

Fusarium Wilt of Strawberry

Management of Soilborne Pathogens

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18th Annual Strawberry Production – Ventura County

September 19, 2019



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Agriculture and Natural Resources

Collaborators:

- Steve Koike
- Mark Bolda
- Steve Knapp
- Glenn Cole



Fusarium wilt

Verticillium wilt

Macrophomina crown rot





Fusarium wilt



Fusarium oxysporum



DETECTION & CONFIRMATION

of Fusarium Wilt Pathogens:

Challenges, Errors, and Limitations

By: Steven T. Koike | Director, TriCal Diagnostics

Tom Gordon | Professor, University of California at Davis

- ✓ ***Fusarium oxysporum* is common in soil**
- ✓ **Most strains are not pathogenic**
- ✓ **Non-pathogenic strains colonize roots**
- ✓ **Pathogen ID requires further testing**

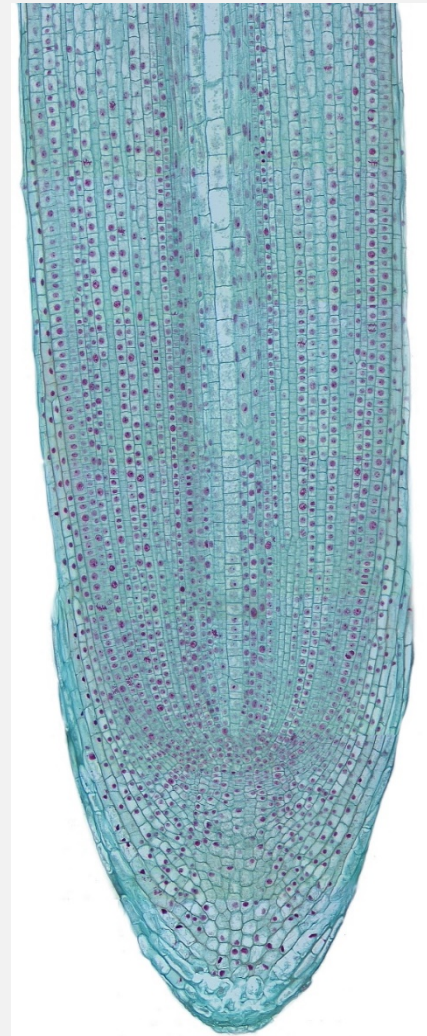


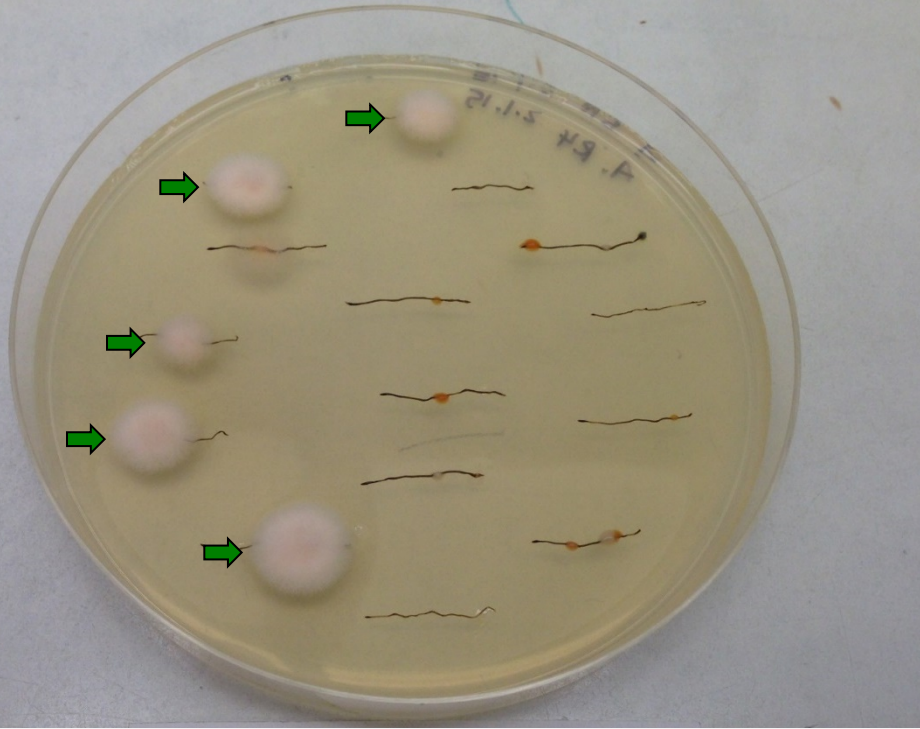
Fusarium wilt



Fusarium oxysporum

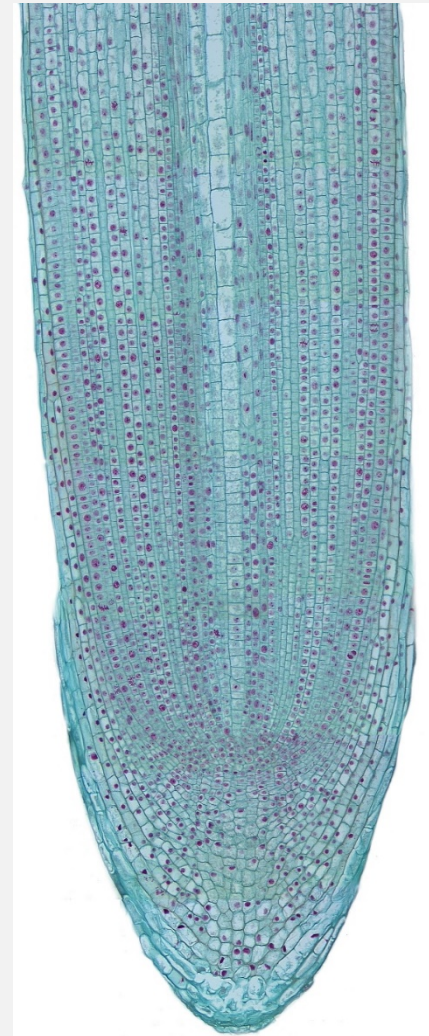
Sugars





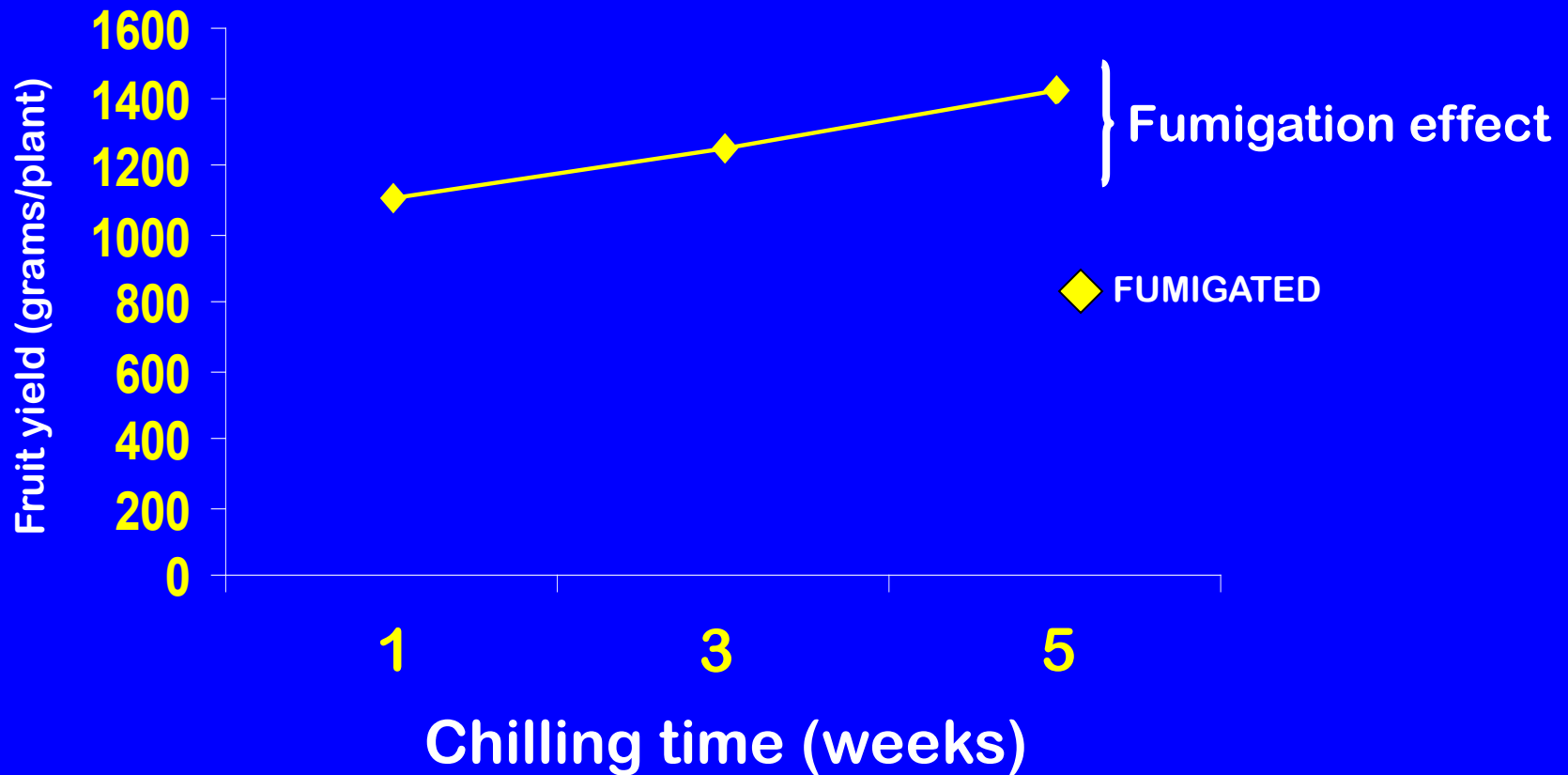
Fusarium wilt

Infection of root tips



Fusarium oxysporum

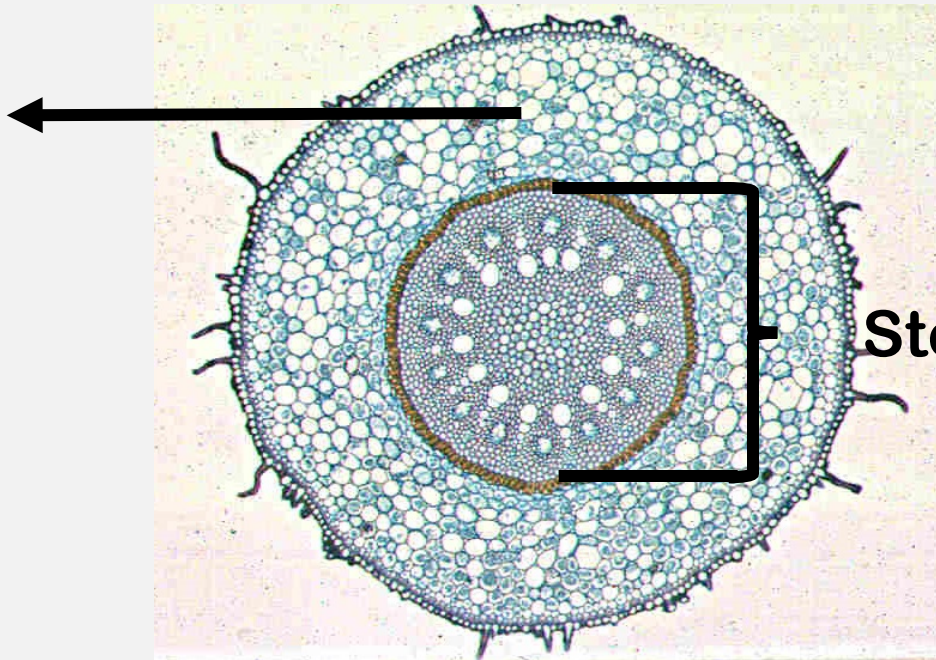
Effect Of Fumigation Treatment And Chilling On Fruit Yield Of Strawberry



10-15% yield increase by eliminating non-pathogenic fungi on roots

Root Cross Section

Cortex

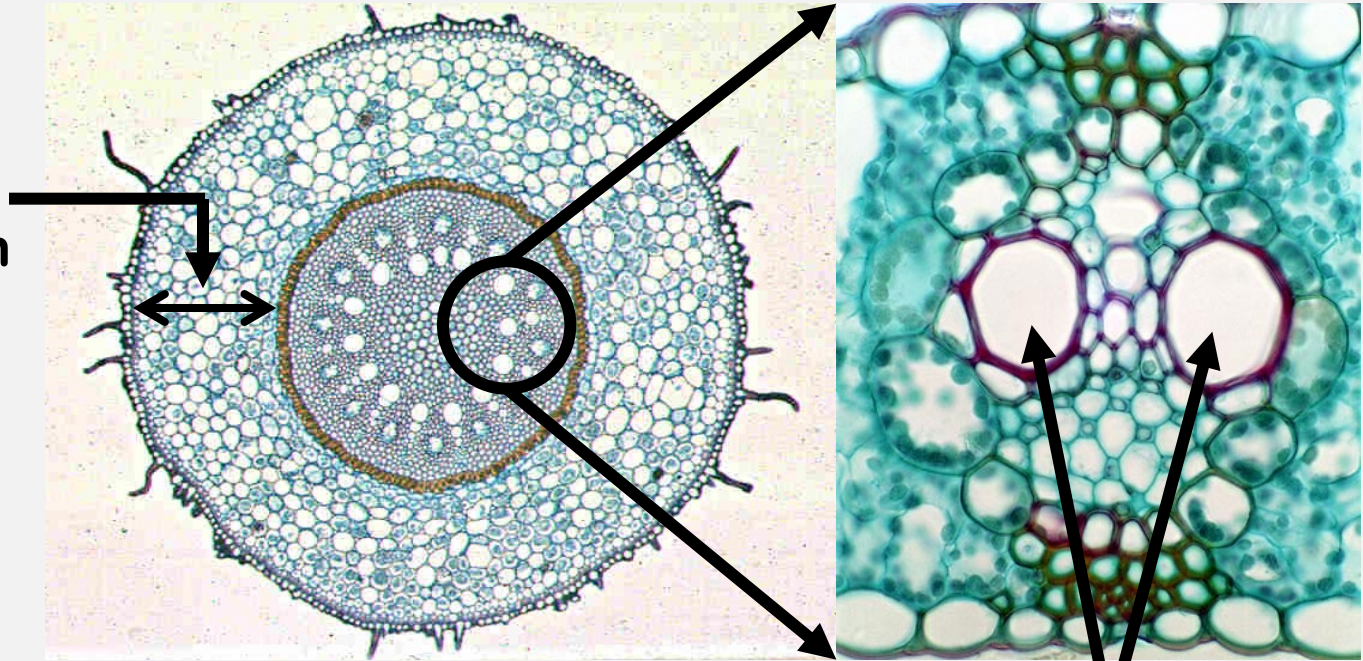


Stele

Non-pathogenic
fungi colonize the
root cortex

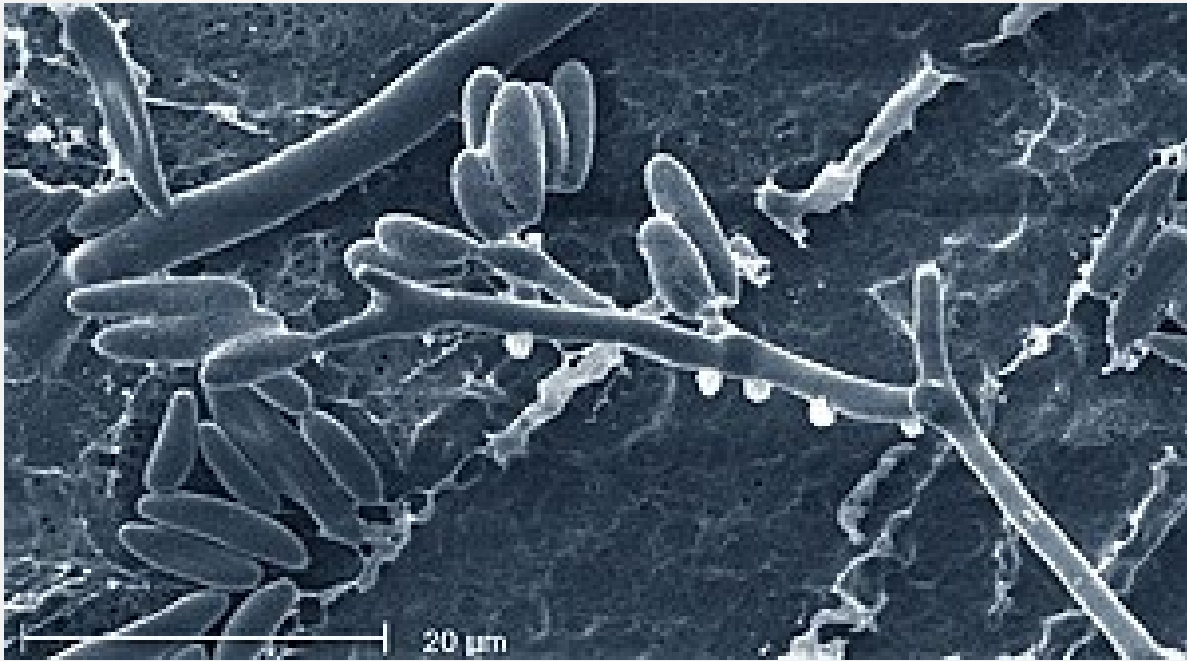
*Fusarium
oxysporum*
f. sp. *fragariae*

↓
Region of
fungal growth

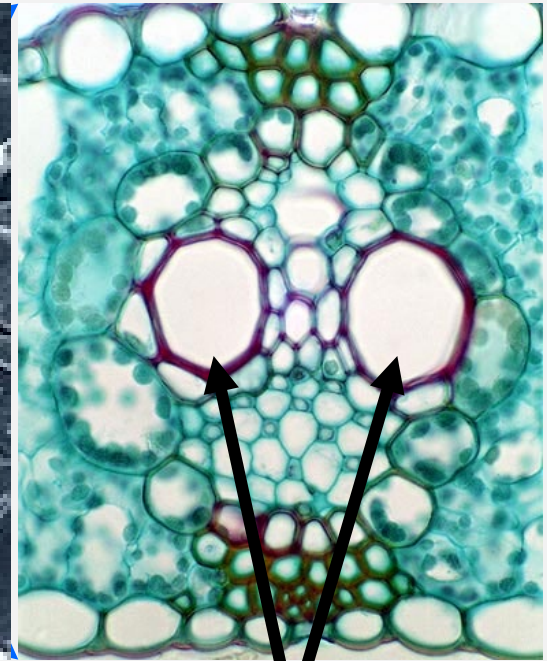


Xylem vessels

The Pathogen Moves Into The Shoot With Water

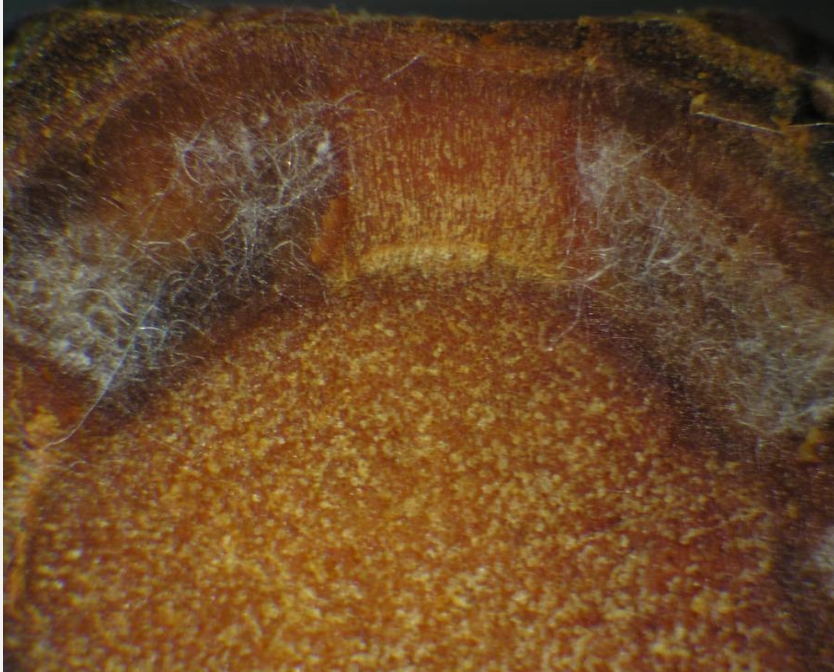


Spores



Xylem vessels

The Pathogen Moves Into The Shoot With Water

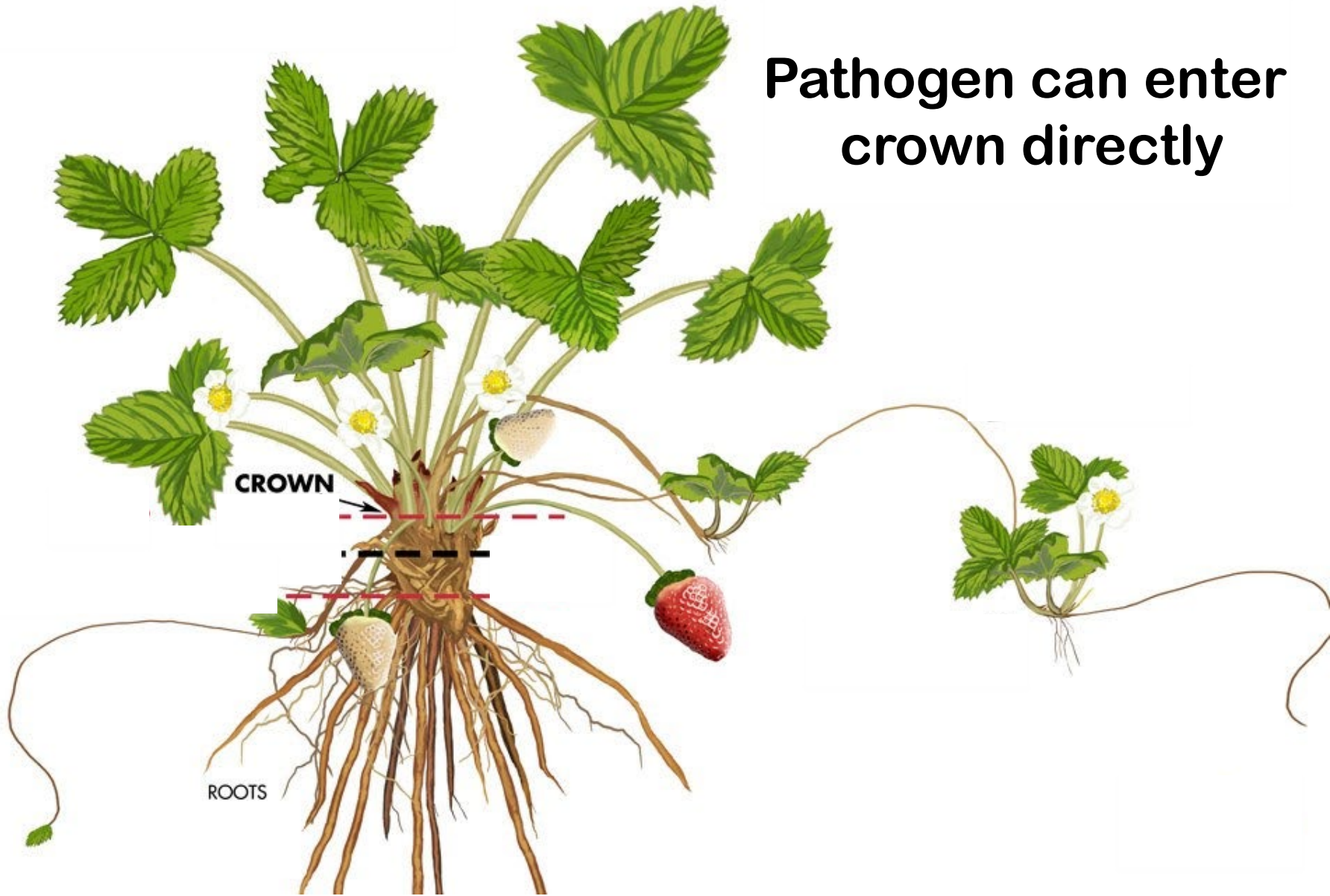


Colonized vascular tissue

Obstruction of water flow



**Pathogen can enter
crown directly**



Management

NO CURATIVE MEASURES

PREVENTION  **AVOID INTRODUCTION**

Avoid Introductions

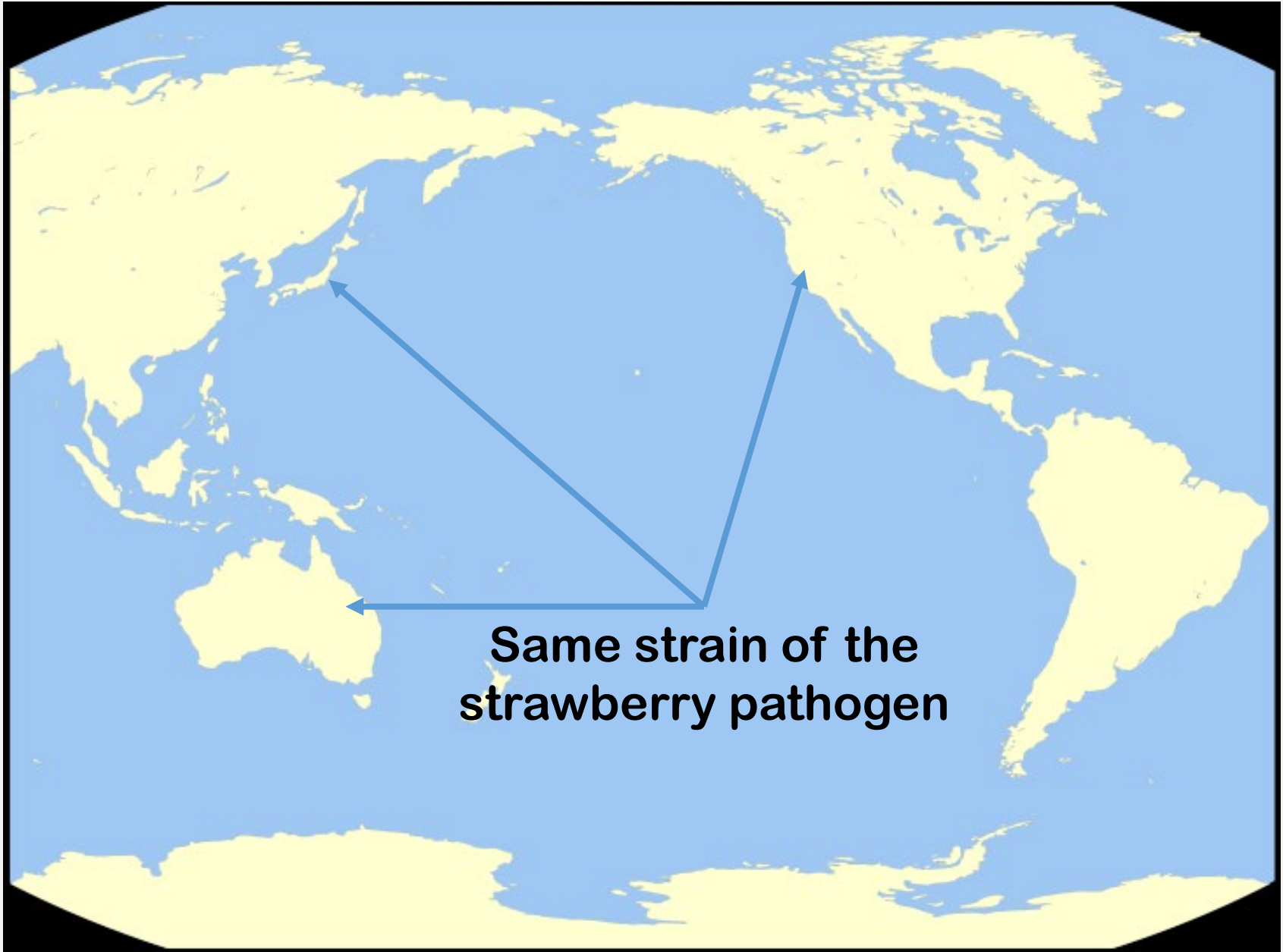
Clean plants



Don't move soil



Fusarium Wilt



**Same strain of the
strawberry pathogen**

Transmission of *Fusarium*
to daughter plants



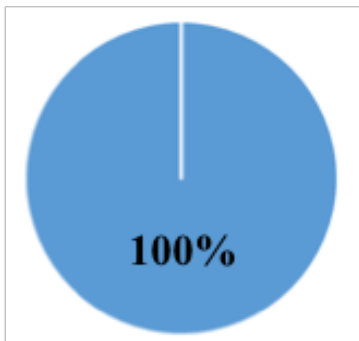
Transmission Of *Fusarium* To Daughter Plants



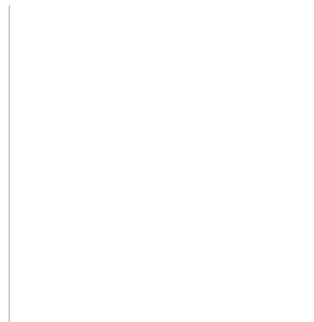
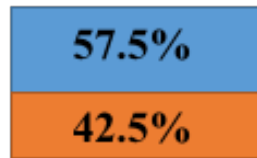
Albion

■ = Infected
■ = Not Infected

Mothers



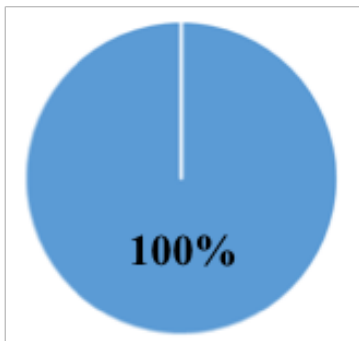
1st Stolons



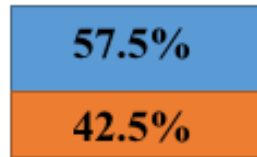
Albion

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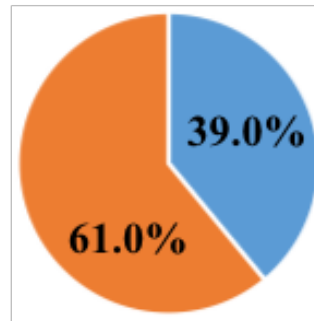
Mothers



1st Stolons



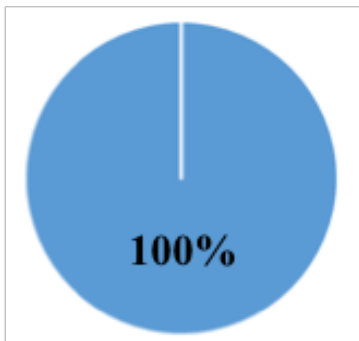
1st Daughters



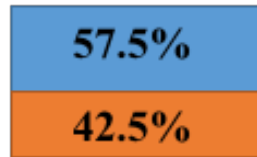
Albion

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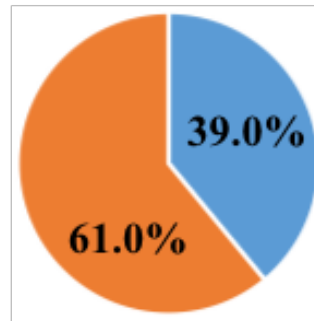
Mothers



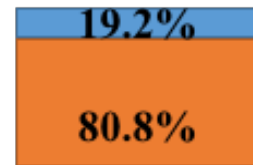
1st Stolons



1st Daughters



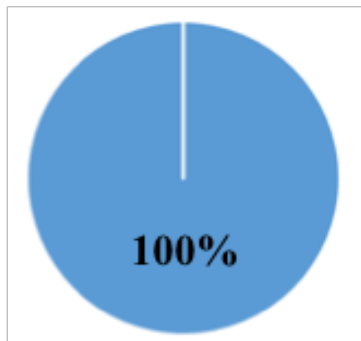
2nd Stolons



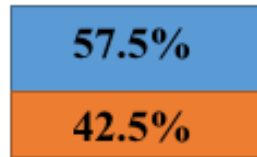
Albion

■ = Infected
■ = Not Infected

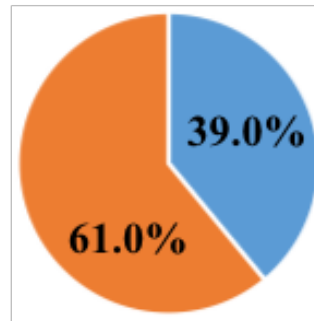
Mothers



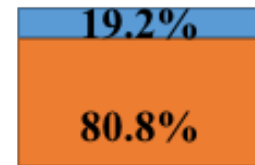
1st Stolons



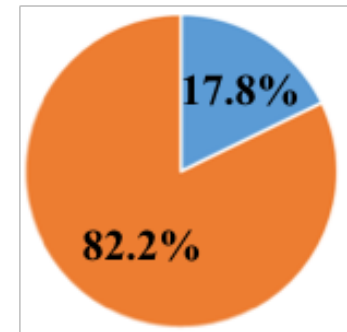
1st Daughters



2nd Stolons



2nd Daughters



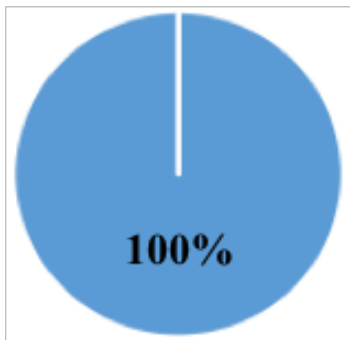
Symptomless



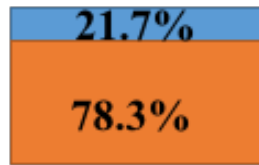
Monterey

■ = Infected
■ = Not Infected

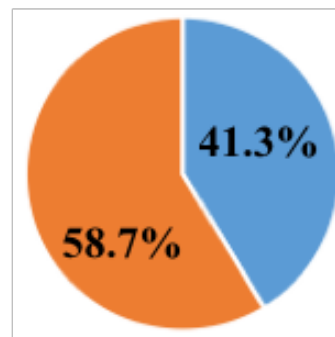
Mothers



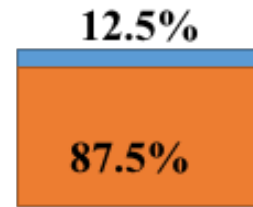
1st Stolons



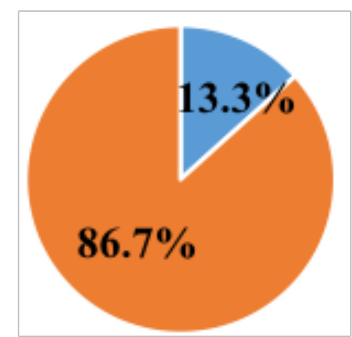
1st Daughters



2nd Stolons



2nd Daughters

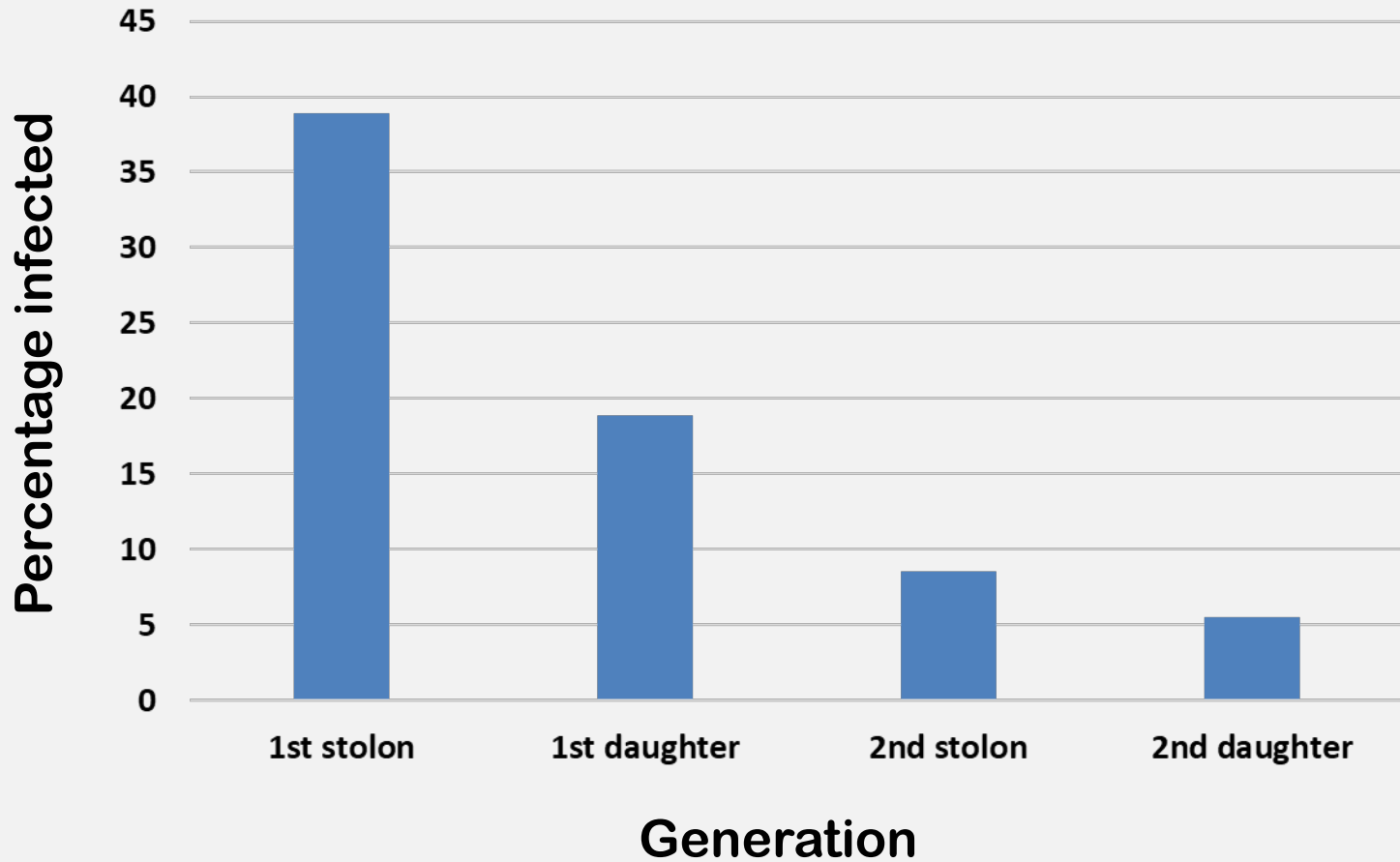


Symptomless



San Andreas

Resistant to Fusarium wilt



Infected Daughter Plants Appear Healthy



Infected Daughter Plants



**Show no symptoms
in nurseries**



**Disease may develop
in a fruit production field**

**Prevention of infection
in nurseries is critical**

Management Of Soilborne Pathogens

**Reduce
inoculum levels**

Pre-plant fumigation

Flat fumigation to treat the entire field

Maximize distribution in beds

Efficacy Of Fumigants

Methyl Bromide:Chloropicrin 2:1 @ 350 pounds/acre

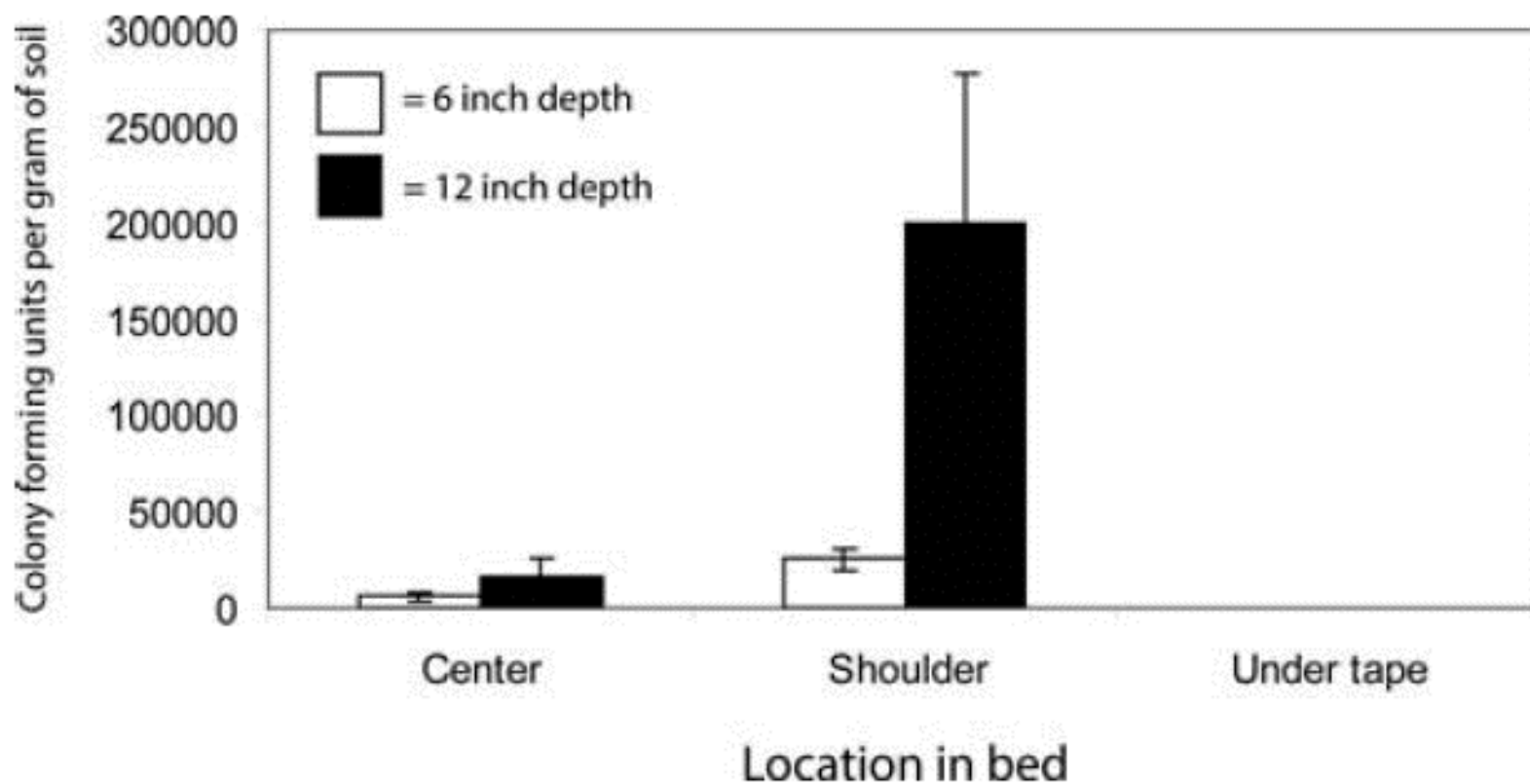
Chloropicrin @ 400 pounds/acre

Telone (1,3-Dichloropropene)

Metam sodium / K-Pam / Dominus

Options for Management of Fusarium Wilt of Strawberry in California

Thomas R. Gordon^a, Oleg Daugovish^b, Steven T. Koike^c, Christina M. Islas^a, Sharon C. Kirkpatrick^a, Jenna A. Yoshisato^a, and Douglas V. Shaw^d



60:40 mix of chloropicrin:telone



Incomplete treatment

Mortality is not evenly distributed across beds

Options for Management of Fusarium Wilt of Strawberry in California

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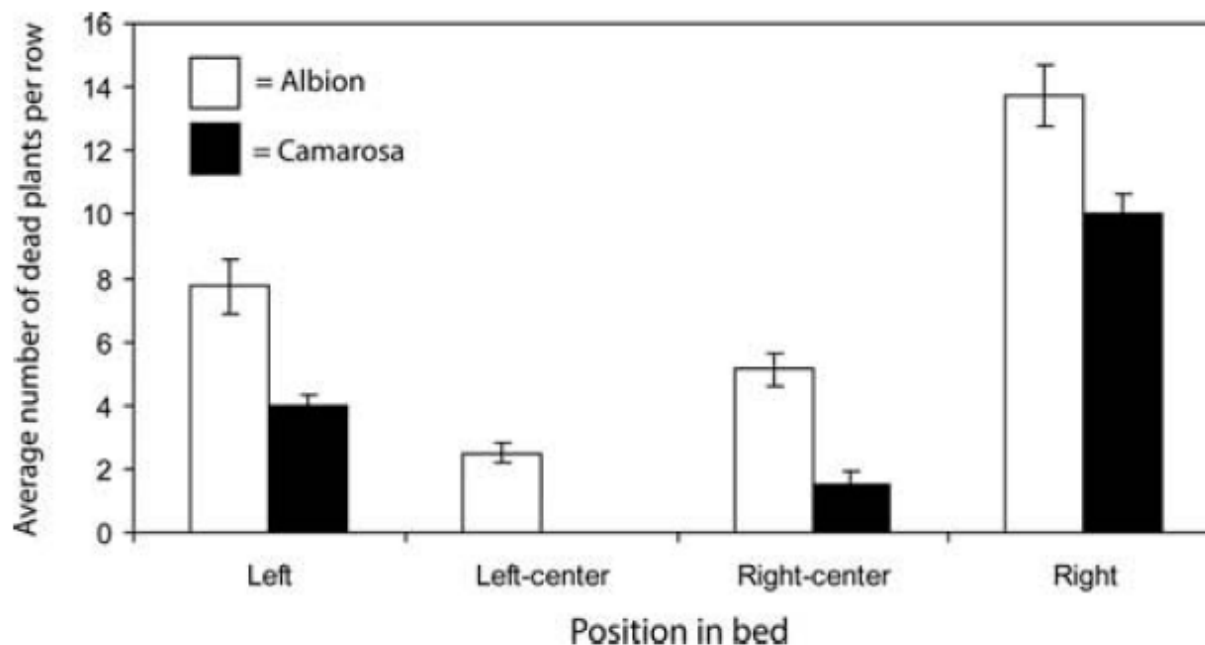


Figure 2. The effect of position in a bed on mortality caused by Fusarium wilt in two strawberry cultivars. Values represent means of four replications and error bars correspond to 2× the standard error of the mean.

60:40 mix of chloropicrin:telone

Conclusions

- ✓ Flat fumigation is best
- ✓ Maximize efficacy of bed fumigation
- ✓ Chloropicrin is good
- ✓ More is better
- ✓ More driplines
- ✓ More water

Don't plant buffer zones



Management Of Soilborne Pathogens

**Reduce
inoculum levels**

Pre-plant fumigation

Flat fumigation to treat the entire field

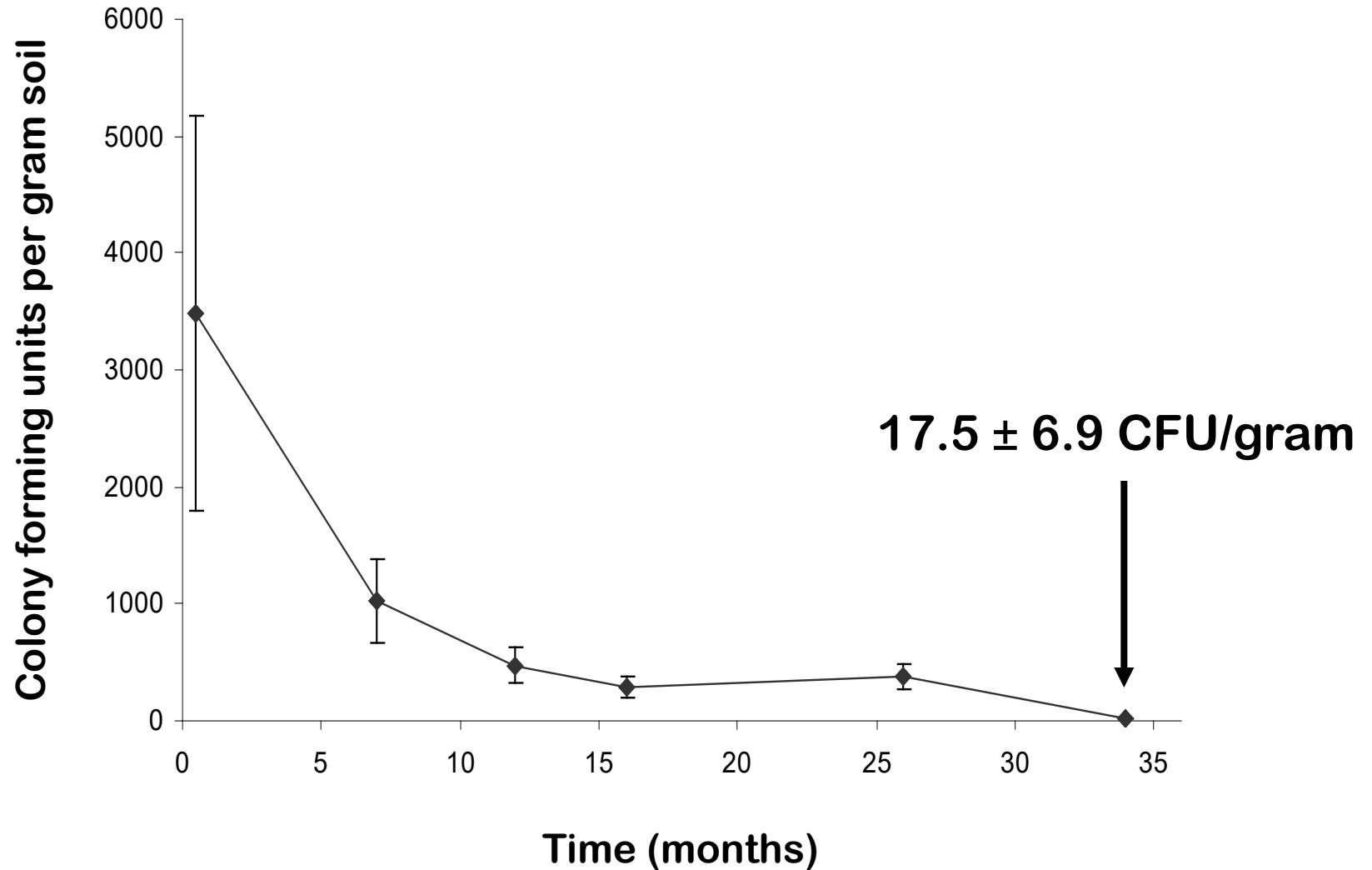
Maximize distribution in beds

Crop rotation

Crop Rotation

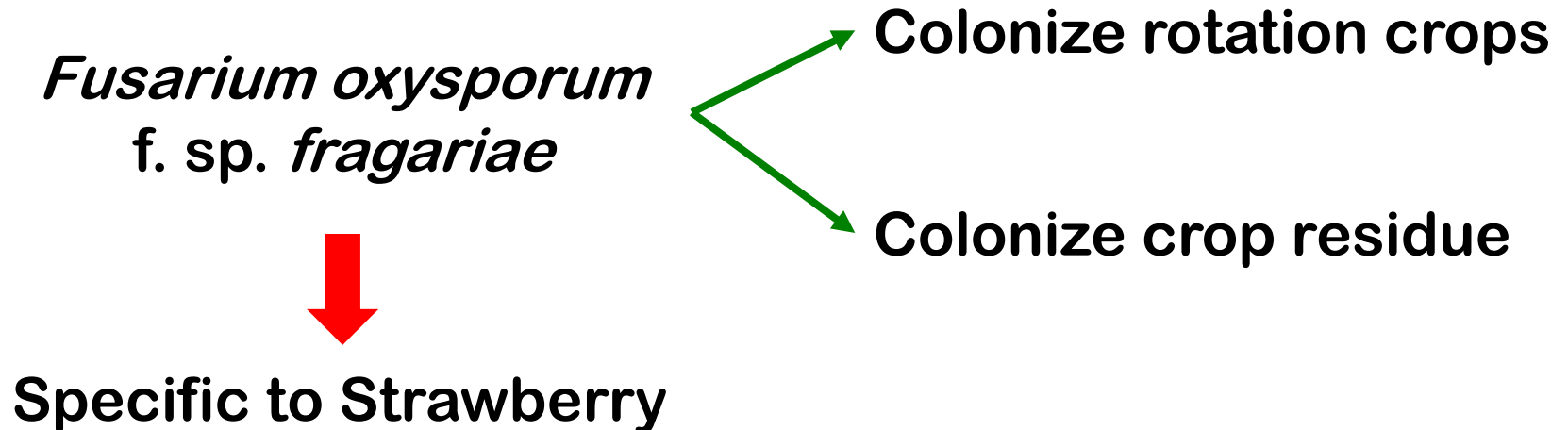
- ❖ Inoculum levels decline when NO crops are grown

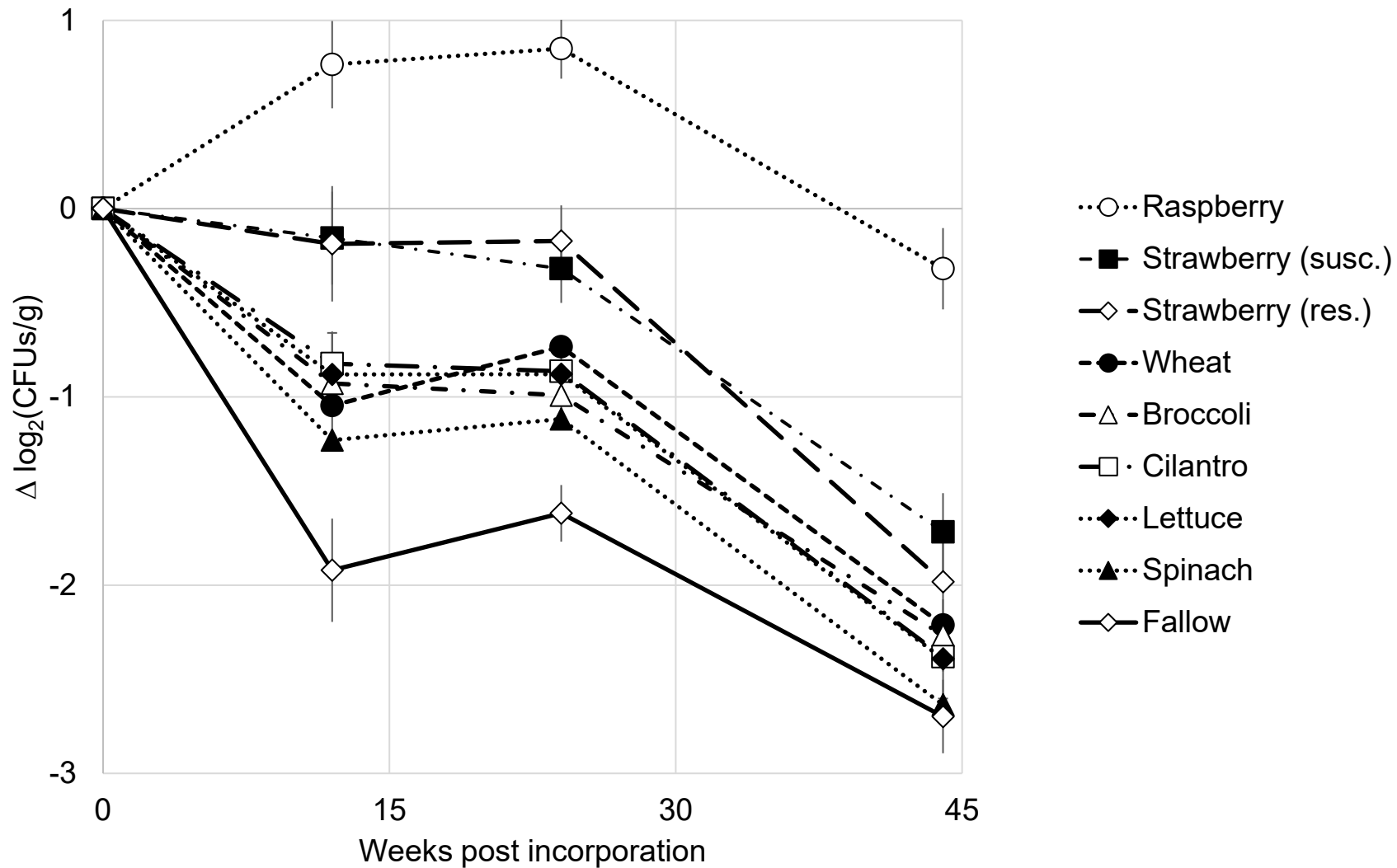
Survival of *F. o. lactucae* in Fallow Soil



Crop Rotation

- ❖ Inoculum levels decline when NO crops are grown
- ❖ Inoculum levels decline when OTHER crops are grown







Blackberry

Fusarium wilt

Fusarium oxysporum

**Effect of blackberry
pathogen on strawberry**

Albion

Monterey

San Andreas

Portola

Petaluma

Susceptibility Of Strawberry To Blackberry Pathogen

1 – 5 scale

| <u>Cultivar</u> | <u><i>F. o. mori</i></u> | <u><i>F. o. fragariae</i></u> |
|-----------------|--------------------------|-------------------------------|
| Albion | 3.0 | 5.0 |
| Monterey | 2.1 | 5.0 |
| San Andreas | 1.0 | 1.0 |
| Portola | 1.0 | 1.0 |
| Petaluma | 1.0 | 5.0 |



OC Monterey Plant 4



MONTEREY
AM-S1 2

Rotation Crops

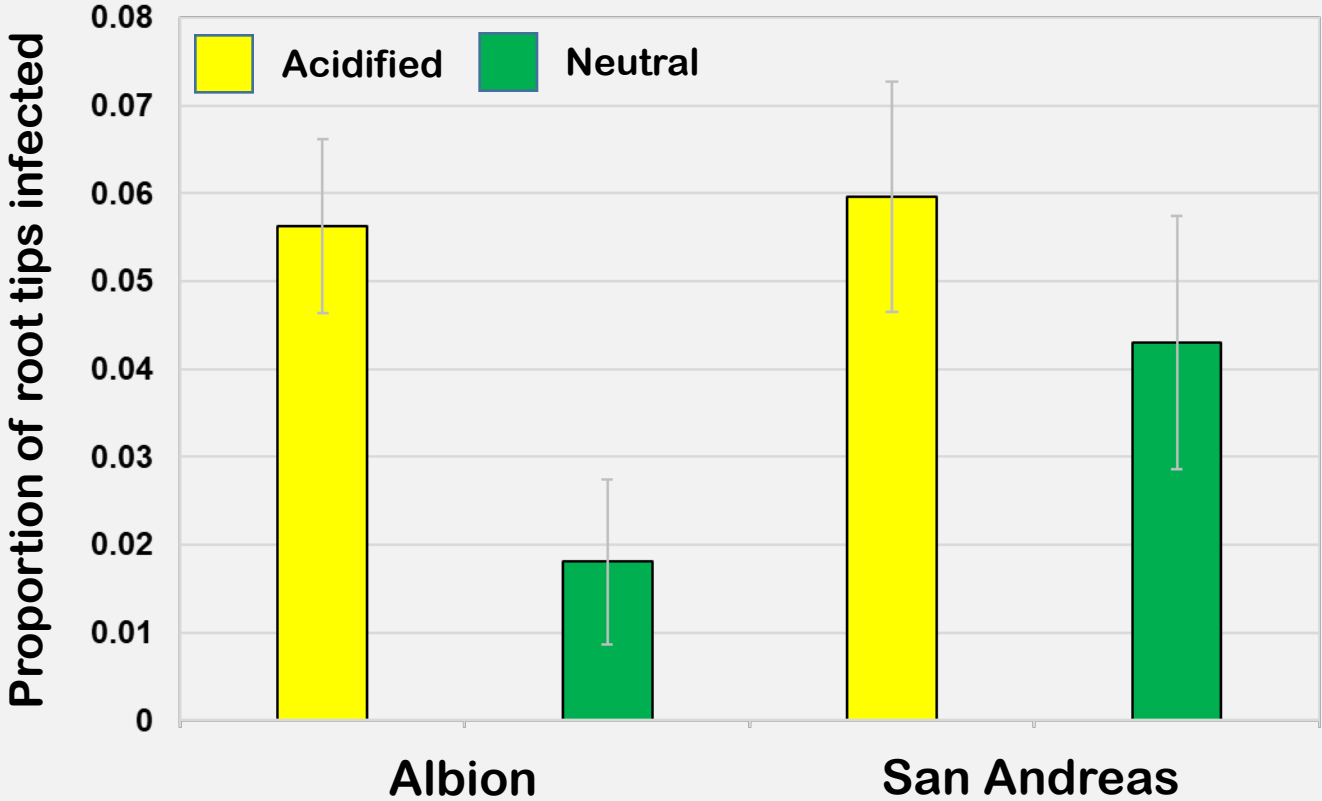
HIGH RISK

- ✓ Raspberry
- ✓ Blackberry

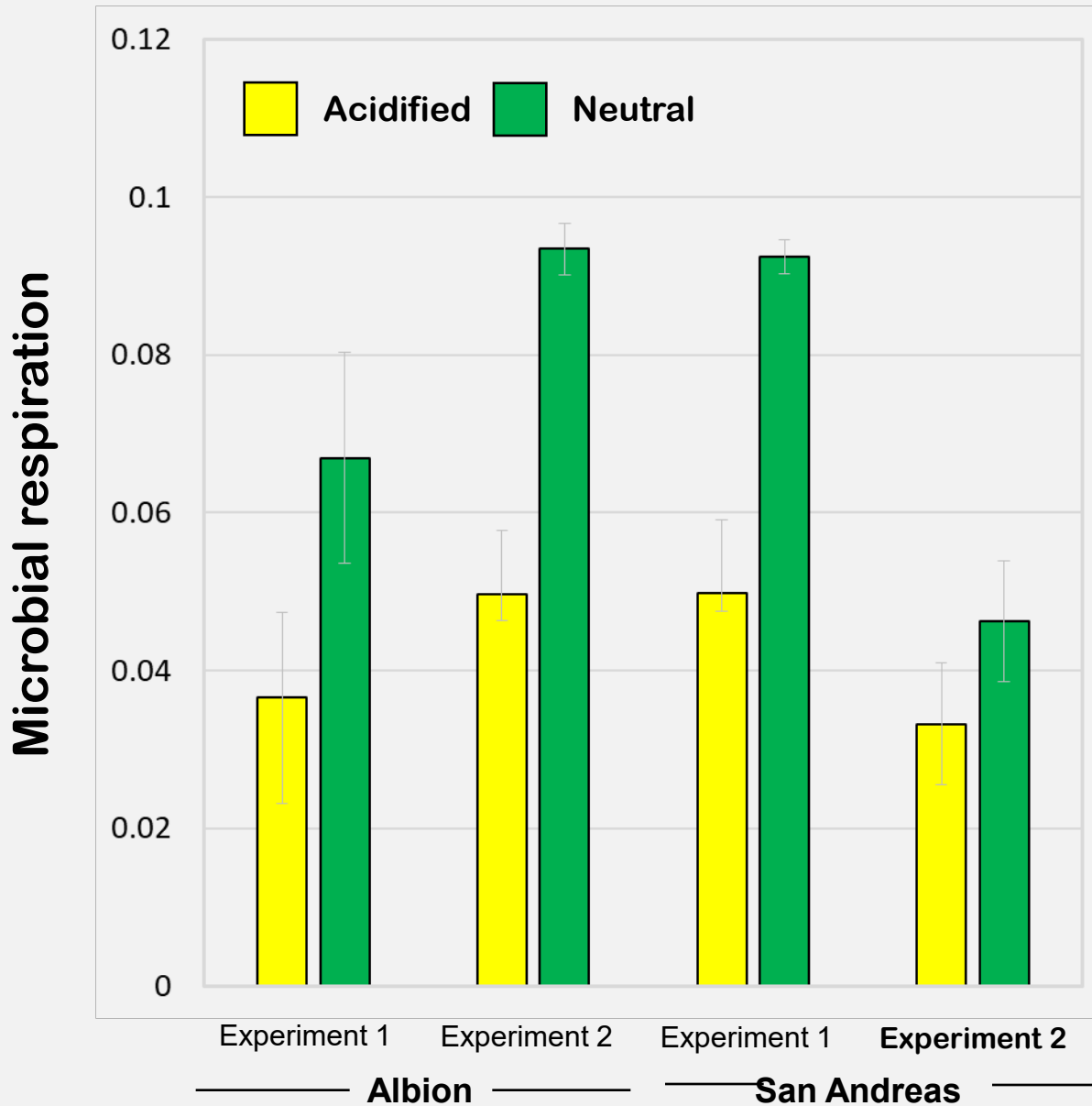
LOW RISK

- ✓ Spinach
- ✓ Wheat
- ✓ Broccoli
- ✓ Cilantro

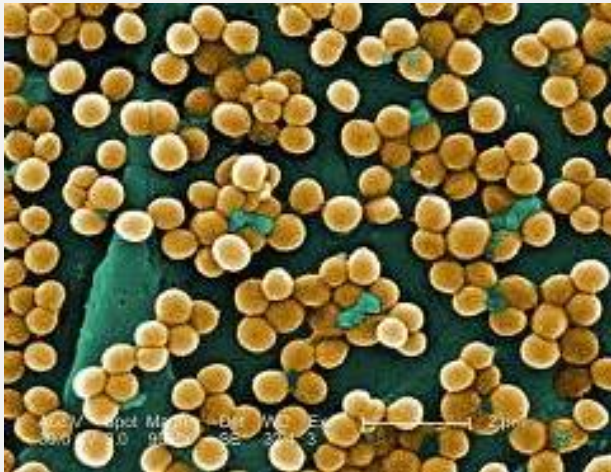
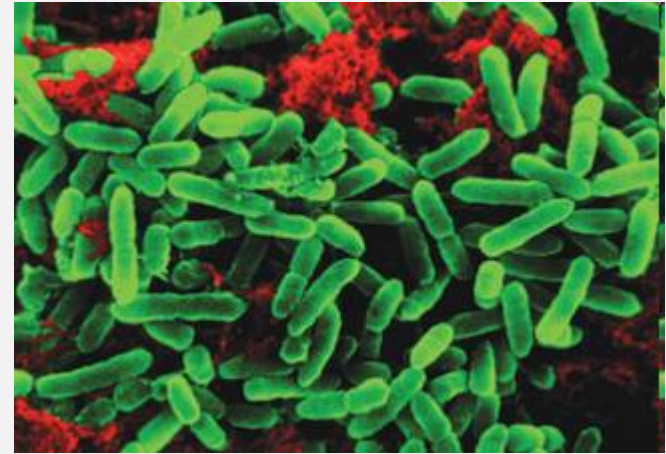
The Effect Of Soil PH On Root Infection



Bacterial respiration is higher in neutral soils



Fusarium oxysporum



In soil fungi compete with bacteria

**pH near neutrality
favors bacteria over fungi**

Elevate Microbial Respiration

- ✓ Soil amendments
- ✓ That do not support pathogen growth

Anaerobic soil disinfestation



Rice hulls at 9 tons per acre



cool conditions

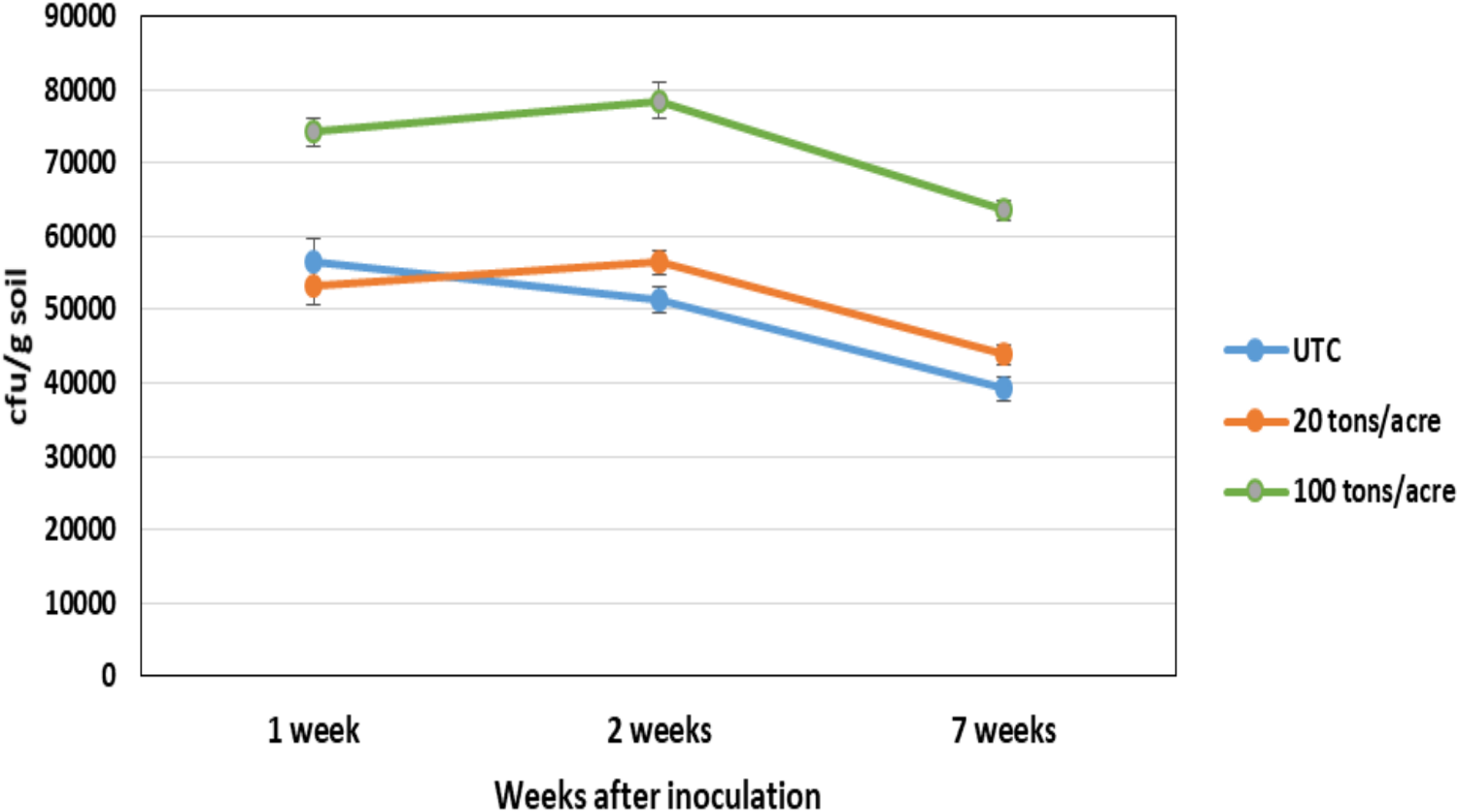
Day/night = 77/64°F



**+ 310% increase in
F. oxysporum f. sp. *fragariae*
population**

Compost

Survival of *F. o. fragariae* in soil



Management Of Soilborne Pathogens

**Reduce
inoculum levels**

**Use resistant
cultivars**

Pre-plant fumigation

Flat fumigation to treat the entire field

Maximize distribution in beds

Crop rotation

Differences in susceptibility to Fusarium wilt

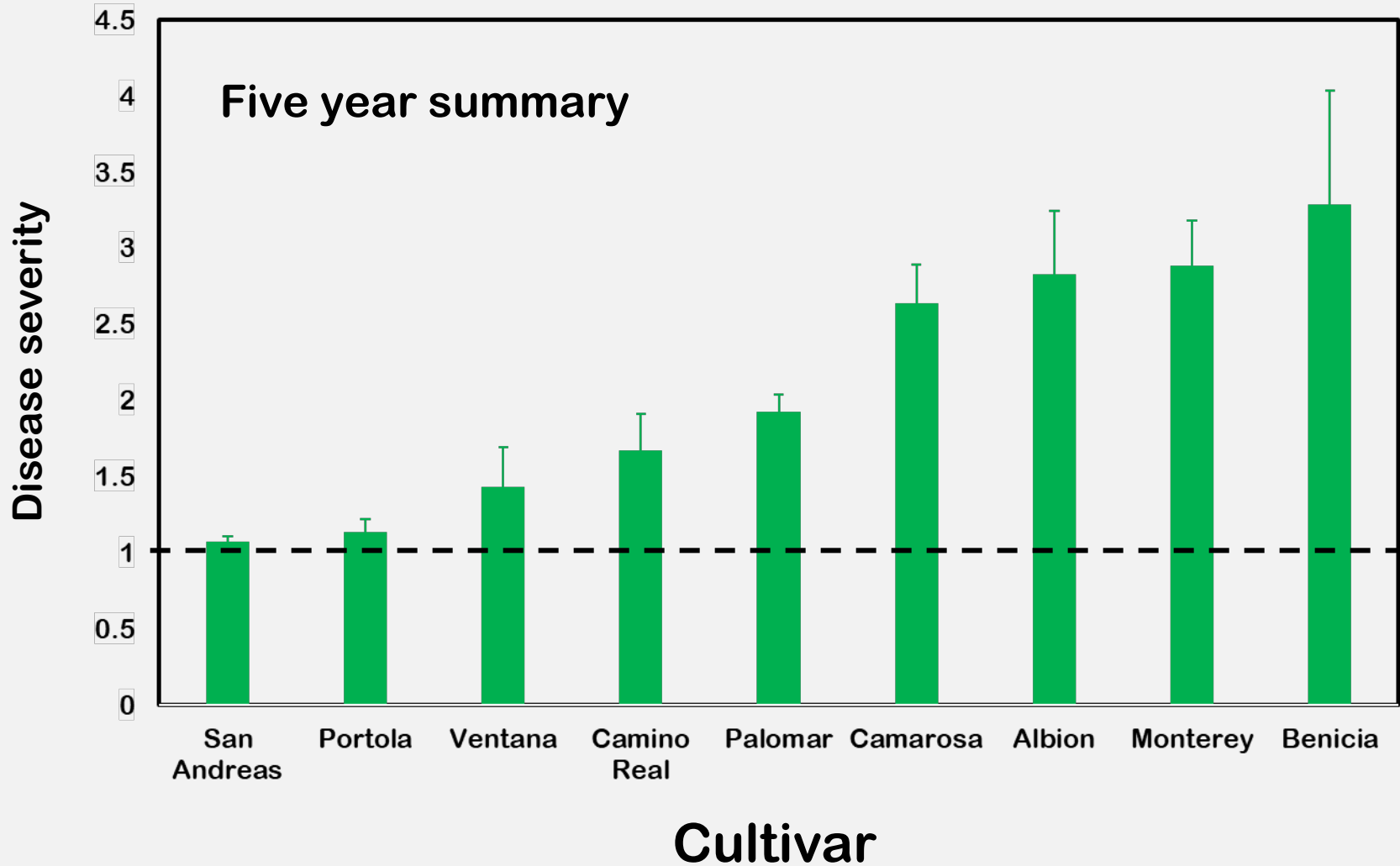


Camarosa



Ventana

Susceptibility to Fusarium wilt

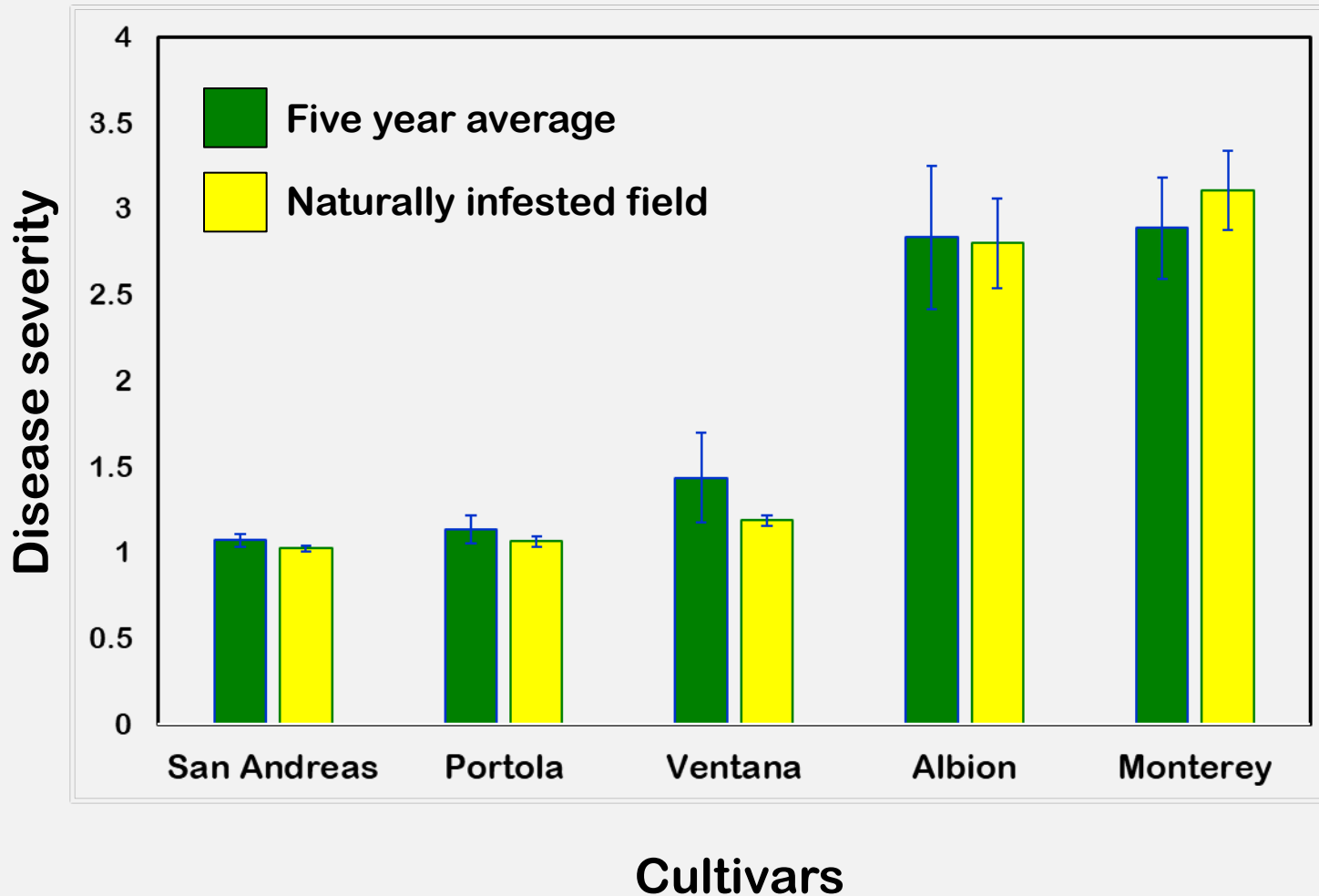


Naturally Infested Field



Comparison of resistance assessments

Correlation coefficient = 0.9908



Genome-Wide Association Mapping Uncovers *Fw1*, a Dominant Gene Conferring Resistance to Fusarium Wilt in Strawberry

Dominique D. A. Pincot,^{*} Thomas J. Poorten,^{*} Michael A. Hardigan,^{*} Julia M. Harshman,^{*} Charlotte B. Acharya,^{*} Glenn S. Cole,^{*} Thomas R. Gordon,[†] Michelle Stueven,[†] Patrick P. Edger,[‡] and Steven J. Knapp^{*,1}

^{*}Department of Plant Sciences and [†]Department of Plant Pathology, University of California, Davis, California, 95616, and

[‡]Department of Horticulture, Michigan State University, East Lansing, Michigan 48824

ORCID IDs: 0000-0001-9768-0740 (T.J.P.); 0000-0002-5188-8084 (J.M.H.); 0000-0001-6498-5409 (S.J.K.)

- ✓ Major gene resistance
- ✓ Can be moved into other cultivars
- ✓ Does not prevent colonization
- ✓ May allow inoculum build-up in soil

Management Of Soilborne Pathogens

- ✓ Avoid introductions

 - Clean plants

 - Don't move soil

- ✓ Reduce inoculum levels

 - Flat fumigation is best

 - Maximize distribution in beds

 - Avoid cane berries and lettuce

- ✓ Use resistant cultivars



Thank You!

california
STRAWBERRY COMMISSION



Lassen Canyon Nursery Inc.



Sierra-Cascade Nursery

"Quality Strawberry Plants"



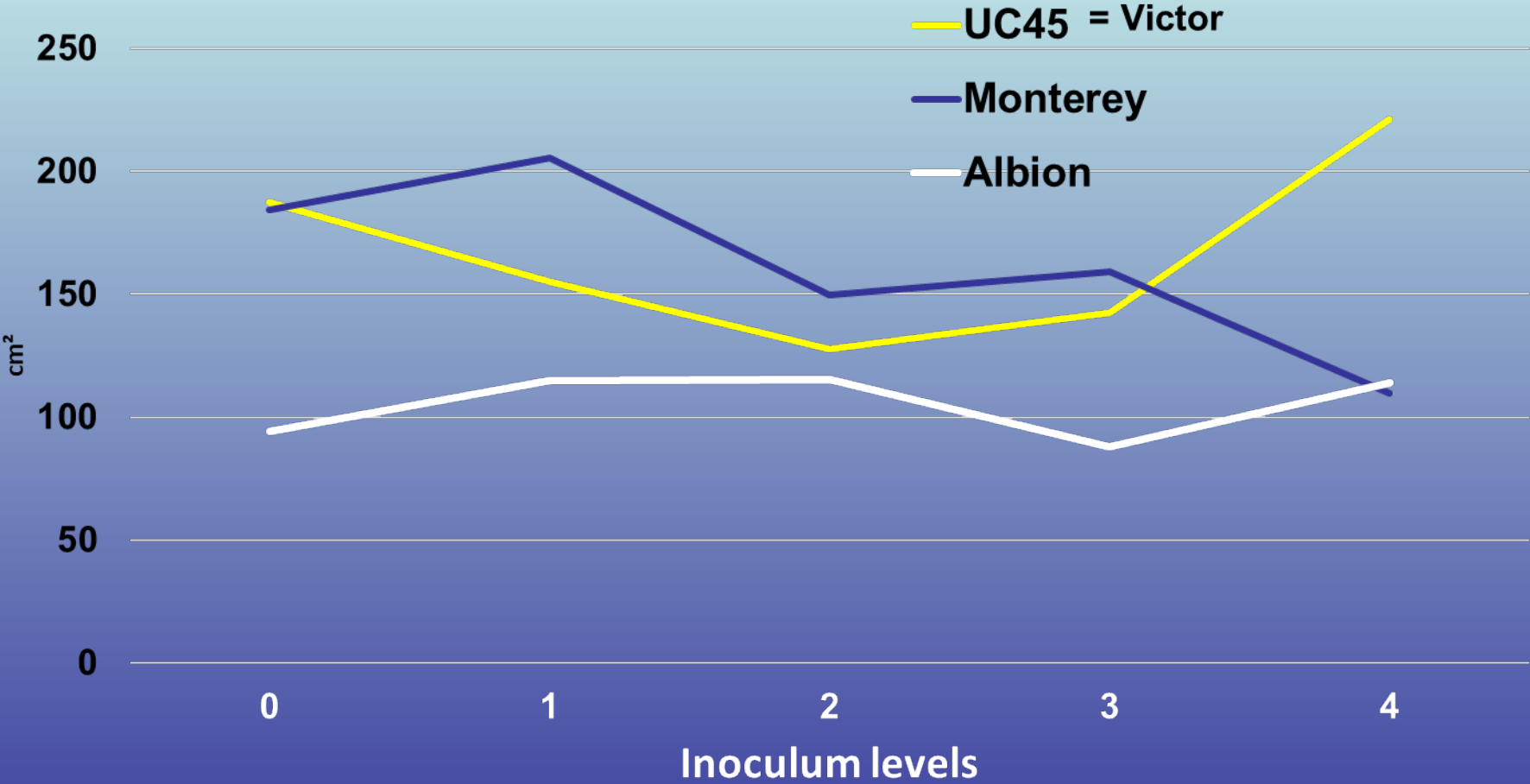
How much Fusarium in soil can my strawberry handle?

2000 CFUs per gram (4),
1000 CFUs per gram (3),
500 CFUs per gram (2),
100 CFUs per gram (1),
0 CFU (just sand) (0).

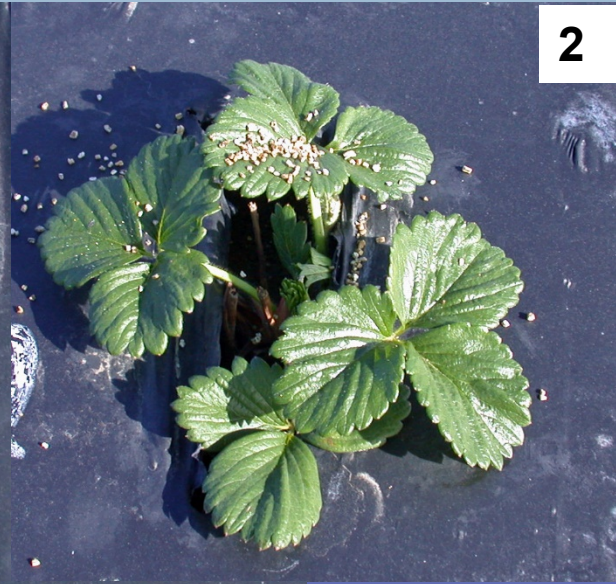
Treatments

- **Soil excavated from planting holes (1L) is mixed with Fusarium-inoculated sand (0.1L) and returned to planting holes**
- **3 cultivars Planted in RCBD plots with 4 reps**

Plant size in response to Fusarium (01/05/2018)



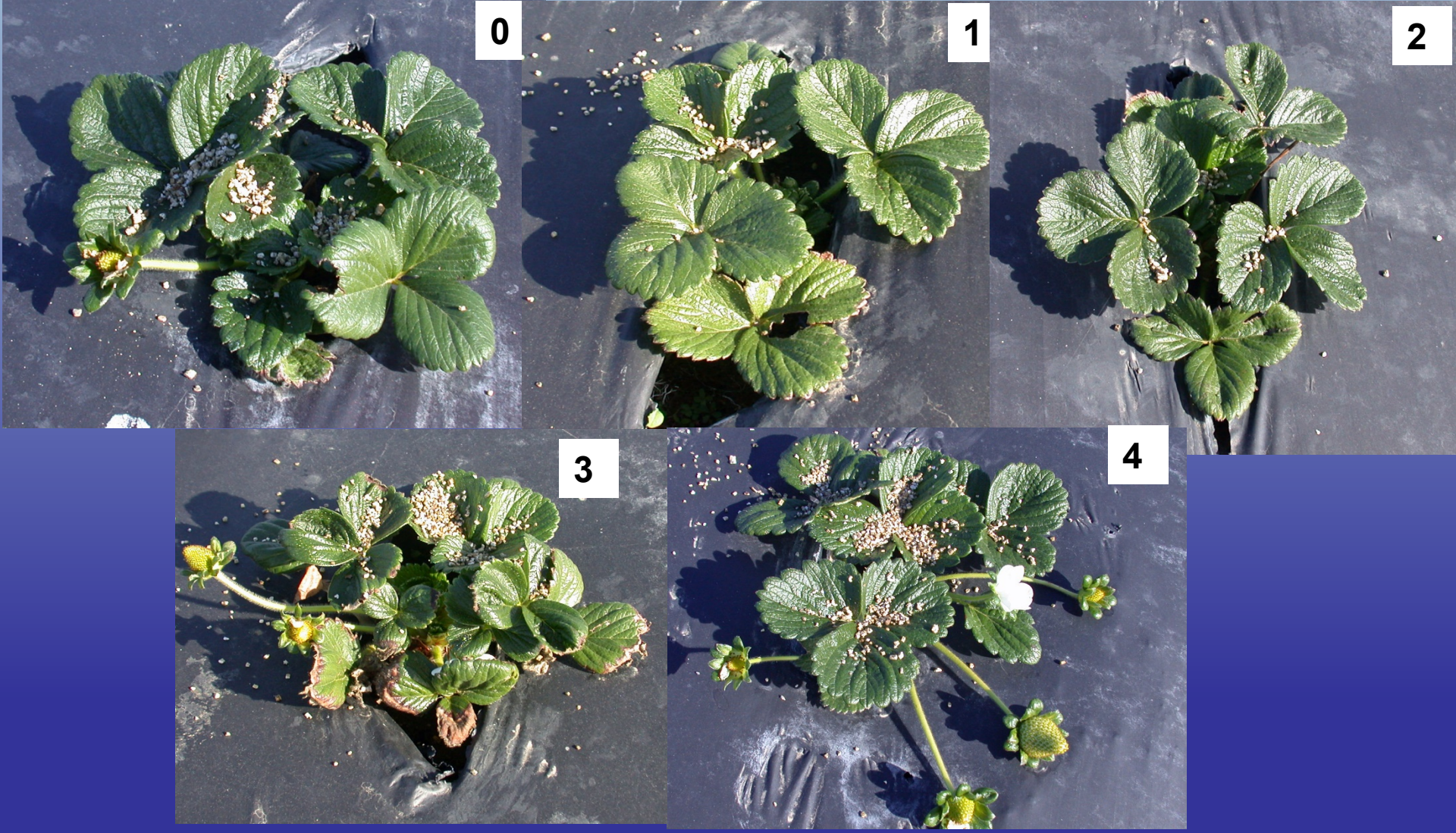
Albion in response to Fusarium (12/02/2018)



Monterey in response to Fusarium (12/02/2018)



Victor in response to Fusarium (12/02/2018)



Albion without Fusarium - May



Albion in response to Fusarium - May



1



2

Albion in response to Fusarium - May

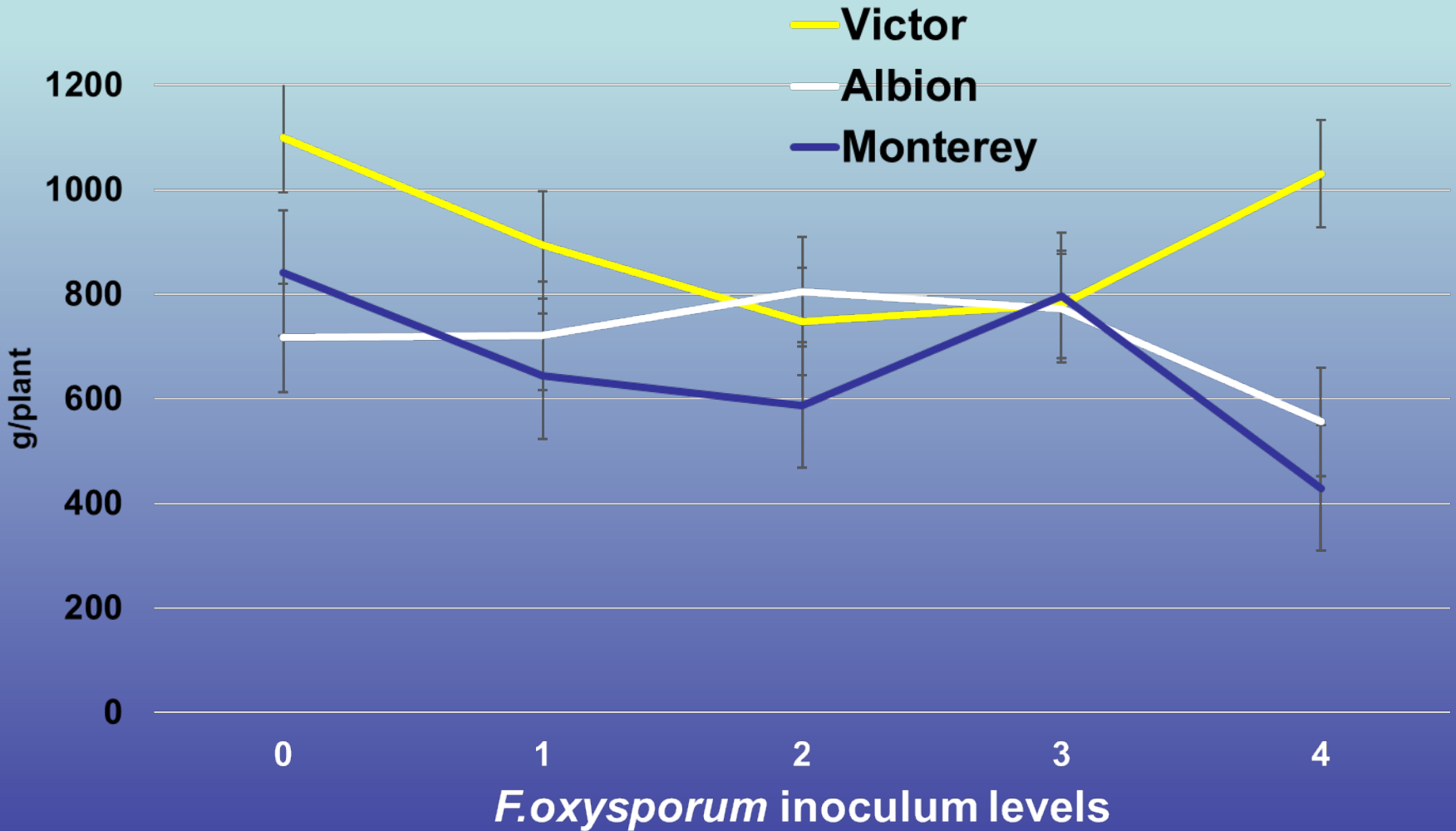


3

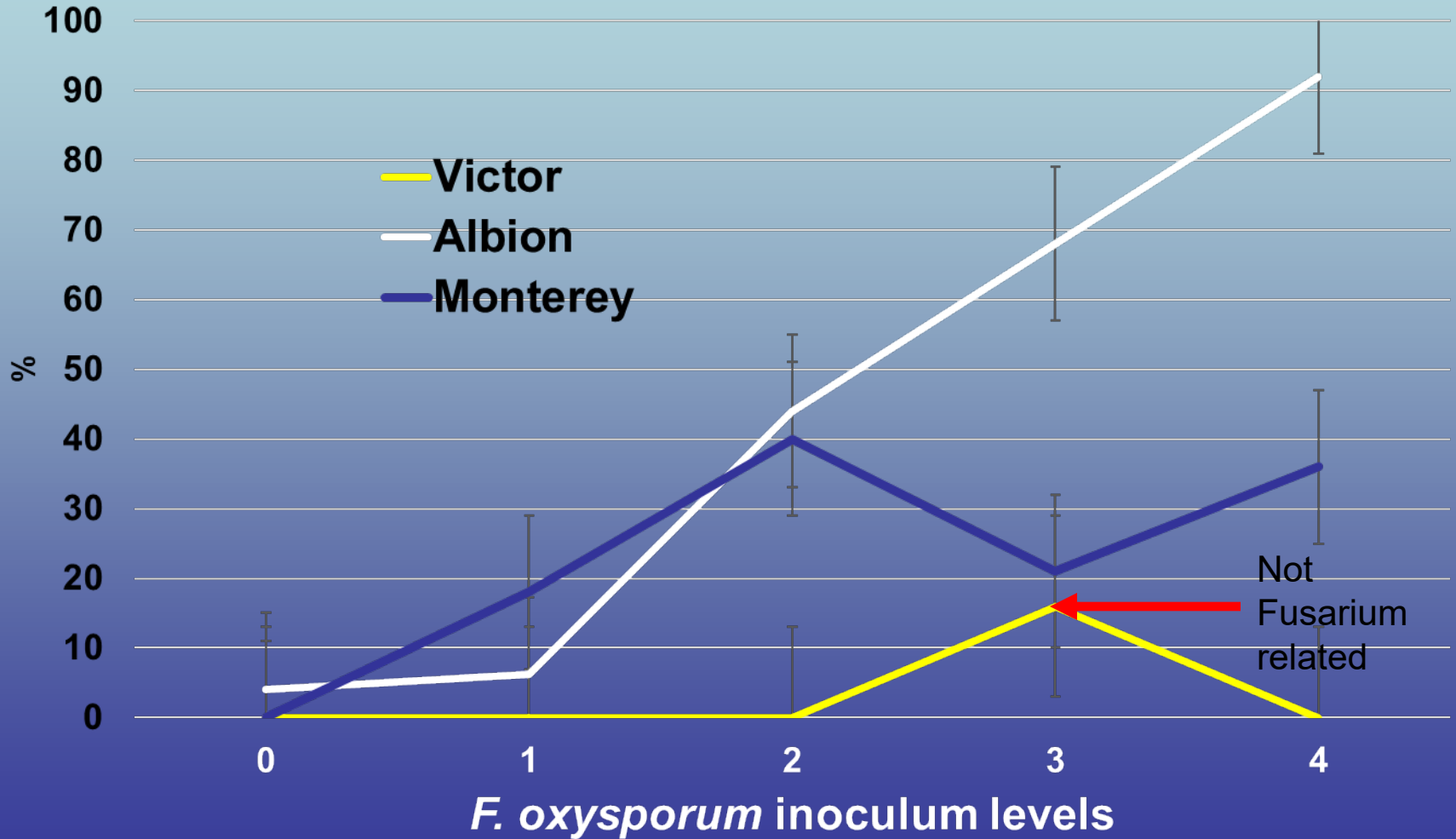


4

Fruit yield (total) in response to Fusarium



Percent mortality due to Fusarium, 07/05/2019



What's next?

- Another season of data to help design prediction models = relationship of pathogen density with cultivar performance
- Do the same for *Macrophomina phaseolina* (charcoal rot pathogen)



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Cooperative Extension



CAL POLY

Leaf blotch (*Zythia fragariae*) an emerging problem to California strawberry industry

Elfar K^{1.}, Hewavitharana, S.S.^{2.}, Holmes, G.^{2.}, Bolda, M.^{3.}, Eskalen, A¹

¹Department of Plant Pathology, UC Davis

²UCCE, Farm Advisor, Monterey and Santa Cruz Co.

³CalPolly, San Luis Obispo

September 19th, 2019

Leaf blotch

- It has been considered a minor problem
- It is an emerging problem especially in **wet years** like 2019



Bolda, M

Symptoms

- Leaf spots that vary from purplish to brownish blotches to light brown necrotic spots
- The blotches are irregular in shape



Symptoms

- The blotches can cover pretty well the **whole leaf**
- Petiole blight



Symptoms

- Lesions on the sepals to completely infected calyx that turned to necrotic and brittle
- As the calyx infections appear those fruits become **unmarketable** causing economic loss to growers and shippers



Steven Koike, UCCE

Symptoms

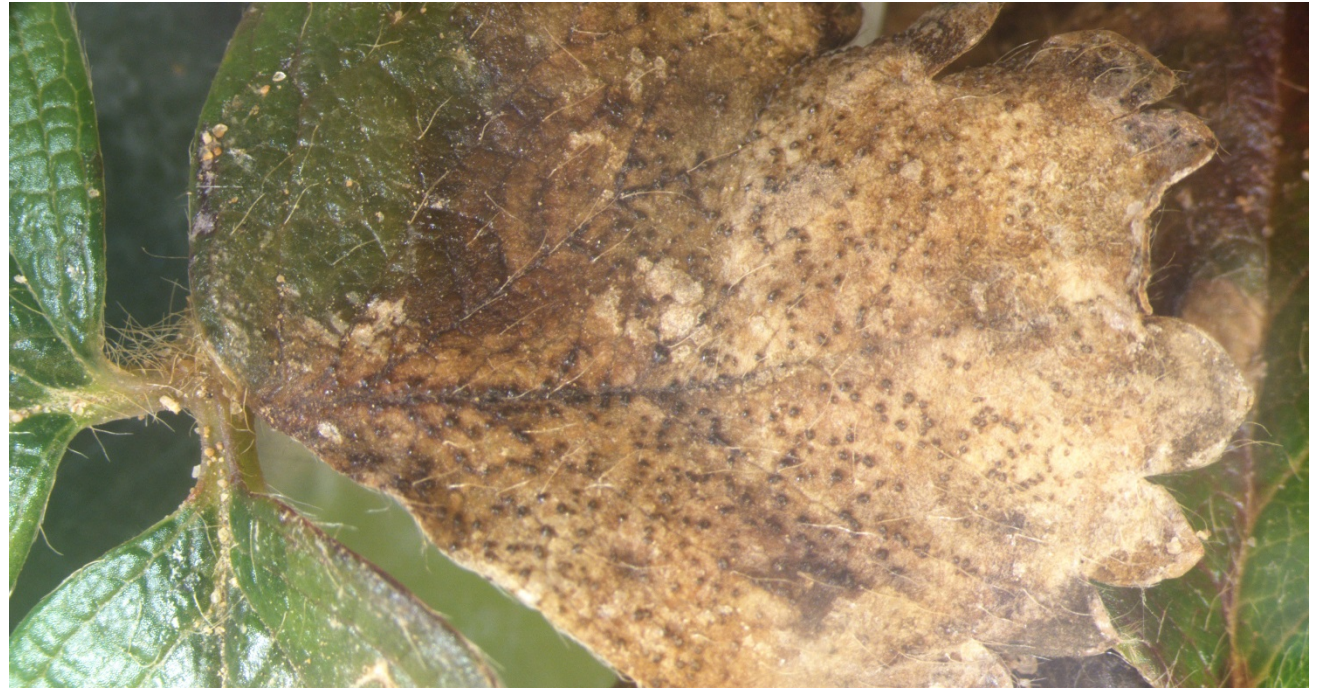
- Fairly firm water-soaked brown rot on nearly ripe fruits, very like the early non-sporulating stage *Botrytis cinerea* infection
- Infected fruit are often invaded by secondary rotting organisms as *B.cinerea*
- Losses due *Z. fragariae* can be attributed to *B. cinerea* due the similarity of symptoms in the early stage



Frank J. Louws

Signs

- The pathogen can produce numerous **pycnidia** containing conidia.



Causal organism

- Anamorph: *Zythia fragariae*
- Teleomorph: *Gnomonia comari*

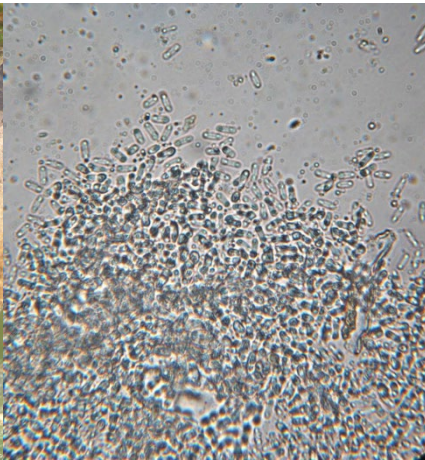


Pycnidia



Eskalen, A

Conidia



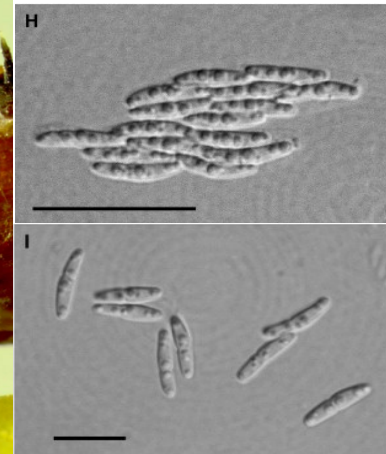
Steven Koike, UCCE

Perithecia



Scott Mattner DPI Vic, 2019

Ascospores



Moročko and Fatehi, 2007

- Leaf blotch is considered a minor disease, nevertheless, **minor disease could get to be a major issue** when appropriate environmental conditions arise.
- It is necessary to be prepared and know the etiology and epidemiology of the disease to be able to control it correctly if necessary

Proposal

(Elfar K., Hewavitharana, S.S., Holmes, G., Bolda, M., Eskalen,A.)

- We propose to study this disease and its pathogen by
 1. collecting and identifying (morphologically and molecularly) isolates from all growing districts
 2. determining optimum growth temperature and moisture requirements and when and under what environmental conditions spores of *Zythia* sp. are released in California strawberry fields
 3. screening for host plant resistance
 4. determining the efficacy of currently labeled fungicides

Thank You



<http://ucanr.edu/sites/eskalenlab>