Soil Disinfestation in Strawberry with Steam

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Collaborators

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

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

The application of the “exothermic reaction” on the Celli machine

1) Reagent release
2) In depth reagent leakage
3) Steam injection (it is possible to fit 2 release bars)
4) Possible covering with plastic film (mulch)
5) FLASH EFFECT

BIOFLASH SYSTEM
• PASTEURISATION
• AND NOT SERILIZATION
• AVOIDING THE BIOLOGICAL VACUUM
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

Steam applied to static soil

Temperature °F

0 20 40 60 minutes

7cm
15cm
23cm

Steam blended with soil

Temperature °F

0 20 40 60 minutes

7cm
15cm
23cm
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.
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)

- 5 cm depth  2 inches
- 15 cm depth  6 inches
- 25 cm depth  10 inches

158 F
# Weed seed viability 2011- MBA

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bluegrass</th>
<th>Chickweed</th>
<th>Knotweed</th>
<th>Little mallow</th>
<th>Yellow nutsedge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>66 a</td>
<td>69 a</td>
<td>96 a</td>
<td>95 a</td>
<td>45 a</td>
</tr>
<tr>
<td>Steam</td>
<td>1 b</td>
<td>2 b</td>
<td>6 b</td>
<td>72 b</td>
<td>0 b</td>
</tr>
<tr>
<td>Pic Clor 60</td>
<td>86 a</td>
<td>4 c</td>
<td>0 b</td>
<td>63 b</td>
<td>0 b</td>
</tr>
</tbody>
</table>

Control (%)
## Hand weeding time

<table>
<thead>
<tr>
<th>Treatment</th>
<th>MBA</th>
<th>Salinas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time (hr./A)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>31 a</td>
<td>89 a</td>
</tr>
<tr>
<td>Steam</td>
<td>18 b</td>
<td>33 b</td>
</tr>
<tr>
<td>Pic clor 60</td>
<td>13 c</td>
<td>39 b</td>
</tr>
</tbody>
</table>
## Season long fruit yields

<table>
<thead>
<tr>
<th>Treatment</th>
<th>MBA</th>
<th>Salinas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fruit (g/plant)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>750</td>
<td>478 b</td>
</tr>
<tr>
<td>Steam</td>
<td>895</td>
<td>565 a</td>
</tr>
<tr>
<td>Pic Clor 60</td>
<td>986</td>
<td>603 a</td>
</tr>
</tbody>
</table>
Proprietary Variety 273M171 Marketable Yield 2012

Mean(MrktLbsPerAcre by Plant Ct) vs. Treatmen

- ASD Bed Rototill: 52,683 a
- STD untreated Treatmen: 42,782 b
- Steam: 54,650 a

*Means with the same letter are not significantly different by Tukey-Kramer HSD.*
## Operation costs for 1 bed vs 2 bed automatic Steam applicator

<table>
<thead>
<tr>
<th>Item</th>
<th>1 bed</th>
<th>2 bed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane</td>
<td>$4,309</td>
<td>$4,309</td>
</tr>
<tr>
<td>Labor</td>
<td>$827</td>
<td>$413</td>
</tr>
<tr>
<td>Machine</td>
<td>$591</td>
<td>$256</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$5,727</strong></td>
<td><strong>$4,979</strong></td>
</tr>
</tbody>
</table>
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


- 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 etc.
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

g/plant

- Pic-Clor 60
- MSM
- Steam
- Steam + MSM
- ASD
- ASD + MSM
- UTC

- A
- B
- C
- AB
- A
- B
- D

- 2010
- 2011
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.
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.
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