Nematol. medit. (1990), 18: 261-264.

Istituto di Nematologia Agraria, C.N.R. — 70126 Bari, Italy

# COMBINED EFFECT OF SOIL SOLARIZATION AND 1,3 DICHLOROPROPENE FOR CONTROL OF *HETERODERA CAROTAE*

by
N. GRECO, T. D'ADDABBO, A. BRANDONISIO and A. ZWEEP[1]

**Summary.** In Italy, the effect of 4, 6, and 8 week soil solarization periods on the control of *Heterodera carotae* on carrot was compared with that of the same treatments combined with fumigation with 100 l or 250 l/ha of 1,3 D. Soil solarization alone was not satisfactory since 51-77% of *H. carotae* eggs remained viable, but when combined with 100 l of 1,3 D/ha the nematode population was almost eradicated, as it was with fumigation with 250 l of 1,3 D/ha. Yields increased 6-6.5 times in the plots treated with 1,3 D alone or combined with soil solarization, but no increases were recorded in plots that were solarized only. The soil population of *H. carotae* declined in all plots.

The carrot cyst nematode, *Heterodera carotae* Jones, causes severe yield losses of carrots in Italy and other european countries (Greco, 1986). Control of this nematode with nematicides is effective (Greco and Lamberti, 1977; Oudinet *et al.*, 1962; Greco *et al.* 1984), but is costly and may cause problems of residues and pollution. Crop rotation could be effective but is difficult to operate where carrots are cultivated very frequently on the same land, as occurs in several areas in Italy. Further, no carrot cultivar resistant to *H. carotae* is available. Recently soil solarization has shown promise for the control of several soil-borne pathogens in warm areas (Katan, 1987), including nematodes (Grinstein *et al.*, 1979; Siti *et al.*, 1982; Porter and Merriman, 1983; Stapleton and DeVay, 1983; Cartia *et al.*, 1988). Attempts to control *H. carotae* by soil solarization have indicated that this can be satisfactory when soil population densities of the nematode do not exceed 20 eggs/g soil (Greco *et al.*, 1985). The efficacy of soil solarization, however, is limited to about the top 25 cm soil. To ascertain the possibility of controlling the nematode at greater depths, an experiment was undertaken in 1987-88 to investigate the effect of soil solarization combined with fumigation with a low rate of 1,3 dichloropropene.

## Materials and methods

A sandy soil, heavily infested with *H. carotae* (45 eggs/g soil), was selected at Margherita di Savoia (Province of Foggia) and divided into 54 plots of 4 $m^2$ (m 2x2) each, spaced 50 cm apart. There were nine treatments of soil solarization alone or in combination with 1,3 dichloropropene (Table I) replicated six times in a randomized block design. Non-treated plots served as controls. The fumigant was applied with a hand injector on 16 June, 1987, at 20 cm depth in the plots fumigated with 250 l/ha of 1,3 D and at 35 cm depth in those treated with 100 l/ha of the fumigant. After treatments the plots were lightly consolidated and irrigated to limit the escape of the fumigant. All the plots were irrigated abundantly on 26 June and those to be solarized were mulched with transparent 50 µm thick polyethylene film for the different experimental periods (Table I).

Soil samples, each a composite of 80 cores and averaging 2 kg, were collected from the central square metre of each plot before sowing (21 August 1987) and again after harvest of the carrot crop (12 January 1988), using an auger 30 cm long and 1 cm diameter. About 3 g of feeder roots were also collected from the same central areas at harvest.

The effect of the treatments on egg viability was assessed by extracting cysts, with a Fenwick can from 200 $cm^3$ soil, from soil samples collected before sowing. The cysts were incubated at 20° C for 14 weeks in 30 day old carrot root leachate (Greco *et al.*, 1982). Emerging juveniles were counted weekly when the hatching solution was renewed. Unhatched eggs were also counted to ascertain total numbers of eggs within cysts at the beginning of the hatching test. Numbers of juveniles emerged from cysts were expressed as per cent of those emerged from the same number of cysts from the control plots.

Soil samples collected after harvest were air dried and cysts extracted from 200 g soil using the Fenwick can, separated from debris by the ethanol flotation method (Sein-

[1] We wish to thank Mr. P. De Cosmis for technical assistance.

horst, 1974), substituting the alcohol with a 1.25 sp. g. magnesium sulphate solution, crushed according Bijloo's modified method (Seinhorst and Den Ouden, 1966) and their egg content determined. Comparison between the nematode populations observed before sowing and after harvest of the carrots was made by the Student t test.

Nematodes were extracted from the feeder roots by the Coolen's method (Coolen, 1979) and counted.

Carrot cv 92 was sown on 21 August 1987 and harvested on 12 January 1988, when total plant and tap root weights were recorded. After sowing, carrots were irrigated until the end of October and received normal maintenance until harvest.

Data were statistically analyzed and means compared according to Duncan's multiple range test. Soil temperatures at 10, 20 and 30 cm depth were continuously recorded in a mulched and in a non mulched plot located near the experiment field.

## Results

Mean maximum temperatures peaked from mid July onwards. They were in the range 45-46, 37-38, and 34-35° C at 10, 20, and 30 cm depth, respectively, in the mulched plots, with an increase over the non mulched plots of about 10, 7, and 5° C at 10, 20, and 30 cm depth, respectively (Fig. 1).

Although only 51% of the eggs hatched in the plots solarized for 8 weeks, this treatment was not considered to be satisfactory (Table I). Good control of the nematode was, however, obtained with 100 l of 1,3 D/ha injected 35 cm deep, while 250 l of 1,3 D/ha and combinations of 100 l of 1,3 D/ha with 4-8 week periods of soil solarization nearly eradicated *H. carotae* in the top 30 cm soil (Table I).

TABLE I - *Effect of soil solarization and 1,3 D on survival of* Heterodera carotae *and soil population densities.*

| Treatments | % of eggs hatched | Soil population densities (eggs/g) | |
|---|---|---|---|
| | | before sowing | after harvest |
| Sol. 4 weeks | 71.5 c C | 46 | 21**(1) |
| » 6 » | 77.2 c C | 63 | 26** |
| » 8 » | 51.0 b B | 48 | 25* |
| » 4 + 1,3 D 100 l/ha | 0.5 a A | 35 | 26** |
| » 6 + » » » | 0.2 a A | 32 | 20* |
| » 8 + » » » | 0.1 a A | 40 | 17** |
| 1,3 D 250 l/ha | 0.5 a A | 41 | 18* |
| Untreated control | 100.0 d D | 50 | 10** |
| 1,3 D 100 l/ha | 6.5 a A | 48 | 14** |

Data on the same column followed by the same letters are not statistically different, according to Duncan's multiple range test: capital letters for P = 0.01, small letters for P = 0.05.
(1) Significantly different at P = 0.05 (*) or P = 0.01 (**) levels, according to Student *t* test.

No significant differences in the soil population densities of *H. carotae* were observed among the plots of different treatments before treating and after harvest of carrots (Table I). However, significant decline of the nematode populations occurred in all plots after harvest of carrots, thus confirming previous findings (Greco *et al.*, 1990). The numbers of eggs and juveniles of the nematode in the feeder roots, were greater in control and solarized plots, intermediate in the plots fumigated with 100 l of 1,3 D/ha at 35 cm depth and smaller, but not significantly less, in those in which the same rate of the fumigant was combined with soil solarization (Table II), or injected alone at the rate of 250 l/ha. Numbers of other juvenile stages and of females and cysts of the nematode in the roots showed the same pattern, but differences among these treatment groups were much more marked.

Carrot yields greatly increased in all fumigated plots (Table III), but the largest yield was obtained from plots in

TABLE II - *Effect of soil solarization by polyethylene mulching and 1,3 D on the numbers of different stages of* H. carotae *in 1 g of carrot feeder roots at harvest.*

| Treatments | Eggs and J2 | Other juveniles | Females and cysts |
|---|---|---|---|
| Sol. 4 weeks | 575 c B | 214 c C | 93 cd BC |
| » 6 » | 661 c B | 417 d C | 182 d C |
| » 8 » | 759 c B | 355 cd C | 174 d C |
| » 4 + 1,3 D 100 l/ha | 81 ab A | 10 b B | 23 ab AB |
| » 6 + » » » | 72 ab A | 10 b B | 11 a A |
| » 8 + » » » | 55 a A | 8 b B | 11 a A |
| 1,3 D 250 l/ha | 81 ab A | 9 b B | 26 ab AB |
| Untreated control | 447 c B | 741 d C | 54 bc BC |
| 1,3 D 100 l/ha | 132 b A | 83 a A | 52 bc BC |

Data followed by the same letters on the same column are not statistically different from each other according to Duncan's multiple range test: capital letters for P = 0.01, small letters for P = 0.05.

TABLE III - *Effect of soil solarization by polyethylene mulching and 1,3 D on carrot yield.*

| Treatments | Marketable tap roots (kg/m$^2$) |
|---|---|
| Sol. 4 weeks | 1.3 c B |
| » 6 » | 0.7 c B |
| » 8 » | 0.7 c B |
| » 4 + 1,3 D 100 l/ha | 6.8 a A |
| » 6 + » » » | 6.6 ab A |
| » 8 + » » » | 6.5 ab A |
| 1,3 D 250 l/ha | 6.2 ab A |
| Untreated control | 0.9 c B |
| 1,3 D 100 l/ha | 5.8 b A |

Data followed by the same letters are not statistically different from each other according to Duncan's multiple range test: capital letters for P = 0.01, small letters for P = 0.05.

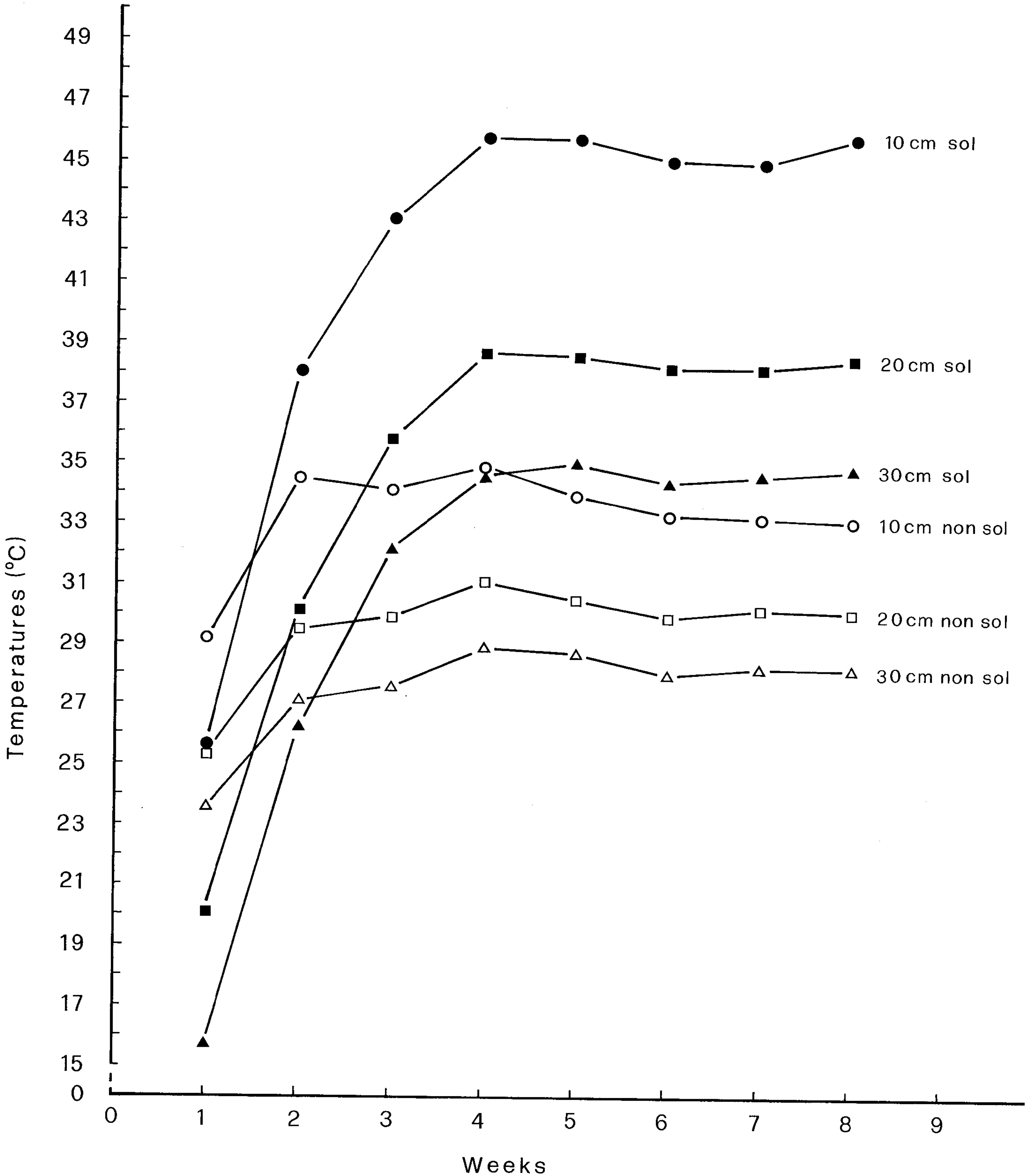


Fig. 1 - Mean maximum soil temperatures recorded from 26 June to 22 August 1987, at different depths in solarized (sol) and non solarized (non sol) plots, at Margherita di Savoia.

which soil solarization was combined with 1,3 D (6.5-6.8 kg marketable tap roots/$m^2$). Yields were negligible (0.7-1.3 kg tap roots/$m^2$) in the solarized (only) and control treatments.

## Discussion

In this trial soil solarization was not as effective as in previous experiments (Greco *et al.*, 1985; Greco and Brandonisio, 1990). Probably this was due to a strong wind which made the plastic film dirty, thus reducing the capture of solar energy. Good nematode control was achieved with 250 l of 1,3 D/ha. Application of 100 l of 1,3 D/ha at 35 cm depth was also satisfactory. Although the combination of fumigation with 100 l 1,3 D/ha with 4-8 week solarization periods increased the control of *H. carotae* and the yield of carrots, the results did not differ from those of 1,3 D alone at 100 or 250 l/ha. Therefore more investigations are required to ascertain the effectiveness of these combined methods of control. Probably soil fumigation at a rate of less than 100 l 1,3 D/ha, when combined with soil solarization, would provide satisfactory results. Our experiment has confirmed once again that in southern Italy harvesting carrot crops early in the winter, when most of the nematode specimens within the roots are young stages, reduces the nematode soil population and, therefore, is recommended as a suitable and effective practice in infested areas.

## Literature cited


Cartia G., Greco N. and Cipriano T. 1989 - Effect of soil solarization and fumigants on soil-borne pathogens of pepper in greenhouse. Proc. Third International Symposium on Soil Disinfestation, Leuven, Belgium, 26-30 September 1988. *Acta Horticulturae*, *255*: 111-115.

Coolen W.A., 1979 - Methods for the extraction of *Meloidogyne* spp. and other nematodes from roots and soil. *In*: Root-Knot Nematodes (*Meloidogyne* species) Systematics, Biology and Control (Lamberti F. and Taylor C.E. eds), Academic Press, London, pp. 317-329.

Greco N., 1986 - The carrot cyst nematode. *In*: Cyst Nematodes (Lamberti F. and Taylor C.E. eds), Plenum Press, New York, pp. 333-346.

Greco N. and Lamberti F., 1977 - Ricerca di dosi ottimali di alcuni nematocidi per la lotta contro *Heterodera carotae*. *Nematol. medit.*, *5*: 25-30.

Greco N., Brandonisio A. and De Marinis G., 1982 - Investigation on the biology of *Heterodera schachtii* in Italy. *Nematol. medit.*, *10*: 201-214.

Greco N., Brandonisio A. and Elia F., 1984 - Effetto di varie dosi di nematocidi fumiganti sulla mortalità delle uova di *Heterodera carotae*. *La Difesa delle Piante*, *7*: 331-338.

Greco N., Brandonisio A, and Elia F., 1985 - Control of *Ditylenchus dipsaci*, *Heterodera carotae* and *Meloidogyne javanica* by soil solarization. *Nematol. medit.*, *13*: 191-197.

Greco N. and Brandonisio A., 1990 - Effect of soil solarization and SIP 5561 on *Heterodera carotae* and *Ditylenchus dipsaci* and on yield of carrot and onion. *Nematol. medit.*, *18*: 189-193.

Grinstein A., Orion D., Greeberger A. and Katan J., 1979 - Solar heating of the soil for the control of *Verticillium dahliae* and *Pratylenchus thornei* in potatoes. *In*: Soil-borne Plant Pathogens (Schippers B. and Gams W. eds), Academic Press, London, pp. 431-439.

Katan J., 1987 - Soil solarization. *In*: Innovative Approaches to Plant Disease Control (Ilan Chet ed.), J. Wiley and Sons, New York, pp. 77-105.

Oudinet R., Cherblanc G., Schneider J. and Deloustal J., 1962 - Quatre années d'essais de traitements contre le nématode de la carotte. *Phytoma*, *14(135)*: 11-15.

Porter I.J. and Merriman P.R., 1983 - Effect of solarization of soil on nematode and fungal pathogens at two sites in Victoria. *Soil Biol. Biochemistry*, *15*: 39-44.

Seinhorst J.W., 1974 - Separation of *Heterodera* cysts from dry organic debris using ethanol. *Nematologica*, *20*: 367-369.

Seinhorst J.W. and Den Ouden H., 1966 - An improvement of Bijloo's method for determining the egg content of *Heterodera* cysts. *Nematologica*, *12*: 170-171.

Siti E., Cohn E., Katan J. and Mordechai M., 1982 - Control of *Ditylenchus dipsaci* in garlic by bulb and soil treatments. *Phytoparasitica*, *10*: 93-100.

Stapleton J.J. and DeVay J.E., 1983 - Response of phytoparasitic and free-living nematodes to soil solarization and 1,3 dichloropropene in California. *Phytopathology*, *73*: 1429-1436.


Accepted for publication on 12 October 1990.