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**EFFECTIVENESS OF SOIL SOLARIZATION COMBINED
WITH A PLANT-DERIVED FORMULATION FOR THE CONTROL
OF THE ROOT-KNOT NEMATODE *MELOIDOGYNE INCognITA*
(KOFOID ET WHITE) CHITW. IN GREENHOUSE TOMATO**

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Soppelsa O., Giacometti R., d'Errico G., D'Alessio M. – Effectiveness of soil solarization combined with a plant-derived formulation for the control of the root-knot nematode *Meloidogyne incognita* (Kofoid et White) Chitw. in greenhouse tomato.

The effectiveness of soil solarization, alone or in combination with oxamyl or a plant-derived formulation (a mixture of aqueous extracts of *Quillaja saponaria* Molina, *Yucca schidigera* Roezl and *Tagetes* spp., 80, 10 and 10%, respectively), for the control of the root-knot nematode *Meloidogyne incognita* (Kofoid et White) Chitw. was assessed in a greenhouse trial on tomato at Battipaglia (province of Salerno), Southern Italy. The combination of soil solarization with the plant-derived formulation resulted in a greater nematode suppression than application of single treatments. Combining soil solarization with the plant-derived formulation resulted in tomato yield and fruit size similar to that of the combination of soil solarization with oxamyl. Therefore the combination of soil solarization with plant-derived formulations may represent a sustainable nematode control strategy, as safe for human health and environment.

KEY WORDS: soil solarization, plant extracts, oxamyl, *Meloidogyne incognita*, tomato crop.

INTRODUCTION

Throughout the past decades, control of plant parasitic nematodes in protected vegetable systems has been traditionally based on soil treatments with fumigants, such as methyl bromide or 1,3 dichloropropene (1,3 D). Nematode control strategies in integrated and organic cropping systems have been complicated by the complete ban of the above fumigants and limitation of the still available chemicals to conventional cropping systems. The reduction in the number of chemical nematicides available is stimulating researches on non-chemical alternative of control, among which soil solarization and treatments with plant-derived formulations (CHITWOOD, 2002; D'ADDABBO *et al.*, 2010).

Soil solarization alone was often found to be not fully effective for nematode control (KATAN, 1981; COLOMBO and NUCIFORA, 2000) and, therefore, was frequently suggested in combination with non-fumigant nematicides such as oxamyl and fenamiphos, in order to enhance its effectiveness (COLOMBO *et al.*, 1995; LAMBERTI *et al.*, 2000; GRECO and CARTIA, 2000; RAGOZZINO *et al.*, 2000; CATALDI *et al.*, 2005). Increasing reduction of chemicals available is leading also to the integration of soil solarization with alternative control means such as plant-derived formulations (COLOMBO *et al.*, 2005), organic amendments (BASILE *et al.*, 2004) and micro-organisms (D'ERRICO and CAPRIO, 2004; COLOMBO *et al.*, 2010).

Aqueous extracts of quillay (*Quillaja saponaria* Molina) and their commercial formulations showed some nematicidal activity and a good bio-stimulating effect on

crops in field trials (D'ADDABBO *et al.*, 2005, 2008; CURTO *et al.*, 2007) and in laboratory tests (GIACOMETTI *et al.*, 2010). Therefore the effectiveness of combination of soil solarization with a commercial quillay extract-based formulation to control the root-knot nematode *Meloidogyne incognita* (Kofoid et White) Chitw. was assessed in a greenhouse experiment on tomato, *Lycopersicon lycopersicum* (L.) Karsten ex Farw.

MATERIALS AND METHODS

The trial was conducted in an unheated, 432 m² wide (m 14.4 × m 30), polyethylene greenhouse at Battipaglia (province of Salerno), with a soil severely and rather uniformly infested by *M. incognita*. On 29th July 2009, the soil was ploughed and divided in twenty-four 18 m² (m 3.6 × m 5) plots, arranged according to a randomized block design with four replicates per treatment. Six treatments were compared. They were soil solarization alone, liquid oxamyl (10% a.i.) at 50 L ha⁻¹ rate, a commercial formulation of plant extracts (80% *Quillaja saponaria*, 10% *Yucca schidigera* Roezl and 10% *Tagetes* spp.) at 45 L ha⁻¹, and soil solarization combined with oxamyl or the above mentioned plant-derived formulation, untreated plots used as a control.

The plots to be solarized were ploughed, levelled out, irrigated to field capacity and then covered with a 0.05 mm thick transparent polyethylene film. Soil solarization was carried out from 18th June to 28th July 2009. Dose of oxamyl was splitted in five 10 L ha⁻¹ applications in

acidified water (pH 5.5), at transplant (30th July) and at 15 days intervals. Dose of the plant-derived formulation was splitted in two applications, the former (30 L ha⁻¹) at transplant and the latter (15 L ha⁻¹) 30 days after. Both liquid formulations were applied through a drip tape with self-blocking and self-compensating drippers at a 2 L ha⁻¹ flow rate placed at 35 cm intervals. The drip tape, in each plot, was laid down next and parallel to irrigation tape and was closed by a cap at one extremity whereas the opposite extremity was connected to a pump injecting the treatment solutions.

On July 30th 2009, one-month old seedlings of tomato cv. Incas (resistant to *Fusarium* F1 and F2 and *Verticillium* wilt), previously raised in polystyrene poly-pots, were transplanted and spaced 1.20 m between the rows and 0.35 m within the row, at a density of 43 plants per plot (23-24,000 plants ha⁻¹).

Irrigation, fertilization and disease and pest control were provided throughout the tomato crop cycle, according to usual agricultural practices in the area.

Nine small soil samples were collected from each plot and thoroughly mixed in a unique bulk sample per plot before the soil solarization (June 18th 2009) and at the end of the crop (January 20th 2010). A 10 cm³ sub-sample was used to extract migratory stages (second stage juveniles and males) of *M. incognita*, according to the cotton-wool filter method (OOSTENBRINK, 1960). Yield per plant was recorded at four harvests (September 27th, October 26th, December 2nd 2009 and January 13th 2010), when number and weight of tomato fruits were recorded on ten plants from the central part of the middle row of each plot. Root galling index was recorded on the same ten plants, according to a 0-5 rating scale (0 = roots completely free of galls and 5 = roots heavily galled with large galls) (LAMBERTI, 1971). The average galling index (AGI) was calculated for each treatment according to the following formula:

$$AGI = \frac{\sum \text{root galling score of the sample plant}}{\text{Number of sample plants}}$$

All data were subjected to analysis of the variance (ANOVA) and means compared by Student-Newman-Keuls Test at $P = 0.05$.

RESULTS AND DISCUSSION

The initial population density of *M. incognita* was high and uniformly distributed, with no significant differences

among the plots (Table 1). At the end of the experiment, soil nematode density in the untreated plots was lower than before transplant, probably due to the cold winter temperatures that reduced the nematode reproduction. However, the final nematode density was always significantly lower in all treated plots than in the untreated control. The lowest nematode population was observed in the plots treated with soil solarization combined with oxamyl or the plant-derived formulation, with no significant difference between them. However, only the combination of soil solarization with oxamyl resulted in a nematode density significantly lower than soil solarization alone. Single application of plant-derived formulation resulted in a final nematode population significantly higher than in plots treated with both oxamyl and soil solarization alone. A similar trend was observed for root gall index (Table 1).

All treatments significantly increased tomato yield (Table 2). The best performance was provided by soil solarization integrated with either oxamyl or the plant-derived formulation, with no significant difference among them. Number and weight of tomato fruits per plant were significantly higher in all treated plots than in the untreated control (Table 2). The number of fruits per plant did not significantly differ among the treatments, whereas fruit weight in the plots where soil solarization was combined with oxamyl or the plant-derived formulation was significantly higher than in the plots receiving the other treatments.

This study has confirmed that single treatments with soil solarization, oxamyl or plant-derived formulations do not provide satisfactory control of root-knot nematodes in presence of a high initial nematode infestation. The nematicidal effectiveness is increased when oxamyl or the plant-derived formulation were combined with soil solarization. The combined treatments increased also crop yield and improved fruit quality, due not only to nematode suppression but also to an increased plant growth stimulation (SCHOLTE and JACOB, 1983; HAFIZ and SUNDARARAJ, 2000; RUSSO *et al.*, 2004; D'ADDABBO *et al.*, 2005; CURTO *et al.*, 2007; D'ADDABBO *et al.*, 2008; D'ERRICO *et al.*, 2011). The biostimulating effect of quillay extract, the main component of the tested plant-derived formulation, was found to be correlated to the high content of saponins acting as plant growth regulators (KINTIA, 2004) and increasing plant resistance to biotic and abiotic stress factors (PAPADOPOLOU *et al.*, 1999).

Therefore soil solarization combined with a plant-

Table 1 – Effects of the different treatments on population density and root gall index of the root-knot nematode *Meloidogyne incognita*.

Treatment	Nematode population (Juveniles and males 10 cm ³ soil)		Root gall index	
	Initial (18 th June 2009)	Final (20 th January 2010)		
Soil solarization	486 a	107 b	2.4	b
Oxamyl	537 a	93 b	2.3	b
Plant-derived formulation	609 a	194 c	2.8	b c
Soil solarization + oxamyl	521 a	19 a	0.7	a
Soil solarization + plant-derived formulation	507 a	67 a b	1.6	a b
Untreated control	617 a	259 d	3.2	c

Means in the same column sharing a common letter are not significantly different according to Student-Newman-Keuls Test at $P = 0.05$.

Table 2- Effects of the different treatments on tomato yield and fruit quality: total yield, number of fruits per plant and fruit weight, as average of four harvests.

Treatment	Yield (kg per plant)	Fruits (per plant)	Fruit weight (g)
Soil solarization	4.1 b	47 a	86.1 b c
Oxamyl	4.0 b	46 a	87.8 b c
Plant-derived formulation	4.2 b	44 a	94.3 b
Soil solarization + oxamyl	4.8 a	48 a	100.4 a
Soil solarization + plant-derived formulation	4.6 a	47 a	99.6 a
Untreated control	3.1 c	39 b	79.8 c

Means in the same column sharing a common letter are not significantly different according to Student-Newman-Keuls Test at $P = 0.05$.

derived formulation seems to be suitable for sustainable nematode management strategies, as it is effective and safe to the environment and the consumer. The control of different target pests in addition to nematodes should also be considered as an additional value of both soil solarization and the two tested formulations.

RIASSUNTO

EFFICACIA DELLA SOLARIZZAZIONE COMBINATA AD UNA MISCELA DI ESTRATTI VEGETALI PER IL CONTROLLO DEL NEMATODE GALLIGENO MELOIDOGYNE INCognITA (KOFOID ET WHITE) CHITW. SU POMODORO

Il lavoro riporta i risultati di una prova di lotta condotta su pomodoro cv. Incas in una serra non riscaldata, con copertura in polietilene, sita nella Piana del Sele (provincia di Salerno), per verificare l'efficacia per il controllo del nematode galligeno *Meloidogyne incognita* della integrazione della solarizzazione del terreno con un formulato commerciale a base degli estratti acquosi di *Quillaja saponaria* (80%) *Yucca schidigera* (10%) e *Tagetes* spp. (10%). Tale combinazione è stata messa a confronto con i trattamenti impiegati singolarmente e con un trattamento con lo standard chimico di riferimento oxamyl. Il terreno non trattato è stato assunto come testimone della prova.

L'integrazione della solarizzazione con la miscela di estratti vegetali ha fornito una risposta tecnica molto valida e più performante rispetto alla sola solarizzazione. L'abbinamento della solarizzazione con la miscela di estratti di piante ha fatto registrare produzioni pari a quella ottenuta con lo standard chimico oxamyl, grazie ad una maggiore pezzatura delle bacche ma non di un incremento del loro numero. L'applicazione integrata della solarizzazione con formulati di origine vegetale sembra costituire una valida strategia di difesa a ridotto impatto sull'ambiente e sulla salute umana.

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