Integrated Soilborne Disease Management in Organic Strawberries

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Outline

1. Three common lethal soilborne diseases in CA strawberries and needs of diagnostics
2. Non-fumigant-based practices
    - Sanitation and prevention
    - Crop rotation
    - Anaerobic soil disinfestation (ASD)
    - Resistant varieties
    - Integrated approaches

Three Common Lethal Soilborne Diseases in California Strawberries

Disease	Pathogen	Host plant	Survival in soil without a host	Saprophytic
Verticillium wilt (1932)*	*Verticillium dahliae*	>400 species incl. >100 weed species	8-10 years	No
Fusarium wilt (2009)	*Fusarium oxysporum* f. sp. *fragariae (Fof)*	Strawberry only	< 3 years	Yes, especially at 50-68 °F
Charcoal rot (2008)	*Macrophomina phaseolina*	Strawberry only** (strawberry strain found in CA)	< 3 years	Yes, especially at 50-68 °F

* The year first reported in CA.

** Non strawberry strains infect grains, legumes, cucurbits, brassicas, and others. However, our recent study indicated that broccoli rotation increased charcoal rot in strawberries. Need more studies.

Soilborne diseases in CA strawberries

Verticillium dahliae

Fusarium oxysporum f. sp. *fragariae* (F.o.f.)

Macrophomina phaseolina + F.o.f.

Verticillium dahliae + F.o.f.

No pathogen (virus?)

Visual identification is impossible!
Use CalPoly diagnostic lab or commercial labs for the identification

Sanitation and Prevention

- Prevent the spread of pathogens from one field to another
  - Wash/disinfect machines, tools, and shoes

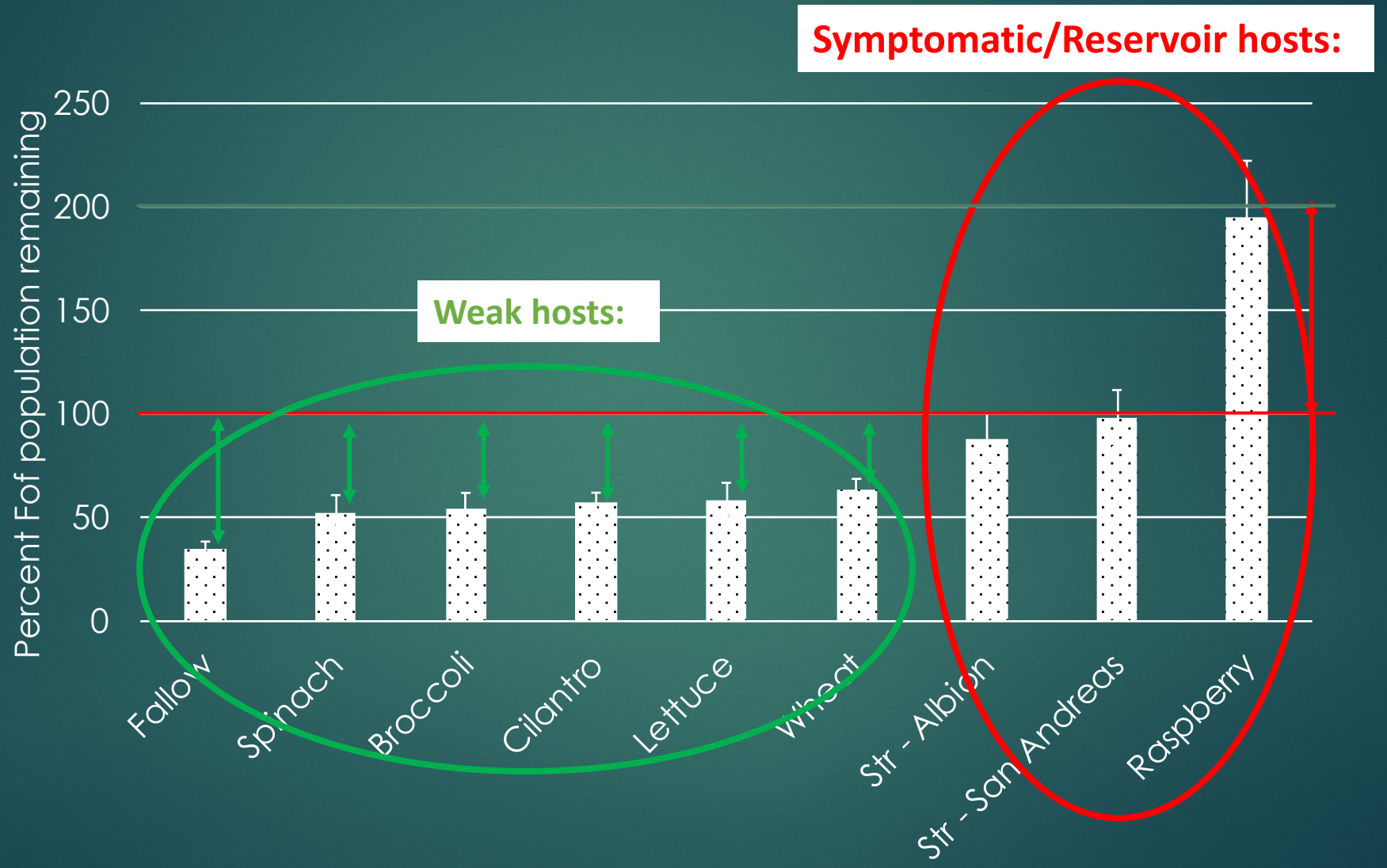
- **Prevention is one of the most important tools** in soilborne disease management in organic strawberries
  - No reactive treatments available

Crop Rotation for Strawberry

- Traditional method employed worldwide to avoid soilborne diseases in strawberries
- Mandatory for organic strawberry production under the National Organic Program
- Minimum of **a 3-year break between two strawberry plantings** recommended in EU and Northeast US and Canada
- Anecdotal local evidence: 2 years or more of break period may be necessary to avoid Fusarium wilt in coastal CA

Change in soil *F.o. fragariae* populations

Inoculated soil, grew 6 weeks, tilled in, then tested at 6 months post tillage

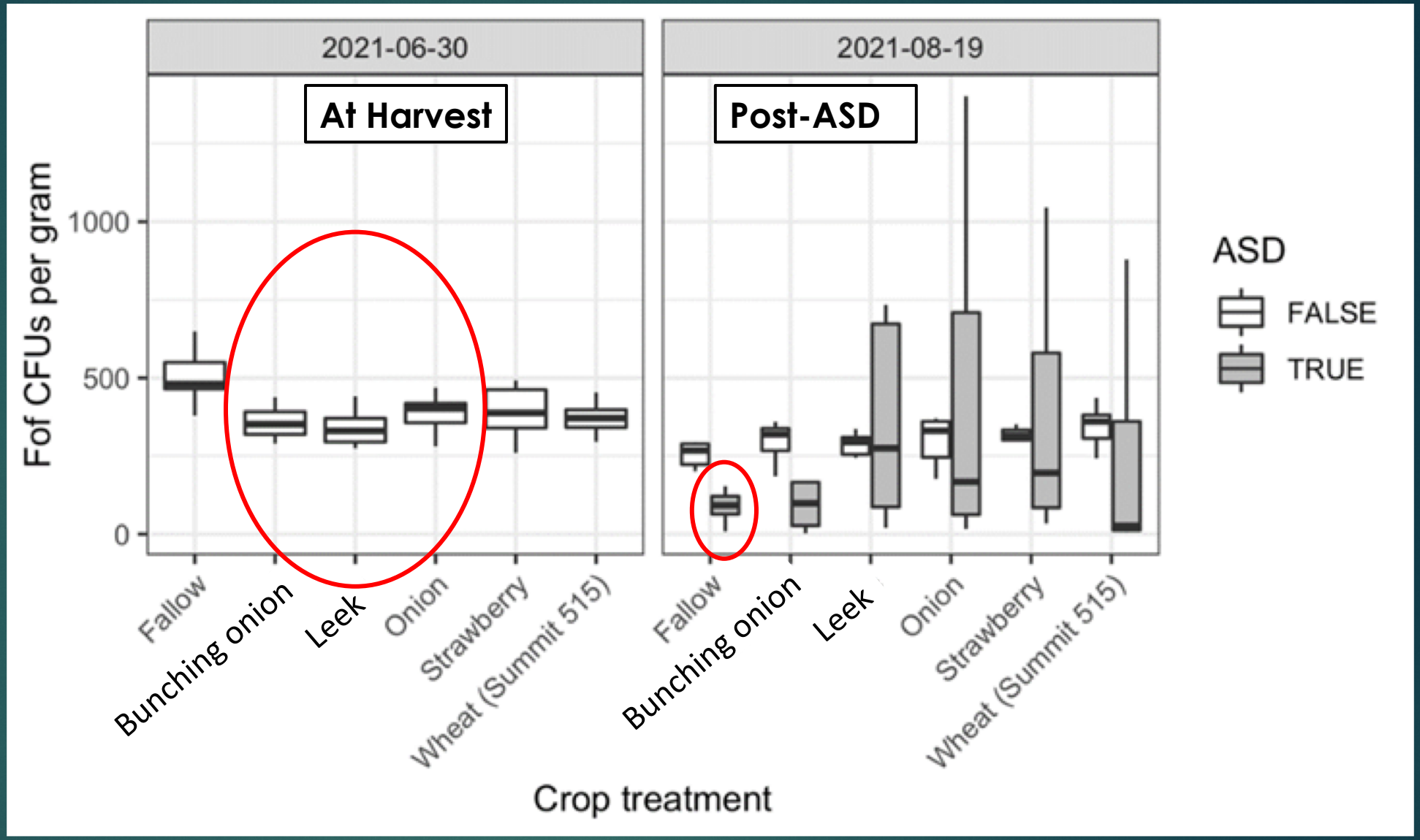


(Courtesy of Peter Henry, USDA-ARS. 2018)

Fusarium wilt suppression by Allium crops

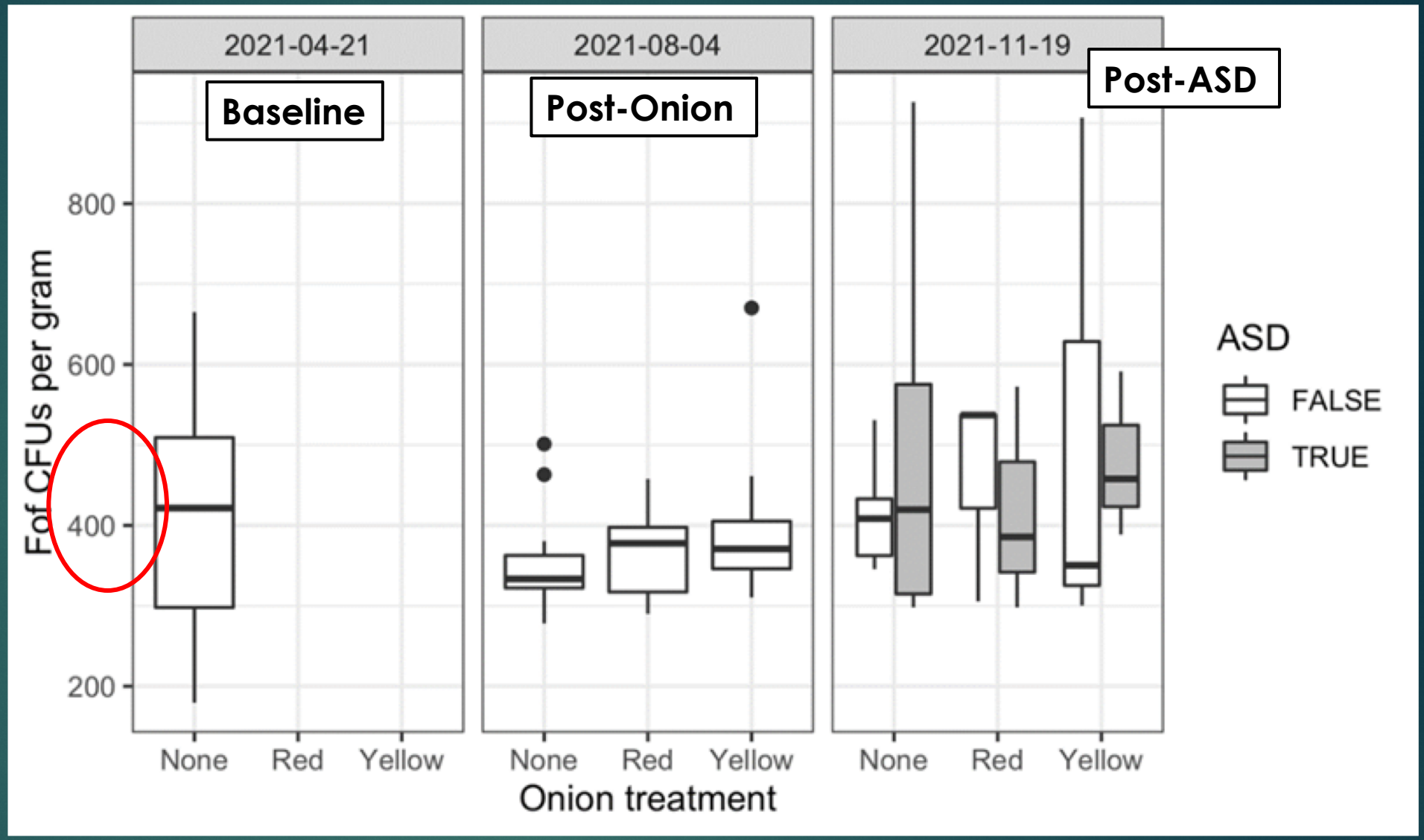
- Asian studies showed Fusarium wilt suppression by onions, leaks, etc.
- Allium roots -> gamma-Glutamyl-S-allylcysteine -> *Flavobacterium* --> *Fusarium wilt suppression*
- *New project in CA (2020-2023)*
  - *Onion as a rotational crop*
  - *Onion as a cover crop*
  - *Co-planting strawberry and bunch onion*

Obj. 1
Pot trial



Effect of growing alliums and other crops and ASD on the *Fusarium oxysporum* f. sp. *fragariae* (*Fof*) population in the soil

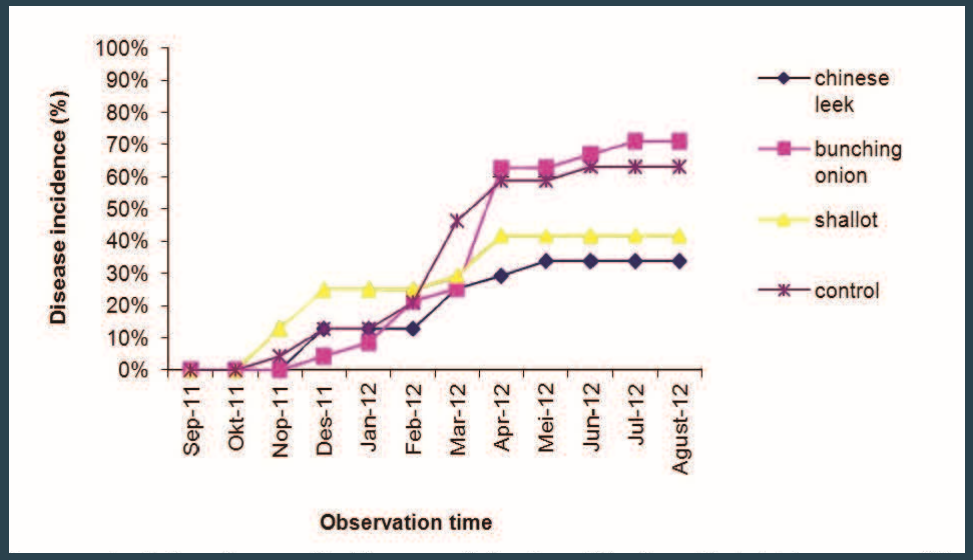
Obj. 3
Field Trial B



Effect of growing and incorporating red and yellow onions and ASD on the *Fusarium oxysporum* f. sp. *fragariae* (*Fof*) population in the soil

Next Steps

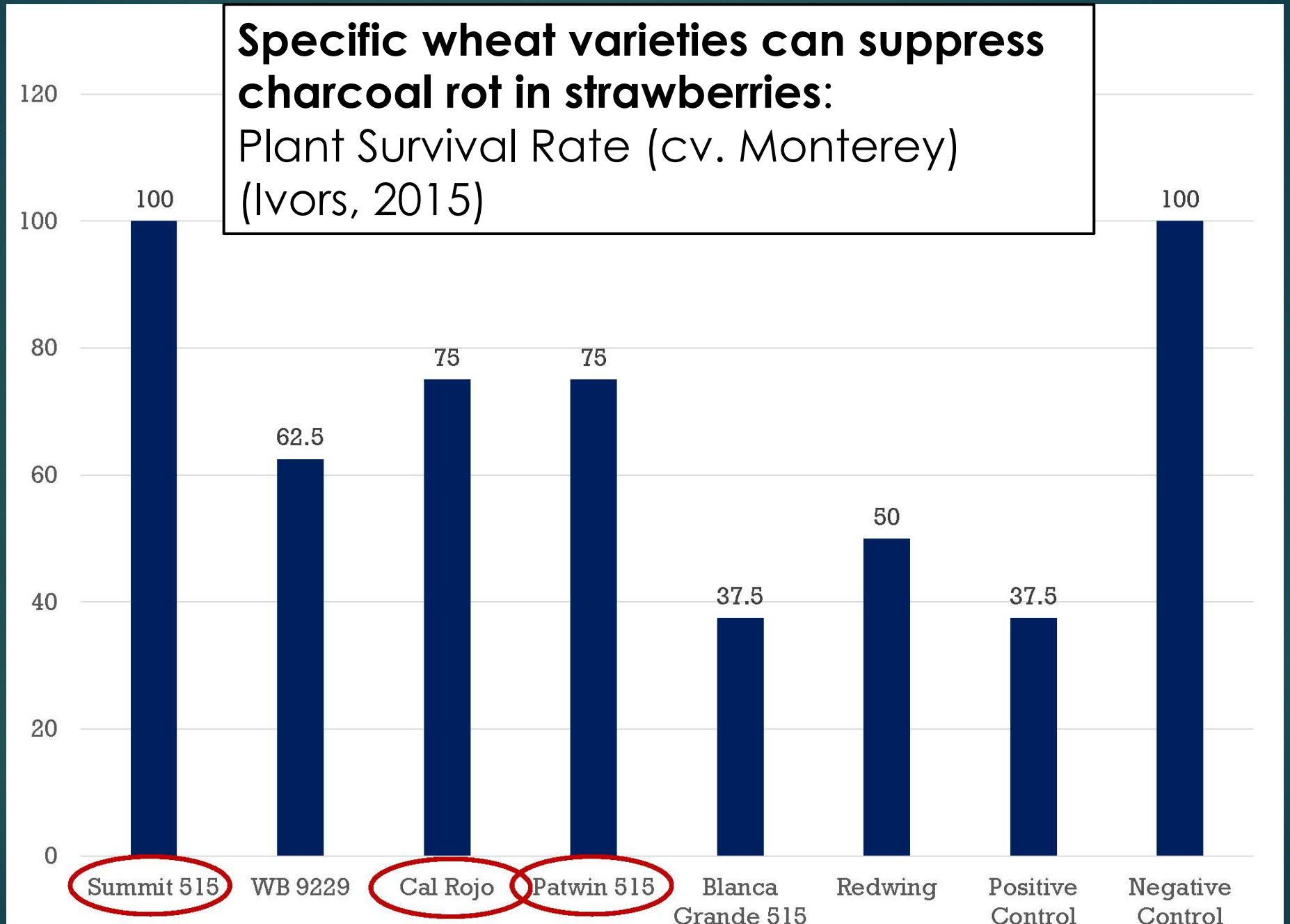
- The pot trials for Objs.1 and 2 are currently being repeated
- Explore the reasons for the ineffectiveness of some alliums
  - Chinese chives (Li et al. 2020; Zhang et al. 2020)?



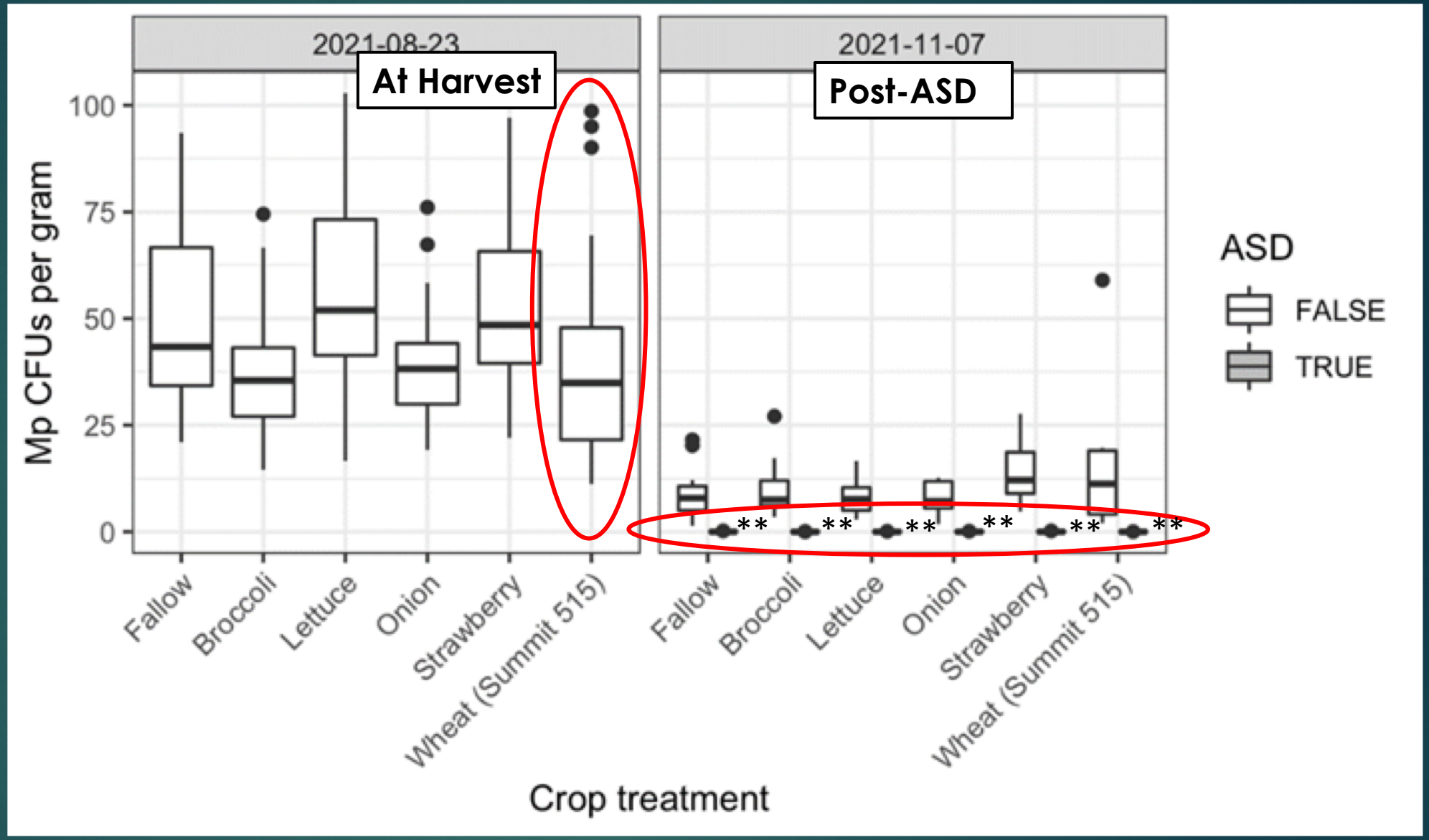
Wibowo et al. 2015

- Suppressing Fo spore germination? (Zhang et al. 2020)
- Demonstration trials for Macrophomina control by ASD

Specific wheat varieties can suppress charcoal rot in strawberries:
Plant Survival Rate (cv. Monterey)
(Ivors, 2015)



Obj. 2
Pot trial



Effect of growing wheat (Summit 515) and other crops and ASD on *Macrophomina phaseolina* (*Mp*) population in the soil

Verticillium dahliae; Host Crops vs. Non-host Crops

- Host crops

  cane berry (raspberry, blackberry), blueberry, artichoke, cucumber, watermelon, pumpkin, mint, eggplant, lettuce, pepper, potato, spinach, tomato

- Non-host crops

  cauliflower, cabbage, celery, parsley, radicchio, onion, garlic, bean, pea, carrot, sweet potato, asparagus

- Suppressive crop

  broccoli

Outbreak of Verticillium wilt at CASFS UCSC Farm in 2001 and 2002 at a field under 7-year crop rotation

Anaerobic Soil Disinfestation (ASD)

Also known as…

- Biological Soil Disinfestation (BSD)
- Reductive Soil Disinfestation (RSD)

~2000: Developed as alternative to methyl bromide fumigation in Netherlands and Japan independently
2002: First ASD trial in CA (UCSC)
2007: USDA MBT grant CA and FL
2011: First commercial scale ASD in CA: 1 acre
2019: **~2,000 acres treated by ASD in CA** (mainly organic berries representing 30-40% of organic strawberry and 4-5% of total strawberry acreages in CA)

ASD research in CA, FL, TN, NC, WA, OR, OH, PA, SC, MI, and VA in the US, and in Netherlands, Japan, China, Italy, Spain, Mexico, Argentina, Sri Lanka, and Nepal for strawberries, vegetables (greenhouses and open fields), tree nuts and fruits, and nurseries

ASD: Three Steps

1.Incorporate organic material

- Provides C source for soil microbes (rice bran in CA)

2.Cover with oxygen impermeable tarp

- Limit the gas exchange and oxygen supply

3.Irrigate to saturation -NOT FLOODING- and maintain the fermentation process for 3 weeks

- Maintain above the field capacity
- Create anaerobic conditions and stimulate anaerobic decomposition of incorporated organic material

Open field in CA

High tunnel in PA

Temporal changes in soil metabolome and microbiome during ASD

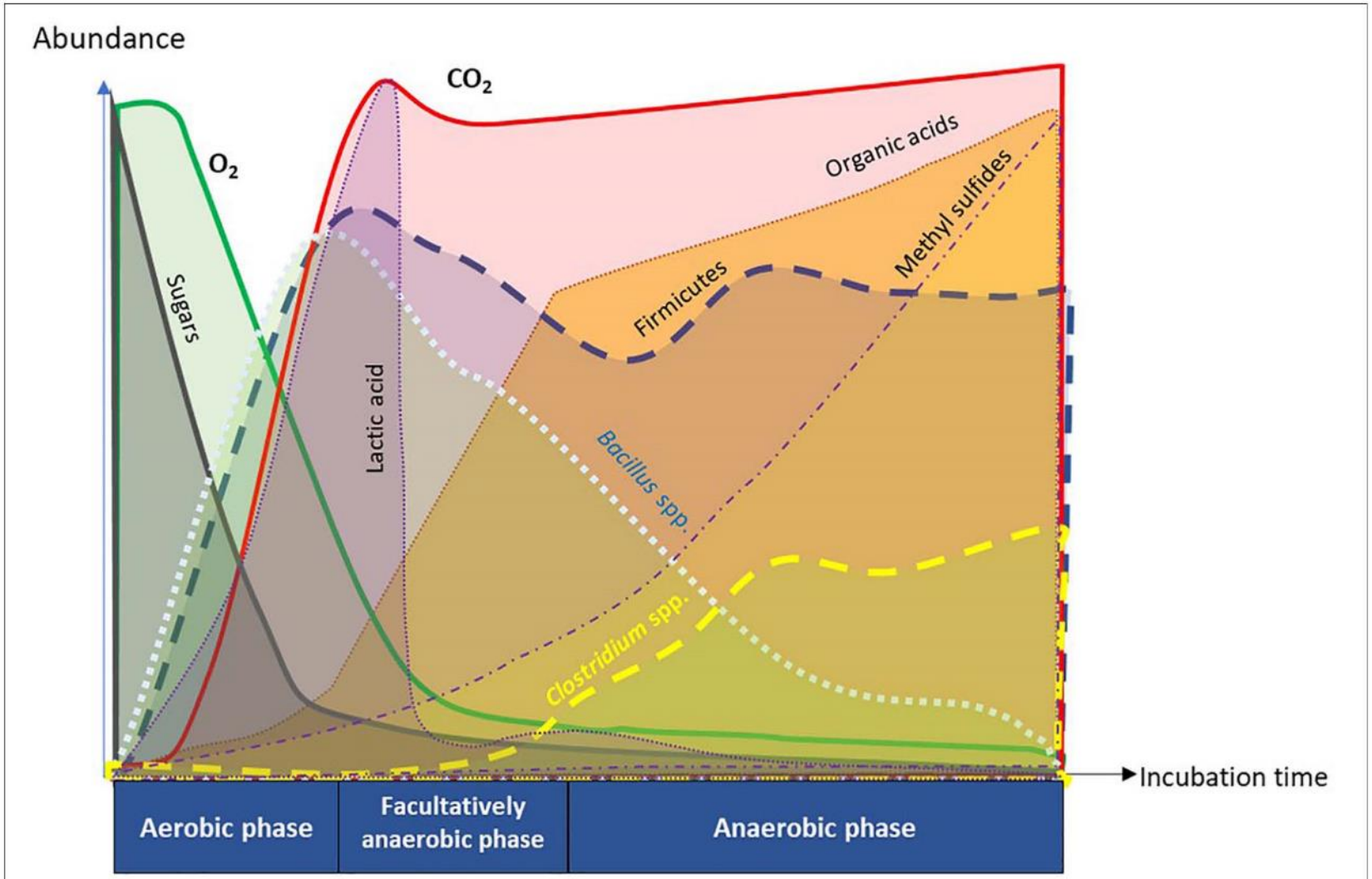


FIGURE 9 | Summary diagram of key functional attributes of anaerobic soil disinfestation (ASD) discerned by temporal dynamics of soil metabolome and microbiome. ASD incubation consists of sequential changes in soil physiology from aerobic, facultatively anaerobic, to anaerobic phases in response to dynamics of O_2 and CO_2. Depletion of O_2 in the soil atmosphere was caused by proliferation of aerobic microorganisms consuming easily degradable organic matter such as sugars. The trend of initial proliferation of *Bacillus* spp. followed by decline was inverse for *Clostridium* spp. in phylum Firmicutes. Population dynamics of *Clostridium* spp. was associated with temporal trends in generation of organic acids and methyl sulfides that are crucial in suppression of soil-borne pathogens.

(Hewavitharana et al., 2019. Frontier in microbio.)

Soilborne disease control by ASD in California strawberries

- Verticillium wilt by *Verticillium dahliae;* 80 to 100% decrease in *V. dahliae* microsclerotia in soil in field trials (Shennan et al., 2018)---**Autumn ASD**

- Charcoal rot by *Macrophomina phaseolina*; ~50% reduction of plant mortality compared to un-treated control (Muramoto et al., 2017)---**Summer ASD**

- Fusarium wilt by *Fusarium oxysporum* f. sp. *fragariea* can be controlled by **summer-ASD** but **autumn-ASD can make the disease worse** (Muramoto et al., 2017, 2020) ---**Rice bran can feed F.o.f!!**

Fusarium oxysporum f. sp. *fragariae** infested field
Strawberry plants (8/14/14)

UTC

ASD Summer
RB 9t/ac

ASD Fall
RB 9t/ac

Higher temperature threshold for *Fusarium oxysporum*

(>460 hours above 86°F at 8” soil depth (Muramoto et al., Acta Hort. 2020))

Good Rotation or Bad Rotation?

Year 1	Year 2	Year 3	Year 4	Year 5	
Strawberry	Potato	Strawberry	Pepper	Strawberry	BAD
Strawberry	Sweet potato	Tomato	Spinach Lettuce	Strawberry	BAD
Strawberry	Spinach Broccoli	Cauliflower Cabbage	Cabbage Broccoli	Strawberry	Too many Brassicas
Strawberry	Lettuce Broccoli	Lettuce Broccoli	Lettuce Broccoli	Strawberry	Maybe Good
Strawberry	Broccoli Lettuce	Broccoli Lettuce	Broccoli Lettuce	Strawberry	Maybe BAD

A S D

A S D

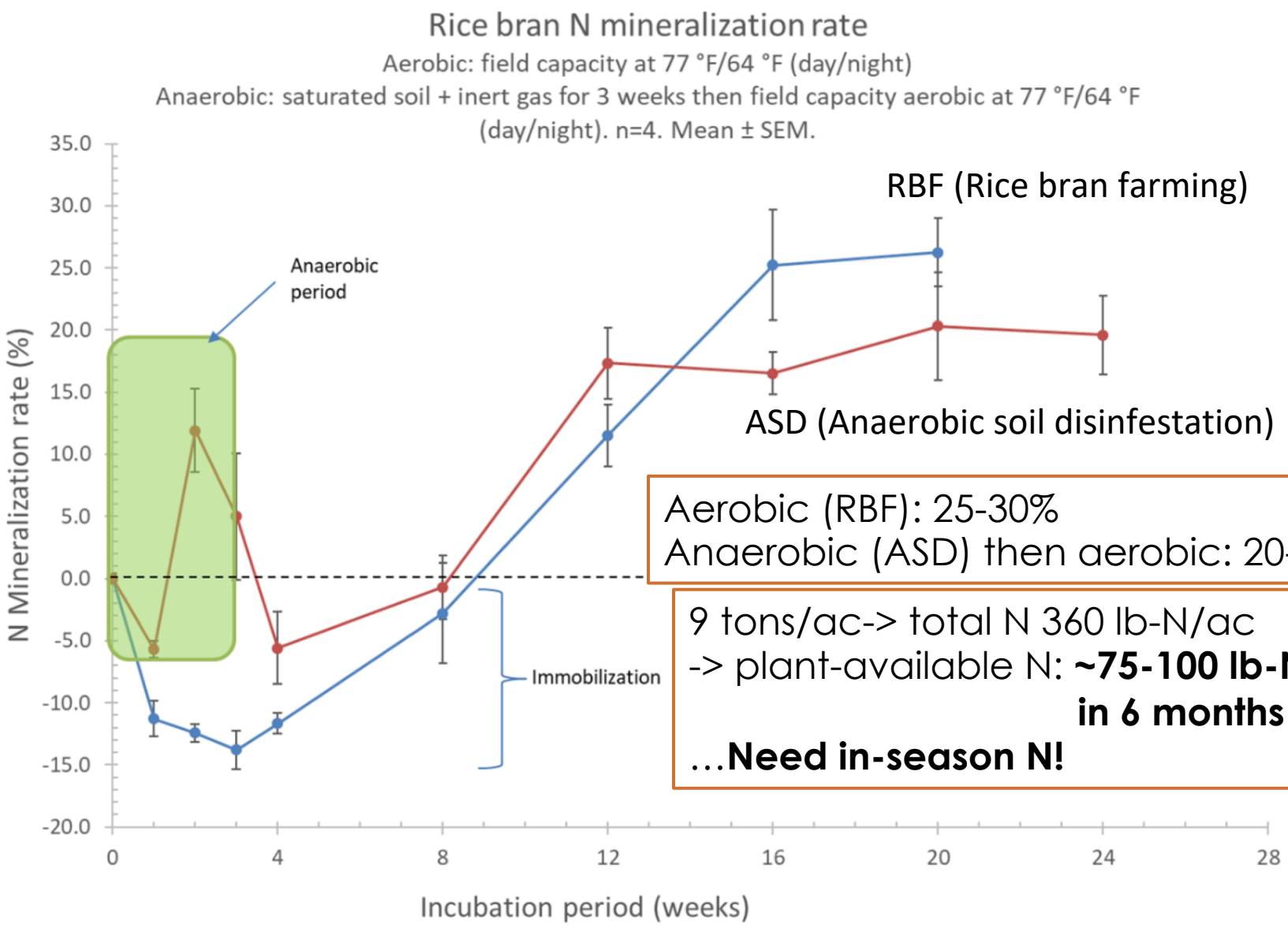
Host

Non-Host

Suppressive

N MINERALIZATION FROM RICE BRAN

(N: 2%, P_2O_5: 3%, K_2O: 1%, CN: 20)



Aerobic (RBF): 25-30%
Anaerobic (ASD) then aerobic: 20-25%

9 tons/ac-> total N 360 lb-N/ac
-> plant-available N: **~75-100 lb-N/ac in 6 months**
…**Need in-season N!**

Use of Resistant Varieties (California Strawberry Commission website)

DN or SD

- ☐ Select all
- ☐ Day Neutral
- ☐ Short Day

Variety

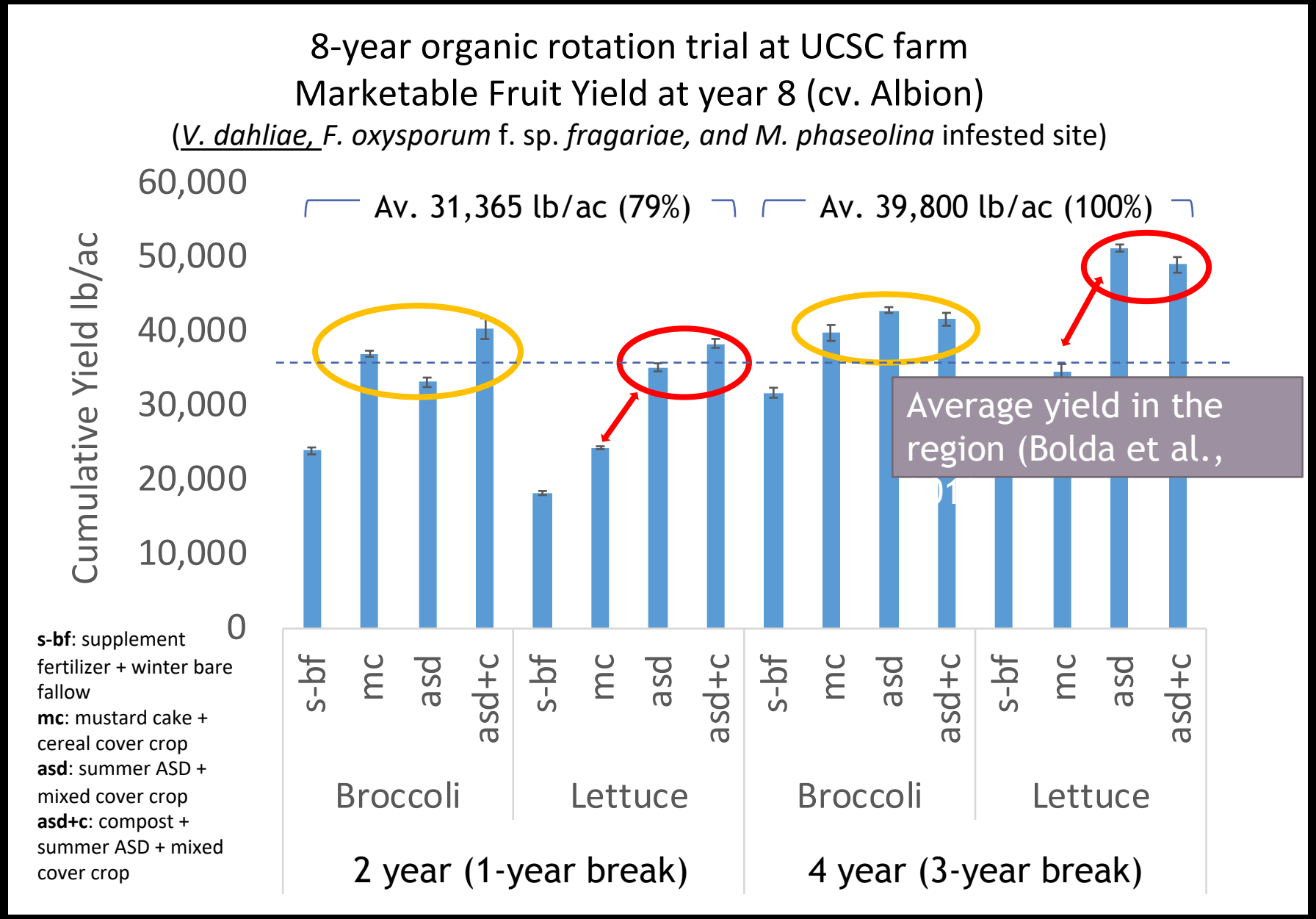
- ☑ Select all
- ☑ Albion
- ☑ Benicia
- ☑ Cabrillo
- ☑ Camarosa
- ☑ Camino Real
- ☑ Diamante
- ☑ Fronteras
- ☑ Gaviota
- ☑ Grenada
- ☑ Merced
- ☑ Mojave
- ☑ Monterey
- ☑ Palomar
- ☑ Petaluma
- ☑ Portola
- ☑ San Andreas
- ☑ Seascape
- ☑ Selva
- ☑ UCD Moxie
- ☑ UCD Royal Royce
- ☑ UCD Valiant
- ☑ UCD Victor
- ☑ UCD Warrior
- ☑ Ventana

Legend Acronym	Legend	Resistance Numerical Category
R	Resistant	1
MR	Moderate Resistance	2
MS	Moderate Susceptibilty	3
S	Susceptible	4

Variety	Type	Macrophomina	Verticillium	Fusarium	Phytophthora
UCD Warrior	SD	2	3	1	2
Portola	DN	4	2	1	2
UCD Victor	SD	3	3	1	2
Camino Real	SD	4	1	3	2
Diamante	DN	3	3	1	3
Fronteras	SD	3	3	1	3
San Andreas	DN	4	2	1	3
UCD Moxie	DN	4	2	1	3
Grenada	SD	2	2	4	3
Petaluma	SD	3	2	3	3
Ventana	SD	4	3	1	3
Palomar	SD	3	3	3	3
Selva	DN	3	2	4	3
UCD Royal Royce	DN	3	2	4	3
Albion	DN	4	2	4	3
Cabrillo	DN	4	2	4	3
Merced	SD	4	3	4	2
UCD Valiant	DN	4	2	4	3
Gaviota	SD	4	3	4	3
Mojave	SD	4	3	4	3
Monterey	DN	4	3	4	3
Benicia	SD	4	4	4	3
Camarosa	SD	4	4	4	3
Seascape	DN	4	4	4	3

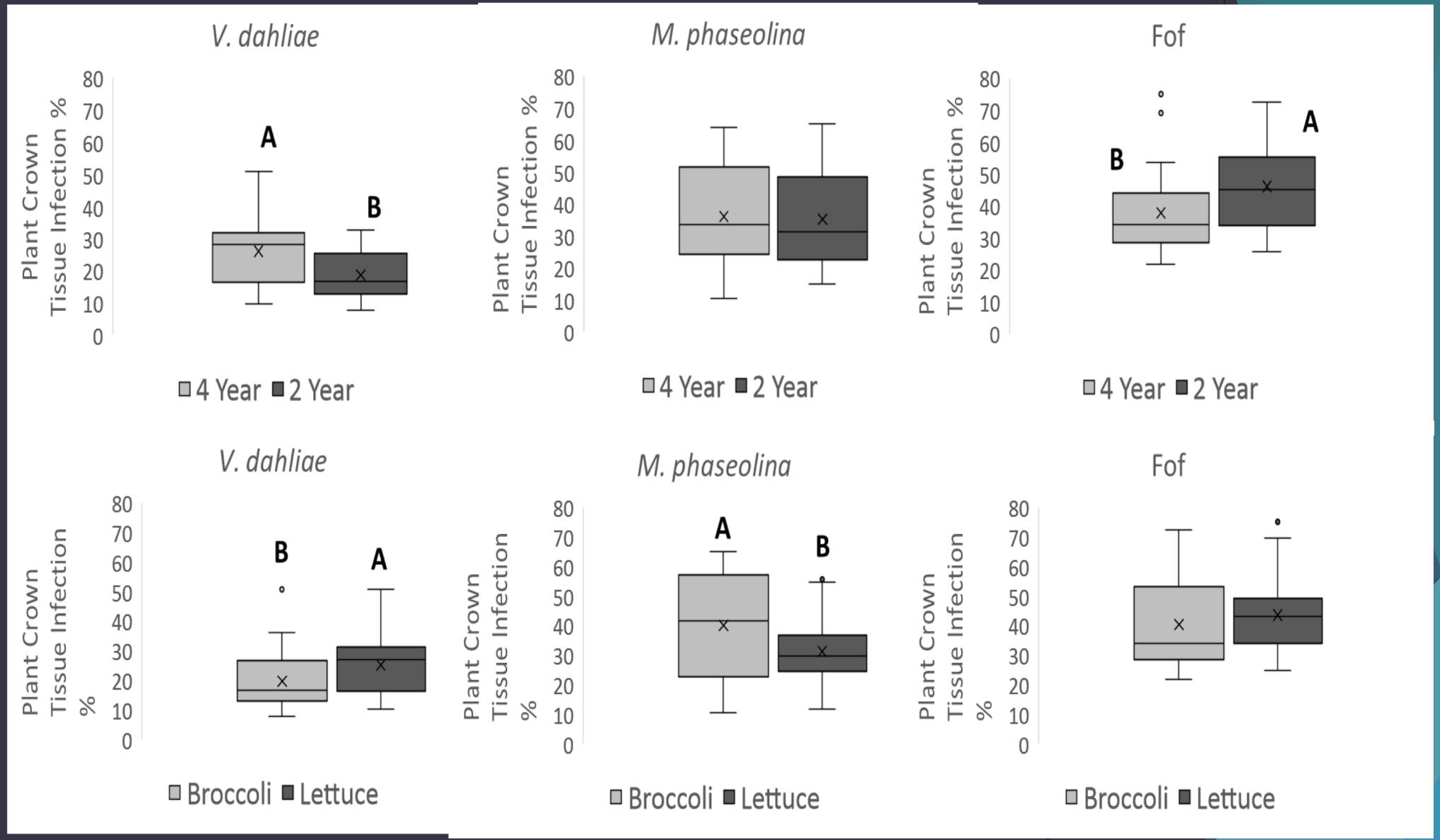
https://www.calstrawberry.com/en-us/Pest-Management/Breeding

Integrated Approach



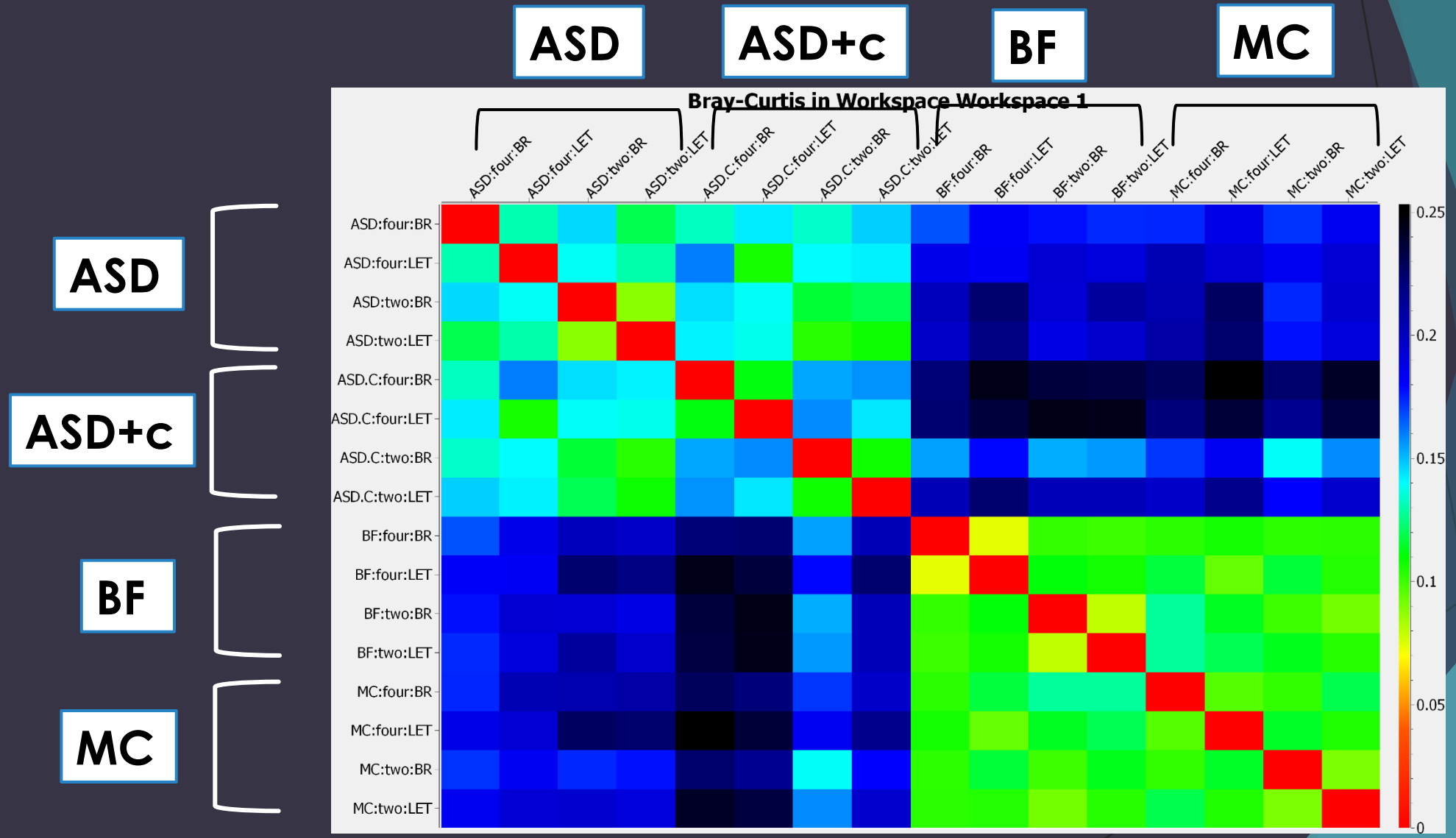
(Zavatta et al., 2021)

Strawberry Crown Infection year 8



(Zavatta et al, 2021)

Bacterial communities cluster by soil management
- the end of year 8 -



(Mazzola et al., unpublished)

Summary (Integrated Soilborne Disease Management in Organic Strawberries)

1. **Sanitation & Prevention**
2. **Diagnostics**

- Plant test → Identify the pathogen! (CalPoly Strawberry Center etc.)

3. **Management practices (Integrate as much as you can)**

- Verticillium wilt (*Verticillium dahliae*)
  Resistant variety, avoid host crops in rotation, broccoli*, Autumn ASD
- Fusarium wilt (*Fusarium oxysporum* f. sp. *fragariae*)
  Resistant variety, 2+ yr break, avoid rose family crops in rotation, allium crop rotation/co-planting*, Summer ASD
- Charcoal rot (*Macrophomina phaseolina*)
  Resistant variety*, grass cover crop, Summer ASD

* Studies in progress

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Thank you!
Question?

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