A Review of Soil Solar Heating in Western Forest Nurseries[1]

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Abstract.--Eleven studies at 10 western forest nurseries are summarized. In 8 studies, solar heating resulted in significant reductions in populations of soil-borne plant pathogens. Five out of 8 studies reported significant reductions in weeds. Three out of 5 studies reported an increased growth reponse in a tree seedling crop. The best results are expected for a tree seedling crop sown soon after the solar heating treatment.

INTRODUCTION

Solar heating of soil, a technique for preplant pest control, was reported in 1976 by Katan and others working in Israel. Solar heating or solarization of soil is accomplished by sealing clear polyethylene sheeting over moist soil for several weeks during the summer. Soil temperature under the polyethylene is raised 8-15°C above that of uncovered soil by the prevention of evaporation and by the greenhouse effect (Mahrer 1979). Continuous or repeated sub-lethal temperatures under moist conditions over long periods of time, either kill pathogens and weeds directly or weaken them so they cannot survive (Pullman et al., 1981). Volatiles released from decomposing organic matter are trapped under the polyethylene and may also play a role in mortality of pests (Zakaria et al., 1980).

Because of successes in agricultural crops (Katan 1981), and in the search for alternatives to fumigation, the solar heating technique has been evaluated at forest tree nurseries across the West. This paper attempts to summarize the results of the various experiments with solar heating in western nurseries. The author apologizes for any studies overlooked or misinterpreted.

SUMMARY OF RESULTS

Six studies reported only the effects of solar heating on pest populations (Table 1). In Placerville, California (38°40' latitude), populations of Fusarium were significantly reduced, while those of Macrophomina were not, after 5 weeks of solar heating. (McCain et al., 1982). In Paradise, California (39°40' latitude), weeds were reduced while Fusarium populations were not after 3 weeks of solar heating [3]. After 8 weeks of solar heating nursery soil at Fort Collins, Colorado (40°30' latitude), populations of Fusarium and Pythium remained significantly reduced through the following spring, while weeds returned to pretreatment levels by the following spring (Hildebrand 1987). In one study in Halsey, Nebraska (41°30' latitude), populations of Fusarium, weeds, and plant-parasitic nematodes were significantly reduced after 6 weeks of solar heating, but the fall-sown crop of eastern redcedar was lost due to an untimely frost (Hildebrand and Dinkel, 1988). In Washington, Oklahoma (35° latitude), weeds (except for yellow nutsedge) and populations of Pythium and Fusarium were significantly reduced while those of Macrophomina were not, after 8 weeks of solar heating (Miles 1988). In Boscobel, Wisconsin (43°10' latitude), pathogen populations were not reduced after 8.5 weeks of solar heating (Zarnstorff and Berbee, 1983).

Five studies reported data on treatment effects on a tree seedling crop (Table 1). In Davis, California (38°30' latitude), Agrobacterium populations were significantly reduced, am walnut and peach showed increased height and weight (Stapleton and DeVay, 1982). In Ames, Iowa (42° latitude), after 4 weeks of solar heating, weeds were reduced and pine seedlings (sown after winter fallow) showed inconsistent growth effects: half of the red pine attained greater seedling height and half of the white pine attained greater seedling weight (Croghan et al., 1984). In another study in Halsey, Nebraska (41°30' latitude), populations of Pythium and weeds returned to pretreatment levels the spring following 8 weeks of solar heating. In this Nebraska study, the lodgepole pine seedlings sown the following spring showed no benefit, but

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[3]Adams, David. 1989. Personal communication about results at Magalia State Nursery. Calif. Dept. Forestry, Davis, Calif.

Table 1.--Summary of results of 11 solar heating studies in western forest nurseries.

LOCATION	PATHOGENS REDUCED	WEEDS REDUCED	TREE SEEDLING GROWTH EFFECTS
Davis, CA	+	--	+
Paradise, CA	no	+	--
Placerville, CA	+	--	--
Fort Collins, CO	+	no	--
Awes, IA	no	+	+
Halsey, NE	+	no	no
Halsey, NE	+	+	--
Washington, OK	+	+	--
Bend, OR	+	no	no
Central Pt., OR	+	+	+
Boscobel, WI	no	--	--

+ = Positive effect; no = No effect; -- = Not reported.

but the winter cover crop of oats sown after solar heating showed an increased growth response (Hildebrand 1987). At Bend, Oregon, (44° latitude), Fusarium populations were significantly reduced while weed populations and growth of ponderosa pine seedlings (sown after winter fallow) were not affected by 4 weeks of solar heating (Cooley 1983). At Central Point, Oregon, (42°23' latitude), populations of weeds and Fusarium, but not of Pythium, were reduced significantly and dry weight of-Douglas-fir seedlings (sown after winter fallow) increased significantly after 6.5 weeks of solar heating (Cooley 1985).

Five of the studies also compared solar heating with chemical treatments (Table 2). Where MC-33 (67% methyl bromide and 33% chloropicrin) was used, fumigation consistently resulted in better seedling survival, but not always better weed control or seedling growth.

Temperature data varied between studies. Highest temperatures reported under the polyethylene were as follows: at Placerville, California, 56.2°C at 10 cm depth and 39.6 °C at 20 cm (McCain et al., 1982); in Ames, Iowa, 51°C at 5 cm and 41.5°C at 15 cm (Croghan et al., 1984); at Bend, Oregon, 50+°C at 5 cm (Cooley 1983); in Boscobel, Wisconsin, 49°C at 5 cm and 41°C at 15 cm (Zarnstorff 1983); in Halsey, Nebraska, 46+°C (offscale on

Table 2.--Summary of comparisons between solar heating and chemical treatments for effects on pest populations and tree seedling growth.

Parameter	Bend, Oregon (1)	Central Point, Oregon (2)	Halsey, Nebraska (4)	Halsey, Nebraska (6)	Ames, Iowa (3)	
PEST POPULATIONS						
Pythium	--	M > S = C	M > S = C	--	-	
Fusarium	M > S > C	M > S > C	--	M > S > PB > C > WB	V > S = C	
Pathogenic Nematodes	--	--	--	M = PB = WB > S » C	--	
Weeds	M > S > C	M = S > C	M > S > C	S > M > WB > PB > C	S > C	
SEEDLING DATA						
Survival	M > S = C	M > S = C	M > S = C	--	V = S = C	
Species	Ponderosa	Douglas-fir	Lodgepole	--	White pine	Red pine
Height	--	M = S = C	--	--	1/2: S > V > C 1/2: C = S = V	V = S > C V = S = C
Weight	--	M = S = C	--	--	1/2: V = S = C 1/2: S > C > V	V = S = C V = S = C
Root Length	--	M = S = C	--	--	--	
Caliper	--	M = S = C	--	--	--	

M = MC-33; V = Vorlex; PB = Basamid sealed with polyethylene; WB = Basamid sealed with water; S = Solar heating; C = Check; > = Better than; _> = Better than or equal to; - = Not reported or populations too low to show a treatment effect.

thermograph) for 6 hours at 8 cm and 44°C for 4 hours at 15 cm (Hildebrand 1987); at Central Point, Oregon 43°C at 5 cm (Cooley 1985); and in Fort Collins, Colorado, 41+°C (offscale of thermograph) for 10 hours at 8 cm and 41+°C for 8 hours at 15 cm (Hildebrand 1987).

In 8 of the 11 studies reviewed, solar heating resulted in significant reductions in pathogen populations. Of 8 studies reporting effects on weeds, 5 showed significant reductions in weeds. Of 5 studies reporting seedling growth effects, 3 studies showed an increased growth response in a tree seedling crop; and none showed increased seedling survival. In conifers sown the spring following solar heating, the increased growth response was inconsistent or non-existent. The best growth response was in a crop sown in the fall after solar heating, as reported for the walnut and peach in California (Stapleton and DeVay, 1982) or in the winter cover crop of oats in Nebraska (Hildebrand 1987).

The solar heating technique works well with only a few weeks of polyethylene cover in hot climates like southern California and Israel for crops sown immediately after solar heating. Here in the western United States, even 8 weeks of polyethylene cover have not proven reliable for controlling pests and increasing growth and survival of conifer crops sown the spring after treatment. The best results would be attained for a fall-sown crop. The effects of solar heating on eastern redcedar sown in late August, 1989, are currently being tested in Nebraska.

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