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FIELD VALIDATION OF SOIL SOLARIZATION FOR FALL PRODUCTION OF TOMATO[1]

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Abstract. **Large scale field demonstration/validation of soil solarization was conducted in 1995 and 1996 on seven commercial tomato farms. Marketable yields with methyl bromide exceeded yields with solarization on three farms. Yield with solarization was greater on one farm and yield with 1,3-dichloropropene (1,3-D) plus chloropicrin was greatest on one farm. Weed suppression in solarized plots was comparable to plots treated with methyl bromide in all locations except when *purslane* and Texas panicum were present. Where southern blight was present, soil solarization provided better control than methyl bromide. Methyl bromide provided better control of root-knot nematodes. Combining solarization with reduced rates of 1,3-D or 1,3-D plus chloropicrin provided levels of nematode control similar to those achieved with methyl bromide. Technical problems evident during the large scale applications included melting of drip irrigation tubing due to direct contact with the clear solarization plastic and heat stress of tomato transplants due to incomplete paint coverage of the clear plastic at the termination of the solarization period. In a survey of participating growers, four of seven indicated the performance of soil solarization was a little below methyl bromide, one indicated it was equivalent, and two indicated it was superior. All participating growers indicated that soil solarization could be utilized in their production systems.**

Introduction

Soil fumigation has been an essential pest control component of the raised bed-plastic mulch production system utilized by Florida fresh market tomato growers (Cantliffe et al., 1995; Geraldson, 1975). Methyl bromide is the most widely used soil fumigant, due in part to its relatively low cost, ease of handling, and broad spectrum of activity. In early 1993, methyl bromide was implicated as a major ozone depleting substance and its use is scheduled to be phased out in 2001 (Federal Registrar, 1993). Florida tomato growers account for 17% of the methyl bromide usage in the United States (Anonymous, 1993) and a ban on its use has been projected to reduce tomato production by 69% (Spreen et al., 1995).

Solarization has been identified as a potential alternative to preplant soil fumigation in Florida tomato production systems (Chellemi et al., 1993; 1997; Overman, 1985; McSorley and Parrado, 1986) but has yet to be proven effective in large acreage systems (Jones et al., 1995). This study was initiated to evaluate, from a grower's perspective, the performance of soil solarization relative to preplant fumigation with methyl bromide. The specific objectives were to: 1) compare the efficacy of soil solarization to fumigation with methyl bromide; 2) identify technical problems not evident in small scale research plots; 3) indicate the potential for new or re-emerging soilborne pests under the range of environmental and cultural practices experienced by growers; 4)develop information on costs incurred at the farm level; and 5) provide growers with the experience to evaluate soil solarization.

Materials and Methods

Field plots were established on seven different commercial tomato farms (Table 1). The locations of the farms ranged from the southeastern coast of Florida (Farm 4) to southern Georgia (Farms 5 and 6). Individual plot size ranged from 0.6 to 2.5 acres. In addition to soil solarization, treatments combining soil solarization with reduced rates of 1,3-dichloropropene (1,3-D) (10 gal per treated acre) or 1,3-D plus chloropicrin (17.5 gal per treated acre) were imple-

Table 1. Type, size, and duration of solarization treatments applied on commercial tomato farms.

Farm	Treatment	Size	Solarization period
		1995	
1[z]	solarization	1.0[y]	Jun 13-Jul 19 (36 days)
2	solarization	1.2	Jun 9 -Jul 19 (40 days)
3	solarization	1.0	Jun 9 -Jul 19 (40 days)
3	solar + 1,3-D + C[x]	1.0	Jun 9 -Jul 19 (40 days)
3	solar + MBC[w]	1.0	Jun 9 -Jul 19 (40 days)
3	1,3-D + C[v]	1.0	Jun 9 -Jul 19 (40 days)
		1996	
4	solarization	0.6	Jul 22-Sep 1 (38 days)
5	solarization	2.0	Jun 13-Jul 26 (43 days)
5	solar + 1,3-D[x]	0.4	Jul 5 -Jul 26 (21 days)
6	solarization	1.4	Jun 20-Jul 26 (36 days)
6	solar + 1,3-D + C[z]	2.5	Jun 20-Jul 26 (36 days)
7	solarization	2.4	Jun 2 -Jul 15 (43 days)

[z]Farms 1, 2 and 3 located in Gadsden County, FL, Farm 4 in St. Lucie County, FL, Farms 5 and 6 in Decatur County, GA, and Farm 7 in Washington County, FL.
[y]Acres.
[x]1,3-D plus chloropicrin (Telone C17) applied at 17.5 gal/treated acre.
[w]Methyl bromide:chloropicrin (98:2) applied at 400 lbs/treated acre.
[v]1,3-D plus chloropicrin (Telone C17) applied at 35 gal/treated acre.
[u]1,3-D (Telone II) applied at 10 gal/treated acre.

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mented on three farms. Plots incorporating the full, labelled rate of 1,3-D plus chloropicrin (35 gal per treated acre) without solarization were included on Farm 3. Plots on all farms were nonreplicated except on Farm 3, where treatments were arranged in a randomized complete block design with four replications per treatment.

Comparisons of yield and pest control were made with methyl bromide by utilizing adjacent areas treated with methyl bromide plus chloropicrin (98:2 applied at 400 lbs per treated acre). Comparisons were made on Farms 1, 2, 3, 5 and 6. Farms 4 and 7 were U-pick operations and yield data were not obtained. On Farm 5, a different fertility treatment in the plot receiving soil solarization alone prevented direct comparisons to plots treated with solarization plus 1,3-D and methyl bromide.

Solarization treatments were conducted using clear, low density polyethylene plastic (LDPE), stretched over raised beds (6-8 inch high, 30-36 inch wide). Film thickness varied from 1-1.2 mil. Solarization periods ranging from 21 to 44 days (Table 1) were terminated by painting the plastic with a white, latex based paint (Kool Grow, Gainesville, FL). Paint was applied using a tractor mounted, boom sprayer with three nozzles per bed. All other cultural and pest management practices were conducted by the growers using their standard operations.

Yield data were obtained by harvesting 12 contiguous plants from four subplots each within the solarized and fumigated areas. In locations where symptoms of soilborne pests were present, disease incidence was assessed by counting the number of plants with symptoms in the solarized area and in an adjacent methyl bromide treated area of the same dimensions. Root galling caused by Meloidogyne species was assessed by removing root systems from five plants in each subplot and rating them for root galling on a 0 to 5 scale (Taylor and Sasser, 1978) in which 0 = no galls per root system, 1 = 1 to 2 galls, 2 = 3 to 10 galls, 3 = 11 to 30 galls per root system, 4 = 31 to 100 galls, and 5 = > 100 galls.

At the completion of the crop production season, individual grower participants were asked to evaluate the performance of soil solarization relative to preplant fumigation with methyl bromide. Questions in the survey were:

1. How much acreage do you farm using a raised bed-plastic mulch production system? 2. How would you rate the performance of soil solarization in your field? (__ Better than methyl bromide, __ Equivalent to methyl bromide, __ A little below methyl bromide, __ Vastly inferior to methyl bromide). 3. Do you see a role for soil solarization in your production system? (__ Yes,__ No). If your answer was yes, what percentage of your acreage could utilize soil solarization?

Results and Discussion

On Farm 1, marketable yield with methyl bromide was 28 cartons per acre greater than yield with solarization (Table 2). Purslane (*Portulaca oleracea*) was observed in the solarized beds in holes made through the plastic by staking or transplanting. Root galling resulting from root-knot nematodes was not observed in either treatment.

On Farm 2, marketable yield from the solarized area exceeded yield from the methyl bromide-treated area by 122 cartons per acre (Table 2). Southern blight of tomato, caused by *Sclerotium rolfsii*, was observed in both treatments. Disease incidence was 3.7% with methyl bromide and < 0.1% with soil solarization. A low level of root galling was evident in both treatments with no differences observed.

Table 2. Marketable yield and root galling on farms where direct comparisons to methyl bromide treated plots were made.

Farm	Treatment (rate per acre)	Yield 25-lb cartons/acre Total	extra-large	Root galls[z]
1	solarization	2162	472	0
1	methyl bromide (400 lbs)	2190	484	0
2	solarization	1940	808	0.3
2	methyl bromide (400 lbs)	1818	734	0.2
3	solarization	1583	450	1.8
3	solar + 1,3-D+chlor.(17.5 gal)	1629	492	0.1
3	solar + methyl bromide (200 lbs)	1841	593	1.0
3	1,3-D + chloropicrin (35 gal)	2151	770	0.2
3	methyl bromide (400 lbs)	1854	632	0.0
5	solarization	1790	1384	0.8
5	solar + 1,3-D (10 gal)	2254	1493	0.8
5	methyl bromide (400 lbs)	2472	1521	0.0
6	solarization	1723	812	0.6
6	solar + 1,3-D + chlor. (17.5 gal)	1466	824	0.1
6	methyl bromide (400 lbs)	1819	1184	0.0

[z]Root gall ratings for damage from root-knot nematodes were made between 89 and 109 days after transplanting using a scale of 0-5 where 0 = 0 galls per root system, 1 = 1 to 2 galls, 2 = 3 to 10 galls, 3 = 11 to 30 galls, 4 = 31 to 100 galls, and 5 = > 100 galls per root system (Taylor and Sasser, 1978).

On Farm 3, highest yields were obtained in plots fumigated with 1,3-D plus chloropicrin at 35 gal per treated acre. Yields were lower in all treatments involving soil solarization. Early in the season, plants were visibly stunted in the solarized areas due to heat stress. Soil temperatures were monitored at 2 inch depths in the plant hole using wire thermocouples attached to a microprocessor (Campbell Scientific, Odgen, Utah). Maximum temperatures exceeded 104°F under the clear film which had been painted and were 7°F higher than under the manufactured white plastic (Fig. 1). Examination of the painted plastic revealed many areas where incomplete paint coverage was obtained, leading to higher temperatures under the solarized treatments. Severity of root galling was highest in the plots receiving only solarization (Table 2). When solarization was combined with reduced rates of methyl bromide or 1,3-D plus chloropicrin, the level of root galling was similar to levels in the standard methyl bromide-treated areas.

Yield and nematode data were not collected from Farms 4 and 7. Texas panicum (*Panicum texanum*) was observed growing in the solarized beds on Farm 7. Root galling was not observed at Farms 4 and 7.

On Farm 5, marketable yields in the methyl bromide-treated plots were greater than yields obtained from the combination of solarization plus 1,3-D (Table 2). Yield from plants in the plot receiving only solarization received different fertilizer rates and thus cannot be compared directly to the other treatments. Low levels of root galling (< 3 galls per root system) were evident in the solarized areas. Purslane was observed in beds receiving soil solarization at the rate of 1.4 plants per linear ft of row. Less than 0.1 plant per linear ft of row was observed in the beds receiving solarization with 1,3-DCP plus chloropicrin or methyl bromide.

Marketable yields from the methyl bromide-treated plot on Farm 6 exceeded yields from the solarized plot by 96 cartons per acre. Low levels of root galling were evident in both solarized areas.

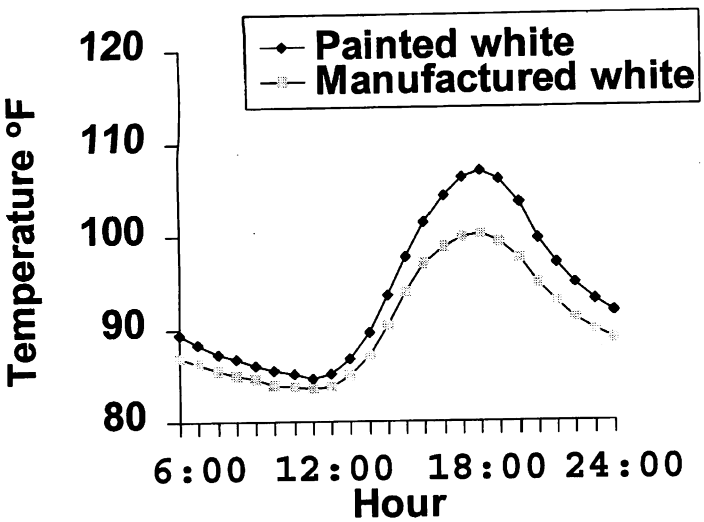

Figure 1. Hourly temperatures over a 24-hr-period on August 17. Painted white = clear LDPE painted with a white latex based paint (Kool Grow, Gainesville, FL), Manufactured white = white over black co-extured LDPE.

Production costs for solarization alone were ca. $300 less per acre than the costs of fumigation with methyl bromide. Savings were obtained through the elimination of fumigant and the use of clear LDPE.

The tomato production operations of participating growers ranged from 10 to 600 acres with an average of 214 acres. Four growers rated the performance of soil solarization as a little below methyl bromide, one grower indicated that performance was equivalent and two indicated that the performance of solarization was better than methyl bromide. No growers indicated that soil solarization was vastly inferior to methyl bromide. All seven growers indicated that soil solarization has a role in their production system. Two growers felt solarization could be used on 50% of their acreage, two would use it on 30%, one on 25%, one on 10%, and one grower was undecided.

Yield response of tomato cultivated using soil solarization as an alternative to soil fumigation with methyl bromide was generally lower than yields in methyl bromide-treated areas. Differences were considerably less than the projected 69% decline in production in the absence of methyl bromide (Spreen et al., 1995). While good control of nutsedge has been reported from soil solarization in Florida (Chellemi et al., 1997), this study provided an indication that other weeds such as purslane and Texas panicum could become an economic problem. At low levels of disease, soil solarization provided better control of southern blight than methyl bromide.

Control of southern blight on pepper and tomato using a combination of soil solarization and a biological control agent was reported in North Carolina (Ristaino et al., 1991; 1996). The results from farm 2 also indicated that moderate control of southern blight can be achieved with soil solarization. Root gall ratings of root systems indicated that soil solarization did not provide adequate control of root-knot nematodes (Meloidogyne species). Combining solarization with reduced rates of 1,3-D or 1,3-D plus chloropicrin provided reductions similar to those achieved with methyl bromide.

Two technical problems which became evident during the large scale applications were: 1) if drip irrigation tubing is used, it must be covered with soil to prevent melting of the tube; and 2) when painting the plastic white to terminate the solarization period, coverage must be uniform and complete to prevent additional solar radiation from penetrating the plastic.

In conclusion, soil solarization appears to be a viable alternative to preplant fumigation with methyl bromide for fall-cropped fresh market vegetables in Florida. However, soil solarization has specific application requirements and limitations which will restrict its widespread application. The precise duration of the solarization period required to control various soilborne pests is not known. Thus fields should be prepared and plastic applied 6 to 8 weeks in advance of planting to ensure an adequate solarization period. Soil moisture requirements are more stringent than those for fumigation with methyl bromide. Soil solarization applied alone does not provide effective control of some plant parasitic nematodes and when used in a nematode-infested field, it should be combined with an effective nematicide treatment. Weed suppression to the point of eliminating their effects on yield are adequate in most situations although weed growth underneath the plastic mulch is not eliminated. Finally, it is highly recommended that soil solarization be used within the context of an IPM program for soilborne pests which includes the coordinated use of multiple pest management tactics based upon scouting reports of prior pest levels. Adoption of this approach will require additional management of information and decision making by the grower.

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