Soil solarization for the control of tomato and eggplant *Verticillium* wilt and its effect on weed and micro-arthropod communities

Raquel Ghini[1]; Wagner Bettiol[1]; Claudio A. Spadotto; Gilberto J. de Moraes; Lourival C. Paraiba & Jeferson L. de C. Mineiro

EMBRAPA/CNPMA. Caixa Postal 69, 13820.000 - Jaguariúna, SP, Brazil.
[1] Fellowship of CNPq.
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ABSTRACT

Ghini, R.; Bettiol, W.; Spadotto, C.A.; Moraes, G.J. de; Paraiba, L.C.; Mineiro, J.L. de C. Soil solarization for the control of tomato and eggplant *Verticillium* wilt and its effect on weed and micro-arthropod communites. **Summa Phytopathologica**, v. 19, p. 183-189, 1993.

Soil solarization for 30 and 50 days significantly reduced the incidence of *Verticillium dahliae* wilt in tomatoes, and had a residual effect on the level of the disease in eggplants transplanted to the same field 45 days after tomato plants had been eliminated. The reduction in the level of the disease did not, however, correspond to an increase in yield in both crops. Weed community was also considerably affected by solarization. The relative importance of dicotiledoneous plants was higher in the control plots and plots treated with methyl bromide; whereas in solarized plots the importances of grasses and dicotiledoneous plants were similar. In general, solarization and treatment with methyl bromide reduced considerably the population of several groups of mites and insects, but 11.5 months later the population of these organisms again became similar to that in control plots.

Key-words: Solar heating, biological control, soil-borne pathogens.

RESUMO

Ghini, R.; Bettiol, W.; Spadotto, C.A.; Moraes, G.J. de; Paraiba, L.C.; Mineiro, J.L. de C. Solarização do solo para o controle da murcha de *Verticillium* do tomate e da berinjela e seus efeitos sobre as comunidades de plantas invasoras e micro-artropodos. **Summa Phytopathologica**, v.19, p.183-189, 1993.

A solarização do solo por 30 e 50 dias reduziu a ocorrência de Verticillium dahliae *na cultura de tomate e apresentou efeito residual no controle da doença em berinjelas transplantadas 45 dias após a retirada das plantas de tomate. Entretanto, o controle não resultou em aumento de produção das duas culturas. A comunidade de plantas invasoras foi sensivelmente reduzida com a solarização, sendo que a importância relativa das dicotiledôneas foi maior na testemunha e com brometo de metila, enquanto que, com a solarização, a importância relativa de gramíneas e dicotiledôneas foi semelhante. De modo geral, a solarização e o brometo de metila reduziram acentuadamente as populações de diversos grupos de ácaros e insetos, sendo que 11,5 meses após os tratamentos, as populações voltaram a ser semelhantes à testemunha.*

Palavras chave: Aquecimento do solo, controle biológico, microrganismos do solo.

Since first tried by Katan et al. (10), solar heating of the soil through mulching with transparent polyethylene sheets (solarization) has been shown as an efficient method to control soil inhabiting pathogens (9). In addition to pathogen control, this method may also result in other modifications of the agroecosystem which can last longer than the vegetative cycle of the crop (9). Because of its effects on a wide range of organisms,. solarization may affect the biological equilibrium of the soil, increasing the suppressiveness to certain pathogens and controling secondary pathogens (14,15).

Besides controlling pathogens, solarization may also control some weed species (16), which are affected by abiotic factors, the depth of the seeds in the soil and intrinsic characteristics of the seeds (4,7,12,18). It has also been reported to effectively control bulb damaging mites (5), and should also affect other soil inhabiting arthropods.

A number of papers has shown that solarization generally results in improved crop development and yield, because of the factors mentioned above and the concurrent improvement in abiotic and biotic characteristics of the soil (9). Solarization is a technic recommended for regions with intensive solar radiation, and its efficiency in the control of *Verticillium* species has been shown (2,6,10,11,20).

The objective of this work was to evaluate the effect of solarization on the plant pathogen *Verticillium dahliae*, associated weeds and micro-arthropods, as well as the resulting effect on soil nutrient concentrations, plant growth and yield of tomatoes and eggplants. *V. dahliae* is an important pathogen of several plant species, particularly those of the family Solanaceae. Its wide host range makes its control difficult by crop rotation. In addition, its survival in the soil is facilitated by the formation of microsclerotia, which often results in turning extensive areas inappropriate for further cultivation of solanaceous crops.

MATERIAL AND METHODS

The experiment was conducted in Jaguariúna, State of São Paulo, from November 1990 to July 1992 in a podzolic soil. In November 1990 the soil was plowed and corrected for pH with an application of lime at a rate of 2 tons/ha. The area was drilled at a spacing of 0.6 x 0.8 m, and 5 kg of manure was subsequently incorporated to the soil of each hole.

A local, recently collected isolate of *V. dahliae* maintained in the laboratory on PDA medium was cultivated on popcorn kernels for 20 days at 25°C and ambient light condition, to provide inoculum for field infestation. Field infestation was done in the beginning of December, incorporating into the soil a suspension of conidia (2×10^8 conidia/ hole) washed from the kernels. Micelia and microsclerodia were also utilized, adding to each hole 7 ml of kernels which had been previously washed for the extraction of conidia.

Two consecutive crops (tomato and eggplant) were planted in the same area, adopting the same experimental pattern. The experimental design was a randomized complete block, with 4 treatments and 6 replicates. Each experimental plot corresponded to an area of 15.4 m^2 (32 plants). Initially 5 tomato plantlets, cultivar "Angela Gigante", and later 2 eggplant plantlets, cultivar "Super F 100", were planted in each hole.

The beginning of each treatment was established so as to finish all of them a day before the tomato plantlets were transplanted to the field (March 19, 1991). Thus, 45 days after the field infestation with *V. dahliae* (end of January), the first solarization treatment (Solar 50) was initiated by weeding 6 experimental plots and covering them with sheets of transparent polyethylene (35 μm thick). Twenty days later (mid February), the second solarization treatment (Solar 30) was initiated by weeding 6 additional plots and covering them with polyethylene sheets. Four days prior to tomato transplanting, 6 other plots were weeded and treated with methyl bromide (393 ml/ plot). Three days later the remaining 6 plots were weeded, and next day, i.e. March 19, tomato plantlets were transplanted to all plots. Eggplants were planted in the field on December 3, 1991, about 3 months after tomato was harvested. Soil temperature were daily monitored at depths of 5 and 15cm in solarized and non-solarized plots, at 15:00h.

During the experiment, tomato plants were sprayed with the fungicides methalaxyl, chlorothalonil, mancozeb and copper oxychloride, and the insecticides deltamethrine, fenitrothion and metamidophos. Eggplants were sprayed with the fungicides copper oxychloride and mancozeb, the insecticide phenitrothion, and the acaricide avermectine.

Biomass production of tomato was evaluated 20, 30 and 40 days after transplanting by taking 1 plant per each of the 32 holes of each plot. Rates of infection by *V. dahliae* were evaluated by taking pieces of vascular tissue with symptoms of discoloration, superficially desinfesting and transferring them to PDA medium containing 500 μg/ml of tetracycline to reisolate *V. dahliae*. The symtomatic vascular tissues were taken from plants collected during the growing season, as indicated previously. All plants remained until the end of the experiment. For eggplants, a single evaluation of plant height was done 40 days after transplantation. Yield and infection by *V. dahliae* were evaluated at the end of the experiment, as described for tomato.

To evaluate the effect of solarization on the chemical properties of the soil, nutrient analyses were performed before and after treatments were applied.

Evaluations of the weeds of each treatment were done 36 days after plantlets of tomato and eggplant were transferred to the field. Numbers of individuals and total dry weight of graminaceous and dicotyledoneous plants were evaluated. Samples were taken from an area of 5.8 m^2 delineated in the central part of each plot. Plants of each weed species were counted, dried for 72 h at 60 - 70°C and weighted.

Alterations in the composition of soil micro-arthropod fauna were determined by periodically collecting those organisms from the soil using a "Tullgren funnel" and mounting them in Hoyer's medium for identification. Two samples were taken from each plot at each sampling date. Each sample consisted of 196 cm^3 of soil collected with a screw auger from the top 10 cm layer. Evaluations were conducted 5 times during the season. First, a compound sample was taken on January 11 from the whole area, before any treatment was applied. Further samplings were conducted on March 15, in plots of the control treatment, which were covered with weeds; and, in plots of methyl bromide treatment, which had been weeded 2 weeks previously. A new sample was taken on March 19, soon after treatments were finished and on the same day when tomato plantlets were transplanted. The last 2 samples were taken on May 24, at the beginning of the tomato harvesting season, and on February 3, at the beginning of the eggplant harvesting season. Diversity of mite groups was also studied by initially calculating Shannon's indexes of family (or superfamily) diversity (13,19), and then statistically comparing those indexes (8). The Shannon's indexes take into account the number of species (family or super family), number of individuals in each species and total number of individuals.

RESULTS

Soil temperature and nutrients. The maximum temperatures at 5 and 15 cm depth were 46 and 42°C, measured daily during the solar treatment, at 15:00h (Figure 1). Solarization had no effect on soil pH, nutrient and organic matter contents (Table 1).

Infection and plant growth. The percentage of tomato plants infected by *V. dahliae* was significantly lower in plots solarized for 30 or 50 days (Table 2). The heights and weights of tomato plants were significantly higher in soil solarized for 30 and 50 days. Partial yield evaluated 3.5 months after transplanting was significantly higher for plants grown in soils solarized for 50 and 30 days, respectively. Total yield, however, did not show any significant differences between treatments, although an antecipation of the harvesting period was observed, which could result in higher profits.

Eggplants growing in control plots were significantly more infected by *V. dahliae* (Table 3). However, no significant differences between treatments were found for plant height 40 days after transplanting and total yield.

Weed development. In the tomato crop, density and dry weight of weeds in the control plots were significantly higher than other treatments, which did not differ between themselves (Table 4). In the eggplant crop, higher density of weeds was observed in the control than in other treatments. However, this difference was not statistically significant, as were not significant the differences between dry weights.

The predominant weeds in all treatments of the tomato crop were *Amaranthus deflexus* L. and *Digitaria horizontalis* Willd (Table 5). Solarization apparently reduced the proportion of *A. deflexus* and increased the proportion of *D. horizontalis*.

The predominant weeds in the eggplant crop were *A. deflexus* and *Eleusine indica* (L.) Gaertn in the control plots and *A. deflexus* and *D. horizontalis* in other treatments (Table 6). The densities of *E. indica* were apparently reduced with solarization, while the density of *D. horizontalis* apparently increased with solarization or methyl bromide treatments.

Soil micro-arthropods. The two major groups collected were mites and insects belonging to different families (Table 7). Three other groups, namely Araneae, Chilopoda and Diplopoda, were collected only ocasionally. The most abundant mite population belonged to the superfamilies Oribatuloidea and Passalozetoidea, both of which belong to the sub-order Oribatida, while the most abundant insect population belonged to the order Collembola. The largest number of mites (233 individuals) was found on March 15, 1991 in the control treatment, while the maximum number of collembolans (1181 individuals) was found on May 24, 1991 in the same treatment. Plots which would receive methyl bromide treatment and which were weeded 2 weeks before the samples were collected on March 15 had considerably less mites (47 individuals) than the control plots which were covered with weeds up to that day (233 individuals).

The number of mites collected from the control treatment on May 24, 1991 (81) was much lower than the number collected on March 19, 1991 (181), which in turn was similar to the number of mites found on February 3, 1992 (185). The opposite was verified with insects in the same treatment; a total of 1202 individuals were found on May 24, but only 65 and 117 were found on March 19 and February 3, respectively.

Table 1. Effect of solarization on soil nutrient contents at Jaguariúna, State of São Paulo.

Treatments[1]	pH	P ($\mu g/cm^3$)	$H^+ + Al^{3+}$	K^+	Ca^{2+}	Mg^{2+}	BS	CEC	V (%)	Org. Mat. (%)
			(me/100 g of soil)							
Control 1	4.8	23	2.6	0.42	1.5	1.0	2.9	5.5	52	2.3
Control 2	4.7	16	3.3	0.28	1.2	0.7	2.2	5.5	41	2.8
Methyl Bromide	4.9	24	2.8	0.34	1.5	0.9	2.7	5.5	50	2.8
Solarization for 30 days	5.0	43	2.9	0.50	1.7	1.2	3.4	6.3	54	3.2
Solarization for 50 days	4.8	22	3.1	0.31	1.2	0.8	2.3	5.4	43	3.0

[1] Control 1 = Evaluations before treatments; Control 2 = Evaluations after treatments.

Table 2. Effect of solarization on development, yield and infection of tomato plants by *Verticillium dahliae*.

Treatments	% Plants Infected	Plant height (cm)[1]	Plant weight (g/plant)[2]		Yield (kg/plant)[3]	
			First	Second	Parcial	Total
Control	14.6b	22.3b	46.8b	99.5b	0.62b	2.71a
Methyl Bromide	6.7ab	23.2b	48.7ab	120.4ab	0.61b	3.01a
Solarization for 30 days	3.1a	26.3a	58.8ab	133.0a	0.77a	2.63a
Solarization for 50 days	4.6a	26.7a	62.1a	141.3a	0.76a	2.85a

[1] 20 days after transplanting.

[2] First = 30 days after transplanting; Second = 40 days after transplanting.

[3] Parcial = 3.5 months after transplanting; Total = 6 months after transplanting.
Mean of 6 replications.
Means followed by the same letter are not significantly different (Tukey 5%).

Table 3. Effect of solarization on development, yield and infection of eggplants by *Verticillium dahliae.*

Treatments	% Plants Infected	Plant height (cm)[1]	Total yield (kg/plant)
Control	18.7b	44.0a	4.1a
Methyl Bromide	9.3ab	45.5a	4.3a
Solarization for 30 days	4.1a	43.2a	3.6a
Solarization for 50 days	5.2a	44.1a	4.0a

[1] 40 days after transplanting.
Means followed by the same letter are not significantly different (Duncan 5%).

Table 4. Effect of solarization on weeds in tomato and eggplant crops.

Treatments	Density (plants/m²)	Total dry weight (g/m²)
	Tomato	
Control	35.9 a	4.9 a
Methyl Bromide	5.0 b	0.3 b
Solarization for 30 days	9.3 b	1.2 b
Solarization for 50 days	6.1 b	1.4 b
	Eggplant	
Control	171.5 a	15.7 a
Methyl Bromide	69.1 a	21.0 a
Solarization for 30 days	84.1 a	13.6 a
Solarization for 50 days	67.8a	19.8a

Means followed by the same letter are not significantly different (Tukey 1%).

Table 5. Relative importance of weed species in tomato crop grown in solarized soils. Jaguariúna, State of São Paulo, 1991.

Treatments	Relative Importance (%)		
	Amarathus deflexus	*Digitaria horizontalis*	Others
Control	68.3	28.5	3.2
Methyl Bromide	72.5	25.2	1.9
Solarization for 30 days	42.2	55.0	2.8
Solarization for 50 days	53.5	44.1	2.4

Table 6. Relative importance of weed species in eggplant crop grown in solarized soils, Jaguariúna, State of São Paulo, 1991.

Treatments	Relative Importance (%)			
	Amaranthus deflexus	*Digitaria horizontalis*	*Eleusine indica*	Others
Control	75.9	13.8	32.1	2.8
Methyl Bromide	40.6	42.1	13.1	4.2
Solarization for 30 days	68.1	19.4	8.3	4.3
Solarization for 50 days	47.9	34.0	14.1	3.9

Treatment with methyl bromide practically eliminated all mites from the soil; a single Oribatuloidea was found in the sample taken on March 19 from that treatment. Solarization for 30 or 50 days also reduced greatly the total number of mites and the number of taxa to which they belonged. Only 15 mites belonging to 7 taxa and 7 mites belonging to 5 taxa were found on March 19, immediately after solarization for periods of 30 and 50 days, respectively, was completed. The number of insects was also reduced considerably in these 3 treatments compared to the control. Only 5 insects belonging to 2 taxa, 4 insects belonging to 3 taxa and 13 insects belonging to 4 taxa were found on May 24 in the methyl bromide, solarization for 30 and solarization for 50 days, respectively.

A slight recovery in the number of individuals occurred until May 24 in the methyl bromide, solarization for 30 days and solarization for 50 days treated plots. Neverthless, the numbers of mites and insects were considerably lower than in the control, what was specially evident for the collembolans. Apparently, mite and insect populations recovered totally until February 3, 1992 in those 3 treatments.

Mite diversity in the control treatment did not differ between samples (Table 8 and Figure 2). In the sampling conducted on March 19, 1991, soon after treatments were finished, mite diversity was lowest (zero) in the methyl bromide treatment, highest in the control treatment and intermediate in the solarization for 30 or 50 days treatments. The same pattern was observed in the sampling conducted on May 24, 1991. In the last sampling, conducted on February 3, 1992, diversity increased in the methyl bromide treatment, approaching the value observed with solarization for 50 days. Solarization of soil for 30 days resulted in progressively lower values of diversity index from the first to the third sampling date.

DISCUSSION

Soil solarization for 30 or 50 days reduced the incidence of *V. dahliae* in tomatoes, and had a residual effect on the consecutive crop. However, the control of *V. dahliae* by soil solarization or by the use of methyl bromide did not result in increase on yield of tomatoes or eggplants, probably because of the low inoculum of the *V. dahliae* strain utilized to infest the soil in this study. Working in the same area where the present study was conducted, Ghini et al. (6) obtained higher yield of eggplants when soil infested with the same pathogen was solarized.

The increased availability of soil nutrients with solarization (3,17) was not observed in this study, probably because of the way the analysis was performed. The evaluation of different forms of nutrients could show more precise information on the effect of solarization, especially in relation to nitrogen (Katan, personal communication).

Horowitz et al. (7) reported good control of weeds when soil temperature was equal to or higher than 45°C. Comparable temperatures were obtained in this study (Figure 1). Solarization had a significant effect on the density and total biomass of weeds in the tomato crop, grown immediately after the treatments were applied. This effect was comparable to that of methyl bromide. However, it did not persist in the second crop, probably because of seeds arriving from the surrounding vegetation. In this study, solarization also affected the relative importance of weed species, raising or reducing

Table 7. Groups of soil micro-arthropods collected from different treatments, at different dates. Jaguariúna, São Paulo. 1991-1992.

Micro arthropods	Pre-evaluations			Evaluations after treatments***											
				Control			Methyl bromide			Solar 30			Solar 50		
	1-11	3-15*	3-15**	1	2	3	1	2	3	1	2	3	1	2	3
ACARI															
Ascidae	13	4	18	29	3	13			19	2	1	6	1	4	7
Laelapidae	7	3	18	11	9	9			32	2		2		2	7
Ologamasidae	2		3	3	1										
Parasitidae		2			2	12									3
Phytoseiidae								1							1
Rhodacaridae		1	8	1		1								1	
Uropodidae	8	1	30	16	15	17					8		2	17	1
Bdellidae														1	
Cunaxidae	1	1	1	3	2	7			12			2		1	3
Eupodidae			3	5						1			1	3	
Nanorchestidae		2	5	29		9		1	1			9			7
Pygmephoridae	4			1		8		1	2						2
Rhagidiidae			1		2										3
Tarsonemidae															1
Tetranychidae			3												
Acaridae			11		1			1					2		
Anoetidae			1												
Cosmochthonoidea										1					
Euphthiracaroidea				2	4						2				
Galumnoidea	3	10	18	24	7	2		1		2				1	1
Microzetoidea		2	2	5		8			1						13
Oppiidae	4	2	3		2	2			5		2				6
Oribatuloidea	22	15	50	25	27	46	1		46	5	9	48	1	9	70
Phthiracaroidea						3						2			2
Passalozetoidea	3	4	58	27	6	46		7	45	2	3	18		6	57
Zetomotrichidae						2									1
Taxa	10	12	17	14	13	15	1	6	9	7	6	7	5	10	17
Individuals	67	47	233	181	81	185	1	12	163	15	25	87	7	45	185
ARANEAE		2				1			1		1	2			
INSECTA															
Hymenoptera	1	13	9	12	4	2	1		2	1	1	1			4
Coleoptera	8	3	1	5	13	5	4	1	9	2	5	4	1	2	6
Collembola	9	32	47	48	1181	88		33	148	1	38	103	6	122	61
Embioptera		3	1		1	9		1				3	5		2
Hemiptera	1	1													
Homoptera								7							
Psocoptera		4	3		3	13		3	9		4	2	1	2	4
Taxa	4	6	5	3	5	5	2	5	4	3	4	5	4	3	5
Individuals	19	56	61	65	1202	117	5	45	168	4	48	113	13	126	77
CHILOPODA		3	4		14	10		3	12		10	4		4	7
DIPLOPODA			1			2						1			

* Samples taken from plots weeded 2 weeks previously; ** Samples taken from unweeded plots; *** 1 = Samples taken on March 19, 1991; 2 Samples taken on May 24, 1991; 3 = Samples taken on February 3, 1992.

them. Abu-Irmaileh (1) observed that some species of weeds were completely controlled by solarization while others only emerged in solarized plots.

Solarization reduced significantly the abundance of mites and insects in the soil. Its effect on those organisms was similar to that caused by treatment with methyl bromide. A recovery of the population of those organisms was already noticeable about 2 months after soil heating treatment, and practically total recovery was verified about 8.5 months later.

Table 8. Shannon's indexes of diversity of mite groups for at three sampling dates. Jaguariúna, São Paulo. 1991-1992.

Treatments	Dates		
	March 19, 1991	May 24, 1991	February 3, 1992
Control	2.24	2.07	2.21
Methyl Bromide	0.00	1.35	1.70
Solarization for 30 days	1.80	1.52	1.33
Solarization for 50 days	1.55	1.83	1.84

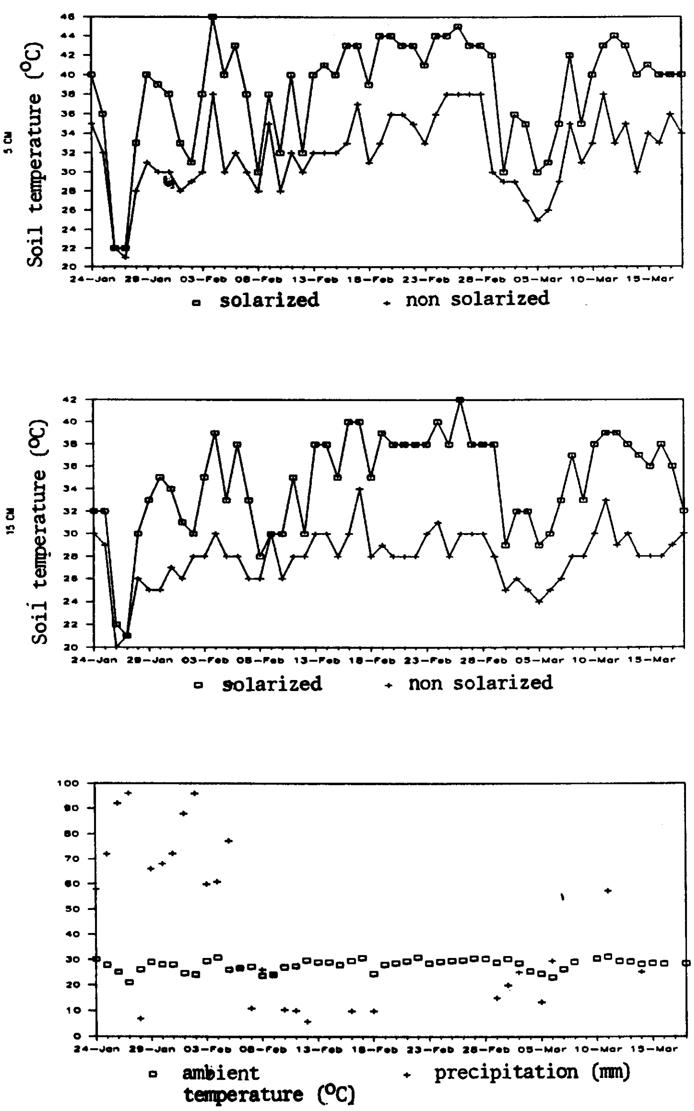

Figure 1. Daily soil temperature in solarized and non solarized soil at depth of 5 and 15 cm.

	C (1)	C (2)	C (3)	MB (1)	MB (2)	MB (3)	S_{30} (1)	S_{30} (2)	S_{30} (3)	S_{50} (1)	S_{50} (2)	S_{50} (3)
C (1)	-											
C (2)	ns	-										
C (3)	ns	ns	-									
MB (1)	*	-	-	-								
MB (2)	-	*	-	*	-							
MB (3)	-	-	*	*	ns	-						
S_{30} (1)	*	-	-	*	-	-	-					
S_{30} (2)	-	*	-	-	ns	-	ns	-				
S_{30} (3)	-	-	*	-	-	*	*	ns	-			
S_{50} (1)	*	-	-	*	-	-	ns	-	-	-		
S_{50} (2)	-	ns	-	-	ns	-	-	*	-	ns	-	
S_{50} (3)	-	-	*	-	-	*	-	-	*	ns	ns	-

* = Significantly different at 5% level (T test) ; ns = non significant difference; - = not evaluated.

Figure 2. Significance of the differences between Shannon's indexes of diversity of mite groups for different soil treatments (C = control; MB = methyl bromide; S_{30} = solarization for 30 days; S_{50} = solarization for 50 days) at three sampling dates (1 = March 19, 1991; 2 = May 24, 1991; 3 = February 3, 1992).

Methyl bromide treatment affected mite diversity much more significantly than solar heating. A significant recovery was observed in plots treated with methyl bromide in the last 2 evaluations. The decline in the index of mite diversity in solarization for 30 days from the first to the third sampling date was not expected, and the reason for it was not assessed in this study.

The role of soil micro-arthropods was not evaluated in this study, and thus a possible indirect negative effect of that treatment on the crop via disruption of the ecological equilibrium in the soil cannot be estimated. Further studies on this aspect are warranted.

LITERATURE CITED

01. ABU-IRMAILEH, B.H. Weed control in squash and tomato fields by soil solarization. **Weed Research**, Edinburgh, v.31, n.3, p.125-133, 1991.
02. ASHWORTH, Jr., L.J.; GAONA, S.A. Evaluating of clear polyethylene mulch for controlling *Verticillium* wilt in established pistachio nut groves. **Phytopathology**, St. Paul, v.72, p.243-246, 1982.
03. CHEN, Y.; KATAN, J. Effect of solar heating of soils by transparent polyethylene mulching on their chemical properties. **Soil Science**, Baltimore, v.130, p.271-277, 1980.
04. EGLEY, G.H. Weed seed and seedling reductions by soil solarization with transparent polyethylene sheets. **Weed Science**, Champaign, v.31, p.404-409, 1983.
05. GERSON, U.; YATHOM, S.; KATAN, J. A demonstration of bulb mite control by solar heating of the soil. **Phytoparasitica**, Bet Dagan, v.9, n.2, p.153-155, 1981.
06. GHINI, R.; BETTIOL, W.; SOUZA, N.L. de. Solarização do solo para o controle de *Verticillium dahliae* em berinjela. **Fitopatologia Brasileira**, Brasília, v.17, n.4, p.384-388, 1992.
07. HOROWITZ, M.; REGEV, Y.; HERZLINGER, G. Solarization for weed control. **Weed Science**, Champaign, v.31, p.170-179, 1983.
08. HUTCHESON, K. A test for comparing diversities based on the Shannon formula. **Journal of Theoretical Biology**, London, v.29, p.151-154, 1970.
09. KATAN, J.; DEVAY, J.E. **Soil solarization.** Boca Raton: CRC Press, 1991. 267p.

10. KATAN, J.; GREENBERGER, A.; ALON, H.; GRINSTEIN, A. Solar heating by polyethylène mulching for the control of disease caused by soil-borne pathogens. **Phytopathology**, St. Paul, v.66, n.5, p.683-688, 1976.

11. PULLMAN, G.S.; DEVAY, J.E.; GARBER, R.H.; WEINHOLD, A.R. Soil solarization:effects on *Verticillium* wilt of cotton and soilborne populations of *Verticillium dahlia*, *Pythium* spp., *Rhizoctonia solani*, and *Thielaviopsis basicola*. **Phytopathology**, St.Paul, v.71, n.9, p.954-959, 1981.

12. RUBIN, B.; BENJAMIN, A. Solar heating of the soil: involvement of environmental factors in the weed control processe. **Weed Science**, Champaign, v.32, p.138-142, 1984.

13. SHANNON, C.E.; WEAVER, W. **The mathematical theory of communications.** Urbana: The University of Illinois Press, 1949. p.19-37, p.82-83, p.104-107.

14. STAPLETON, J.J.; DEVAY, J.E. Effect of soil solarization on populations of selected soilborne microorganism and growth of deciduous fruit tree seedlings. **Phytopathology**, St.Paul, v.72, n.3, p.323-326, 1982.

15. STAPLETON, J.J.; DEVAY, J.E. Thermal components of soil solarization as related to changes in soil and root microflora and increased plant growth response. **Phytopathology**, St. Paul, v.74, p.255-259, 1984.

16. STAPLETON, J.J.; DEVAY, J.E. Soil solarization: a non-chemical approach for management of plant pathogens and pests. **Crop Protection**, Guildford, v.5, n.3, p.190-198, 1986.

17. STAPLETON, J.J.; QUICK, J.; DEVAY, J.E. Soil solarization: effects on soil properties, crop fertilization and plant growth. **Soil Biology and Biochemistry**, Elmsford, v.17, p.369-373, 1985.

18. STANDIFER, L.C.; WILSON, P.W.; PORCHE-SORBET, R. Effects of solarization on soil weed populations. **Weed Science**, Champaign, v.32, p.569-573, 1984.

19. WASHINGTON, H.G. Diversity, biotic and similarity indices: A review with special relevance to aquatic ecosystems. **Water Research**, Elmsford, v.18, n.6, p.653-694, 1984.

20. WELVAERT, W.; POPPE, J. Influence of plastic mulching and disinfection on the fungal flora of soils in Belgium. **Bulletin OEPP**, Oxford, v.16, n.2, p.311-316, 1986.