Soil Polarization and Dacthal: Influence on Weeds, Growth, and Root Microflora of Collards

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Abstract. Soil polarization for 98 days in 1985 resulted in a 91% reduction of weeds present in collard greens (*Brassica oleracea acephafa* L.) plots during 1986. Soil solarization was more effective in controlling weeds in collard green plots when compared to an application of Dacthal-75W herbicide in nonsolarized plots. Collard green plants grown in solarized soil showed an increase in yield and other growth responses. Soil samples from the rhizosphere of plants grown in solarized soil showed higher population levels of bacteria and thermotolerant fungi than from nonsolarized soil. There were significant negative responses in marketable yield and root growth of collard greens and in soil microflora in solarized soil in response to Dacthal-75W herbicide application. Chemical name used: dimethyltetrachloroterephthalate (Dacthal-75W).

Collards are widely grown by vegetable farmers, but a major problem is weed invasion. Questions have been raised concerning the intensive use of herbicides and their long-term residual effects on the environment. Soil polarization is a relatively new method for heating soil by use of clear polyethylene sheets to trap solar energy during a summer fallow period (Katan et al., 1976). The principles of soil 'polarization have been reviewed (Katan, 1981).

Studies conducted in the Negev desert in Israel (Horowitz et al., 1983; Jacobsohn et al., 1980; Katan et al., 1976; Rabinowitch et al., 1981; Rubin and Benjamin, 1983) and the San Joaquin Valley in California. (Pullman et al., 1981; Stapleton and DeVay, 1982, 1984) have shown that polarization controlled soilborne pests in agronomic and horticultural crops. In these regions, the summer is hot and dry, whereas the summer climate in central Alabama is hot and humid, with extensive cloud cover and rainfall that reduce the radiation available for heating the soil during polarization. Because of the limited cloud cover in California and Israel (Katan, 1981), polarization was effective as early as 4 to 8 weeks after placement of the plastic.

The first objective of this study was to test

the effects of soil polarization for 14 weeks alone and in combination with Dacthal herbicide on weed control, rhizosphere microflora, and growth and yield of collards in central Alabama. The second objective was to determine the effect of polarization in

combination with various Dacthal herbicide application rates on the growth response of collards and rhizosphere microflora. A preliminary study was reported (Stevens et al., 1987).

Two soil polarization experiments were conducted at the same time in 1985 on a Norfolk sandy loam (Typic Pleudult) with a pH of 5.9 and a low (< 1.0%) organic matter content at the George Washington Carver Experiment Station, Tuskegee, Ala. Plots were prepared by ploughing and rotovating the soil to a fine tilth. The soil then was mulched with 50-µm-thick clear polyethylene plastic on 14 June 1985. All plots were immediately irrigated to field capacity over 5 days using drip irrigation tubing. Solar and nonsolar plots (5 × 3 m) were replicated three and four times, respectively, in a randomized complete-block design. Soil temperature was measured at noon at 5-, 10-, and 20-cm depths using soil thermometers.

After 98 days of polarization, the plastic was removed and the soil was rotovated to a depth of 7.5-cm. At this time, soil samples were taken from the upper layers (0 to 10 cm) at six locations and were composite into a single sample for mineral nutrients analysis by the Soil Testing Laboratory, Auburn Univ., Ala. At transplanting, N, P, and K were applied to all plots at 134, 112, and 224 kg-ha⁻¹, respectively. 'Vates' collards seedlings (6 weeks old) were transplanted on 22 Mar. 1986, five rows per plot, at a rate of 14,520 seedlings/ha.

In the first study, solarized and nonsolarized plots received a pre-emergence application of Dacthal-75W herbicide at O and

Table 1. Mid-day soil and air temperatures during soil solarization, 14 June to 20 Sept. 1985 (98 days) at Tuskegee, Ala.

Soil depth (cm)	Temp range (°C)	Days in range (no.)	Mean
<i>Soil temperatures—solarized</i>			
5	57.2–48.8	51	46.7
	48.3–42.7	23	
	42.2–37.7	10	
	37.2–29.4	14	
10	49.4–43.8	34	41.7
	43.3–40.5	23	
	40.0–33.3	27	
	32.7–27.7	14	
20	41.6–37.3	27	34.4
	37.2–32.2	38	
	31.6–28.3	19	
	27.7–26.6	14	
<i>Soil temperatures—control</i>			
5	40.0–35.0	41	33.7
	34.4–29.4	31	
	28.8–24.4	26	
10	37.2–32.2	49	28.8
	31.7–26.7	32	
	26.1–22.2	17	
20	33.8–31.7	12	27.6
	31.1–22.2	86	
<i>Air temperatures</i>			
	37.2–35.0	13	32.2
	34.4–32.2	44	
	31.6–26.6	30	
	26.1–22.2	11	

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Table 2. Number of weeds per square meter in solarized and nonsolarized soil with or without Dacthal (11.2 kg·ha⁻¹) in the field on 3 June 1986, 9 months following the end of solarization.^{a,y}

Weed	Nonsolarized		Solarized	
	No Dacthal	Dacthal	No Dacthal	Dacthal
Purple nutsedge	159 a	95 b	22 c	23 c
Southern crabgrass	16 a	3.0 b	2.7 b	1.0 b
Barnyardgrass	68 a	0.3 b	2.3 b	1.0 b
Florida pusley	132 a	6.6 b	2.3 b	0.7 c
Pigweed	0.40 a	0.02 b	0.0 b	0.0 b
Other annuals	8.6 a	6.6 b	2.3 b	0.7 b
Total	384 a	118 b	35 c	28 c

^aWeed count after rotoation of soil to 6-cm depth 22 Mar. 1986.

^yMean separation by Duncan's multiple range test, $P = 0.05$.

Table 3. Collard yield, root growth, and microflora population in solarized and nonsolarized soil with or without Dacthal herbicide (11.2 kg·ha⁻¹).

Treatment ^y	Yield (t·ha ⁻¹)	Root growth per plant		Microflora ^z (colony-forming units/g soil)	
		Fresh wt (g)	Root branches (no.)	Thermotolerant fungi (× 10 ⁴)	Bacteria (× 10 ⁷)
Solarized + Dacthal	7.74 b	11.6 b	18 bc	2.7	2.2
Solarized	18.1 a	16.2 a	30 ab	8.7	4.0
Nonsolarized + Dacthal	6.7 c	9.5 b	20 bc	2.4	1.9
Nonsolarized	4.2 d	4.7 c	14 c	1.8	1.8

^zThe most prominent groups of bacteria were *Pseudomonas* spp. and *Bacillus* spp. The dominant thermotolerant fungi were *Aspergillus* spp., *Mucor* spp., and *Penicillium* spp.

^yMean values among treatment not followed by the same letter within columns are significantly different, $P = 0.05$, according to Duncan's multiple range test.

Table 4. Regressions of plant growth and soil rhizosphere microflora on Dacthal herbicide concentration.

Response	Regression	r ²
Marketable yield	16678 - 863X**	0.77
Fresh root weight (g)	15.9 - 0.39X*	0.59
Number of lateral roots	30.5 - 1.06X**	0.66
Fungi ^z	8.0 × 10 ⁴ - 7.6 × 10 ³ X**	0.77
Bacteria ^z	4.2 × 10 ⁷ - 1.9 × 10 ⁶ X**	0.86

^zColony-forming units per gram of soil.

*,**Significant at $P = 0.05$ and 0.01 , respectively.

11.2 kg·ha⁻¹. In the second study, herbicide rates applied to the solarized plots were at 0, 2.8, 5.6, and 11.2 kg·ha⁻¹.

The collard greens were harvested on 5 June 1986 and fresh weights were recorded. The effect of the treatment on collard green root growth was determined by randomly removing and weighing five roots and counting the number of branches per root from each treatment.

Soil samples from the rhizosphere were plated for bacteria on King B agar and for thermotolerant fungi on yeast glucose agar using the dilution-plant method (Stapleton and DeVay, 1984).

The effect of polarization and herbicide treatments on weed infestation were determined by counting and identifying weeds present in randomly selected 1-m² areas in each plot.

A marked increase in soil temperature fol-

lowing mulching with transparent polyethylene sheets was evident (Table 1) in the top layers. Here, mid-day temperature ranged from 49 to 57°C at a 5-cm depth and occurred for 51 of the 98 days during polarization. The average temperature of the solarized soil exceeded nonsolarized soil by 12.3°C at 5 cm and 6.6°C at a 20-cm depth. The average mid-day temperature at a depth of 5 cm in the nonsolarized soil closely followed that of the average noon air temperature (Table 1).

Soil polarization for 98 days during 1985 effectively controlled purple nutsedge (*Cyperus rotundus* L.), southern crabgrass (*Digitaria ciliaris* L.), barnyardgrass [*Echinochloa crusgalli* (L.) Beauvois (Retz.) Koel], Florida pusley (*Richardia scabra* L.), and pigweed (*Anaranthus retroflexus* L.), the predominant weeds present in plots 10 months after removing the plastic mulch (Table 2). Incorporation of Dacthal in the nonsolarized

plots resulted in a 69% reduction in the total number of weeds relative to no herbicide application. In contrast, there was a 91% reduction of weeds by polarizing alone. Except for Florida pusley, application of Dacthal to solarized soil did not significantly improve weed control over polarization alone (Table 2).

Polarization without herbicide significantly increased marketable yield of collard greens, compared to nonsolarized soil with or without herbicide application (Table 3). Dacthal increased yield of collard greens grown in nonsolarized soil. Dacthal applied to solarized soil reduced yield relative to solarized plots without herbicide (Table 3). Avidov et al. (1985) suggested that the rate of herbicide applied to previously solarized soil must be reduced to avoid phytotoxicity.

Increased yield of collard greens in this study appeared to be related to a better developed root system, as indicated by the increased root fresh weight and number of branches per root (Table 3).

The rhizosphere in solarized plots had more thermotolerant fungi and bacteria than those of nonsolarized soil (Table 3). Some beneficial *Bacillus* spp., *Pseudomonas* spp., and thermotolerant fungi increased growth of agronomic and horticultural crops in solarized or steamed soil (Broadbent et al., 1977; Chen and Katan, 1980; Stapleton and DeVay, 1982, 1984).

The second study measured the responses of plant growth and soil rhizosphere microflora at different rates of Dacthal application. Simple linear regression analysis indicated a negative dosage response of marketable yield, root fresh weight, number of lateral roots, and number of colony-forming units of soil fungi and bacteria (Table 4).

Studies in Israel (Horowitz et al., 1983; Rubin and Benjamin, 1983) showed that many weeds can be controlled in shorter solarization periods (30 days) than tested in our study. The present study showed that polarization of soil for 98 days controlled most weeds. Soil polarization for 30 days was not as effective as 98 days for weed control in Alabama (C. S., unpublished data). With the longer period, the incidence of nutsedge, for example, was significantly reduced in solarized soil almost 1 year after removal of the mulch. Earlier reports showed that solarization only partially controlled nutsedge during a short polarization period in Israel (Rubin and Benjamin, 1983) and stimulated its emergence in Mississippi (Egley, 1983). Generally, the longer the soil solarization period, the more effective the pest control (Horowitz et al., 1983; Katan, 1981; Katan et al., 1976). Poor nutsedge control reported in some studies might have been due to short polarization periods.

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