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2015 ODA Nursery Research Final Report

Soil Solarization for Improved Growth and Root Health of Field Grown Seedlings

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Objective: To compare different types of plastic film for effectiveness of soil solarization to reduce weeds and pathogen populations and improve growth of field grown tree seedlings.

Materials and methods:

A field study was conducted in 2015-2016 at a field production nursery in Boring, OR with a silt loam soil. Four different transparent plastic films for soil solarization were tested in addition to a non-solarized control treatment. The characteristics of each film are provided below, including the thickness (in mil, or thousandths of an inch), anti-drip properties (AD, yes or no), and infrared properties (IR, yes or no).

Table 1. Solarization treatments and characteristics of plastic films.

Solarization Treatment #	Manufacturer	Part #	Mil	AD	IR
1	Ginegar	C636	1.4	Yes	No
2	Omega	Clear Film	1.5	No	No
3	Ginegar	Suncover - UVA C643	6	No	No
4	Ginegar	Sunsaver - C921	6	Yes	Yes
5	None	Non-solarized control			

Each treatment was tested on beds 4' wide x 90' long separated by non-solarized aisles 3' wide. The five treatments were randomized in each of four blocks.

Beds were formed with machinery according to nursery practices. On July 14, 2015, bulk soil samples were collected from each plot at a depth of 2" to 6", composited, and sieved (2 mm mesh opening). Approximately 125 g of composite soil was placed in each of 50 nylon mesh sachets (105 µm mesh opening). Ten sachets were placed in a cooler and transported to the lab for processing to determine initial gravimetric water content and pathogen population densities. The remaining 40 sachets were buried in each of the 20 plots (=5 treatments x 4 blocks) at each of two depths, 2" and 6".

To measure soil temperature and soil moisture continuously throughout the trial, soil temperature/moisture reflectometers (CS655, Campbell Scientific, Logan, UT) were buried at 2" and 6" in each bed and connected to a CR1000 datalogger. Soil temperature at the soil surface (0 cm) and at 5, 10, 15 and 30 cm was measured with button dataloggers. Air temperature, windspeed, and solar radiation were also measured continuously at a weather station positioned in the center of the field trial.

The field was irrigated with overhead sprinklers to thoroughly moisten the soil, then allowed to drain overnight. On July 15, beds were covered with plastic (Treatments 1 through 4) or left uncovered (Treatment 5=non-solarized control) (Figure 1). Plastic covering the ends and sloped sides of each bed was covered manually with soil to secure the plastic film.

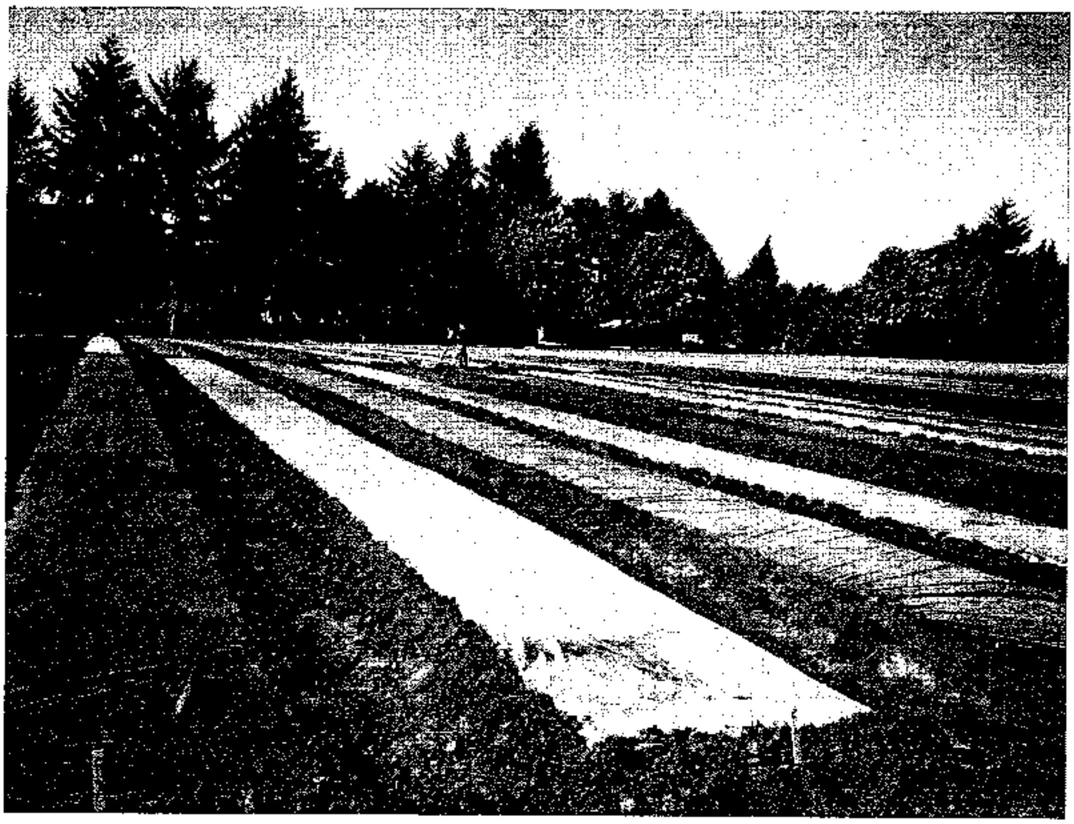

Fig. 1. Field trial layout on July 15, 2015. Note differences in clarity of anti-drip plastic (first and third row from left) vs. regular plastic (second row from left).

Weeds occurring in the nonsolarized treatment and aisles were sprayed twice with glyphosate during the 8-week trial to control weeds.

On Sept. 10, 2015, 8 weeks after initiation of the solarization trial, plastic film, dataloggers and sensors were removed, and soil sachets were excavated and taken to the lab for processing.

Total *Fusarium* colonies from soil sachets pre- and post-treatment were enumerated on Komada's medium. For *Pythium,* soil from each sample was diluted and plated onto PARP, a semi-selective medium for Pythiaceous species. *Fusarium* and *Pythium* colonies were expressed as propagules per gram (ppg) soil on a dry weight basis.

Each block was seeded with one of four tree species: linden, hawthorn, Mazzard cherry, or red oak on Sept. 15-17, 2015 and covered with a thin layer of composted sawdust.

Fall weed emergence counts were taken on October 26, 2015 and spring weed emergence was determined on April 20, 2016. Plots were hand weeded by the nursery work force on May 20, 2016 and the time required to weed each plot was recorded.

Seedling stand density and growth parameters (stem caliper, seedling height) were determined in early August, 2016. Shoot dry weight, root dry weight, mycorrhizal colonization and stem caliper will be measured in November, 2016 at time of lifting.

Results:

Soil Temperatures

For simplicity, only the temperatures at 2" and 6" will be reported. Plastic film Treatment 4, the 6-mil-AD-IR film, resulted in the highest maximum soil temperatures (135.5° F at 2" depth and 113.7° F at 6" depth), the highest average temperature (93.4° F and 90.4 ° F at 2" and 6", respectively) and the greatest number of hours above threshold temperatures of any of the solarization treatments (Tables 2 and 3).

Table 2. Maximum, minimum, and average soil temperatures in each of the solarization treatments. Treatments are arranged in order of decreasing average temperature.

			Temperature, Degrees F		
Treatment #	Description	Soil Depth	Maximum	Minimum	Average
4	6-mil AD, IR film	2 in.	135.6	60.4	93.4
		6 in.	113.7	67.0	90.4
1	1.4-mil AD film	2 in.	134.6	60.1	91.5
		6 in.	112.6	65.9	88.1
3	6-mil film	2 in.	124.1	68.5	88.5
		6 in.	104.9	65.3	86.0
2	1.5-mil film	2 in.	124.6	59.5	88.3
		6 in.	106.2	64.7	85.7
5	nonsolarized control	2 in.	107.1	50.7	77.0
		6 in.	92.3	58.4	76.2

Treatment 1, the 1.4-mil-AD film, resulted in a similarly high soil temperature maximum (134.6° F at 2" depth and 112.6° F at 6" depth) and the second greatest number of hours above threshold temperatures (Tables 2 and 3). The other two plastic films, both of which lacked the anti-drip characteristic, resulted in much lower soil temperature maxima and average temperatures and fewer cumulative hours above threshold temperatures. Nonsolarized beds had the lowest average temperature maxima of any treatment (107.1° F at 2" and 92.3° F at 6"), with an average of 77° F at the 2" depth and 76.1° F at the 6" depth.

Table 3. Cumulative hours above "threshold" soil temperatures in each of the treatments. Treatments are arranged in order of decreasing average temperature.

			Cumulative Hours Above Threshold Temperature				
Treatment #	**Description**	**Soil Depth**	**95° F**	**104° F**	**113°F**	**122° F**	**131° F**
4	6-mil AD, IR film	2 in.	539	363	226	112	22
		6 in.	416	124	3	0	0
1	1.4-mil AD film	2 in.	487	316	190	75	15
		6 in.	303	57	0	0	0
3	6-mil film	2 in.	422	248	94	9	0
		6 in.	207	20	0	0	0
2	1.5-mil film	2 in.	415	246	94	11	0
		6 in.	205	9	0	0	0
5	nonsolarized control	2 in.	163	18	0	0	0
		6 in.	0	0	0	0	0

Maximum soil volumetric water content for the solarized treatments, which occurred at the beginning of the trial, averaged 9% (2" depth) or 10.6% (6" depth). The nonsolarized treatment experienced greater variability during the trial, with volumetric water content ranging from a high of 22% following rain to a low of 3%, but averaging 5% (2" depth) or 8% (6" depth) over the trial.

Pathogens

Initial counts of soilborne fungi in the soil sachets pre-solarization were 6,507 propagules total per gram (ppg) soil for *Fusarium*, and 131 ppg for *Pythium*. Counts of *Fusarium* and *Pythium* after the solarization trial are shown in Figure 2.

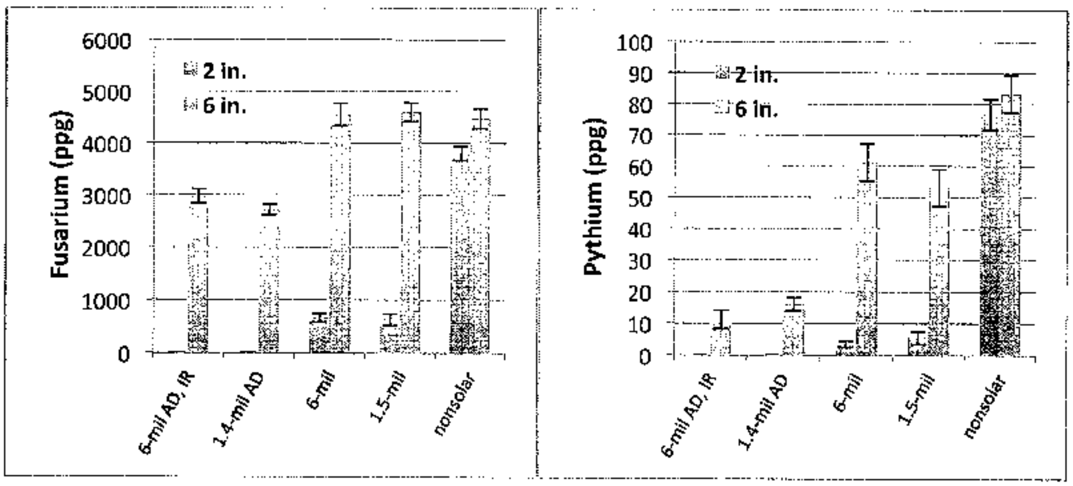

Figure 2. Counts of total *Fusarium* (left) and *Pythium* (right) after the 8-week solarization trial. Initial counts, pre-solarization, were 6,507 ppg for *Fusarium* and 131 ppg for *Pythium*. Values are average propagules per gram soil (ppg) ± std. error.

Weeds

Weed counts on Oct. 26, 2015, 6 weeks after fall seeding, were 22.7 weeds per sq. ft. in the nonsolarized plots, and ranged from 0.08 weeds per sq. ft. in Treatment 4 (6-mil, AD, IR solarization treatment) to 1.12 weeds per sq. ft. in the 6-mil non-AD, non-IR solarization treatment (Figures 3 and 4).

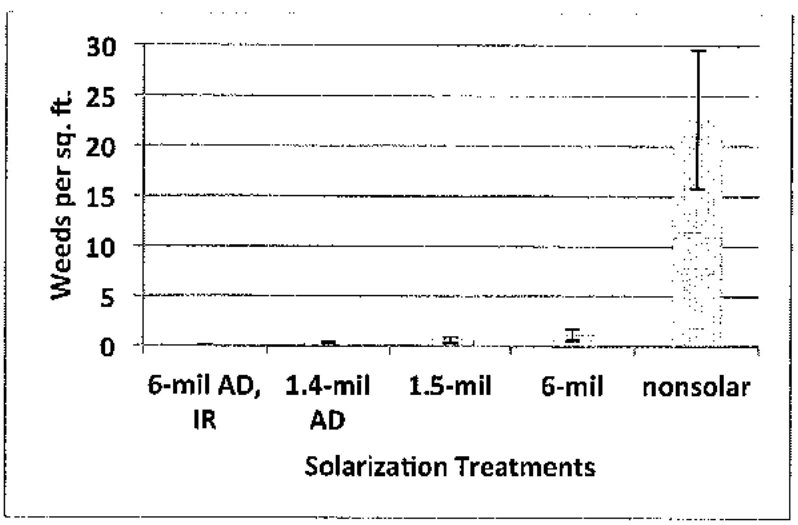

Figure 3. Fall weed emergence counts on Oct. 26, 2015.

The species most commonly encountered in the nonsolarized plots were lambsquarters (*Chenopodium album*), common henbit (*Lamium amplexicaule*), common chickweed (*Stellaria media*), shepard's-purse (*Capsella bursa-pastoris*) and a grass. Plots were subsequently hand weeded in November, 2015.

Figure 4. Oct. 26, 2015. Nonsolarized plot (left), solarized with Treatment 4 (right). Photo was taken 6 weeks after seeding.

Spring weed emergence was counted on April 20, 2016. Average weed counts ranged from 0.058 to 0.103 weeds per sq. ft. in the solarized plots, compared to 0.31 weeds per sq. ft. in the nonsolarized control treatment. The most common weed species were little bittercress (*Cardamine oligosperma*), common henbit (*Lamium amplexicaule*), mouse-ear chickweed (*Cerastium vulgare*), common chickweed (*Stellaria media*), prostrate knotweed (*Polygonum aviculare*), annual bluegrass (*Poa annua*), *Aster* sp., and a Brassicaceae sp. On May 20 and June 20, 2016, all plots were hand weeded by the nursery labor force and the time required to weed each plot was recorded. Labor to hand weed was reduced by 56-67% relative to the nonsolarized plots (Table 4).

Table 4. Time required to hand weed plots from the 2015 solarization trial.

	Ave. time (seconds) to hand weed*			
2015 Solarization Treatment	**on 5/20/2016**	**on 6/20/2016**	**sum**	**% labor reduction**
1	105	91	196	59
2	116	69	185	62
3	84	75	159	67
4	112	99	211	56
Nonsolarized control	274	210	484	-

*Plots=360 sq. ft.

Seedling growth parameters

Stand density, stem height, and stem caliper were measured on Aug. 4 and 9, 2016 on four 1 m^2 quadrats in each bed. Stand density was converted to the average number of seedlings in 3 linear feet of bed with 5 rows of seedlings (Table 5). Stem height and stem caliper were measured in one or two rows per quadrat to achieve a minimum of 100 seedlings per bed (Tables 6 and 7).

Table 5. Stand density of tree seedlings planted after the 2015 solarization trial as determined in August, 2016.

	Ave. seedling stand per 3 linear ft. of bed (Aug. 4-9, 2016)			
Solarization Treatment	Mazzard cherry	hawthorne	linden	oak
1	44.2	51.0	90.7	53.5
2	43.2	66.6	128.0	46.2
3	44.5	83.7	85.9	51.3
4	49.3	50.0	124.6	51.3
nonsolar control	37.8	55.8	64.4	43.7

Patches of damping-off disease and seedling mortality were observed in Mazzard cherry, particularly in Treatment 1. The cause of disease is under investigation. In addition, cherry leaf spot (*Blumeriella jaapii*) was observed in all Mazzard cherry treatments, causing some lower leaves to defoliate. There did not appear to be a disease pattern associated with soil solarization treatments.

Table 6. Stem caliper of seedlings planted after the 2015 solarization trial as determined in August, 2016.

	Average of Stem caliper (mm)			
Solarization Treatment	Mazzard cherry	hawthorne	linden	red oak
1	5.12	5.12	5.33	4.80
2	6.58	4.74	5.79	4.74
3	6.36	3.78	5.73	5.32
4	6.74	4.97	5.86	5.13
nonsolar control	6.14	5.05	5.68	4.54

Table 7. Height of seedlings planted after the 2015 solarization trial as determined in August, 2016.

	Average of Seedling height (cm)			
Solarization Treatment	Mazzard cherry	hawthorne	linden	red oak
1	25.9	56.7	21.6	25.1
2	49.4	52.2	26.9	22.9
3	45.9	37.5	23.5	25.4
4	49.7	52.8	27.4	23.0
nonsolar control	41.6	54.1	25.5	21.2

Plant growth parameters (stem caliper, stem height, biomass, and mycorrhizal colonization) will be measured in November, 2016.

Discussion:
Soil solarization with each of the plastic films resulted in a dramatic reduction in both fall and spring weed emergence relative to the nonsolarized control treatment. The time required to hand weed was reduced by 56-67% in the solarized plots in two episodes of spring weeding. Because labor costs generally represent the single largest component of nursery budgets, and nurseries typically also face significant labor shortages, the potential economic benefits of soil solarization for weed control in field production systems in the nursery industry could be considerable. Additional benefits of soil solarization would include a reduction in herbicide use.

For the two plant pathogens that were studied, total *Fusarium* and *Pythium* were reduced by all solarization treatments at the 2" depth, but at the 6" depth it appears that only the films with the anti-drip (AD) properties (Treatments 4 and 1) were effective. These two films resulted in the highest soil temperatures of any of the solarization treatments. It is not yet known if the reduction in *Fusarium* and *Pythium* in the soil surface layer will result in greater seedling emergence or healthier plants. The genus *Fusarium* includes both plant pathogenic as well as saprophytic species, and only total *Fusarium* counts were made in this study. Follow-up research should test the temperature thresholds of plant pathogenic strains as well as individual weed species.

It is not yet known if there are any statistically significant plant growth effects from the solarization treatments. However, stand density in all of the solarized treatments appears to be improved relative to the nonsolarized control for all species except for hawthorne treatments 1 and 4, and in the case of linden, treatments 2 and 4 resulted in nearly double the stand density relative to the nonsolarized control.

Treatment 4 (6-mil, AD, IR) resulted in the highest soil temperature of any of the solarization treatments, but the other film with anti-drip properties (Treatment 1, 1.4-mil, AD) was almost as effective. These two films differed from each other in IR properties and film thickness, therefore further comparison of AD and IR properties of films at one thickness (1.5-mil) is in progress. The similar effectiveness, lower cost of thinner film and reduced volume for recycling makes use of the thinner AD film more feasible for solarization on a commercial scale. However, once factors important for solar heating under Pacific Northwest conditions are identified, even more effective films can potentially be engineered.

Conclusions: Soil solarization during a summer fallow period can be very effective in reducing weeds and certain soilborne fungi in nursery field production systems, saving on labor costs, reducing herbicide use, and potentially reducing plant disease. Additional research is underway to optimize solarization for Pacific Northwest conditions by understanding the most favorable soil moisture conditions and minimum duration of solarization, selecting solarization films with specific properties (e.g. anti-drip, infrared) beneficial for our region, and knowing the temperature thresholds of specific weed species and plant pathogen species. Research is also needed to understand the effects of soil solarization on beneficial microbes and soil organic matter. Data obtained from this experiment will contribute to the eventual development of an online tool that growers can use to predict conditions when solarization will be effective in their location.