Neth. J. Pl. Path. 99(1993) 45–50

# A solar collector for soil disinfestation

R. GHINI

Empresa Brasileira de Pesquisa Agropecuária, Centro Nacional de Pesquisa de Defesa da Agricultura, Caixa Postal 69, 13820-000 Jaguariúna, SP, Brazil

Accepted 10 December 1992

**Abstract**

A solar collector to be used for disinfestation of substrates for plant propagation is described. At a high solar radiation intensity (more than 1 cal $cm^{-2}$ $min^{-1}$), one day of treatment was sufficient for disinfestation of soil infested with *Sclerotium rolfsii*, *Sclerotinia sclerotiorum*, *Fusarium solani* f.sp. *phaseoli* or *Pythium aphanidermatum*.
Treatment of soil in the solar collector strongly reduced the total numbers of fungi, bacteria and actinomycetes. The nutrient status of the soil was only slightly changed and did not result in an effect on plant growth.

*Additional keywords*: solarization, heat treatment, soil-borne pathogens, damping-off.

## Introduction

Disinfestation of substrates for the production of seedlings is a common problem for many growers as well as for research workers performing pot experiments. Usually disinfestation is achieved by the application of heat of a steam generator or autoclave, or a chemical agent such as methyl bromide. Both methods have their limitations, caused by phytotoxicity, costs, security, efficiency and residues.

Applying the principles of soil solarization (Katan, 1987) for disinfestation of substrates for the production of seedlings in pots, solar radiation was used as a heat source by Armond et al. (1990). The prototype of the solar collector basically comprised gutters of aluminium or galvanized iron with insulation by glasswool and a transparent plastic cover. The method was shown to be highly efficient for the control of pathogens, without risks to the operator and easy to construct and operate (Ghini et al., 1991a).

In order to facilitate loading and unloading the substrate, Ghini and Bettiol (1991) designed a prototype of a solar collector with tubes, in which higher temperatures could be attained. The purpose of this work was to evaluate the effectiveness of this solar collector for the disinfestation of substrates. Tubes of different diameters were compared for their effect on the temperature of the treated substrate, the control of selected pathogens, the number of viable counts of fungi, bacteria and actinomycetes, the nutrient content and plant growth.

## Materials and methods

*Description of the solar collectors.* The solar collector comprises black galvanized iron tubes parallely placed in a wooden box of 1.5 m in length, 1.0 m in width, and 0.3 m in depth. A sheet of transparent plastic is placed over the top of the box and the lid is covered

Fig. 1. Solar collector with tubes of 15 cm diameter and aluminium lid positioned to reflect the sun to the tubes filled with infested soil.

by a sheet of aluminium foil which is lifted to increase the solar radiation inside the box. Soil is placed in the tubes through the upper hatch and recovered through the lower.

Three prototypes with tubes of different diameters were tested: (1) four tubes of 10 cm diameter, total capacity 47 l of substrate; (2) six tubes of 15 cm diameter, total capacity 116 l of substrate (Fig. 1); and (3) six tubes of 20 cm diameter, total capacity 207 l of substrate. Another type without tubes and with a black galvanized iron box inside a wooden box with transparent plastic and aluminium covers (100 × 100 × 21.5 cm, capacity 215 l of substrate), was tested also.

In order to receive the maximum intensity of solar radiation at a latitude of 23 °S, the solar collectors were exposed to the north at an inclination of 33°.

*Measurement of temperature of substrate in the solar collectors.* The temperature of the substrate inside the solar collectors was measured with a digital temperature multi-sensor for a period of 10 days at intervals of 30 min. The sensors were placed along the middle of the tubes.

*Effect on number of fungi, bacteria, actinomycetes and on selected soil-borne pathogens.* A soil mixture (3 soil : 1 sand : 1 manure) was treated in the solar collector with tubes of 10 cm diameter for 1 and 7 days. A mixture of untreated soil was kept under laboratory conditions as a control. After treatment in the solar collector a dilution series of samples from treated and untreated soil was made. The suspensions were transferred to selective media for the determination of populations of fungi (Martin medium), bacteria (soil

extract with pH 7.2; glucose 1.0 g; $K_2HPO_4$ 0.5 g; agar 20 g; modified from Tuite, 1969), and actinomycetes ($K_2HPO_4$ 1.0 g; asparagine 0.6 g; glycerol 10 ml; micronutrients solution 1.0 ml; agar 20 g; distilled water to make 1000 ml). The suspensions transferred were of a dilution in the range of $10^{-2}$ to $10^{-5}$ propagules of fungi, and $10^{-4}$ to $10^{-6}$ of bacteria and actinomycetes, with five replications.

For assessment of the survival of *Sclerotium rolfsii*, 20 sclerotia were mixed with 5 g of soil and tied into a small nylon bag. Twenty such bags were submitted to treatment for 1, 2 and 3 days in three collectors with tubes of 10, 15 and 20 cm diameter. The sclerotia were recovered by wet-sieving (50 mesh per inch) with tap water. The sclerotia were then disinfested with 0.5% sodium hypochlorite for 2 min and transferred onto PDA plates containing 500 $\mu$g $ml^{-1}$ tetracyclin. The viability of the sclerotia was determined by assessing the percentage of germination.

The same method was used for *Sclerotinia sclerotiorum*, except that six sclerotia were mixed with 5 g of soil and that ten small nylon bags were placed in the solar collectors with tubes of 10 and 15 cm diameter

An isolate of *Fusarium solani* f.sp. *phaseoli* grown on autoclaved popcorn grains was mixed with disinfested soil and treated in the solar collector with tubes of 15 cm diameter for 1, 2 and 3 days. After the treatment the viability of the pathogen was evaluated on plates with the selective medium of Komada (1975).

*Pythium aphanidermatum* grown on a cornmeal–sand medium (cornmeal 40 g; sand 200 g; water 60 g) was mixed with soil and oat flakes (20 g $kg^{-1}$ of soil) and treated in the solar collector with tubes of 15 cm diameter for 1 and 2 days. After the treatment, seeds of cucumber were planted in the soil in pots (10 seeds and 4 kg of soil per pot), in four replications. The percentage of germination of cucumber seeds in solar-collector-treated soil was compared with that in autoclaved and in untreated soils.

*Effect on soil nutrients and plant growth.* Nutrient contents in soil that had been heat-treated for 7 days in the collector with tubes of 10 cm diameter were assessed by routine soil analysis.

For evaluation of plant growth, seeds of corn, bean and tomato were placed in the soil that had been treated for 1, 3 and 7 days in autoclaved and untreated soil. A comparison of germination, plant height and weight of dry material was made 14 days after sowing, in three replications per treatment. Each replicate consisted of a pot (4 kg of soil) with 15 plants.

## Results

The temperatures of the substrates were higher when placed in the solar collectors with the smaller diameter tubes than in those with the wider tubes. The highest temperatures were recorded during the afternoon and the lowest ones during the night (Fig. 2).

The total numbers of micro-organisms were reduced by the heat treatment, but even a prolonged treatment did not completely eliminate the microbial population. After 7 days of treatment in the collector with the 10-cm tubes, the total numbers of fungi, bacteria and actinomycetes were 25, 400, and 60 cfu $g^{-1}$ treated soil, respectively. The populations at the beginning of the treatment were $3.3 \times 10^3$, $2.0 \times 10^5$, and $1.2 \times 10^5$ cfu $g^{-1}$, respectively.

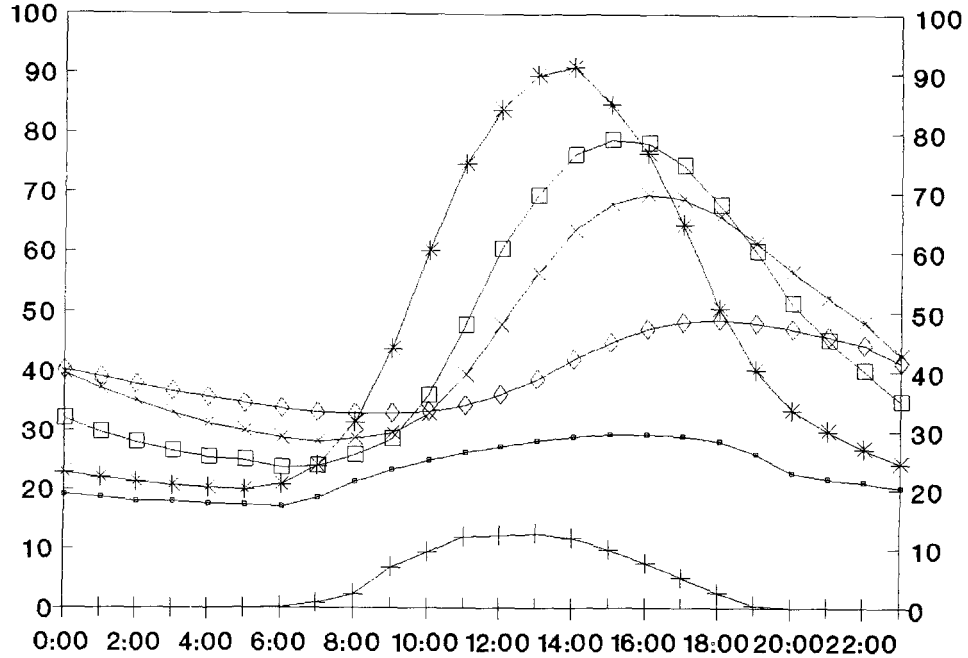


Fig. 2. Mean diurnal temperature (°C) during the 10 days of treatment of a soil mixture in solar collectors. The diameters of the tubes were 10 cm (*), 15 cm (□) and 20 cm (×); ◇ = without tubes; □ = ambient temperature; + = light intensity (November) ($10^{-1}$ cal $cm^{-2}$ $min^{-1}$).

## Discussion

The substrate in the solar collector without tubes did not reach temperatures that are high enough to control pathogens (Baker and Roistacher, 1957; Pullman et al., 1981; Bollen, 1985). Higher temperatures were achieved by the solar collectors with tubes. In the collector with tubes of 15 cm diameter an adequate temperature for the control of pathogens was reached. At the same time, this type has a suitable capacity. At a high solar radiation intensity (more than 1 cal $cm^{-2}$ $min^{-1}$; Fig. 2) 1 day of treatment was enough for control of *S. rolfsii*, *S. sclerotiorum*, *F. solani* f.sp. *phaseoli* and *P. aphanidermatum* (Table 1). In an earlier study it was shown that the same applied to *Meloidogyne arenaria* (Ghini et al., 1991b). It is postulated that a moist substrate would lead to better conductance of heat and thus to a higher temperature in the centre of the tubes. However, a high humidity may damage the equipment, or, at least, it will require more maintenance. A moist substrate is also less easy to handle during loading and unloading.

The heating of soil was sufficient for the control of pathogens but did not completely sterilize the substrate. This is considered to be an advantage of this system since it does not create a 'biological vacuum' to the same extent as in other disinfestation systems, such as treatment with methyl bromide, soil steaming or autoclaving (Bollen, 1974; Cook and Baker, 1983). Infestation of solarized soil is less likely than that of soil disinfestated by treatments creating a biological vacuum.

A solar treatment of 7 days did not significantly alter the nutrient contents of the soil and did not affect plant growth either (Tables 2 and 3). This was often observed for steamed or autoclaved soil.

Table 1. Effect of duration of soil treatment on the survival of *Sclerotium rolfsii*, *Sclerotinia sclerotiorum*, *Fusarium solani* f.sp. *phaseoli* and *Pythium aphanidermatum*.

| Duration of treatment (days) | *S. rolfsii* (viability of sclerotia) | *S. sclerotiorum* (viability of sclerotia) | *F. solani* f.sp. *phaseoli* (cfu $g^{-1}$ soil) | *P. aphanidermatum* (% germination of cucumber seeds) |
|---|---|---|---|---|
| 0 | 79.0[a] | 90.0[b] | $11.4 \times 10^{5}$[c] | 12.5[d] x |
| 1 | 0.0 | 0.0 | 0.0 | 65.0 y |
| 2 | 0.0 | 0.0 | 0.0 | 85.0 y |
| 3 | 0.0 | 0.0 | 0.0 | – |
| Autoclaved | – | – | – | 85.0 y |

[a] Mean of twenty sclerotia in twenty replications, including treatment in collectors with tubes of 10, 15 and 20 cm diameter.
[b] Mean of six sclerotia in ten replications, including treatment in collectors with tubes of 10 and 15 cm diameter.
[c] Mean of six plates per dilution after treatment in a collector with tubes of 15 cm diameter.
[d] Mean of ten seeds in four replications after treatment in a collector with tubes of 15 cm diameter.
Means followed by the same letter are not significantly different (Tukey, $\alpha = 0.05$).

The solar collectors with tubes offer a cheap and safe system for the production of healthy seedlings and can be useful to growers. Modifications of this type of equipment can be made according to the requirements of the user.

Table 2. Effect of treatment in the solar collector with 10-cm tubes on nutrient contents of the soil.

| Duration of treatment (days) | pH in water | Al (mg/eq. 100 $ml^{-1}$) | Ca (mg/eq. 100 $ml^{-1}$) | Mg (mg/eq. 100 $ml^{-1}$) | P (mg/eq. 100 $ml^{-1}$) | K ($\mu g\ g^{-1}$) | C ($\mu g\ g^{-1}$) | Organic matter (%) | N (%) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 6.4 | 0 | 2.4 | 1.8 | 65.0 | 600 | 1.47 | 2.53 | 0.087 |
| 7 | 6.6 | 0 | 2.3 | 1.8 | 71.5 | 576 | 1.08 | 1.86 | 0.079 |

Table 3. Effect of substrate treatment in the solar collector with 15-cm tubes on the germination of seeds and plant growth[a].

| Treatment | Germination (%) | | | Plant height (cm)[b] | | | Dry weight (g per plant)[b] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Corn | Bean | Tomato | Corn | Bean | Tomato | Corn | Bean | Tomato |
| Untreated | 91.0 | 91.0 | 62.2 | 6.2 | 3.8 | 3.3 | 0.25 | 0.20 | 0.029 |
| 1 day | 93.3 | 86.6 | 66.6 | 5.8 | 4.2 | 3.2 | 0.27 | 0.24 | 0.030 |
| 3 days | 100.0 | 88.8 | 79.9 | 5.9 | 4.6 | 3.0 | 0.27 | 0.24 | 0.034 |
| 7 days | 86.6 | 86.6 | 82.2 | 7.2 | 4.3 | 3.3 | 0.32 | 0.28 | 0.036 |
| Autoclaved | 88.8 | 79.9 | 82.2 | 6.4 | 4.3 | 3.0 | 0.30 | 0.23 | 0.027 |

[a] Mean of fifteen plants in three replications; means did not differ significantly (Tukey, $\alpha = 0.05$).
[b] Two-week-old plants.

## References


Armond, G., Braga, C.A.S., Bettiol, W. & Ghini, R., 1990. Coletor solar plano para tratamento térmico do solo. Agronômico 42: 185–189.

Baker, K.F. & Roistacher, C.N., 1957. Heat treatment of soil. In: The U.C. system for producing healthy container grown plants. California Agriculture Experiment Station, Extension Service, Berkeley. p. 123–137.

Bollen, G.J., 1974. Fungal recolonization of heat-treated glasshouse soils. Agro-Ecosystems 1: 139–155.

Bollen, G.J., 1985. Lethal temperatures of soil fungi. In C.A. Parker, A.D. Rovira, K.J. Moore & P.T.W. Wong (Eds), Ecology and management of soil-borne plant pathogens. American Phytopathological Society, St. Paul. p. 191–193.

Cook, R.J. & Baker, K.F., 1983. The nature and practice of biological control of plant pathogens. American Phytopathological Society, St. Paul. 539 pp.

Ghini, R. & Bettiol, W., 1991. Coletor solar para desinfestaçao de substratos. Summa Phytopathologica 17: 281–286.

Ghini, R., Bettiol, W., Armond, G., Braga, C.A.S. & Inomoto, M.M., 1991a. Utilization of solar collector for treatment of plant growth substrates. Abstracts of the XIIth International Plant Protection Congress, Rio de Janeiro, Brazil, 11–16 August 1991.

Ghini, R., Inomoto, M.M., Armond, G. & Braga, C.A.S., 1991b. Utilização de coletor solar para controle de *Meloidogyne arenaria*. XV. Congresso Brasileiro de Nematologia, Botucatu, Brazil 18–22 February 1991. p. 27.

Katan, J., 1987. Soil solarization. In: J. Chet (Ed.), Innovative approaches to plant disease control. J. Wiley & Sons, New York. p. 77–105.

Komada, H., 1975. Development of a selective medium for quantitative isolation of *Fusarium oxysporum* from natural soil. Review of Plant Protection Research 8: 114–125.

Pullman, G.S., DeVay, J.E. & Garber, R.H., 1981. Soil solarization and thermal death: a logarithmic relationship between time and temperature for four soil-borne plant pathogens. Phytopathology 71: 959–964.

Tuite, J., 1969. Plant pathological methods – Fungi and bacteria. Burgess Publishing Company, Minneapolis. 239 pp.