SOLARIZATION IN TWO PACIFIC NORTHWEST FOREST NURSERIES

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ABSTRACT: Fumigation and solarization were compared at two Oregon forest nurseries for disease and weed control. Fumigation resulted in significantly reduced levels of both weeds and disease. Solarization, while reducing the number of weeds, did not reduce disease levels. The reasons for ineffective disease control with solarization are discussed.

INTRODUCTION

Solar heating of soil has been used in recent years to rid large areas of soil of plant pests such as fungi, nematodes, and weed seeds. "Solarization" has been most successful in areas of the world where summer temperatures are relatively high and soils can become correspondingly hot (Ashworth and Gaona 1982; Elad and Chet 1980; Katan 1981; Katan and others 1976; Pullman and others 1979; Pullman and others 1981). Solarization is simple and inexpensive. Clear polyethylene tarping is used to cover the soil and generate high temperatures in the top layers of soil. Pest propagules such as spores, seeds, or eggs are destroyed by lethal high temperatures or disabled by prolonged sublethal temperatures. The following requirements must be met for effective solarization (Katan 1981):

1. Thin transparent polyethylene tarping is necessary. Thin (2 ml) is both cheaper and more effective in heating than thicker polyethylene. Polyethylene has low water vapor permeability; water droplets formed on the inner surface create a greenhouse effect which results in better heating.

2. Tarping must be done during the hottest time of year so that high lethal temperatures are created under the tarp.

3. Application of polyethylene tarping must be made before planting to avoid injury to plants or seeds.

4. Soil must be kept wet during tarping to improve thermal sensitivity of pest propagules and to improve heat conduction in the soil.

5. A long treatment duration is needed (at least 4 weeks in most locations) to adequately heat the soil in cooler, deeper layers. Killing of propagules with prolonged temperatures only a few degrees higher than normal often is superior to a short period of very high temperature.

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METHODS

Solarization trials at the Bend Forest Service Nursery, Bend, Oregon, and at the J. Herbert Stone (JHS) Forest Service Nursery, Central Point, Oregon, were carried out in 1981-1982 and 1983-1984, respectively.

Treatments consisted of fumigation and solarization. Treatment plots were 2,000 square feet (20 feet wide by 100 feet long). Each treatment was replicated four times in a randomized block design. For fumigation treatments, methyl bromide-chloropicrin fumigant was applied at 300 (Bend) to 350 (JHS) pounds per acre in September by a commercial contractor. For solarization treatments, 2 mil clear polyethylene tarps (20 feet x 100 feet) were applied to soil after the soil had been watered well (6 to 8 hours). The tarps were secured at the edges with soil. Tarps were removed after 4 weeks (Bend, July 29 - August 24, 1981) or 6.5 weeks (JHS, June 15 - August 1, 1983). No substance was applied on or into soil in control plots.

Soil temperature and moisture were monitored at four different depths in solarized and check plots during the solarization period.

At JHS, populations of the plant pathogenic fungi, *Fusarium* spp. and *Pythium* spp., were monitored in all treatments before and after solarization and fumigation. At Bend, only *Fusarium* populations were measured.

Ponderosa pine (Bend) and Douglas-fir (JHS) were sown in treated and control areas the spring following treatments. Weed populations were measured prior to sowing and seedling survival was measured periodically after emergence.

RESULTS

Figure 1 shows temperatures at Bend and JHS, and figure 2 shows percent soil moisture at JHS.

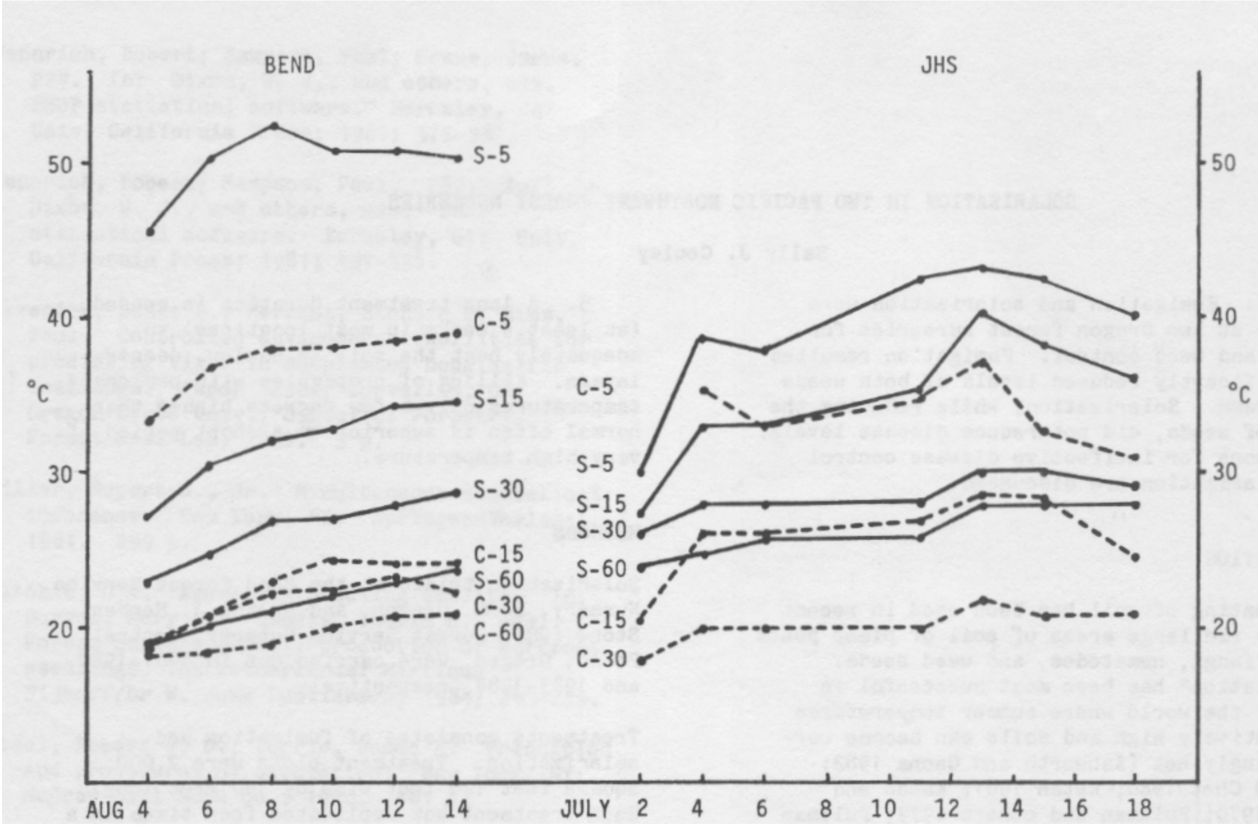

Figure 1.--Soil temperature in untarped (C) and solar tarped (s) plots at the Bend and J. Herbert Stone Nurseries.

At JHS, populations of Fusarium were reduced with both fumigation and solarization in soil between 0 and 12 inches deep (table 1). Fusarium was completely eradicated by fumigation and reduced significantly (statistically) by solarization. Fusarium populations increased in control plots. Similar results were obtained at Bend. Pythium populations at JHS were reduced to zero following fumigation; little or no reduction occurred in solar and control plots and there was no significant difference in Pythium levels between control and solar treatments (table 2).

Table 1.--Number of Fusarium propagules per gram of soil, at two depths, before and after solarization and fumigation. J. Herbert Stone Nursery.

	PRETREATMENT 0 - 6"	PRETREATMENT 6 - 12"	POSTTREATMENT 0 - 6"	POSTTREATMENT 6 - 12"
Control	2320 a*	1880 a	3400 a	2760 a
Solarization	2640 a	2040 a	920 b	1120 b
Fumigation	2680 a	2600 a	0 b	80 b

* Means followed by the same letter do not differ significantly according to Student Newman-Keuls Test (P = .05).

Table 2.--Number of Pythium propagules per gram of soil, at two depths, before and after solarization and fumigation. J. Herbert Stone Nursery.

	PRETREATMENT 0 - 6"	PRETREATMENT 6 - 12"	POSTTREATMENT 0 - 6"	POSTTREATMENT 6 - 12"
Control	180 a*	188 a	136 a	146 a
Solarization	184 a	184 a	144 a	128 a
Fumigation	194 a	208 a	0 b	0 b

* Means followed by the same letter do not differ significantly according to Student Newman Keuls Test (P = .05).

Weed control was best in fumigated areas and poorest in control areas. The number of weeds per unit area is given in table 3.

Table 3.--Number of weeds in fumigated, solarized, and control plots at the Bend and J. Herbert Stone Nurseries.

	Bend (Per Sq. Yd.)	JHS (Per Sq. Yd.)
Control	5.5 a*	36.4 a
Solarization	3.8 ab	5.1 b
Fumigation	1.6 b	4.4 b

* Means followed by the same letter do not differ significantly according to Student Newman-Keuls Test (P = .05).

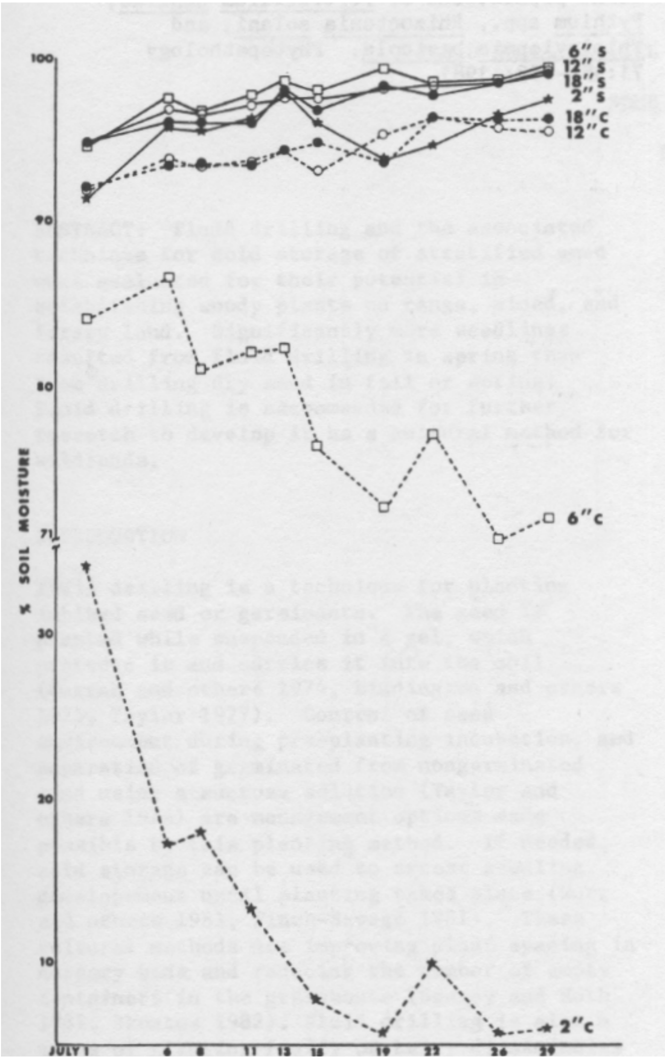

Figure 2.--Soil moisture in untarped (C) and solar tarped (S) plots at J. Herbert Stone Nursery, July 1 - 29, 1983.

Seedling survival after 20 weeks (Bend) and 8 weeks (JHS) is shown in table 4. Survival is best in fumigated areas and similarly poor in solarized and control areas. The average number of seedlings per square foot was four to five times higher in fumigated soil than in solar or control soil at Bend and about one-third higher at JHS.

Table 4.--Percent survival and seedlings per square foot in fumigated, solarized, and control plots at the Bend and J. Herbert Stone Nurseries.

	Bend (10 Weeks)		JHS (14 Weeks)	
	% Survival	Trees/Sq. Ft.	% Survival	Trees/Sq. Ft.
Control	31.9 a*	3	57.7 a	16
Solarization	27.6 a	4	61.4 a	17
Fumigation	69.7 b	15	83.5 b	23

* Means followed by the same letter do not differ significantly according to Student Newman-Keuls Test (P = .05).

DISCUSSION

Soil temperatures under tarps were raised about 10 degrees higher at 5, 15, and 30 cm depth than soil temperatures in untarped areas. At Bend, temperatures as high as 53^0 C (126° F) were obtained at 5 cm, 35° C (93^0 F) at 15 cm, and 29° C (84° F) at 30 cm. Lower temperatures were seen at JHS due to an abnormally cool summer in 1983. Temperature at the shallow depth at Bend was similar to that seen in solarization trials in Israel and California, but temperatures at 15 and 30 cm were somewhat lower than those elsewhere. Katan (1981) reports that temperatures at 20 cm in solarized soils reached 39° to 45° C in various trials in Israel and were similar or higher in California. Apparently temperatures of 40° to 50° C are needed to significantly reduce populations of most soil-borne pathogens; at the lower end of the range, longer exposure times are needed.

At JHS, seedling mortality was caused primarily by Fusarium oxysporum, causing root rot and lower stem infections. Pathogens responsible for seedling mortality were not identified at Bend; both Fusarium spp. and P tY hium spp. have been isolated previously from dead or dying seedlings from the Bend Nursery. Numerous reports indicate that soil solarization can effectively control diseases caused by Fusarium species on a variety of crops (Katan 1981). Populations of P thium spp. also have been reduced or eliminated after 14 to 58 days of solar tarping (Pullman and others 1981).

At Bend, the number of weeds in solarized plots was intermediary between control and fumigated plots. At JHS, both solarized and fumigated areas had significantly fewer weeds than control areas. Katan (1981) reports good control of most annual and many perennial weeds with solarization; control of grasses is more variable.

Several factors may have contributed to the poor results seen in these two solarization trials:

1. Poor reduction of pathogen populations during solarization due to inadequate temperatures in the lower soil layers. This could be corrected or improved by an extended tarping period. Temperatures achieved in solarized soil will be expected to vary from year to year, as they are very dependent on weather at the time of solarization.

2. Buildup of residual pathogenic fungi in solarized soil in the period between solarization and sowing the following year. Presence of organic matter from cover or green manure crops in the soil may provide an adequate food base for buildup of pathogenic fungi (e.g., Fusarium) that are able to exist as saprophytes in the absence of host plants.

3. Inadequate soil moisture during the solarization period (Bend only) due to very sandy, porous soil. Pest propagules, such as seeds and spores, are much more resistant to high temperatures in dry rather than wet environments (i.e., moisture induces germination, imbibitien of water, etc. resulting in increased sensitivity to heat).

Although solarization proved to be ineffective in controlling diseases in two Pacific Northwest forest nurseries, given the necessary climate and the appropriate management of solarized soil, solarization may be effective in some forest nurseries.

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