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Weed Population Dynamics after Summer Solarization

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Soil solarization, a non-chemical method of soil pest control, has been used to manage insects, nematodes, and weeds in agricultural systems. This study focused on optimizing the duration of solarization for weed management in northern Florida by examining weed coverage, density, and biomass, and comparing solarization effects on several summer weeds. In the summer of 2003, solarization plots were installed for durations of 2, 4, and 6 weeks, concluding on 12 Aug. After treatment, weed coverage and density were monitored every 2 weeks. All durations of solarization reduced weed coverage compared to non-solarized plots throughout the experiment. Weed densities were 200 times lower in solarized than non-solarized plots at 14 days post-treatment. Even at the conclusion of the experiment (56 days post treatment), population counts were lower in solarized plots; there was no difference in weed density among solarization durations; and there was a 90% reduction in total weed biomass in solarized treatments when compared to non-solarized treatments. *Indigofera hirsuta* and *Cyperus rotundu*s, the two dominant species, responded better to 4- and 6-week solarization treatments than to the 2-week treatment.

Solarization is an effective method for the management of many pests in soil, including weeds, and in some cases may serve as an effective non-chemical alternative to soil fumigation (Saha et al., 2007). Clear plastic allows for the transmission of solar radiation that heats the soil to temperatures of 30 to 60 °C, which are lethal or near-lethal to many organisms (Katan, 1981; Seman-Varner, 2005). Several mechanisms of weed control by solarization have been proposed. These mechanisms include direct thermal damage to seeds, germinating seeds, and shoots; morphological changes in shoots and other plant organs; breaking of dormancy and promotion of germination at greater depths; an imbalance of gases in soil; and indirect effects on soil microbial seed pathogens (Chase et al., 1998; Elmore, 1991; Rubin and Benjamin, 1984).

Several solarization studies have focused on direct thermal damage to a variety of weed species. In a field experiment, Rubin and Benjamin (1984) found that weed species responded differently to exposure to temperatures from 30 to 90 °C. For example, *Amaranthus retroflexus* L. (redroot pigweed) emergence was reduced when exposed to 50 °C for just 30 min, while even at 90 °C *Melilotus sulcatus* Desf. (sweet clover) emergence was not affected (Rubin and Benjamin, 1984). Rhizomes of *Cynodon dactylon* (L.) Pers. (bermudagrass) were killed when exposed to temperatures above 40 °C for 30 min, but tubers of *Cyperus rotundus* L. (purple nutsedge) required temperatures above 60 °C to show any reduction in viability (Rubin and Benjamin, 1984). In a field experiment in India, 30 d of solarization treatment reduced the germination of *Avena fatua* L. and *Phalaris minor* Retz. seeds by 90% at 5-cm depth. However, the germination of *Trianthema monogyna* L., *Asphodelus tenuifolius* Cav., and *Melilotus indica* (L.) All. were not reduced much in comparison to the affected species or not reduced at all (Arora and Yaduraju, 1998).

Dahlquist et al. (2007) developed a general linear model predicting weed seed thermal death by testing several weed species, including *Sonchus oleraceus* L. (annual sowthistle), *Echinochloa crus-galli* (L.) Beauv. (barnyardgrass), *Solanum nigrum* L. (black nightshade), *Portulaca oleracea* L. (common purslane), *Sisymbrium irio* L. (London rocket), and *Amaranthus albus* L. (tumble pigweed), in a controlled laboratory experiment. In that study, weed seeds of all species tested were dead within 3 h of exposure to 60 °C. At 50 °C, there was greater variability among species in the duration of exposure that caused thermal death, ranging from 4 h for *S. oleraceus* to 113 h for *A. albus.* Even at temperatures at or under 42 °C, seeds of *S. oleraceus, S. irio,* and *S. nigrum* were mortally damaged. However, the duration of exposure required for thermal death to occur ranged from 96 to 672 h (Dahlquist et al., 2007).

In another laboratory experiment, the effects of temperature and soil moisture were measured on the seeds of eight weed species (Egley, 1990). Seeds in dry soil tolerated up to 7 d of exposure to 60 °C, while most seeds were killed when exposed to 70 °C for 7 d. However, in moist soil, 1% to 12% of seeds of *P. oleracea, A. retroflexus*, *Sorghum halepense* (L.) Pers. (johnsongrass), and *Anoda cristata* (L.) Schlecht. (spurred anoda) survived exposure to 70 °C for up to 3 d, and 4% to 30% of the seeds of *Abutilon theophrasti* Medik. (velvetleaf), *Ipomoea lacunose* L. (pitted morningglory), *P. oleracea, A. retroflexus, S. halepense*, and *A. cristata* survived when exposed to 60 °C for up to 7 d.

When laboratory experiments have mimicked field conditions, the effects of high temperature have been more applicable to solarization methods. Shorter, more frequent exposure of *A. theophrasti* to high temperatures, which would mimic the diurnal heating produced by solarization, reduced germination rates compared to a single exposure (Horowitz and Taylorson, 1982).

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When seeds were exposed to 1 week of diurnal temperature cycles in moist soil (55 °C for 6 h then 30 °C for 18 h, and 60 °C for 2 h then 30 °C for 22 h), weed seed survival ranged from 0 to 91% and it was concluded that exposure to a longer period of lower temperatures was more destructive than a shorter period at higher temperatures (Egley, 1990).

Cyperus species have been of particular concern in solarization research, in part because they are among the world's worst weeds (Holm et al., 1977). Several studies have focused on *Cyperus* spp. control by various types of solarization methods (Chase et al., 1998, 1999; Patterson, 1998). *Cyperus rotundus* shoots were able to penetrate opaque polyethylene mulches and some clear mulches of various thicknesses and plastic types, but penetration was reduced when a 5 to 10 mm space was created between plastic and soil (Chase et al., 1998). Solarization treatment using clear mulch caused a morphological change in the *C. rotundus* shoots that reduced penetration substantially and caused the shoots to be scorched beneath the plastic (Chase et al., 1998).

In laboratory experiments, nutsedge tuber viability was reduced at 45 °C or higher (Chase et al. 1999; Webster, 2003). One hundred percent mortality of *C. rotundus* tubers resulted when tubers were treated with a laboratory temperature regime that mimicked solarization with a maximum temperature of 50 °C for 6 h, and exposure to a maximum of 45 °C slowed emergence of shoots (Chase et al., 1999). *Cyperus rotundus* tuber viability was reduced by 50% when exposed to temperatures of 45, 50, or 55 °C for 71, 23, and 1.8 h, respectively (Webster, 2003). This information can be applied to a management plan that includes solarization as a method of killing the shoots and depleting the plant reserves in the nutsedge tubers.

This study was designed to examine the effects of solarization on populations of several economically important summer weeds, including *Cyperus* spp., *Indigofera hirsuta* L. (hairy indigo), *Mollugo verticillata* L. (carpetweed), *Eleusine indica* (L.) Gaertn. (goosegrass), *Digitaria ciliaris* (Retz.) Koeler (southern crabgrass), and *Cynodon dactylon* (L.) Pers. (bermudagrass). The primary hypothesis was that as solarization treatment duration increased, weed emergence would decrease. We further hypothesized that the residual effects (up to 56 d post-treatment) would vary based on initial treatment duration. Additionally, the effects of solarization were expected to vary among individual weed species.

Materials and Methods

The experiment was conducted during the summer of 2003 at the University of Florida Plant Science Research and Education Unit near Citra in northern Florida. The soils in the experimental area were hyperthermic, uncoated, typic Quartzipsamments of the Candler series with a 0 to 5% slope (Thomas et al., 1979). Average soil pH of the site was measured as 5.9, and soil texture was 95% sand, 3% clay, and 2% silt. A cover crop of *Trifolium incarnatum* L. 'Dixie' (crimson clover) was planted during the winter season prior to the experiment and disked 2 d before the first plots were constructed.

The experiment was designed as a split-plot with duration of treatment as the main effect and solarization as the sub effect. Five replicates were arranged in a randomized complete block on the main effect. The experimental plots were raised beds 6 m long × 1 m wide × 20 cm high. The soil was moistened by overhead irrigation to provide sufficient moisture before the application of solarization plastic. The solarization plastic was a single layer of clear, 25-mm-thick, UV-stabilized, low-density polyethylene mulch (ISO Poly Films, Inc., Gray Court, SC). Installation of solarization treatments and non-solarization control treatments of 2, 4, and 6-week durations occurred during July and August of 2003. Temperature data loggers (Watch Dog® Model 425; Spectrum Technologies, Inc., Plainfield, IL) were inserted into the soil at depths of 5, 10, and 15 cm in 6-week solarized and non-solarized plots, 4-week solarized plots, and 2-week solarized plots. Treatments started on sequential dates and concluded on 12 August 2003.

Following solarization treatment, all plastic was removed, and the 2.0 m in the center of each 6.0-m plot was planted with 5-week-old *Hibiscus esculentus* L. 'Clemson spineless' (okra) seedlings, which were used as a bioassay to monitor plant nutrition, soil chemistry, and insect, and nematode populations (Seman-Varner, 2005; Seman-Varner et al., 2008). On both sides of the okra plants, a 1.0-m^2 subplot was established to monitor weed populations. Weed populations were monitored at 2-week intervals following solarization treatment and plastic removal. The Horsfall-Barratt (HB) scale (Horsfall and Barratt, 1945) was used to estimate the percent ground coverage by weeds in each plot on a scale from 1 to 12, where 1 = 0%; 2 = 0–3%; 3 = 3–6%; 4 = 6–12%; 5 = 12–25%; 6 = 25–50%; 7 = 50–75%; 8 = 75–88%; 9 = 88–94%; 10 = 94–97%; 11 = 97–100%; 12 = 100% of ground area covered. Individual plants were counted by species and then totaled for each plot. When plots reached 100% coverage, individual plants were no longer counted. A separate category for individual seedling counts was used for newly germinated seedlings that were visible but not identifiable and not a contributing factor to overall coverage. In order to determine how much, if any, of the weed seed population was dispersed in the area by wind, plastic trays (54.6 cm long × 26.7 wide cm × 6.4 cm deep) of sterilized soil were placed at each corner and at each mid-point of the experimental area. At the termination of the study, weed biomass was measured by determining fresh weight from a 0.25-m^2 section of the weed subplot within each plot.

Weed coverage based on HB ratings, total and individual species populations, and weed biomass were examined using analysis of variance (ANOVA) for a split-plot design. However, since significant ($P < 0.05$) duration × solarization interactions occurred in nearly every case, data were further compared among durations and between solarized and non-solarized treatments using ANOVA. If significant differences were detected among duration treatments, means were separated using a Least Significant Difference (LSD) test at the $\alpha = 0.05$ level. All data were analyzed using MSTAT-C software (Michigan State University, East Lansing, MI).

Results

Weed cover

Weed coverage was significantly lower ($P < 0.05$) in solarized treatments than in non-solarized treatments on every sampling date (Table 1). The HB ratings on the first and second sampling dates (0 and 14 d post-treatment) were between 1.0 and 2.0, or less than 3% coverage, in solarized plots and showed no significant differences among the three duration treatments. During these two samplings, the weed coverage ratings in non-solarized treatments varied between 2.0 and 10.0, or between 3% and 97% of the area covered. Among the non-solarized treatments, weed coverage was greatest in the 6-week treatment and least in the 2-week treatment ($P < 0.05$) on all sampling dates except the

Table 1. Horsfall-Barratt ratings for weed coverage during summer solarization experiment near Citra, FL.

Duration	Horsfall-Barratt rating[z] by sampling day														
	0 d[y]			14 d			28 d			43 d			56 d		
(wk)	Sol[x]	Non	Mean	Sol	Non	Mean	Sol	Non	Mean	Sol	Non	Mean	Sol	Non	Mean
2	1.2 A[w]	2.0 C**[v]	1.6	1.8 A	3.4 C**	2.6	2.8 A	6.1 B*	4.4	5.2 A	8.0 B*	6.6	6.4 A	9.5 A**	7.9
4	1.0 A	3.1 B***	2.0	1.9 A	5.1 B***	3.5	2.1 A	7.4 B***	4.7	4.1 A	9.6 AB**	6.8	4.9 A	11.1 A***	8.0
6	1.2 A	7.1 A***	4.1	1.6 A	9.3 A***	5.5	3.2 A	12.0 A***	7.6	3.9 A	12.0 A***	8.0	4.5 A	12.0 A**	8.2
Mean	1.1	4.0		1.8	5.9		2.7	8.5		4.4	9.8		5.2	10.9	

[z] Rated on a scale of 1 (0% of plot area covered) to 12 (100% of plot area covered) (Horsfall and Barratt, 1945) for percentage of plot area covered by weeds.

[y] Sampling days are post-treatment times measured after 12 Aug. 2003.

[x] Solarized (Sol) and non-solarized (Non) treatments.

[w] Means in columns followed by the same letter do not differ at $P < 0.05$ according to LSD test.

[v] $^{*, **, ***}$Indicate significant differences between solarized and non-solarized at $P < 0.05$, 0.01, and 0.001, respectively.

last date (56 d), when weed coverage was similar and extremely heavy in all non-solarized plots. There were no significant differences in weed cover among durations in solarized treatments throughout the experiment.

Weed populations

Total weed populations, as determined by number of stems or plants per 1.0 m^2, were significantly lower ($P < 0.05$) in solarized plots than in non-solarized plots at 0 and 14 d post-treatment, by as much as a factor of 200 (Table 2). Among non-solarized treatments, there were significantly more weeds per plot in the 6-week treatment than in the 4- or the 2-week treatments ($P < 0.05$). Some non-solarized plots reached 100% weed coverage by 28 d post-treatment, making counting of plants impractical and limiting the comparison of solarized plots with non-solarized plots. There were no significant differences in total weed populations among solarization duration treatments at 28, 43, and 56 d post-treatment ($P > 0.10$).

Individual weed species populations

Based on population density of individual weeds, the most dominant species was *I. hirsuta*. At 0 d post treatment, *I. hirsuta* was eliminated in all solarized treatments and significantly lower ($P < 0.05$) than in all non-solarized treatments (Table 3). In non-solarized treatments, the 6-week plots had more than six times the number of *I. hirsuta* plants than in the 2-week plots and almost three times the number in the 4-week plots ($P < 0.05$). By 14 d post-treatment, population size of *I. hirsuta* in 2-week solarized plots was similar to the population size of *I. hirsuta* in the 2-week non-solarized treatment. However, in the 6-week solarized treat-

Table 2. Weed population (number of plants or stems) during summer solarization experiment near Citra, FL.

Duration	No. of weed plants or stems per m^2								
	0 d[z]			14 d			28 d[y]	43 d	56 d
(wk)	Sol[x]	Non	Mean	Sol	Non	Mean	Sol	Sol	Sol
2	0.2 A[w]	16.0 B**	8.1	1.9 A	10.4 B**	6.2**	5.8 A	6.6 A	6.2 A
4	0.0 A	58.6 B**	29.3	0.6 A	10.5 B**	5.6	2.2 A	2.5 A	2.6 A
6	0.8 A	200.8 A*	100.8	1.2 A	25.1 A***	13.2	6.5 A	4.5 A	6.0 A
Mean	0.3	91.8		1.2	15.3				

[z] Sampling days are post-treatment times measured after 12 Aug. 2003.

[y] Non-solarized plots reached 100% coverage by 28 d post-treatment, therefore only solarization treatments were examined for total weed counts.

[x] Solarized (Sol) and non-solarized (Non) treatments.

[w] Means in columns followed by the same letter do not differ at $P < 0.05$ according to LSD test; no letters indicate no differences at $P < 0.05$.

[v] $^{*, **}$Indicate significant differences between solarized and non-solarized at $P < 0.05$ and 0.01, respectively.

Table 3. Number of hairy indigo (*Indigofera hirsuta*) plants during 2003 summer solarization experiment. Hairy indigo represents an important regional weed and was the most dominant species in this study.

Duration	No. of hairy indigo plants per m^2								
	0 d[z]			14 d			28 d[y]	43 d	56 d
(wk)	Sol[x]	Non	Mean	Sol	Non	Mean	Sol	Sol	Sol
2	0.0 A[w]	12.2 B*[v]	6.1	1.7 A	2.3 B	2.0	3.0 A	2.8 A	2.8 A
4	0.0 A	27.2 B**	13.6	0.4 A	4.8 B*	2.6	1.0 B	1.0 B	1.0 B
6	0.0 A	78.0 A**	39.0	0.0 A	12.4 A**	6.2	1.0 B	0.6 B	0.6 B
Mean	0.0	39.1		0.7	6.5				

[z] Sampling days are post-treatment times measured after 12 Aug. 2003.

[y] Non-solarized plots reached 100% coverage by 28 d post-treatment, therefore only solarization treatments were examined for hairy indigo plant counts.

[x] Solarized (Sol) and non-solarized (Non) treatments.

[w] Means in columns followed by the same letter do not differ at $P < 0.05$ according to LSD test; no letters indicate no differences at $P < 0.05$.

[v] $^{*, **}$Indicate significant differences between solarized and non-solarized at $P < 0.05$ and 0.01, respectively.

Table 4. Number of purple nutsedge (*Cyperus rotundus*) stems during 2003 summer solarization experiment. Purple nutsedge is an important global weed pest and a dominant species in this study.

Duration	No. of purple nutsedge stems per m^2								
	0 d[z]			14 d			28 d[y]	43 d	56 d
(wk)	Sol[x]	Non	Mean	Sol	Non	Mean	Sol	Sol	Sol
2	0.2 A[w]	1.2 B	0.7	0.0	1.4	0.7	0.9	1.1	0.8
4	0.0 A	2.6 B*[v]	1.3	0.1	0.9	0.5	0.6	0.2	0.4
6	0.6 A	11.2 A**	5.9	1.0	1.1	1.1	0.0	0.6	1.4
Mean	0.3	5.0		0.4	1.1				

[z] Sampling days are post-treatment times measured after 12 Aug. 2003.

[y] Non-solarized plots reached 100% coverage by 28 d post-treatment, therefore only solarization treatments were examined for total weed counts.

[x] Solarized (Sol) and non-solarized (Non) treatments.

[w] Means in columns followed by the same letter do not differ at $P < 0.05$ according to LSD test; no letters indicate no differences at $P < 0.05$.

[v] *, **Indicate significant differences between solarized and non-solarized at $P < 0.05$ and 0.01, respectively.

ment, *I. hirsuta* emergence was completely suppressed and few plants (average of 0.4/plot) appeared in the 4-week solarized treatments. Both 4- and 6-week solarized treatments remained significantly lower than the corresponding non-solarized treatments ($P < 0.05$). Once non-solarized plots reached 100% coverage (28 d post-treatment), *I. hirsuta* numbers were significantly lower in 4- and 6-week solarization treatments than in 2-week solarization treatments until the conclusion of the experiment (at 56 d post-treatment).

Cyperus rotundus was also an important species, based on number of stems contributing to the total weed count (Table 4). Initially (0 d post-treatment), all three solarization treatments almost completely eliminated *C. rotundus* plants. Solarized treatments of 4- and 6-week durations significantly reduced the number of *C. rotundus* sprouts compared with the non-solarized treatments ($P < 0.05$). At 14 d post-treatment, *C. rotundus* sprouts remained low in solarized plots, but decreased in non-solarized plots, showing no significant difference from solarized plots. Once plots reached 100% weed coverage, there were no significant differences among durations of solarization treatment.

Due in part to the size and dominance of *I. hirsuta* and *C. rotundus*, other weeds such as *E. indica* and *D. ciliaris* were not dominant species in the total weed counts or weed coverage.

Wind-dispersed seed

No germinated seeds were found in the wind-dispersed seed traps, indicating that all weeds were germinated from the soil seed bank.

Weed biomass

Weed plant biomass was reduced ($P < 0.01$) by 90% in solarized treatments compared to non-solarized treatments (Table 5). *Indigofera hirsuta* biomass was reduced by 98% in solarized treatments (data not shown). *Indigofera hirsuta* made up 75% of the total weed biomass in non-solarized plots. In contrast, *I. hirsuta* accounted for only 16% of the total biomass in solarized treatments. *Cynodon dactylon* (L.) Pers. was the dominant species by weight in solarized plots and comprised nearly 30% of the total weed biomass. *Mollugo verticillata* comprised the next largest proportion of total biomass in solarized plots at 18%.

Table 5. Total weed biomass at conclusion of summer solarization experiment (56 d post-treatment) near Citra, FL.

Duration	Fresh wt of total weed biomass per 0.25 m^2 (g)		
	Treatment[z]		
(wk)	Sol	Non	Mean
2	50.9	259.2	155.0
4	23.2	226.7	124.9
6	65.8	849.7	457.7
Mean	46.6	445.2**[y]	

[z] Solarized (Sol) and non-solarized (Non) treatments, ending on 12 Aug. 2003.

[y] **Indicates significant differences between solarized and non-solarized at $P < 0.01$.

Discussion

Solarization for all treatment durations effectively reduced weed coverage and weed populations. There were no significant differences in weed coverage among durations of solarization treatment for the first 28 d post-treatment, and weed coverage for all solarized treatments remained less than 6%. All 6-week non-solarized plots reached 100% coverage by 28 d post-treatment. By the conclusion of the experiment (56 d post-treatment), two of the 4-week non-solarized plots also reached 100% coverage, while the average coverage of all non-solarized plots was 94% to 97%, and all solarized plots had less than 50% weed coverage. After solarization treatment, weed densities were reduced to almost zero and reductions of 80% or more were maintained compared with non-solarized plots.

Although several control plots reached 100% coverage at 28 d post-treatment, which limited effective counting of weeds and analysis between solarized and non-solarized treatments, average total weed density for each duration in solarized plots remained very low, with fewer than seven stems per m^2 across all solarized plots. As with weed coverage, there were no differences among durations of solarization based on total weed density, suggesting that all solarization treatment durations were effective in decreasing weed emergence.

Individual species densities showed that the two dominant species, *I. hirsuta* and *C. rotundus*, were variably affected by solarization treatments. Other studies also have shown that high-temperature effects, like those caused by solarization or other methods, vary with species and depth of the seed (Egley, 1990; Horowitz et al., 1983; Standifer et al., 1984). *Indigofera hirsuta* population was reduced by solarization and continued to be affected by 4-and 6-week solarization durations up to 56 d post-treatment. *Cyperus rotundus* was initially reduced by 4- and 6-week solarization treatments. However, at 14 d post-treatment, numbers of *C. rotundus* had dropped to <1.5 per m^2 in the non-solarized plots. The reduction in *C. rotundus* may have been due to competition with the larger plants of *I. hirsuta*, which quickly became the dominant weed in those plots. At 14 d post-treatment and beyond, there were no significant differences among durations of solarization treatment on *C. rotundus* populations.

The 90% reduction in weed biomass recorded in solarized treatments was another indicator that solarization was highly effective in reducing weed populations, even up to 56 d post-treatment. This information suggests that solarization could be a practical and effective method of weed management for the production of many economically important vegetable crops.

The mechanisms for reduced weed cover, density, and biomass in solarized treatments likely vary by species. *Indigofera hirsuta* germination may have been inhibited by the effects of high soil temperatures on seeds, while young *C. rotundus* shoots may have been affected by soil temperatures after emergence. The maximum soil temperature at a depth of 5 cm in solarized plots was 54 °C and temperatures were at or above 45 °C for 28 of 41 d of solarization treatment (Fig. 1). Even at 10-cm depth, temperatures reached 45 °C or more on 5 of the 41 d. The maximum soil temperatures indicate a relatively even distribution of high temperature days throughout the duration of the treatment (Fig. 1). Periodic decreases in maximum daily soil temperature at 5 cm are related to days with greater than 1 inch (2.5 cm) of rainfall or at least 50% reduction in solar radiation (Anonymous, 2010). Even with the decrease in maximum soil temperatures during rainy or cloudy days, the frequent high temperature days would have damaged seeds and emerging plants at this depth and were high enough to kill *C. rotundus* tubers based on temperature data from previous studies (Chase et al., 1998; Webster, 2003).

Solarization was effective in reducing weed coverage, density, and biomass. Increasing the duration of solarization treatment from 2 to 6 weeks did not significantly affect initial weed coverage or density. Studies have shown effective control of some winter and summer annual weed species with as little as 1 to 2 weeks of solarization treatment (Egley, 1983; Horowitz et al., 1983; Elmore, 1991). However, the effect of both 4- and 6-week treatments on these Florida weed populations appeared to continue beyond that of the 2-week treatment, in which weed populations began to recover at an earlier date. Durations of 4 and 6 weeks also more effectively reduced individual weed species in Florida, specifically *I. hirsuta* and *C. rotundus*.

Further study on weed populations to determine the time needed to recover and reach 100% coverage may add to our understanding of the lasting effects of solarization, although this may not have practical application to agricultural production. An in-depth study on populations of individual species would further our understanding of the best management practices for individual species that may be more resistant to the effects of high temperatures. It would also be worthwhile to understand the mechanisms for reduced germination or emergence by species and how seeds in the soil seed bank resist damage or recover from solarization treatment. By adding to the body of research, solarization can be improved as an effective tool for weed management and an alternative to chemical or fumigant pre-planting treatments.

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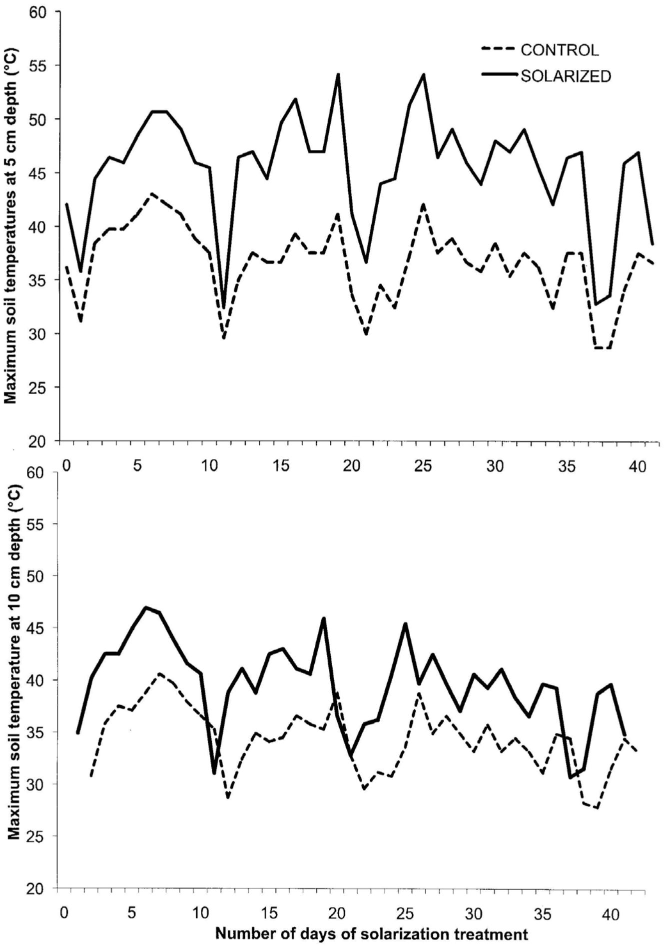

Fig. 1. Daily maximum soil temperatures at 5-cm soil depth (top graph) and at 10-cm depth (bottom graph) during 6-week solarized and non-solarized treatments in an experiment near Citra, FL.

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