Optimizing Anaerobic Soil Disinfestation (ASD) for California Strawberries


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Project Goals

• To test ability of ASD to consistently control *V. dahliae* and other pathogens and monitor effect on strawberry yields

• To assess the economic feasibility of ASD

• To determine the mechanisms of disease reduction by ASD

• To determine effect of ASD on N fertility and cycling with different C-sources

• To test ASD at commercial scales
ASD: some target Pests and Crops

- **Soil-borne pathogens**
  - *Verticillium dahliae*\(^1,2,4\)
  - *Fusarium oxysporum*\(^1,2\)
  - *Fusarium redolens*\(^2\)
  - *Ralstonia solanacearum*\(^2\)
  - *Rhizoctonia solani*\(^1\)
  - *Sclerotium rolfsii*\(^3\)

- **Nematode**
  - *Meloidogyne incognita*\(^1\)
  - *Pratylenchus fallax*\(^2\)

- **Weed**
  - *Nutsedge*\(^3\)

- **Crops tested**
  - Welsh onion\(^2\)
  - Tomatoes\(^2\)
  - Strawberries\(^2,4\)
  - Eggplant\(^2,3\)
  - Spinach\(^2\)
  - Peppers\(^3\)
  - Maple\(^1\)
  - Catalpa\(^1\)

\(^1\) Dutch studies; \(^2\) Japanese studies; \(^3\) Florida studies; \(^4\) California
ASD: Three Steps

1. Incorporate organic material
   - Provides C source for soil microbes

2. Cover with tarp

3. Irrigate to field capacity
   - Water-filled pore space
   - Create anaerobic (no oxygen) conditions and stimulate anaerobic decomposition of incorporated organic material
Spreading rice bran – broadcast with manure spreader
Applying rice bran to beds only, then rototilling to incorporate
Findings to 2012

1. Good yields obtained with 9ton/ac rice bran
   1. Salinas 2010 - equal to MeBr (and UTC) yields
   2. Watsonville 2010 - within 15% of MeBr yields
   3. Ventura 2011 – 75% increase yield over UTC
   4. Castroville 2011- as good or better than Pic-Clor
   5. Watsonville 2011 – equal to Pic-Clor and steam

2. Can get consistently good *V. dahliae* suppression - 80 to 100% decrease in # microsclerotia in soil, using a range of C sources

3. Standard tarp as effective as TIF and VIF

4. Weed suppression limited in the central coast of CA
Findings to 2012 (contd):

5. Need to accumulate 50,000 mVhr of Eh below 200mV to get suppression, and for soil temps to be above 65°F for at least first week of ASD treatment.
Watsonville 2010/11, 2011/12

Marketable Fruit Yield
(MBA 2011, 2012)

Fruit yield lbs/acre

2011

2012

Untreated control
MM
ASD
Steam
ASD + MM
Steam + MM
Pic-Clor 60

B
B
A
A
A
A

F
DE
CD
E
BC
AB
A
Cumulative Eh mV hrs at 21 days at ASD plots
(Rice bran 9 t/acre)

* Average soil temperature at 6" depth during the first week of ASD treatment. Threshold is >65 °F.
Pythium spp.

% roots from which fungi was isolated

Cylindrocarpon spp.
% roots from which Rhizoctonia was isolated
% roots from which Fusarium spp. were isolated
MBA, Post-treatment Total bacteria: November 2011

All ASD and mustard-based treatments stimulated bacterial communities, likely inducing an elevated competitive environment.
All ASD and mustard-based treatments stimulated total fungal densities, likely inducing an elevated competitive environment.
Pre treatment  Oct 2011

Post treatment – Nov 2011

Fungal community composition determined by T-RFLP analysis
MBA, Watsonville. 2011/12

Post harvest Sept 2012
Treatment effects on soil chemical characteristics MBA trial, Watsonville (0”-6” depth. 5/2/2012). Numbers with the same letter are not significantly different ($P=0.05$).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>EC 1:2 dS/m</th>
<th>Olsen-P$_2$O$_5$ ppm</th>
<th>Ex. Ca ppm</th>
<th>Ex. Mg ppm</th>
<th>Ex. K ppm</th>
<th>Ex. Na ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTC</td>
<td>6.7</td>
<td>0.14</td>
<td>44.8 b</td>
<td>10500</td>
<td>3125 bc</td>
<td>1328 b</td>
<td>305</td>
</tr>
<tr>
<td>MM</td>
<td>6.6</td>
<td>0.16</td>
<td>46.5 b</td>
<td>9800</td>
<td>2925 c</td>
<td>1298 b</td>
<td>270</td>
</tr>
<tr>
<td>ASD</td>
<td><strong>6.3</strong></td>
<td><strong>0.31</strong></td>
<td><strong>79.8 a</strong></td>
<td>9800</td>
<td><strong>3775 a</strong></td>
<td><strong>2362 a</strong></td>
<td>270</td>
</tr>
<tr>
<td>Steam</td>
<td>6.6</td>
<td>0.18</td>
<td>44.0 b</td>
<td>10100</td>
<td>3138 bc</td>
<td>1995 b</td>
<td>310</td>
</tr>
<tr>
<td>MM+ASD</td>
<td><strong>6.4</strong></td>
<td><strong>0.29</strong></td>
<td><strong>74.3 a</strong></td>
<td>10275</td>
<td><strong>3863 a</strong></td>
<td><strong>2420 a</strong></td>
<td>295</td>
</tr>
<tr>
<td>Steam+MM</td>
<td><strong>6.4</strong></td>
<td><strong>0.27</strong></td>
<td><strong>45.8 b</strong></td>
<td>10725</td>
<td><strong>3325 b</strong></td>
<td>1463 b</td>
<td>323</td>
</tr>
<tr>
<td>Pic-Clor</td>
<td>6.7</td>
<td>0.14</td>
<td>43.3 b</td>
<td>10025</td>
<td>3175 bc</td>
<td>1188 b</td>
<td>308</td>
</tr>
<tr>
<td>P value</td>
<td>0.07</td>
<td>0.05</td>
<td>0.0001</td>
<td>0.77</td>
<td>0.0001</td>
<td>&lt;0.0001</td>
<td>0.48</td>
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</table>
• Soil pH and Nitrate Content Changes at ASD Plots (MBA, 2012-13)

Soil pH and Nitrate Content changes over time for two different treatments: ASD molasses 9 t/ac and ASD rice bran 9 t/ac.
Santa Maria 2011/12
Partial Costs and Net Returns ($ per Acre)
Injecting molasses
2012-2013 season
Commercial Implementation of ASD in CA

<table>
<thead>
<tr>
<th>Crop</th>
<th># of site</th>
<th>C-source * (# of site)</th>
<th>Acreage per site Ave. (Min. – Max.)</th>
<th>Acreage Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberry</td>
<td>16</td>
<td>RB 6-9 t/ac (14) ML 6 t/ac (2)</td>
<td>5.8 (1-20)</td>
<td>94</td>
</tr>
<tr>
<td>Raspberry</td>
<td>11</td>
<td>RB 6-9 t/ac (11)</td>
<td>2.2 (1-5)</td>
<td>24</td>
</tr>
<tr>
<td>Blueberry</td>
<td>1</td>
<td>RB 6-9 t/ac (1)</td>
<td>5.0 (5-5)</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>28**</td>
<td>RB 6-9 t/ac (26) ML 6 t/ac (2)</td>
<td>4.4 (1-20)</td>
<td>123</td>
</tr>
</tbody>
</table>

* RB: rice bran, ML: molasses. ** 26 organic sites and 2 conventional sites.

## 2012-2013 demonstration trials – detailed monitoring

<table>
<thead>
<tr>
<th>Location</th>
<th>C-source</th>
<th>Acre age</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watsonville</td>
<td>9t/ac Rice Bran or 4.5t/ac RB+4.5t/ac Molasses +/- preplant fertilizer</td>
<td>1</td>
<td>Organic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>Conventional</td>
</tr>
<tr>
<td>Salinas</td>
<td>9 t/ac Molasses</td>
<td>0.5</td>
<td>Conventional</td>
</tr>
<tr>
<td>Salinas</td>
<td>9 t/ac Molasses</td>
<td>1</td>
<td>Conventional</td>
</tr>
<tr>
<td>Santa Maria</td>
<td>9 t/ac Molasses</td>
<td>0.5</td>
<td>Conventional</td>
</tr>
<tr>
<td>Location</td>
<td>C-source/treatments</td>
<td>type</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>Watsonville</td>
<td>Rice bran 6, 9 t/ac Molasses 6, 9 t/ac RB 4.5 + Mol 4.5 t/ac UTC</td>
<td>Conventional</td>
<td></td>
</tr>
<tr>
<td>Watsonville</td>
<td>Rice bran 6, 9 t/ac Molasses 6, 9 t/ac RB 4.5 + Mol 4.5 t/ac Controls: UTC, Water only, Rice bran 9 t/ac – no water</td>
<td>Conventional</td>
<td></td>
</tr>
<tr>
<td>Watsonville</td>
<td>Rice Bran 9 t/ac Molasses 9 t/ac Steam Steam + Mustard Seed meal UTC</td>
<td>Conventional</td>
<td></td>
</tr>
<tr>
<td>Santa Cruz</td>
<td>RB 4.5 + Mol 4.5 t/ac +/- compost Mustard Seed meal UTC</td>
<td>Organic</td>
<td></td>
</tr>
</tbody>
</table>
Fungal community composition determined by T-RFLP analysis
ASD rice bran 9 t/ac w/o pre-plant fertilizer

Untreated check w/ pre-plant fertilizer

ASD trial at the MBA site, Watsonville. 4/18/2013
ASD rice bran 9 t/ac w/o pre-plant fertilizer

Rice bran 9 t/ac w/o water and pre-plant fertilizer

ASD trial at the MBA site, Watsonville. 4/18/2013
Fungal community composition determined by T-RFLP analysis

Rice bran treatments represent 1 distinct cluster, with depth representing a sub-cluster

Outlier, need to check
Changes in Cumulative Eh mV hours (MBA)

- ASD Rice Bran 9t
- Rice bran 9t w/o water
- UTC

Cum Eh mV hrs vs. ASD treatment (days)
Conclusions

• When get sufficient anaerobic conditions yields equivalent or better than Pic-Clor
• Cost for ASD around $1000/ac higher than Pic-Chlor with 9ton/ac rice bran
• Get good control with ASD of number of pathogens – Verticillium, Rhizoctonia, and Pythium
• Some control of Fusarium with rice bran, but not if use mustard meal in ASD.
• Can get long term decrease in soil pH due to production of nitrate from the rice bran carbon source
• Use of rice bran also increases soil phosphate, potassium, and magnesium levels
Future work planned

- Continue to evaluate ASD for control of other pathogens including Macrophomina
- Test alternative C sources such as molasses, cover crops, alone and in combination with rice bran
- Do more large field demonstrations – assess uniformity
- Continue economic analysis of various ASD options
- Further explore mechanism of action of ASD and suppressiveness of soil following ASD
- Document nitrogen dynamics for different ASD options
- Monitor $\text{N}_2\text{O}$, $\text{CH}_4$, and $\text{CO}_2$ emission during ASD and $\text{NO}_3$ leaching during the winter after ASD
QUESTIONS?

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