Effects of soil temperature and tuber depth on *Cyperus* spp. control

Carlene A. Chase  
Corresponding author. U.S. Department of Agriculture-Agricultural Research Service, Gainesville, FL 32611. Mailing address: Agronomy Physiology and Genetics Laboratory, P.O. Box 110965, University of Florida, Gainesville, FL 32611-0965; cach@gnv.ifas.ufl.edu

Thomas R. Sinclair  
U.S. Department of Agriculture-Agricultural Research Service, Gainesville, FL 32611-0965

Salvadore J. Locascio  
Horticultural Sciences Department, University of Florida, Gainesville, FL 32611-0690

Studies were conducted to determine lethal temperatures for *Cyperus esculentus* and *Cyperus rotundus* tubers using diurnal oscillations in soil temperature with maxima of 40, 45, 50, and 55°C and a minimum of 26°C. Growth of *Cyperus* spp. plants was faster at 40°C than at a constant temperature of 26°C. The 45°C treatment delayed *Cyperus* spp. emergence but was not lethal to tubers. Tuber mortality was 100% for both *Cyperus* spp. with the 50 and 55°C temperature regimes. Soil solarization with thermal-infrared-reflective (TIR) films resulted in higher soil temperatures than with a 30-μm low-density polyethylene (LDPE) clear film. With TIR films, greater proportions of emerged *C. rotundus* plants were killed by foliar scorching, and 6 wk of soil solarization was more effective at reducing *C. rotundus* density than with the LDPE film. Four weeks after film removal, the lowest level of control was obtained with the LDPE film. For *C. rotundus* tubers planted 5 and 10 cm deep, 62% control was obtained with the LDPE film, and it decreased to 32% with a 15-cm planting depth. The best residual control was 95 and 92% with the 75- and 100-μm TIR films, respectively. With the TIR films, there was no significant change in *C. rotundus* control with planting depth.

**Nomenclature:** Methyl bromide; *Cyperus rotundus* L. CYPRO, purple nutseed; *Cyperus esculentus* L. CYPES, yellow nutseed.

**Key words:** Methyl bromide alternatives, lethal temperature, CYPES, CYPRO.

Black polyethylene or white-on-black polyethylene mulches are used commonly in association with methyl-bromide: chloropicrin soil fumigation in Florida for the production of high-value horticultural crops such as *Lycopersicon esculentum* Mill. (tomato), *Capsicum annuum* L. (bell pepper), and *Fragaria xanassa* Duchesne (strawberry). The ban on the production and importation of methyl bromide after January 1, 2005, has stimulated a concerted effort to find suitable alternatives. In evaluations of chemical alternatives to methyl bromide, Gilreath et al. (1994) found that in most of their tests, *C. rotundus* and *C. esculentus* were the most damaging pests and the most difficult to control with fumigants alone. Fumigation with 1,3-dichloropropene: chloropicrin plus a preplant-incorporated application of pebbleulat provided some control of *Cyperus* spp. (Locascio et al. 1997). Summer soil solarization for fall production is another alternative that has shown promise as an alternative to methyl-bromide fumigation. Chellemi et al. (1997) reported that *Cyperus* spp. (mixed populations) control by soil solarization was equivalent to that of methyl bromide at a site with a low *Cyperus* spp. population (12 plants 0.27 m⁻² with white film) and was more effective than methyl bromide at a site with a high *Cyperus* spp. population (33.4 plants 0.27 m⁻²). In soil solarization, radiant energy from the sun is transmitted through clear polyethylene film so that soil can be heated to biologically lethal temperatures. The solarization of soil has been successfully utilized in arid climates for weed and soilborne disease control (Katan et al. 1976).

Soil solarization has been shown to provide excellent control of annual weeds but is less effective for control of perennial weeds. Rubin and Benjamin (1983) found that control of *C. rotundus*, *Sorghum halepense* (L.) Pers. (johnsongrass), and *Cynodon dactylon* (L.) Pers. (bermudagrass) was significantly improved by an extended solarization period of 8 to 10 wk. Egley (1983) found that 3 to 4 wk of solarization did not decrease *C. rotundus* emergence and that, in some cases, emergence increased. Fluctuating temperatures were more effective than constant temperatures in promoting rapid and complete sprouting of *C. rotundus* tubers (Miles et al. 1996), suggesting that stimulation of *Cyperus* spp. emergence in some studies was probably due to the more pronounced diurnal temperature variation that is a characteristic of solarization. A single temperature pulse from 20 to 35°C has been shown to release dormancy in *C. rotundus* tubers (Sun and Nishimoto 1997).

Soil solarization controls weeds directly by killing weed propagules and indirectly by the foliar scorching of plants that emerge under the polyethylene mulch (Horowitz et al. 1983). Rubin and Benjamin (1984) proposed that only weed propagules in the top 10 cm were being killed by soil solarization and that those located at greater depths were escaping. In the studies of Standifer et al. (1984), seeds of *Cyperus* spp. (annual sedges) and *Echinochloa crus-galli* (L.) Beauv. (barnyardgrass) were killed only in the upper 3 to 4 cm of soil, whereas seeds of *Eleusine indica* (L.) Gaertn. (goosegrass) and *Commelina communis* L. (Asian dayflower) were killed within the upper 5 and 11 cm, respectively. It is likely that *Cyperus* spp. tubers are directly killed by soil solarization in the shallower soil depths and stimulated to sprout at depths that do not heat to lethal temperature (Rubin and Benjamin 1984). A light-dependent morphogenic change from rhizome elongation to leaf expansion was proposed to explain differential penetration of opaque and clear mulch films (Chase et al. 1998). Expanding leaves are
trapped under the clear mulch, and the shoots succumb to foliar scorching.

Lethal temperatures for *C. esculentus* and *C. rotundus* tubers have been previously investigated. Holt and Orcutt (1996) found that when incubated for 2 wk at constant temperature, the lethal temperatures were 43 and 44 C, respectively. Rubin and Benjamin (1984) found that when *C. rotundus* tubers were subjected to a single 30-min exposure, temperatures > 60 C were required to reduce tuber viability significantly. Because solarization produces a pronounced diurnal variation in soil temperature, the objectives of these studies were (1) to determine the cumulative effect of diurnal temperature fluctuation on *Gypserus* spp. tuber viability, with a maximum temperature range of 40 to 55 C; and (2) to compare the effects of TIR films of varying thickness with a conventional LDPE clear film on soil temperature and *C. rotundus* control.

Materials and Methods

Laboratory Experiments

Laboratory experiments were conducted in pots to determine the lethal temperature for *C. esculentus* and *C. rotundus* tubers under temperature regimes that approximated those of solarization in the field. *Gypserus* spp. tubers1,2 were pre-sprouted to ensure viability. *Gypserus rotundus* tubers were stored at 25 C wrapped in moist newspaper. Sprouted tubers were selected for use in experiments. *Gypserus esculentus* tubers were placed in moist soil (Scotts Terralite Agricultural Mix)3 and exposed to 30 C for 6 h followed by 25 C for 18 h over a 3-d incubation period. The buds and roots were removed by trimming, and four tubers were planted 5 cm deep in each pot (11 cm in diam, 11 cm tall). The soil was a Millhopper fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleudult) obtained from the University of Florida Horticultural Research Unit, Gainesville. Pots were covered with LDPE film that was secured around the pots with rubber bands to limit convective heat loss from the soil surface. All but 2 cm of the pots were immersed in well-stirred water baths and heated, with maximum soil temperatures of 40, 45, 50, or 55 C. Pots without drain holes were used to prevent direct contact between the soil in the pots and the water in the baths. Four replicate pots were randomly allocated to temperature treatments. Water baths were controlled by timers to allow heating for just 6 h each day, beginning at 10 A.M., and allowed to cool to 26 C after the heating period to generate the diurnal oscillations of soil temperature. The control treatment was held at 26 C. Soil temperatures were monitored at 30-min intervals 5 cm deep at the center of each pot using a CR10 data logger.4

The temperature treatments were discontinued after 2 wk, and the number of shoots was recorded. Pots with unsprouted tubers were held at 30/25 C (12 h each daily) in a growth chamber for another week, after which the viability of unsprouted tubers was determined using 0.1% triphenyl tetrazolium chloride (TTC) (Miles et al. 1996). Unsprouted tubers and tubers from the control plants were washed and sectioned into halves. One-half of each tuber was immersed in 0.1% TTC and held at 30 C for 2 h. The other half was held in deionized water at room temperature.

Experiments were conducted twice with each *Gypserus* sp. There was no interaction between experiment and temperature, and data were pooled and analyzed using ANOVA. Fisher's Protected LSD test with a 5% level of significance was used for mean separation.

Field Experiment

A soil solarization experiment was conducted in summer 1997 on a Millhopper fine sand soil (loamy, siliceous, hyperthermic, Grossarenic Paleudult) at Gainesville, FL, to confirm the laboratory data, determine the soil depths at which lethal temperatures occurred, and evaluate the efficacy of *C. rotundus* control. The experimental design was a split plot, with four solarization films and a nonmulched (bare) treatment as the main plot treatments, and subplot treatments were three tuber planting depths (5, 10, and 15 cm). The main plots (3.6 m long and 0.9 m wide) were arranged in a 5 by 5 Latin square. Subplots (0.9 by 0.9 m) were completely randomized within the main plots.

The 0.9-m-wide planting beds on 1.8-m centers were treated with methyl bromide at 44.8 g m-2 and covered with black polyethylene mulch to kill existing weed species. The fumigation mulch was removed after 1 wk, the field was irrigated, and 12 *C. rotundus* tubers were planted in each subplot in a rectangular grid with 0.2 m between planting positions. Solarization films were then installed. Three of the solarization films consisted of a TIR formulation that had been extruded in thicknesses of 50, 75, and 100 μm.5 The fourth film was a conventional 30-μm clear LDPE film.6

Soil temperatures in three main plot replications were recorded at 30-min intervals using a CR10 data logger. A copper-constantan thermocouple was inserted in the middle of each subplot to the depth of planting. Soil surface temperatures were also measured in a single replication of the 100-μm TIR and the 30-μm LDPE treatments.

Soil solarization was conducted from July 23, 1997, to September 3, 1997. During the 6-wk solarization period, counts were made of live and dead (foliar scorched) *C. rotundus* plants trapped under the films and plants penetrating the films. *Gypserus rotundus* plants that emerged under and through the films were counted again at the end of the solarization period. The solarization films were removed, *C. rotundus* shoots were cut off at soil level, and shoot dry weights were determined. *Gypserus rotundus* shoot density and biomass were expressed on a per square meter basis. In addition, *C. rotundus* control was determined by expressing the plant density from each treatment as a percentage of the density of the nonsolarized treatment. The persistence of control was assessed 4 wk later on October 1, 1997, by counting the number of emerged *C. rotundus* plants and expressing the counts as a percentage of the nonsolarized treatment. ANOVA was performed using the MIXED procedure in SAS (1996). Film and depth were considered to be fixed effects, and column and row were considered random effects. Multiple comparisons of films and depths were performed by use of contrasts or by applying Fisher's Protected LSD test to the least-squares means.

Results and Discussion

Laboratory Experiments

The diurnal variation in temperature obtained using the water baths is illustrated in Figure 1. Soil temperatures in
increased rapidly when the heaters were turned on and reached the prescribed treatment temperature within 1 h. After the heaters were turned off, soil temperature decreased slowly, approaching 26°C before the heaters were again turned on. The daily cycle of temperature was similar to that observed in the field 5 cm deep, except that soil heating occurred at a faster rate and resulted in more of a plateau at maximum temperature (Figure 2).

*Cyperus* spp. sprouting and growth were faster at 40°C than at room temperature. Multiple sprouts arose from some tubers, so that there was more than one shoot per tuber in some pots. This resulted in a significantly greater number of *C. rotundus* shoots at the end of the 2-wk incubation (Table 1). Although shoot emergence was delayed (data not shown), the 45°C treatment was not lethal to tubers. Sprouting in both *Cyperus* spp. was completely inhibited by the 50 and 55°C treatments (Table 1).

The nonviability of tubers from the 50 and 55°C treatments was confirmed using the TTC test (data not shown). Tubers held at room temperature were ivory in cross-section and retained that color when held in deionized water. After a 2-h incubation in 0.1% TTC, these tubers developed an intense pink color around the pith. The tubers subjected to 50°C were a dark cream color with light brown streaks when first cut. Some of the 50°C-treated tubers developed a slightly pink color, but the intensity was not comparable to that of the control tubers, and they were considered nonviable.

### Table 1. Effect of soil temperature on *Cyperus* spp. shoot emergence.

<table>
<thead>
<tr>
<th>Soil temperature</th>
<th><em>C. rotundus</em></th>
<th><em>C. esculentus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>(C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>40</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>45</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>55</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

*Values in each column are means of two experiments.*

Tubers held at 55°C were light brown when sectioned and did not develop color after incubation.

Although it has been reported that a constant incubation temperature of 44°C was sufficient to kill *C. rotundus* and *C. esculentus* tubers (Holt and Orcutt 1996), diurnally fluctuating temperatures with a maximum temperature of 45°C in our experiments only slowed emergence. Miles et al. (1996) have pointed out the limitation of studying *C. rotundus* sprouting at constant temperatures. There is a characteristic diurnal variation in field soil temperature that is even more pronounced with soil solarization.

### Field Experiment

The typical diurnal variation of temperature that occurred in soil on a sunny day and the increase in soil temperature under clear polyethylene films are illustrated in Figure 2. Soil under clear mulches heated more rapidly than nonmulched soil, resulting in higher daily maximum temperatures. Minimum soil temperatures of mulched soil were also not as low as those of nonmulched soil (Figure 2). All of the solarization films increased the mean daily maximum soil temperature by at least 10.3, 8.7, and 7.3°C over non-solarized soil, 5, 10, and 15 cm deep, respectively (Table 2). Surface soil temperatures were higher under the 100-μm TIR film than under the 30-μm LDPE, so that temperature exceeded 60°C on 49% of the days of the solarization period under TIR and attained those temperatures only 8% of the days under the LDPE film. Although temperatures > 50°C occurred on at least 18% of the days under solarization mulches, 50°C was never attained at 10- or 15-cm depths. The TIR films promoted higher soil temperatures than the other films.

### Table 2. Soil temperatures* and the percentage of days on which threshold temperatures were exceeded at Gainesville from July 24 to September 2, 1997.

<table>
<thead>
<tr>
<th>Film</th>
<th>Mean daily maximum temperature (°C)</th>
<th>Percentage of days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&gt; 60°C</td>
</tr>
<tr>
<td></td>
<td>(°C)</td>
<td>Soil depth (cm)</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Bare soil</td>
<td>—</td>
<td>36.5</td>
</tr>
<tr>
<td>LDPE-30 μm</td>
<td>53.5</td>
<td>46.8</td>
</tr>
<tr>
<td>TIR-50 μm</td>
<td>—</td>
<td>47.6</td>
</tr>
<tr>
<td>TIR-75 μm</td>
<td>—</td>
<td>47.6</td>
</tr>
<tr>
<td>TIR-100 μm</td>
<td>58.8</td>
<td>47.9</td>
</tr>
</tbody>
</table>

*Temperatures measured in three replications of each main plot treatment for 34 d of the solarization period were used.*

Chase et al.: *Cyperus* spp. soil solarization • 469
LDPE film. This resulted in 9 to 12% more days on which maximum soil temperature exceeded 50 C and thus TIR film had greater potential for promoting \emph{C. rotundus} tuber mortality.

Because laboratory soil temperatures > 45 C were required for tuber mortality, the field soil temperature data were summarized to determine the percentage of days during the solarization period on which the daily maximum soil temperature exceeded 45 C (Table 3). Bare soil did not heat to 45 C at any of the depths measured. At 5-cm depth, the three TIR films resulted in daily maximum temperatures > 45 C for at least 80% of the days, compared with 77% for the 30-μm LDPE film. With TIR film, at least 38% of the days resulted in > 45 C soil temperatures 10 cm deep but only 32% with the 30-μm LDPE film. For all of the solarization films, temperatures 15 cm deep exceeded 45 C for just 3% of the days. Therefore, only the upper 10 cm of soil consistently produced soil temperatures that would have been lethal to \emph{Cyperus} spp. tubers. Horowitz et al. (1983) ascribed the resistance of perennial weeds to soil solarization to the occurrence of perennating organs at depths that do not heat to lethal temperature.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Film & Soil depth (cm) & 5 & 10 & 15 \\
\hline
Bare soil & 0 & 0 & 0 \\
LDPE-30 & 77 & 32 & 3 \\
TIR-50 & 80 & 44 & 3 \\
TIR-75 & 82 & 38 & 3 \\
TIR-100 & 80 & 44 & 3 \\
\hline
\end{tabular}
\caption{Percentage of days during solarization when soil temperature exceeded 45 C (based on temperatures for 34 d of the solarization period).}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Tuber depth (cm) & \emph{C. rotundus} density (plants m⁻²) & Week 2 & Week 4 & Week 6 \\
\hline
5 & 32 & 203 & 315 \\
10 & 23 & 183 & 292 \\
15 & 14 & 155 & 280 \\
\hline
P (linear effect) & 0.0001 & 0.0004 & 0.02 \\
\hline
\end{tabular}
\caption{Effect of soil depth of tuber planting on \emph{C. rotundus} density in nonsolarized soil.}
\end{table}

\emph{Cyperus rotundus} Control in Solarized Soil

There was no interaction between solarization film and tuber planting depth; therefore, the main effects of film and planting depth were assessed. The effect of solarization film on \emph{C. rotundus} density was significant (Table 5). Fewer \emph{C. rotundus} plants emerged with the solarization treatments than with the bare soil. This appeared to result from a combination of factors associated with having a clear film over the soil. Temperatures were sufficiently high to cause thermal death of tubers in the upper 10 cm of soil. We have previously reported that the differential penetration of opaque and clear films by \emph{Cyperus} spp. plants was due to a photomorphogenic change from rhizome to leaf growth under clear film, which does not occur under opaque film (Chase et al. 1998). As a result of this light-dependent morphological change to leaf growth, there was a reduction in \emph{C. rotundus} density as plants were trapped under the films, and foliar scorching resulted in necrosis and death (Table 5).

A greater proportion of the emerged plants were killed by foliar scorching with the TIR treatments than with LDPE film (Table 6). After 4 wk of solarization, the LDPE film resulted in 21 live plants m⁻², whereas the plant densities with the TIR films were 3, 0, and 0 for TIR-50, TIR-75, and TIR-100, respectively. This probably was due to hotter soil surface temperatures under the TIR films than under the LDPE film. Mean daily soil temperature at the soil surface with TIR-100 film was 5.3 C higher than with LDPE film (Table 2). For 49% of the solarization period, soil surface temperatures under TIR-100 exceeded 60 C, compared with 8% with LDPE film.

At the end of the 6-wk soil solarization period, in the nonsolarized treatment, the initial 12 tubers resulted in a \emph{C. rotundus} density of 296 plants m⁻² (Table 5). The use of solarization considerably reduced \emph{C. rotundus} density. TIR films were more effective than the LDPE film. While solarization with TIR films resulted in < 15 plants m⁻², the \emph{C. rotundus} density with LDPE film was 65 plants m⁻². In the nonsolarized treatment is considered to be a weedy check, this density of 65 plants m⁻² represents a control level of 78%. The least effective of the TIR films, the TIR-50, provided 95% control of \emph{C. rotundus}. TIR-75 and TIR-100 resulted in nearly 100% control of \emph{C. rotundus}. The effect of soil solarization on shoot biomass paralleled that of shoot density.
Table 5. Comparative effects of solarization film on *C. rotundus* control at the end of a 6-wk period of soil solarization.

<table>
<thead>
<tr>
<th>Film</th>
<th>C. rotundus density (plants m⁻²)</th>
<th>Control (%)</th>
<th>Shoot biomass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Undera</td>
<td>Throughb</td>
<td>Total</td>
</tr>
<tr>
<td>Bare</td>
<td>—</td>
<td>—</td>
<td>296 a</td>
</tr>
<tr>
<td>LDPE-30</td>
<td>58 a&lt;sup&gt;d&lt;/sup&gt;</td>
<td>7 a</td>
<td>65 b</td>
</tr>
<tr>
<td>TIR-50</td>
<td>12 b</td>
<td>2 b</td>
<td>14 c</td>
</tr>
<tr>
<td>TIR-75</td>
<td>1 b</td>
<td>0 b</td>
<td>1 d</td>
</tr>
<tr>
<td>TIR-100</td>
<td>1 b</td>
<td>0 b</td>
<td>1 d</td>
</tr>
</tbody>
</table>

<sup>a</sup> *C. rotundus* plants trapped under solarization film.
<sup>b</sup> *C. rotundus* plants penetrating solarization film.
<sup>c</sup> *C. rotundus* densities of solarized treatments were expressed as percentages of the nonsolarized treatment.
<sup>d</sup> Means followed by the same letter within columns are not significantly different (α = 0.05) as determined by contrasts. Values are means of 15 replicates, averaged over depth.

The thinner films (LDPE-30 and TIR-50) were more susceptible to puncture by the sharp leaf tips of the *C. rotundus* plants (Table 5). Plants that emerged through the films generally survived soil solarization and resulted in a proliferation of daughter plants from their basal bulbs. This contributed to the greater number of plants present under the thinner films at the end of the solarization period.

The main effect of soil depth of tuber planting (averaged over film with the nonsolarized treatment included) on *C. rotundus* density was not significant (Table 7). This indicated that there was no change in *C. rotundus* density with increasing planting depths, a result that was probably strongly influenced by the densities obtained with the nonsolarized treatment (Table 4). Because nonsolarized soil was not expected to, and did not, result in lethal temperatures, the main effect of planting depth on *C. rotundus* density was reassessed after excluding the nonsolarized treatment. Although there was a trend for *C. rotundus* density to increase as depth of tuber planting increased, the effect of planting depth on *C. rotundus* density was not significant. The biological implication of this trend is that the control by soil solarization of *C. rotundus* tubers located at soil depths where they are not exposed to lethal temperatures is dependent on tuber inactivation or depletion as a result of foliar scorching of successive shoots that arise from the tubers. Another explanation could be that there is decreased *C. rotundus* emergence as tuber planting depth increases that may contribute to the reduced densities observed with increased depth. However, despite a previous report of significant reductions in *C. rotundus* emergence with tuber planting depths of ≥ 20 cm (Rubin and Benjamin 1984), the lack of difference in *C. rotundus* density with soil depth in this study is unlikely to be related to poor emergence from 15 cm deep. In the absence of solarization, *C. rotundus* density with a 15-cm planting depth was 280 plants m⁻² compared with 25 plants m⁻² with solarized soil. This indicates considerable *C. rotundus* suppression resulting from the use of solarization film.

### Persistence of Control After Film Removal

When the persistence of *C. rotundus* control was assessed 4 wk after the films had been removed, the lowest level of control was obtained with the LDPE film (Figure 3). With the LDPE film, the 5- and 10-cm planting depths both resulted in 62% control. However, *C. rotundus* control decreased to 32% when planting depth increased to 15 cm. There was a trend for a decrease in control with planting depth with the 50- and 100-μm TIR films, which was not significant. *Cyperus rotundus* control with 75- and 100-μm TIR films was still quite high 4 wk after removing the solarization films. Control with these two films did not differ significantly and was equally effective for all planting depths.

In this study, lethal temperature for *Cyperus* spp. tubers under diurnally fluctuating temperatures was discovered to be ≥ 45 C. While 45 C slowed the rate of emergence, it was not lethal to *Cyperus* spp. tubers in a diurnally fluctuating temperature regime. However, 50 and 55 C completely eliminated sprouting and resulted in 100% tuber mortality. In the field test, lethal temperatures were recorded 5 cm deep under all of the solarization films. TIR films resulted in lethal soil temperatures on a greater proportion of days and hotter temperatures at all soil depths than the non-TIR film. This is expected to contribute both to more extensive tuber mortality and to foliar scorching. Thinner so-

Table 6. Evaluation of *C. rotundus* density after 2 and 4 wk of soil solarization.

<table>
<thead>
<tr>
<th>Film</th>
<th>C. rotundus (plants m⁻²)</th>
<th>Alive</th>
<th>Dead&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Alive</th>
<th>Dead&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Week 2</td>
<td>Week 4</td>
<td>Week 2</td>
<td>Week 4</td>
</tr>
<tr>
<td>LDPE-30</td>
<td>12 ab</td>
<td>2 a</td>
<td>21 a</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>TIR-50</td>
<td>3 b</td>
<td>8 b</td>
<td>3 b</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>TIR-75</td>
<td>4 b</td>
<td>8 b</td>
<td>0 b</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>TIR-100</td>
<td>4 b</td>
<td>9 b</td>
<td>0 b</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Plants were killed by foliar scorching.
<sup>b</sup> Multiple comparisons performed by applying Fisher's LSD test to the least-squares means.

Table 7. Effect of soil depth of tuber planting on *C. rotundus* density after 6 wk of soil solarization.

<table>
<thead>
<tr>
<th>Tuber depth</th>
<th>Bare and solarized&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Solarized&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>Plants m⁻²</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>76</td>
<td>17</td>
</tr>
<tr>
<td>10</td>
<td>73</td>
<td>19</td>
</tr>
<tr>
<td>15</td>
<td>76</td>
<td>25</td>
</tr>
<tr>
<td>P &gt; F&lt;sub&gt;0.05&lt;/sub&gt;&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.8</td>
<td>0.4</td>
</tr>
</tbody>
</table>

<sup>a</sup> ANOVA included all main plot treatments: bare or nonsolarized and solarized with 30-μm LDPE film and 50-, 75-, and 100-μm TIR.
<sup>b</sup> ANOVA included only *C. rotundus* densities obtained with the LDPE and the three TIR solarization films.
<sup>c</sup> Probability values > 0.05 are not significant.
Acknowledgments

We thank Dr. D. O. Chellemi for his suggestions and advice and Dr. V. Chew and Jay Harrison for guidance with statistical analysis. Florida Agricultural Experiment Station, Journal Ser. R-06869. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply approval or the exclusion of other products that may also be suitable.

Literature Cited


Sources of Materials

1 Cyperus esculentus tubers, Valley Seed Service, P.O. Box 9335, Fresno, CA 93791.
2 Cyperus rotundus tubers, clones from tubers collected at the University of Florida Horticultural Research Unit, Gainesville, FL 32611.
3 Scotts Terralite Agricultural Mix, V. J. Growers Supply, Inc., 500 Orange Blossom Trail, Apopka, FL 32712-3498.
5 TIR film, courtesy AT Plastics Inc., 4405 101st Avenue, Edmonton, Alberta, Canada T5J 2K1.
6 LDPE film, courtesy AEP Industries, 125 Phillips Avenue, Hackensack, NJ 07606.