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AUGMENTATION OF SOIL SOLARIZATION EFFECTS BY APPLICATION OF SOLAR-HEATED WATER

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Summary. Combining solarization, using a plastic cover, with hot water treatment raised the temperature of the soil at 10 and 20 cm depths to 60 and 56°C, respectively for one hour, compared with a maximum temperature of 46°C achieved with solarization alone. In samples taken 40 days after planting tomato, the numbers of *Meloidogyne javanica* juveniles had decresead by 96% in the solarization plus hot water treatment and by 62% in solarization alone.

The disinfestation of the soil by solarization involves the use of transparent plastic covers to capture solar energy and heat the soil to temperatures that are lethal to soil-borne pathogens (Katan *et al.*, 1976; Pullman *et al.*, 1979; Katan, 1980, 1981 and Pullman and DeVay, 1984). Transparent plastic has been recommended in preference to black plastic and a tarping period of at least four weeks to achieve pathogen control at all desired depths (Katan, 1980, 1981). Investigations in the Jordan Valley demonstrated that black plastic, though less effective than transparent plastic in soil heating was equally effective in improving the yield of tomato, eggplant (Al-Asa'd, 1983) and cucumber (Barakat, 1987). Thus in the Jordan Valley black plastic could be used for solarization as well as a mulch for crop production. The objectives of the present investigations were: a) to evaluate the possibility of using solar-heated water to reduce the time needed for solarization and b) to improve soil heating at lower depths.

Materials and methods

A domestic solar heater of the type «Thermocyphon» was used to provide hot water. The heater consists of six units each of one meter square and a 350 l capacity hot water reservoir mounted at the edge of the field where the investigations were carried out. Hot water (75-80°C) was added through a normal drip irrigation system as row treatment at the rate of 25 l/m in a single application over five hours. The study was carried out on a sandy loam soil and included two experiments.

The first experiment (Expt. I) was carried out in a plastic house in which the soil was infested with *Meloidogyne javanica* (Treub) Chitw. and consisted of four treatments and four replicates in a complete block design. Treatments were: 1) Soil solarization by covering soil with black plastic for six weeks (Aug. 15 - Oct. 1, 1987); 2) Soil solarization as for (1) plus solar hot water-treatment applied Sept. 25; 3) Soil solarization for one week (Sept. 21-28) plus hot water treatment applied Sept. 21 and 4) No solarization, no hot water treatment (Control). Except for the second and third treatments that received one hot water application in the fourth week of September, all treatments were irrigated weekly with non-heated water at 25 l/m^2 during the solarization period. The experiment was planted with tomato *Lycopersicon esculentum* Mill. cv. «Claudia RAF», on Oct. 8, nearly one week after the black plastic was perforated.

The second experiment (Expt. II) was done in a *M. javanica* infested field and included two treatments and four replicates: 1) Control: covering soil with plastic mulch two days before planting (Oct. 22-24, 1987); 2) Similar mulch plus hot water treatment on Oct. 23.

Two cheese cloth sacks (20 cm long, 7 cm diam) were filled with a homogeneously *M. javanica*-infested soil and buried in the soil of each plot before covering. One was placed immediately underneath the irrigation drippers and the other midway between drippers. These were removed one day after the application of hot water and the nematodes extracted and counted. The experiment was planted with tomato on Oct. 25.

In both experiments unperforated black plastic was used to cover each plot (1 × 3 m) but after the completion of the experimental treatments the plastic was perforated at 30 cm intervals in two rows to plant the tomato seedlings. In Expt. I soil temperature was recorded at 10 cm depth at five minute intervals during the solarization period using T-type thermocouples connected to an Orion monitor. In Expt. II, soil thermometers were used to read the temperatures at 10 and 20 cm during the application of hot water. Agricultural practices such as irrigation, fertilization etc. were applied routinely. Data on plant growth and yield were recorded. *M. javanica* second stage juveniles (J2) were extracted from 100 ml soil using a modified Baermann funnel technique (Barker, 1985). Root galling was assessed using a 1-5 scale index (Barker, 1985). In Exp. I, the numbers of *Fusarium oxysporum* Schlecht propagules (colonies)/g soil were recorded at the end of the solarization period using the dilution (Crossan, 1967). Root rotting was assessed at the end of the experiment using a 1-5 scale (1 = no rotting, 2 = light rotting, 3 = moderate rotting, 4 = heavy rotting and 5 = decaying roots).

Results and discussion

In the solarization treatment of Expt. I, the mean weekly maximum soil temperature under black plastic at 10 cm soil depth ranged between 37 and 45°C over the treatment period (Fig. 1a), which is an increase of 4-8°C over the non-covered soil. The maximum temperature reached under black plastic was 46°C which is lower than the maximum soil temperatures (50-52°C) reached in the Jordan Valley using transparent plastic (Katan, 1981; Al-Asa'd, 1983; Barakat, 1978). Solarization combined with hot water treatment increased the temperature of the upper 10 and 20 cm soil depths by 15 and 20°C, respectively, for several hours as compared to the treatment of solarization alone (Fig. 1b). The sopil temperature at those depths reached 60 and 56°C for at least one hour, respectively. Even higher temperatures (60-65°C) were reached and for a longer duration during investigations done in hotter period of summer (unpublished). At these temperatures many soilborne pathogens are killed (Grooshevoy, 1939; Dowson and Johnson, 1965; Olsen and Baker, 1968; Pullman and DeVay, 1984).

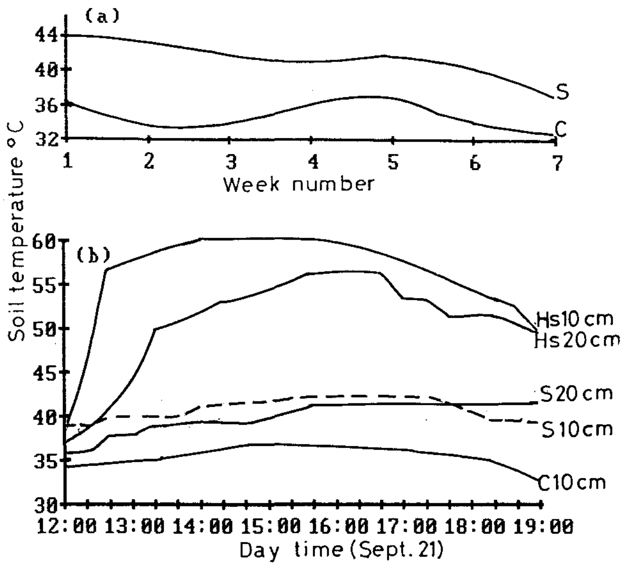

Fig. 1 - Effect of (a) solarization with black plastic (S) on soil temperature at 10 cm depth compared with non-covered control (C), and (b) solar hot water treatment of solarized soil (Hs) on soil temperature at two depths compared with solarization (S) or non-covered control (C) as recorded for 7 hours starting 12 a.m. on Sept. 21, 20 minutes after the beginning of hot application.

In Expt. I no juvenile *M. javanica* were found in all treatments at the end of the solarization period. Forty days after planting, J2 populations in the solarization and solarization plus hot water treatments were significantly lower than in the control (Table I) and the galling indices were also less (9-36%) but not significantly. At the end of the experiment J2 numbers were higher in the solarization treatment than in the control and higher in the control than in the two treatments. The presence of higher levels of J2s in the solarization treatment than in the control might be due to the fact that roots of the latter treatment exhibited higher rotting (Table I). At the end of the solarization period, *Fusarium oxysporum* propagules in the soil were undetectable in solarization plus hot water, while lower by 85 and 64% in solarization alone and hot water plus one week of solarization than in the control, respectively. Tomato yield did not differ significantly among treatments (Table II), but all plants were severely affected by tomato yellow leaf curl virus and the experiment was therefore terminated four months after planting (Feb. 10, 1988).

The application of hot water under the black plastic tarp in Expt. II reduced the population density of *M. javanica* J2 in the upper 20 cm soil by 88% as found in buried samples (Table II). At the end of the experiment (May

TABLE I - *Combined effect of soil solarization and solar hot water treatment on* Meloidogyne javanica, Fusarium oxysporum *and yield of tomato.*

Treatment	*Meloidogyne javanica*				*Fusarium oxysporum*		Yield (kg/plot)
	J2/100 ml soil		Galling		Propagules/ g soil	Rotting index	
	DI[1]	DII	DI	DII			
S[2]	23b[3]	2838	2.0	3.1	46b	1.5	14.3
SH	3b	634	1.8	2.1	0b	1.3	17.4
Hs	11b	454	1.4	2.0	112ab	1.6·	11.0
C	60a	1721	2.2	2.2	309a	2.2	14.5

[1] DI: forty days after planting, DII: at the end of the experiment.
[2] S: solarization for six weeks, SH: solarization for six weeks plus hot water, Hs: solarization for one week plus hot water treatment, C: control (no solarization or hot water application).
[3] Means in each column without letters or with a similar letter are not significantly different.

TABLE II - *Effect of hot water treatment of mulched soil on* Meloidogyne javanica *in buried sacks*[1] *at two soil depths and on tomato yield.*

Treatment	*M. javanica*			Yield kg/plot
	Number of J2/100ml		Galling index	
	0-10 cm	10-20 cm		
Hot water	480a[2]	793a	1.4a	16.4a
Control	3775b	6530b	2.5b	12.8b

[1] Containing 5655 juveniles/100 ml soil.
[2] Means in each column followed with a similar letter are not significantly different.

21, 1988) the galling index in the hot water treated soil was 45% lower than that of the control. Also, yield was significantly higher (27%) in the hot water treatment than in the control. The severity of tomato yellow leaf curl virus was much lower in this experiment than in Expt. I, which allowed a longer growing period (6 months).

The present investigation demonstrates that hot water can be a useful adjunct to solarization using plastic cover. There was an improvement in heating especially in the subsoil and consequently an improvement in the control of soilborne pathogens. It can reduce the crop-free period needed for soil disinfestation by «conventional solarization» which is the main limitation of this method (Katan, 1981). The relative increase in soil temperature over the solarization alone treatment depends on the amount and the temperature of the applied hot water. Moreover, the increase in absolute maximum soil temperature depends on the magnitude of soil temperature at the time of hot water application.

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Literature cited

AL-ASA'D M.A., 1983 - Effect of solarization on soil-borne fungi and nematodes in the Central Jordan Valley. M. Sc. Thesis, University of Jordan, pp. 74.

BARAKAT R.M., 1987 - Comparative effect of different colors of polyethylene tarping on soilborne pathogens, M. Sc. Thesis, University of Jordan, pp. 82.

BARKER K.R., 1985 - Nematode extraction and bioassays, pp. 19-38. *In*: An Advanced Treatise on *Meloidogyne*, vol. II, Methodology. (Eds K.R. Barker, C.C. Carter and J.N. Sasser), North Carolina State University Graphics.

CROSSAN D.F., 1967 - Selective isolation of soil microorganisms by means af differential media. *In*: Sourcebook of Laboratory Excercises in Plant Pathology. Eds. American Pytopathol. Soc., pp. 19-21. London.

DOWSON J.R. and JOHNSON R.A.H., 1968 - Influence of steam air mixture, when used for heating soil on biological and chemical properties that affect seedling growth. *Ann. app. Biol.*, *56*: 243-251.

GROOSHEVOY S.E., 1939 - Disinfestation of seedbed soil in cold frames by solar energy. *Rev. app. Mycol.*, *18*: 635-636.

KATAN J.A., 1980 - Solar pasteurization of soils for disease control, status and prospects. *Plant Disease*, *64*: 450-454.

KATAN J., 1981 - Solar heating (Solarization) of soil for control of soilborne pests. *Ann. Rev. Phytopathol.*, *19*: 211-236.

KATAN J.A., GREENBERGER H.A. and FEINSTEIN A., 1976 - Solar heating by polyethylene mulching for control of disease caused by soil-borne pathogens. *Phytopathology*, *66*: 683-688.

OLSEN C.M. and BAKER K.F., 1968 - Selective heat treatment of soil and its effect on inhibition of *Rhizoctonia solani* by *Bacillus subtilis*. *Phytopathology*, *58*: 79-87.

PULLMAN G.S. and DEVAY J.E., 1984 - Soil solarization a non chemical method for controlling diseases and pests. Cooperation Extension, University of California, Division of Agriculture and Natural Resources, Leaflet 21377. State University Graphics, USA, pp. 1-7.

PULLMAN G.S., DEVAY J.E., GRABER R.H. and WEINHOLD A.R., 1979 - Control of soil-borne fungal pathogens by plastic tarping of soil, pp. 439-446. *In*: Soil-borne Plant Pathogens (Eds B. Schippers and W. Gams) Academic Press, London.

PULLMAN G.S., DEVAY J.E. and GRABER R.H., 1981 - Soil solarization and thermal death: A logarithmic relationship between time and temperature for four soliborne pathogens. *Phytopathology*, *71*: 959-964.

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