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Effect of Fall Sowing and Solar Heating of Soil on Two Conifer Seedling Diseases

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Solar heating did not reduce Macrophomina phaseolina *at any soil depth and eliminated* Fusarium oxysporum *f. sp.* pini *in the top 10 centimeters only. Fall sowing of* Abies concolor *and* Pseudotsuga menziesii *did not reduce disease, but did result in taller seedlings than did spring sowing.* Tree Planters' Notes 37(4):17-20; 1986.

Conifer seedlings are susceptible to a number of common soilborne fungi, including *Rhizoctonia solani* Kuehn, *Pythium* spp., *Phytophthora* spp., *Fusarium oxysporum* (Schlecht.), and *Macrophomina phaseolina* (Tassi) G. Goid. (10). These pathogens are controlled primarily by fumigation with a methyl bromide-chloropicrin mixture applied in the late summer or fall when the soils are warm.

A cover crop, usually vetch (*Vicia sativa* L.), is sown in the fall to control winter soil erosion.

In spring, as early as weather permits, the cover crop is turned under, and the soil is prepared for sowing. Sowing is usually done in April or May. Recent research with *Pinus lambertiana* Dougl. has shown that early sowing (before March 15) results in larger seedlings and reduced losses from disease (3).

Solar heating (solarization) of soil for control of soilborne pathogens is an accepted disease control practice in agricultural regions with high summer temperatures (4) and has been effective in reducing damping-off in a forest tree nursery (2). The purpose of this study was to determine the effectiveness of solar heating for controlling soilborne pathogens of conifer seedlings in a California forest tree nursery and to evaluate the effect of fall sowing on seedling growth and survival. A preliminary report has been published (6).

Material and Methods

Two nursery experiments were conducted at the Institute of Forest Genetics (Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture), Placerville, CA. The nursery is situated on a broad ridge below the snow line in the American River watershed of the western Sierra Nevada (38°45' N. 120°44' W). Elevation is 838 meters, and the soil is Aiken clay loam (11).

Experiment 1. In 1981, inocula of *F. oxysporum* (originally isolated from *P. lambertiana* and grown on autoclaved, chopped alfalfa hay) and inoculum of *M. phaseolina* (recovered from soil) were rototilled into the top 15 centimeters of soil. The soil was brought to field capacity, and then covered with 0.1-millimeter-thick clear polyethylene from July 1 to September 9.

The sampling design consisted of four solarized and four nonsolarized areas each measuring 1.5 by 7.5 meters arranged in randomized blocks. Nylon mesh bags containing 25 grams of soil infested with *F. oxysporum* f. sp. *pini* and *M. phaseolina* were buried along with thermocouples at depths of 0, 2.5, 10, 20, 30, and 40 centimeters.

The nylon bags were retrieved at the end of the solarization period, and the propagule levels were determined according to the methods of Komada (S) and McCain and Smith (7).

For fall sowing, seeds of rape (*Brassica napus* L.), annual ryegrass (*Lolium multiflorum* Lam.), and common vetch (*Vicia sativa* L.) were sown on November 3 in rows located between 1.5-m rows of seeds of P. *lambertiana* spaced 7.5 cm apart.

Eighteen rows of *P. lambertiana* were sown for a total of 360 seeds per cover crop subplot in the solarized and nonsolarized plots. Nonplanted areas were reserved for spring sowing. Cover crops were killed by spraying with glyphosate on March 24, 1982, prior to emergence of the conifer seedlings. *P. lambertiana* seeds for the spring sowing on April 22, 1982, had been soaked for 36 hours in aerated water at 25 °C, drained, and placed in polyethylene bags held at 1 °C for 90 days.

Experiment 2. A similar solarization trial was conducted in 1982. The solarized and nonsolarized subplots were smaller than before (1.5 by 3.7 meters), and thermocouples were buried with mesh bags of infested soil at depths of 10, 20, and 30 centimeters. The 0.05-millimeter-thick polyethylene solarization covers were placed on June 17 and removed on August 22, 1982. Vetch seeds were distributed throughout the fall planting subplots and 3 species of conifers-*Pinus lambertiana, Pseudotsuga menziesii* (Mirb.) Franco, and *Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.-were sown on October 4, 1982. The vetch was removed by hand on April 4, 1982, because some conifer seedlings had emerged and application of herbicide might have damaged them. Spring sowing was done on May 4, 1982.

A mechanical pyranograph (Weathermeasure 8401) recorded solar radiation in both the 1981 and 1982 trials.

Isolations from dead or dying conifer seedlings were grown on water agar plus 1- to 2-millimeter bits of propylene oxide-sterilized pea straw.

Height measurements were made in October, after the seedlings ceased apical growth.

Results

In 1981 the weather during the 55-day solarization treatment was clear except for partly cloudy days on July 22 and August 18. The maximum solar radiation on July 15 was 1.05 calories per square centimeter per minute and on September 9 it was 0.855. The relative humidity averaged 26 percent, and the maximum and minimum air temperatures were 34.4 °C and 19.4 °C. Soil temperatures beneath the polyethylene tarps were maximum between July 28 and August 14.

In 1981 the rototilled soil contained an average of 8.4 propagules per gram of *M. phaseolina* before solarization. After solarization, the average was 5.1 propagules per gram of *M. phaseolina* in the solarized plots and 30 propagules per gram in the nonsolarized plots. After rototilling and prior to solarization the soil contained 1.9 x 10^3 propagules of *F. oxysporum* f. sp. *pini.* After solarization the level of *F. oxysporum* had dropped to 8.5 propagules per gram in the solarized soil and 1.2 x 10^3 in the nonsolarized plots.

There were 31 cloudy days during the 66-day solarization period in 1982 with rain on several of those days. The maximum solar radiation, 1.07 calories per square centimeter per minute, was recorded on July 4 and the lowest value, 0.885, was recorded on August 22. During the solarization period the average relative humidity was 38 percent, the maximum air temperature of 36.7 °C occurred on July 13 and the minimum air temperature of 8.3 °C occurred on July 4. Solarization was interrupted for 10 days beginning on July 29 because of wind damage to the polyethylene sheeting. The 0.05-millimeter-thick polyethylene was not strong enough for the wind conditions that occurred during the summer of 1982.

In 1982 the rototilled soil contained an average of 15 propagules per gram of *M. phaseolina* and 1.1 x 10^3 propagules per gram of *F. oxysporum*. After solarization, the average was 8.2 propagules per gram of *M. phaseolina* in the solarized plots and 14 propagules per gram in the nonsolarized plots, whereas 5.4 propagules per gram of *F. oxysporum* were detected in samples taken from

Table 1—*Survival of* Fusarium oxysporum *and* Macrophomina phaseolina *in solarized (S) and nonsolarized (N) soil*

Soil depth (cm)	Max. soil temp. (°C)			Propagules/g of soil: Fusarium (× 10^4)				Propagules/g of soil: Macrophomina			
	1981		1982	1981		1982		1981		1982	
	N	S	S	S	N	S	N	S	N	S	N
0	47	62	—	0	0.10	—	—	102	12	—	—
2.5	47	59	—	0	19[a]	—	—	241	1050	—	—
10	37	48	50	0.01	13	0.60[b]	81	718	882	16	17
20	30	38	40	10	11	65	72	1490	945	23	12
30	28	36	37	32[a]	11	55	63	1210	815	20	22
40	27	36	—	31[a]	25[a]	—	—	692	1320	—	—

[a]Significantly different from the surface-solarized soil. (P = 0.05).
[b]Significantly different from the deeper solarized and from the nonsolarized soil (P = 0.05).

the top 10 centimeters of solarized soil and an average of 4.9×10^2 from the nonsolarized plots.

The magnitude and duration of the temperatures achieved in both 1981 and 1982 were sufficient to achieve control of *F. oxysporum* in the surface soil but not at greater depths. *M. phaseolina* was not controlled at any depth although there may have been some reduction in propagule survival in the bare surface soil (table 1).

Rodents ate most of the *P. lambertiana* seeds in the 1981 fall and spring sowings, and no significant survival or growth measurements were possible. The three cover crops made satisfactory growth in the fall and would have provided erosion control on sloping land. Vetch was chosen for the 1982 trial because it is commonly used for erosion control and appeared to cause minimal disruption of the conifer seeds.

Rodents again ate the fall-planted *P. lambertiana* seeds in 1982 and mortality from disease could not be accurately assessed. There was no significant difference in survival between the fall and spring sowings of *A. concolor* and *P. menziesii*. There were differences in the populations of pathogens involved in mortality. Diseased seedlings from solarized plots yielded *M. phaseolina*, whereas seedlings from nonsolarized plots primarily yielded *F. oxysporum*.

No benefit in seedling survival from the solarization treatment was detected in either 1981 or 1982.

Seedlings of *A. concolor* and *P. menziesii* that developed from fall-sown seeds were larger than those from the spring sowing. Seedlings from fall-sown *P. lambertiana* were also larger but this difference was not statistically significant in this trial (table 2).

Discussion

Fall and winter sowings most closely simulate natural environmental conditions for seed germination, seedling emergence, and early growth (3). The major advantage of fall sowing is the ease of soil preparation and planting during favorable weather. Fewer soil preparation operations are necessary with fall planting, and it is unnecessary to cold treat the seed because this occurs in the field.

However, possible rodent damage is a major disadvantage of fall sowing. In this study the nursery beds were adjacent to

Table 2—*Survival and growth of conifer seedlings in fall and spring sowings in solarized (S) and nonsolarized (N) soil*

	Survival (%)		Height (mm)	
	S	N	S	N
Abies conconor				
Fall	62.5	52.1	62*	84*
Spring	43.6	51.1	42	43
Pinus lambertiana				
Fall[1]	3.4	4.1	165	117
Spring	87.5	88.0	132	117
Pseudotsuga menziesii				
Fall	56.2	70.4	115*	145*
Spring	66.1	72.0	88	113

*Significantly different ($P = 0.05$).
[1]Poor survival because of rodents.

uncultivated areas that harbored the rodents. This situation should be considerably less of a problem in large nurseries, and poisons could be applied to the seeds to eliminate the rodents.

The failure of fall sowing in these trials to reduce mortality due to disease was probably related to the high inoculum levels of *F. oxysporum* and *M. phaseolina* in the soil. Fall sowing into fumigated soil should result in the production of superior healthy seedlings.

It is not surprising that *M. phaseolina* was not controlled by solar heating of soil, for sclerotia of the fungus are resistant to prolonged high temperatures *(1). M. phaseolina was* not eliminated by soil solarization in trials conducted in Arizona (9).

It may be possible to control conifer seedling diseases through solar heating of soil where *M. phaseolina* is absent or in very low numbers. The monitoring of nursery soil for sclerotia of the fungus would be a simple matter because improved assay methods are available (8).

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