Effectiveness of Soil Solarization in Furrow-Irrigated Egyptian Soils

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ABSTRACT

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Soil solarization of furrow-irrigated soils in Egypt effectively controlled weeds, broomrape, corky root, and root-knot diseases in tomatoes. It also controlled *Rotylenchulus reniformis* for 60 days after planting. It improved plant growth and increased the yields by 25–432% in broad beans, onions, tomatoes, and clover in various types of soils. In one experiment with broad beans, *Rhizobium* nodulation was adversely affected by solarization, and the plants were stunted but later recovered. Solarization had a long-term effect (two or three seasons) in both disease control and yield increase. It also decreased soil salinity.

Additional key words: electrical conductivity, *Meloidogyne, Orobanche,* plastic mulching, *Pyrenochaeta lycopersici,* solar heating, tarping

Soil solarization is a relatively new method for controlling soilborne pests (14). It has been tested with a variety of crops and diseases in several countries, frequently with successful results for both short and long term (7,8,10, 12–16,19,20). Because most of these studies were carried out under sprinkler or drip irrigation, they do not ensure similar success in furrow-irrigated soils, where pathogen spread may be enhanced (6), leading to possible recontamination of disinfested soils. In Egypt, furrow irrigation is common; many soils have a long history of cropping, and the agricultural regimes for certain crops often differ from cropping systems in countries where solarization has been tested. Increased plant growth by solarization is a common phenomenon, evident even in the absence of known pathogens (1,10,22). Higher quantities of mineral nutrients appear in solutions of the solarized soils compared with nonsolarized soils (1,22), but other factors might also be involved in the increased growth response phenomenon in solarized soils.

The purpose of this study was to investigate the short- and long-term effects of solarization in furrow-irrigated soils in Egypt on soilborne pests, on plant growth and yield, and on soil salinity with crops and pathogens that are important in Egypt.

MATERIALS AND METHODS

Field experiments were set up during 1981–1985 in various furrow-irrigated sites in Egypt with a variety of crops. The experiments were at Giza (1981–1982, broad bean), Giza (1983–1984, broad bean), Ismailia (1983–1984, onion), El Manayef (1985–1986, tomato), and Fayed (1983–1984, tomato). The experimental plots at El Manayef and an additional one at Youth Farms-Sinai (1984–1985) served for soil analysis for salinity studies. Additional experimental data are specified in Tables 1–4 and Figures 1 and 2. Soil types were clay loam at Giza and loamy sandy or sandy in the other field sites.

Experimental design. All experiments, carried out in four or five replicates in a randomized block design, were based on a basic unit (replicate) consisting of a bed 7 m wide and 14–24 m long divided by eight irrigation furrows. Irrigation water was directed either separately to each plot or from solarized to nonsolarized plots to reduce the chances of contamination. The supply canals were also solarized.

Soil solarization. Solarized and nonsolarized plots were preirrigated by flooding. Irrigation furrows were opened manually 1 day later in the sandy soils or 4 days later in the other soils. Solarized plots were covered continuously with two transparent polyethylene sheets, containing ultraviolet absorbent, side by side as described (7) (450 cm wide and 0.04 mm thick, Ginegar Plastic Products, Israel). Solarization started usually in mid-July and lasted 10 wk at each of the two Giza experiments and 8, 9, and 7 wk at Ismailia, El Manayef, and Fayed, respectively. Soil temperatures were measured at depths of 10 and 20 cm by a continuously recording soil thermograph

Table 1. Effects of soil solarization on broomrape and weed populations and on broad bean growth, nodulation, and yield (Giza 1981–1982)[w]

Soil treatment	Weeds,[x] excluding *Mellilotus* (no./m²)	*Mellilotus* (no./m²)	Broomrape[x] (no./m²)	Plant height 12 Feb.	Plant height 27 Mar.	Nodules[y] (no./plant)	Yield (kg/ha)
Nonsolar	109 a[z]	22 a	1.3 a	64 a	126 a	88 a	2,384 b
Solar	33 b	33 a	0.0 b	52 b	114 a	20 b	2,992 a

[w] Broad beans (cultivar Giza 2) were planted on 19 November 1981 and harvested in May 1982.
[x] Counts made on 6 March 1982.
[y] Counts made on 12 February 1982.
[z] Numbers in each column followed by the same letter are not significantly different ($P = 0.05$).

Table 2. Effects of soil solarization (S) and *Rhizobium* inoculation (R) on broomrape population and on broad bean growth and yield (Giza, 1983–1984)[w]

Soil treatment	R	Broomrape[x] (no./m²)	Plant height[y] (cm)	Branches[y] (no./plant)	Yield (kg/ha)	Percent yield increase over control by S	Percent yield increase over control by R
Nonsolarized	−	30.0 a[z]	80.2 a	6.0 b	472 c	–	–
Solarized	−	0.0 b	89.6 a	7.7 a	2,512 a	432	–
Nonsolarized	+	30.2 a	86.2 a	5.7 b	1,480 b	–	214
Solarized	+	0.0 b	98.2 a	8.1 a	2,456 a	66	−2

[w] Broad beans (cultivar Giza 4) were planted on 30 October 1983 and harvested in May 1984.
[x] Counts made on 23 May 1984.
[y] Counts made on 2 February 1984.
[z] Numbers in each column followed by the same letter are not significantly different ($P = 0.05$).

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(Distance thermograph, Lambrecht, Germany).

Typical maximal temperatures of nonsolarized soil, recorded in August 1983 at Giza and Fayed at a depth of 20 cm, were 33–34 C; temperatures of the solarized soil were about 8 C higher. Parameters used to evaluate the effectiveness of solarization included counts of soilborne pathogens (nematodes, broomrape) and weed, disease rating (root-knot, corky root), assessment of plant development at various stages, e.g., plant weight, number of leaves, branching, and measurements of yield components, as specified in each experiment. In one experiment (Table 2), *Rhizobium* preparation was mixed with the seeds at a rate of 3 g/kg of seeds. After harvest, the experimental plots were replanted with crops as specified for each experiment to assess the prolonged effects of soil solarization on crop growth, yield, and disease control.

Nematode counts. Recovery of *Rotylenchulus reniformis* from composite soil samples (200 g each) taken from the soil layer 0–15 cm was carried out by the sieve technique (2). The resulting suspension was left for 48 hr in a Baermann pan for extraction before counting. The soil samples were taken at various periods after the termination of solarization, as indicated.

Salinity measurements. For the Fayed loamy sandy soil, a water-saturated paste was prepared and extracted, then electrical conductivity (EC) and anions and cation concentrations were determined (17). SO_4^{2-} was calculated from the difference between the sums of concentrations of cations ($Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}$) and that of the anions ($HCO_3^{-} + Cl^{-}$). For the Youth Farms-Sinai sandy soil, a 1:1 paste with water was prepared and EC was determined in the extract. Ion concentrations and EC were then corrected for saturation (26%, w/w) by multiplication. Soil was sampled according to the following procedure: The nonsolarized and solarized plots were divided into three strips (replicates) of 15 × 60 m each. Soil samples of about 1,000 g were taken from 10 sites along the strip, then mixed into one composite sample, forming three composite replicates for each of the two treatments.

Data were statistically analyzed by multiple range test according to Student-Newman-Keuls at $P = 0.05$.

Table 3. Effects of soil solarization on incidence of root diseases, growth, and yield of tomatoes (El Manayef, 1985–1986)[y]

Soil treatment	Plant stand (no./m)	Plant fresh wt (g)	Root-knot (%)	Corky root (%)	Fruits (no./plant)	Av. fruit wt (g)	Yield g/plant	Yield kg/ha
Nonsolarized	1.5 b[z]	266 b	48 a	6 a	31.7 a	26.6 b	844 b	15,832 b
Solarized	3.0 a	484 a	6 b	0 a	37.8 a	38.2 a	1,443 a	54,142 a

[y]Tomatoes (cultivar Peto 6) were transplanted on 21 September 1985. Measurements were made on 10 February 1986 with 50 individual plants for each treatment.
[z]Numbers in each column followed by the same letter are not significantly different ($P = 0.05$).

Table 4. Long-term effects of soil solarization on incidence of root diseases, growth, and yield of tomatoes as a second crop after solarization (Ismailia, 1985)[x]

Treatment	Plant wt (g)	Corky root[y] (%)	Root-knot[y] (%)	Fruits (no./plant)	Av. fruit wt (g)	Yield (kg/ha)
Nonsolarized	175 a[z]	60 a	52 a	24 a	24.8 b	24,103 a
Solarized	498 b	24 b	56 a	22 a	38.3 a	33,497 b

[x]Soil was solarized in the summer of 1983 and planted with onions (first crop), and after harvesting, the soil was planted with tomatoes (cultivar UC 82) on 15 November 1984. Measurements and harvest were carried out on 4 June 1985.
[y]Percentage of plants showing typical disease symptoms.
[z]Numbers in each column followed by the same letter are not significantly different ($P = 0.05$).

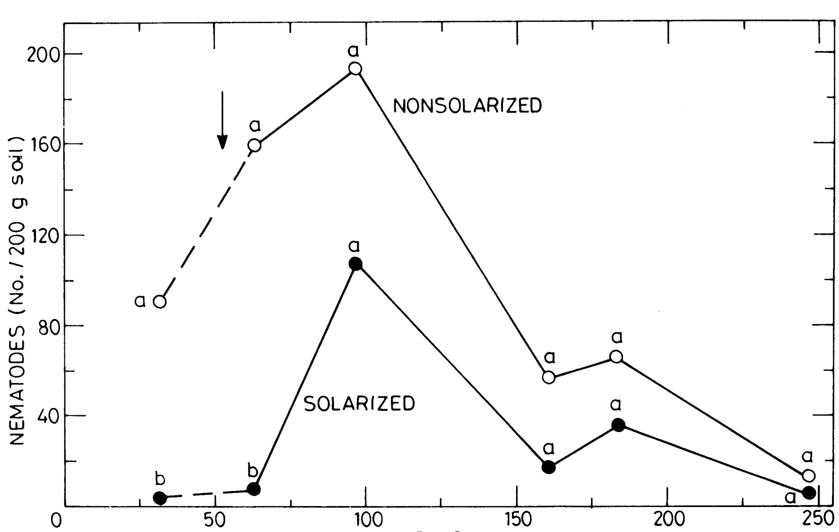

Fig. 1. Effects of soil solarization on *Rotylenchulus reniformis* populations at various periods after the termination of solarization on 1 October 1981 (Giza 1981–1982). Arrow indicates broad bean planting time. Numbers followed by the same letter, at the same sampling date, are not significantly different ($P = 0.05$).

RESULTS

Effects of soil solarization on weeds, pathogens, and crops. The first soil solarization experiment in Egypt was carried out at the Giza Experiment Station (ARC) in 1981–1982. A pronounced reduction in weed populations was visually observed soon after removal of the polyethylene sheets and was still significant 4 mo after planting (Table 1). Species of *Amaranthus, Chenopodium, Plantago, Portulaca,* and *Solanum nigrum* were controlled (95–100% reduction), whereas *Melilotus* sp. and *Cyperus rotundus* were not. A similar weed control was evident in all solarization experiments. Broad bean plants were stunted during the first stages of growth in the solarized soil (19% reduction in plant height) but recovered later in the season (Table 1). The stunted plants had significantly fewer *Rhizobium* nodules but yield was increased by 25%. Broomrape (*Orobanche crenata* Forsk.), first detected 3 mo after planting in the nonsolarized plots, was not detected in the solarized plots.

Counts of *R. reniformis* were made at various periods before and after planting. Nematode populations were reduced significantly (Fig. 1) by 93–95% by solarization in the first two samplings (before and shortly after planting), but later, the differences between the solarized and nonsolarized treatments were not significant.

The effects of solarization, with or without *Rhizobium* inoculation of seeds, were examined in a second experiment at Giza (Table 2). In this experiment, plant growth was not adversely affected by solarization. The effect of inoculation with *Rhizobium* on the yield was very pronounced in nonsolarized plots (214% yield increase) but not in solarized ones. Solarization increased yield by 66–432%.

(10,12,21). Thus, in the present study, certain weeds were not controlled in the solarized plots, root-knot nematodes were controlled for only one season, *R. reniformis* was only partially controlled, and *Rhizobium* nodulation was adversely affected in one case by solarization. Thus, combining solarization with biological or chemical means of control, which improved the results (3,4,20), should be considered in future studies.

Improved plant growth that has frequently been shown in disinfested soils in the absence of known pathogens was attributed to a variety of chemical, physical, and biological factors (1,10,22). An additional chemical mechanism by solarization, demonstrated here for the first time, is a decrease in salt concentrations in the upper layer of soils maintaining shallow ground water. These changes in the distribution of salts in the soil profile probably result from the fact that the plastic mulch prevents evaporation, thereby slowing the upward movement of salts from relatively shallow, brakish ground water. Excessive concentrations of salts may cause severe damage to crops in certain soils. This beneficial side-effect of solarization should be taken into consideration whenever applicable.

In the experiments presented in this study, the yields were frequently increased by solarization to high levels. This may be attributed, among other factors, to the long history of cropping of these soils, resulting in an accumulation of abiotic and biotic detrimental factors (11) including unidentified pests. Hence, soil disinfestation may also be used as a tool for identifying the causes for yield decline.

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