

Prunus replant biology and use of anaerobic soil disinfestation (ASD) and whole orchard recycling (WOR) as preplant soil management options

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- California DPR

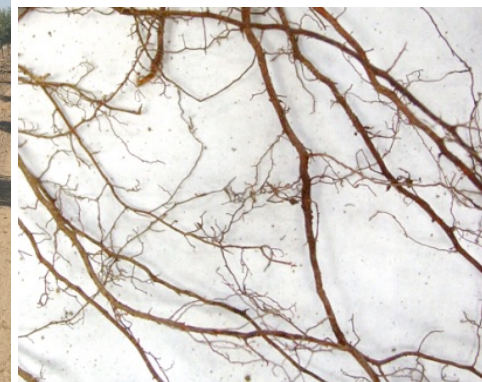


Agricultural
Research
Service



Overview, Prunus replant problems

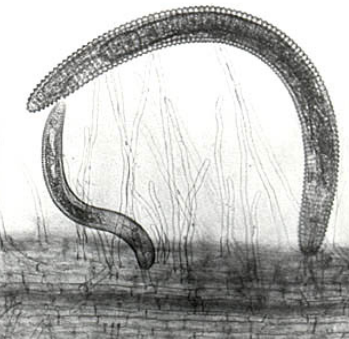
- **Prunus replant disease (PRD)** Microbe-induced growth suppression; commonly occurs in *Prunus* after *Prunus*; severity varies
- **Plant-parasitic nematodes** (ring, lesion, root knot), approx. 35% of almond and fresh stone fruit acreage (McKenry)
- **Aggressive pathogens & pests** (e.g., *Phytophthora*, *Armillaria*, *Verticillium*, Ten-Lined June Beetle, gophers!)
- **Abiotic factors** (physical, chemical conditions related to previous production)



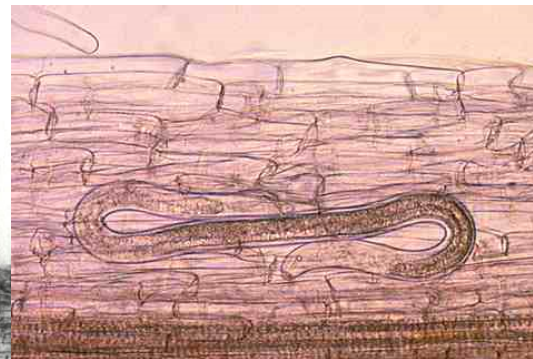
Healthy tree

RD-affected tree

(Butte County)



Ring nematode



Lesion nematode

Phytophthora crown rot

Prunus replant disease (PRD)

Madera
County, near
Firebaugh



Current effective preplant fumigation options for *PRD* vs. *plant parasitic nematodes*

1,3 dichloropropene (1,3-D) (Telone II)

- Good for mgt. of nematodes, weak on PRD

Chloropicrin (CP)

- Good for mgt. of PRD, weak on nematodes

1,3-D + CP (mixtures & co-applications)

- Good for mgt. of both PRD and nematodes

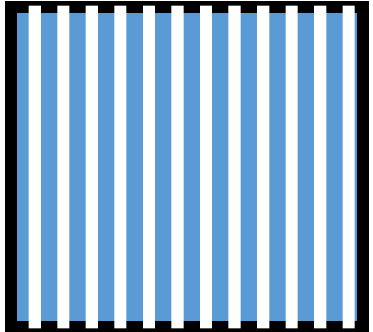


New GPS-controlled technology offers varied and precise fumigant placement (TriCal, Inc.)

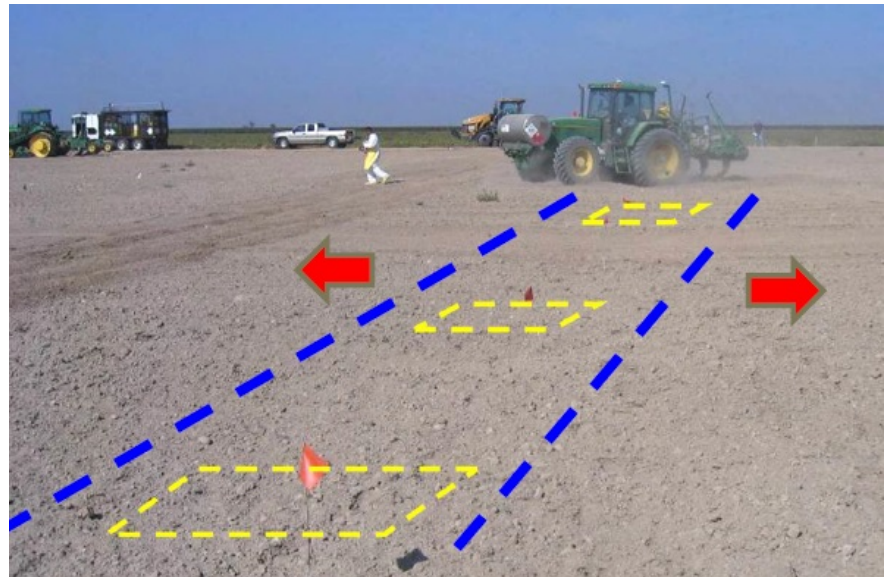
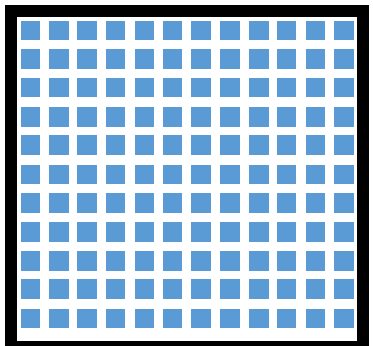
Broadcast
100% coverage



Strip
50% coverage



GPS-Grid
<20% coverage



Summaries of fumigation studies available online:
<http://californiaagriculture.ucanr.edu>

**California
Agriculture**

**Methyl bromide
alternatives**

Volume 67 Number 3

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Challenges related to fumigant use for fruit, nut, and vine perennials in California



- Large footprint >2 million acres
- Water use scrutiny, production efficiency important
- Need to replace many 10's of thousands of ac / yr
- Air quality, human safety issues; urban proximity
- Increasing regulatory restrictions

Challenges continued: Old orchard residue management:

Burning often not allowed, yet many cogeneration plants closed. Delays vs. whole orchard recycling (WOR). Residue management decisions critical, impactful.



Scheduling and proper ground preparation complicated, WOR implications for replant biology and remediation treatments not well known, being studied.



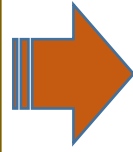
One approach to addressing fumigation challenges...



Roots, soil collected pre- and post-plant.

Multiple trials, orchards & greenhouse

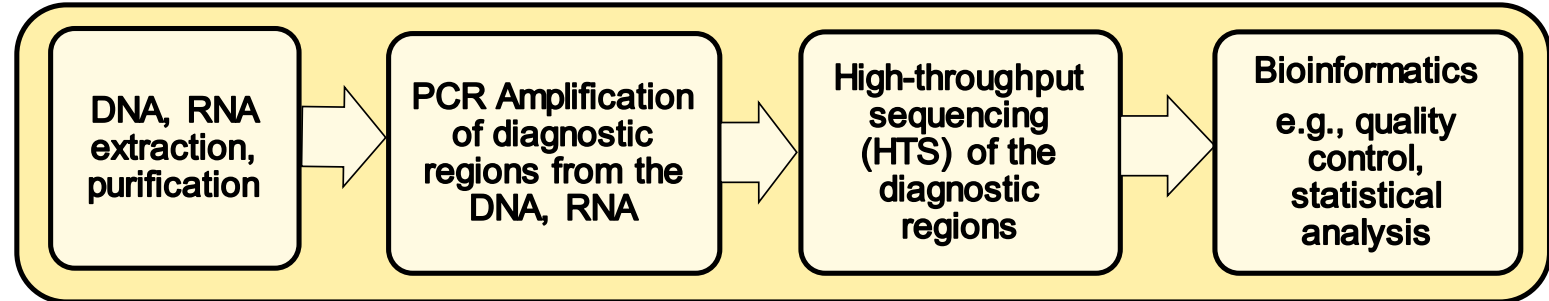
Elucidate mechanisms of PRD induction, develop predictive diagnostics



Relate tree growth to soil physical and chemical properties



Relate tree growth to characteristics of root and soil microbial communities



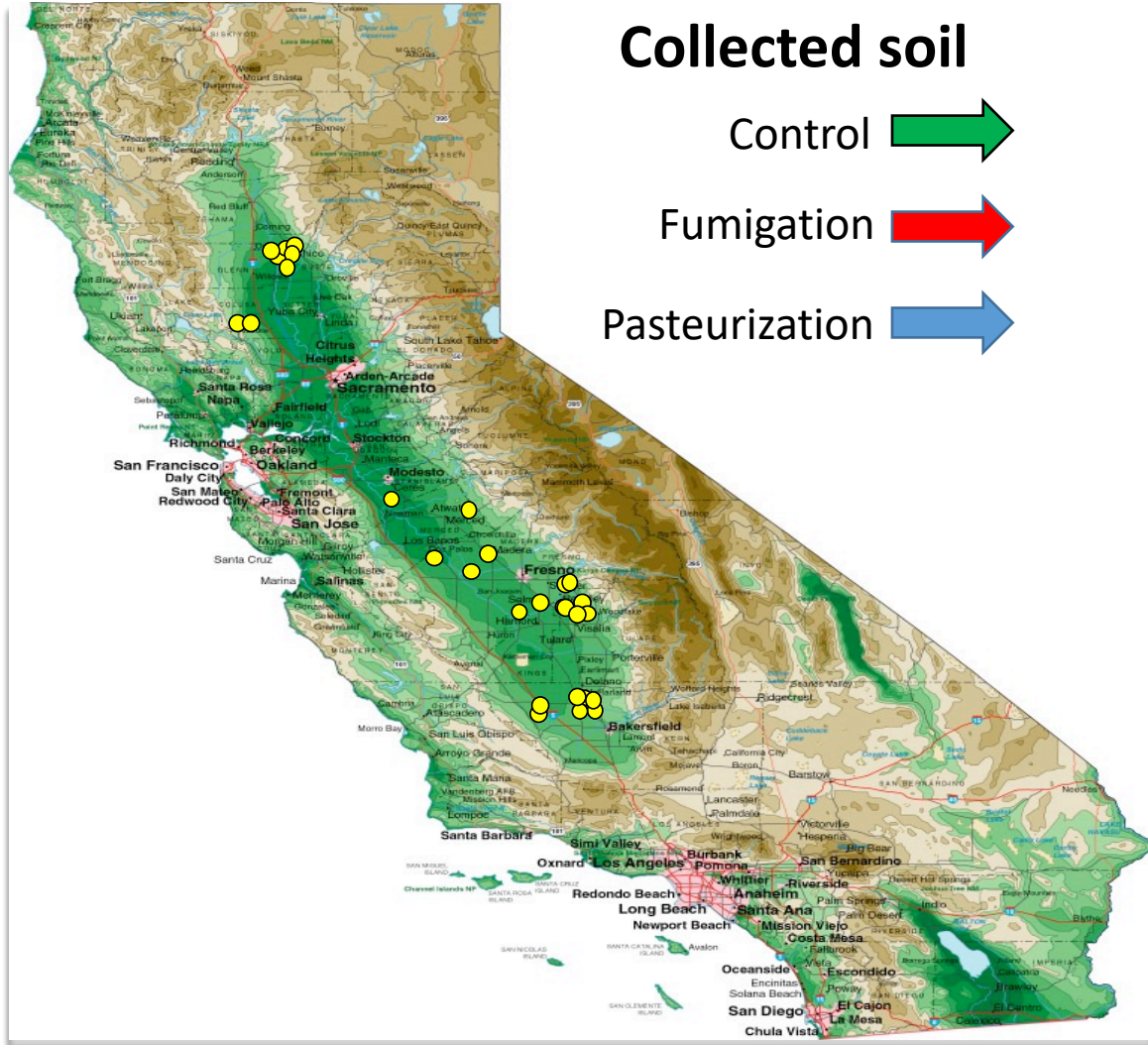
PCR primers used:

- 515F-806R (v4 16S, bacteria)
- 799F-1192R (v5-v7 16S, bacteria) used for WOR
- ITS1f-ITS2 (ITS1, fungi)
- fITS7-ITS4 (ITS2, fungi)
- ITS1oo-ITS7 (ITS1, oomycetes)
- ITS3oo-ITS4 (ITS2, oomycetes)

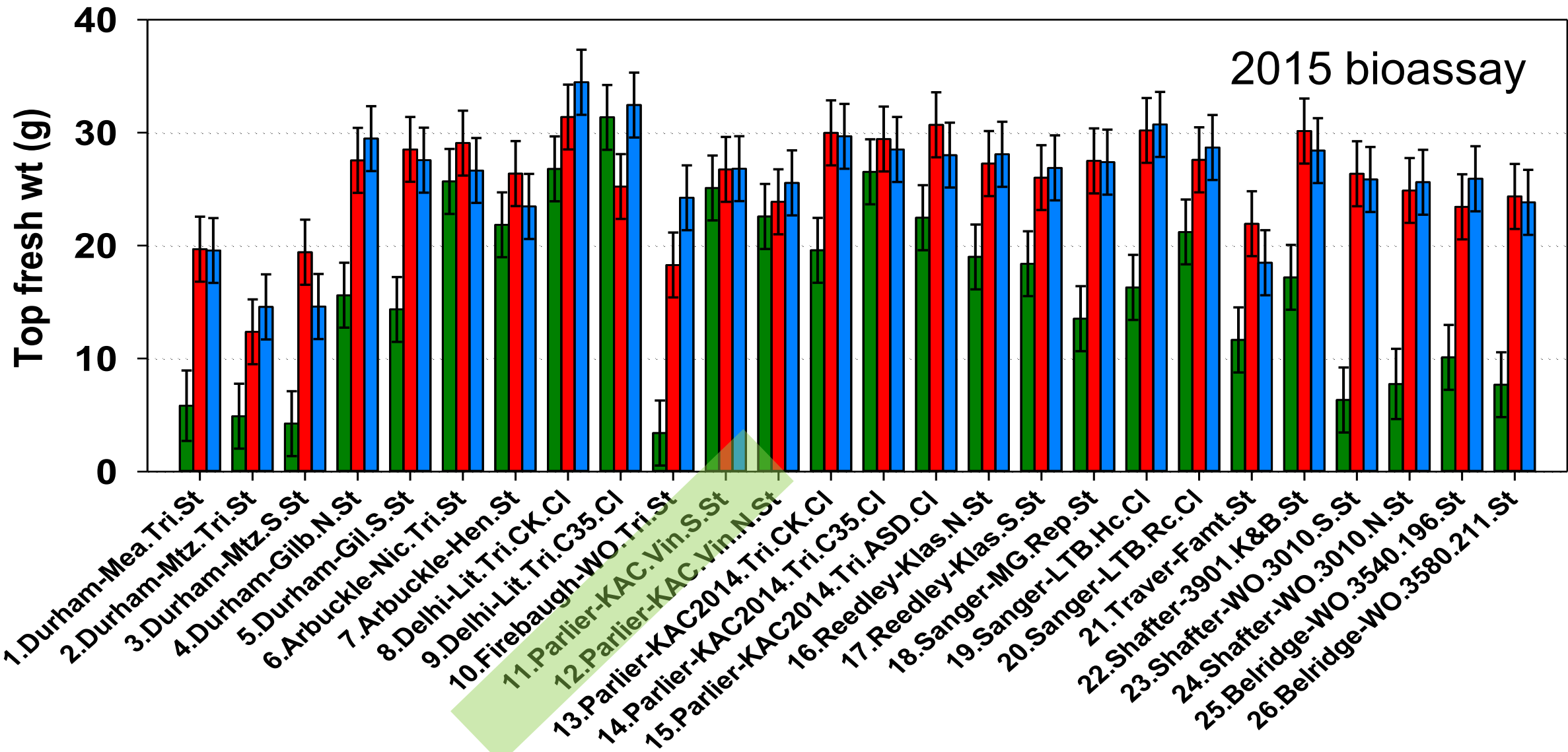
Goal:

Identification of **soil properties** and **organisms** well-linked to replanted orchard performance

Bioassays revealed that PRD widespread but not a problem in all soils, a basis for predictive diagnostics

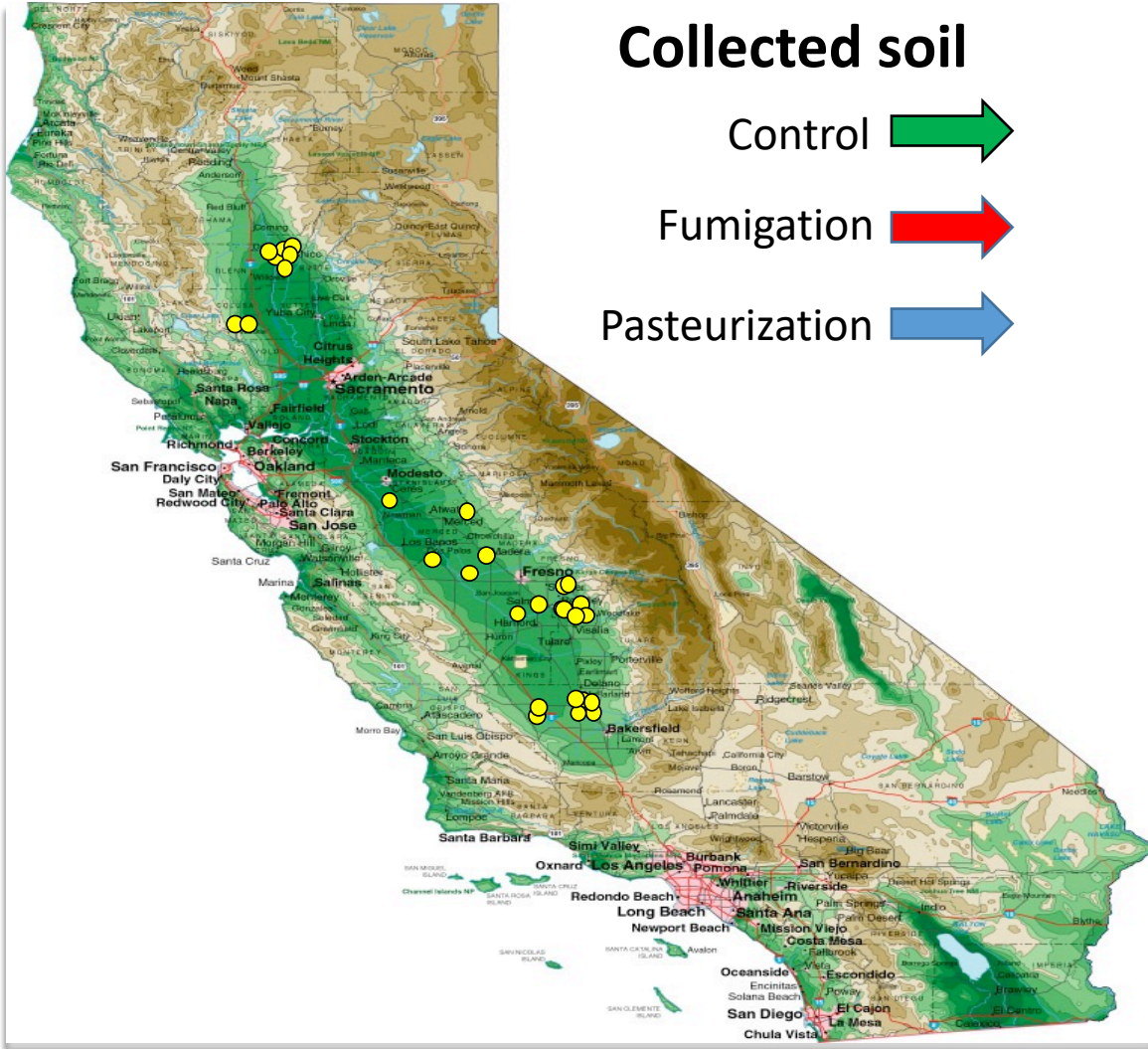


Control **Fumigated** **Pasteurized**



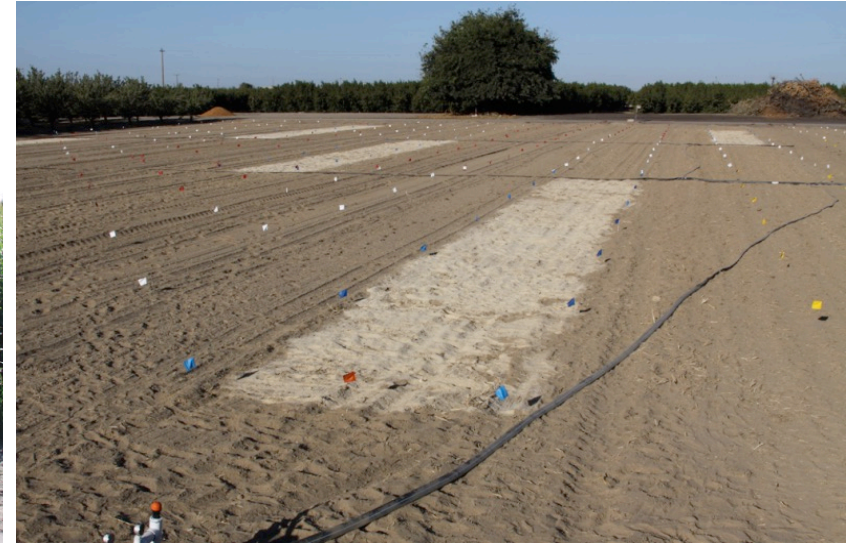
Bioassay results

Growers and PCAs may be able to help in development of predictive diagnostics; **soil bioassays and orchard trials, within limits**



Another approach to address fumigation challenges...

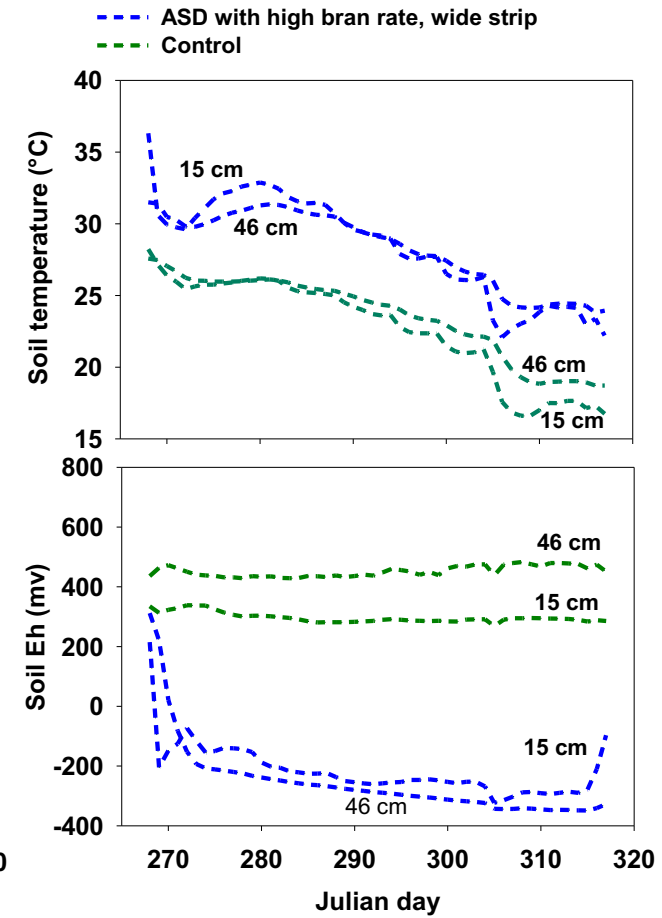
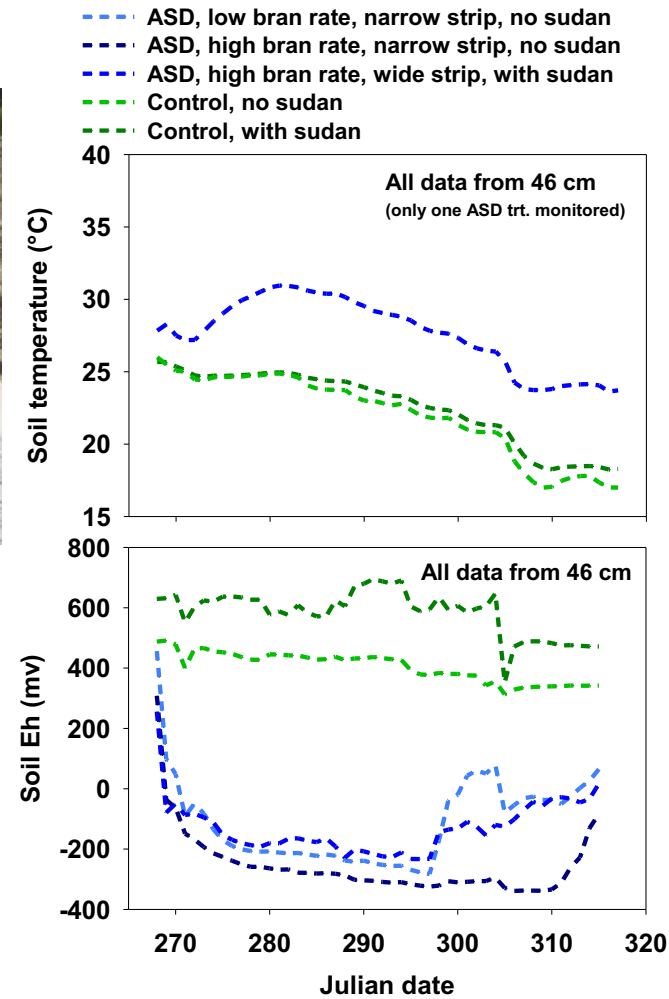
Anerobic soil disinfestation (ASD). “First-generation” trials, related activities



First-generation ASD trials



- Rice bran hand-applied (shovel)
- Tractor rotovation to 15 cm depth
- Auxiliary drip system, TIF tarp

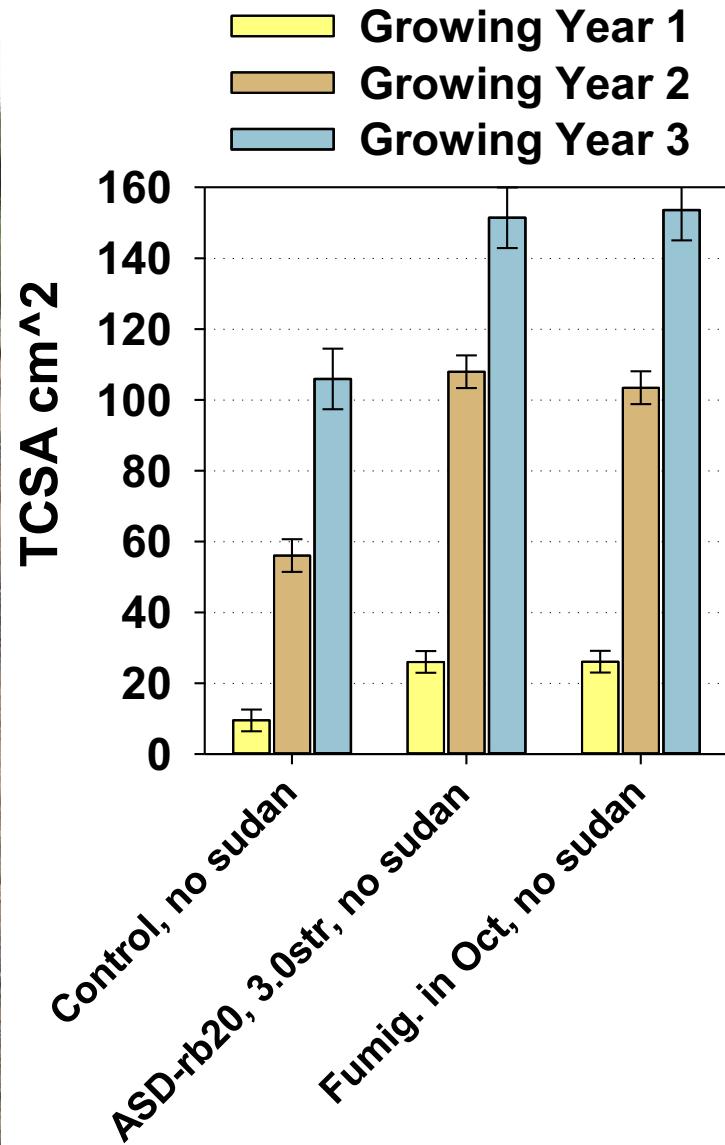


Effects on tree growth

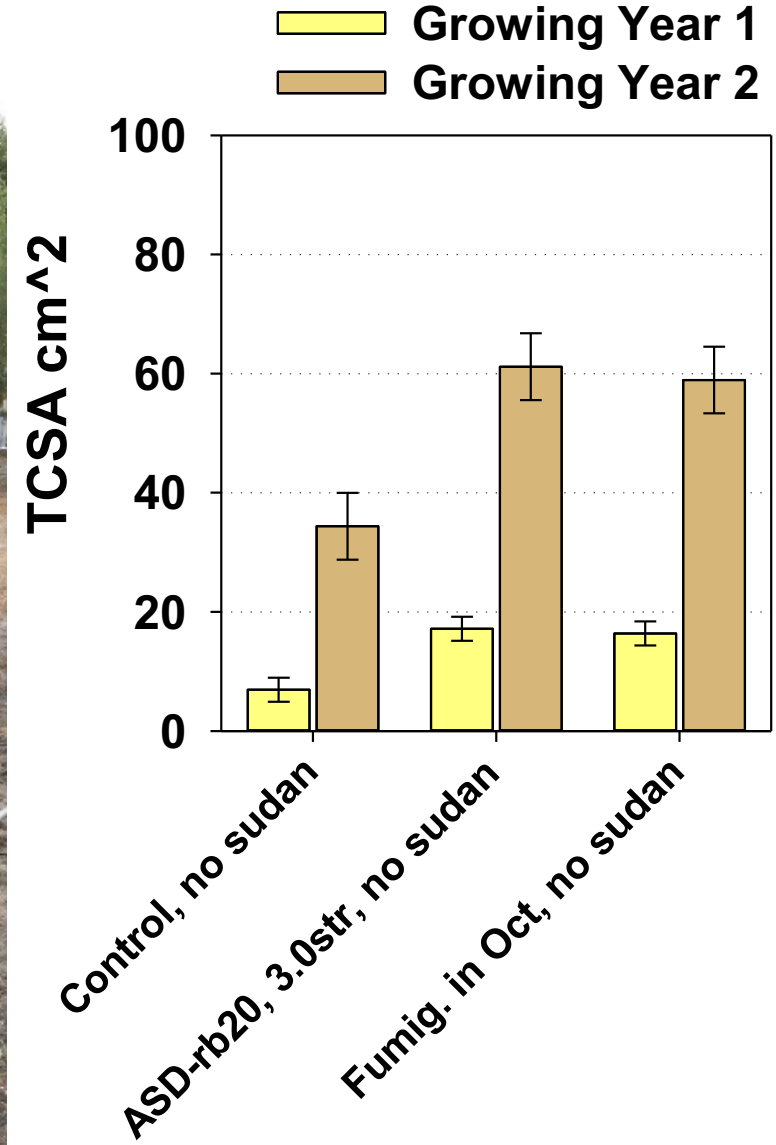


Tree growth, “small” repeated experiments

Trial started 2013:



Trial started 2014:

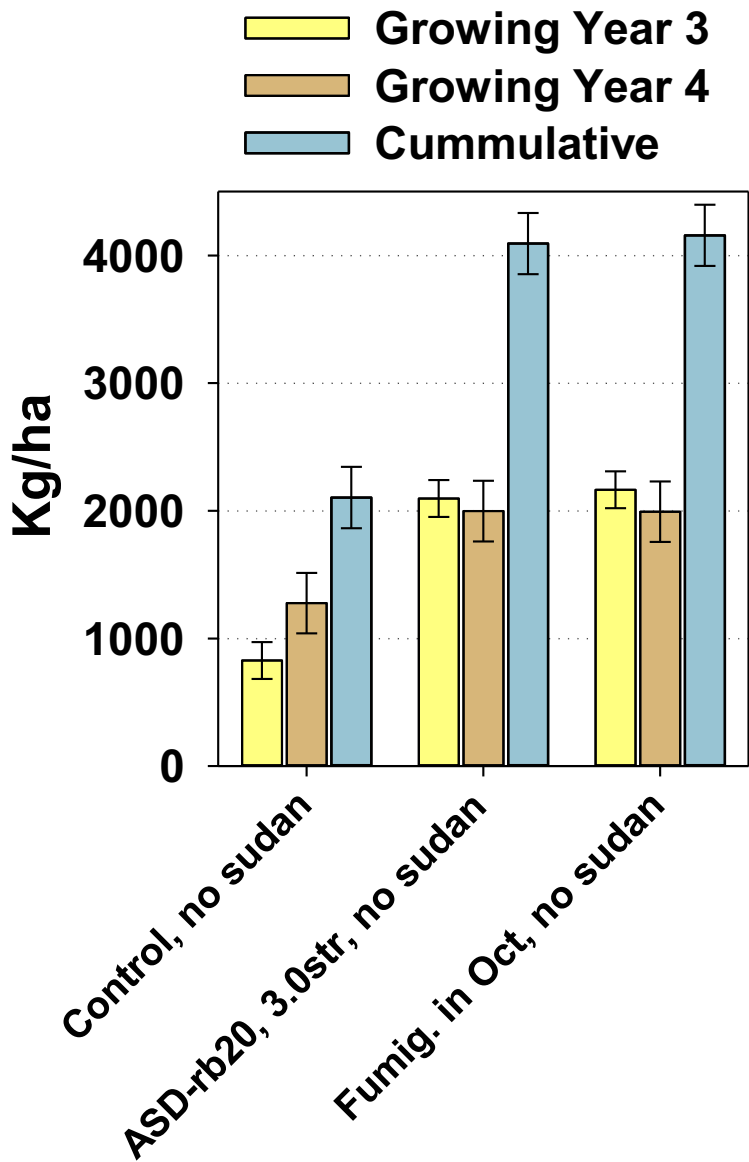


Effects
on crop
yield

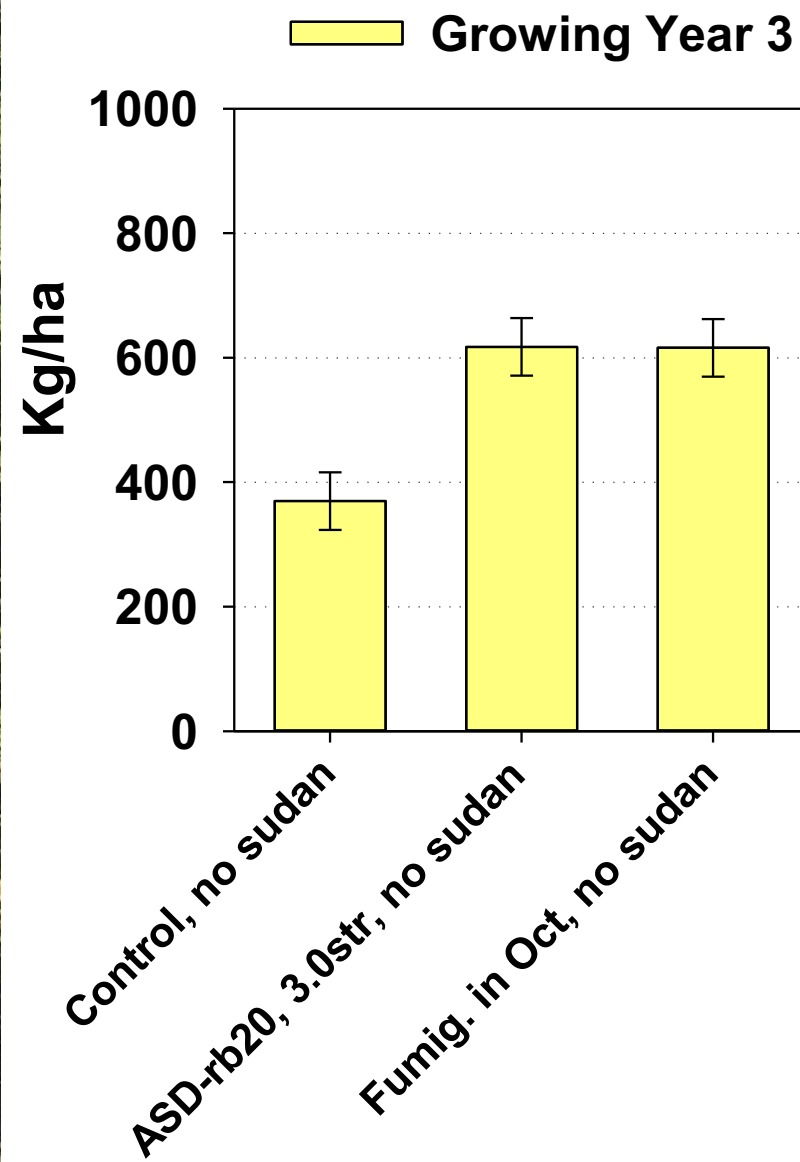


Yield, “small” repeated experiments

Trial started 2013:



Trial started 2014:



Microbial community analyses, growing year 1



Collected fine roots,
rhizosphere soil



PCR and HTS of
rDNA amplicons
from **bacteria**,
fungi, **oomycetes**

Sampling dates:

Sm. expt. started 2013:

- May 2014
- Aug 2014

Sm. expt. started 2014

- July 2015
- Nov 2015

Sampled treatments :

- Control
- ASD
- Fumigated (Telone C35)

Analysis “pipeline”:

**DNA extraction,
purification**



PCR Amplification

- Oomycete: ITS 6+7
- Fungi: BITS + B58S3
- Bacteria: 799+1193



illumina Miseq

- PE250



Postprocessing
(**NMDS, PERMANOVA,**
CCA, DESeq2)

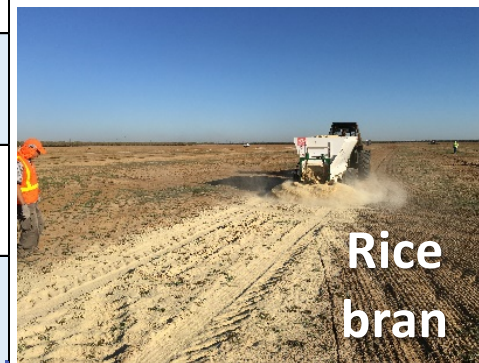
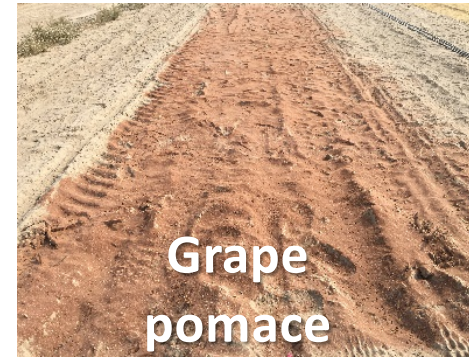
Second-generation ASD trials: Optimization for management of almond replant problems

- Trials: Parlier (KARE), Kern Co. (Wonderful Orchards), CSUF
- Nine alternative **carbon substrates**
- Evaluating carbon substrate, water, tarp **components; application methods**
- Fumigation standards (strip and GPS-spot)
- Rootstocks of Nemaguard and Hansen 536
- Factorial with **orchard recycling treatments**
- **PRD, with and without phytopathogenic nematodes**



Carbon substrates in second generation ASD trials

Ground carbon source	Estimated \$ / ton	Rate Tons / trt. ac.	Estimated material \$ / ac for "50% strips"	2016 trials that include
Mustard seed meal	\$1,700	3	\$2,550	Parlier
Rice bran	\$283	9	\$1,274	Parlier; Kern 1, 2
Almond hull	\$192	9	\$864	Parlier
Tomato pomace	\$185	9	\$833	Parlier
Grape pomace	\$155	9	\$698	Parlier
Pistachio hull	\$150	9	\$675	Parlier
Olive pomace	\$115	9	\$518	Parlier
Almond hull/shell, "pollinator"	\$104	9	\$468	Parlier; Kern 1, 2
Almond shell	\$80	9	\$360	Parlier

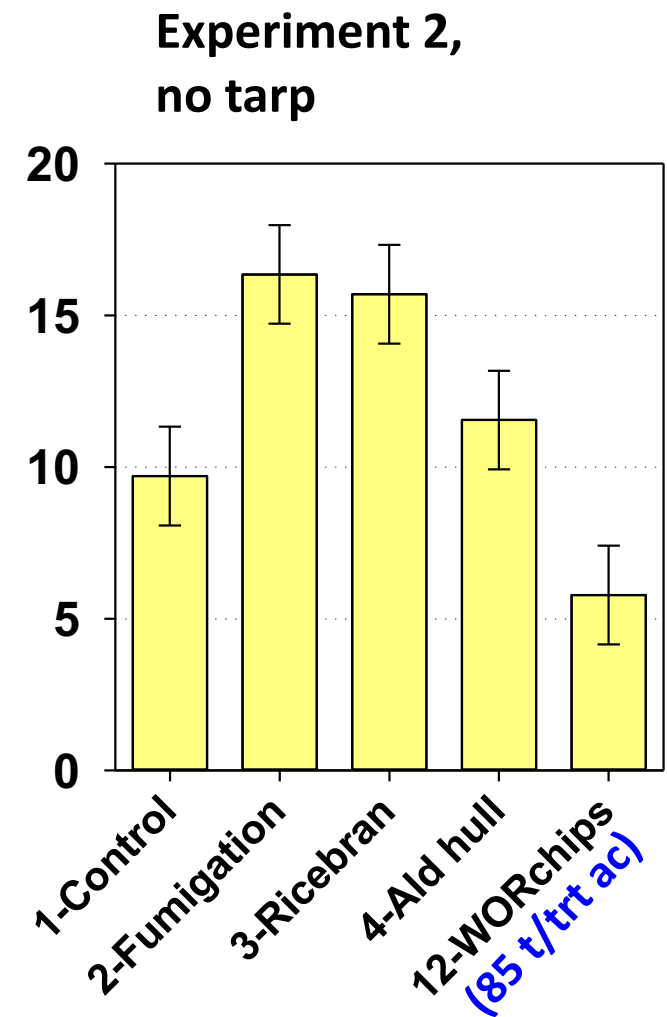
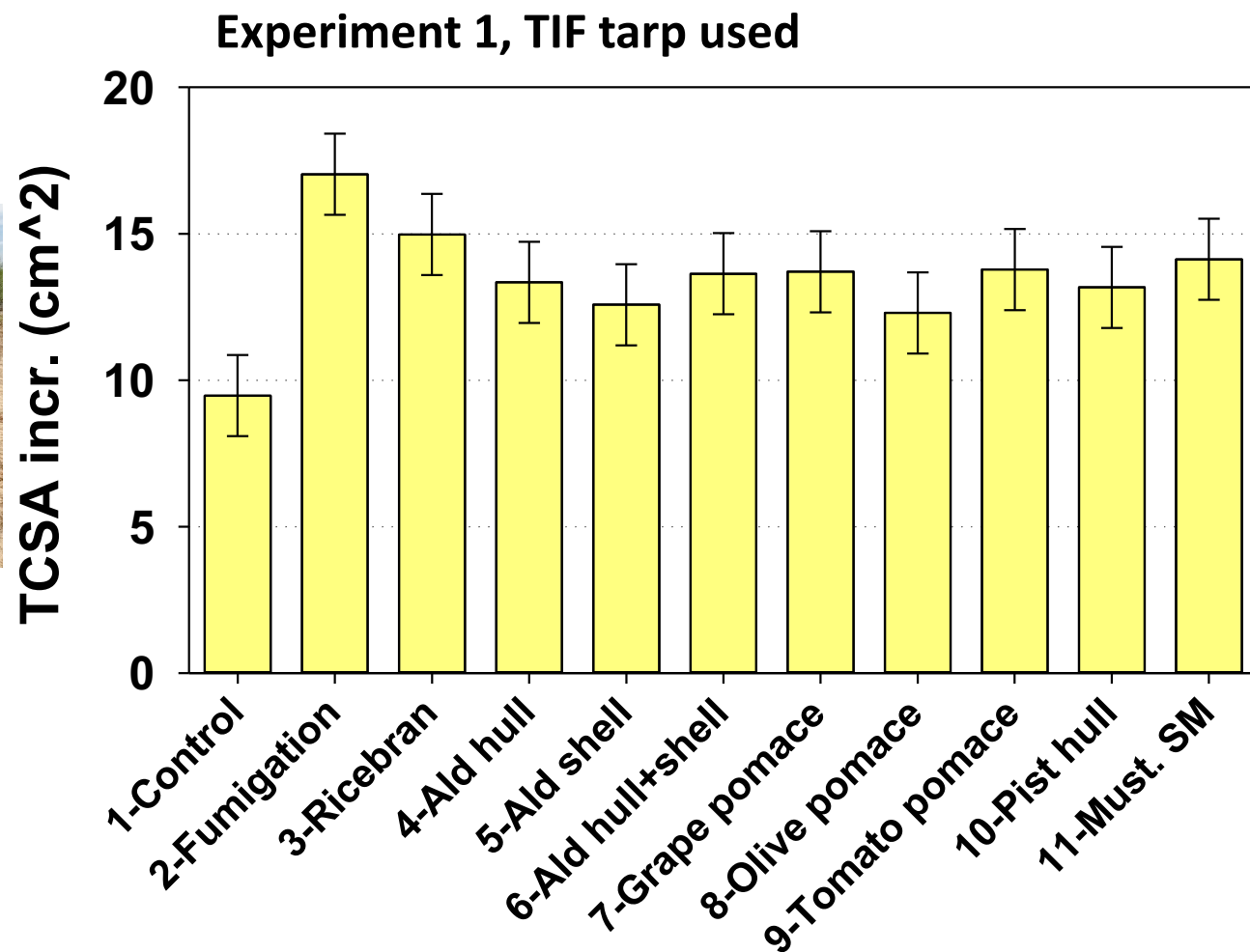


Estimated ASD vs. fumigation costs

ASD trt.	Substrate costs					Applic. costs (\$/orch ac)				Total trt. cost (\$/orch ac)
	Rate (t/trt.ac)	Prop. treated area	Amt. (t/orch ac)	Price (\$/t)	Total (\$/orch ac)	Spreading @ 10\$/ton	Incorp.	Irrig. System	TIF tarp	
Almond hull-shell	9	0.5	5	100	450	45	15	200	380	1,090
Rice bran	9	0.5	5	283	1,274	45	15	200	380	1,914
Mustard seed meal	3	0.5	2	1,700	2,550	15	15	200	380	3,160

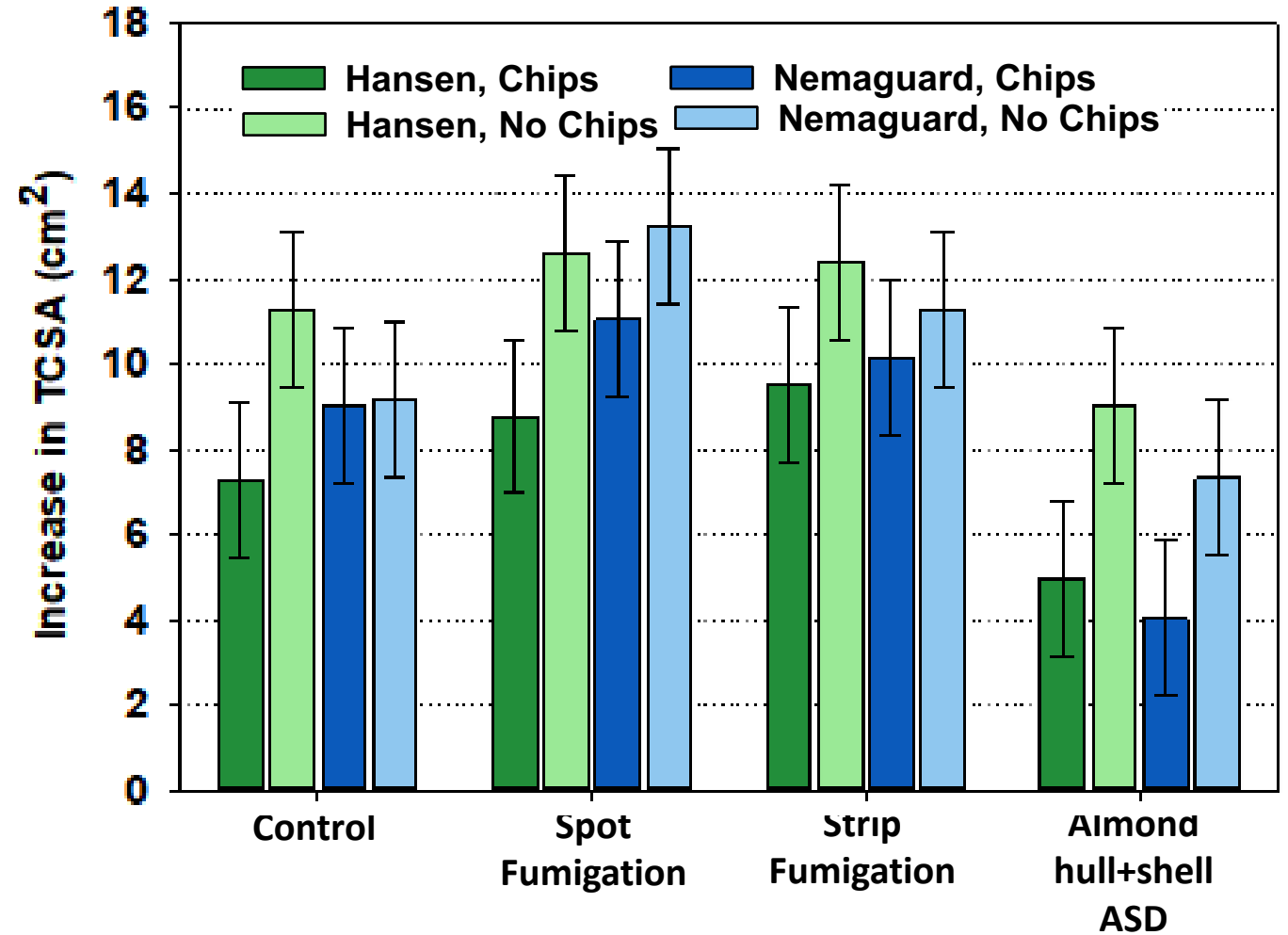
Fumigation trt.	Total trt. cost (\$/orchard ac)
Telone II BC + Cplic 0.38 strip	1,745
Telone II BC + Cplic 0.15 spot	1,219
Telone II 0.5 strip + Cplic 0.15 spot	817

First-year growth responses KARE trial, 2016-17



WOR trials Kern County, initiated 2016-17, **WO3381 (chips~50 t/a)**

Mainplot treatment	Subplot treatment	Subplot treatment details
No orchard recycling chips	Control	--
	ASD	Almond hull:shell substrate; 4-drip line soil wetting + TIF tarp; 4 weeks
	Strip fumigation	11.7 ft-wide strips, down tree rows
	Spot fumigation	8 x 8 ft spots, centered on tree sites
Recycled almond orchard chips	Control	--
	ASD	Almond hull:shell substrate; 4-drip line soil wetting + TIF tarp; 4 weeks
	Strip fumigation	11.7 ft-wide strips, down tree rows
	Spot fumigation	8 x 8 ft spots, centered on tree sites



Significant treatment effects:

- **Soil disinfestation** ($P < 0.0001$); Fum trts. increased TCSA, ASD decreased
- **Rootstock x WOR** ($P = 0.02$) chips inhibitory to potted Hansen, less so to bareroot NG

Bacterial community – pre-plant

Chips



C



NC

Treatment



ASD-AHS

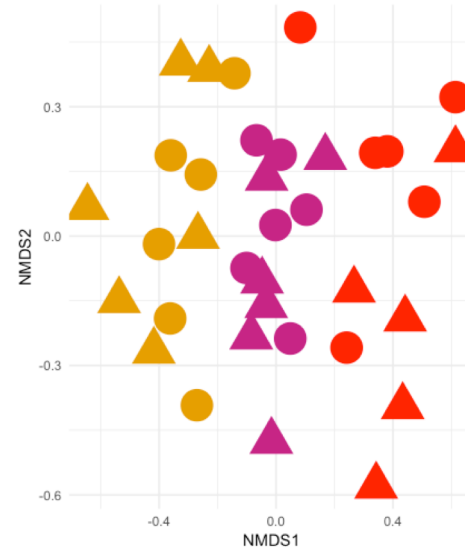


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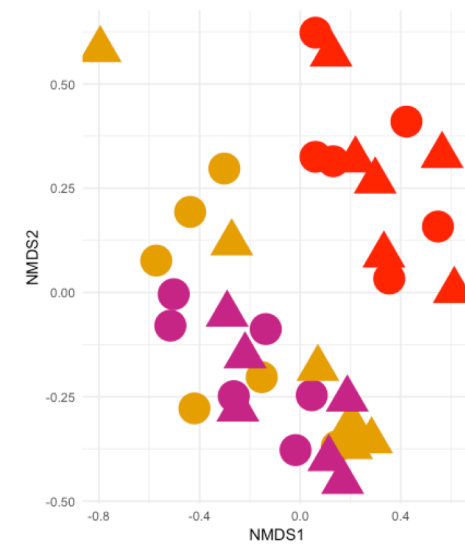


FUM

3371



3381



Treatments	Microbial diversity		PERMANOVA	
	P value		R ² value	P value
	Chao	Shannon		
3371				
Soil treatment	0.001**	<0.001**	0.224	0.001**
Chip vs non	0.001**	0.033	0.031	0.119
STvsC	0.393	0.881	0.054	0.195
3381				
Soil treatment	<0.001**	<0.001**	0.271	0.001**
Chip vs non	0.765	0.699	0.029	0.136
STvsC	0.720	0.856	0.035	0.773

**CSUF trials
2017-18**

**ASD
and
WOR**



CSUF trials, treated 2017, planted 2018

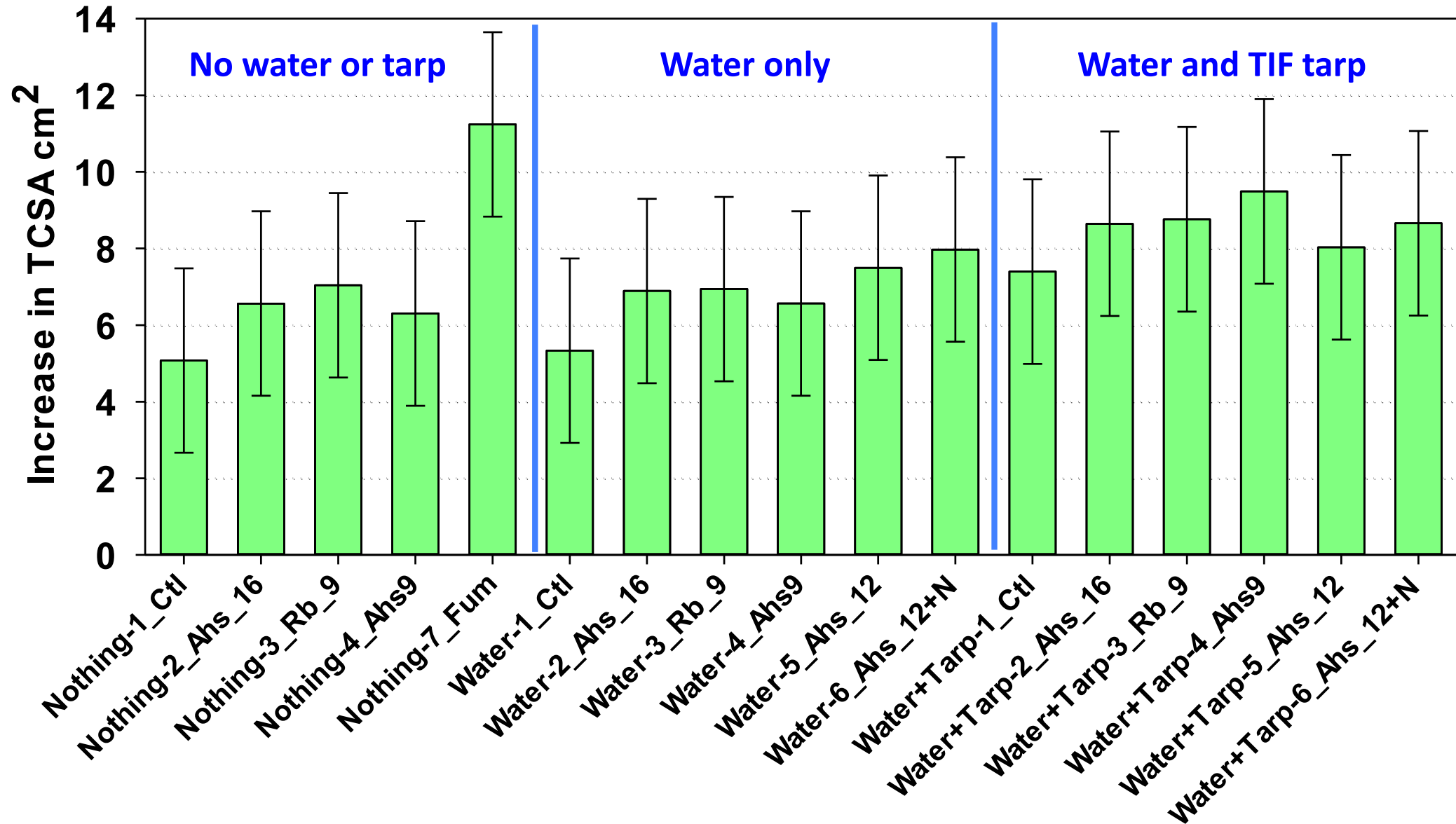
Expt. 1: ASD components, **no WOR**

Mainplot trt.	Subplot Treatment
Nothing	Control
	Strip fumigation 1,3-D + Pic 330 + 200 lb/trt. ac
	Almond hull:shell, 16 tons/trt. ac.
	Rice bran, 9 tons/trt. ac.
	Almond hull:shell, 9 tons/trt. ac.
Water	Control
	Almond hull:shell, 16 tons/trt. ac.
	Rice bran, 9 tons/trt. ac.
	Almond hull:shell, 9 tons/trt. ac.
	Almond hull:shell, 12 tons/trt. ac.
	Almond hull:shell, 12 tons/trt. acre + AMS 360 lb./trt. ac.
Water+tarp	Control
	Almond hull:shell, 16 tons/trt. ac.
	Rice bran, 9 tons/trt. ac.
	Almond hull:shell, 9 tons/trt. ac.
	Almond hull:shell, 12 tons/trt. ac.
	Almond hull:shell, 12 tons/trt. acre + AMS 360 lb./trt. ac.

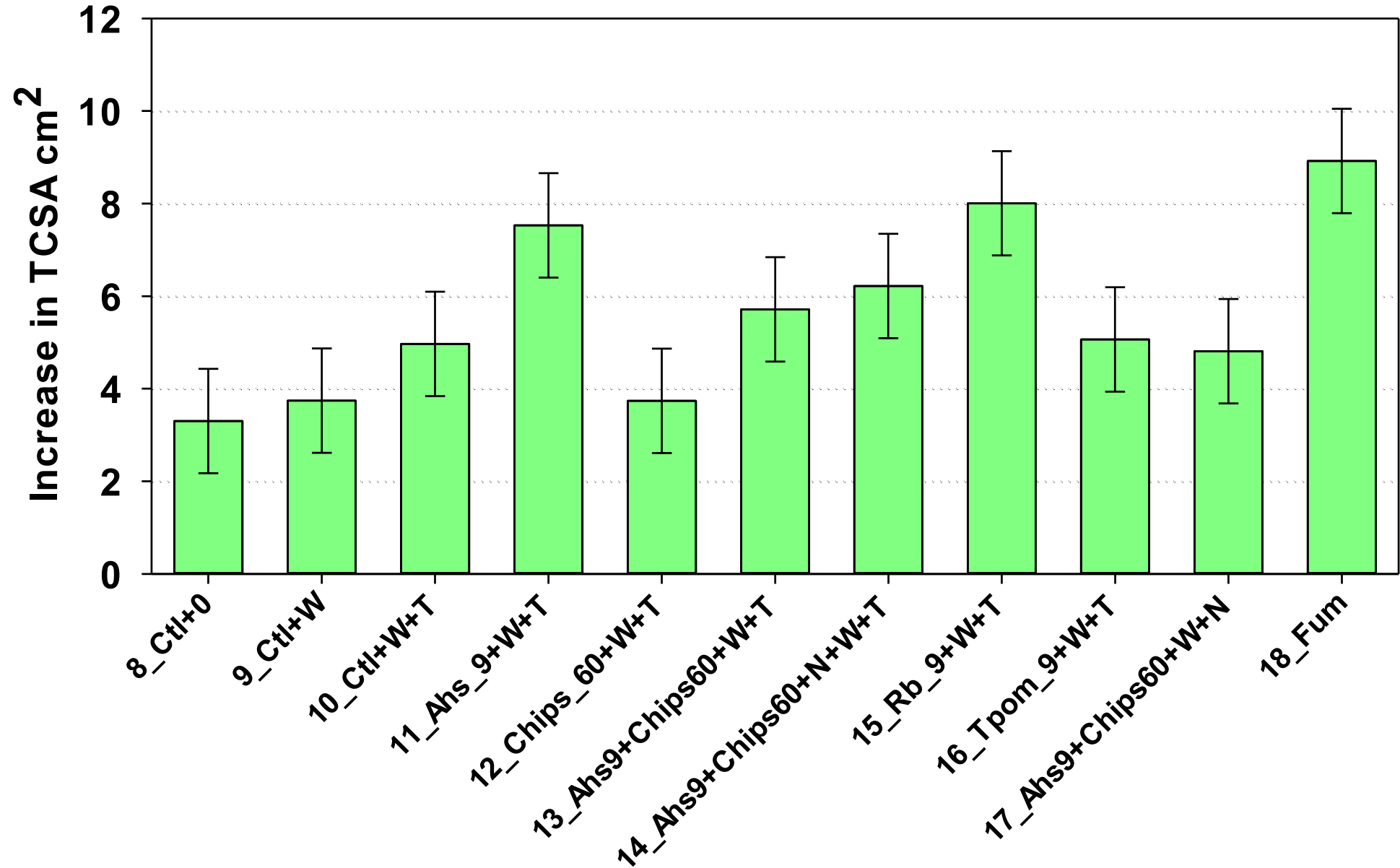
Expt. 2: ASD components, **with WOR**

Preplant treatment combination		
Soil amendment / disinfestation	Water (ASD irrigation)	TIF tarp
Control	No	No
Control	Yes	No
Control	Yes	Yes
Strip fumigation 1,3-D + Pic 330 + 200 lb/trt.	No	No
Ald hull+shell, 9 t/trt. ac.	Yes	Yes
WOR chips, 60 t/trt. ac.	Yes	Yes
Ald hull+shell, 9 t/trt. ac. + WOR chips 60 t/trt.	Yes	Yes
Ald hull:shell, 9 t/trt. ac. + WOR chips 60 t/trt.	Yes	Yes
Rice bran 9 t/trt. ac.	Yes	Yes
Tomato pomace 9 t/trt.ac.	Yes	Yes
Ald hull+shell, 9 t/trt. ac. + WOR chips 60 t/trt.	Yes	No

Expt. 1: ASD components, **no WOR**, results as of Aug. 2018



Expt. 2: ASD components, with WOR



Summary

- Replant problems can have multiple biotic and abiotic components.
- Fumigation still a standard for replant problem management, GPS-spot technologies facilitating efficiency and economy, but reduced fumigant dependence needed.
- Microbial ecology approaches being used for PRD and its prediction; growers and PCAs can help (soil, plots).
- ASD offers promise as a fumigation alternative, being optimized for economy & utility.
- Diverse ASD carbon-sources available, vary greatly in cost.
- WOR chips can induce tree stunting at high rates, but seems to be manageable w/ N applic.
- Second-generation trials are ongoing in PRD + nematode-infested soils

Thank you!