TRUNK AND SCAFFOLD DISEASES OF ALMONDS IN CALIFORNIA

Moderator: Drew Wolter (ABC)
Speakers: Florent P. Trouillas (UC ANR), Themis Michailides (UC ANR), Gregory Browne (USDA)

california almonds
Almond Board of California

Speaker Line Up

1) Dr. Florent P. Trouillas-
UCCE Plant Pathology Specialist, UC Davis

2) Dr. Themis J. Michailides-
UCCE Plant Pathology Specialist, UC Davis

3) Dr. Greg Browne-
USDA-ARS, Plant Pathology

Diagnosis and Management of Fungal Canker Diseases of Almond

Florent Trouillas
Associate Professor of Cooperative Extension
UC Davis, Department of Plant Pathology
Kearney Agricultural Research and Extension Center

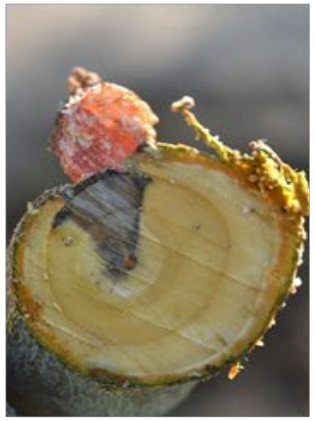
Almond fungal canker diseases:





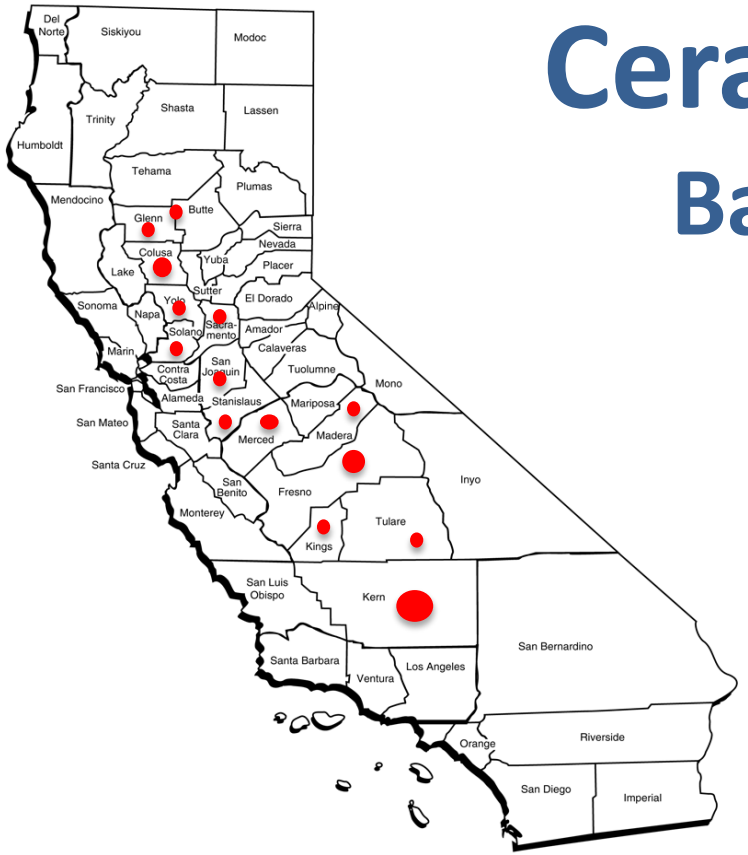






Field surveys:

Holland et al. 2020. Plant Disease.



Ceratocystis canker

Band (Bot) canker

Phytophthora cankers

Cytospora canker

Eutypa canker

Collophora canker

Fungal pathogens associated with cankers:

Holland et al. 2020. Plant Disease.

Botryosphaeriaceae

- *Botryosphaeria dothidea*
- *Neofusicoccum mediterraneum*
- *Neofusicoccum vitifusiforme*
- *Neofusicoccum parvum*
- *Neofusicoccum arbuti*
- *Diplodia seriata*
- *Diplodia mutila*
- *Dothiorella iberica*
- *Macrophomina phaseolina*
- *Spencermartinsia viticola*
- *Neoscytalidium dimidiatum*

26 fungal species!

Ceratocystis fimbriata

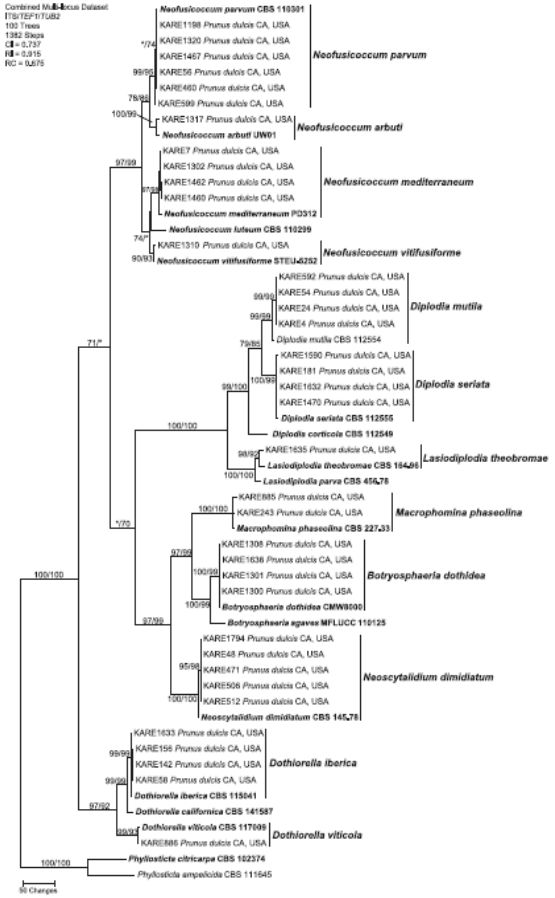
Collophora hispanica
Collophora paarla

Cytospora eucalypti
Cytospora sorbicola
Cytospora sp. 1
Cytospora sp. 2
Cytospora sp. 11
Cytospora sp. 13

Diaporthe australafricana
Diaporthe eres
Diaporthe rhusicola

Eutypa lata

Phytophthora cinnamomi
Phytophthora cactorum



Ceratocystis canker: caused by *Ceratocystis destructans*

- Associated with shaker injuries




Ceratocystis canker: caused by *Ceratocystis destructans*

- Associated with pruning wounds and mechanical injuries




Botryosphaeria canker diseases: caused by Botryosphaeriaceae fungi

- Band Canker:
  - Associated with growth cracks and pruning wounds
  - 2 to 5-year-old trees, vigorous cultivars (NP, Carmel, Padre, Butte)

Cytospora canker: caused by several *Cytospora* spp.

- Common in prune and cherry orchards

Cytospora canker: caused by several *Cytospora* spp.

- Also found in almond




Eutypa canker: caused by *Eutypa lata*

- Infect at pruning wounds
- Infect at cracks near the tree crotch




Silver leaf: Wood decay/canker

- *Chondrostereum purpureum*
- Also infect at pruning wounds
- Severe cases last few years in California




Field diagnosis:

Phytophthora cankers

Ceratocystis canker

Eutypa canker

Band (Bot) canker

Foamy canker:

- Tree physiological response to biotic or abiotic stress
  - Example: Aerial Phytophthora, herbicide injury, etc…

Abiotic injuries:

Herbicide injury

Acid burn

Boron toxicity

Molecular diagnosis:

- Developed using 23 species-specific primers targeting all canker pathogens
- Processing time for the diagnosis has been reduced to about 24 hours, compared to the 3 week

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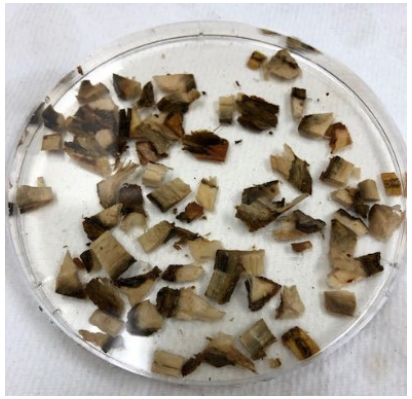
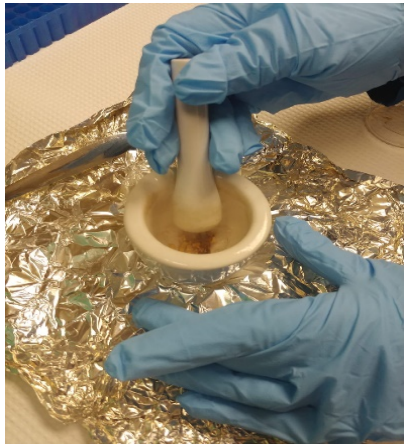




UCDAVIS

Main infection courts of fungal canker diseases:

- Infections occurs at wounds caused by cultural practices
- Mainly during primary and secondary **scaffold selection**
- **Not seen when hedging or topping trees**

Scaffold selection

Harvest (Ceratocystis only)

Maintenance pruning (removing or large branches)

Main infection courts of fungal canker diseases:

- Most infections occur at pruning wounds made for primary or secondary scaffold selection

Botryosphaeria

Ceratocystis

Eutypa

Cytospora

Almond tree pruning:

Slide credits: Roger Duncan

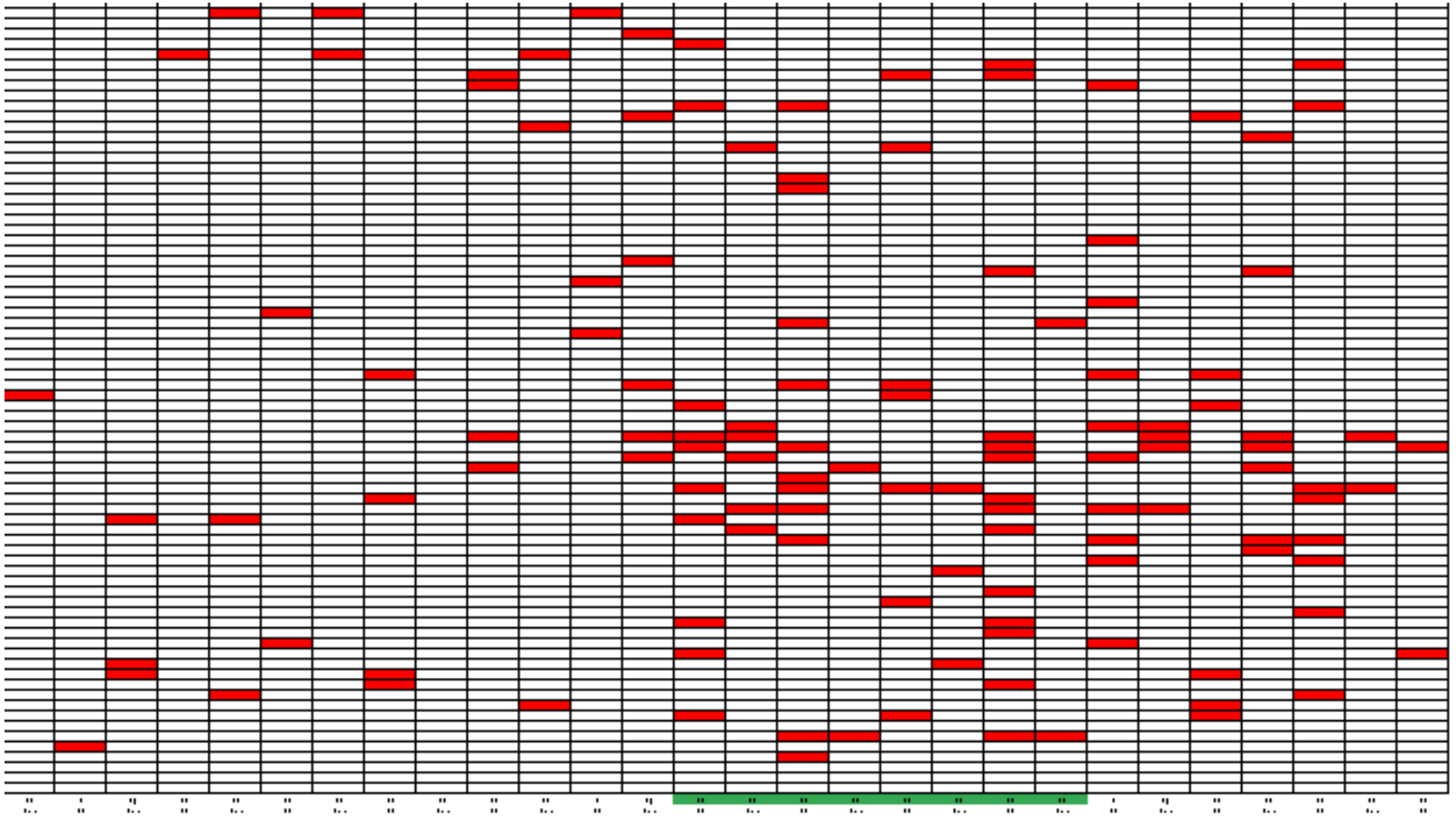
Standard trained, pruned annually

Minimally trained, minimally pruned

Untrained, unpruned

Main infection courts of fungal canker diseases:

- Most infections occur at pruning wounds made for primary or secondary scaffold selection



Management of canker diseases:

- **PREVENTION (No curative options)**
  - Protect pruning wounds on the trunk **following scaffold collection**
  - Prevent disease establishment in the early years of trees




Management of canker diseases:

- Pruning wound protection trials



Management of canker diseases:

- Fungicides, pastes, sealants, paints, biocontrol agents were tested (Holland et al. 2021. Plant Disease.)

Fungicides (single a.i.)

FRAC 1 (MBC)
- Topsin M

FRAC 3 (DMI-triazole)
- Indar
- Rhyme
- Quash
- Rally

FRAC 7 (SDHI)
- Fontelis

FRAC 11 (QoI)
- Abound

FRAC M3 (Carbamate)
- Ziram

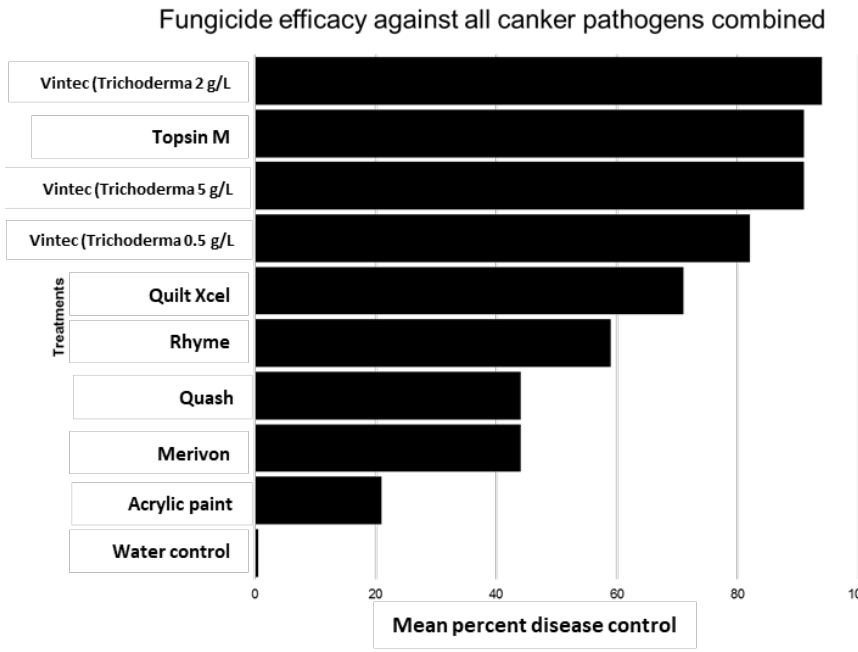
FRAC M5 (Chloronitrile)
- Bravo

Fungicides (premixtures)
- Inspire Super (FRAC 3 + 9)
- Luna Experience (FRAC 3 + 7)
- Luna Sensation (FRAC 7 + 11)
- Merivon (FRAC 7 + 11)
- Pristine (FRAC 7 + 11)
- Quadris Top (FRAC 3 + 11)
- Quilt Xcel (FRAC 3 + 11)
- Viathon (FRAC 3 + 33)

Biological Control Agents
- Vintec (*Trichoderma atroviride* SC1)
- RootShield (*Trichoderma* spp.)

Biofungicides
- Neem oil
- Thyme oils

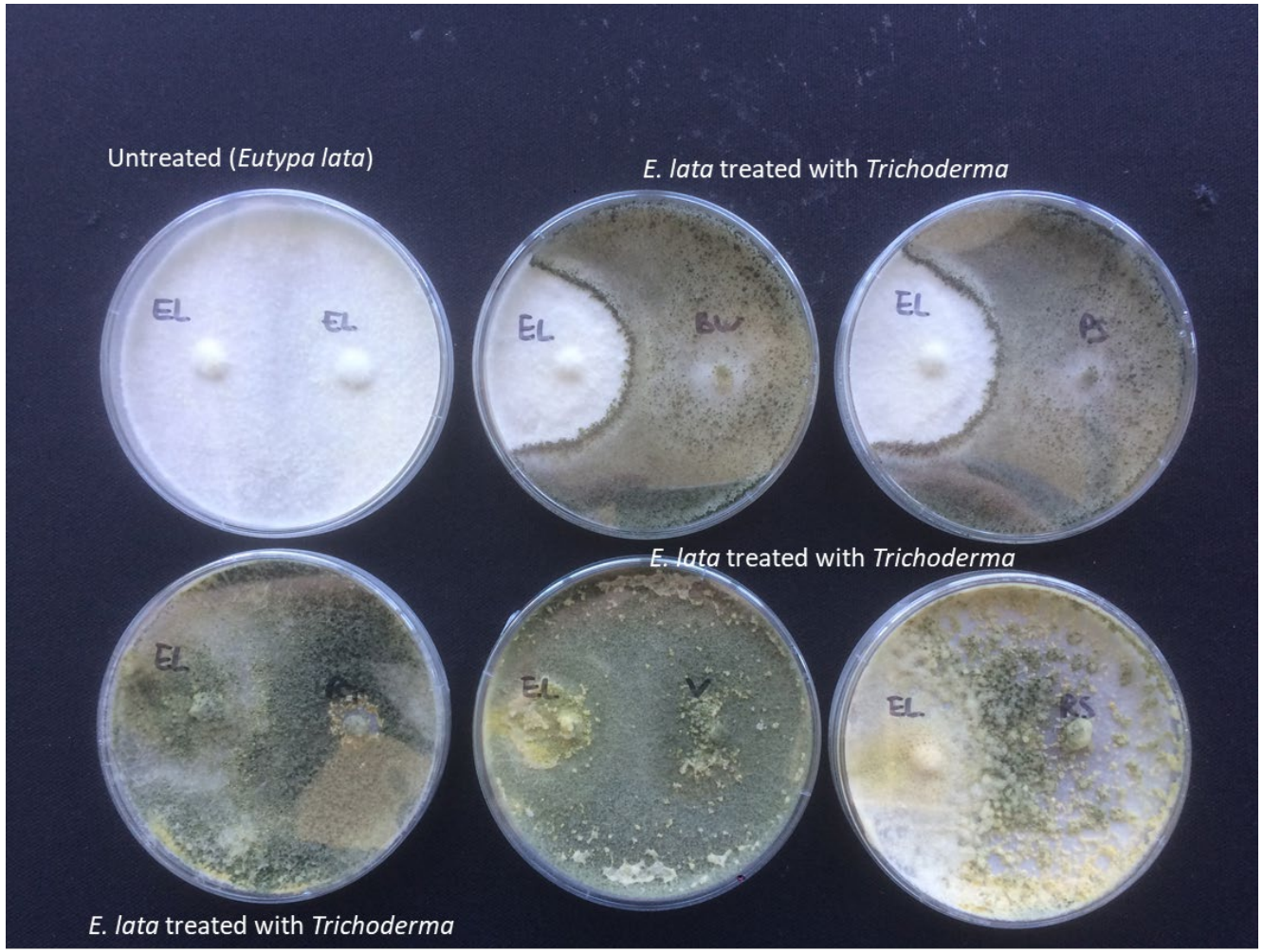
Sealants and Paint
- Acrylic Paint
- Crop Seal
- SpurShield

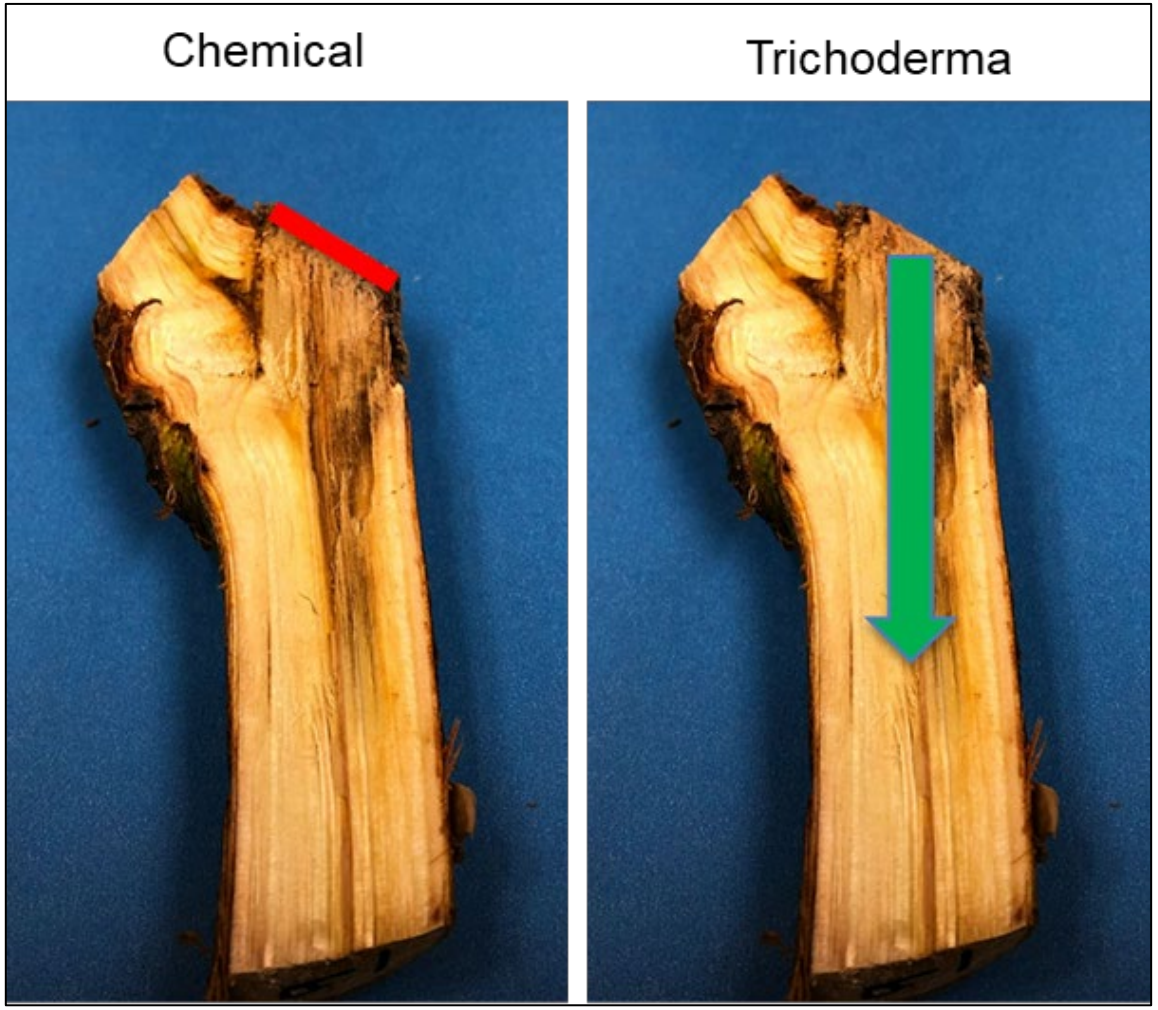


Eutypa lata, Ceratocystis destructans, Cytospora sp., Botryosphaeria dothidea, Neoscytalidium dimidiatum, Neofusicoccum parvum, Neofusicoccum mediterraneum, Diplodia mutila

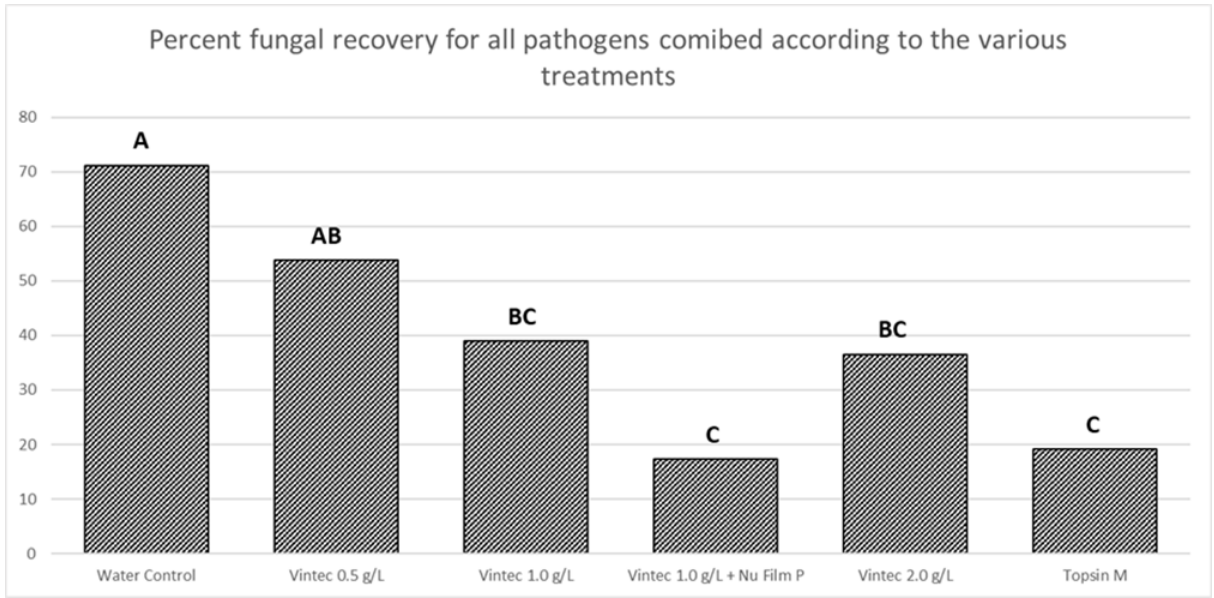
Trichoderma: Antagonistic fungi – Non toxic

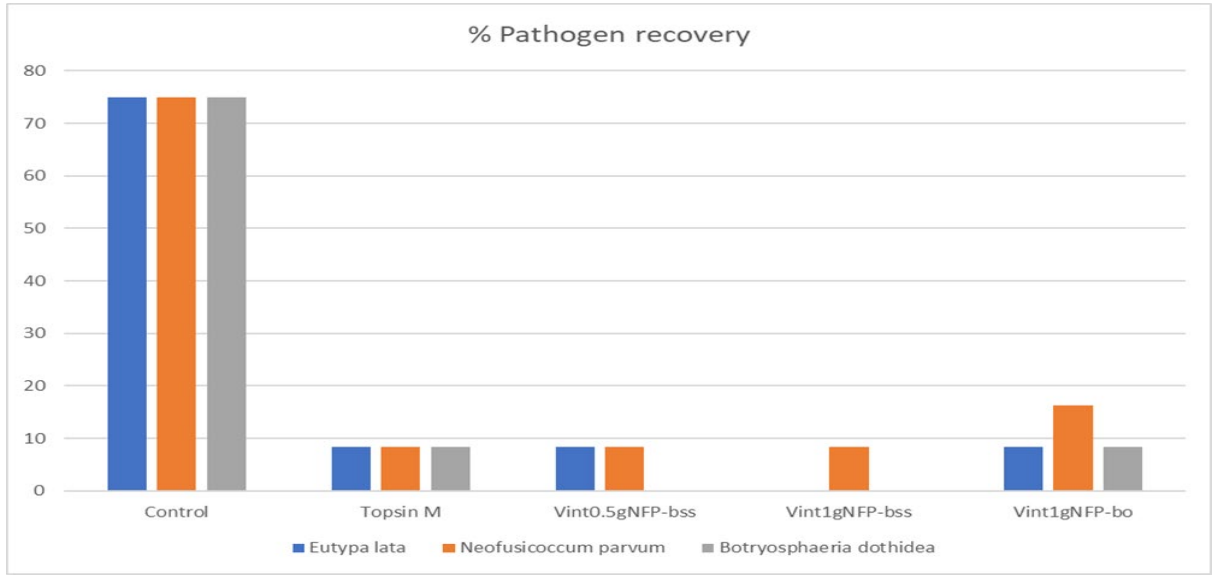
Acts as a competitor and mycoparasite





Application of Trichoderma biocontrol agent (Vintec) at pruning:





Biocontrol of canker diseases:

- Trichoderma products

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Table 5. Field assays – *Neofusicoccum parvum*. Mean percent recovery (MPR; %) for *Neofusicoccum parvum* when inoculated (500 conidia / wound) onto almond pruning wounds after applications of biological control agents (BCA). Values are presented separately for each almond cultivar (Sonora vs. Non-Pareil) and each timing of inoculations (24h vs. 7d after BCA application). Included as chemical, positive control was the application of thiophante-methyl whereas negative control wounds were sprayed with water before pathogen inoculations. Mean percent disease control (MDPC) was calculated as the reduction in MPR as a proportion of the water inoculated controls: 100 × [1 – (MPRtreatment/MPRcontrol)]. Field experiments included 20 biological replicates with experiments conducted in duplicate. MPR for each BCA are presented.

			N. parvum - Sonora cv. - 24h			*N. parvum* - Sonora cv. - 7d			*N. parvum* - Non-Pareil cv. - 24h			*N. parvum* - Non-Pareil cv. - 7d		
Treatment	**Active ingredient(s)**	**Manufacturer**	**MPR (%)**	**MDPC (%)**	**MPR BCA (%)**	**MPR (%)**	**MDPC (%)**	**MPR BCA (%)**	**MPR (%)**	**MDPC (%)**	**MPR BCA (%)**	**MPR (%)**	**MDPC (%)**	**MPR BCA (%)**
Control	water	NA	95	NA	0.0	66.7	NA	0.0	82.1	NA	0.0	59.5	NA	0.0
BioTam	*Trichoderma gamsii* ICC080 and *T. asperellum* ICC012	Isagro	67.5	28.9	2.5	56.8	14.8	16.2	52.6	35.9	13.2	28.9	51.4	13.2
RootShield WP	*T. harzianum* KRL-AG2	BioWorks	87.5	7.9	7.5	45	32.5	10.0	60.5	26.3	18.4	20	66.4	28.6
RTFT014	*T. artroviride* RTFT014	NA	69.2	27.2	23.1	30.8	53.8	33.3	42.1	48.7	23.7	19.4	67.4	38.9
Topsin M	thiophanate-methyl	United Phosphorus	12.8	86.5	2.6	15.8	76.3	0.0	0	100.0	0.0	0	100.0	0.0
Vintec	*T. atroviride* SC1	Bi-PA	52.6	44.6	47.4	21.1	68.4	44.7	34.2	58.3	50.0	14.7	75.3	41.2

[a] Application rates are detailed in Table 2. Treatments were applied with spray bottles 24h or 7d before pathogen inoculations. Thiophanate-methyl applied at a rate of 0.8 g/L.

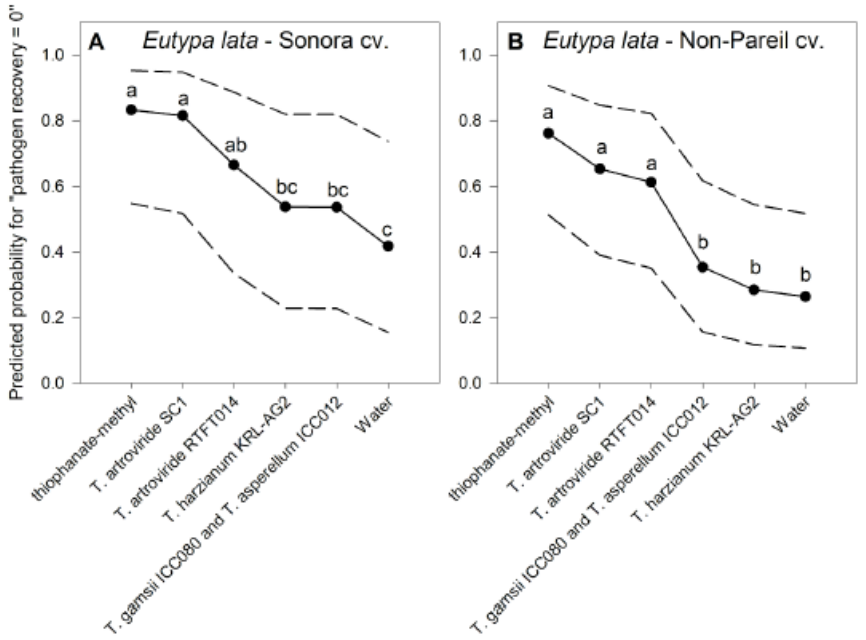
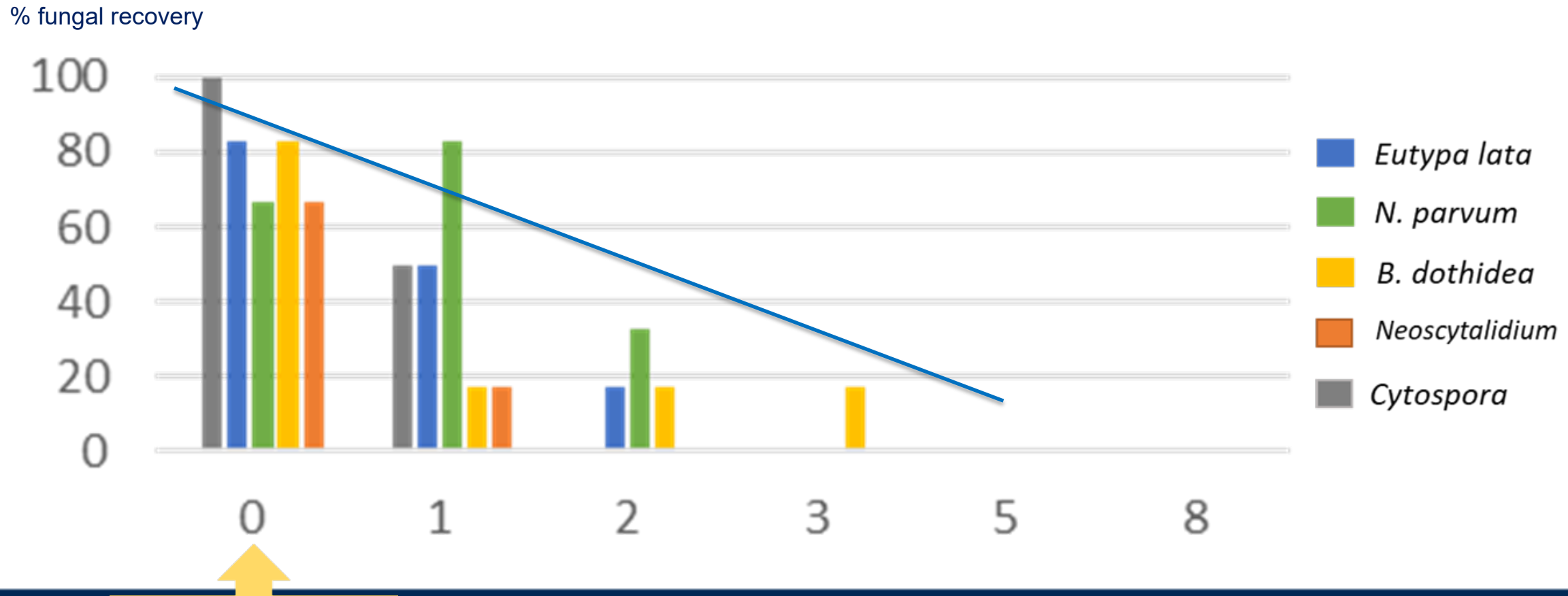


Figure 3. Field assays – *Eutypa lata*. Predicted probabilities of the event "pathogen recovery = 0" (i.e. no infection) for *Eutypa lata* when inoculated (500 ascospores / wound) onto almond pruning wounds after applications of biological control agents. Included as chemical, positive control was the application of thiophante-methyl whereas negative control wounds were sprayed with water before pathogen inoculations. Values were obtained from a linear mixed logistic regression model and based on duplicated experiments with 40 biological units per experiment either conducted in (A) Colusa county on almond cultivar Sonora or in (B) Yolo county conducted on Non-Pareil cultivar. The solid black lines with black dots represent the predicted probabilities and the dashed lines represent the 95% confidence limits around the predicted probabilities. In each panel, protectants are sorted from the largest to smallest predicted probability values. Tukey-Kramer (α = 0.05) mean separation is indicated by letters.

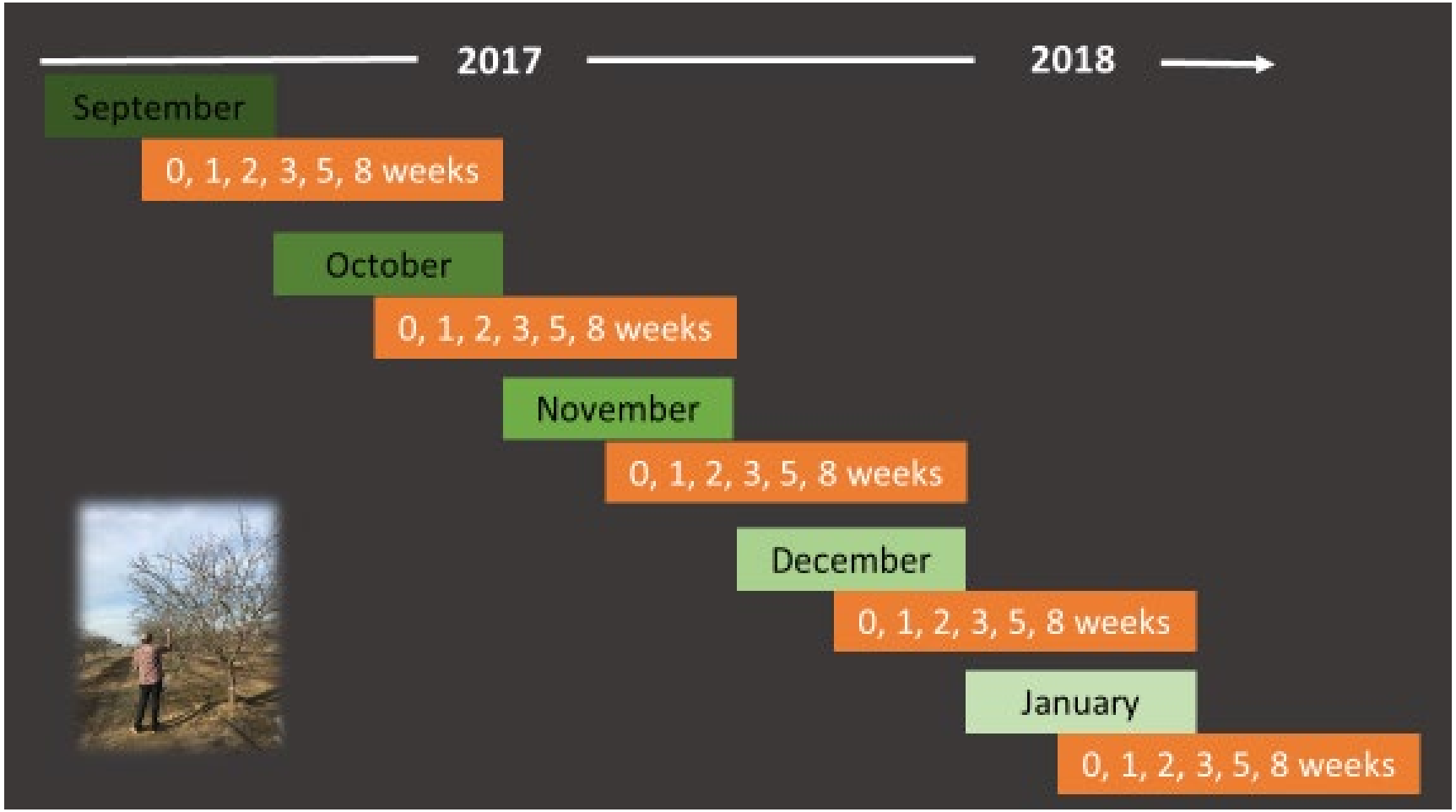
Management of canker diseases:

- How often should growers spray after pruning?
- Duration of pruning wound susceptibility



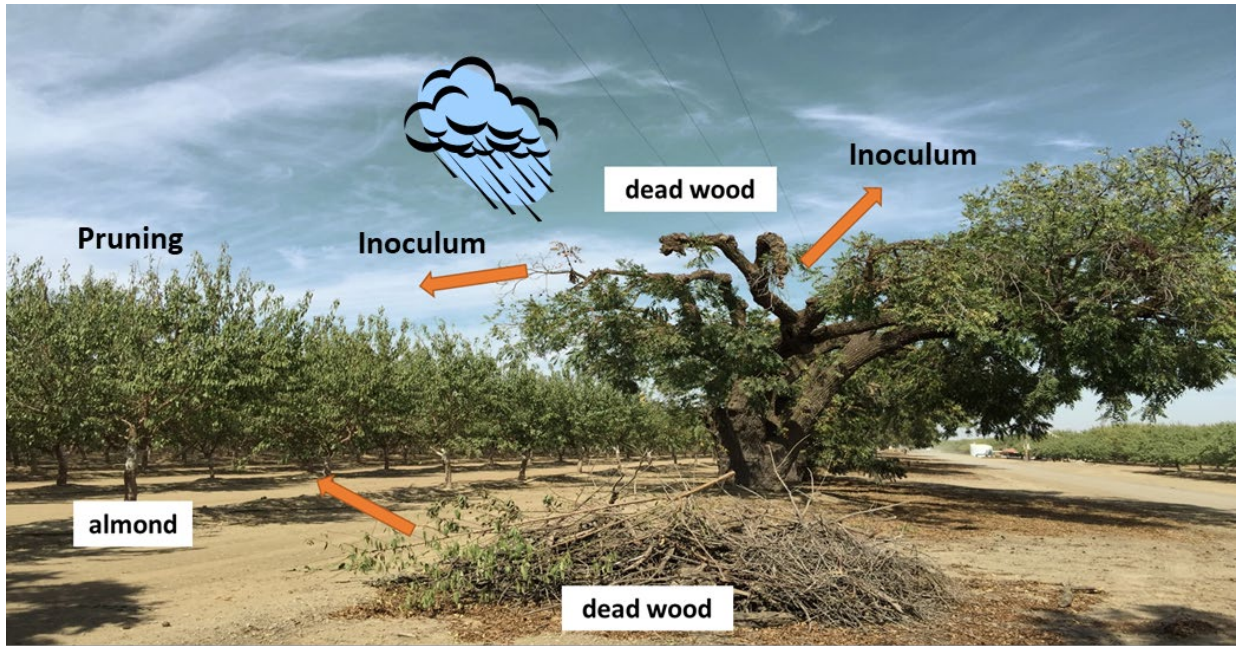
Management of canker diseases:

- When to prune?

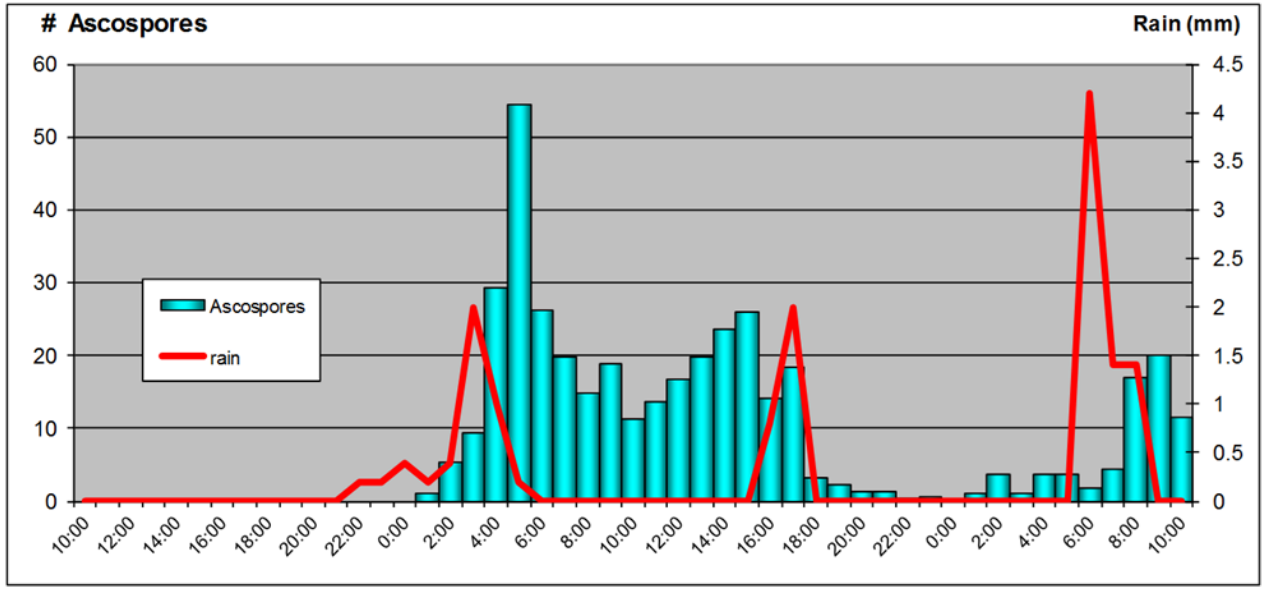


Management of canker diseases:

- When to prune?
- Avoid rain events

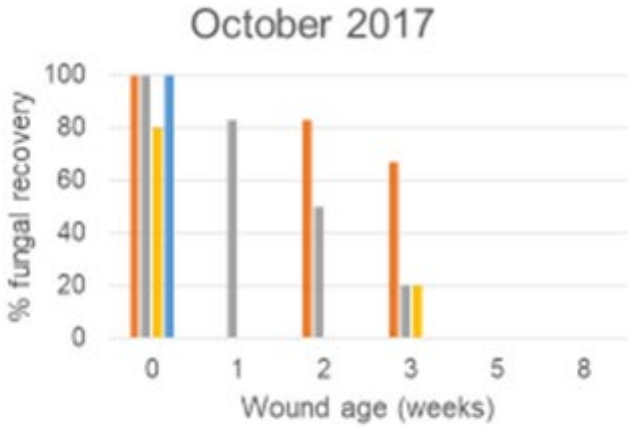


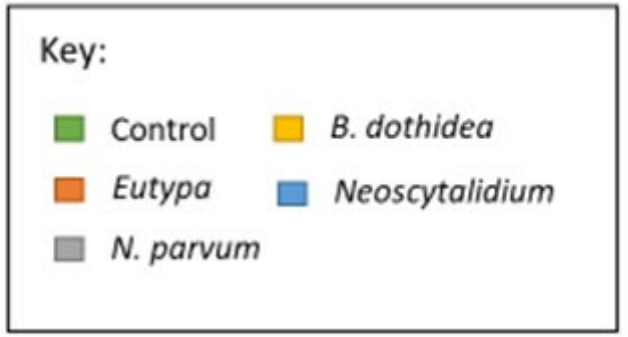
➢ Fungal spores are released during rain events



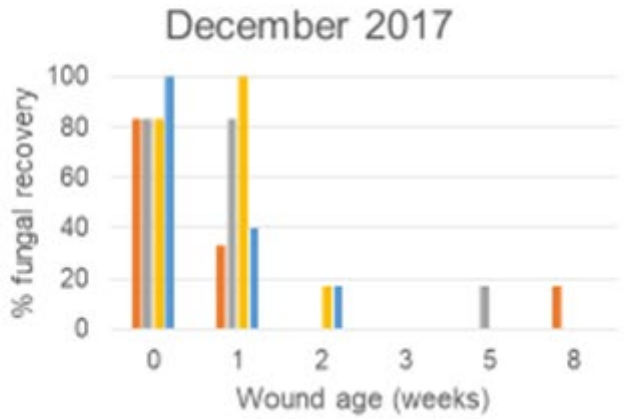
Management of canker diseases:

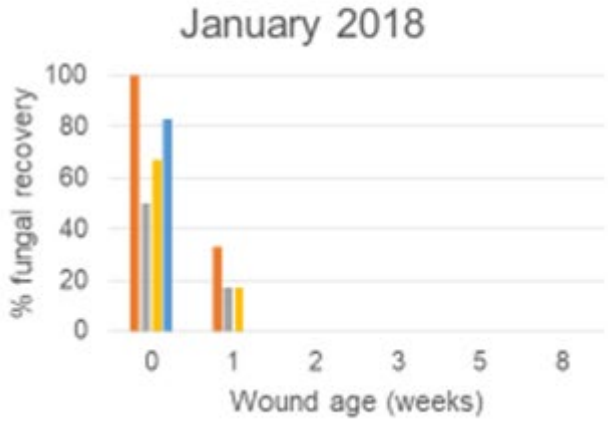
- When to prune?





Delayed pruning





Thank you!

Holland et al. 2020. Plant Disease

Holland et al. 2021. Plant Disease

Rooted IN SUCCESS 2021
the almond conference

Managing Band Canker of Almond

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TABLE OF CONTENTS

Relationship of Botryosphaeria dothidea and Hendersonula toruloidea to a Canker Disease of Almond

Harley English, James R. Davis and J. E. DeVay

Department of Plant Pathology, University of California, Davis 95616. Present address of second author: Branch Experiment Station, University of Idaho, Aberdeen 83210.

Accepted for publication 5 August 1974.

ABSTRACT

An unusual canker disease of almond (*Prunus amygdalus*) caused by *Botryosphaeria dothidea* is described. Bandlike or irregular cankers are formed on the trunk or scaffold branches of vigorous young trees, occasionally causing death of the parts distal to the point of infection. A second fungus (*Hendersonula toruloidea*) was found in many of the cankers, but in nature it appears to be mainly, if not entirely, a secondary invader. Both fungi, however, were able to induce canker formation when mycelial inoculum was placed in cortical wounds on the cambium, or on xylem exposed by pruning. Natural infection by *B. dothidea* appeared to be through cortical growth cracks. The cankers induced by both largely annual rather than perennial, and

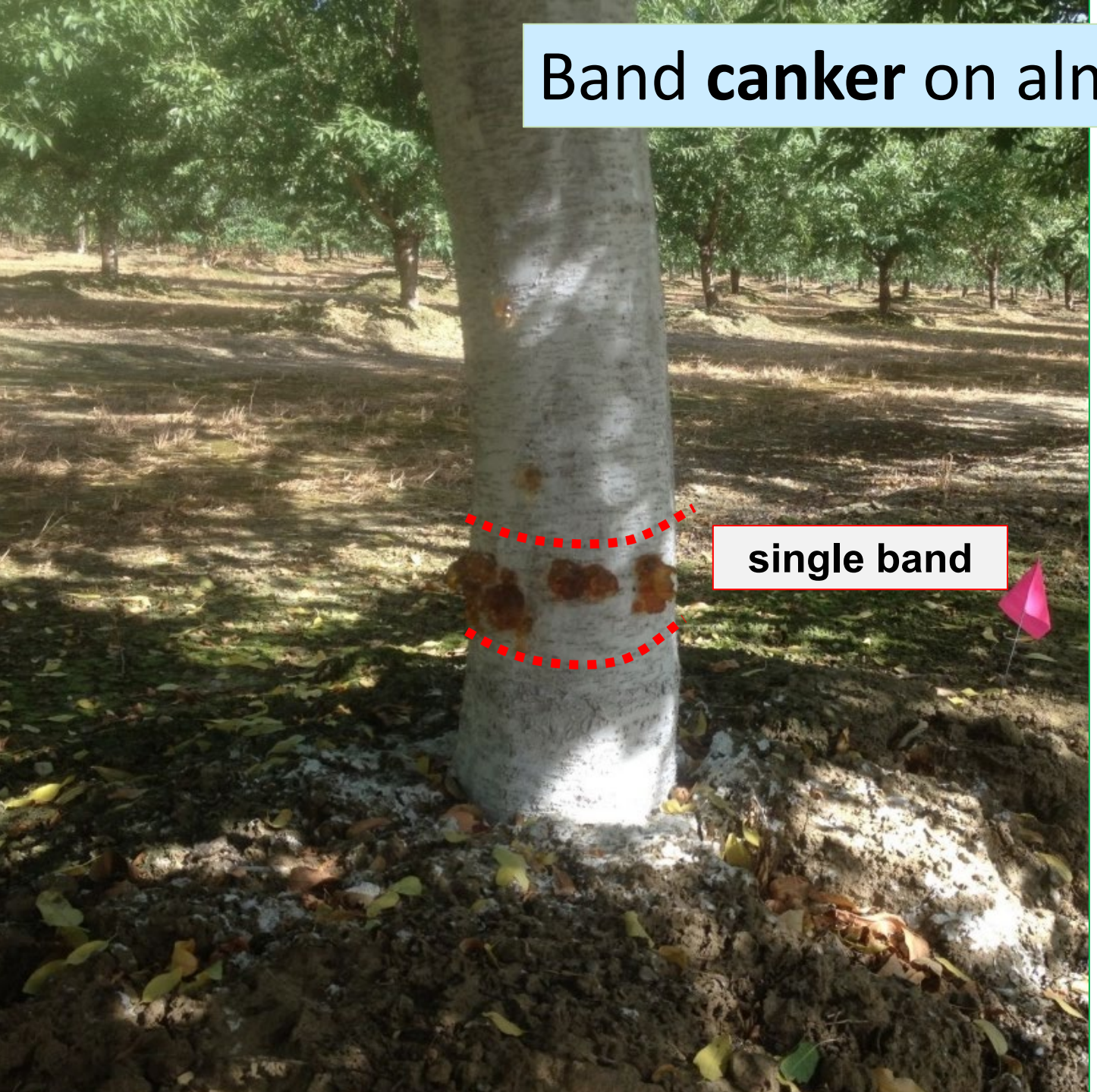
there was no evidence of a synergistic relationship between these two fungi in the formation of cankers. The mycelium of both organisms was found principally in the lumen of cells in both xylem and phloem, and it passed from cell-to-cell mostly through pits. Since the sexual stage of *B. dothidea* was not found, the identification of the almond isolate as *dothidea* was based on asexual stage (*Dothiorella* morphology, serology, and pathology. The almond cultivar Nonpareil was more susceptible to canker than either Ne Plus Ultra or Mission. [illegible] protectant, was of [illegible]

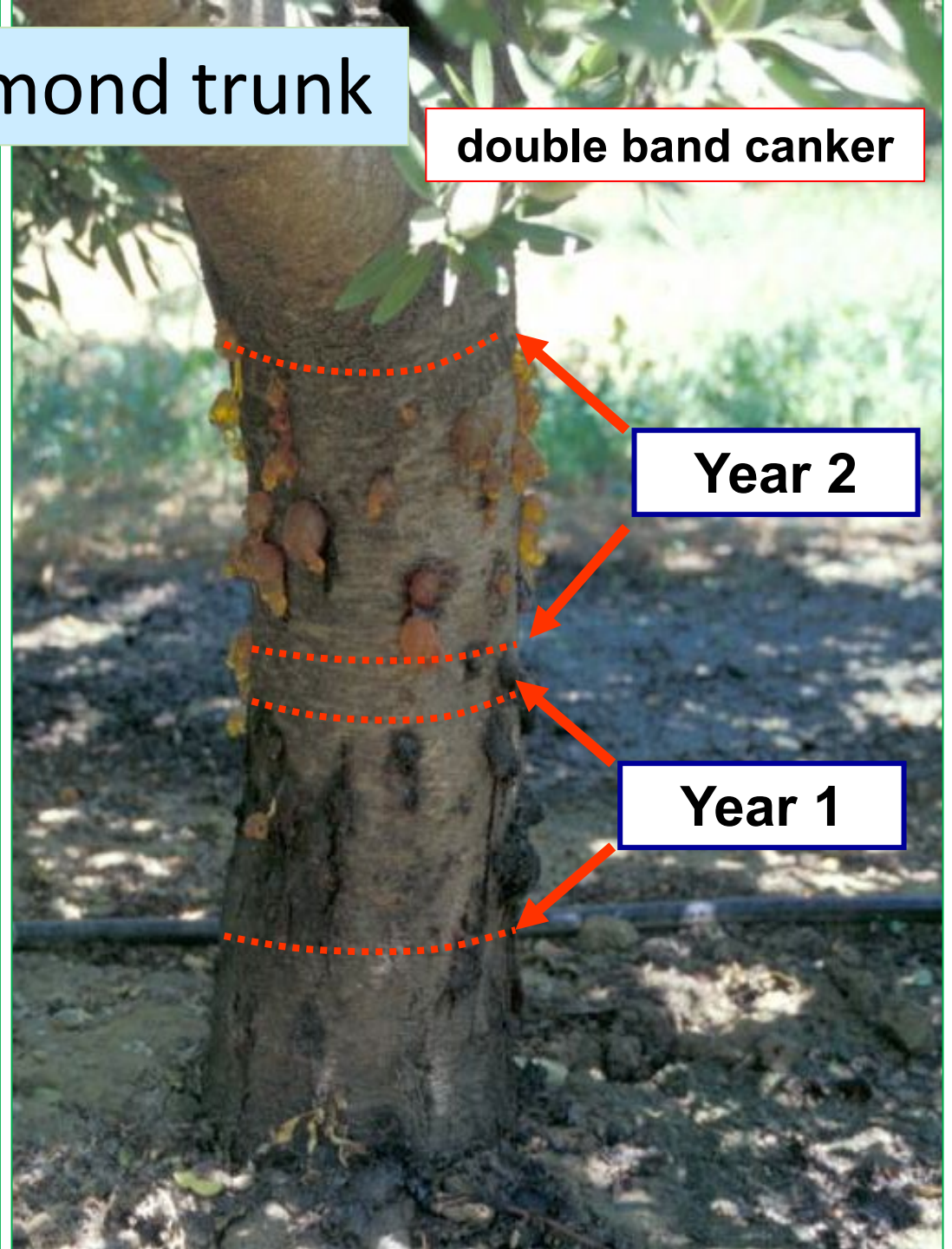
2021

A conclusion from 2005 research:

Band canker has potential of becoming a devastating disease in almond.

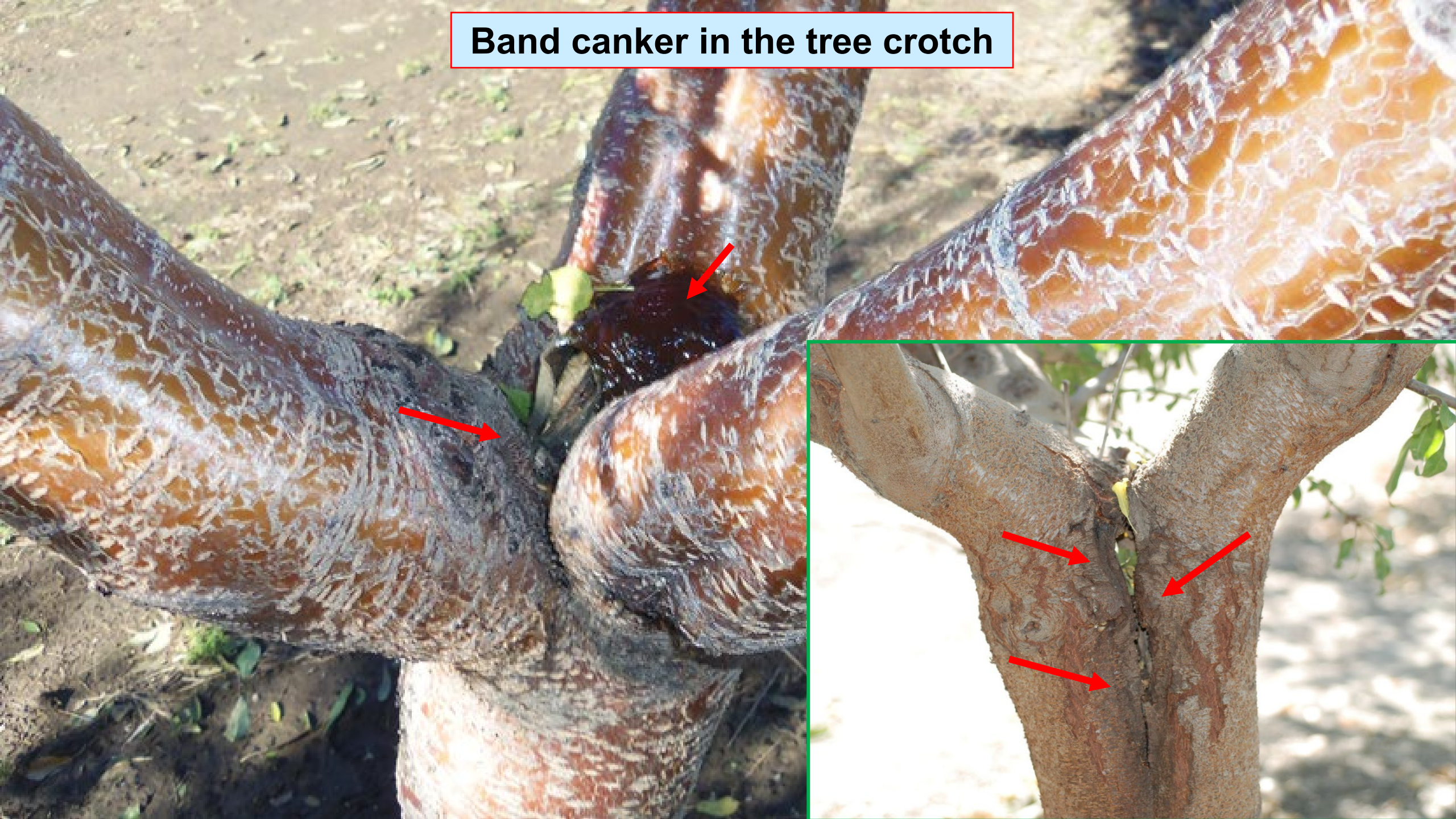
Band **canker** on almond trunk





Band canker on scaffold and major branch

Band canker in the tree crotch



Tree death (note excess suckering)

Infection of pruning wounds

The Causes:

Summary of Botryosphaeriaceae in nut crops – California

Fungal species	Almond	Pistachio	Walnut
Botryosphaeria dothidea	+	+	+
Neofusicoccum parvum	+	+	+
Neofusicoccum mediterraneum	+	+	+
Diplodia mutila	---	---	+
Neofusicoccum nonquaesitum	+	---	+
Neofusicoccum vitifusiforme	---	+	+
Diplodia seriata	+	+	+
Dothiorella iberica	+	+	+
Lasiodiplodia citricola	+	+	+
Neoscytalidium dimitiatum (=*Hendersonula toruloidea*)	+	+	+
Diaporthe rhusicola (*Phomopsis*)	+	+	+
Diaporthe neitheicola (*Phomopsis*)	---	---	+

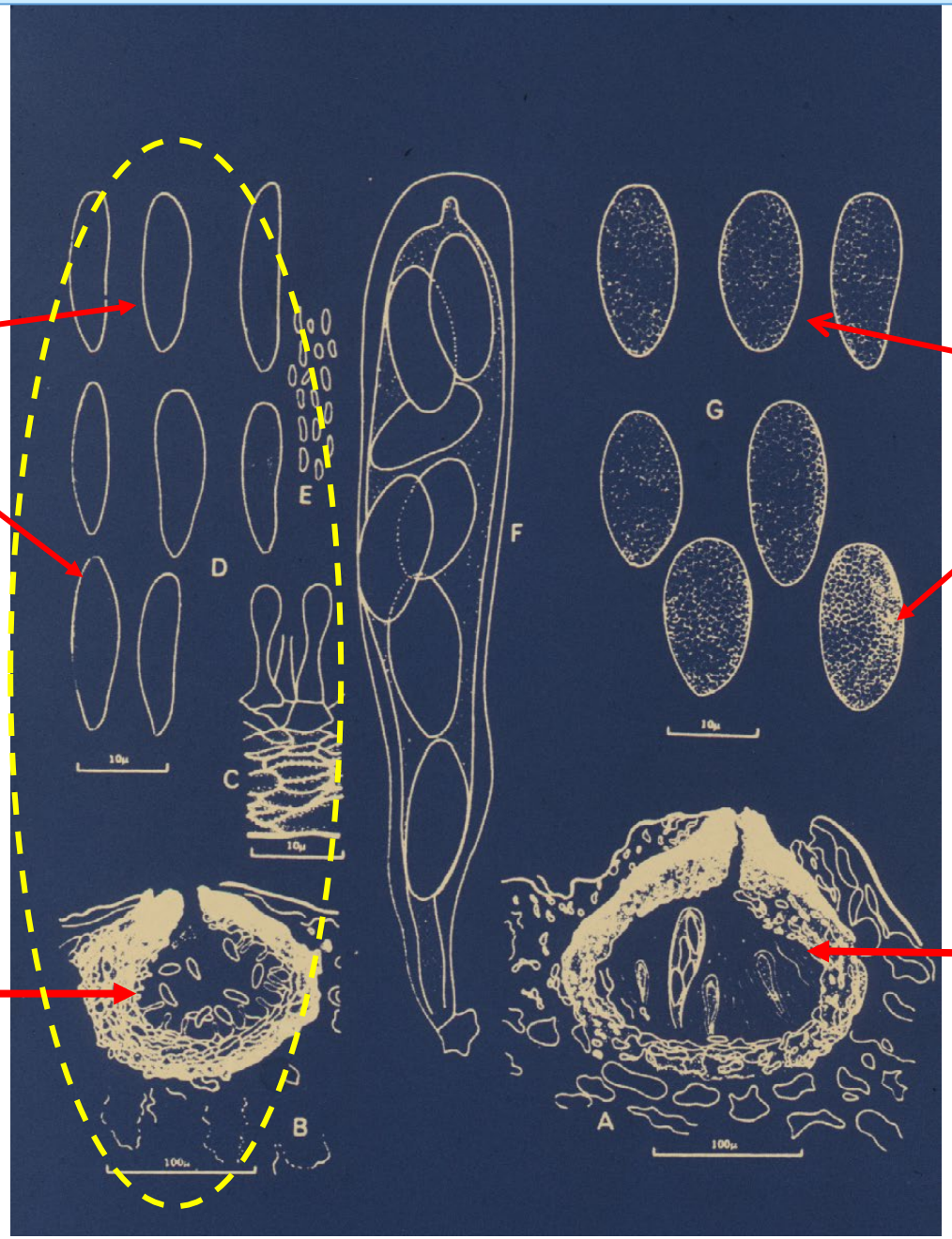
Botryosphaeria dothidea reproductive structures

conidia

water splashed

or insect spread

pycnidia



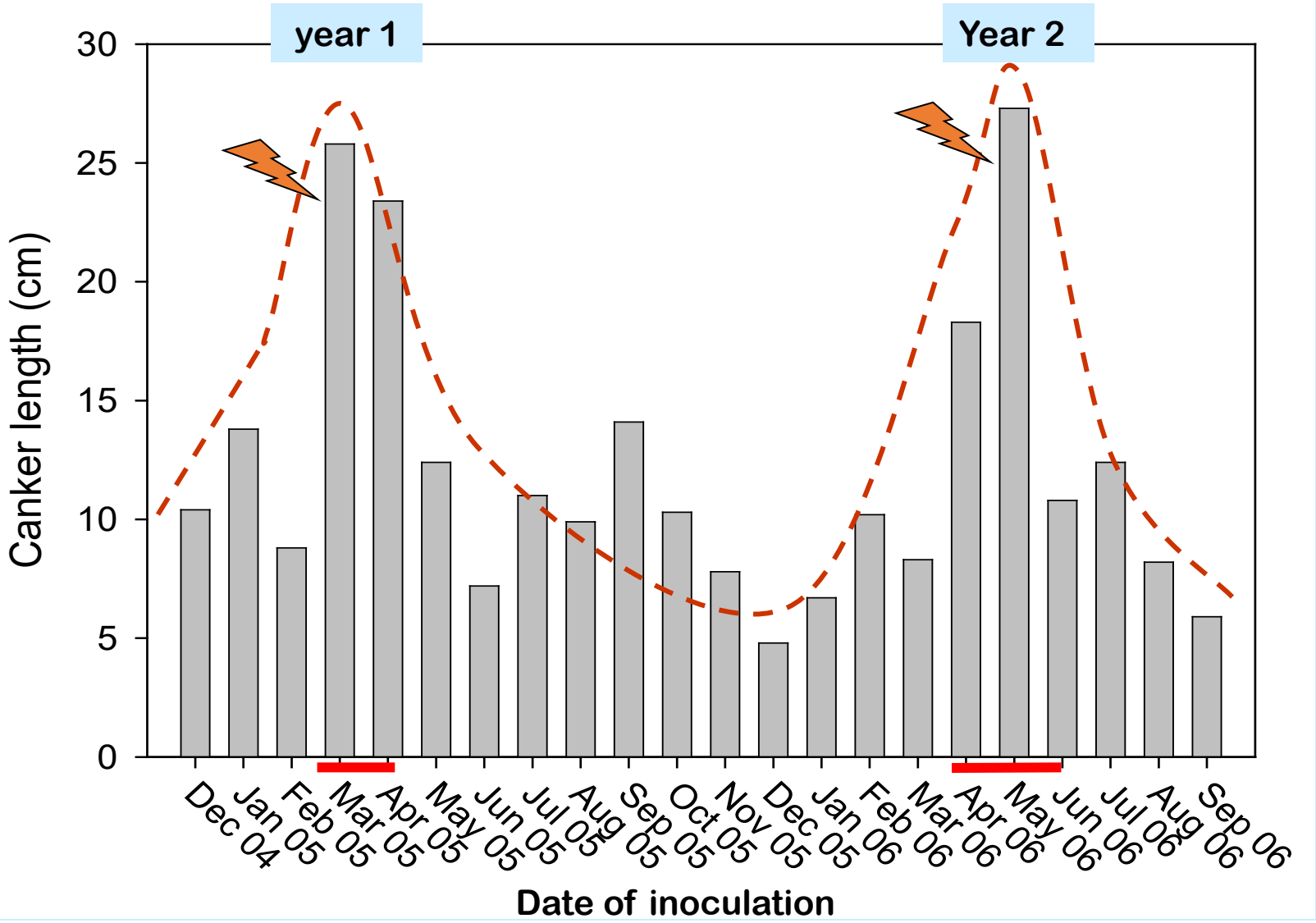
asco-spores

airborne

ascocarps

When do infections develop the most?

Inoculations of potted trees

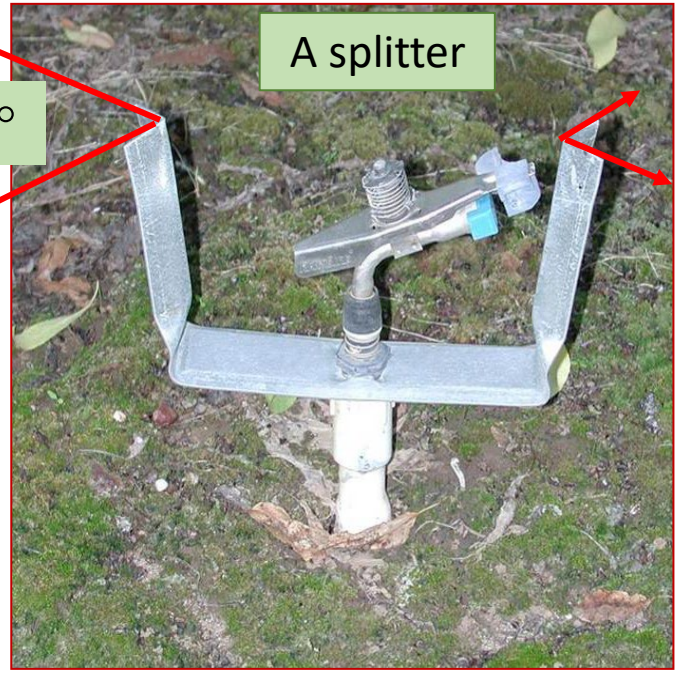


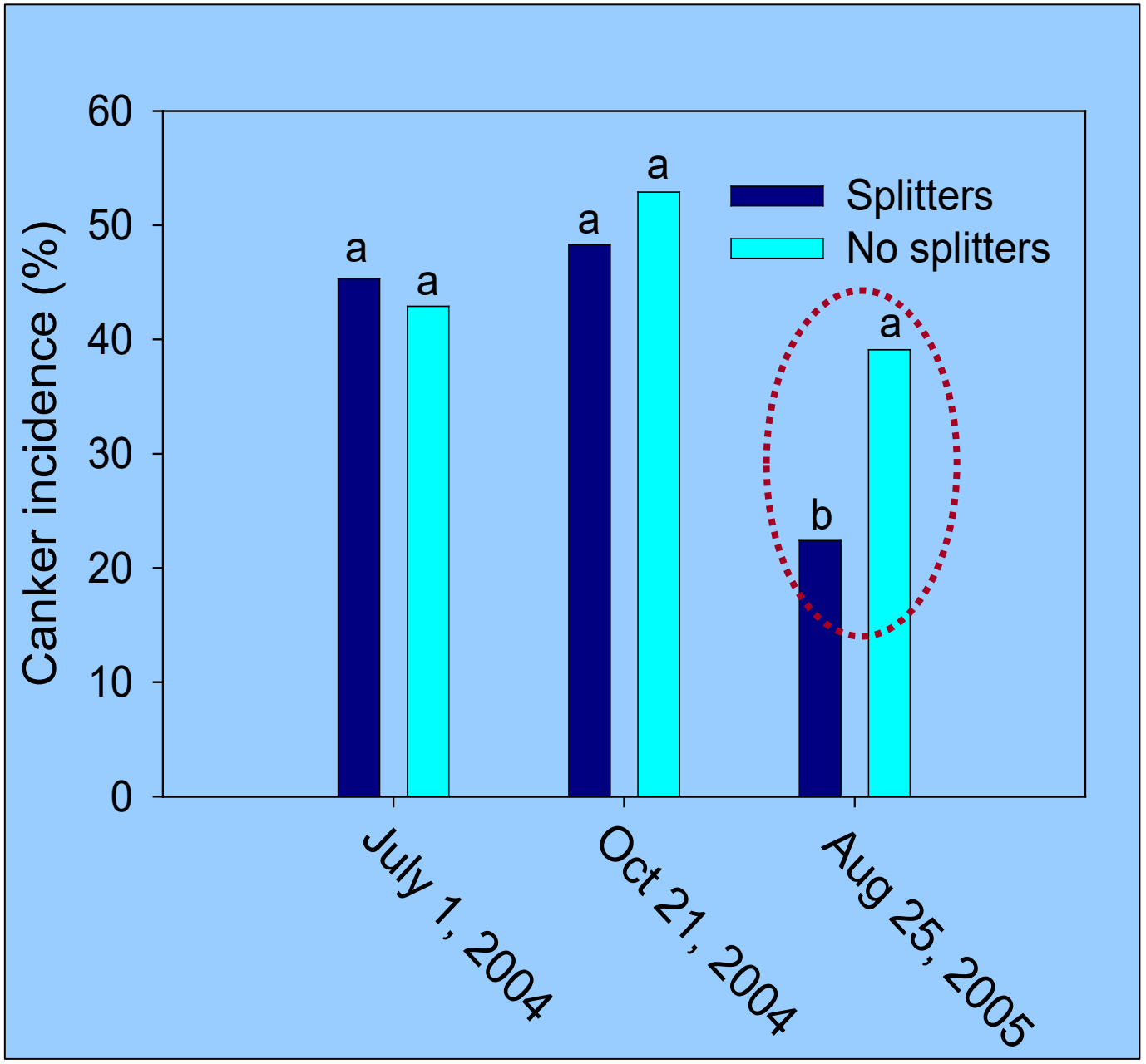
Disease management

Canker curing with fungicides

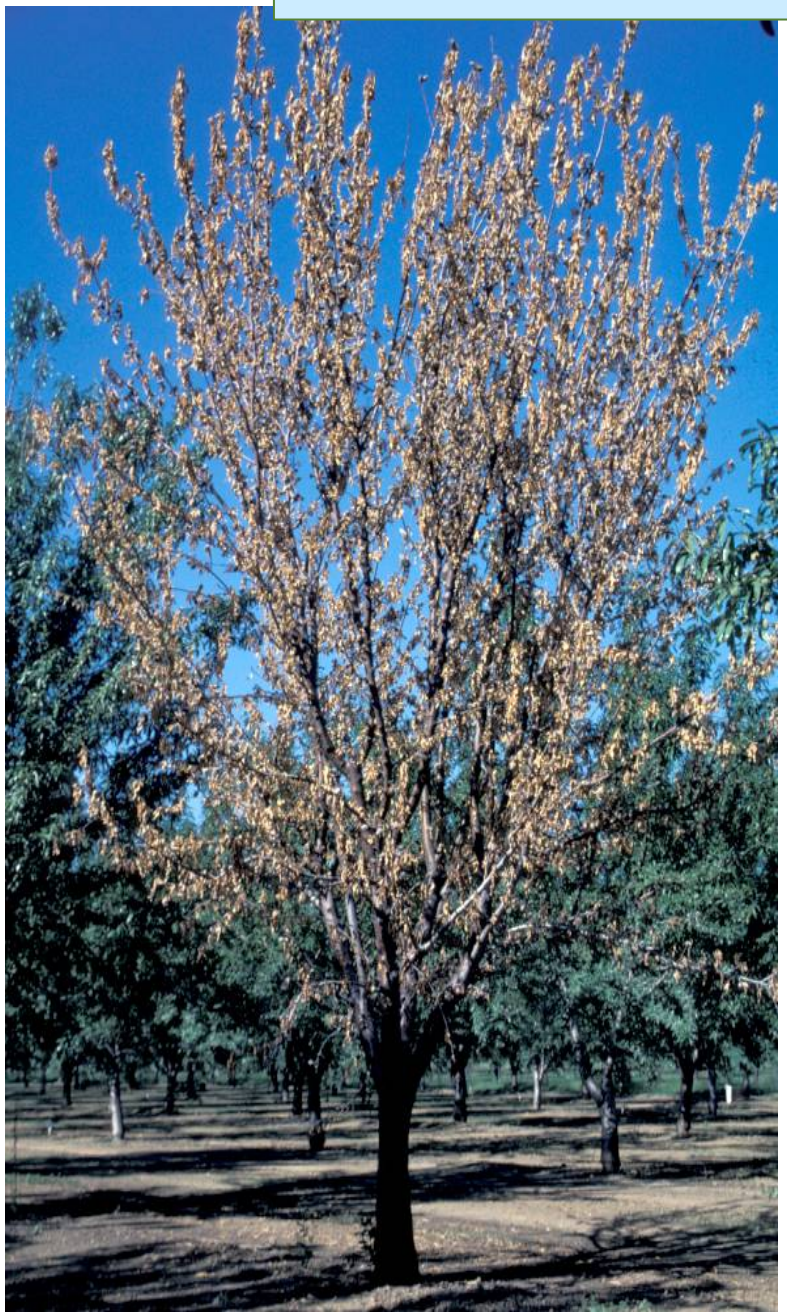
Canker curing by injecting fungicides

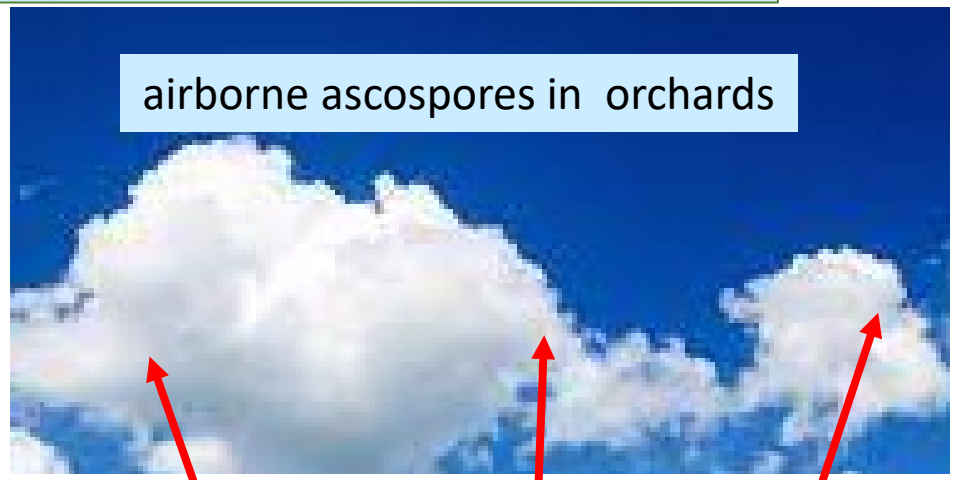
Irrigation management reduces band canker

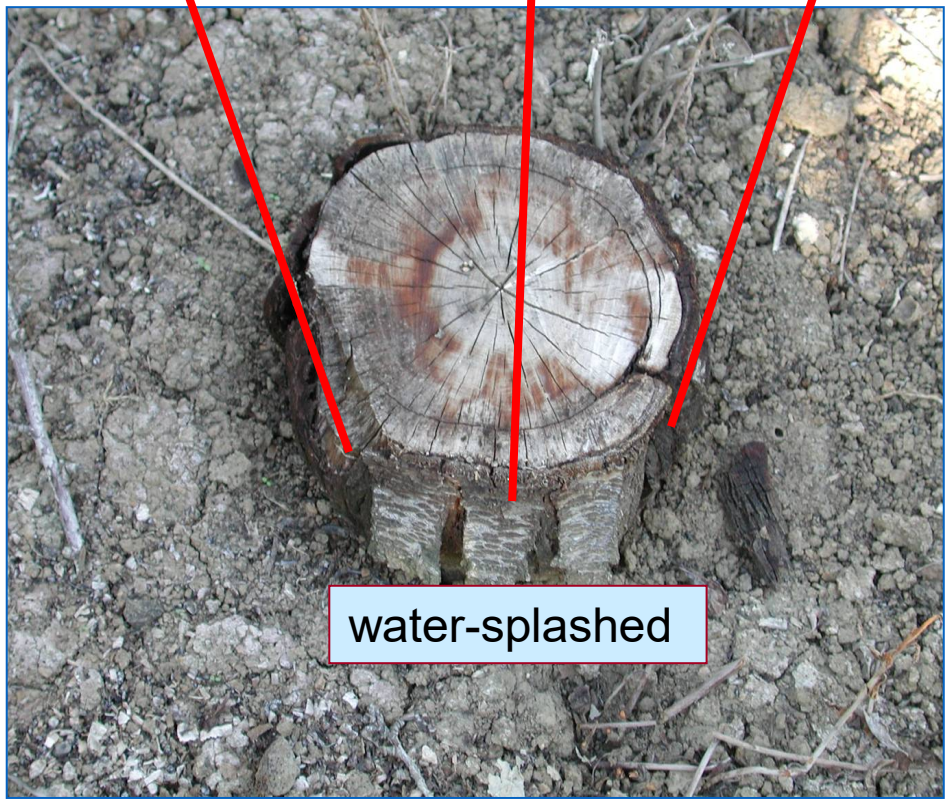




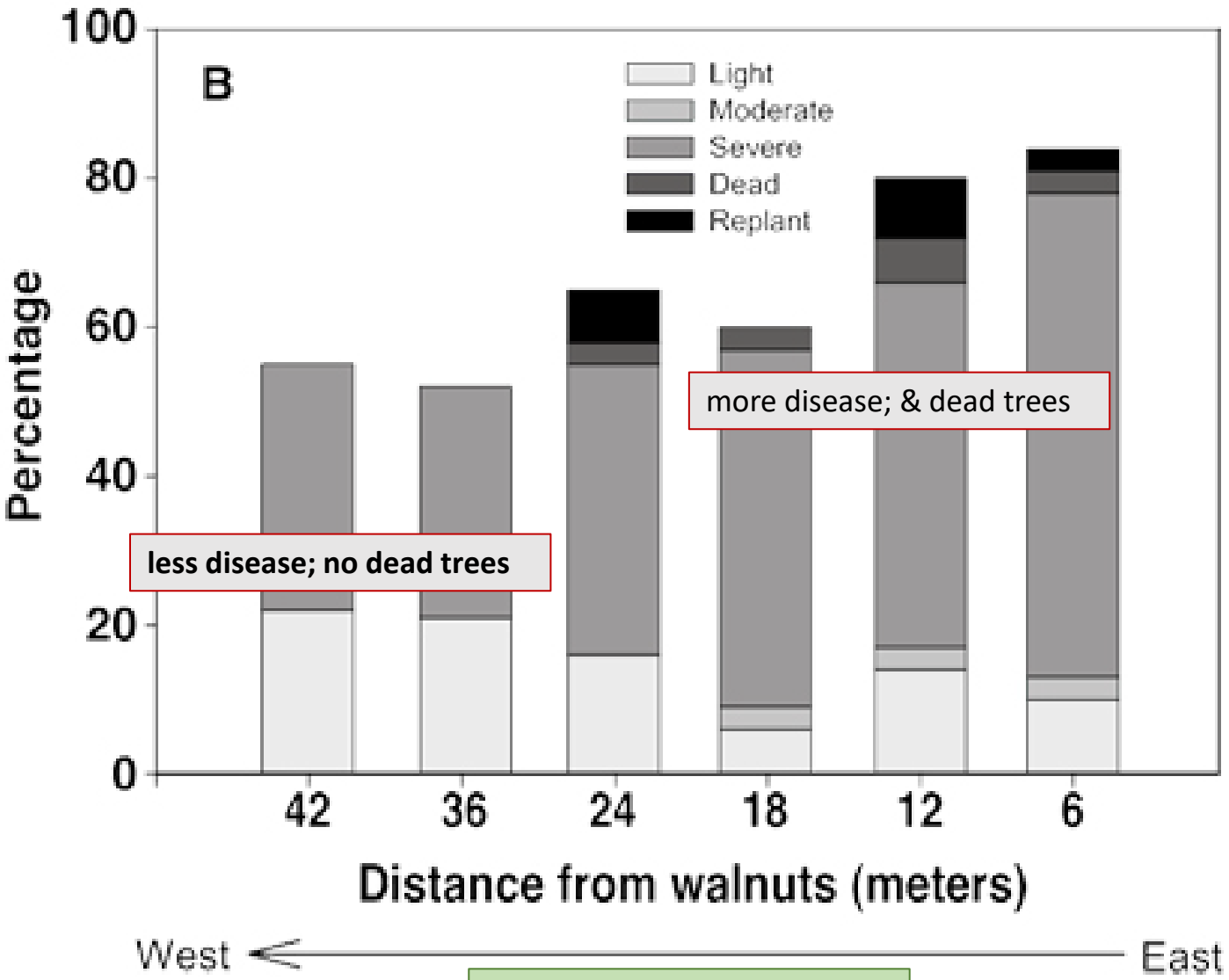
Infected trees need to be removed entirely







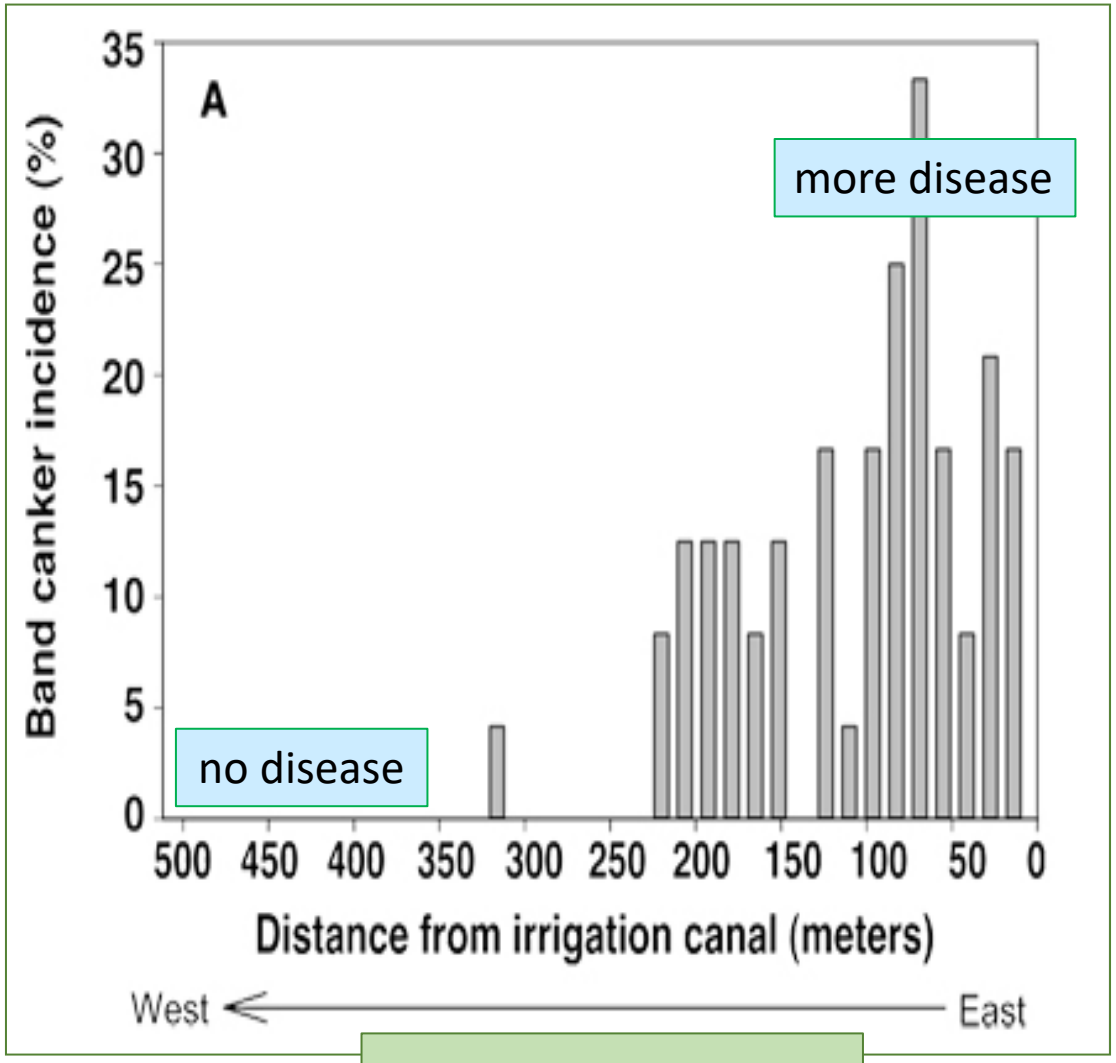
Band canker gradient with distance from the walnut orchard



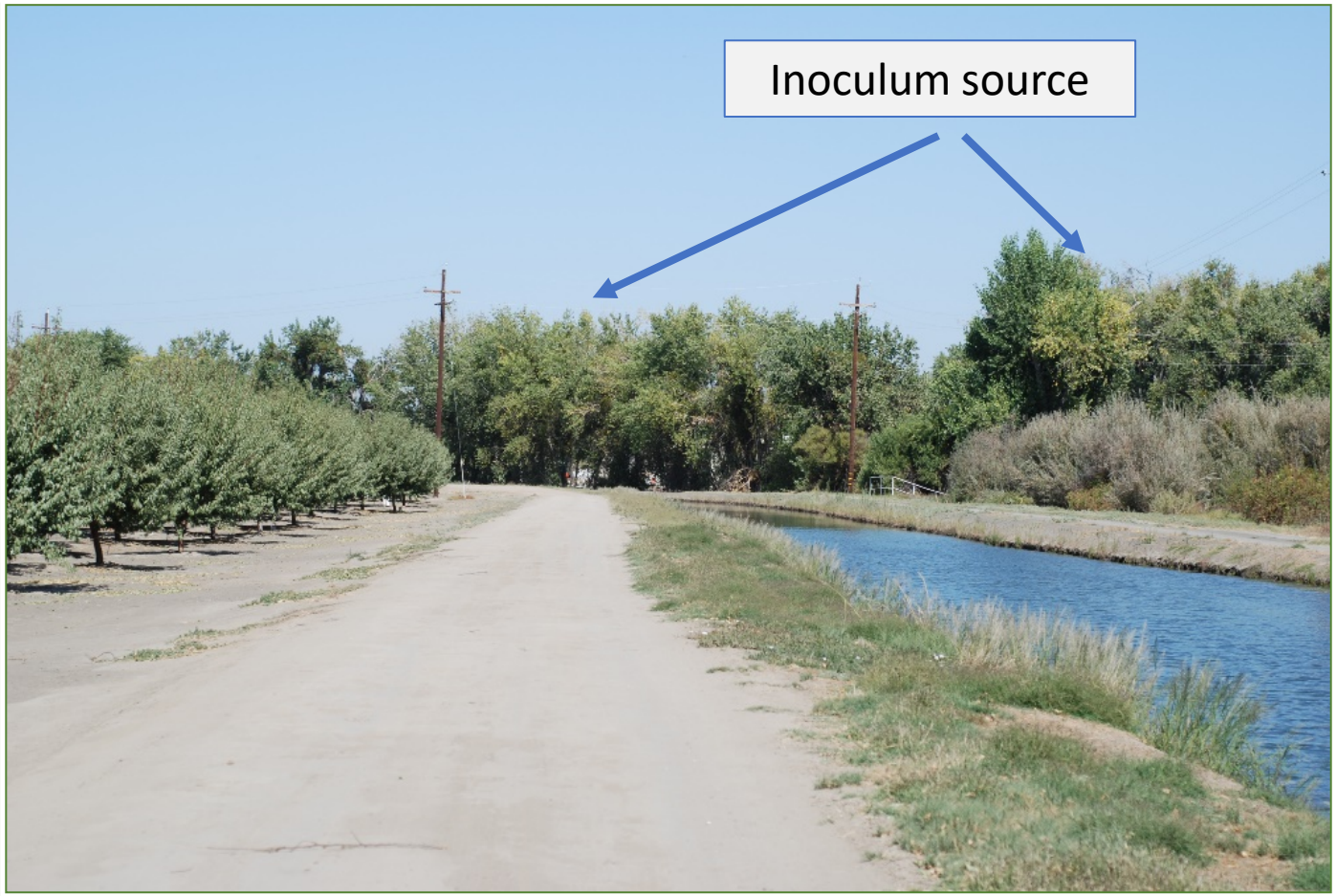
Almond orchard

Walnut orchard

Band canker **gradient with distance from the** inoculum source (riparian trees along the water canal)



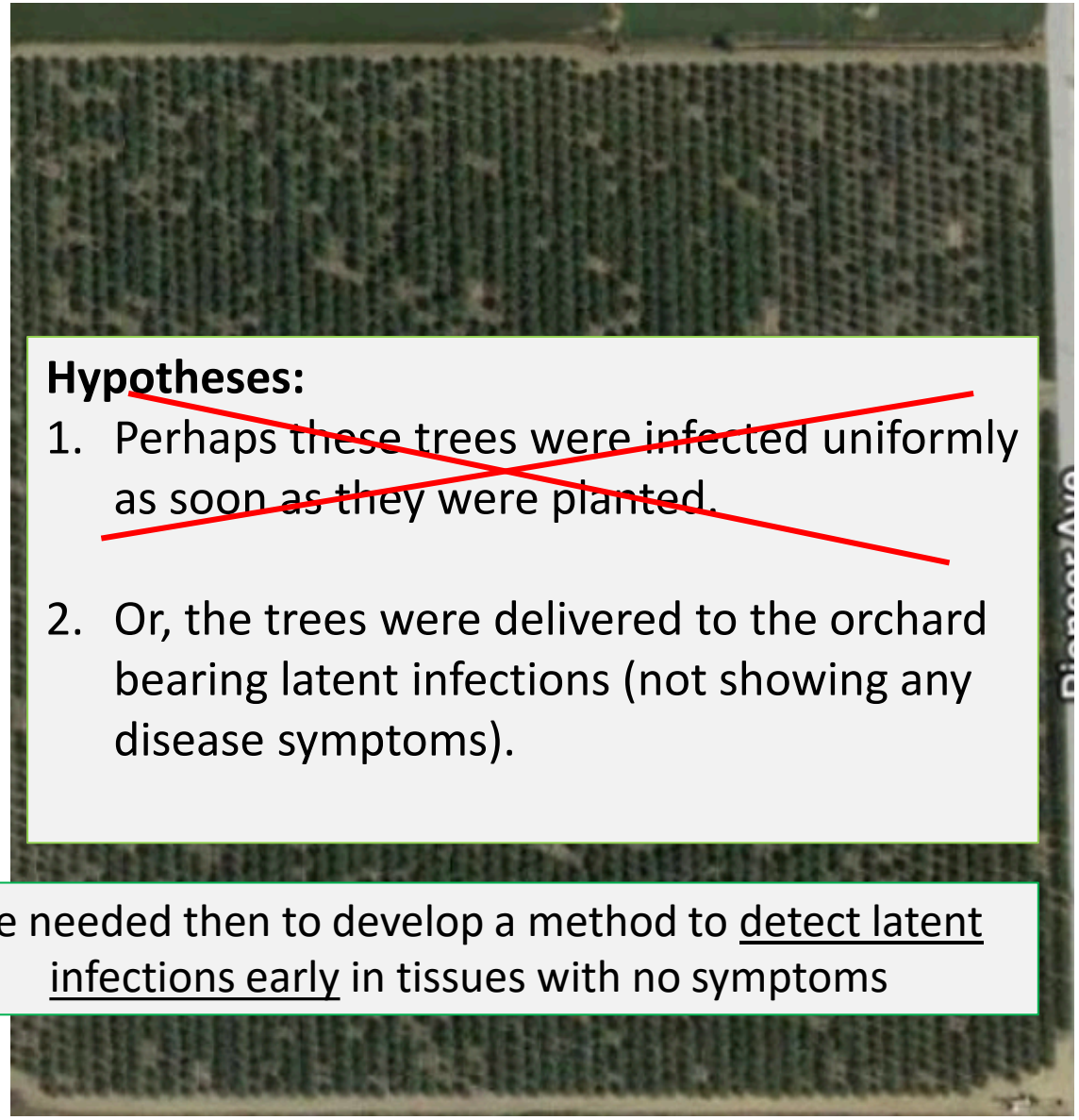
Almond orchard



3rd leaf Nonpareil/Padre; inoculum source: riparian trees and water canal

2nd - leaf orchard severely damaged by band canker (Butte County)

3rd-leaf almond orchard with gaps due to Band Canker (Stanislaus Co.)



Hypotheses:

1. ~~Perhaps these trees were infected uniformly as soon as they were planted.~~

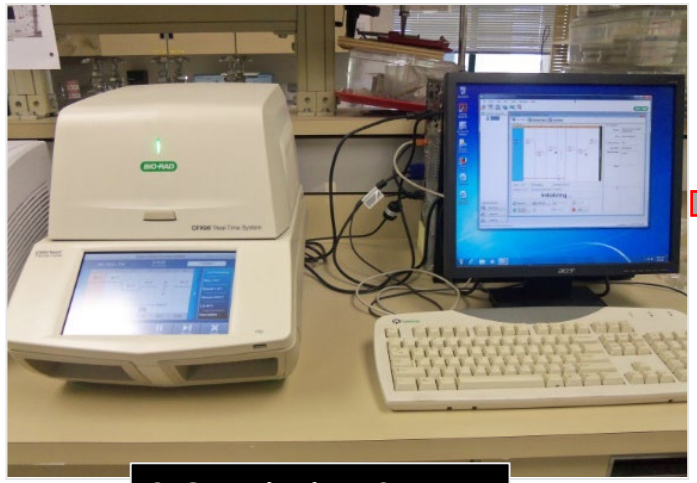
2. Or, the trees were delivered to the orchard bearing latent infections (not showing any disease symptoms).

We needed then to develop a method to <u>detect latent infections early</u> in tissues with no symptoms

*q*PCR, a molecular technique to quantify the DNA of canker pathogens

1. Sample collection and processing

2. Grinding and DNA extraction



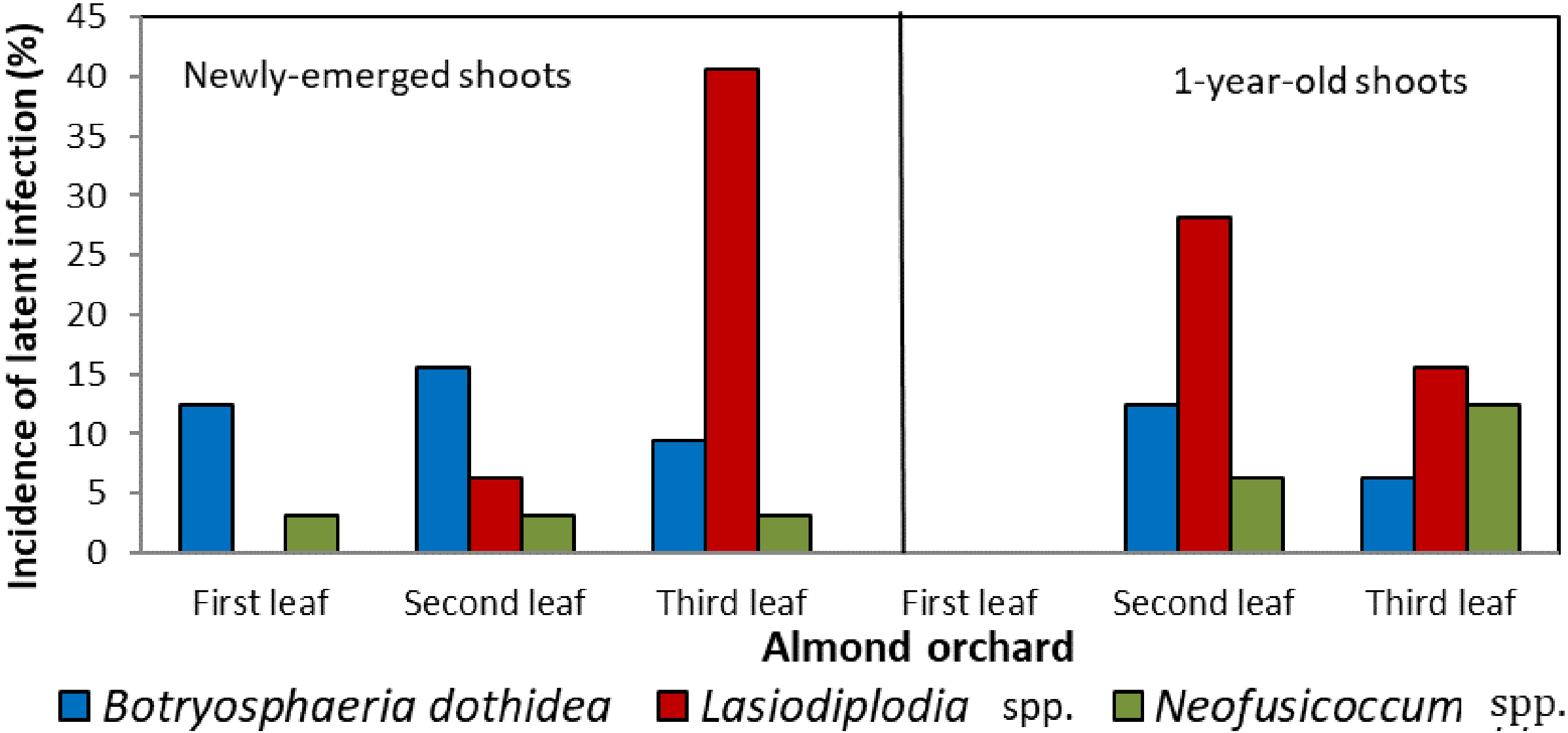
3. Quantitative PCR assay

Sample	weight (g)	Dilution	Ct	calculation of fg		total fg	/weight	MS(a)
PAN4-1	0.32	60	36.47	2.194821	156.6105	4698.316	14682.24	4.17
PAN4-2	0.34	60	36.62	2.150466	141.4054	4242.162	12476.95	4.10
PAN4-3	0.33	60	N/A	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
PAN4-4	0.36	60	36.03	2.324929	211.3144	6339.431	17609.53	4.25
PAN4-5	0.29	60	36.62	2.150466	141.4054	4242.162	14628.15	4.17
PAN4-6	0.4	60	36.54	2.174122	149.3214	4479.641	11199.1	4.05
PAN4-7	0.32	60	35.65	2.437295	273.7127	8211.382	25660.57	4.41
PAN4-8	0.3	60	38.18	1.689174	48.88482	1466.545	4888.482	3.69
PAN4-9	0.34	60	38.29	1.656647	45.35728	1360.718	4002.113	3.60
PAN4-10	0.36	60	39.03	1.437829	27.40495	822.1485	2283.746	3.36
PAN4-11	0.27	60	37.79	1.804497	63.75247	1912.574	7083.608	3.85
PAN4-12	0.31	60	36.88	2.073584	118.4633	3553.9	11464.19	4.06
PAN4-13	0.35	60	37.21	1.976003	94.62437	2838.731	8110.66	3.91
PAN4-14	0.38	60	37.68	1.837024	68.71064	2061.319	5424.524	3.73
PAN4-15	0.42	60	36.78	2.103154	126.8101	3804.304	9057.868	3.96
PAN4-16	0.39	60	36.38	2.221434	166.5076	4995.227	12808.28	4.11
PAN4-17	0.28	60	36.17	2.283531	192.1016	5763.048	20582.32	4.31
PAN4-18	0.37	60	3			015	3702.743	3.57

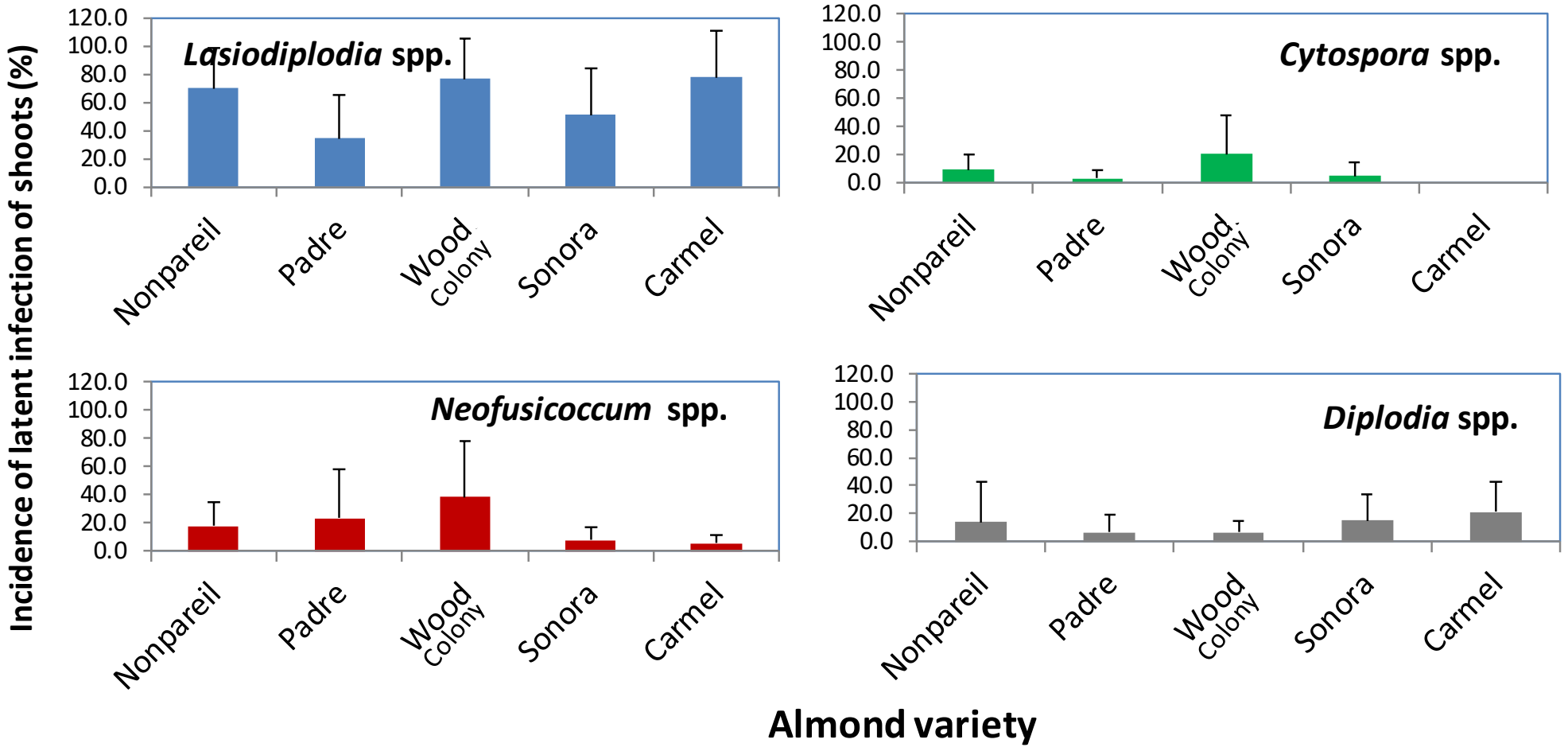
4. Data analysis

Results

Incidence of latent infection of canker pathogens in new and 1-year-old shoots from 3 almond orchards



Incidence of latent infection by 4 canker pathogen groups from shoots of different almond varieties from a nursery.

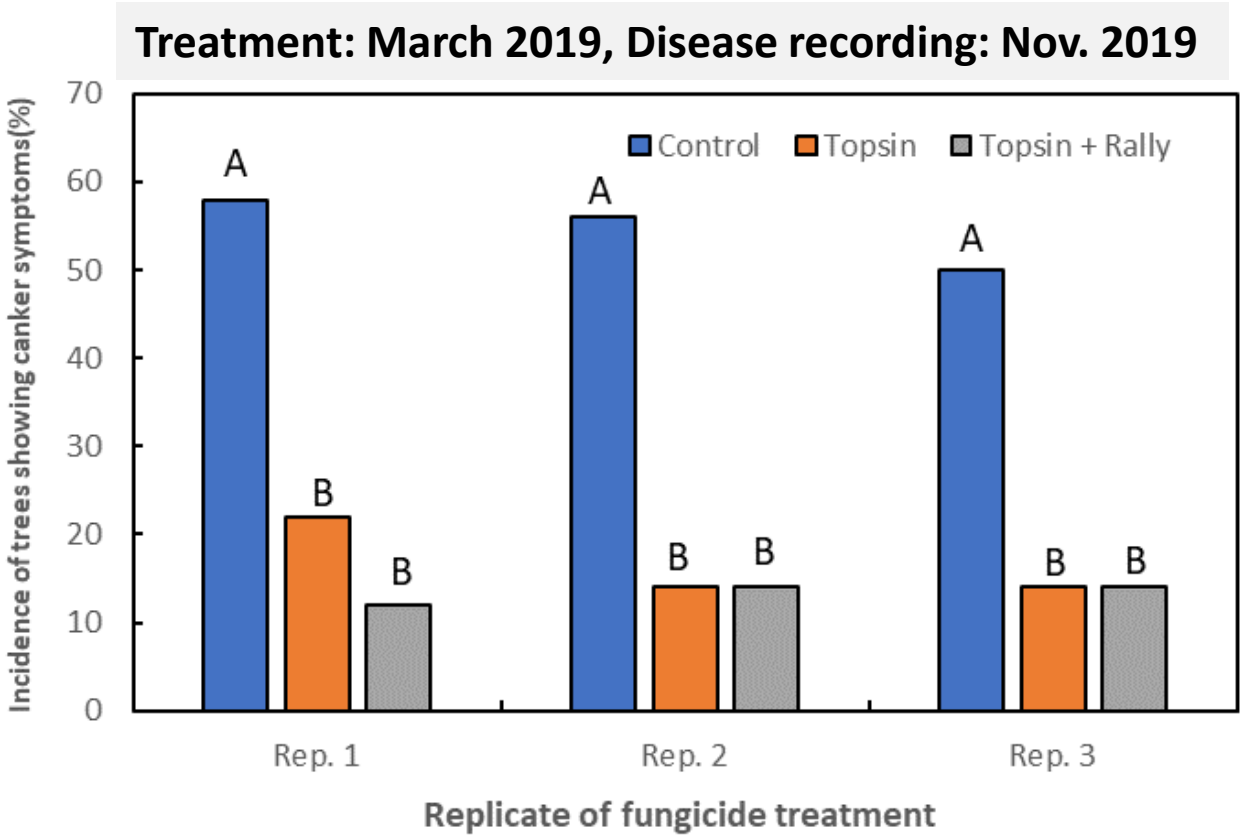


We started to focus on nurseries to investigate possible infections on young trees

Effects of Topsin-M applied in March 2019 in a 2nd - leaf orchard (before any symptoms of band canker were noticed)

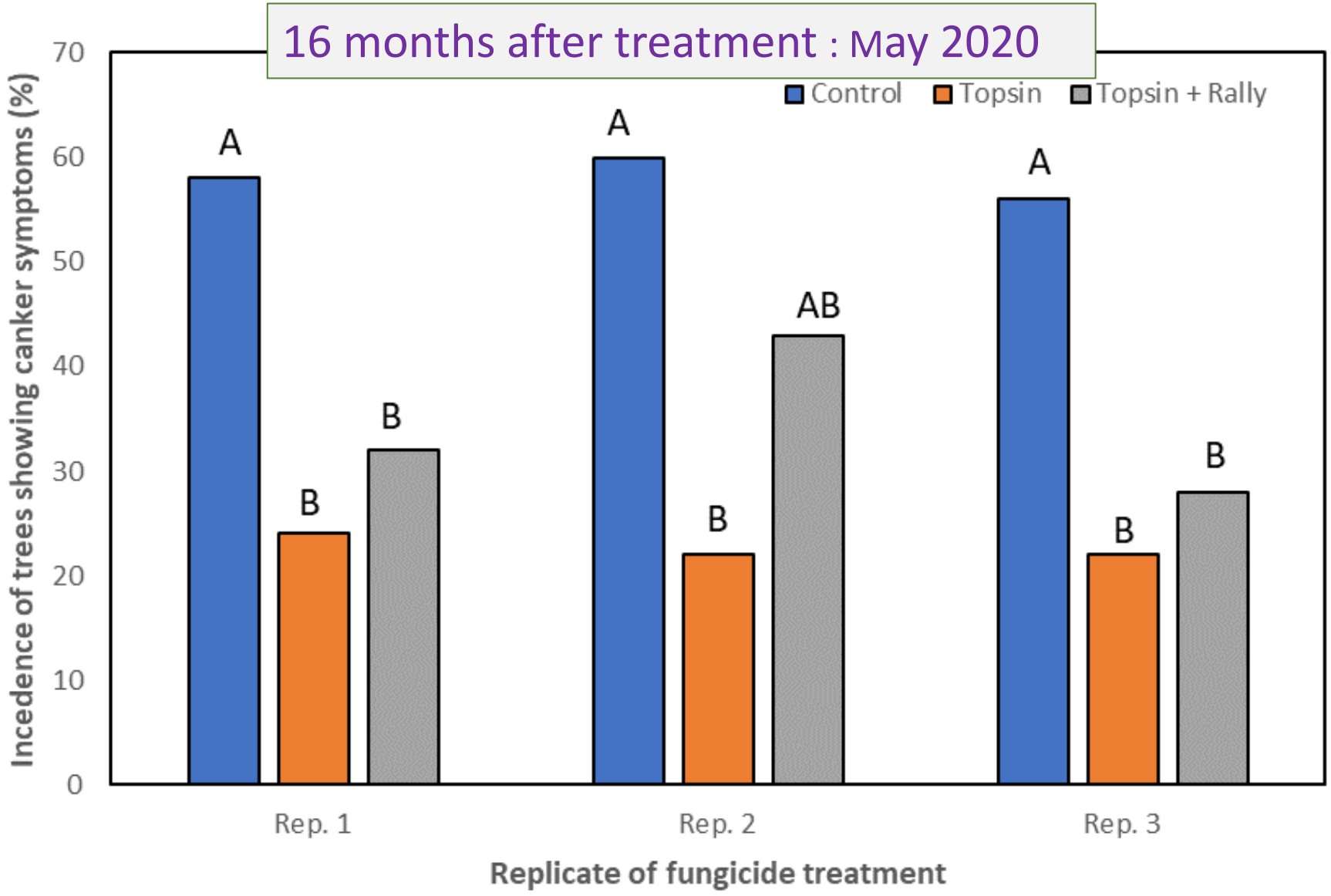
8 months after treatment

Topsin M WP 70 at 1.51 lb/acre; Rally at 8.0 oz/acre



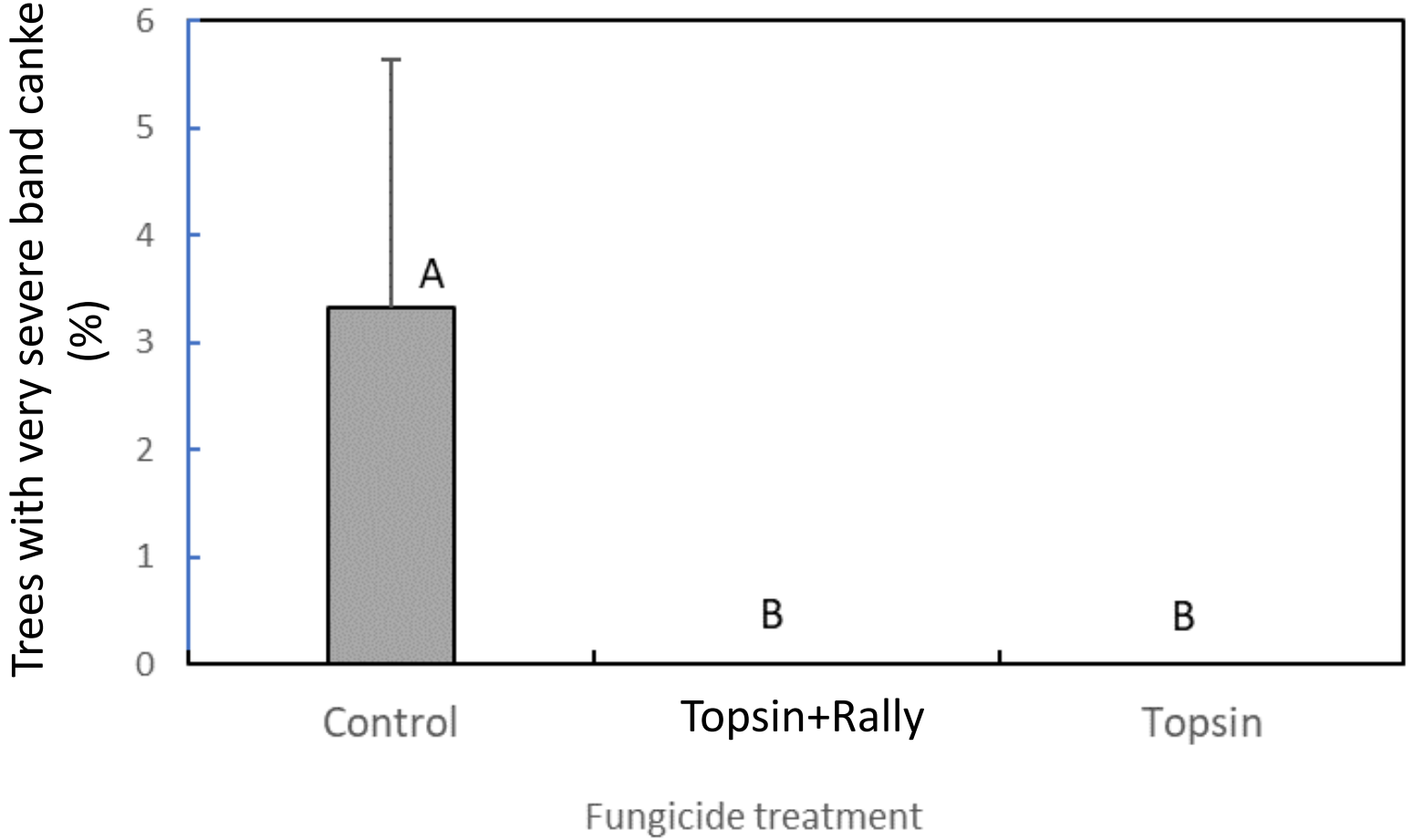
(Each replication includes 50 trees)

The almond orchard treated in 2019 with fungicides in 3rd leaf now



The almond orchard treated in 2019 with fungicides in 4th - leaf now

33 months after treatment: October 2021



Effect of Topsin M spray(s) in reducing the incidence of band canker in a 3rd-leaf almond orchard in Yuba Co. (after symptoms of band canker were noticed)

Treatments:

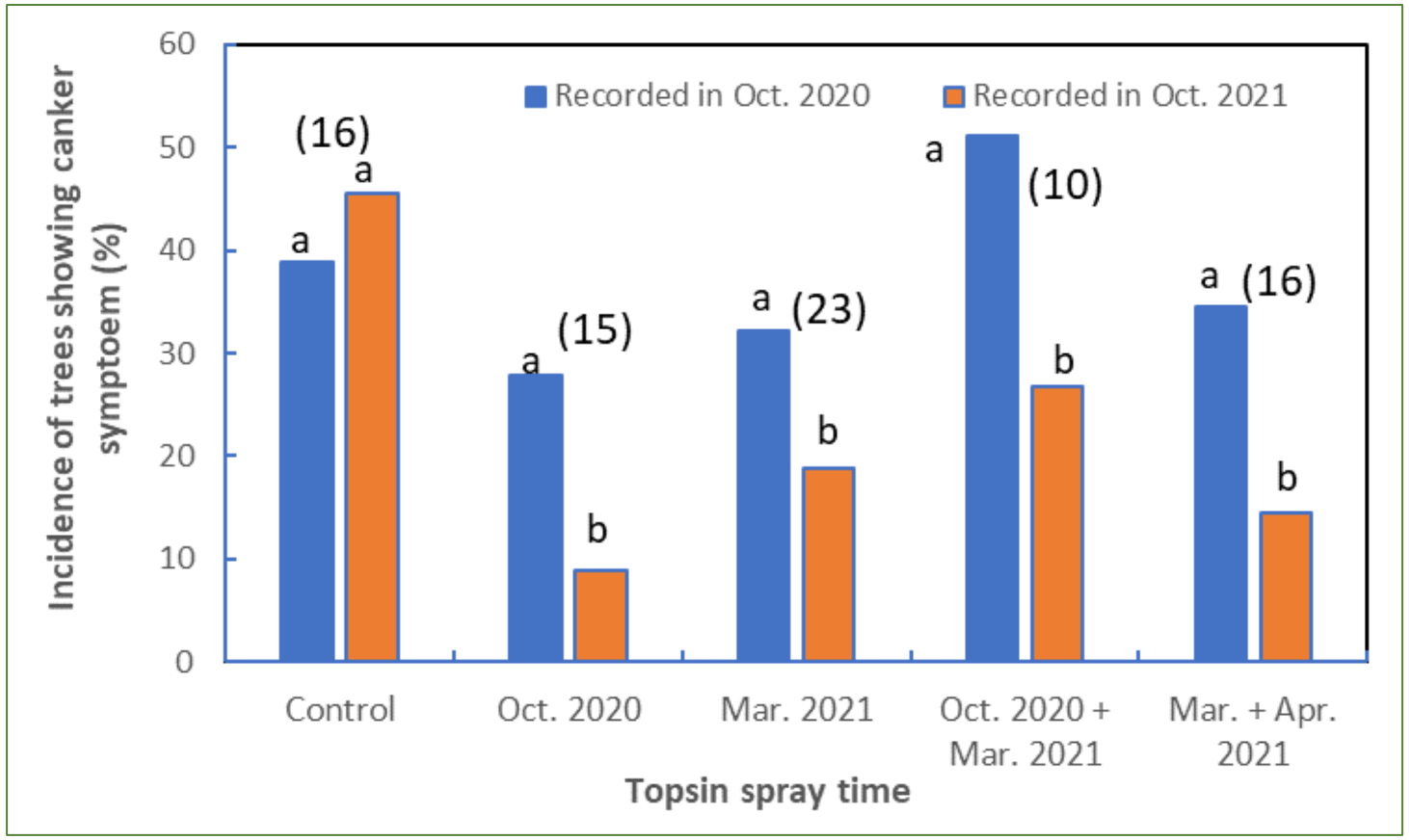
a) Sprayed only in October 2020

b) Sprayed only in March 2021

c) Sprayed both in October 2020 & March 2021

d) Sprayed in March 2021 & in April 2021

e) Untreated control



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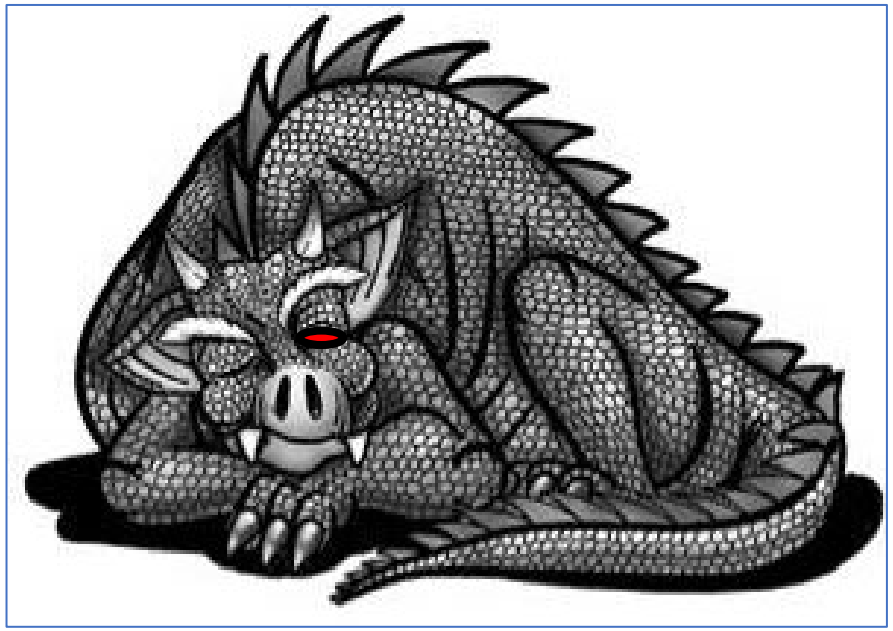
CONCLUSIONS:

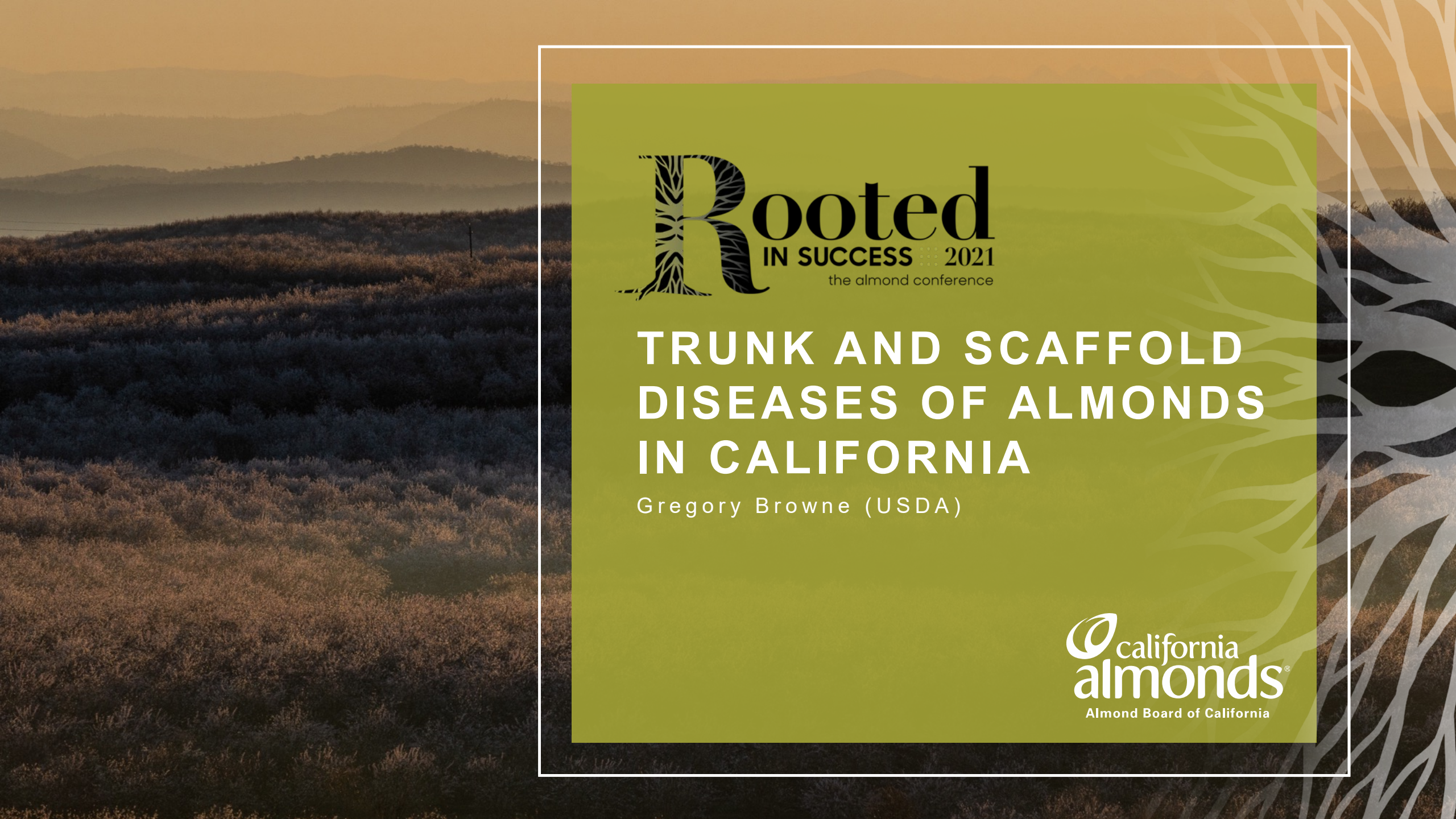
PREVENTATIVE APPROACH (YOUNG ORCHARDS):

- Obtain “clean” trees from nurseries
- Spray the trunks in 1st,2nd, or 3rd leaf orchards with Topsin®-M at label rate.
- Keep the trunk of trees dry.
- Protect pruning wounds by spraying Topsin®-M at label rate.



WHEN BAND CANKER IS PRESENT (YOUNG ORCHARDS):

- Keep the trunk of trees dry.
- Spray trunk and scaffolds with Topsin®–M.
- Protect pruning wounds by spraying Topsin®-M at label rate.
- Remove killed trees and stumps (sanitation).
- Keep wood piles (spore inoculum) away from the orchard.



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TRUNK AND SCAFFOLD DISEASES OF ALMONDS IN CALIFORNIA

Gregory Browne (USDA)

california almonds
Almond Board of California

Thank You