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Effect of Different Inorganic/Synthetic Mulches on Weed Suppression during Soil Solarization

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Soil solarization is a method in which clear plastic films are used to increase soil temperature to manage soilborne plant pests such as insects, diseases, nematodes, and weeds during the summer time. Several different kinds of plastic films were evaluated in 2007 and 2008 for weed suppression. Treatments were arranged in a randomized complete block design with five replications. In 2007, treatments included five plastic films (ISO, VeriPack, Poly Pak, Bromostop®, white plastic), and a control (no plastic). In 2008, treatments were Polydak®, Poly Pak, Bromostop®, white plastic, and control. Films were evaluated for weed suppression based on weed ratings, using a scale that estimated amount of ground covered by weeds. Purple nutsedge (*Cyperus rotundus*) was a major weed problem throughout both years. Transparent plastic films such as ISO, Polydak®, and Poly Pak consistently outperformed white plastic and control treatments, but the clear plastics differed in suppression of nutsedges. Best results were achieved with UV-stabilized plastic films, which were highly effective for weed control.

Soil solarization is a hydrothermal method accomplished by passive heating of moist soil covered with transparent plastic films for the disinfestation of soil-borne pests (Katan et al., 1976; Stapleton, 2000). This is an effective nonchemical technique of controlling nematodes (Chellemi et al., 1997; McGovern and McSorley, 1997; McGovern et al., 2002; Stapleton and Heald, 1991) as well as weeds (Chase et al., 1998; Daelemans, 1989; Horowitz et al., 1983). Although not used as frequently against insect pests, 7 weeks of soil solarization was found to reduce incidence of stalk borer (*Papaipema* spp.) in corn cultivars by 8.9% (Ahmad et al., 1996).

Solarization has been shown to be most effective in regions that are cloudless and have hot temperatures (Heald and Robinson, 1987; Katan, 1981; Stapleton and DeVay, 1983). However, this method is also useful in regions with humid climates, such as Florida (Chase, 2007; Chellemi et al., 1993, 1997; McSorley and Parrado, 1986; McGovern et al., 2004). In the past, soil solarization has been combined with other management practices like fumigants, hot water, organic amendments, host plant resistance, and biocontrol to manage soil-borne plant pathogens (Antonio and Giovanni, 2006; Antonio et al., 2005; Gamliel and Stapleton, 1997; McGovern and McSorley, 1997), although results differed depending on the type of pathogens involved.

Previous research has defined several characteristics of optimal polyethylene films for solarization (McGovern and McSorley, 1997). Thin plastic films (e.g., 1-mil or 2-mil) were more effective than thick films (e.g., 4-mil) for trapping solar radiation and increasing soil heating. Transparent mulches were more effective than translucent or opaque mulches for suppressing pathogens. In Florida, several successful solarization studies were conducted using ISO polyethylene film (ISO Poly Films, Inc., Gray Court, SC) (McGovern et al., 2004; Saha et al., 2007; Wang et al., 2006). The objective of the present study was to compare plastic sheets from different manufacturers for their efficiency in managing weeds by solarization. Information is reported on the performance of newer films relative to ISO, which is particularly relevant due to the increasing use of newer films by growers and in the event that ISO film ultimately becomes unavailable for use.

Materials and Methods

Field experiments were conducted in the 2007 and 2008 summer seasons at the University of Florida Plant Science Research and Education Unit (29°24´N, 82°9´W), located near Citra, in Marion Co., FL. The soil at the experiment field was Arredondo sand (95% sand, 2% silt, 3% clay) with 1.5% organic matter (Thomas et al., 1979).

2007 Experiment. The site was rototilled in June to prepare soil and improve heat conduction through the soil for solarization. Soil was irrigated on 9 July because moist soils are better conductors of heat (Katan, 1981). Soil moisture content (by weight) prior to bed formation on 10 July averaged 9.6%. Beds were 10.67 m (35 ft) long, 0.76 m (30 in) wide at the top, with total bed surface area of 8.10 m^2 (87.14 ft^2), and a distance of 2.44 m (8 ft) between bed centers. On the morning of 11 July,

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five treatments were applied manually by covering the beds with one of four types of transparent polyethylene films: ISO [25-mm (1 mil) thick, UV-stabilized, ISO Poly Films, Inc., Gray Court, SC]; VeriPack [51-mm (2 mil) thick, VeriPack Inc., Framingham, MA]; Poly Pak [51-μm (2 mil) thick, Poly Pak Plastics, Medford, MN]; Bromostop® [35-μm (1.4 mil) thick, Bruno Rimini Corp.,London, UK]; or a semi-opaque white plastic film [51-mm (2 mil) thick, Rodeo Plastic Bag and Film, Mesquite, TX]. After application, plastic was sealed into soil by adding soil to cover the plastic at the base of each bed. Beds without any plastic served as controls. The 6 treatments were arranged in a randomized complete-block design with 5 replications (30 plots). Soil temperature sensors (WatchDog® Spectrum Technologies, Inc., Plainfield, IL) were placed in the field on 11 July, and detailed temperature data at 5-cm (1.97 inches) and 15-cm (5.91 inches) soil depths are reported elsewhere (Gill et al., 2009). The experiment was terminated after 10 weeks.

2008 Experiment. This test was repeated at the same site as the 2007 experiment. Protocol was similar to that described for the 2007 season, with minor changes as specified below. Soil was rototilled on 13 June, and on 24 June, beds were prepared. Average soil moisture content prior to bed formation was 6.4% (by weight). Polyethylene films as well as soil temperature sensors were applied in the field on 25 June. During the 2008 season, treatments remained the same except that ISO and VeriPack polyethylene films were no longer manufactured, so a different polyethylene film was substituted: Polydak® [32-mm (1.3 mil) thick, UV- stabilized, transparent film; Ginegar Plastics Products Ltd., Ginegar, Israel]. Five treatments (4 films + control) were arranged in a randomized complete-block design with 5 replications (25 plots).

Data collection and analysis. Data on grasses, nutsedges, broadleaf weeds, and total area covered with weeds were collected on four sampling dates (1 Aug., 5 Aug., 6 Sept., and 16 Sept.) in 2007 and two sampling dates (22 July and 5 Aug.) in 2008. Each plot was rated for the percentage of surface area covered with weeds using the 1 to 12 Horsfall and Barratt (1945) rating scale, where 1 = 0%, 2 = 0% to 3%, 3 = 3% to 6%, 4 = 6% to 12%, 5 = 12% to 25%, 6 = 25% to 50% of ground covered with weeds; whereas 7 = 25% to 50%, 8 = 12% to 25%, 9 = 6% to 12%, 10 = 3% to 6%, 11 = 0% to 3%, and 12 = 0% of ground not covered with weeds. Data were analyzed using a one-way analysis of variance (ANOVA) with the Statistical Analysis System (version 9.1; SAS Institute, Cary, NC). When analysis of variance showed a significant treatment effect ($P \leq 0.05$), treatment means were separated using the LSD (Least Significant Difference) range test. Data on durability of the various polyethylene films are reported elsewhere (Gill et al., 2009).

Results and Discussion

2007 Experiment. Total bed areas covered with weeds were generally significantly less under Poly Pak, VeriPack, and ISO polyethylene films than with unmulched control, white plastic, and Bromostop® film (Table 1). The rating of purple nutsedge (*Cyperus rotundus*) was greater in raised beds covered with white plastic film, Bromostop®, and unmulched control (Table 1), which may be due to lower penetration of light through the white film and poor durability of Bromostop®. Higher ratings of grasses and broadleaf weeds were observed in the unmulched control treatment as compared with all other treatments. Grasses consisted mainly of crabgrass (*Digitari*a spp.) and bermudagrass (*Cynodon dactylon*), while dominant broadleaf weeds were cudweed (*Gnaphalium* spp.), purslane (*Portulaca oleracea*), and hairy indigo (*Indigofera hirsuta*).

2008 Experiment. As in 2007, purple nutsedge was present early in the season and its coverage increased as the season progressed (Table 2). Significantly greater coverage by purple nutsedge was found in the unmulched control treatment compared with other treatments. A rating in excess of 10 indicates that the entire bed was nearly covered in the control treatment, with ≤6% weed-free area remaining. Poly Pak and Polydak® polyethylene films generally provided the lowest levels of weed coverage. They also were superior in terms of their durability while exposed to sunlight, compared with white plastic and Bromostop® polyethylene films (Gill et al., 2009).

Soil temperature data reported elsewhere (Gill et al., 2009) indicated that temperature was higher at 5-cm than 15-cm soil

Table 1.Weed coverage on beds rated among treatments using Horsfall and Barrett (1945) rating scale[z] on different sampling dates, 2007.

	Total weed covered area			Nutsedge	Grasses[y]	Broadleaf
Treatments[x]	1 Aug.	22 Aug.	6 Sept.	6 Sept.	6 Sept.	16 Sept.
Control	4.6 a[w]	8.4 a	9.4 a	3.0 ab	5.8 a	4.6 a
White film	2.6 b	2.4 b	3.6 b	3.6 a	2.6 b	2.2 b
Bromostop®	2.4 bc	2.0 bc	2.8 bc	2.8 ab	1.0 b	1.0 b
VeriPack®	2.0 bcd	1.4 bc	2.0 cd	2.0 bc	1.0 b	1.0 b
Poly Pak	1.6 cd	1.4 bc	1.4 d	1.4 c	1.0 b	1.0 b
ISO	1.2 d	1.0 c	1.2 d	1.2 c	1.0 b	1.0 b
ANOVA[v]						
F	17.80	107.22	74.53	6.80	6.09	6.67
P	<0.0001	<0.0001	<0.0001	0.0004	0.0009	0.0005

[z]Horsfall and Barrett (1945) rating scale where 1 = 0%, 2 = 0% to 3%, 3 = 3% to 6%, 4 = 6% to 12%, 5 = 12% to 25%, 6 = 25% to 50% of ground covered with weeds, whereas 7 = 25% to 50%, 8 = 12% to 25%, 9 = 6% to 12%, 10 = 3% to 6%, 11 = 0% to 3%, and 12 = 0% of ground not covered with weeds.
[y]Grasses = predominantly crabgrass and bermudagrass.
[x]Treatments = unmulched control; white plastic (Rodeo Plastic Bag and Film, Mesquite, TX); Bromostop® (Bruno Rimini,London, UK); VeriPack (VeriPack, Framingham, MA); Poly Pak (Poly Pak Plastics, Medford, MN); ISO film (ISO Poly Films, Gray Court, SC).
[w]Mean values within the same column followed by same letter are not significantly different according to least significant difference test at ($P \leq 0.05$)
[v]Statistics from analysis of variance (ANOVA).

Table 2. Nutsedge coverage on beds rated among treatments using Horsfall and Barrett (1945) rating scale[z] on different sampling dates, 2008.

Treatments[y]	22 July	5 Aug.
Control	4.2 a[x]	10.6 a
White Plastic	2.0 bc	3.0 b
Polydak®	2.0 bc	2.0 c
Bromostop®	2.4 b	3.0 b
Poly Pak	1.6 c	1.6 c
ANOVA[w]		
F	32.75	34.27
P	<0.0001	<0.0001

[z]Horsfall and Barrett (1945) rating scale where 1 = 0%, 2 = 0% to 3%, 3 = 3% to 6%, 4 = 6% to 12%, 5 = 12% to 25%, 6 = 25% to 50% of ground covered with weeds, whereas 7 = 25% to 50%, 8 = 12% to 25%, 9 = 6% to 12%, 10 = 3% to 6%, 11 = 0% to 3%, and 12 = 0% of ground not covered with weeds.

[y]Treatments = unmulched control; white plastic (Rodeo Plastic Bag and Film, Mesquite, TX); Polydak® (Ginegar Plastics Products, Ginegar, Israel); Bromostop® (Bruno Rimini,London, UK); Poly Pak (Poly Pak Plastics, Medford, MN).

[x]Mean values within the same column followed by same letter are not significantly different according to least significant difference test at ($P \leq 0.05$).

[w]Statistics from analysis of variance (ANOVA).

depth. During 2007, soil temperatures above 50 °C (112 °F) were recorded on 12 d under the best clear films. In 2008, soil temperatures above 50 °C were recorded on 11 d.

Purple nutsedge was the major weed present throughout both seasons. Generally, ISO and Poly Pak polyethylene films were more effective for managing purple nutsedge compared with unmulched control, white plastic, and Bromostop® film. Bromostop® polyethylene film was not persistent under prolonged sunlight and was more prone to tearing, which led to the emergence of weeds on raised beds (Gill et al., 2009). In a previous study, solarization was effective in producing lethal temperatures (46 to 49 °C) for many weed species at a 5-cm soil depth (Horowitz et al., 1983). The differential penetration of opaque and clear plastic mulches might be explained by a light-dependent morphological change from rhizome elongation to leaf expansion (Chase et al., 1998).

In previous studies, soil solarization controlled annual weeds better than perennial weeds (Elmore et al., 1997; Gill et al., 2009). Some perennial weeds may regenerate from buried underground structures, and therefore control of nutsedges (*Cyperus* spp.) can be difficult (Elmore et al., 1997). However, Daelemans (1989) managed a variety of different weeds using soil solarization in the West-Cameroonian highlands.

In the current study, purple nutsedge was controlled fairly well by using more durable plastic films such as Polydak®, Poly Pak, and ISO compared with Bromostop® and white plastic films. Purple nutsedge was a dominant weed in this site in both seasons, and can cause punctures and breaks in polyethylene sheets (Chase, 1998). Nevertheless, the best solarization films managed weeds well compared to control plots with extremely high levels of purple nutsedge. Several of these films reduced nutsedge levels to ≤3% of the bed covered with weeds (rating of ≤2.0). Polydak® and ISO (UV-stabilized films) were durable, while the durability of polyethylene films that were not UV-stabilized was variable (Gill et al., 2009). Poly Pak and VeriPack were stable under field conditions, but Bromostop® and white plastic deteriorated quickly and did not provide season-long control of nutsedges. Although Polydak® polyethylene film is very thin (1.3 mil), it was also strong and durable and remained intact throughout the experiment.

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