SOIL SOLARIZATION, REACTION, AND FUMIGATION EFFECTS ON DOUBLE-CROPPED TOMATO UNDER FULL-BED MULCH

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Abstract. EauGallie fine sand was solarized and compared to a Sesbania macrocarpa Muhl. cover cropped area. Both areas were adjusted to pH 6.0 or 7.5, further divided by soil fumigant treatments [none; methyl isothiocyanate 17% + 1,3 dichloropropene 34% + chloropicrin 15% (V-201) 35 gal/acre; or methyl bromide 98% + chloropicrin 2% (MBC) 300 lb./acre], transplanted with 'Sunny' tomato (Lycopersicon esculentum Mill.) in the fall 1985 and replanted with 'Sunny' tomato in the spring 1986 without disrupting the mulched bed. Solarization reduced the incidence of Verticillium albo-atrum race 2 Reinke & Berth. through both crop seasons but Meloidogyne incognita (Kofoid and White, 1912) Chitwood, 1949 nematodes only during the fall. Tomato yield was improved by solarization 26% in the fall but not affected in the spring. The higher pH level controlled Fusarium oxysporum race 3, Meloidogyne incognita and Cyperus esculentus L. in Manatee County improved tomato yield only in nonsolarized blocks, MBC controlled Fusarium oxysporum race 2, and Fusarium oxysporum race 3 was chosen for establishing off-season treatments in the summer 1985. The field, with a moisture content of 13-15% (dry weight basis), was cultivated to seedbed tilth prior to seeding 4 randomized 16x100 ft plots with Sesbania macrocarpa on 1 July. Four similar plots were sealed with 4 mil clear polyethylene film on 10 July. Wells were placed 430 ft apart to measure water table fluctuation up and down the slope. Recording thermographs measured air temperature and soil temperature at 6 and 12 inch depths under the plastic film and the cover crop. Rainfall was recorded. The film was removed 9 Sept., all plots were rototilled and 2 pH levels (6.0 an 7.5) were developed in each plot with appropriate use of lime or sulfur, thereby establishing subplots of 16x50 ft in size.

Pests such as nematodes, insects, weeds, and soil-borne disease organisms can be limiting to crops grown on the sandy soils of Florida. Several management procedures have been developed in the past 20 years to alleviate the crop loss in infested fields: a) full-bed mulch which damps the extremes of environmental stress on crop plants has been shown to protect plant production potential by reducing incidence of wilt (7) or increasing tolerance to nematodes (14); b) Jones and Overman (5, 6) demonstrated that soil reaction can be a constraint on development of soil-borne disease and that control of Fusarium wilt and crown rot can be obtained with appropriate manipulation of the naturally low pH of Myakka fine sand, and c) soil fumigation for control of soil-inhabiting plant pests is well entrenched in crop management systems for vegetable production on sandy soil (15).

Solarization currently is receiving attention (1, 11, 12) and is an environmentally attractive procedure developed in the 1970s (8, 9). It is a tool for harnessing the sun's rays to kill the numerous organisms which attack roots of growing plants. Heat induced by sunlight beneath a clear plastic film sealed over the soil surface penetrates the soil to varying degrees, depending on duration and intensity of sun-light and the soil type, friability, and moisture. Preliminary work in Florida indicated that solarization in the summer off-season did not benefit tomato crops grown on Rockdale soil in Dade County (10). However, solarization of an EauGallie fine sand infested with Verticillium albo-atrum, Fusarium oxysporum race 3, Meloidogyne incognita and Cyperus esculentus L. in Manatee County improved tomato yield (12).

The current work combined the established practices of soil reaction adjustment and fumigation with solarization to develop a potential crop management system for double-cropping vegetables under the full-bed mulch culture. Double-cropping fall tomato beds in Florida was introduced to improve the economics of land use. Re-use of established beds decreases turnaround time in preparing the field for a second crop, conserves plastic film, and reduces labor involved in bed reconstruction.

The goal of this work was to determine the contribution of off-season soil solarization on tomato disease control and yields of fall/spring double-crops as a supplement to or a replacement for soil fumigation, both for the initial fall crop and the spring re-crop.

Materials and Methods

A field of subsurface seep-irrigated EauGallie fine sand with a history of Meloidogyne incognita, Verticillium albo-atrum race 2, and Fusarium oxysporum race 3 was chosen for establishing off-season treatments in the summer 1985.

The field, with a moisture content of 13-15% (dry weight basis), was cultivated to seedbed tilth prior to seeding 4 randomized 16x100 ft plots with Sesbania macrocarpa on 1 July. Four similar plots were sealed with 4 mil clear polyethylene film on 10 July. Wells were placed 430 ft apart to measure water table fluctuation up and down the slope. Recording thermographs measured air temperature and soil temperature at 6 and 12 inch depths under the plastic film and the cover crop. Rainfall was recorded. The film was removed 9 Sept., all plots were rototilled and 2 pH levels (6.0 an 7.5) were developed in each plot with appropriate use of lime or sulfur, thereby establishing subplots of 16x50 ft in size.

Three beds 4.5x50 ft long were constructed in each subplot and fertilized in a manner consistent with the full-bed mulch crop management system (3). These sub-subplots received the following treatments 18 Sept.: a) control (no fumigant); b) MBC formulated as Terr-0-Gas 98 (98% methyl bromide, 2% chloropicrin) at a rate of 300 lb./acre, c) V-201 formulated as Vorlex 201 (34% 1,3-dichloropropene and other related chlorinated C2 hydrocarbons, 17% methyl isothiocyanate, 15% chloropicrin, and 34% inert ingredients) at 35 gal/acre. The fumigants were injected 6 inches deep through 3 shanks spaced 8 inches apart in a formed bed. White/black laminated 1.25 mil polyethylene film was sealed over the bed within 3 minutes of treatment.

'Sunny' tomato was set as 5 week old containerized transplants on 2 Nov. Following harvest on 18 and 27 Dec.,

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stakes were removed and plants were abandoned on the beds.

On 19 Feb. the tomato vine debris was swept into the row middles and the entire field was treated with a herbicide. New plant holes were located midway between the holes for the fall crop and supplemental fertilizer (1 oz 18-0-21 N-P-K) was placed in 1x2 inch holes in the mulch 9 inches to one side of the new plants. Three weeks after planting, an equal application of 18-0-21 fertilizer was placed 12 inches to the other side of each transplant. Containerized 'Sunny' tomato plants were set on 25 Feb.

Foliar pesticides were applied as required in the fall and spring. Emergence of nutfedge, *Cyperus esculentus*, was recorded and root-knot nematode gall severity estimates were made following harvest in both seasons where 1 = no galling and 5 = severe galling of roots.

Disease indices were recorded for 4 consecutive weeks beginning with early symptoms of plant wilt in the field.

![Graphs showing environmental conditions](image)

Fig. 1. Environmental conditions during the period that experimental plots supported *Sesbania macrocarpa* or were sealed beneath solarizing polyethylene film: maxima and minima of water table depth, daily air temperature, rainfall and temperatures at 6 and 12 inch depths in the soil beneath cover crop and plastic film.
Table 1. Effect of off-season management*, soil reactiony, and soil fumigationx on marketable tomato yield (25-lb. boxes/acre).

<table>
<thead>
<tr>
<th>Season</th>
<th>Fumigant</th>
<th>Solarized pH 6.0</th>
<th>Solarized pH 7.5</th>
<th>Sesbania pH 6.0</th>
<th>Sesbania pH 7.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 1985</td>
<td>Control</td>
<td>1107 a&quot;</td>
<td>983 abc</td>
<td>556 d</td>
<td>701 cd</td>
</tr>
<tr>
<td></td>
<td>V-201</td>
<td>1253 a</td>
<td>892 bc</td>
<td>971 abc</td>
<td>798 cd</td>
</tr>
<tr>
<td></td>
<td>MB</td>
<td>1125 a</td>
<td>976 abc</td>
<td>1209 a</td>
<td>790 cd</td>
</tr>
<tr>
<td>Spring 1986</td>
<td>Control</td>
<td>1104 e</td>
<td>1847 d</td>
<td>983 e</td>
<td>2131 d</td>
</tr>
<tr>
<td></td>
<td>V-201</td>
<td>2284 c</td>
<td>2559 c</td>
<td>1261 e</td>
<td>1798 d</td>
</tr>
<tr>
<td></td>
<td>MBC</td>
<td>3031 ab</td>
<td>3324 a</td>
<td>2679 bc</td>
<td>3289 a</td>
</tr>
</tbody>
</table>

*Eight weeks solarization under 4 mil clear polyethylene film, 10 July-9 Sept. vs. Sesbania macrocarpa cover crop in summer 1985.
#pH 6.0 and 7.5.
#Control = no fumigant; V-201 = methyl isothiocyanate 17%, 1,3 dichloropropene 34%, chloropicrin 15% at 35 gal/acre; MBC = methyl bromide 98%, chloropicrin 2% at 300 lb./acre.
#Mean separation by DMR (P = .05). within season.

Marketable fruit were harvested on 19 and 27 May. All data were submitted to statistical evaluation.

**Results and Discussion**

Soil temperatures were elevated 5-10°F by the polyethylene solarization film over the 80-85°F maintained in the upper 12 inch layer of the soil under a heavy cover of Sesbania (Fig. 1). Rainfall during July and Aug. was seasonal, exceeding 1 inch of rain only 7 of the 44 days in which measurable rain fell. The water table fluctuated between extremes of 2 and 34 inches from the soil surface. Although no supplemental irrigation was used during the off-season and drainage ditches were operative, the mean water table approached 20 inches from the soil surface and the downslope table was deeper than the upslope.

**Solarization.** Off-season summer solarization increased tomato yields of the fall crop but not that of spring double-crop (Table 1). Benefit to the fall crop was evident in the first picking, but benefit to the double-crop yield in the spring occurred only at the third picking. This suggests that the double crop in previously solarized plots senesced more slowly than those following a summer cover crop.

In the fall crop solarization reduced the severity of root damage due to the root-knot nematode (Table 2), the incidence of Verticillium wilt (Table 3), and the emergence of Fusarium and Verticillium wilt of tomato affected by off-season management*, soil reaction#, and soil fumigation* (% of plants with visible symptoms).

Table 2. Effect of off-season management*, soil reaction#, and soil fumigation* on root-knot nematode infestations.

<table>
<thead>
<tr>
<th>Season</th>
<th>Fumigant</th>
<th>Solarized pH 6.0</th>
<th>Solarized pH 7.5</th>
<th>Sesbania pH 6.0</th>
<th>Sesbania pH 7.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 1985</td>
<td>Control</td>
<td>1.7 c&quot;</td>
<td>2.4 bc</td>
<td>4.8 d</td>
<td>3.2 d</td>
</tr>
<tr>
<td></td>
<td>V-201</td>
<td>1.0 a</td>
<td>0.6 a</td>
<td>2.7 c</td>
<td>2.0 b</td>
</tr>
<tr>
<td></td>
<td>MBC</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Spring 1986</td>
<td>Control</td>
<td>4.5 c</td>
<td>2.6 b</td>
<td>1.5 b</td>
<td>1.8 b</td>
</tr>
<tr>
<td></td>
<td>V-201</td>
<td>1.6 a</td>
<td>5.0 c</td>
<td>0.0 a</td>
<td>0.3 a</td>
</tr>
<tr>
<td></td>
<td>MBC</td>
<td>0.3 a</td>
<td>0.0 a</td>
<td>0.3 a</td>
<td>0.2 a</td>
</tr>
</tbody>
</table>

*Eight weeks solarization under 4 mil clear polyethylene film, 10 July-9 Sept. vs. Sesbania macrocarpa cover crop in summer 1985.
#pH 6.0 and 7.5.
#Control = no fumigant; V-201 = methyl isothiocyanate 17%, 1,3 dichloropropene 34%, chloropicrin 15% at 35 gal/acre; MBC = methyl bromide 98%, chloropicrin 2% at 300 lb./acre.
#Mean separation by DMR (P = .05). within season.

Fifty-six per cent fewer plants showed the typical yellowing of the disease 90 days after the spring planting than in non-solarized plots. Nutsedge infestations in the double crop were not affected by the off-season treatments, and few weeds emerged on the undisturbed beds of the second tomato crop.

**Soil reaction.** Control of Fusarium wilt during both crop seasons at soil pH 7.5 (Table 3) was reflected in the increased yield at the higher pH level of the spring crop (607 25-lb. boxes/acre). However, during the fall season, yields were reversed and the low pH 6.0 produced 180 25-lb. boxes/acre more fruit than the higher pH 7.5. Solarization was not additive to the benefit derived by liming to pH 7.5. At the low pH, solarization was an advantage to the management system in controlling Fusarium wilt.

**Fumigation.** During the fall tomato season, MBC and V-201 controlled root-knot nematodes and nutsedge.

Table 3. Incidence of Fusarium and Verticillium wilt of tomato affected by off-season management*, soil reaction#, and soil fumigation* (% of plants with visible symptoms).

<table>
<thead>
<tr>
<th>Season</th>
<th>Fumigant</th>
<th>Solarized pH 6.0</th>
<th>Solarized pH 7.5</th>
<th>Sesbania pH 6.0</th>
<th>Sesbania pH 7.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 1985</td>
<td>Control</td>
<td>8.8 a&quot;</td>
<td>7.2 a</td>
<td>23.4 b</td>
<td>3.1 a</td>
</tr>
<tr>
<td>(71 days)*</td>
<td>V-201</td>
<td>5.6 a</td>
<td>3.1 a</td>
<td>16.6 ab</td>
<td>0.0 a</td>
</tr>
<tr>
<td></td>
<td>MBC</td>
<td>2.5 a</td>
<td>0.0 a</td>
<td>4.1 a</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Spring 1986</td>
<td>Control</td>
<td>58.0 c</td>
<td>72.9 e</td>
<td>56.6 d</td>
<td>12.9 ab</td>
</tr>
<tr>
<td></td>
<td>V-201</td>
<td>49.4 cd</td>
<td>38.0 c</td>
<td>45.7 cd</td>
<td>12.9 ab</td>
</tr>
<tr>
<td></td>
<td>MBC</td>
<td>19.4 ab</td>
<td>3.7 a</td>
<td>22.9 bc</td>
<td>3.7 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.7 a</td>
<td>9.0 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.3 a</td>
<td>1.5 a</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>2.3 a</td>
<td>5.7 a</td>
</tr>
</tbody>
</table>

*Eight weeks solarization under 4 mil clear polyethylene film, 10 July-9 Sept. vs. Sesbania macrocarpa cover crops in summer 1985.
#pH 6.0 and 7.5.
#Control = no fumigant; V-201 = methyl isothiocyanate 17%, 1,3 dichloropropene 34%, chloropicrin 15% at 35 gal/acre; MBC = methyl bromide 98%, chloropicrin 2% at 300 lb./acre.
*Days after planting.
#Mean separation by DMR (P = .05).
Table 4. Effect of off-season management* and soil treatments on nut-  
sedge emergence in mulched beds 26 days after fumigation.

<table>
<thead>
<tr>
<th>Season</th>
<th>Fumigant</th>
<th>Nutsedge plants/bed ft.</th>
<th>Solarized</th>
<th>Sesbania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 1985</td>
<td>Control</td>
<td>7.1 b</td>
<td>20.6 c</td>
<td>0.0 a</td>
</tr>
<tr>
<td></td>
<td>V-201</td>
<td>1.1 a</td>
<td>12.9 b</td>
<td>0.0 a</td>
</tr>
<tr>
<td></td>
<td>MBC</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>0.0 a</td>
</tr>
</tbody>
</table>

*Eight weeks solarization under 4 mil clear polyethylene film (10 July-9  
Sept.) vs Sesbania macrocarpa cover crop in summer 1985.

Conclusions

Although Florida summer conditions are not ideal for soil solarization (rainfall and high water tables mitigate against maintaining the high soil temperatures developed in some other agricultural areas) the pest management procedure has potential as an alternative method for controlling nematodes, weeds, and soil-borne diseases of tomato.

Literature Cited


CONTROL OF EARLY BLIGHT OF TOMATO WITH FOLIAR SPRAY MIXTURES  
AND HIGH FERTILIZER RATES

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Additional index words. mancozeb, chlorothalonil, tribasic copper sulfate, cupric hydroxide, Lycopersicon esculentum, Alternaria solani.

Abstract. Once-weekly sprays of mancozeb + tribasic copper sulfate applied to cherry tomatoes (Lycopersicon esculentum

Mill, cv. BHN 12) provided better early blight (Alternaria solani) control than either material alone. Mancozeb cupric hydroxide sprays resulted in control better than mancozeb alone and equal to cupric hydroxide alone. Chlorothalonil + Cu sprays gave better control than any other spray mixture or any component material alone. All mancozeb + Cu and chlorothalonil + Cu mixtures appeared to be compatible. The severity of early blight on 'Walter' tomatoes was greatly inhibited by 748, 1,122, or 1,496 pounds per acre rates of an 18-0-20.75:1.2 N-P-K-Mg fertilizer compared to 167 or 374 pounds per acre rates. In general, disease severity increased with decreasing fertilizer rate.

Early blight, caused by the fungus Alternaria solani (Ell. & Mart.) Jones and Grout, is one of the most common