

# SOIL DISINFESTATION WITH STEAM IN CALIFORNIA STRAWBERRY PRODUCTION

Mark Hoffmann<sup>1</sup>, Tom Miller<sup>1</sup>, John Rachuy<sup>1</sup>, Nathan Dorn<sup>2</sup>, Ian Greene<sup>3</sup>, Janet Broome<sup>4</sup>, Alexandra Barbella<sup>4</sup>, Rachael Goodhue<sup>1</sup> & Steven Fennimore<sup>1</sup>

<sup>1</sup>University of California, Davis, CA  
<sup>2</sup>Reiter Affiliated Companies, Salinas, CA  
<sup>3</sup>Ramco Norcal, Salinas, CA  
<sup>4</sup>Driscoll's Strawberry Assoc. Inc., Watsonville, CA



# AGRICULTURAL SOILS

***‘The history of civilization is the history of the soil’***

(E. V. Wilcox, 1947: ‘Acres and People – The Eternal Problem of China and India’)

***‘Many factors may contribute to ending a civilization, but an adequate supply of fertile soil is necessary to sustain one’***

(D. R. Montgomery, 2007: ‘Dirt – The Erosion of Civilizations’)



**‘Suicidal farming’** (Wilcox, 1947, p. 142): Mismanagement leads to loss of soil fertility

- Loss of capacity to hold and/or distribute nutrients
- Soil erosion
- Accumulation of toxic substances
- Pathogen supportive conditions

**Soil Management: Need of site specific short-term and long-term management systems**

# SOIL-MANAGEMENT

## MB Alternatives for Pre-Plant:

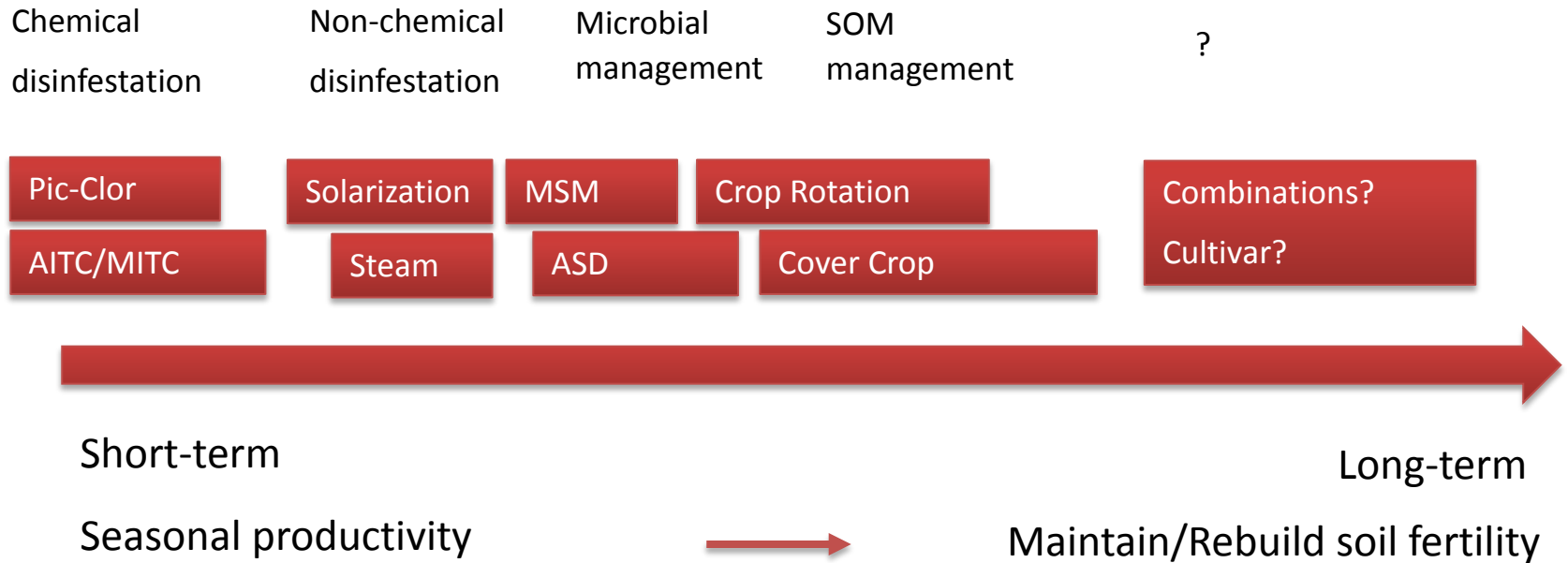
- Managing soil fertility
- Controlling/Suppressing pests and weeds
- Environmental friendly

## Current Problems:

- Site specific decisions (site history? database?)
- Impact of soil quality parameters on pathogen suppression and yield (e.g. microbial communities, SOM quality, humus quality, fertilizer)
- Distribution of pathogens in soil (more specific assessment methods)
- Inconsistency of currently available non-fumigant methods
- Short-term lease of agricultural ground



# SOIL-MANAGEMENT





## WHY STEAM?

- Provides relative consistency
- Ability to treat areas which are restricted by township caps and pesticide regulations
- No chemicals involved: Interesting for organic farming
- Potential for service and potential for technical improvement: Interesting for industry
- Easy to combine with other management methods
- *Potentially useful technique for future precise soil microbial management systems*



**Steam is a valuable addition to alternative soil disinfestation and soil management methods**

## EFFECTS OF STEAM

- Increases granularity of heavy soils
- Increases nutrient availability
- Increased Ammonium levels and increased soluble salts
- Acidic soils release toxic amounts of manganese
- Kills bacteria and fungi (disease control)
- Kills weed seeds



(K.F. Baker, 1957: 'The U.C. System for Producing Healthy Container-Grown Plants')

### *No plants, blank soil, laboratory*

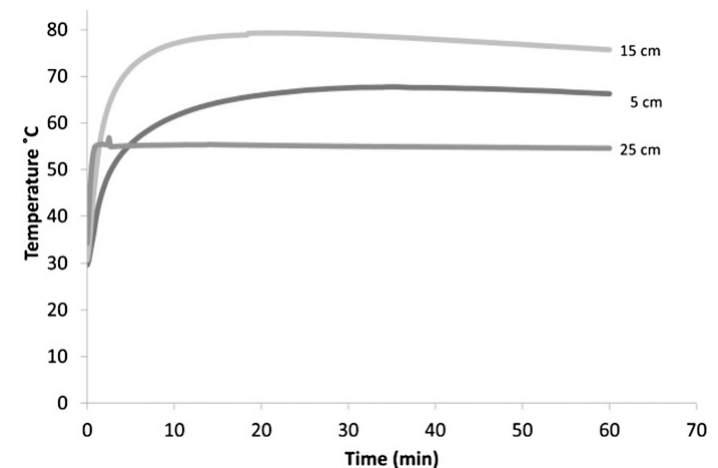
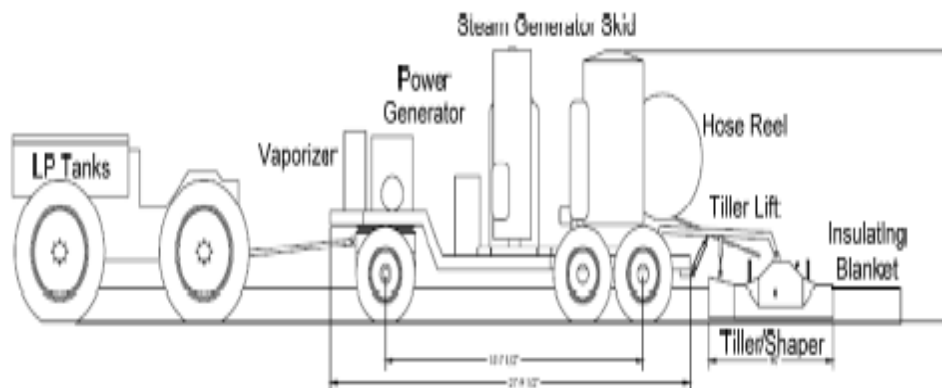
	Non-treated	Steam
<b>NH<sub>4</sub><sup>+</sup> (N ppm)</b>	4.03	6.02
<b>NO<sub>3</sub><sup>-</sup> (N ppm)</b>	41.3	58.4
<b>SOM (% LOI)</b>	3.66	3.75

### *Commercial field*

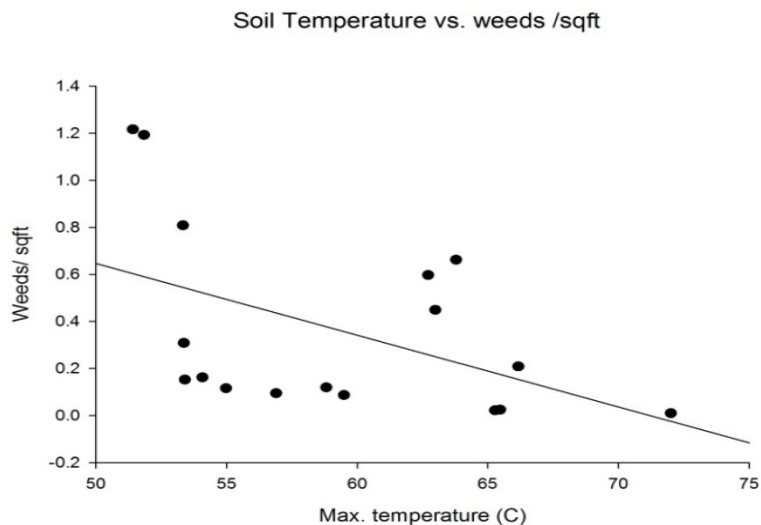
	Non-treated	Steam
<b>NH<sub>4</sub><sup>+</sup> (N ppm)</b>	19.705	17.83
<b>NO<sub>3</sub><sup>-</sup> (N ppm)</b>	18.7425	33.74
<b>SOM (% LOI)</b>	3.73	4.03

# ALPHA PROTOTYPE STEAM MACHINE

- Tractor towed and propane fired
- Clayton 100 HP Steam generator
- Tiller/Shaper system to inject steam in bed
- Build for **52" beds**
- Speed: 31 – 51 hours/acre
- Propane consumption: 1500 – 2500 gal/acre
- Water consumption: 10.000 – 17.000 gal/acre
- Ca. \$ 3.500 - 4.500 / acre
- Year of construction: 2011



# WEED CONTROL VIA STEAM



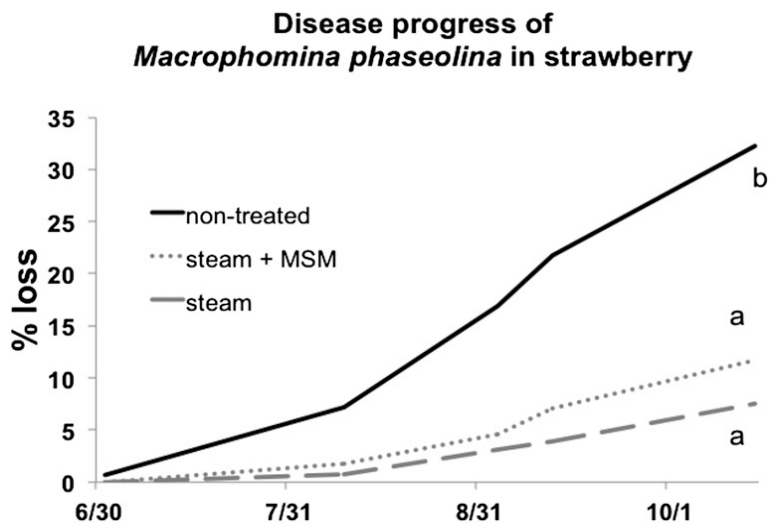
Weeds in a strawberry field in Salinas, CA

	Steam compared to Pic-Clor (Weeds / sqft)	
Trial and Season	MBA 2011/12	Spence 2011/12
Non-treated	0.4b	0.833b
Steam	0.02a	0.165a
Pic-Clor-60	0.03a	0.39a

	Steam compared to ASD (Weeds/ sqft)	
Trial and Season	Fuji 2014/15	TCR 2012/2013
Non-treated	0.46b	2.32b
ASD	0.25ab	2.98b
Steam + MSM	0.03a	0.138a
Steam	-	0.047a



# PATHOGEN CONTROL VIA STEAM



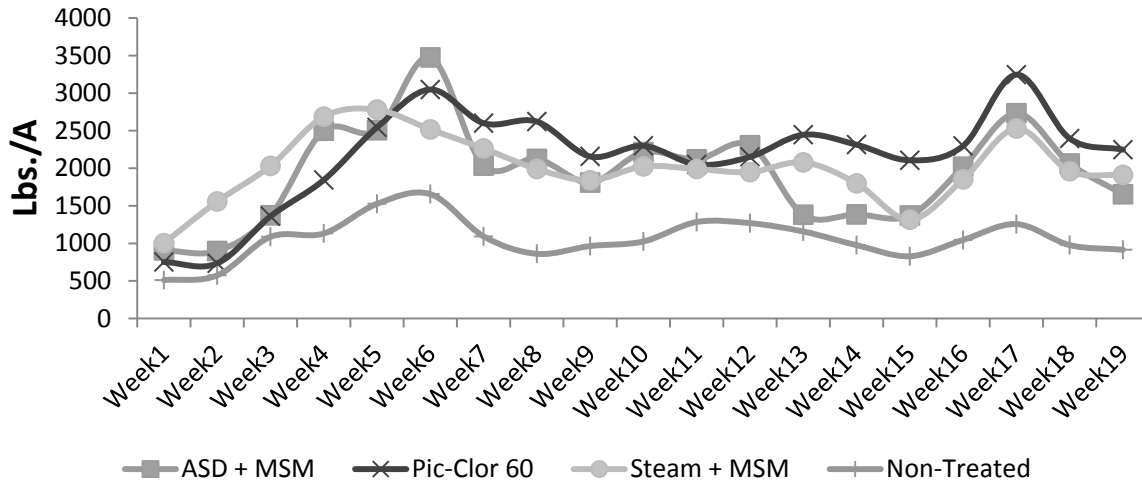
Organic Ranch infested with *M. phaseolina*

	% Reduction of <i>Verticillium dahliae</i> in soil
<b>Trial and Season</b>	Fuji 2014/15
<b>Non-treated</b>	12.5% b
<b>ASD</b>	25% ab
<b>Steam + MSM</b>	45.8 % a

	% Reduction of <i>Pythium ultimum</i>	
<b>Trial and Season</b>	TCR 2012/13	Spence 2014/15
<b>Non-treated</b>	48.1 % b	72.7 % ns.
<b>Steam</b>	89.3 % a	86.7 % ns.
<b>ASD</b>	50.1 % b	-
<b>Steam + MSM</b>	96.4 % a	81.2 % n.s.

# YIELDS WITH STEAM

Weekly average yields (lbs/a) at MBA (1) 2011/2012



	Steam compared to Pic-Clor	
Trial and Season	MBA (2) 2011/12	Spence 2011/12
Non-treated	24,401 ns.	16,887 b
Steam	32,320 ns.	19,876 a
Pic-Clor-60	29,492 ns.	21,169 a

	Steam compared to ASD & MSM		
Trial and Season	TCR 2012/13	Mc Fadden 2013/14	Fuji 2014/15
Non-treated	23,028 b	33,411 b	100 % c
Steam	49,207 a	38,134 ab	-
ASD + Rice	29,175 b	42,972 a	121 % b
MSM	-	39,335 ab	-
Steam+MSM	50,479 a	42,455 a	151 % a



## EXAMPLE: VIGOR

Organic Ranch (Fuji Rd., Salinas CA) high salt levels in Spring and *Verticillium dahliae* pressure

Non-Treated

Steam + MSM



Steam + MSM

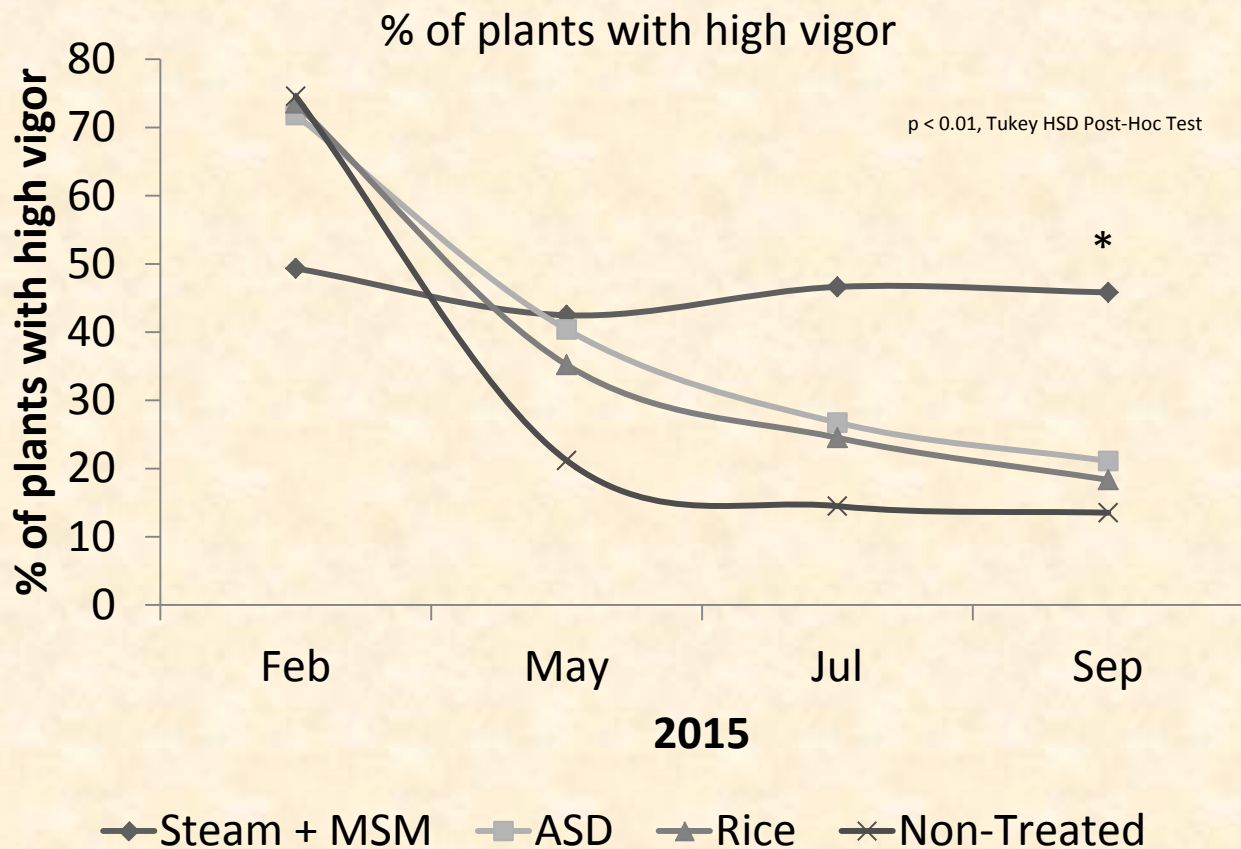
ASD + Rice



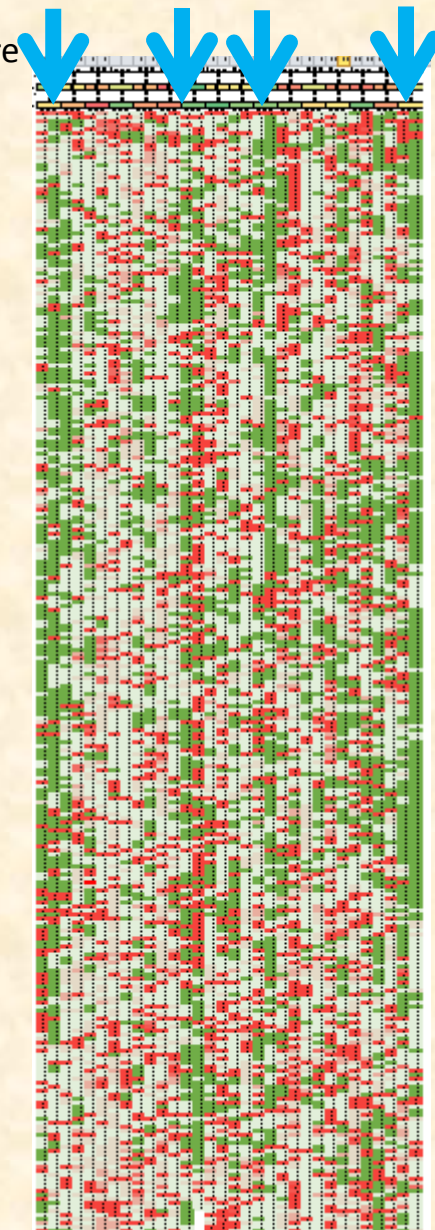
September 2015

## EXAMPLE: VIGOR

Organic Ranch (Fuji Rd., Salinas CA) high salt levels in Spring and *Verticillium dahliae* pressure



September 2015



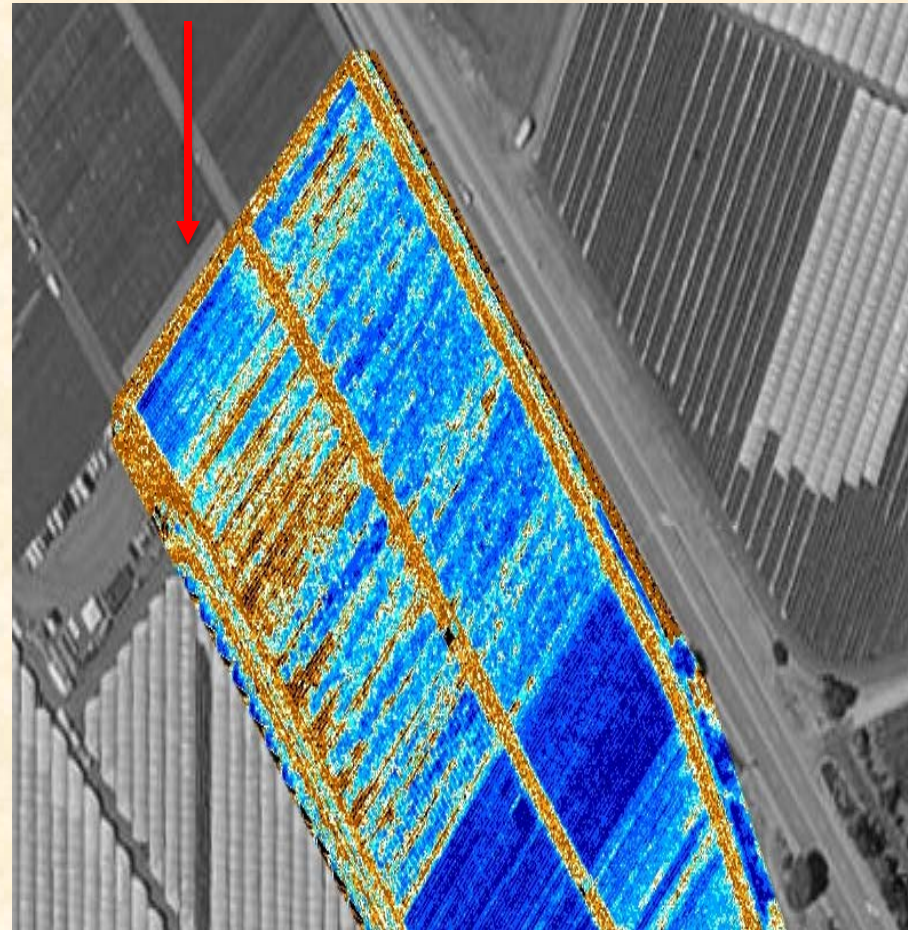
	Total Yield per season(%)
<b>Non-Treated</b>	100 %
<b>Rice</b>	113 %
<b>ASD + Rice</b>	121 %
<b>Steam + MSM</b>	151 %

Dark Green = high vigor. Red = dead. Blue arrows indicate steamed beds



## EXAMPLE: VIGOR

Organic Ranch (TCR, Watsonville, CA): *Macrophomina phaseolina* pressure

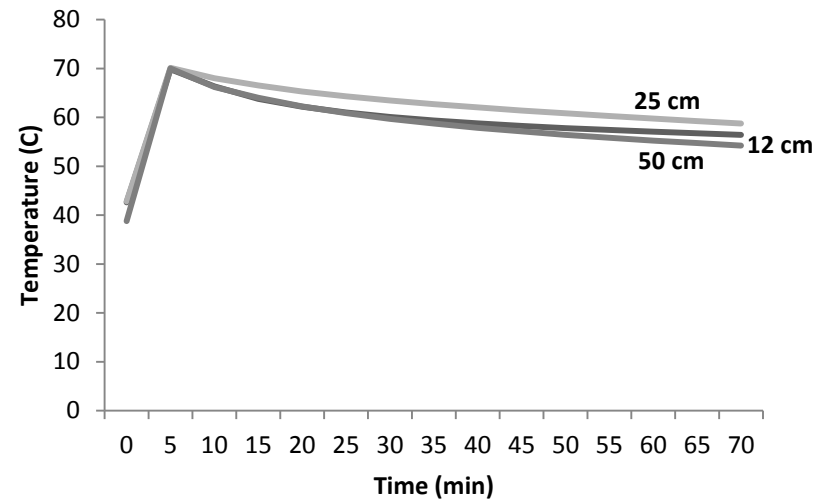
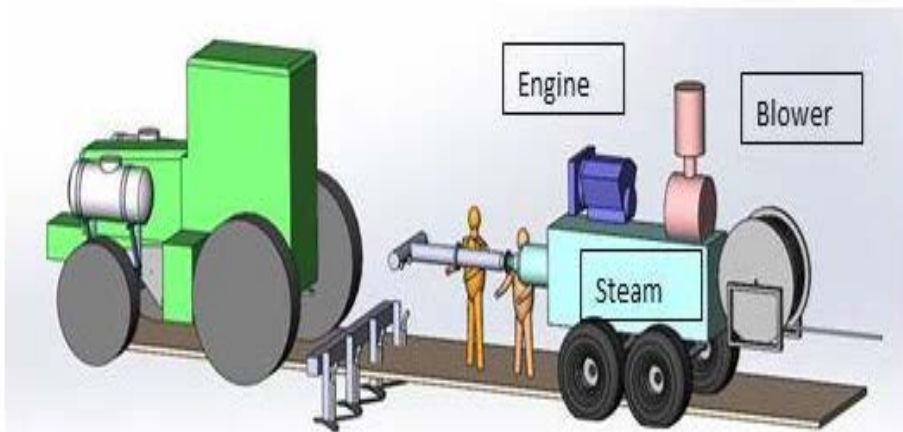


May 2015

September 2015

## 2015: FASTER, CHEAPER, MORE EFFICIENT: NEW DIRECT FIRE STEAM MACHINE

- Tractor towed & propane fired
- Build to treat **flat fields**
- Johnson direct-fire combustion burner
- Plows which inject steam at 12" depth
- Estimated speed: ca.10 – 15 hours/acre
- Propane consumption: 800– 900 gal/acre
- Water consumption: ca. 10.000 gal/acre
- Estimated costs ca. \$ 2.500 / acre
- Year of construction: 2015



**2015: FASTER, CHEAPER, MORE EFFICIENT:  
NEW DIRECT FIRE STEAM MACHINE**



## FUTURE: COVER CROPS, AITC & STEAM?

USDA #2015-07297 (MB Transition Program)

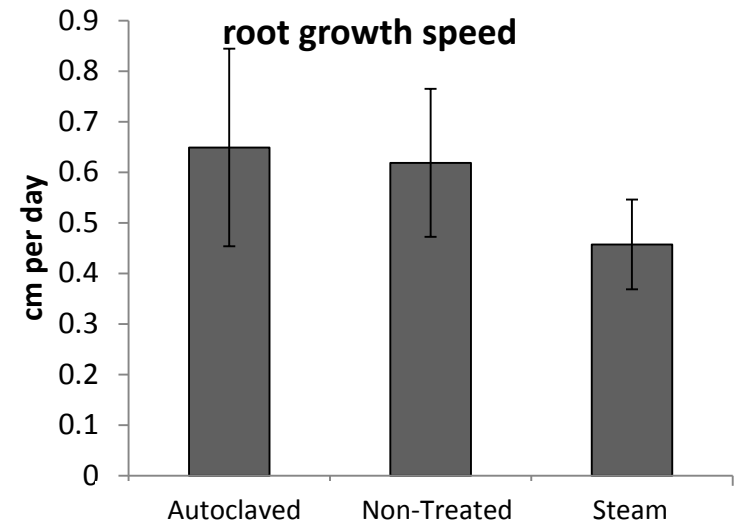
- Combine AITC with Steam to increase pathogen control efficacy
- Effect of cover crops on pathogen suppressive conditions in AITC/Steam based pest management systems
- Increase energy efficacy of Steam treatments via catalytic chemicals (e.g. Quicklime)



Photo by Eric Brennan & Mark Bolda

### Other projects:

- Temporal changes in soil microbial community due to Steam treatment
- Physiological effects of steam treated soil on strawberry plants





## CONCLUSIONS

- Steam controls weeds/pathogens and on similar levels than Pic-Clor 60
- Yields on similar levels than Pic-Clor 60
- Critical: Achievement of temperatures over 60 C for 20 min
- Even when temperatures are not achieved, steamed usually yields 20-30 % more than in non-treated areas (due to N-release)
- With new prototype steam machine, soil disinfestation via steam is becoming more economical and also commercial available.
- **Valuable tool in the tool box**

### Future of Soil Management in Strawberry:

- Site specific!
- Chemical disinfestation: e.g. Pic-Clor, AITC/MITC,...
- Non-chemical disinfestation: e.g. Solarization, **Steam**,....
- Microbial management: e.g. Cover Crops, ASD, MSM,...

# Thank you for your attention

## Funding:



USDA #2013-04491 (MB Transition Program)



Tri Cal Inc.



Propane Education and Research Council



Reiter Aff. Comp. Inc.



California Department of Pesticide Regulations

## Collaborations:



## People:

Frank Martin, USDA Salinas, CA

Steve Koike, UC ANR, Salinas, CA

Peter de Groot, Valley Fabrications, Salinas, CA

Tim Kingston, Gas Technology Institute, Des Plaines, IL

Dan Hodel, Johnson Gas Appliance Comp., Cedar Rapids, IA

Jason Tracy, Valley Fabrications, Salinas, CA

Mike Stanghellini, TriCal. Inc., Hollister, CA

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