations.

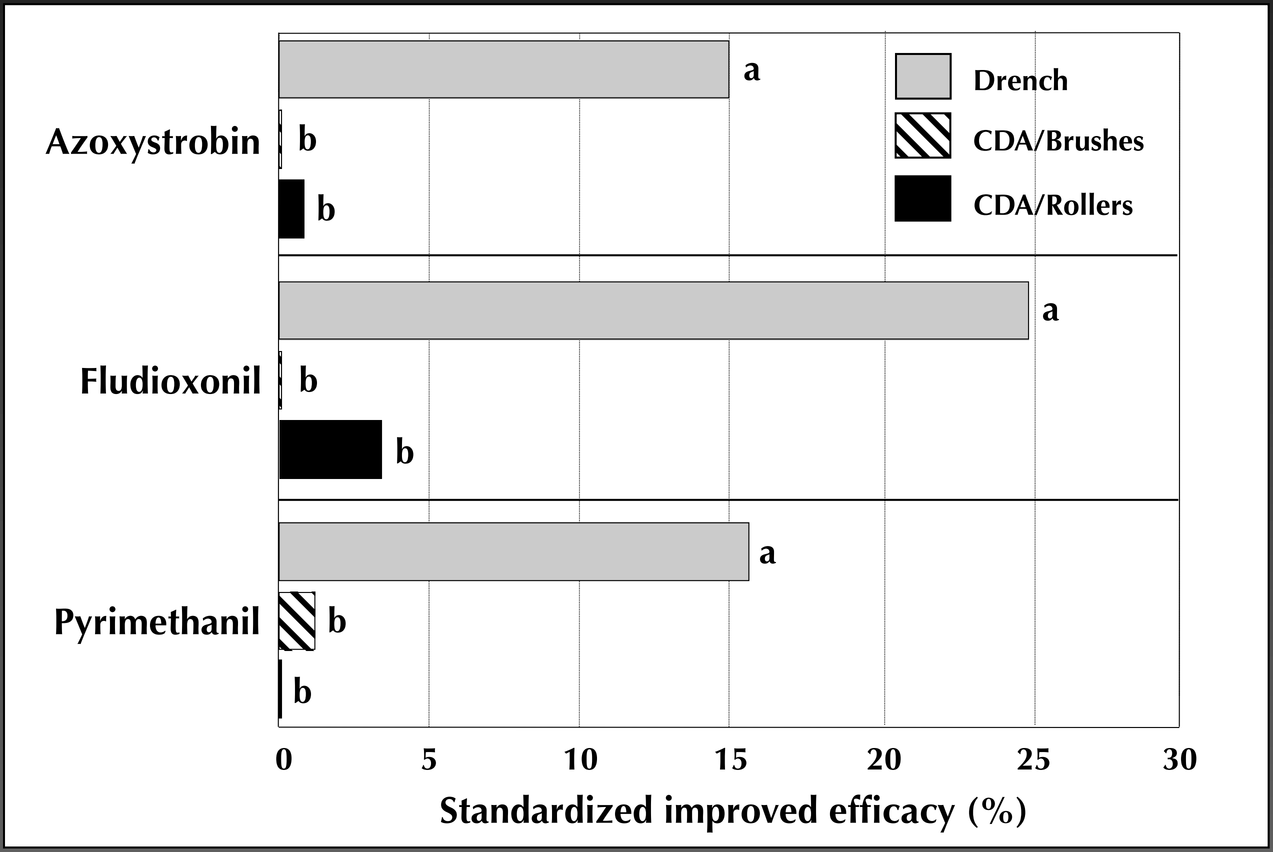
Optimizing treatment efficacy

Fungicide application methods

Application methods for postharvest fungicide treatments

Flooder application

Comparative efficacy of postharvest application methods



In-line drench (flooder) applications provide the highest efficacy.

- ✓ **Efficacies for each fungicide were compared to the least efficient application method.**
- ✓ **Statistical comparisons of application methods were done for each fungicide.**

Sanitizing re-circulating fungicide solutions

- Compatibility of fungicides with sanitizers -

Common name	Trade name	Compatibility: Chlorine	Compatibility: Peroxyacetic acid	Compatibility: Sodium bicarbonate
Imazalil	Imazalil	-	+	+
TBZ	Mertect	+	+	+
Azoxystrobin	Abound	+	+	-
Fludioxonil	Graduate	+	+	+
Pyrimethanil	Penbotec	-	+	+

Compatibility ratings:

- = Incompatible or negative effects on fruit (phytotoxicity) or on fungicide efficacy.

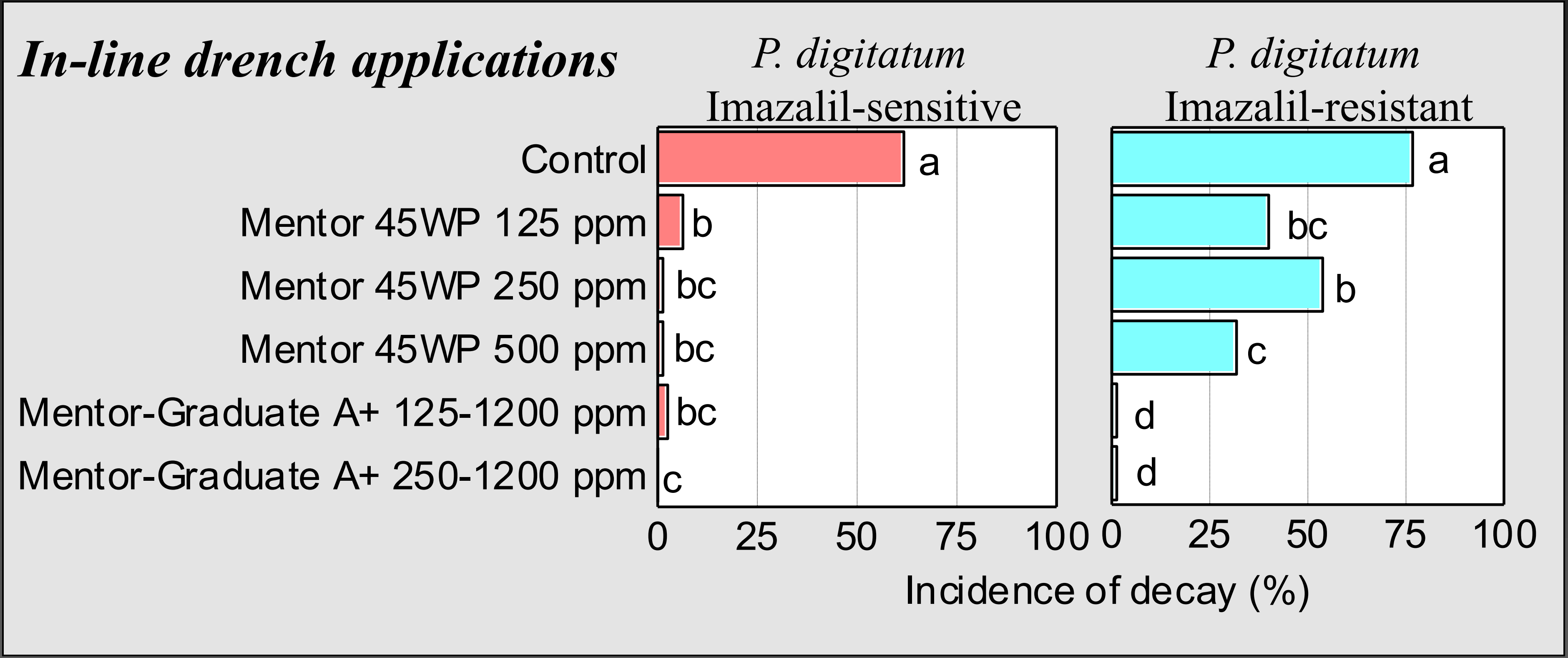
+ = Compatible or no phytotoxicity on fruit and/or decrease in fungicide efficacy.

Summary: Optimizing treatment efficacy

- Treatment efficacy and post-infection activity of fludioxonil are improved when applications are done in **mixture with sodium bicarbonate** (SBC).
- **Heated (50°C) applications** may improve efficacy of pyrimethanil or fludioxonil especially with SBC.
- **Drenches and flooders** optimize coverage and performance
- **Maximum performance:**
  - (Heated) drench application with fludioxonil-SBC
  - + Spray application with fludioxonil-wax
- **Re-circulating solutions** of fludioxonil or pyrimethanil can be safely sanitized with chlorine or PAA, respectively

Propiconazole – another new postharvest fungicide for citrus

Efficacy of propiconazole (Mentor) for managing green mold of inoculated Eureka lemons

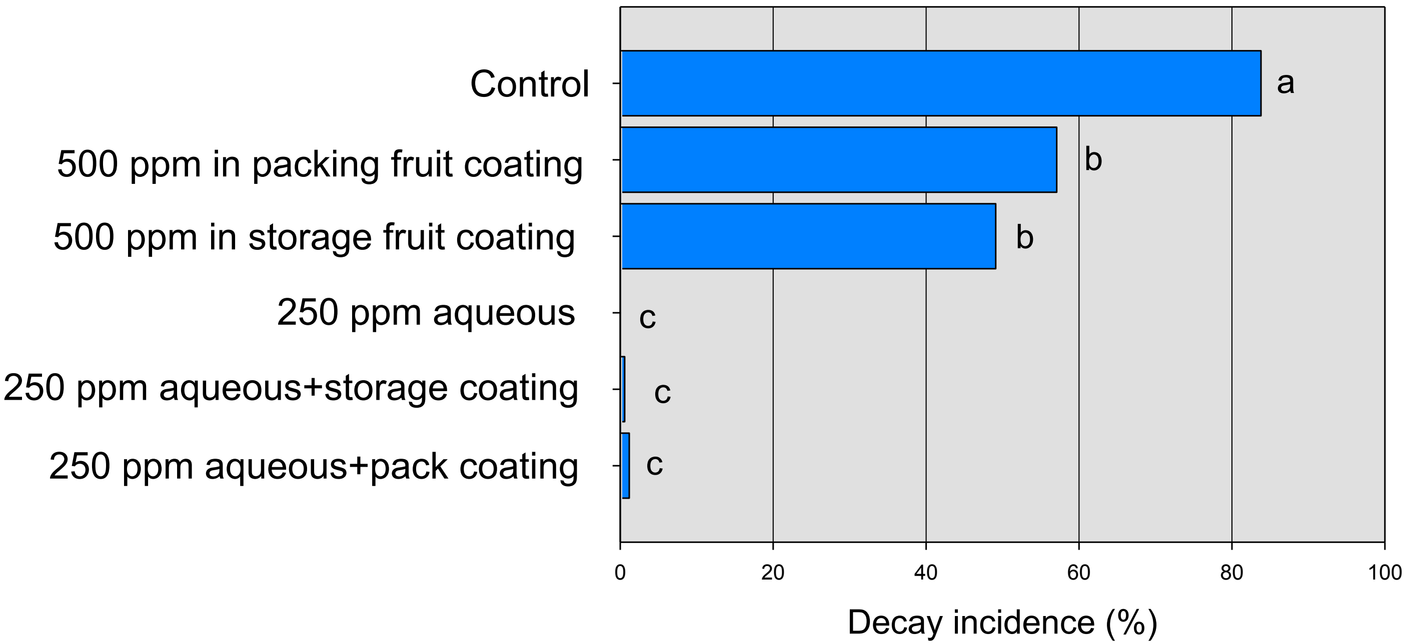


Fruit were treated 11-13 hours after inoculation with *P. digitatum*. Drench applications were done on an experimental packingline.

- Cross resistance between imazalil and propiconazole – both are DMI fungicides

Efficacy of propiconazole against sour rot

Experimental Packingline



Fruit were treated 11-13 hours after inoculation with *G. citri-aurantii*. Drench applications were done on an experimental packingline.

Control

Propiconazole 45WP 12 oz

FUNGICIDE RESISTANCE MANAGEMENT IN CITRUS

A Coordinated Effort for the Prevention of Fungicide Resistance with the Widespread Use of New Pre- and Postharvest Fungicides in Citrus

All new fungicides should be considered high risk for developing resistance.

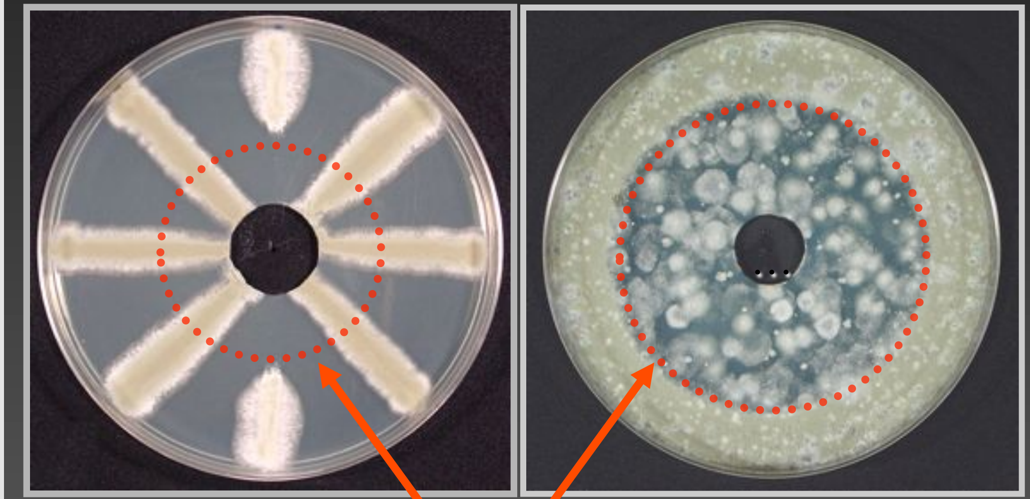
Fungicide resistance management for postharvest decays of citrus fruit

A high risk for resistance development in postharvest pathogens of citrus fruit:

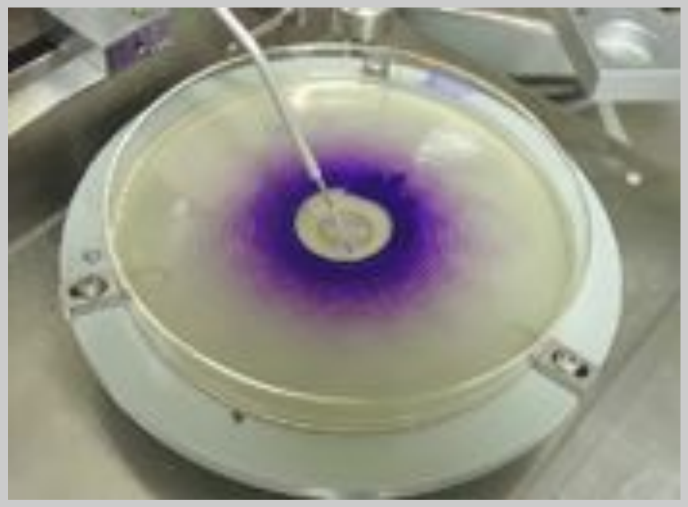
- Treated fruit are sometimes stored for long periods and the pathogen is exposed to the fungicides.
- Sometimes repeated treatments of the same fruit lot
- The pathogens produce abundant spores.
- All postharvest fungicides are single-site mode of action materials.
- Many parallels to postharvest aspects of pome fruit.

Method for detecting rare resistant variants within a population

Selection plates amended with a fungicide concentration gradient used for air-sampling



EC_{95} for mycelial growth Pd^{s}



P. digitatum radially streaked on a plate with a fungicide conc. gradient (e.g. imazalil)

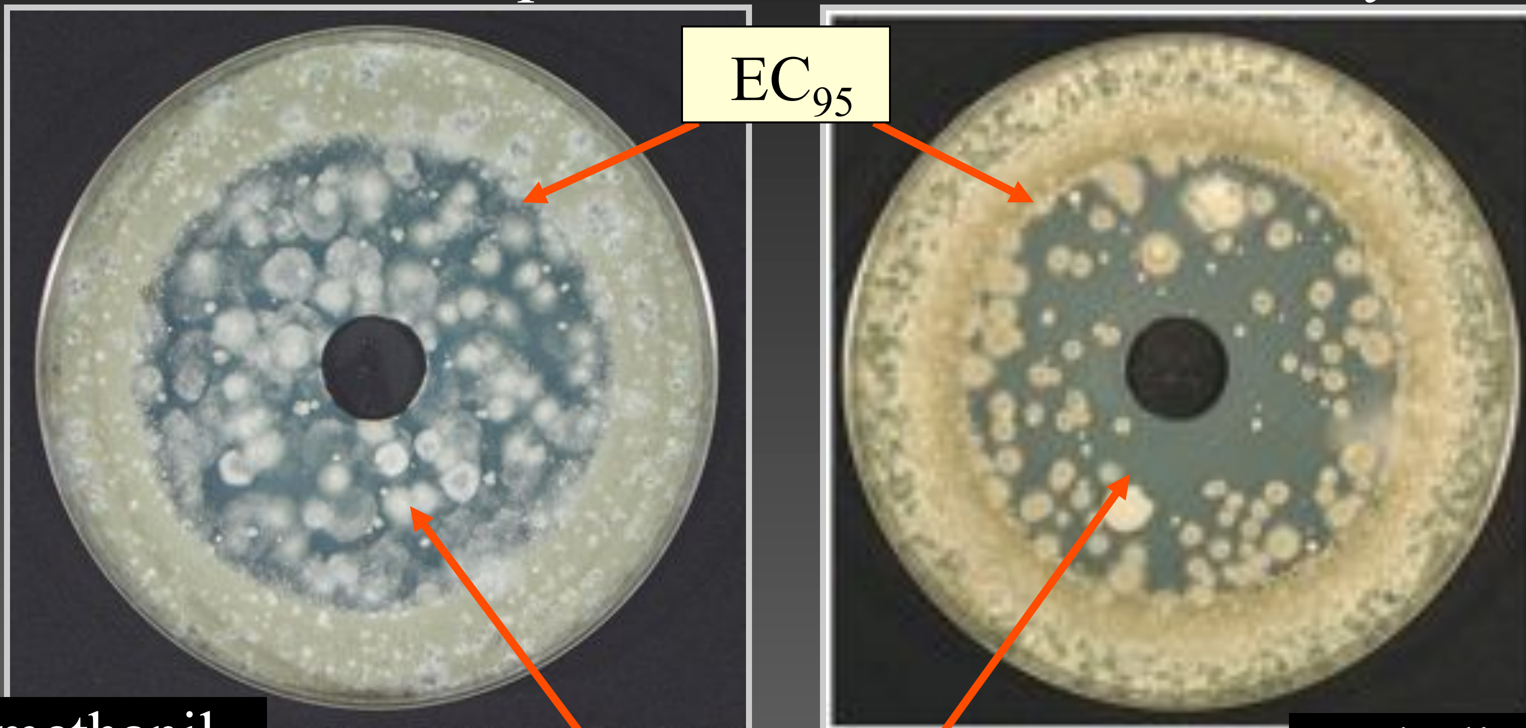
Air sampling plate with *P. digitatum* (EC_{95} concentration indicated)

Method for detecting rare resistant variants within a population

Exposure of selection plates in a packinghouse

Sampling of large pathogen populations in the packinghouse using spiral gradient dilution plates

Plates after exposure and incubation for 5 days



Isolates of *P. digitatum* with EC_{95} higher than those of baseline isolates

Resistance frequency in different populations sampled:

10^{-4} to $7x10^{-6}$ 10^{-6} to 10^{-9}

Studies on resistance against azoxystrobin, fludioxonil, pyrimethanil

- **Isolates resistant to fludioxonil or pyrimethanil** (but not azoxystrobin) could be recovered in **mass platings** of fungal spores in the laboratory and in packinghouses.
- **Natural resistance frequencies** were calculated Pyrimethanil: 10^{-4}, fludioxonil 10^{-6} - 10^{-7}.
- Thus the **risk for resistance development** against the new postharvest fungicides is real and measurable.
- To avoid treatment failures, **resistance management practices** have to be followed.

Kanetis et al., Phytopathology, in press

Strategies for using pre- and postharvest fungicide programs to minimize resistance development in *Penicillium* populations

1. **Fruit sorting, decay removal** – reduce development of decay and increase of pathogen populations
2. **Sanitation washes** – minimize pathogen populations from fruit and equipment
3. **Timely application of treatments** (within 24 h of harvest)
4. **Use any class of fungicide only once on a fruit lot.**
   - When using a preharvest fungicide, use a fungicide of a different class for the first (storage) postharvest treatment
   - When doing 2 postharvest treatments, use fungicides of a different class for the two treatments

Integrated resistance management practices *Contd.*

5. **Use effective application methods** based on the characteristics of the fungicide (e.g., contact vs. systemic, activity against decay and sporulation, compatibility with fruit coatings, …)
6. Use postharvest fungicides in combination with **SBC** (only when compatible) in drench treatments prior to storage fruit coating applications when possible.
7. **Use a postharvest treatment with good anti-sporulation activity for fruit being stored.**
8. **Isolate set-back and hold-back fruit** from packinghouse

Integrated resistance management using fungicide pre-mixtures

Trends in postharvest fungicide registrations in the US: *Pre-mixtures*

Imidazole Imazalil + **Anilinopyrimidine** pyrimethanil = **Philabuster** **citrus - registered**

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

Fludioxonil + Azoxy-strobin + **SBI** Propicon-azole = **Citrus – in development**

Use of fungicide mixtures: The resistance potential of fungicide mixtures is lower than for single active ingredients

Single applications

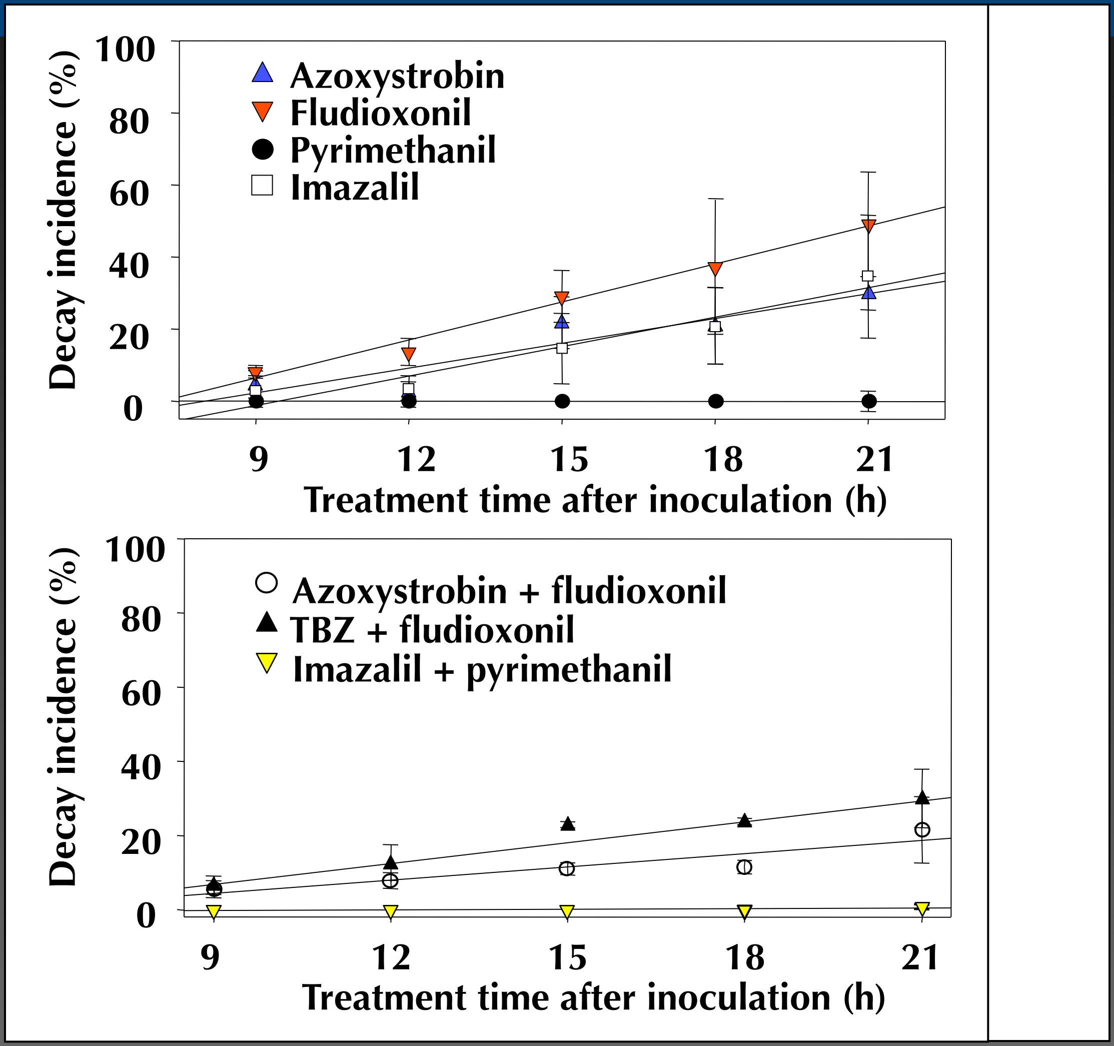
- Resistance frequency of azoxystrobin (Rf_{pyr}): ca. 10^{-9}
- Resistance frequency of fludioxonil (Rf_{fld}): 10^{-6} - 10^{-7}

Mixture applications (i.e., Graduate A+)

$$Rf_{mix} = 10^{-15} - 10^{-16}$$

Each application is still a selection event, but the probability for changes to occur concurrently at independent loci is lower than for a single locus.

New mixture treatments improve post-infection activity



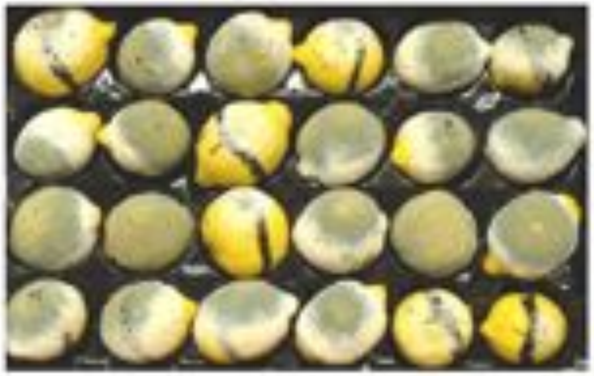
Inoculated fruit studies -

- *P. digitatum* resistant to imazalil and TBZ
- Spray treatments selected times after inoculation
- Single-fungicides: each at 1,000 ppm, mixtures: each at 500 ppm

Incidence of decay in the controls was

Mixture treatments improve the post-infection activity while using the same amount of chemical.

Postharvest treatments of lemons for management of green mold



Untreated control

Heated soda ash

Philabuster 350/350 flooder + Imazalil 500 CDA

Graduate A+ 300/300 flooder

Graduate A+ 600/600 flooder

The study was conducted at Saticoy Lemon Packing. Fruit were wound-inoculated with *P. digitatum*. Aqueous fungicide flooder treatments were preceded by a heated soda ash treatment and were followed by either a fungicide CDA treatment (in D202) or by a hand spray with diluted D202.

Postharvest treatments of lemons for control of green mold sporulation

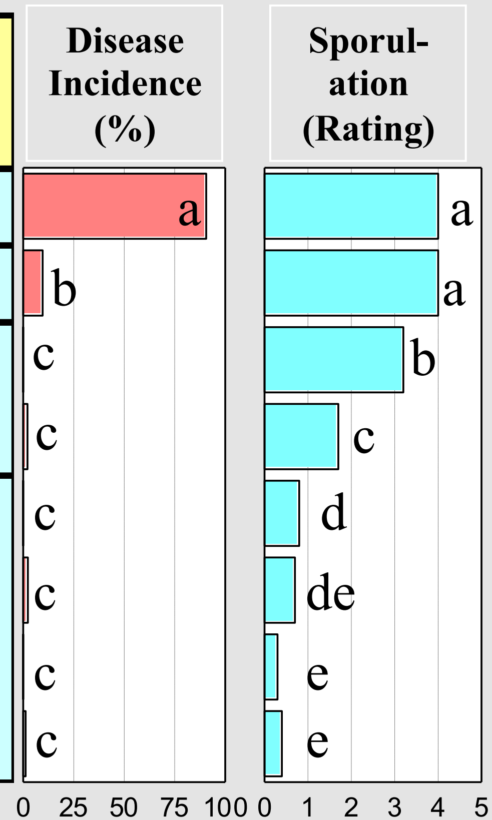
Heated soda ash | Philabuster 350/350 flooder + Imazalil 500 CDA | Philabuster 350/700 flooder + Imazalil 500 CDA

Graduate A+ 300/300 flooder | Graduate A+ 300/300 flooder + Graduate A+ 300/300 CDA | Graduate A+ 600/600 flooder + Graduate A+ 600/600 CDA

The study was conducted at Saticoy Lemon Packing. Fruit were inoculated with *P. digitatum* at the center. Aqueous fungicide flooder treatments were preceded by a heated soda ash treatment and were followed by either a fungicide CDA treatment (in D202) or by a hand spray with diluted D202. Note that sporulation in the Graduate treatments is often found on the black marker lines.

Efficacy of commercial packinghouse treatments for management of green mold of inoculated lemon fruit

Aqueous fungicide treatment - flooder	Fungicide treatment - CDA
Control	---
Control / Soda Ash	---
Philabuster 350/350	Imazalil 500 / D202
Philabuster 350/700	Imazalil 500 / D202
Graduate A+ 300/300	---
Graduate A+ 300/300	Graduate A+ 300/300 / D202
Graduate A+ 600/600	---
Graduate A+ 600/600	Graduate A+ 600/600 / D202

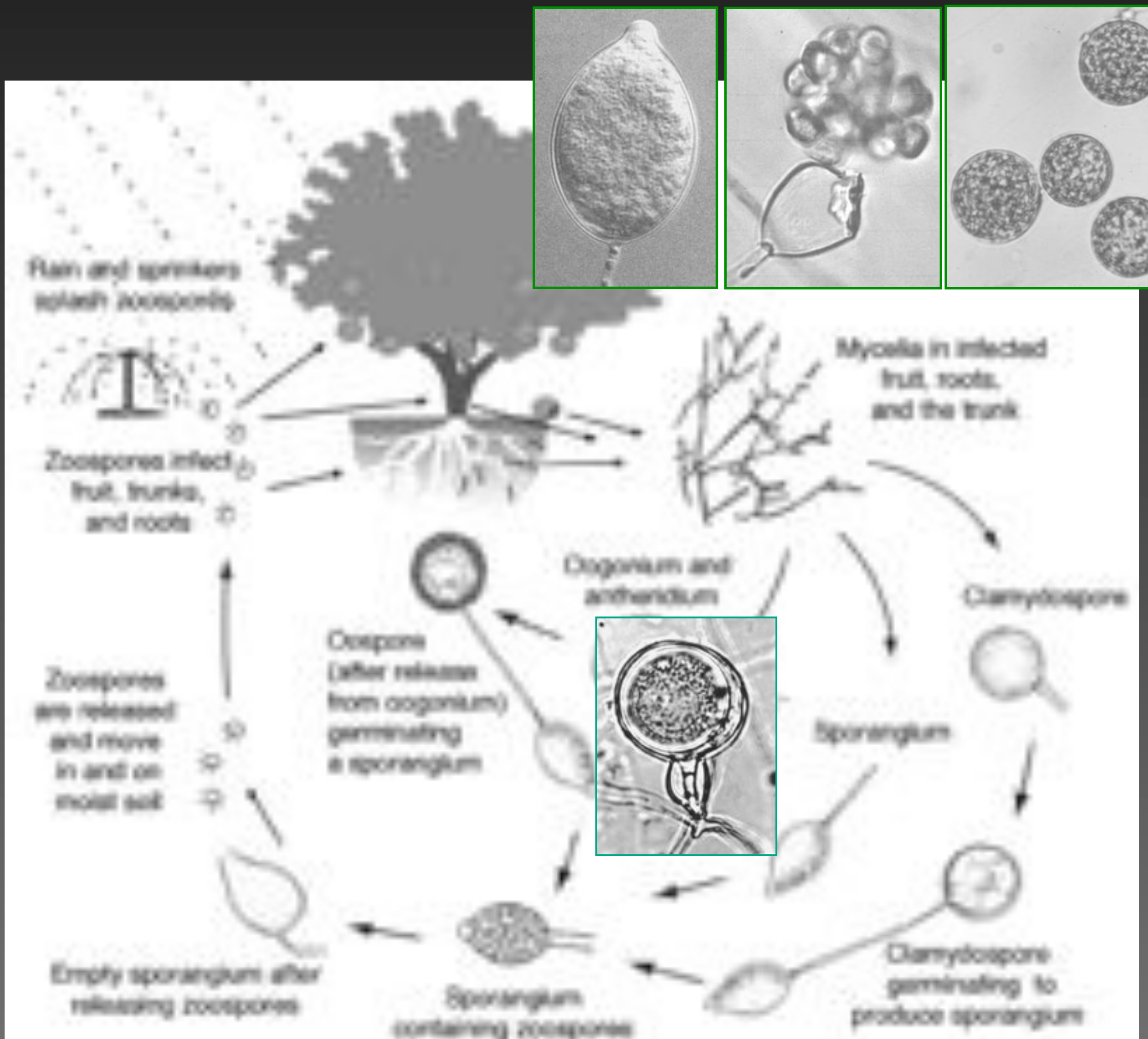


Treatments were applied 13-14 hr after inoculation with an imazalil-moderately resistant isolate of *P. digitatum*. All fungicide applications were preceded by a heated soda ash treatment. For sporulation studies, fruit were center-inoculated using a syringe.

Citrus Brown Rot

- Species of *Phytophthora* involved:
  - *P. citrophthora*
  - ***P. parasitica (P. nicotianae)***
  - *P. syringae*
  - *P. hibernalis*
- Occur in all growing regions of CA.
- *P. citrophthora* and *P. parasitica* are considered most important.
- Losses are associated with periods of high rainfall.

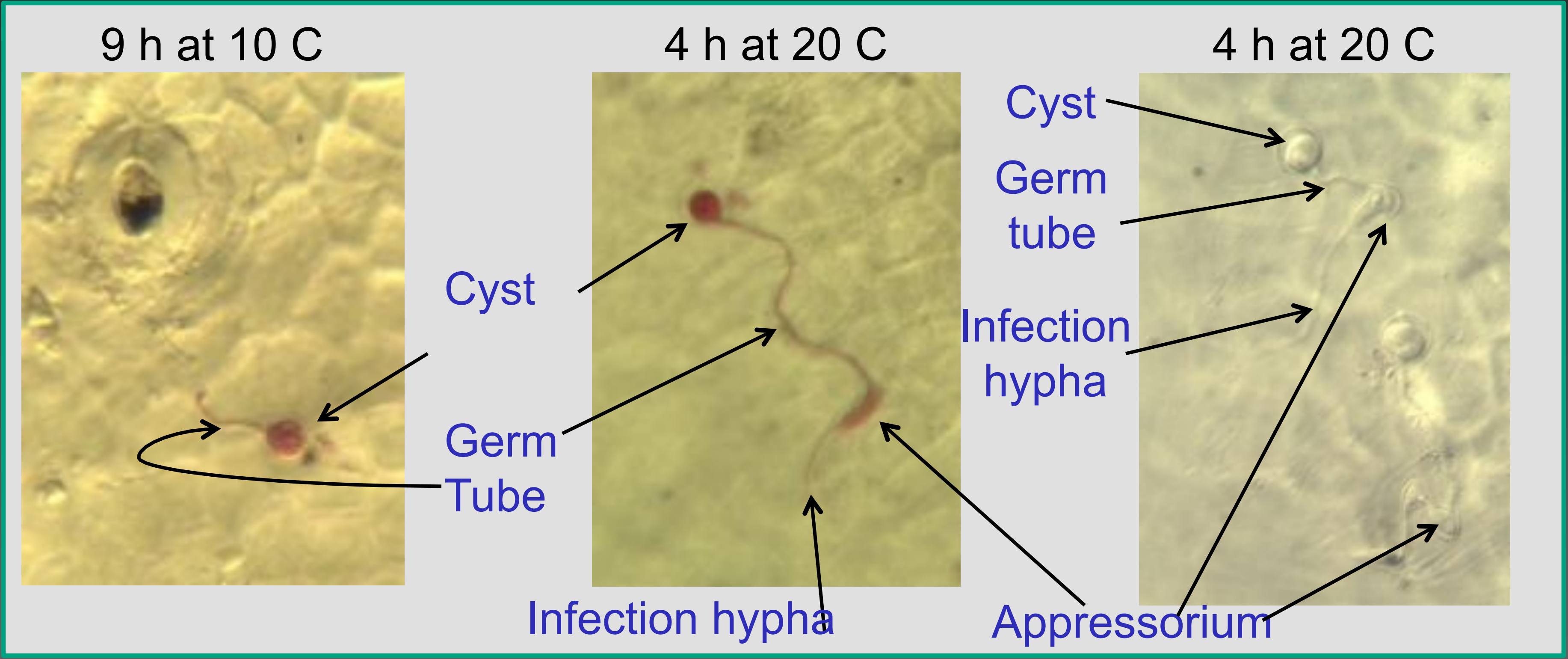
Disease cycle of *Phytophthora* spp. – The root rot and brown rot phases are connected



- 18 h of wetness required for sporangia production and zoospore release.
- 3 h of wetness required for infection.
- Zoospores from sporangia on the ground may be splashed up onto low-hanging fruit and the trunk.
- Inoculum levels and wetness length are the most important predictors of brown rot epidemics.
- Sample *P. parasitica* July through September, *P. citrophthora* January through March.
- *Phytophthora* populations >15 to 20 propagules/g root zone soil may warrant treatment.

Wetness and temperature effects on infection of Navel oranges by *P. citrophthora*

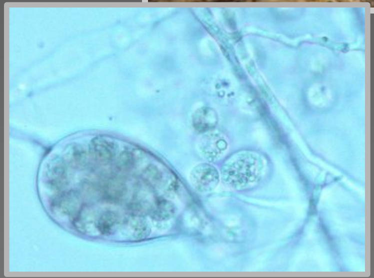
- Zoospores encysted within an hour at incubation at 20C.
- Germ tubes were observed after 1 h.



Fruit inoculation studies at 20C: 1 h wetness - no disease
1.5 h wetness - 10% incidence
2 h wetness - 70% incidence

Experiments with *P. syringae* are currently being done

Management of Phytophthora Diseases



P. citrophthora releasing zoospores

- Cultural practices
  - Resistant rootstocks
  - Planting on berms for adequate drainage
  - Avoid over-irrigation
    - Alternate side irrigation
    - Drainage tiles
  - Skirting of trees
- Fumigation
- Surfactants
- Fungicides
  - Preharvest
  - Postharvest

Management of Phytophthora Brown Rot - Preharvest Fungicide Sprays -

Management of Phytophthora Brown Rot - Preharvest Fungicide Sprays -

Current guidelines:

- One spray of copper fungicide between October and December before or just after the first rain.
- Apply at 400-700 gal/A (high volume).
- If frequent and high rainfall after the first application, repeat applications in January or February.
- Spray the skirts to about 1.2 m above ground; whole tree applications may be necessary for some varieties or in orchards with a history of the disease.
- Spraying the ground underneath the trees may also reduce brown rot infections.

Management of Phytophthora Brown Rot
- Preharvest fungicide sprays -

Most effective orchard sprays:

Bordeaux mixture (copper sulfate + lime) with 0.6 to 0.8 lb of metallic copper/100 gal.

Neutral (fixed) coppers (copper hydroxide, copper oxide)

Phosphonates (e.g., fosetyl-al - Aliette 5 lb/A), potassium phosphite - Prophyt 4 pints/A, etc.) are systemic and provide effective control when applied up to 5 weeks prior to infection.

New preharvest treatments for control of brown rot caused by *Phytophthora* spp.

Control

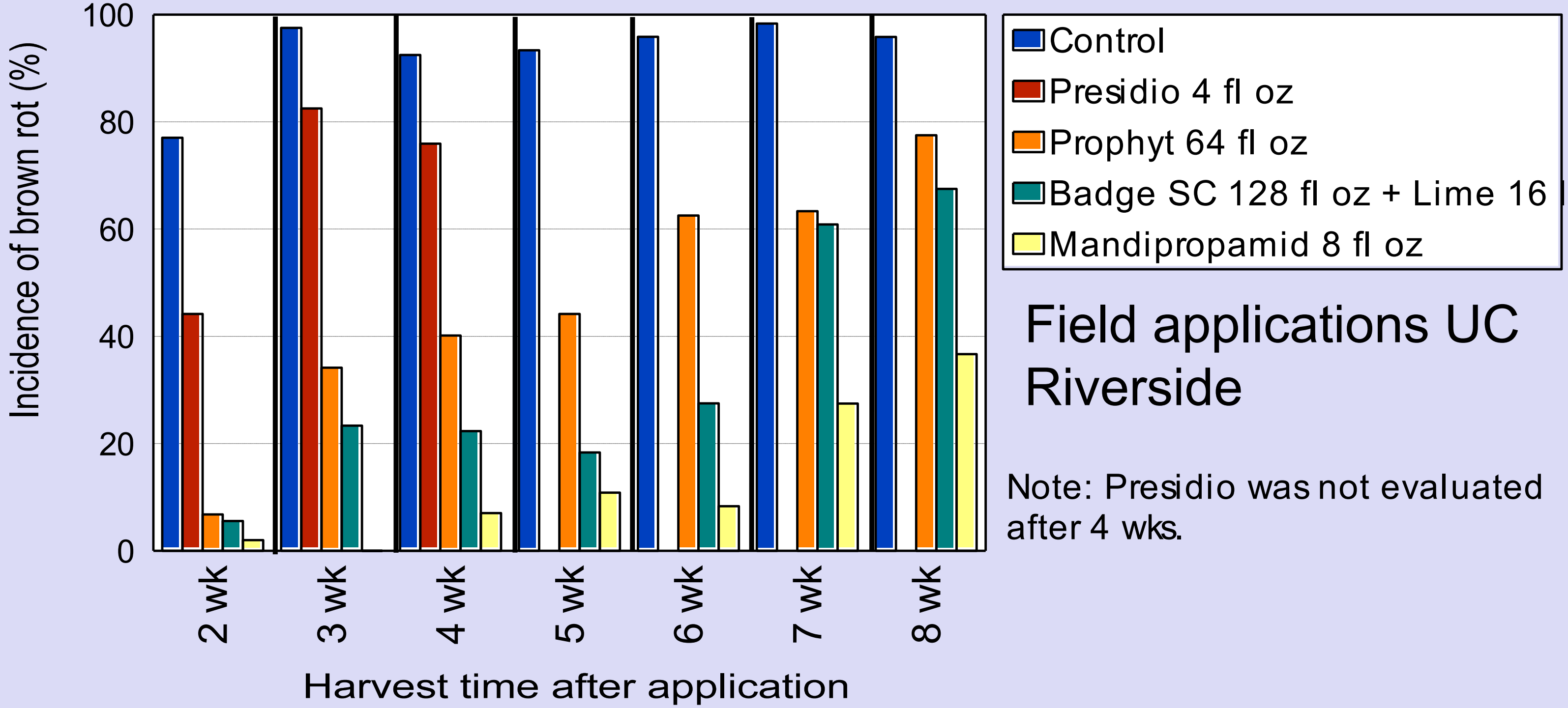
Badge 7 pts + Lime 3.5 lb

Revus 8 fl oz

Oxathiapiproline 4.8 fl oz

Fruit harvested 6 weeks after field treatment and inoculated with *P. citrophthora*

Persistence of new preharvest treatments for control of brown rot caused by *Phytophthora* spp. 2013



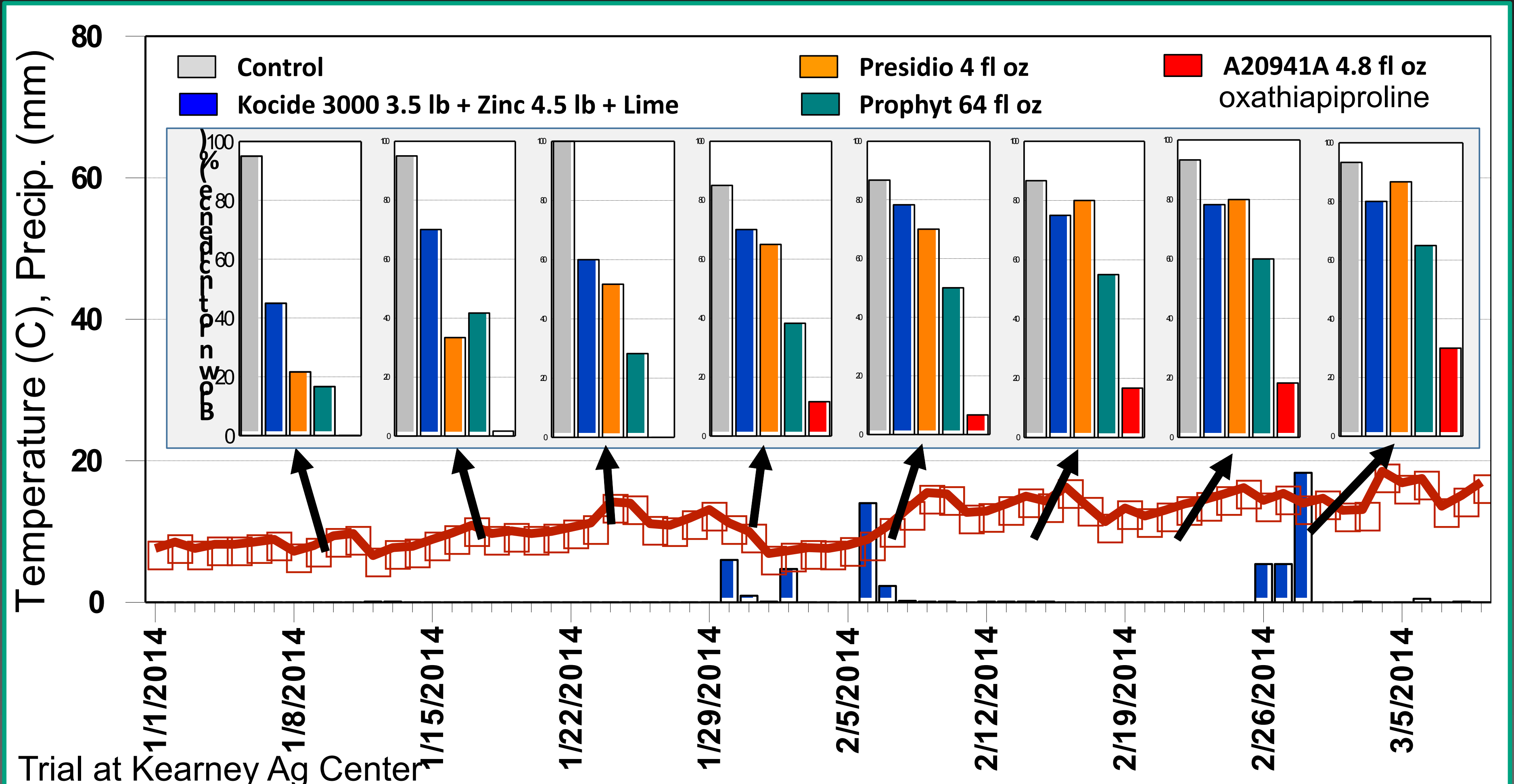
Field applications UC Riverside

Note: Presidio was not evaluated after 4 wks.

- Revus (Mandipropamid), Prophyt (Phosphorous acid), and Badge-Lime (copper oxychloride- copper hydroxide) were very effective when fruit were harvested 2 weeks after application.
- After 21 days, Presidio was no longer effective, whereas efficacy of Prophyt was reduced after 4 weeks.
- Copper effective for ca. 6 wk; whereas Revus was still very effective for 8 wk.

New preharvest treatments for brown rot - 2014

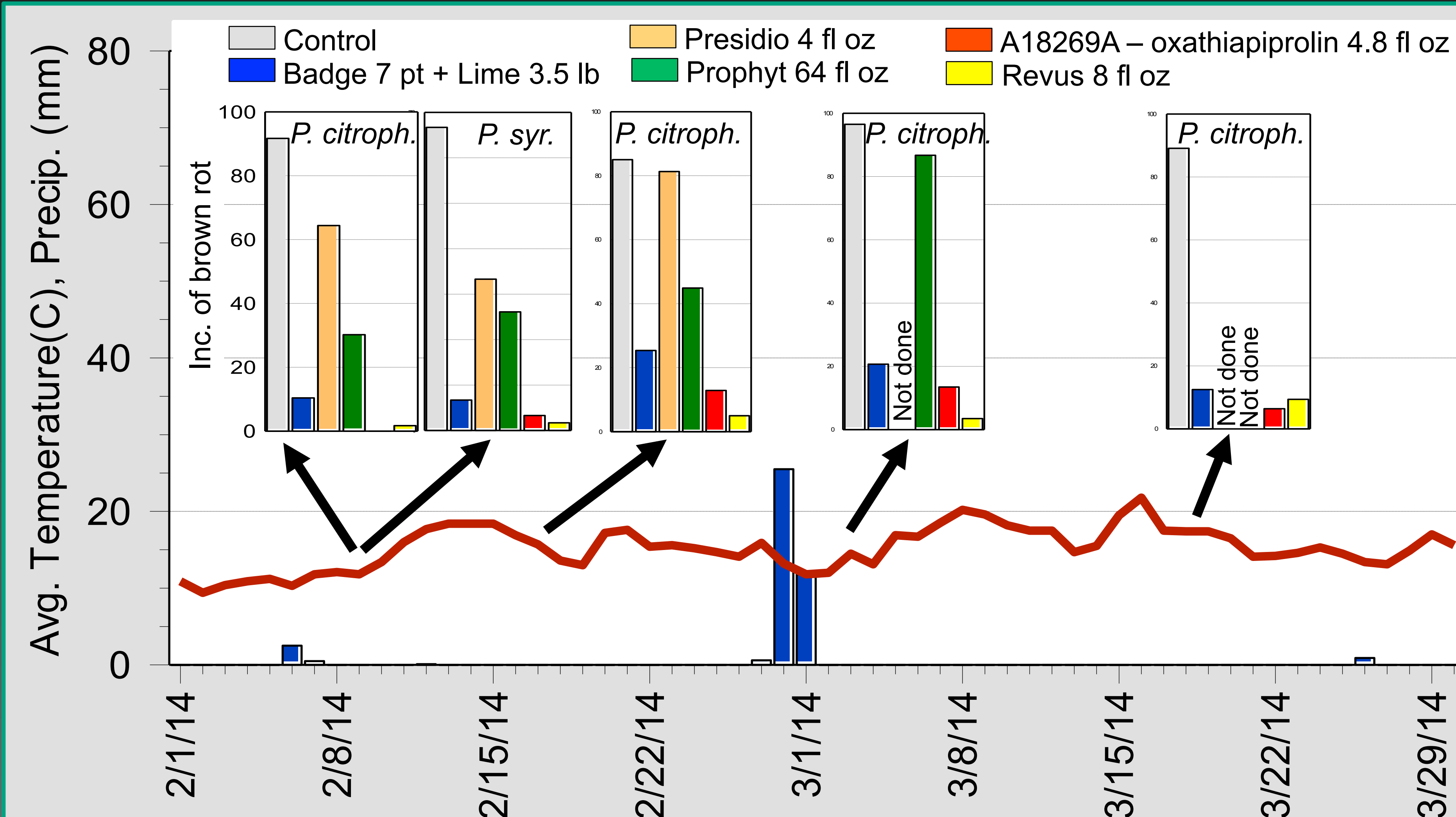
Temporal efficacy of preharvest treatments to navel oranges



- Treatments applied at 400 gal/A on Jan. 3, 2014.
- Fruit were harvested weekly for 8 weeks and inoculated with *P. citrophthora*.
- Total precipitation during trial period 55 mm.

New preharvest treatments for brown rot - 2014

Temporal efficacy of preharvest treatments to navel oranges



Trial at UC Riverside

- Treatments applied at 400 gal/A on
- Fruit were harvested at selected inte

New treatments for brown rot and root rot

In vitro fungicide sensitivities against mycelial growth

Fungicide	FRAC	*P. parasitica* (ppm) (16 isolates)	*P. syringae* (ppm) (28 isolates)
Mefenoxam	4	0.08 – 0.28	0.004 – 0.03
Fluopicolide	43	0.04 – 0.08	0.02 – 0.05
Mandipropamid	40	0.003 – 0.008	0.002 – 0.006
Oxathiapiprolin	New*	0.0004 – 0.0011	<0.001

- Mandipropamid and oxathiapiprolin are most effective
- Oxathiapiprolin: new class - piperidinyl thiazole isoxazoline
- Additional isolates and isolates of *P. citrophthora* are being evaluated
- Toxicity against other stages in the life cycle (zoospore production, cyst germination, oospore production) are also being evaluated

Management of Phytophthora Brown Rot
- Postharvest Fungicide Treatments -

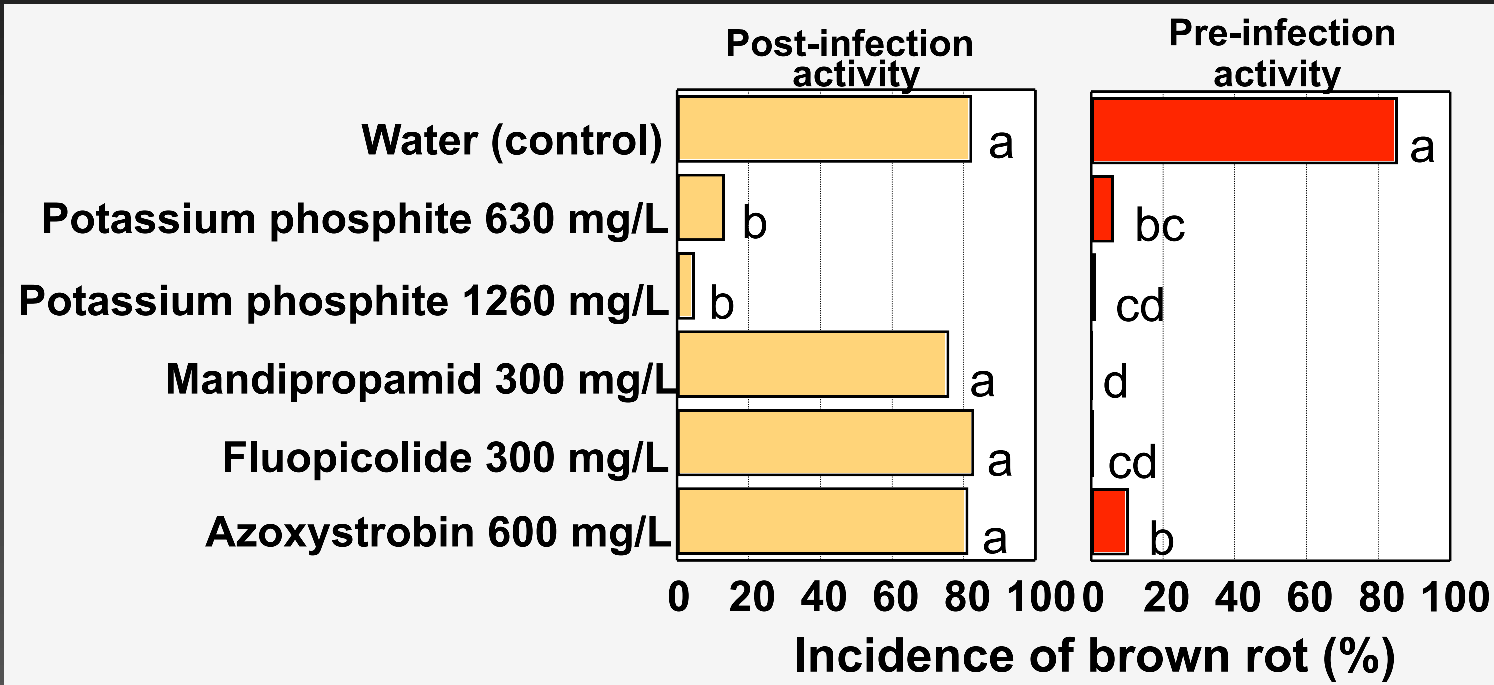
New postharvest treatments for control of brown rot caused by *Phytophthora* spp.

Laboratory studies: Treatment of fruit 15 h after inoculation

Control

Potassium phosphite
1260 ppm

New postharvest treatments for control of brown rot caused by *P. citrophthora*



Post-infection activity: Dip treatments 15 h after inoculation

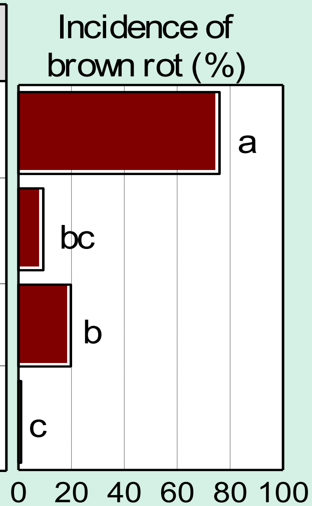
Pre-infection activity: Inoculation 6 h after treatment

- Azoxystrobin, mandipropamid (Revus), fluopicolide (Presidio), and potassium phosphite (Prophyt, Fungiphite) were highly effective as pre-infection treatments
- Only potassium phosphite was effective as a post-infection treatment.
- Potassium phosphite was also highly effective against brown rot caused by *P. syringae* and *P. hibernalis* in other studies.

Potassium phosphite and heat treatments for control of brown rot caused by *P. citrophthora*

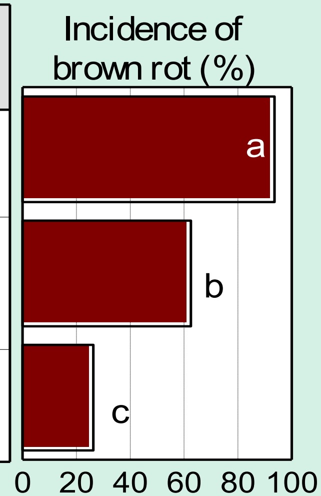
Treatment temperature ambient and 140F = 60C

Aqueous dip 15 sec	Dip temperature	Wax spray
Water	ambient	---
K- phosphite 2000 ppm	ambient	---
K- phosphite 2000 ppm + Imzl. 1000 ppm	ambient	Imzl 1000 ppm + TBZ 3500 ppm
K- phosphite 2000 ppm + Imzl. 1000 ppm	140F	Imzl 1000 ppm + TBZ 3500 ppm



Treatment temperature ambient and 130F = 54C

Aqueous dip 15 sec	Dip temperature	Wax spray
Water	ambient	---
Water	130F	---
K- phosphite 2000 ppm + Imzl. 1000 ppm	130F	Imzl 1000 ppm + TBZ 3500 ppm



Lab studies, 15-sec dip treatments 20-24 h after inoculation.

Treatments at 140F were consistently highly effective.
Treatments at 130F were variable in efficacy.

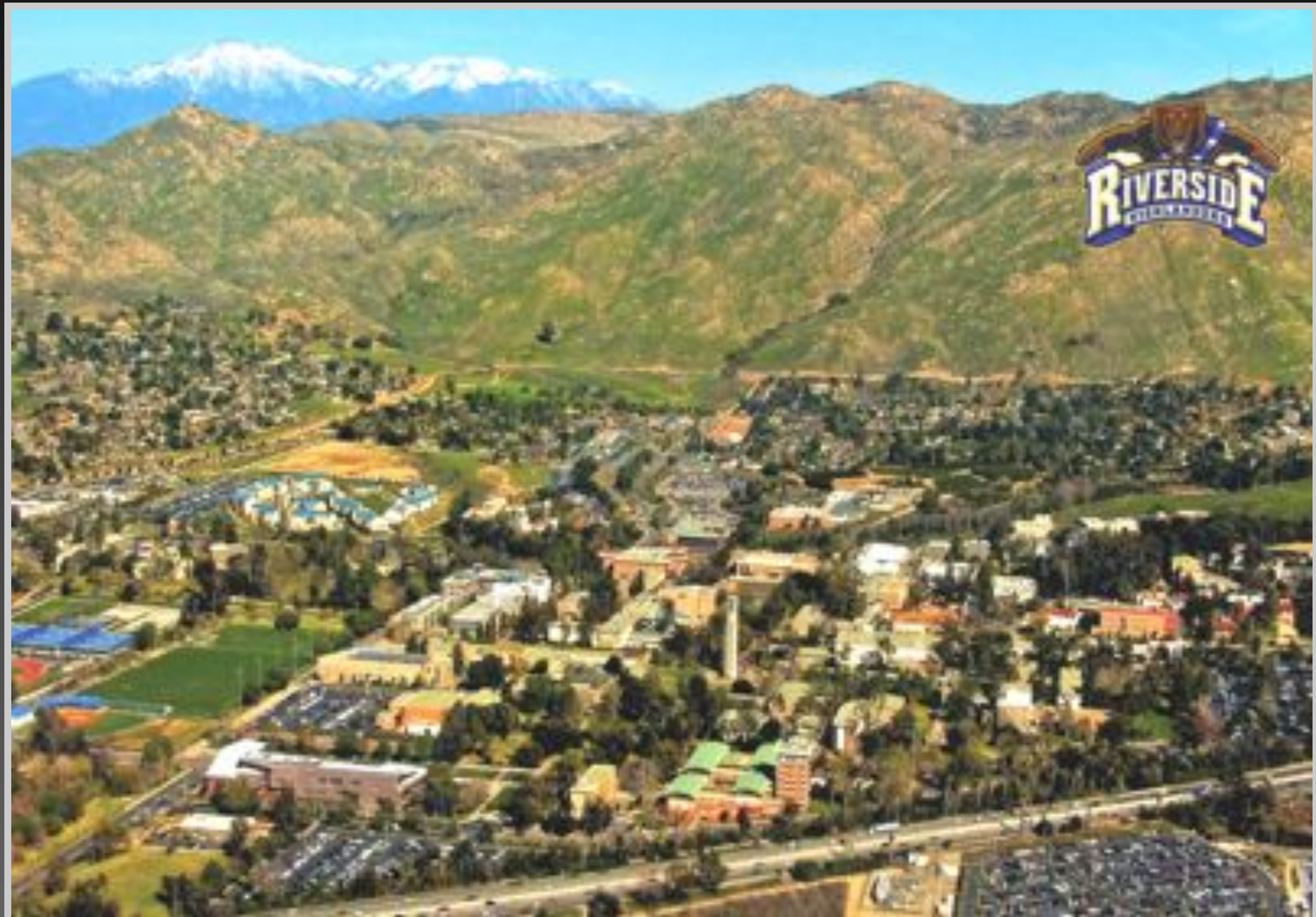
New postharvest treatments for Phytophthora brown rot

Brown rot studies with inoculated fruit:

- 15-sec water dips at **140F** were highly effective
- 15-sec water dips at **130F** were moderately and inconsistently effective
- 15-sec dips with **K-phosphite at 2000 ppm** were highly effective
- Negative interaction with imazalil and subsequent application of fruit coating
- Heated K-phosphite treatments are the best option: contact activity and residual activity.

Summary: New treatments for Phytophthora brown rot of citrus

- Potassium phosphite is highly effective against Phytophthora brown rot and can be used preharvest and postharvest to prevent decay.
- Several phosphite products are registered. They have exempt status in the US.
  - IR-4 residue studies are being done to obtain international MRLs/FAT
  - As always, check MRL databases for the limits of a specific export country. (Some countries consider phosphites as pesticides).
- The postharvest fungicide Graduate A+ can also be used as a protective treatment to prevent the spread of brown rot.
- Additional materials (mandipropamid, fluopicolide, oxathiapiprolpine) have been identified for pre- or postharvest use and are considered for registration.



Thank you