History and Principles of Anaerobic Soil Disinfestation

Francesco Di Gioia¹, Monica Ozores-Hampton¹, Erin Rosskopf²

¹ Institute of Food and Agricultural Sciences, SWFREC – University of Florida
² United States Department of Agriculture

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What is Anaerobic Soil Disinfestation?

known also as **Biological Soil Disinfestation** (Blok et al. 2000) or as **Reductive Soil Disinfestation** (Shinmura et al. 1999), ASD is considered one of the most promising non-chemical methods for the (simultaneous) control of soil-borne pathogens, plant-parasitic nematodes and weeds.
ASD: Background

- Developed as an alternative to **methyl bromide** and other soil **chemical fumigants** independently in **Japan** (Shinmura & Sakamoto, 1998; Shinmura, 2000) and in **The Netherlands** (Blok et al., 2000)

**ASD** has proved to be effective against several soil-borne **fungal** and **bacterial** plant diseases, plant-parasitic **nematodes** and **weeds**, across a wide range of **crops** and **environments** (Momma, 2008; Shennan et al., 2014)
Crops tested

- Onion
- Tomatoes
- Strawberries
- Eggplant
- Spinach
- Peppers
- Cut flowers
- Cucurbits
- Banana
- Asparagus

Soil-borne pathogens

- *Verticillium dahliae*¹,²,⁴
- *Fusarium oxysporum*¹,²,³
- *Fusarium redolens*
- *Ralstonia solanacearum*²,³
- *Rhizoctonia solani*¹
- *Sclerotium rolfsii*³

Nematodes

- *Meloidogyne incognita*¹,³
- *Pratylenchus fallax*²

Weeds

- Nutsedge³
- Grasses³

Studies: ¹Dutch; ²Japanese; ³Florida; ⁴California; ⁵China
ASD: in The Netherlands

How ASD was developed?

1944-45 Wieringermeer flood  (Hoes et al. 2013)
How ASD was developed?

1944-45 Wieringermeer flood (Hoes et al. 2013)
Bulb growers saw flooding controlled soil-borne diseases
Nematode control with 8-12 weeks of flooding
ASD: in Japan

How ASD was developed?

Paddy-upland field rotation system

Photo credits Noriaki Momma
ASD: in Japan

How ASD was developed?

Soil solarization
ASD: in Japan

How ASD was developed?

- **Flooding** and **Soil solarization** efficacy was facilitated by **organic amendments** inducing activation of soil microbes and accumulation of volatile compounds (Momma et al. 2013)

- Until **methyl bromide** was available, **non-chemical** disease-controlling methods received little attention and were not developed
How ASD was developed?

- After Montreal and Kyoto protocol and with the increasing concern about human health and environmental sustainability, **Shinmura (2000)** combined the classical flooding and soil solarization technique with organic amendment developing the **reductive soil disinfestation** method.
How ASD was developed?

The **reductive soil disinfestation** method developed by Shinmura consists of:

1) incorporation of organic matter (wheat bran, rice bran, molasses, ...)

2) irrigation to soil saturation

3) covering the soil with plastic film
Today ASD is applied at commercial level in both open field and greenhouse, in organic and conventional farms, in Japan in 33 prefectures out of 47 (Momma 2015, personal communication), in The Netherlands, in USA (California) on about 1,000 acres, and is gaining large interest in China, Europe and other Countries.
ASD: in Japan

Open field

Greenhouse

Momma et al., 2013
ASD is applied even in soilless systems

Momma et al., 2013
ASD: in California

Strawberry

Farm Fuel Inc. (FFI) personal communication  www.farmfuelinc.com
Cumulative ASD-treated acreages in California (all crops)

Year | Acres
--- | ---
2012 | 130
2013 | 431
2014 | 1017
2015 | 850

Farm Fuel Inc. (FFI) personal communication [www.farmfuelinc.com]
Using mainly rice bran as carbon source
In 2013 on a total ASD-treated area of 431 acres (29 growers and 49 sites):

- **71%** were *organic* and **29%** conventional
- **59%** were located in Northern California and **31%** in Southern California
- Crop distribution was **71% strawberry**, **19% raspberry**, **10%** other crops (vegetables, almond and walnut)

Farm Fuel Inc. (FFI) personal communication  www.farmfuelinc.com
ASD: in China

Xinqi Huang, MBAO 2015
Control of Banana Fusarium wilt (Xinqi Huang, MBAO 2015)
Control of Banana Fusarium wilt

Xinqi Huang, MBAO 2015
How to apply the anaerobic soil disinfestatio? in 3 steps
ASD: principle & application method

- Incorporate in the soil readily decomposable organic material (optimal C:N = 30:1)
  ✓ provide C source and activate soil microbes

- Cover with oxygen impermeable tarp
  ✓ create/maintain anaerobic conditions and stimulate anaerobic decomposition of incorporated organic material

- Irrigate the soil to saturation
  ✓ saturate the soil, create anaerobic conditions and stimulate the anaerobic decomposition of incorporated organic material
  ✓ enhance diffusion of by-products in the soil
Accumulation of toxic/suppressive products deriving from the anaerobic decomposition (e.g. organic acids, volatile organic compounds)

**Biological control** by facultative anaerobic microorganisms

- Low pH
- Low oxygen
- Generation of $\text{Fe}^{2+}$ and $\text{Mn}^{2+}$ ions

Combination of all of these
Is ASD suitable for the Florida vegetable production system?
Florida vegetable production system:

- Crops: tomato, pepper, eggplant, cucurbits
- Raised-bed plasticulture
- Sandy soils
- Seepage and drip irrigation system
- Good water availability
- Summer fallow period (good for cover crops)
- Solarization potential (Fall season)
ASD demonstrated to be effective against all the key soil-borne pathogens, nematodes and weed:

- Phytophthora blight (*P. capsici*)
- Fusarium wilts (*F. oxysporum*)
- Southern blight (*Sclerotium rolfsii*)
- Charcoal Rot (*Macrophomina phaseolina*)
- Root-knot nematodes (*Meloidogyne spp.*)
- Yellow and purple *nutsedges* (*Cyperus spp.*)
ASD: obstacles to adoption in Florida

- **Availability of low cost and consistent C sources**
  - locally-sourced waste products
  - cover crops

- **Organic amendment and Food Safety**
  - salmonella testing

- **Nitrogen management**
  - nitrate leaching and GHG emissions

Composting is the solution
ASD: Carbon sources and rates

- **Japan:** Rice bran, wheat bran, ethanol
- **The Netherlands:** Grass, potato haulms, crop residues
- **California:** Rice bran (4.5 to 9 t/acre; ~5.5 to 11 mg C g\(^{-1}\) soil)
  Mustard cake, mustard seed meal, almond hulls
- **Florida:** Liquid molasses (1,500 gal/acre 3.5 t DM/acre)
  Cover crop residue (variable)
- **Tennessee:** Dry molasses (~1.3 to 2.5 t/acre)
  Cover crop residue (variable, 1 to 4.2 mg C/g soil)
  wheat bran
Warm-season cover crops fit well into existing Florida production systems

Greenhouse study
- 2 legumes: cowpea, sunn hemp
- 2 grasses: pearl millet, sorghum-sudangrass
- Cowpea mixed with each grass

All cover crops assured a level of anaerobiocity similar to that of molasses (Butler et al. 2012)
• Yard waste compost

Immokalee, FL
2015 Spring experiment on fresh-market tomato

Treatments:
PicClor 60 (200 lb/acre)
ASD1 (9 t/acre CPL + 1,500 gal/acre of molasses)
ASD2 (9 t/acre CPL + 3,000 gal/acre of molasses)


Irrigation: hybrid seepage - drip irrigation system

Objective:
evaluate the effect of ASD on weed and nematode control, fruit yield and quality
Application of bottom mix
Form false beds
ASD: on tomato in Florida

Composted poultry litter application

9 t/acre
Molasses application
Diluted 1:1 with water to facilitate application

ASD1 1,500 gal/acre  
ASD2 3,000 gal/acre
Organic material tilled into the top 8”
ASD: on tomato in Florida

Form the bed and tarp the soil with Totally Impermeable Film

Apply 2” of water via drip irrigation
ASD: cumulative anaerobicity

Means separation by Duncan’s multiple range test at P = 0.05.
3 weeks after ASD treatment it is possible to transplant...
ASD weed control in the alleys between beds
### ASD parasitic and non-parasitic nematode control

<table>
<thead>
<tr>
<th>Assessment timing</th>
<th>Treatments</th>
<th>Root-knot nematodes (J2 cm(^{-3}) soil)</th>
<th>Non pathogen (number cm(^{-3}) soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td></td>
<td>2.84</td>
<td>238.14</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>PicClor</td>
<td>0.00</td>
<td>0.00 b</td>
</tr>
<tr>
<td>(21 DATA)</td>
<td>ASD1</td>
<td>0.00</td>
<td>2098.00 a</td>
</tr>
<tr>
<td></td>
<td>ASD2</td>
<td>0.00</td>
<td>2840.80 a</td>
</tr>
<tr>
<td></td>
<td><strong>P-values</strong></td>
<td>na</td>
<td><strong>0.004</strong></td>
</tr>
<tr>
<td>Harvest</td>
<td>PicClor</td>
<td>2.84</td>
<td>209.75</td>
</tr>
<tr>
<td></td>
<td>ASD1</td>
<td>17.01</td>
<td>572.75</td>
</tr>
<tr>
<td></td>
<td>ASD2</td>
<td>0.00</td>
<td>303.25</td>
</tr>
<tr>
<td></td>
<td><strong>P-values</strong></td>
<td>0.36</td>
<td>0.50</td>
</tr>
</tbody>
</table>

NA by Nancy Burelle, Means separation by Duncan’s multiple range test at P = 0.05.
ASD effects on tomato marketable yield

Means separation by Duncan’s multiple range test at P = 0.05.
## ASD effects on tomato fruit quality

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Deformation (mm)</th>
<th>Color (1-6 scale)</th>
<th>Total soluble solids (Brix°)</th>
<th>pH (0-14)</th>
<th>Dry matter (g kg(^{-1}) FW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PicClor</td>
<td>2.42 a</td>
<td>5.8</td>
<td>4.09</td>
<td>4.09</td>
<td>34.1</td>
</tr>
<tr>
<td>ASD1</td>
<td>2.01 b</td>
<td>5.6</td>
<td>4.08</td>
<td>4.12</td>
<td>32.7</td>
</tr>
<tr>
<td>ASD2</td>
<td>1.91 b</td>
<td>5.4</td>
<td>4.11</td>
<td>4.15</td>
<td>35.4</td>
</tr>
</tbody>
</table>

P values: 0.02, 0.17, 0.93, 0.42, 0.4

Means separation by Duncan’s multiple range test at P = 0.05.
Acknowledgements

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Thank you!

fdigioia@ufl.edu