The Potential of Soil Solarization in Nurseries to Control Soilborne Diseases[1]

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Abstract.--Use of clear polyethylene sheeting to heat soil, through the technique called soil solarization, is being evaluated as a method to control soilborne pathogens at the Oklahoma Division of Forestry Nursery and at Stillwater, OK. Studies are directed at the effects of solarization on population densities of Pythium spp., Macrophomina phaseolina, and Sclerotium rolfsii. Soil temperatures under polyethylene sheeting during August-September at the Stillwater location reached maxima of 10 to 12 C greater than bare ground controls.

INTRODUCTION

Soilborne diseases incited by several genera of fungi can be economically destructive in a forest nursery. Pathogens of particular importance in Oklahoma are: Fusarium spp., Pythium spp., Rhizoctonia solani, Sclerotium rolfsii, and Macrophomina phaseolina. Techniques used to control these pathogens have included crop rotation, fungicides (seed treatments, broadcast applications, and drenches), and soil fumigation. Each has its limitations due to the wide host range of soilborne pathogens, environmental contamination, or economics. The use of thin, clear polyethylene sheeting to transfer solar energy to soil to increase soil temperature is an alternative technique that needs to be investigated for use in the nursery.

This technique is called soil solarization and is based on our knowledge of thermal inactivation of soilborne organisms (Table 1). A 30 minute exposure to temperatures of 66 C will destroy most pathogenic bacteria and fungi. Pullman, et al. (1981) explored the relationships between increased temperatures and length of exposure to those temperatures on the survival of several soilborne fungi. Temperatures of 37 C for 18-28 days were needed to reach LD_{90} levels (90% reduction in populations) for Pythium ultimum and Verticillium

dahliae. However, when temperatures were increased to 50 C, LD_{90} levels were achieved in 27-33 minutes. Therefore, lower temperatures can reduce populations of soilborne pathogens, but longer exposure times will be necessary.

Maximum soil temperatures of 60 C have been reported at depths of 5 cm in soil using solarization (Pullman,, et al. 1981). However, these maxima are attained for only short periods of time. Reduction of population densities of soilborne pathogens is more realistically achieved by increasing soil temperatures 5 to 10 C above normal for an extended period of time. The effect of solarization on soilborne pathogens is a chronic effect that weakens and debilitates the survival structures (conidia, sclerotia, etc.) of these fungi. Other soil organisms are more thermo-tolerant and are not affected by solarization. These residual organisms multiply and prevent the recolonization of soil by the pathogen after solarization.

Table 1.--Temperatures required to inactivate pests in compost soils[a]

Pests	Temperatures[b]	
	(F°)	(C°)
Nematodes	120	49
Damping-Off Organisms	130	54
Most Pathogenic Bacteria and Fungi	150	66
Soil Insects and Most Viruses	160	71
Most Weed Seeds	175	79
Resistant Weeds and Viruses	212	100

[a] Modified from Baker and Cook, 1974
[b] Temperatures maintain for a minimum of 30 minutes

Soil solarization has been used successfully

to control a number of pathogens in various cropping systems (Conway, et al. 1983; Grinstein, et al. 1979; Jacobsohn, 1980; Katan, et al. 1983). Other research has indicated control of nematodes, weeds, and growth enhancement of crops planted in solarized soil (Heald and Robinson, 1987; Jacobsohn, et al. 1980; Grinstein, et al. 1979; Stapleton and DeVay, 1984). There have also been studies in which control of soilborne diseases was not achieved, particularly for Macrophomina phaseolina (McCain, et al. 1982; Mihail and Alcorn, 1984). Charcoal root rot, incited by _M. phaseolina has been a severe problem in southern tree nursery production. Unfortunately, reports on the use of solarization in forest nurseries are very limited. Hildebrand (1985a, 1985b) used soil solarization to reduce levels of Pythium and Fusarium spp. and weed seeds in Colorado and Nebraska forest nurseries. She estimated that, compared to chemical fumigation, solarization saved approximately $350.00/A in production costs.

In order to evaluate soil solarization as a technique to control soilborne diseases, experiments were initiated in 1986 at the Oklahoma Forestry Division Nursery at Washington, OK, by Mr. Mark Miles, a graduate student in the Department of Plant Pathology at Oklahoma State University. Additional experiments were performed at Stillwater, OK. Although much of this work is preliminary and will be used for Mr. Miles' M.S. thesis, a generalized overview of the research is presented below.

METHODS

Previous work (Conway, unpublished) has indicated that Pythium irregulare and Fusarium spp. were the primary soilborne pathogens at the Forest Nursery. Recently, stunted sycamore and Virginia pine seedlings were removed from the Nursery and isolations from the roots indicated that M. phaseolina was also an active pathogen. At Stillwater, populations of Sclerotium rolfsii and _M. phaseolina have been documented in our apple seedling nursery (Conway and Tomasino, 1987; Tomasino and Conway, 1987). To ascertain the effectiveness of solarization, populations of Pythium spp. and _M. phaseolina at the Forest Nursery, and of _S. rolfsii and _M. phaseolina at Stillwater will be enumerated before and after solarization.

Solarization experiments were performed at the Forest Nursery during April-May 1986 and August-September 1987. Experiments at Stillwater were conducted during August-September 1986 and 1987. In 1986, temperature data were collected through use of a system developed by Dr. V. Pederson, North Dakota State University. The computer program was modified to allow for 22 separate temperature probes.

Prior to placement of the polyethylene sheets, soil samples were randomly removed from all plots and stored at 4 C. Soil was bulked and thoroughly mixed before subsamples were removed.

Population densities were determined for Pythium app. and _M. phaseolina using selective media (Conway, 1985; Campbell and Nelson, 1986). At Stillwater, spun-bound polyester packets containing 50 sclerotic of _S. rolfsii were placed at 0, 5, 10, and 15 cm depths in soil to be solarized or used as controls. All soils were moistened prior to solarization. At Stillwater, drip irrigation was installed beneath the polyethylene sheets. Temperature probes were buried at 2, 4, 12, and 20 cm depths in soils of both solarized and control plots. The computer was programmed to record input from each probe every 30 minutes. Polyethylene sheets (4 mil thick) were applied to the plots using a mulch-laying apparatus. Appropriate sections of the polyethylene sheet within the row were removed to provide for control plots. Solarization lasted for approximately 6 weeks and soil samples were, again, randomly collected to determine densities of selected pathogens. Packets containing sclerotia of _S. rolfsii were also removed, at that time, and percent viability was determined.

RESULTS AND DISCUSSION

Weather during April-May 1986 at the Nursery was unusually cloudy and greater than average precipitation occurred. On clear days, soil temperature at a depth, of 4 cm in solarized plots reached 49-50 C with a daily average of only 4 hr during which temperatures were greater than 37 C. Nonsolarized soils at the same depth attained temperatures of only 24-32 C. Population densities of selected fungi have been determined but differences among treatments have not been analyzed.

At the Stillwater location during August 1986, solarized plots reached temperatures of 57 C, with 6 to 7 hr greater than 45 C, at 4 cm depths. Non-solarized soils reached a maximum of 45-46 C. Packets containing sclerotia of S. rolfsii were retrieved from the soil after 4 weeks. Viability of sclerotia was determined by placing sclerotia on moistened filter paper in petri dishes and observing germination. No significant differences in viability between solarized and non-solarized soils were found at that time.

Soil solarization will not be a panacea for all nursery problems related to soilborne fungal pathogens, nematodes and weed seeds. Problems of polyethylene residue are similar to those involved with the use of chemical fumigants. Another concern is that soil solarization may not be effective in reducing population densities of particular fungi, such as Macrophomina phaseolina. In order to study this further, we have initiated laboratory experiments to determine the thermal death points in soil of Pythium irregulare isolated from the Nursery and isolates of _M. phaseolina from several different hosts. Analysis of these data will enable us to make predictions regarding the effectiveness of solarization in the control of these pathogens.

To improve the effectiveness of soil solarization, future research should involve the integration of solarization with biological control agents (Elad, et al. 1980), the use of crop residue amendments (Ramirez-Villapudua and Munnecke, 1987), and the use of ammonia-based fertilizers. Data should be collected on the total effect of solarization and should include reductions in pathogen (including nematodes), weed and insect population densities.

Although our work is preliminary, we feel that we are in an exciting area of research, one that may have very real benefits for nursery production and management.

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