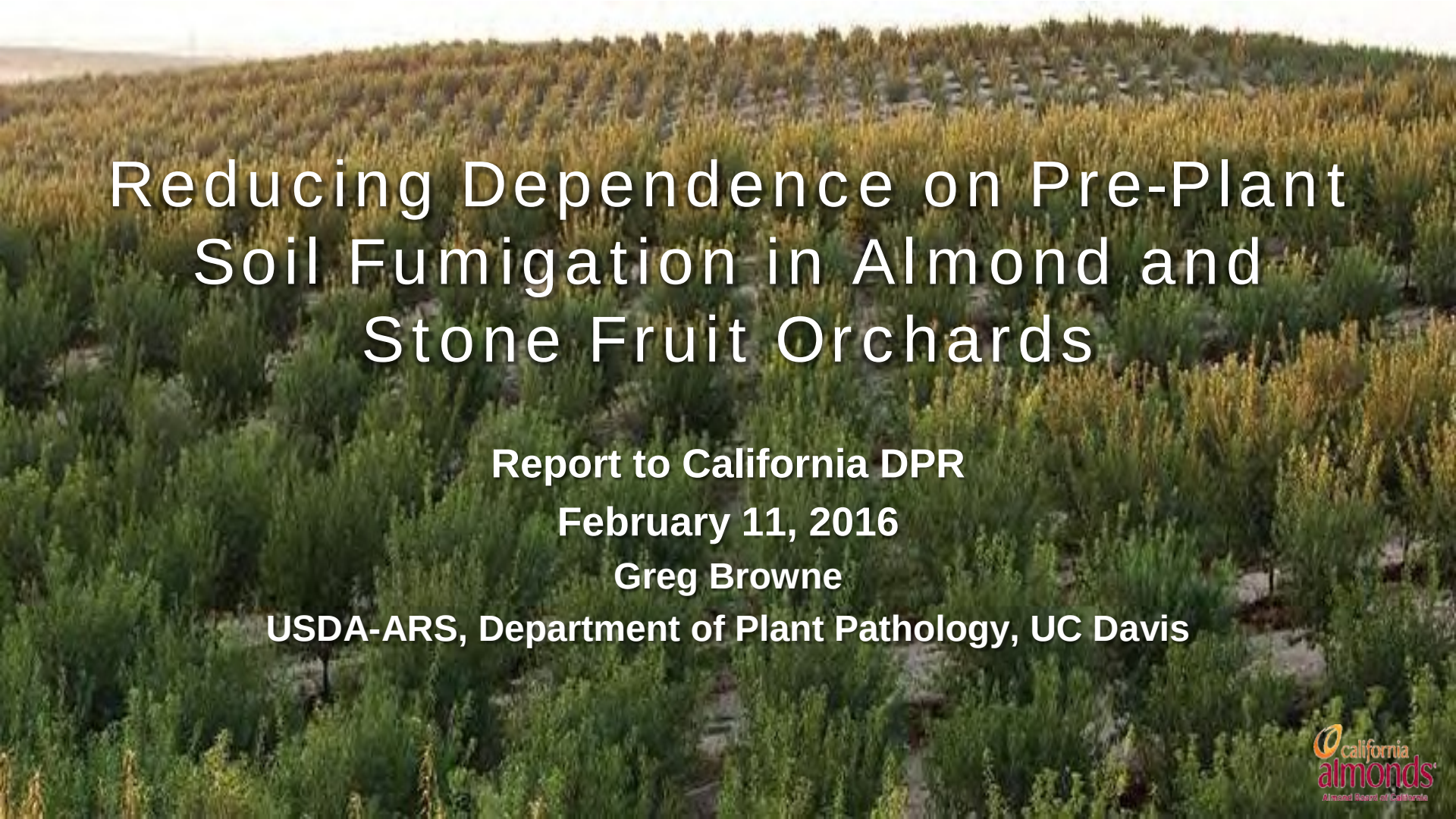

Reducing Dependence on Pre-Plant Soil Fumigation in Almond and Stone Fruit Orchards

Report to California DPR

February 11, 2016

Greg Browne

USDA-ARS, Department of Plant Pathology, UC Davis

Acknowledgements:

USDA-ARS

- **Natalia Blackburn, Suduan Gao, and Dan Kluepfel**

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- **Doug Downie and Steve Blecker**

Almond Board of California

- **Gabriele Ludwig and Bob Curtis**

TriCal, Inc.

- **Matt Gillis, Mike Stanghellini, and Dave Miller**

California almond and stonefruit growers statewide

USDA Agricultural Research Service

UC CE

Presentation Overview:

- Project objectives
- Background, biological replant problems
- Bioassay results (objectives 1, 2)
- Spot fumigation results (objective 3)
- Outreach
- Summary
- Questions, discussion

california almonds

I. Objectives focused on use of a bioassay approach to reducing fumigant use…

1. Use a greenhouse-based peach seedling bioassay to increase knowledge available on the need for preplant fumigation among different orchard soils

2. Augment bioassay testing results with orchard validations

=

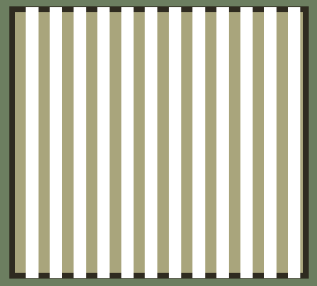
??

II. Objective focused on use of “spot fumigation” to reduce fumigant use…

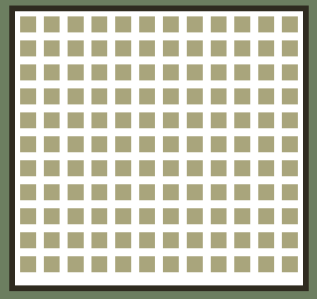
3. Demonstrate and optimize GPS-controlled spot fumigation in commercial almond orchards

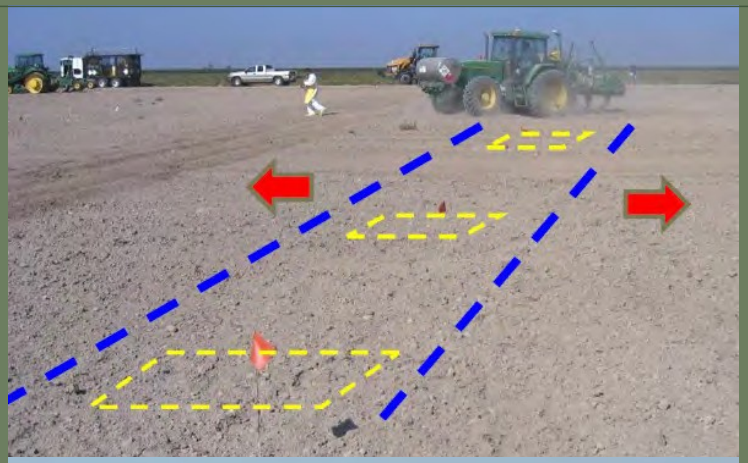
Broadcast
100% coverage

Strip
50% coverage



GPS-Grid
<20% coverage

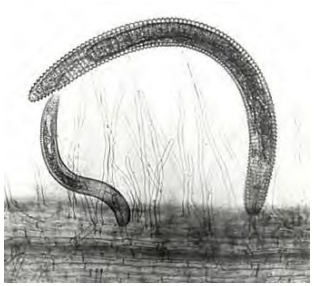




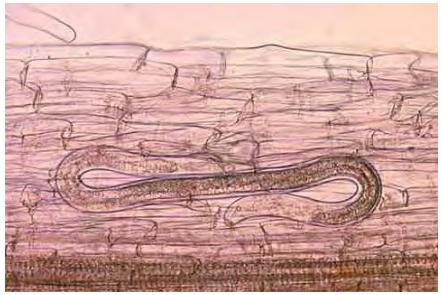
Replant problems targeted effectively by fumigation

Prunus replant disease (PRD)
Microbe-induced growth suppression in *Prunus* planted after *Prunus;* common, but severity varies greatly. Impact early.

- **Plant-parasitic nematodes (ring, lesion, root knot), approx. 35% of almond and fresh stone fruit acreage (McKenry). Impact can be delayed, long-term.**
- **Aggressive pests (e.g., *Phytophthora*, *Armillaria*, *Verticillium*, Ten-Lined June Beetle, gophers!)**
- **Abiotic factors (physical, chemical conditions related to previous production)**



Ring nematode



Lesion nematode

Plant parasitic nematodes

Healthy tree **RD-affected tree**

Replant disease

PRD, near Chico, almond after almond

PRD, near Madera, almond after almond

PRD, near Firebaugh, almond after almond

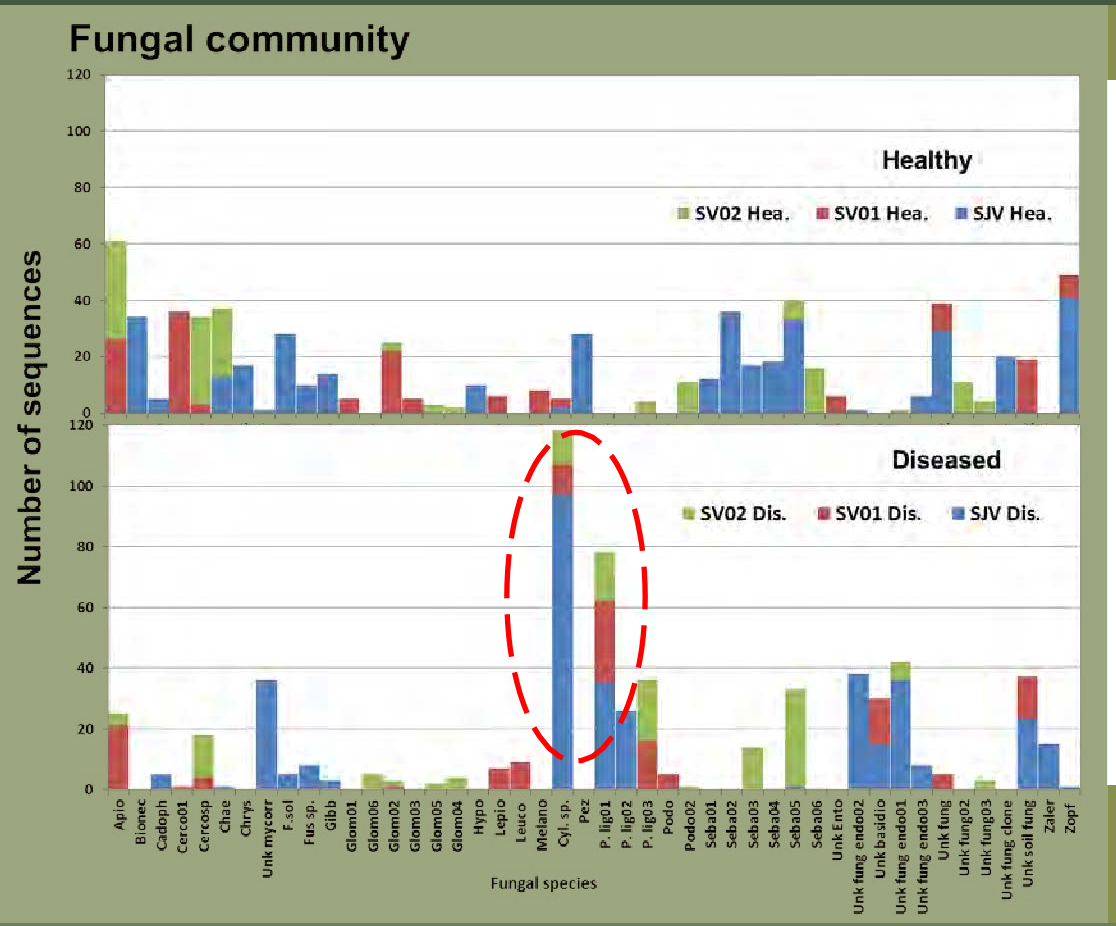
PRD, near Parlier, peach after plum

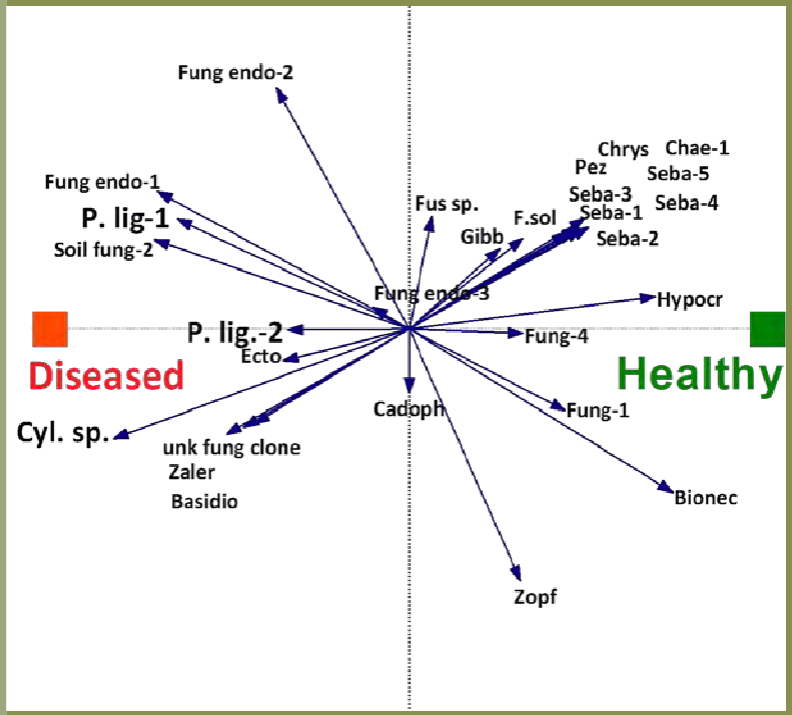
PRD near Parlier, almond after peach

Association of *Pythium* species with PRD

Experiment	Preplant soil treatment	Incidence of *Pythium* spp. (isolates of Pythium sp. / number of root pieces cultured)	Incidence Pythium (%)
Rootstock trial	Control	*108/948*	*11.4*
	Fumigation	28/892	3.1
Bioassay trial 1	Control	*94/460*	*20.4*
	Fumigation	2/480	0.4
Bioassay trial 2	Control	*421/790*	*53.3*
	Pasteurization	3/800	0.4

Culture-independent profile of fungal community associated with PRD

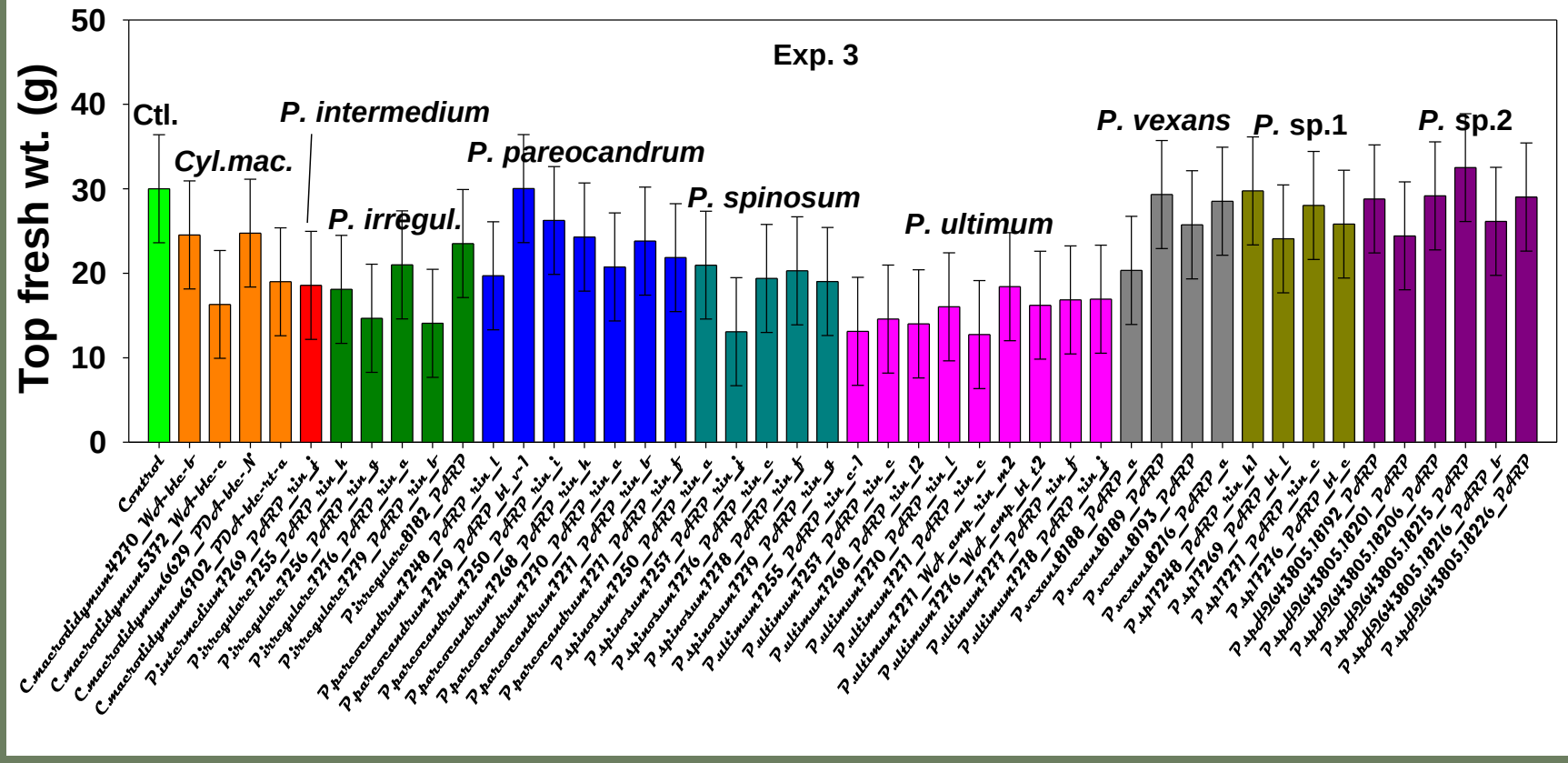




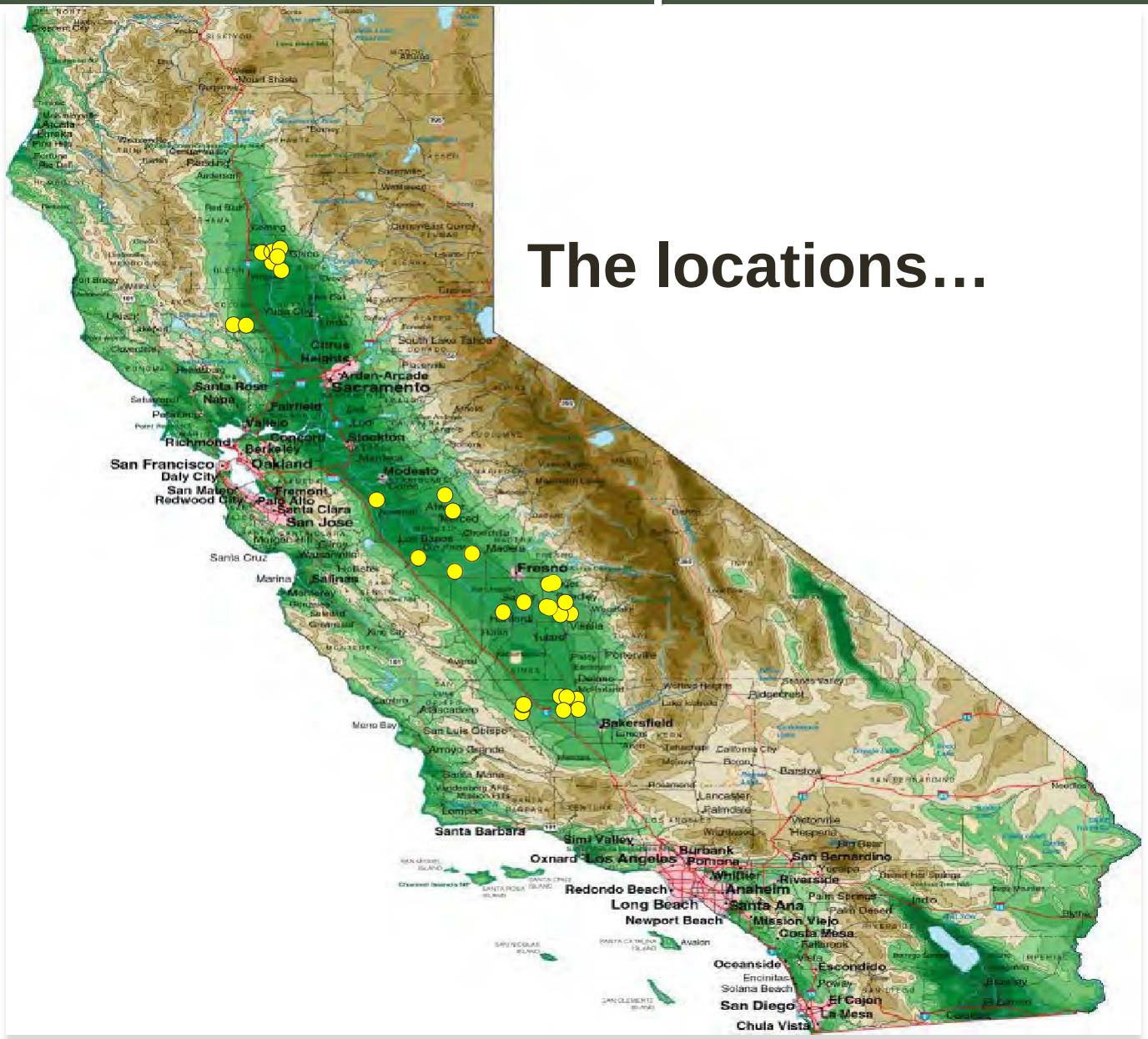
Contributors to RD: *Cylindrocarpon* and *Pythium* species

Ck *Cyl. macrodidymum*

Ck *Pythium ultimum*



Objective 1. Use bioassay to predict and examine PRD in almond and stone fruit replant soils

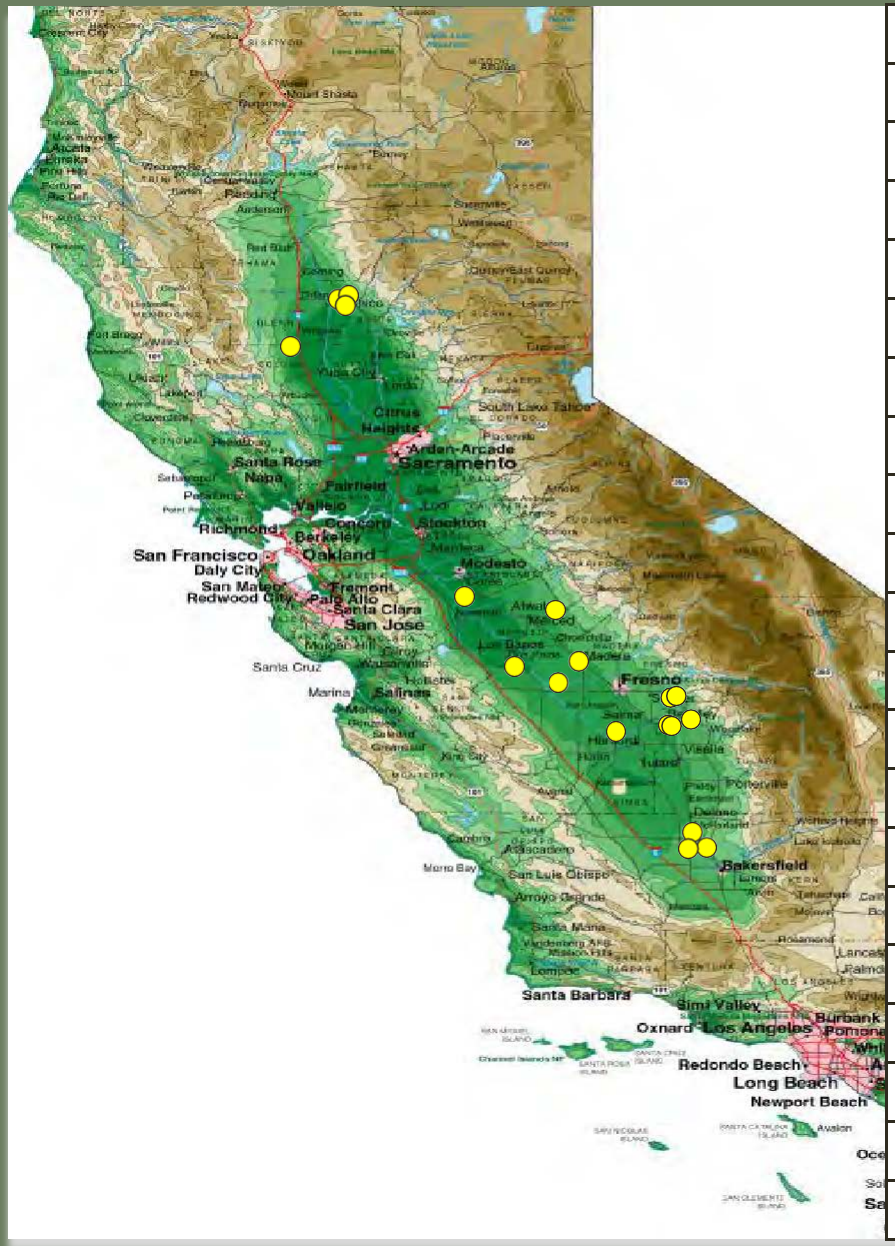


Soil collection, preparation

Nematodes detected in 2014 bioassay soils…

Soil Source	Root Knot Meloidogyne	Ring CX	Dagger XA	Lesion PV	Pin Paratylen.	Stunt Tylenchor.	Free-Living Composite
1. Durham MdS	0	0	0	0	276	0	8
2. Durham MdT	0	0	0	0	228	4	16
3. Durham MaT	0	0	0	0	90	0	38
4. Arbuckle NiT	0	0	0	16	292	0	54
5. Crows Ldg GoT	0	0	0	86	402	56	224
6. Snelling DoT	0	0	0	0	0	2	16
7. Fresno GuT	0	0	0	14	482	0	22
8. Firebaugh PaT	0	0	0	0	844	0	26
9. Kerman AvT	0	0	0	0	58	0	50
10. Sanger Ge	0	0	32	0	206	0	10
11. Sanger Br	0	682	0	0	1112	0	86
12. Parlier KAC	0	0	0	0	198	0	42
13. Parlier ARS	26	0	0	22	240	0	28
14. Dinuba Kla	0	8	0	176	4	0	58
15.Hanford JWPlu	0	14	2	0	268	0	96
16. Hanford JWPeD	0	18	0	0	12	0	84
17.Hanford JWPeH	0	52	10	0	84	0	32
18. Wasco Pa	0	0	0	0	52	0	38
19. Shafter PaE99	0	0	18	0	534	0	20
20.Shafter PaW99	0	0	0	0	54	0	16

2014 bioassay soils….



Soil Source	Soil Series	pH
1. Durham MdS	Farwell Loam	5.6
2. Durham MdT	Farwell Loam	8.0
3. Durham MaT	Farwell Loam	8.0
4. Arbuckle NiT	Arbuckle Sa Loam	6.0
5. Crows Ldg GoT	Caypay Clay	6.7
6. Snelling DoT	Snel. & Wh. Sa Loam	6.9
7. Fresno GuT	Hanf. F Sa Lo	6.0
8. Firebaugh PaT	Various F Sa L , L	8.2
9. Kerman AvT	Grangev. Sa L F Sa Lo	8.0
10. Sanger Ge	Hanf. F Sa L	7.6
11. Sanger Br	Various L to Sa L	6.0
12. Parlier KAC	Hanf. F Sa L	8.2
13. Parlier ARS	Hanf. F Sa L	7.9
14. Dinuba Kla	Greenfield Sa L	7.4
15.Hanford JWPlu	Nord F Sa L	7.6
16. Hanford JWPeD	Nord F Sa L	7.8
17.Hanford JWPeH	Nord F Sa L	7.6
18. Wasco Pa	Wasco Sa L	7.6
19. Shafter PaE99	Driver Course Sa L	7.9
20.Shafter PaW99	Various Sa L	6.5

Nematodes detected in 2015 bioassay soils....

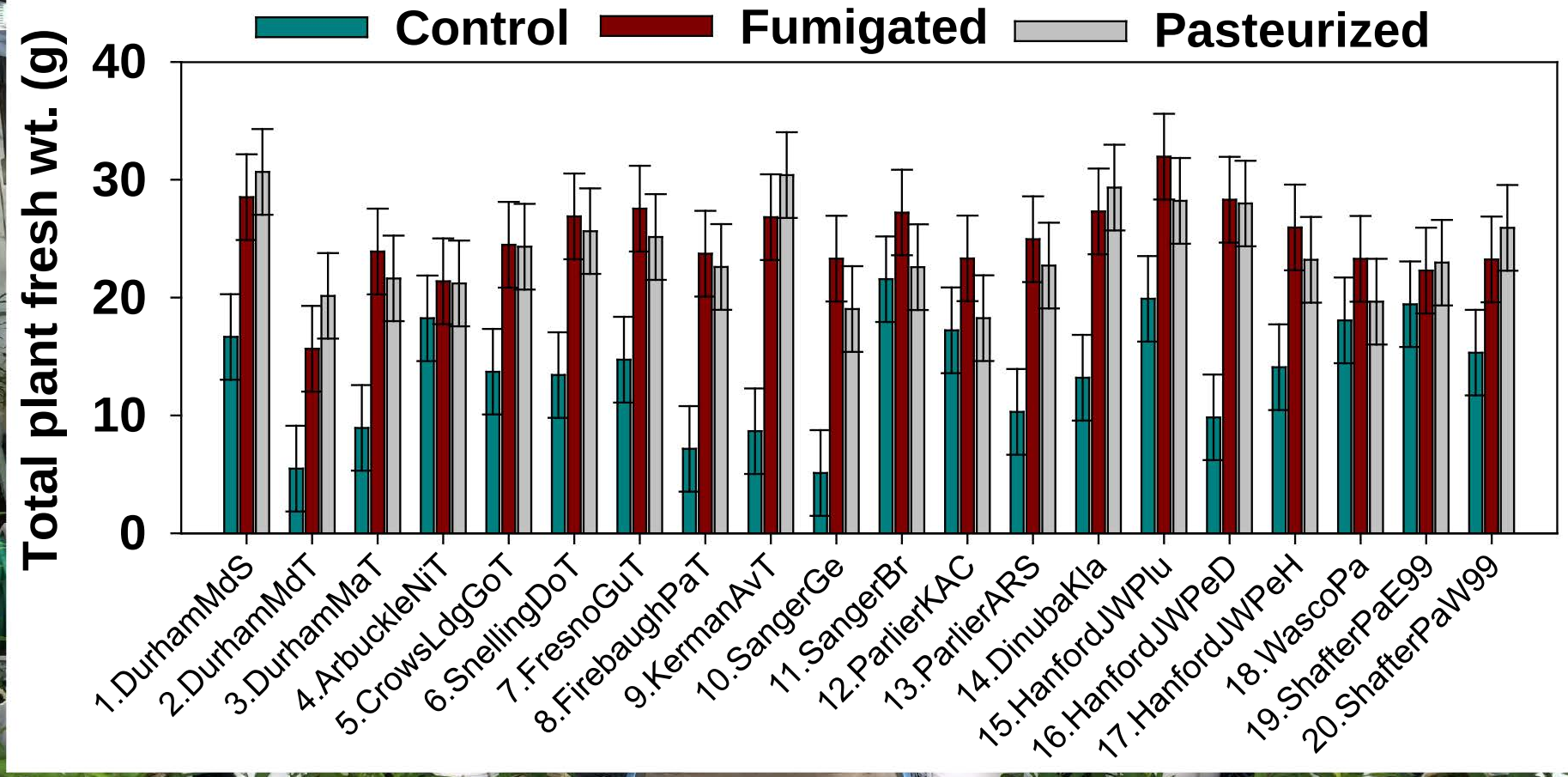
2015 soil number and code[a]	Crop history[b]	Nematode count (per 250 cc)[c]					
		Ring	Lesion	RKN	Dagger	Pin	Free living
1.Durham-Mea.Tri.CK.St	Almond/Lovell, 11 yr	0	0	0	0	62	92
2.Durham-Mtz.Tri.CK.St	Almond/Lovell, 11 yr	0	0	0	2	112	134
3.Durham-Mtz.S.St	Almond/Lovell, >20 yr	0	0	0	0	360	54
4.Durham-Gilb.N.St	Almond/Lovell, >20 yr	0	0	0	0	104	8
5.Durham-Gil.S.St	Almond/Lovell, >20 yr	0	0	0	0	26	22
6.Arbuckle-Nic.Tri.CK.St	Almond/Nemaguard, 6 yr	0	0	0	0	646	64
7.Arbuckle-Hen.St	Almond/Lovell, >20 yr	0	0	0	36	318	6
8.Delhi-Lit.Tri.CK.Cl	Almond/Nemaguard, >20 yr	30	0	0	0	0	54
9.Delhi-Lit.Tri.C35.Cl	Almond/Nemaguard, >20 yr	14	0	0	0	0	132
10.Firebaugh-WO.Tri.CK.St	Almond/Nemaguard, 8 yr	0	0	0	0	883	29
11.Parlier-KAC.Vin.S.St	Vineyard, >20 yr	808	0	15	7	317	149
12.Parlier-KAC.Vin.N.St	Vineyard, >20 yr	56	0	0	22	544	336
13.Parlier-KAC2014.Tri.CK.Cl	Peach/Nemaguard, ca. 12 yr	0	0	0	0	4	248
14.Parlier-KAC2014.Tri.C35.Cl	Peach/Nemaguard, ca. 12 yr	0	0	0	0	0	178
15.Parlier-KAC2014.Tri.ASD.Cl	Peach/Nemaguard, ca. 12 yr	0	0	0	0	0	586
16.Reedley-Klas.N.St	Nectarine/Nemaguard, ca. 12 yr	37	4	0	0	900	35
17.Reedley-Klas.S.St	Peach/Nemaguard, ca 15 yr	0	13	0	0	538	134
18.Sanger-MG.Rep.St	Plum/Nemaguard, 1 yr	0	38	0	0	45	70
19.Sanger-LTB.Hc.Cl	Almond/Nemaguard, >20 yr	0	0	0	0	186	146
20.Sanger-LTB.Rc.Cl	Almond/Nemaguard, >20yr	29	0	0	1	941	80
21.Traver-Famt.St	Nectarine/Nemaguard, ca. 15 yr	0	0	0	27	662	92
22.Shafter-3901.K&B.St	Almond/Nemaguard, >20 yr	892	184	3	38	179	42
23.Shafter-WO.3010.S.St	Almond/Nemaguard, >20 yr	0	0	0	0	268	34
24.Shafter-WO.3010.N.Stb	Almond/Nemaguard, >20 yr	0	0	0	0	184	33
25.Belridge-WO.3540.196.St	Almond/Nemaguard, >20 yr	0	0	0	0	824	58
26.Belridge-WO.3580.211.St	Almond/Nemaguard, >20 yr	0	4	0	45	500	89

2015 bioassay soils....

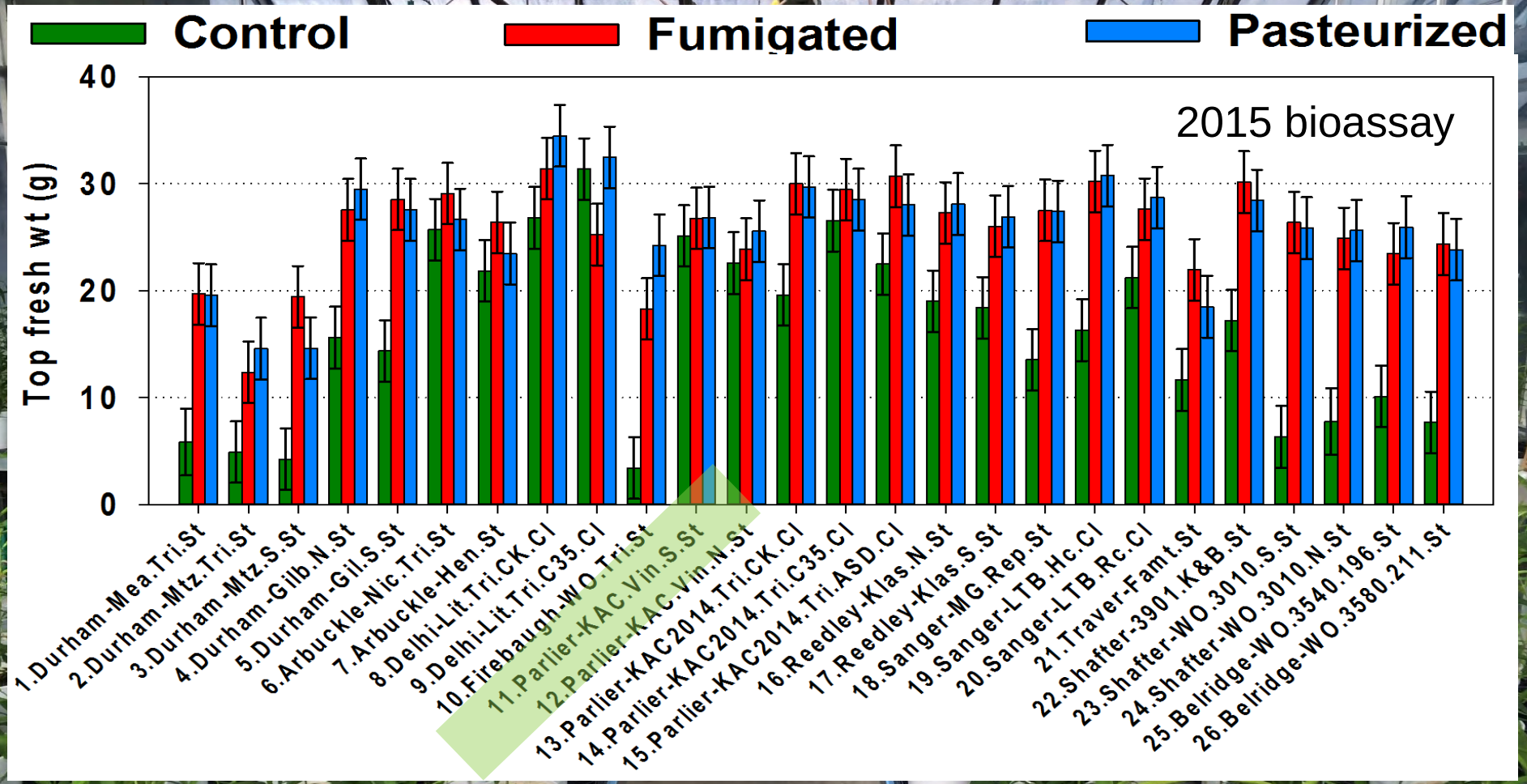
2015 soil number and code[a]	Nominal soil series	Selected properties							
		pH	CEC (meq/100g)	**EC (dS/m)**	Ca (meq/L)	**Mg (meq/L)**	**Na (meq/L)**	SAR	exch. K (ppm)
1.Durham-Mea.Tri.CK.St	Edjobe silty clay	7.81	27.2	0.77	3.56	3.19	0.77	<1	179
2.Durham-Mtz.Tri.CK.St	Conejo clay loam	7.91	23.7	0.82	3.81	2.68	0.74	<1	276
3.Durham-Mtz.S.St	Conejo/Busacca clay loam	7.95	23.6	0.96	4.66	3.02	1.06	<1	119
4.Durham-Gilb.N.St	Almendra loam	7.08	31.8	0.70	2.90	2.70	0.85	<1	153
5.Durham-Gil.S.St	Conejo clay loam	6.95	37.1	0.55	2.24	1.99	0.73	<1	134
6.Arbuckle-Nic.Tri.CK.St	Arbuckle sandy loam	5.75	9.8	0.81	2.89	1.81	2.71	2	76
7.Arbuckle-Hen.St	Arbuckle-Hillgate complex	5.61	11.0	1.44	5.45	4.65	3.61	2	93
8.Delhi-Lit.Tri.CK.Cl	Delhi sand	6.34	3.2	1.07	5.50	2.38	1.65	<1	32
9.Delhi-Lit.Tri.C35.Cl	Delhi sand	6.80	2.8	0.50	2.63	1.00	0.83	<1	24
10.Firebaugh-WO.Tri.CK.St	Dinuba/El Peco fine sandy loam	7.85	6.0	2.98	14.39	2.39	16.00	6	254
11.Parlier-KAC.Vin.S.St	Hanford fine sandy loam	7.34	4.1	0.59	2.87	1.41	1.31	<1	52
12.Parlier-KAC.Vin.N.St	Hesperia fine sandy loam	7.57	6.5	0.60	2.74	1.21	1.75	1	63
13.Parlier-KAC2014.Tri.CK.Cl	Hanford fine sandy loam	7.55	6.0	1.81	7.54	3.73	5.80	2	50
14.Parlier-KAC2014.Tri.C35.Cl	Hanford fine sandy loam	7.12	5.8	1.69	7.72	3.93	4.15	2	51
15.Parlier-KAC2014.Tri.ASD.Cl	Hanford fine sandy loam	6.43	6.5	1.26	6.47	3.46	1.33	<1	64
16.Reedley-Klas.N.St	Hanford course sandy loam	6.80	6.7	1.04	5.48	2.76	1.56	<1	77
17.Reedley-Klas.S.St	Greenfield sandy loam	7.28	8.0	2.94	21.32	10.17	3.84	<1	65
18.Sanger-MG.Rep.St	Hanford sandy loam	6.79	7.1	1.62	6.66	7.13	2.08	<1	58
19.Sanger-LTB.Hc.Cl	Hanford sandy loam	6.18	4.5	1.02	4.70	3.12	1.55	<1	51
20.Sanger-LTB.Rc.Cl	Ramona loam	6.68	9.3	0.78	2.48	3.09	1.58	<1	92
21.Traver-Famt.St	Calgro complex	7.60	7.5	1.29	5.94	1.92	4.47	2	79
22.Shafter-3901.K&B.St	Wasco sandy loam	6.07	4.3	1.78	8.72	1.53	7.19	3	45
23.Shafter-WO.3010.S.St	Wasco sandy loam	7.57	6.3	1.99	7.16	1.08	12.24	6	117
24.Shafter-WO.3010.N.Stb	Driver coarse sandy loam	--	--	--	--	--	--	--	--
25.Belridge-WO.3540.196.St	Milham sandy loam	7.68	12.0	3.30	19.34	5.98	11.38	3	99
26.Belridge-WO.3580.211.St	Panoche clay loam	7.79	18.1	3.02	16.13	4.34	12.46	4	132

Steam pasteurization and fumigation treatments

Bioassay procedure



Bioassay results, spring-summer 2014 trial



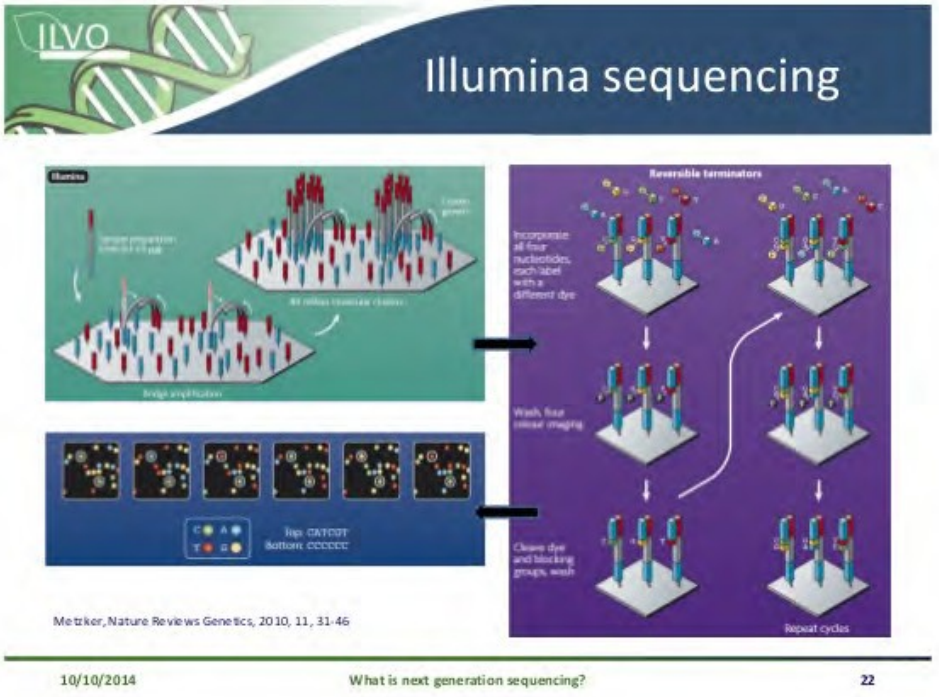
Bioassay results, spring-summer 2015 trial

Bioassay results, spring-summer 2014 trial

- Soil pasteurization increased plant weights by 8 to 268%
- Fumigation increased plant weight by 19 to 351%
- Plant weights negatively correlated with root incidence of *Pythium* spp. (r= -0.67, $P<0.0001$)
- Plant weights negatively correlated with root incidence of *Cylindrocarpon* sp. (r= -0.67, $P<0.0001$).
- Across all soils, the % increase in plant weight resulting from pasteurization and fumigation positively correlated with pH (r=0.43 to 0.45, $P=0.05$).

Ongoing impact of bioassay and orchard replant work: facilitating metagenomic approach to PRD <u>etiology</u> and <u>prediction</u> among fields

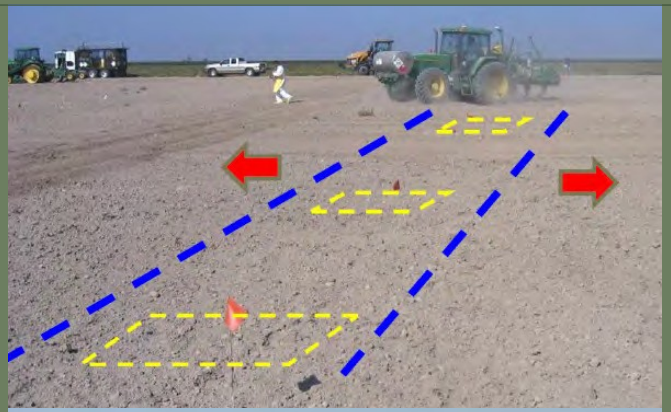
Roots, soil



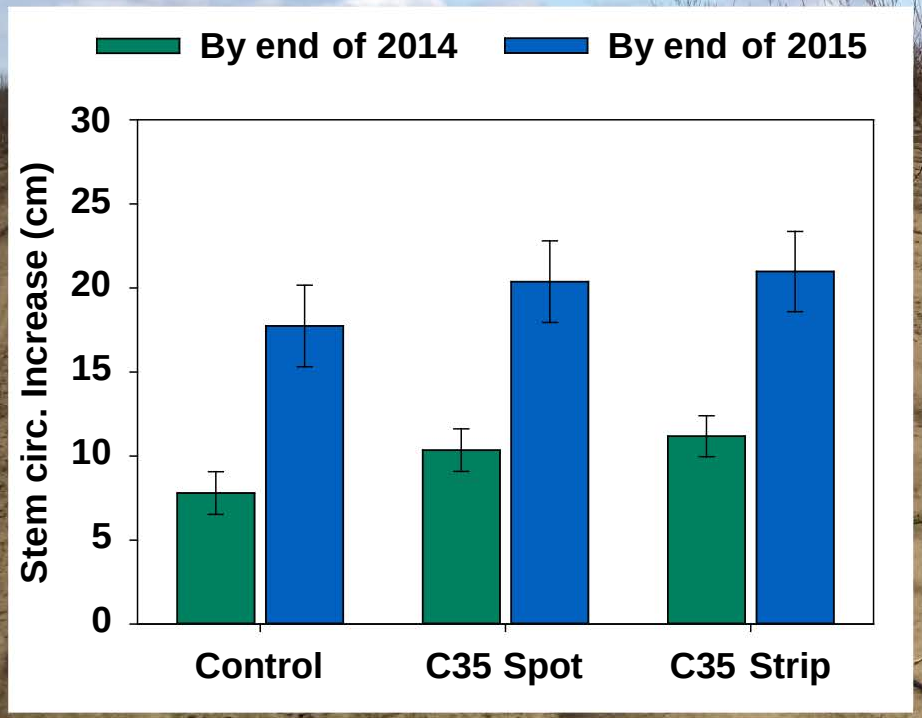
Illumina amplicon and metagenomic (shotgun) sequencing underway

II. Objective focused on use of “spot fumigation” to reduce fumigant use…

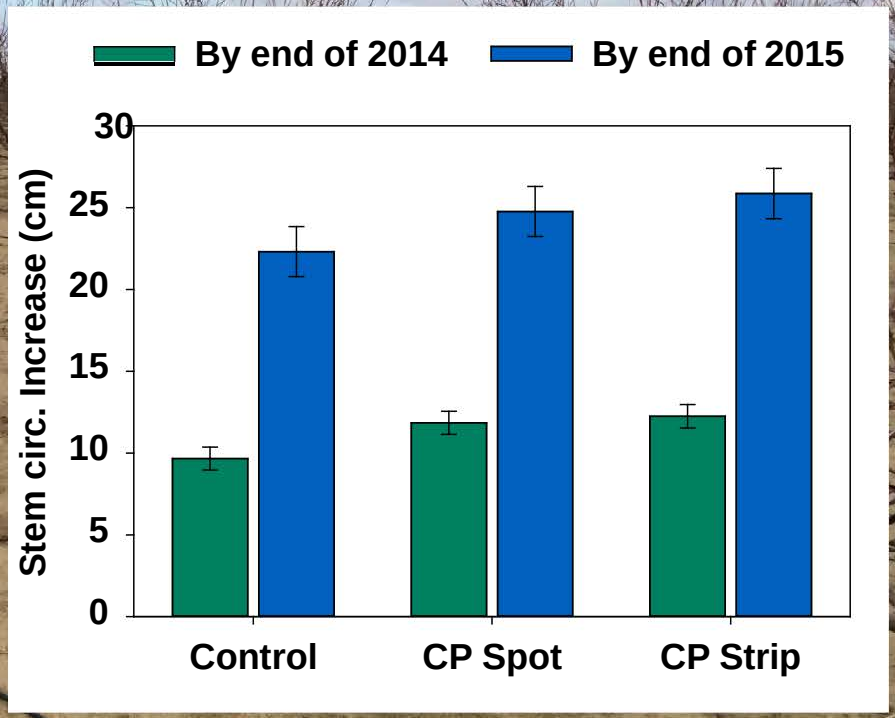
3. Demonstrate and optimize GPS-controlled spot fumigation in commercial almond orchards



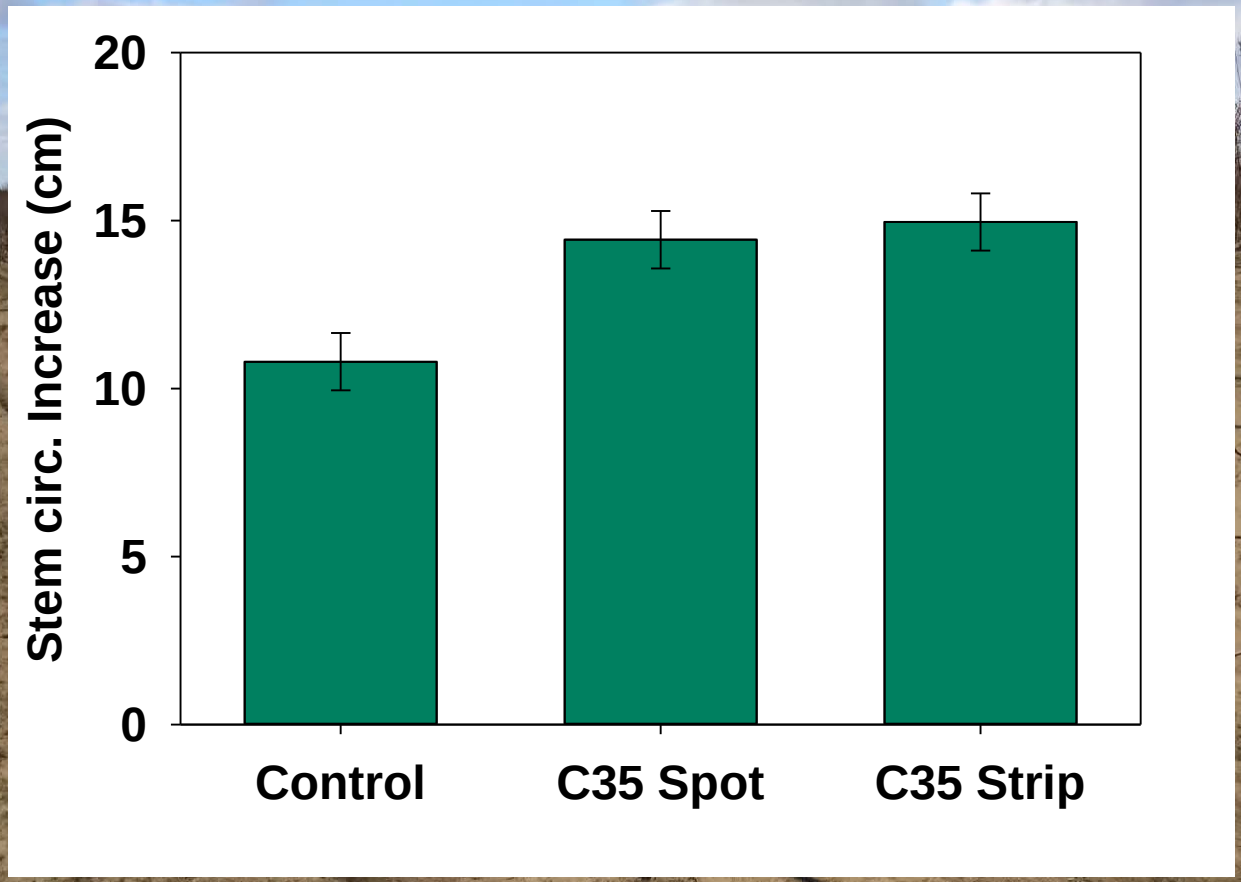
Mapping an orchard grid from 3 points



Crows Landing trial



Kerman trial



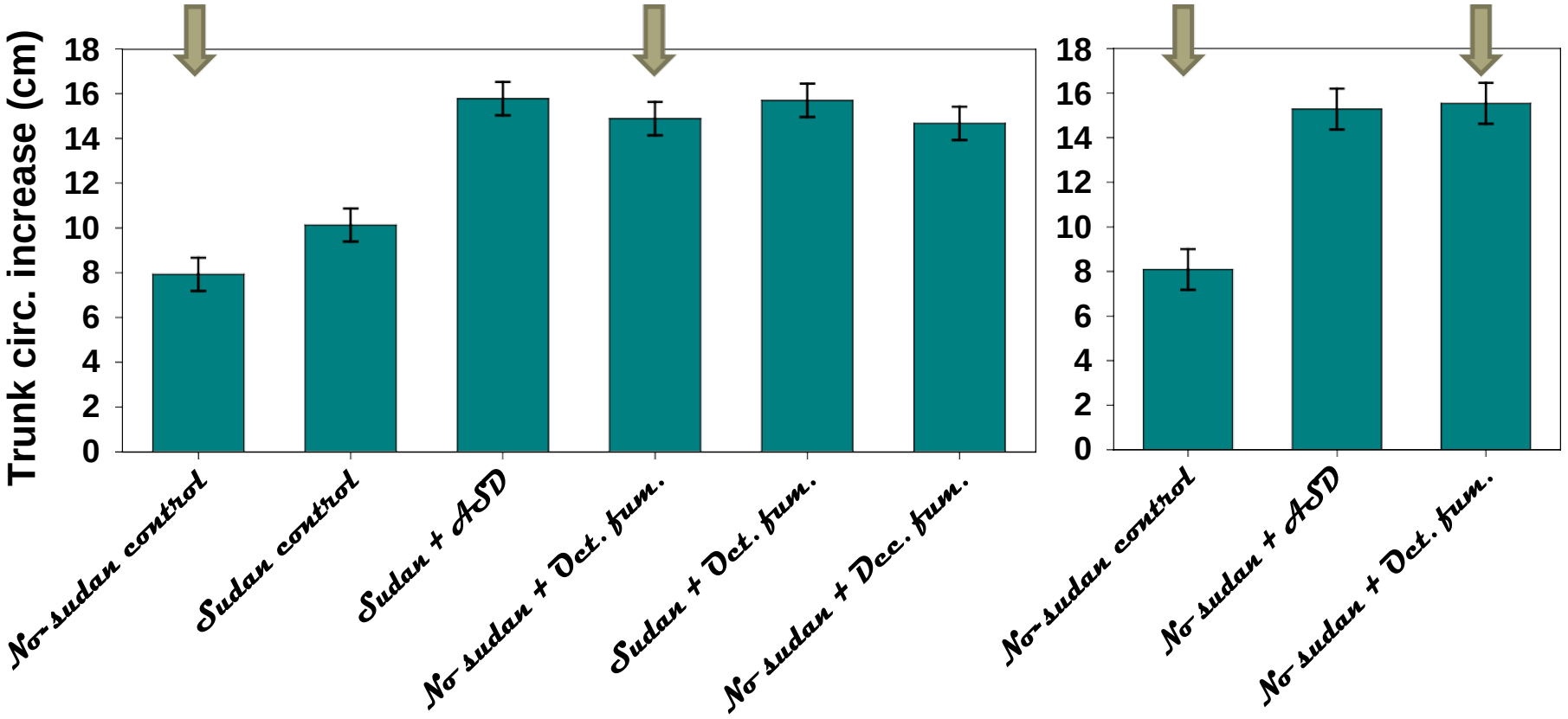
Delhi trial

Impact: Commercial availability of GPS-controlled spot fumigation technology, TriCal, Inc.

Ongoing: two large, commercial-scale replicated spot fumigation vs. strip fumigation trials planned in Kern County for 2016

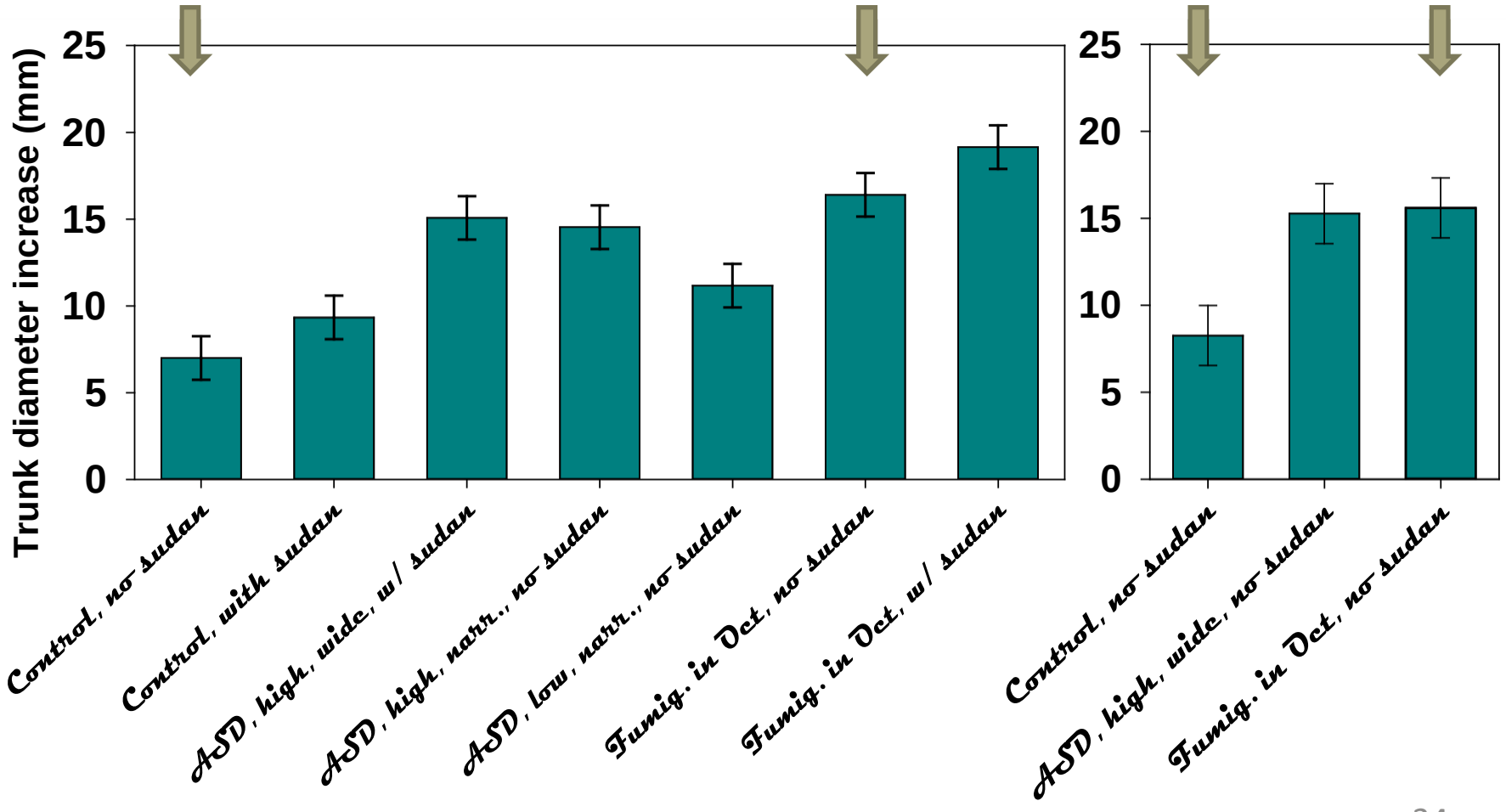
KAC trials contributing to bioassay validation (no spot fumig), 2014:

Effects of preplant soil treatments on 1st-year growth of almond (after peach on Nemaguard), Trials 1 and 2

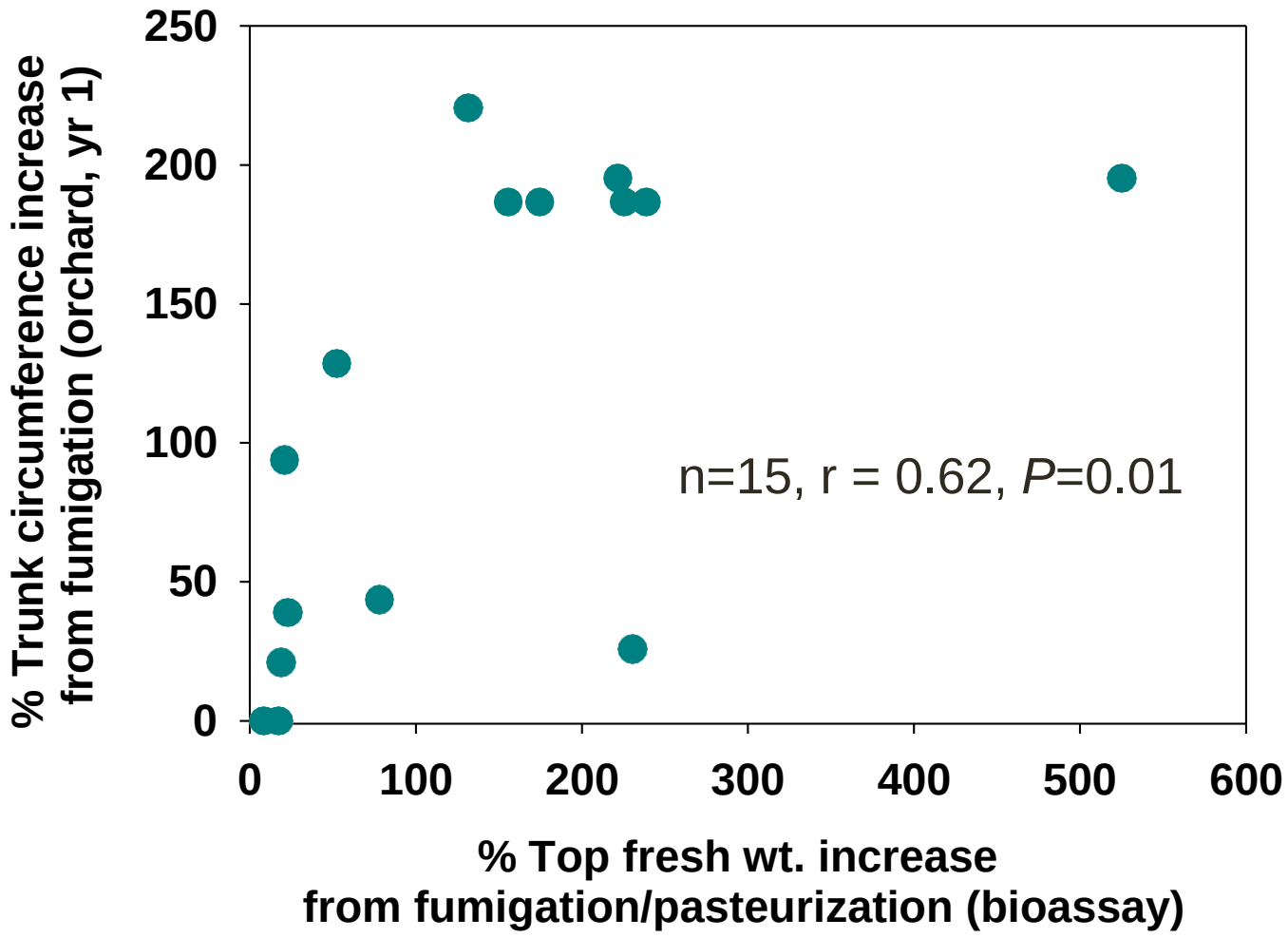


KAC trials contributing to bioassay validation (no spot fumig), 2015:

Effects of preplant soil treatments on **1st-year** growth of almond (after peach on Nemaguard), July 2015, Trials 3 & 4



Overall relationship of orchard tree responses to bioassay responses



Project Outreach

September 25, 2015

University of California
Agriculture and Natural Resources

Almond Replant Field Day

at Nectarine Hall
University of California
Kearney Ag. Center,
9240 S Riverbend Ave, Parlier, CA

Time:
8 am to noon

Coffee & refreshments will be provided

No cost to register

2.5 PCA Credits

Agenda

8:00 am	Update on fumigant regulations from the Fresno Co. Agriculture Commissioner *Bill Griffin, Fresno County Ag. Commissioner's office*
8:30 am	Choosing a Rootstock and replanting preparation *Gurreet Brar, UCCE Farm Advisor, Fresno & Madera*
8:45 am	Nematode issues in almonds- an overview *Andreas Westphal, UCCE Extension Nematologist*
9:15 am	Prunus replant disease & its implications for almonds *Greg Browne, USDA Research Scientist*
9:45 am	Break
10:00 am	Fumigant selection & application strategies for almond replanting in soils infested with parasitic nematodes. *David Doll, UCCE Farm Advisor, Merced Co.*
10:30 am	Fumigation alternatives for replant disease management *Greg Browne, USDA Research Scientist*
11:00 am	Field visit to various research trials

http://ucanr.edu/almondreplantfieldday

RSVP by Sept. 18:
Call Gurreet Brar
559-241-7526 or use link below

- **PRD widespread in *Prunus* planted after *Prunus*, but not impactful in all soils or settings.**
- **Bioassay responses correlated positively (r=0.62, *P*=0.01) with orchard responses (data set limited, n=15).**
- **Good potential for continued improvement of IPM approaches to PRD management (treat based on need, with less or no fumigant)**
- **Root & soil samples from this project being used in metagenomic studies on PRD etiology and prediction (Almond Board of California)**
- **Spot (intermittent strip) fumigation optimized, cost effective, and available (TriCal, Inc.); grower interest in it growing**
- **Outreach indicates replant challenges are complex and dynamic, will benefit from IPM approaches, fumigant and non-fumigant based**


Questions and Discussion?
Thank you!
gtbrowne@ucdavis.edu

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