Soil Disinfestation in Strawberry with Steam

Steve Fennimore, University of California, Davis

Collaborators

- Tom Miller, Univ. of California
- Jayesh Samtani, Univ. of California
- Tim Kingston, Gas Technology Institute
- Nathan Dorn, Reiter Affiliated Companies
- Rachael Goodhue, Univ. of California
- Ian Greene, Driscoll's

Outline

- Why we need alternatives to fumigants
- Review our methods and results
- Costs of steam for soil disinfestation
- Strategies for integrating steam use into the field
- What is the niche for steam?
- Summary & future directions

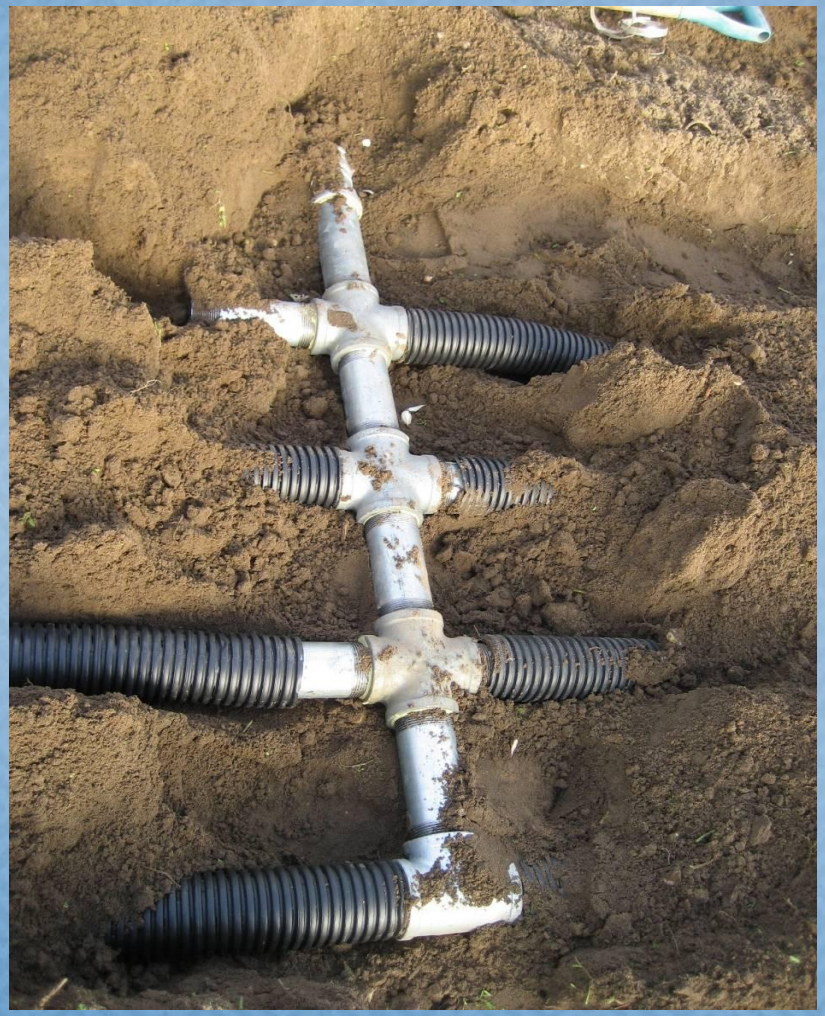
Why nonfumigant alternatives are needed

- Fumigants cannot be used everywhere
  - Organic fields
  - Buffer zones- sensitive sites
- Fumigants have external costs & can be pollutants
- Justification for the development of new fumigants in the model of MB is tenuous
  - Propargyl bromide
  - Methyl iodide
- An integrated system with multiple inputs is more stable in the long-term

School buffer zones

Automatic steam application

Fixed vs mobile system

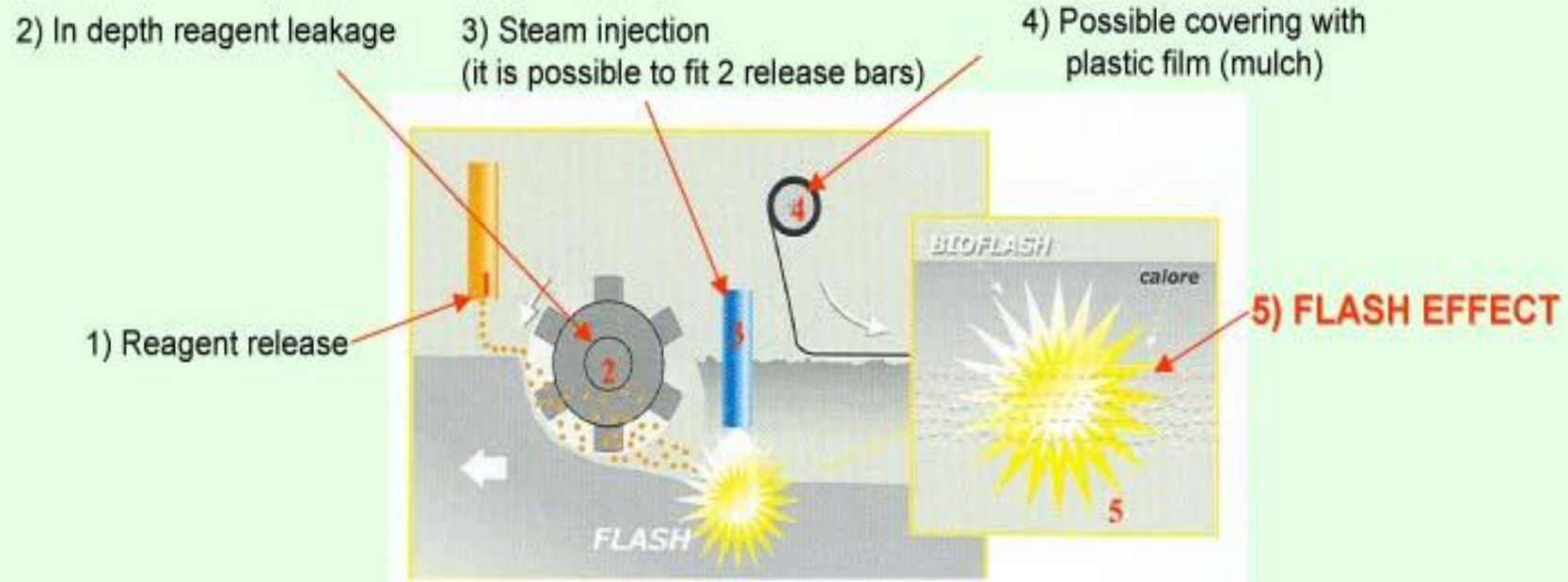


THE MACHINE AT WORK

THE BIOFLASH SYSTEM

works at controlled temperatures for a long period of time, at a deep homogeneous layer

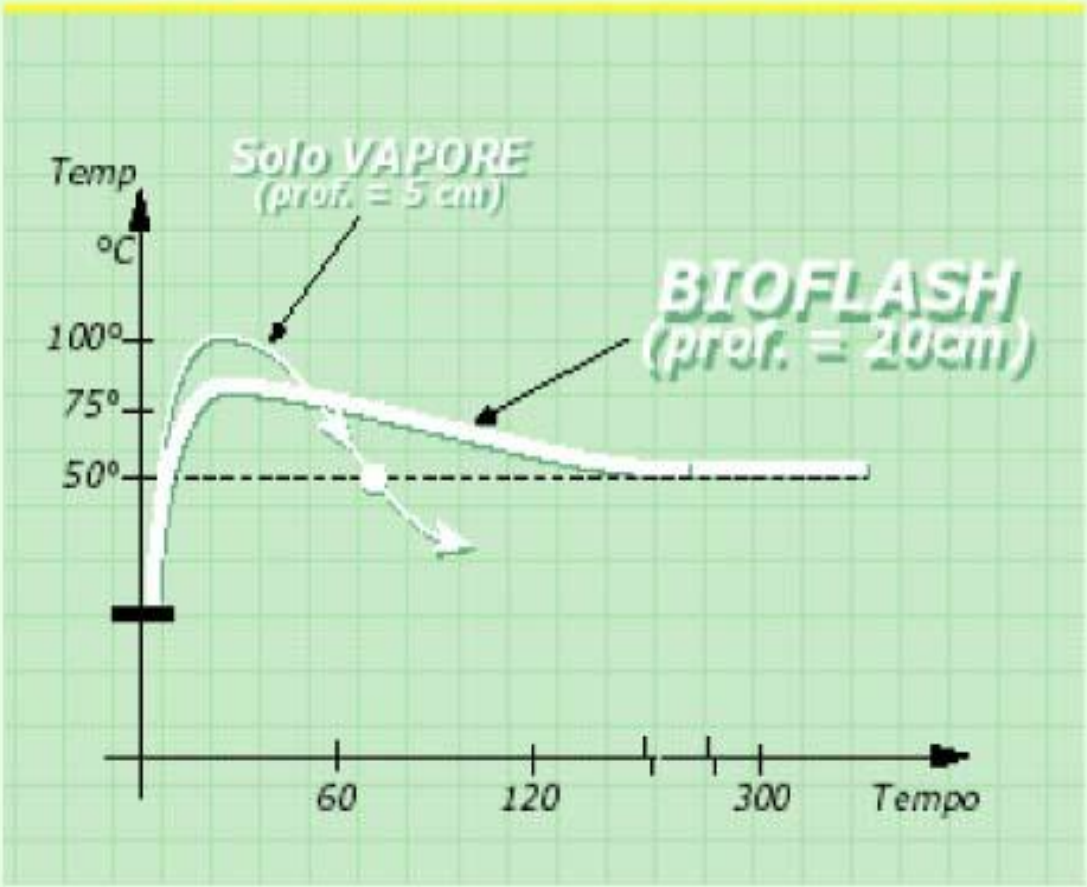
The application of the "exotermic reaction" on the Celli machine



BIOFLASH SYSTEM

- PASTEURISATION
- AND NOT SERILIZATION
- AVOIDING THE BIOLOGICAL VACUUM

DIFFERENCES BETWEEN BIOFLASH AND TRADITIONAL SYSTEMS



Barberi et al. 2009 Weed Research 49:55-66

The curves of temperatures show the difference between the BIOFLASH system and the traditional system based on steam only: with less steam we obtain much longer heating effect

Strategies to increase steam application efficiency

- Physically blend soil with steam.
- Limit the soil volume treated with steam to the minimum required.
- Apply steam with an automatic applicator & reduce steam distribution costs.
- Combine steam with supplemental materials like mustard seed meal (MSM) or quicklime to decrease fuel consumption.

Steam distribution

- **Conduction – transmission of heat from a hot mass to a cool mass through solid, liquid or gas**
- **Convection – transmission of heat through a liquid or gas phase – this is the most important method for steam**
- **Steam moves slowly through static soil.**
- **Can steam movement be speeded up if steam is physically mixed with soil?**

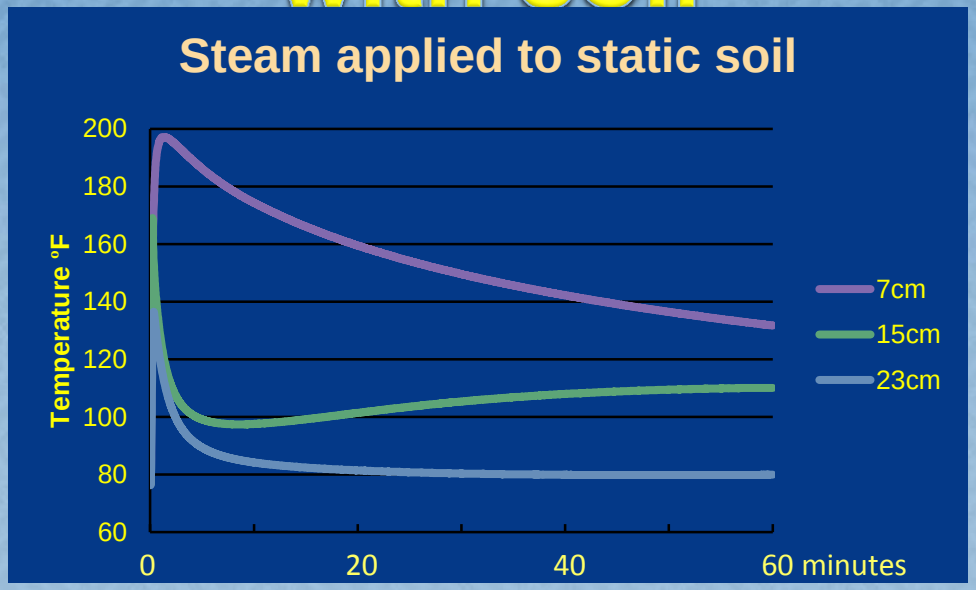
Baker 1957

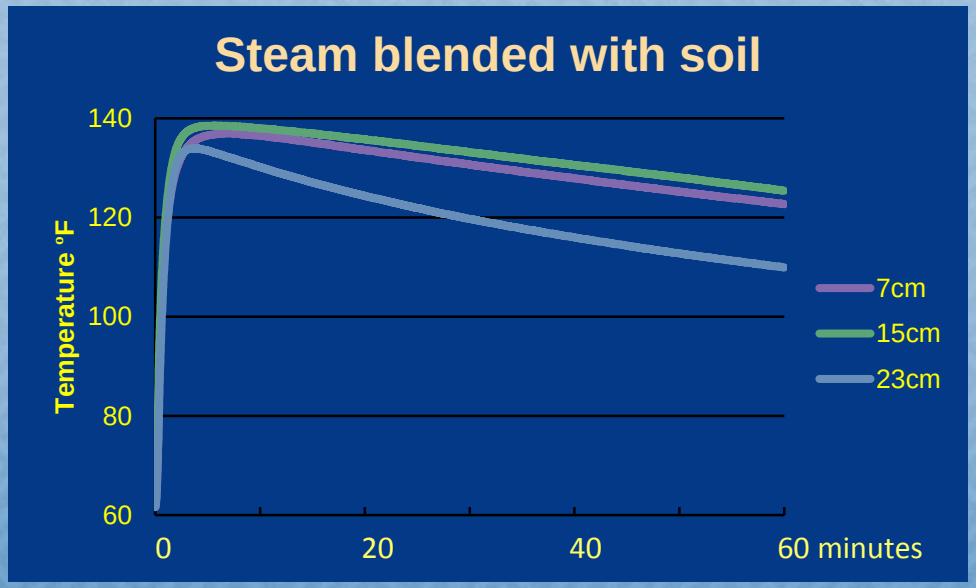
Static steam vs. mixing

- We conducted a test to compare heat distribution in static soil vs. mixing soil using a cement mixer.
- The experiment was repeated in time.

Does blending steam with soil help speed up soil heating?

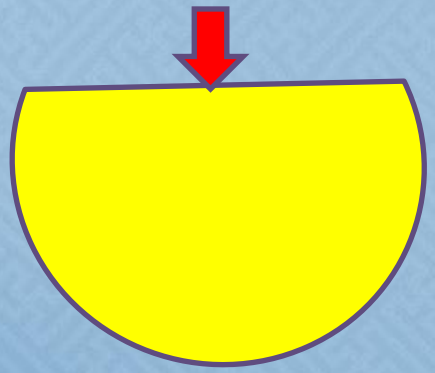
Steam applied to static vs blending with soil



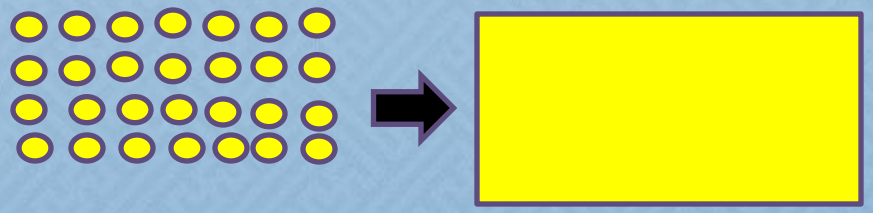


Conclusion steam/soil mixing

- Steam moves mainly by convection in static soil
- Steam moves from the injection point in a “spheroid shape” (Baker 1957)
- The distance to travel is less where soil is blended than where soil is static.



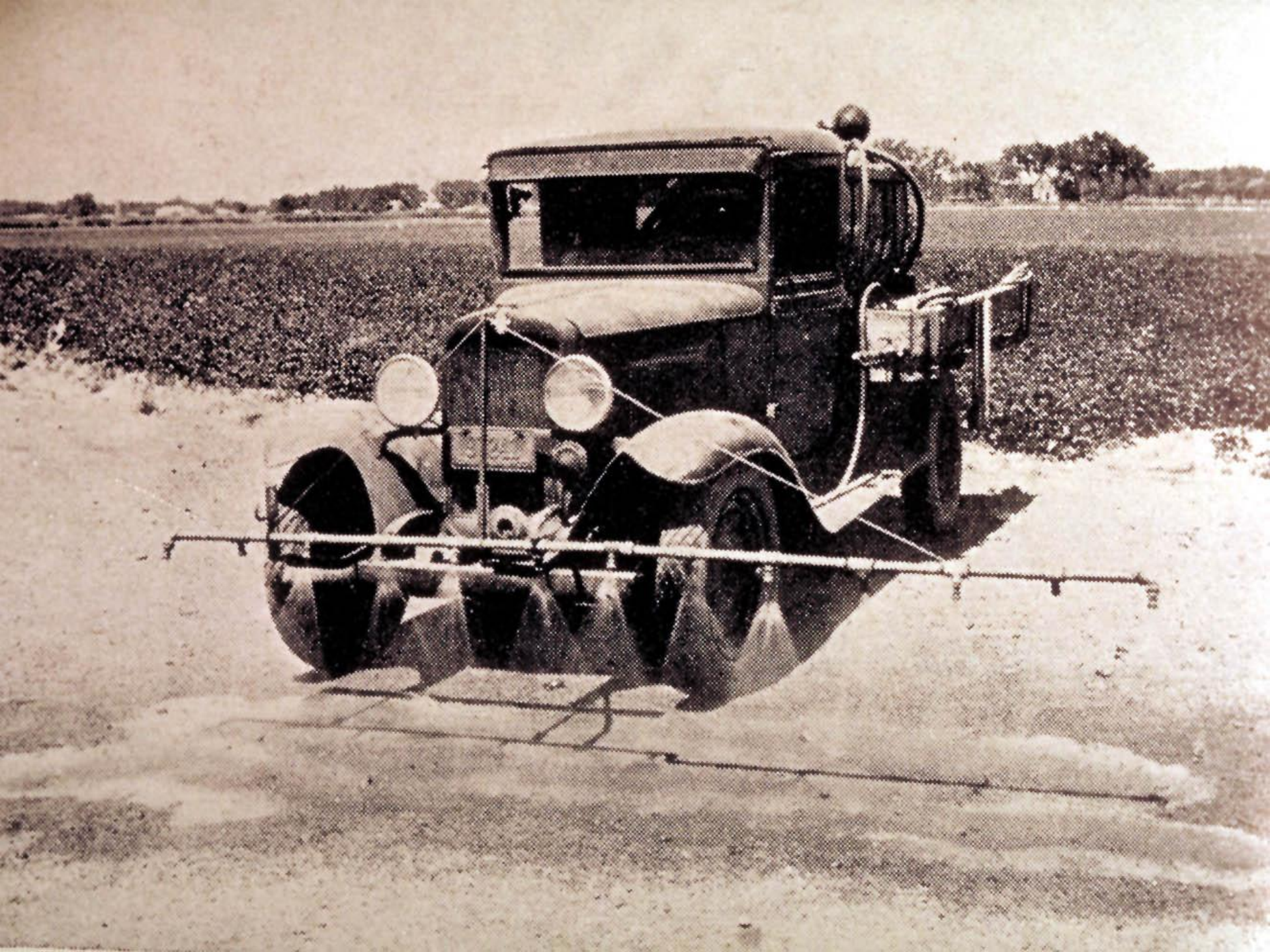
static



blended

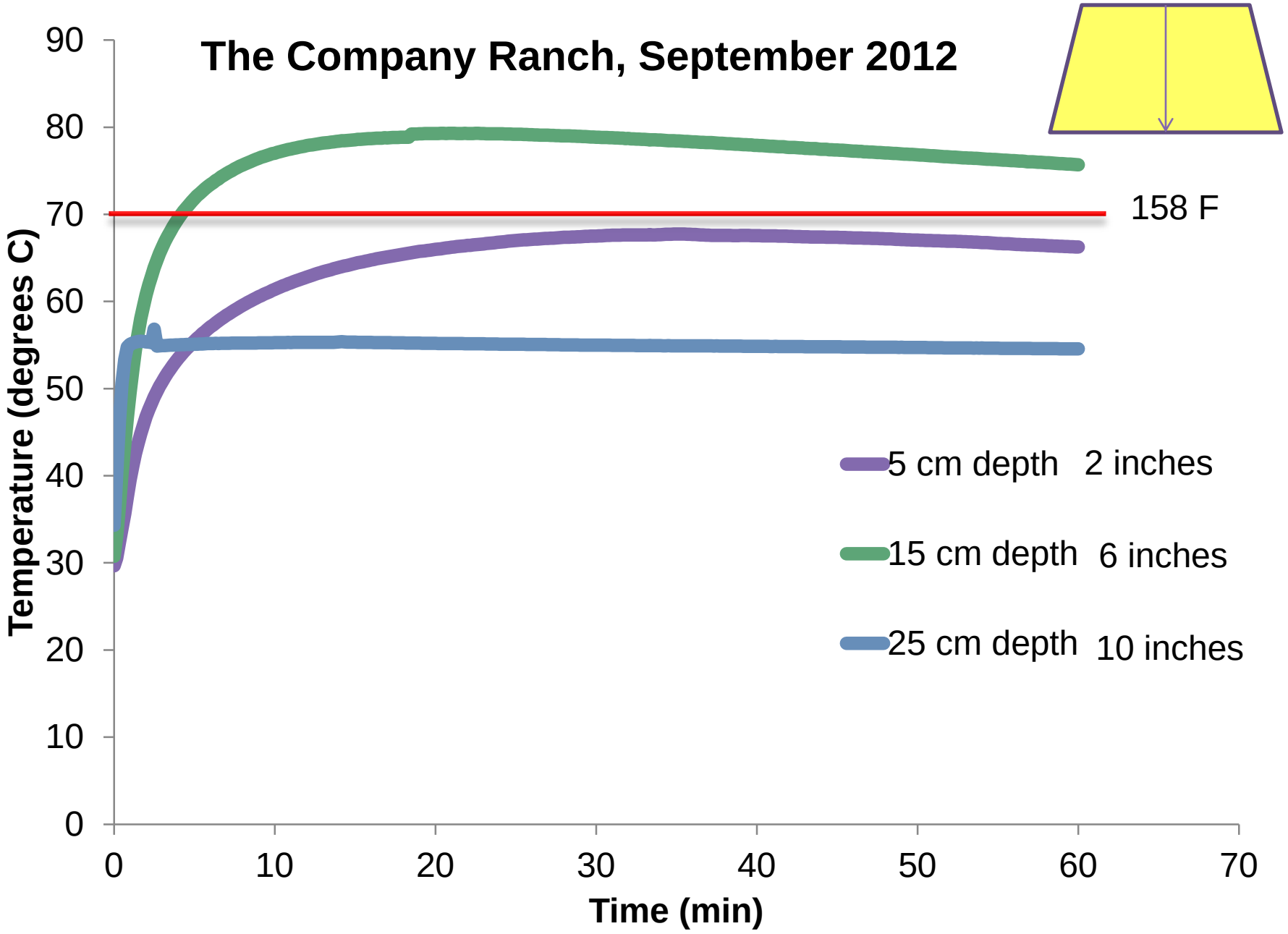
Evaluations of Steam in the Field

- Conducted near Salinas and Watsonville, CA during 2011-12 (below Cassin Ranch, Watsonville).
- Steam was applied with our automatic steam applicator
-



Trial setup

- Conducted near Salinas and Watsonville, CA during 2011-12 and two sites in Watsonville in 2012-13.
- Steam was applied with our automatic steam applicator.
- Treatments were replicated 4 times
- In 2011-12 the standard was Pic Clor 60, in 2012-13 the standard is MBPic.
- In 2012-13 we are also comparing to ASD.
- Economic analysis conducted by Rachael Goodhue at UC Davis included material costs, labor and machine costs.


The Company Ranch, September 2012
Temperature (degrees C)
Time (min)
0
10
20
30
40
50
60
70
80
90
158 F
5 cm depth 2 inches
15 cm depth 6 inches
25 cm depth 10 inches

Weed seed viability 2011- MBA

Treatment	Bluegrass	Chickweed	Knotweed	Little mallow	Yellow nutsedge
	Control (%)				
Control	66 a	69 a	96 a	95 a	45 a
Steam	1 b	2 b	6 b	72 b	0 b
Pic Clor 60	86 a	4 c	0 b	63 b	0 b

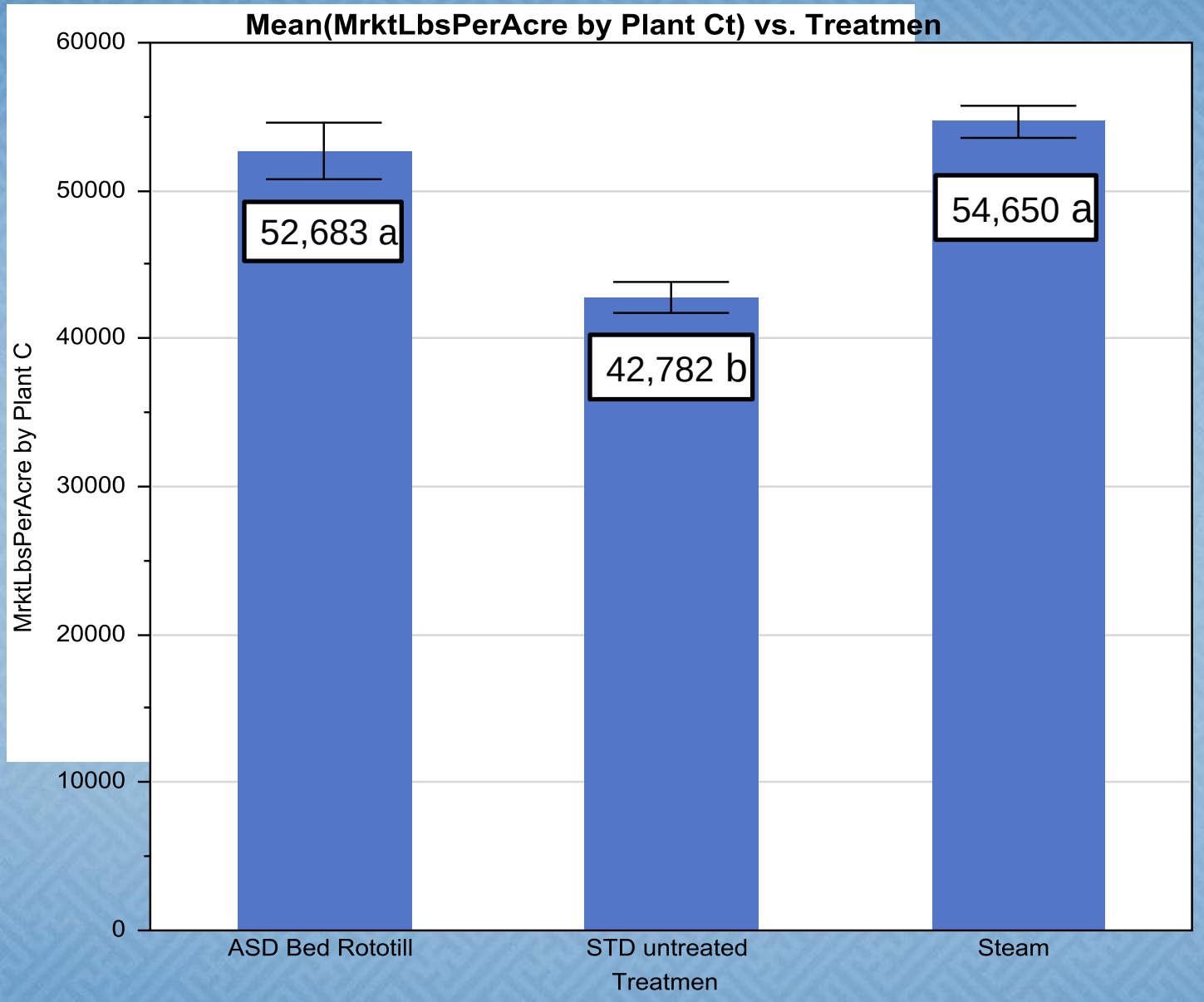
Hand weeding time

Treatment	MBA	Salinas
	Time (hr./A)	
Control	31 a	89 a
Steam	18 b	33 b
Pic clor 60	13 c	39 b

Season long fruit yields

Treatment	MBA	Salinas
	Fruit (g/plant)	
Control	750	478 b
Steam	895	565 a
Pic Clor 60	986	603 a

Proprietary Variety 273M171 Marketable Yield 2012



*Means with the same letter are not significantly different by Tukey-Kramer HSD.

Operation costs for 1 bed vs 2 bed automatic Steam applicator

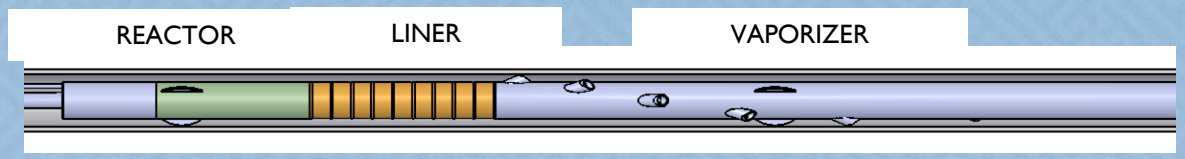
Item	1 bed	2 bed
	$/A	
Propane	4,309	4,309
Labor	827	413
machine	591	256
Total	$5,727	$4,979

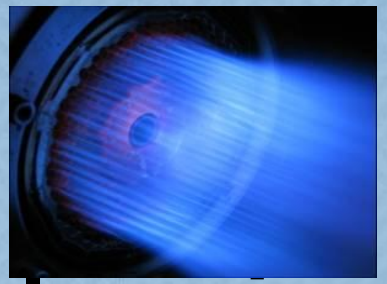
2010-2012 findings

- **Steam controls soil pests such as verticillium and weeds.**
- **These costs while expensive are much cheaper than fixed pipe or sheet steam application methods.**

New steam generation technology

- Downhole steam generator – oil field technology. http://www.precision-combustion.com/cdownhole.html



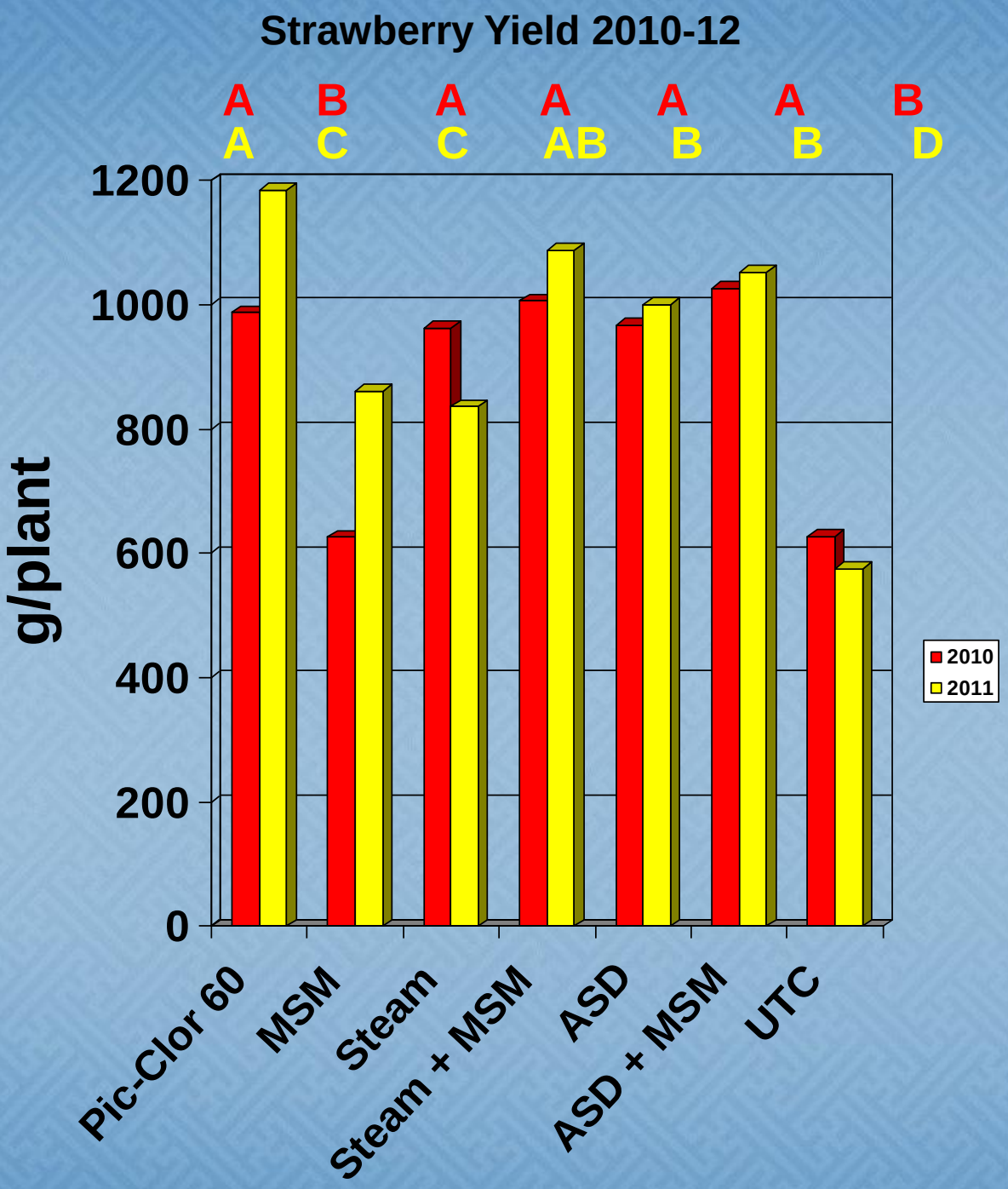


- The advantage to this technology is that it does not use a steam boiler, water hardness is not the problem it is with steam boilers. Fewer pumps, lighter ect.

Steam plus additives

- **Steam applied with exothermic compounds such as CaO (quicklime), KOH or other compounds may allow faster steaming. Barberi et al. 2009 Weed Research 49:55-66**

- **Steam plus mustard seed meals may be complimentary Fennimore et al.– MBAO 2011, 2012**


Strawberry Yield 2010-12
A A
B C
A C
A AB
A B
A B
B D
1200
1000
800
600
400
200
0
g/plant
2010
2011
Pic-Clor 60
MSM
Steam
Steam + MSM
ASD
ASD + MSM
UTC

Summary

- Steam can be used to disinfest field soils.
- Blending soil with steam improves heat distribution in soil.
- Additives such as mustard seed meal or exothermic (quicklime) compounds may be a way of increasing steam use efficiency.

Summary: II

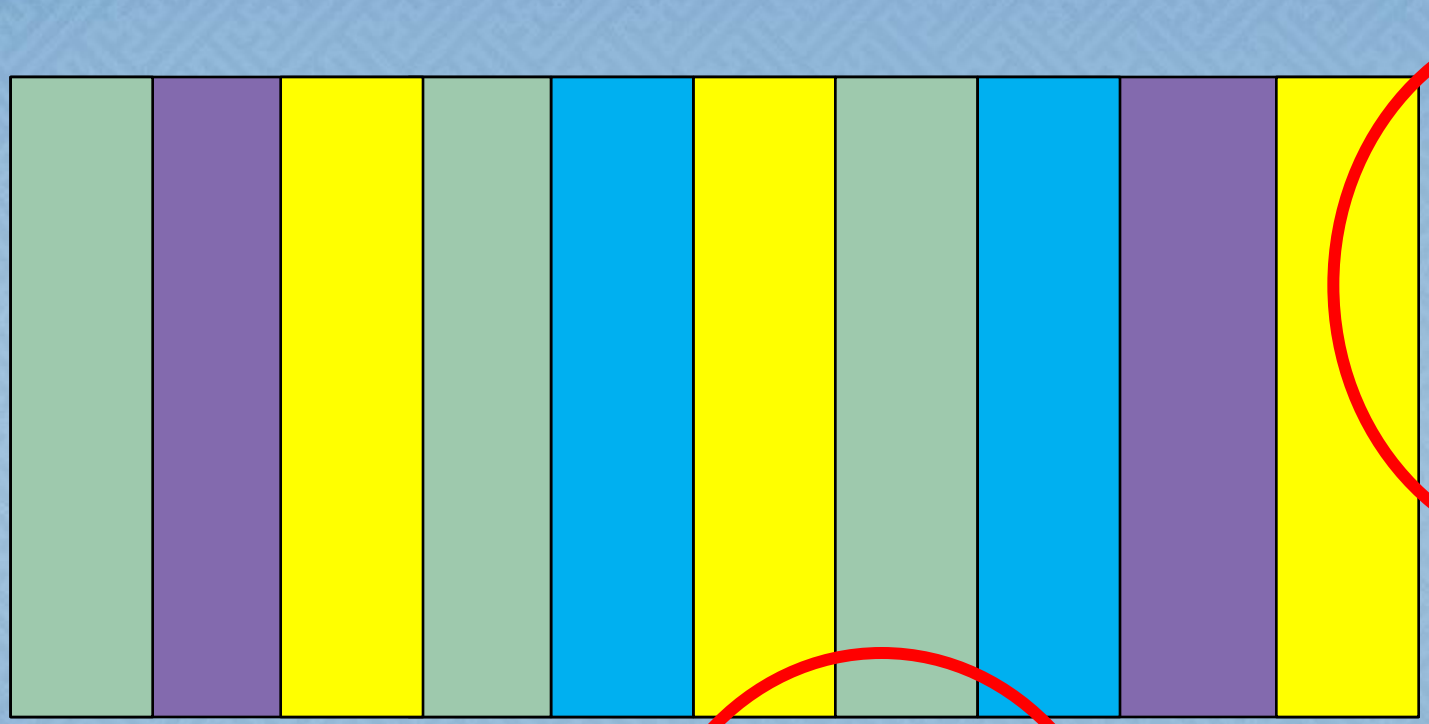
- **Automatic steam application systems may be the way to reduce costs of steam application in the field.**
- **Conversion from propane to natural gas would cut fuel costs.**

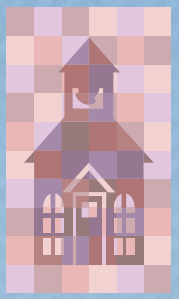
Future directions

- Continue with steam technology development.
  - Maximize applicator efficiency
  - Maximize fuel use efficiency
  - Reduce fuel costs
- Pursue downhole steam generation technology
- Use additives such as MSM or exothermic compounds to allow faster steam application or improved performance.

School buffer zones

An 80 acre field impacted by sensitive sites





A business role for steam

- **An 80 acre farm with 72 acres farmable**
- **65 acres can be fumigated, 7 acres cannot be fumigated**
- **Fumigant cost $1,350/A or $87,480; steam costs $7,000/A or 49,000 for total treatment cost of $1,899/A or $136,750.**
- **The farm gross value is $44,168/A * 72 A = $3.2 M or $44,168 * 65 A = $2.9 M**

Dara et al. 2011.
http://coststudies.ucdavis.edu/files/Strawberry_SC_SMV2011.pdf

Financial support

- **USDA NIFA Methyl Bromide Transitions 2010-51102-21648**
- **California Strawberry Commission**
- **Propane Education and Research Council**
- **In-kind support from Reiter Affiliated Companies & Driscoll's**