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SUSTAINABLE AGRICULTURE IN THE LIGHT OF CLIMATE CHANGE: EFFECT OF TEMPERATURES AND EXPOSURE TIMES ON THE MORTALITY OF THE DAGGER NEMATODE *Xiphinema index*

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Summary. The gradual rising of average temperatures due to climate change are increasing the problem caused by phytoparasitic nematodes. To predict the effect of soil solarization on *Xiphinema index*, an experiment was undertaken to investigate the effect of different temperatures (from 25 to 42.5 °C) and exposure times (from 2 up to 2,048 hrs) on the mortality of the nematode. Surviving nematodes were expressed as percentages of those surviving at 25 °C. The differences to 100 were considered as mortality percentages. To kill 50% of nematode population were necessary 180, 34, 4.7 and 2.5 hours at 35, 37.5, 40 and 42.5 °C, respectively. Data fitted the model $P_t=P_o10^{-\Delta t/(q+mT)}$ reported in literature.

Keywords: *Longidoridae, nematode control, soil solarization, lethal temperatures*

Introduction. *Xiphinema index* Thorne & Allen is one of the most important nematode pests of grapevine. Besides causing direct damage by its feeding on the plant roots, this nematode is the natural vector of grapevine fanleaf virus (GFLV). Due to the economic importance of grapevine world-wide, biology, ecology and ability of this species to transmit GFLV were extensively investigated. Nematicides are widely used to control the nematode. However, these chemicals are expensive and pollutant. Therefore, alternative strategies, preferably environmentally friendly, are required for the control of plant parasitic nematodes, including *X. index*. Among them soil solarization is pratical, economic and feasible in warm areas. This method of control has

shown promise against several soil-borne plant pathogens and parasites, including nematodes (Lamberti & Greco, 1991). It is a relatively slow process (4-8 weeks). Although the temperature increase in the soil covered with plastic film can kill the nematodes in a relatively short time (1-2 hours) in the very top soil layers (5-6 cm), in deeper soil layers the temperature increase is less and can be lethal to nematodes only if it last for several weeks. To predict the efficacy of soil solarization against a given nematode species in a certain area or to estimate the duration of the soil solarization process to reduce nematode population to no damaging levels, information is required on the relationship between mortality of nematodes and temperatures x exposure times. Sasanelli and Greco (2000) derived a mathematical model to relate nematode populations with exposure times to a range of temperatures describing this relationship. Therefore, an investigation was undertaken to: i) assess the effect of a range of exposure times at different temperatures on *X. index*; ii) ascertain whether the mentioned model can also be adapted to this nematode; iii) calculate the parameters in this model for *X. index*.

Materials and methods. The *X. index* population used in the study was from a sandy soil collected in a vineyard at Palagiano, Province of Taranto (Apulia region, Southern Italy) (40°57'09''N, 17°02'33''E).

Effect of different combinations of temperatures x exposures

The effect on the nematode of temperatures, which did not kill all nematodes after two hours exposure, was investigated for up an exposure time of 2,048 hours. Plastic cups of 250 mL were filled with *X. index* infested soil (averaging 65 nematodes/100 mL) and the soil moisture content was adjusted to field capacity (25% of dry soil weight). The cups were tightly closed in plastic bags and transferred to thermostats maintained at 25, 30, 32.5, 35, 37.5, 40, 42.5 °C. Each temperature was tested at the following exposure times: 2, 4, 8, 16, 323, 64,128, 256. 512, 1,024 or 2,048 hours. There were four cups for each combination temperature x exposure time. The exposure times were considered to have begun when the soil temperature within the cups was reached. At the end of each exposure time, the nematodes were extracted from soil by Cobb's sieves and Bearman's funnels techniques and counted. At the end of the experiment, cumulative numbers of surviving nematodes were expressed as percentages of those surviving at 25 °C and at the same exposure time. The difference to 100 of these percentages were considered as percentages of mortality. Data of nematode mortalities, at each temperature, comprised

between the minimum exposure causing nematode death and the maximum exposure to achieve nearly complete (not 100%) nematode kill were subject to probit analysis to estimate values of lethal times (LT_{50}) (Finney, 1971). To predict the efficacy of a method to control nematodes, information is necessary on the relationship between the rates of the control method and the nematode mortalities that can be achieved. Therefore, to evaluate the performance of soil solarization in controlling *X. index*, the model proposed by Sasanelli and Greco (2000)

$$P_t = P_o\ 10^{-\Delta t/(q+mT)} \text{ (eq.1)},$$

describing the relationship between nematode survival and exposure times to different temperatures, is necessary. The model based on the statement of Brown and Melling (1971) that during heat sterilization the Log_{10} of microrganisms survival x exposure time at a constant temperature is a linear relationship.

In the eq. 1, P_t is the nematode population after Δt exposure time in hours, P_o is the nematode population before heat treatment; Δt is the exposure time above t_t (defined as the threshold exposure time x temperature below which the nematode is not killed), q and m are the known term (y-axis intercept) and the angular coefficient, respectively, of the straight line that represents the function α = f (T); T is the temperature in °C to which the nematode population is exposed. The value of α is defined as nematode decimal reduction time that corresponds to the exposure time, above the threshold time at a constant T, required to reduce P_o to 1/10 (Sasanelli and Greco, 2000). The value of α is assumed to be constant for each nematode species and temperature and therefore α = f (T).

To calculate α, for each temperature that reduced *X. index* survival, Log_{10} of per cent survival, observed at exposure times higher than exposure times to a fixed T up to which no survival reduction occurred, were plotted against exposure times at a given T and a straight line was fitted according to Sasanelli and Greco (2000).

The equation α = f (T) was derived plotting α values against temperature. In this obtained equation, the y intercept and the slope correspond to q and m in eq. 1.

Therefore, Log_{10} of *X. index* survival observed in the experiment was used to characterize the relationship between nematode survival as affected by a range of temperatures to calculate q and m in eq. 1.

Results and disscusions. No mortality of *X. index* was observed when the nematode was exposed for two hours at 20-37.5 °C.

Effect of different combinations of temperatures x exposures

In the experiment for all the tested exposure times (2-2,048 hours) no mortality was observed at 25 °C and it was negligible at 30 °C. The suppressive effect of the heat started clearly at 32.5 °C after 32 hours exposure time and the mortality of 50% was noted between 1,024 and 2,048 hours (Tab. 1). At higher temperatures the increase of mortality was noted at lower exposure times which ranged between 2 and 16 hours for 42.5 and 37.5 °C, respectively. Probit analysis was conducted, therefore, only on data for temperatures ≥32.5 °C. Exposure times required to kill 50% of *X. index* population were 1,386, 180, 34, 4.7 and 2.5 hours at 32.5, 35, 37.5, 40 and 42.5 °C, respectively (Fig. 1). A ninety per cent mortality could be reached after 251,600, 1,131, 1,932, 22 and 4.1 hours exposure at the same above indicated temperatures (Table 2). Data fitted the model $P_t = P_o \ 10^{-\Delta t/(q+mT)}$ for q=11.88 and m=-0.27 expecially for temperatures higher than 37.5 °C (Tab. 2).

Table 1. Percentages of *Xiphinema index* survival after exposures of different duration to different temperatures.

Temp. (°C)	Exposure (hours)										
	2	4	8	16	32	64	128	256	512	1,024	2,048
25	100	100	100	100	100	100	100	100	100	100	100
30	100	99	98.6	100	96.8	99	100	99.5	98.7	98.7	98.7
32.5	100	100	94	100	91.7	70.7	67.5	63.5	59.6	54.4	49.2
35	100	94.7	100	94.6	92.7	83.1	41.3	40.9	29.5	51.6	49.2
37.5	80.1	72.3	76.6	61.5	49.5	38.1	26.7	25.9	25	54.7	15.4
40	76.1	50.5	40.8	9.4	10.1	0	0.5	0	0	0	0
42.5	76.6	4.4	0.5	0.5	0	0	0	0	0	0	0

Table 2. Exposure times required to kill 50, 60, 70, 80 and 90% *Xiphinema index* population at different exposure times according to probit analysis and the model $P_t = P_o\ 10^{-\Delta t/(q+mT)}$.

% Mort.	Temperatures (°C)									
	32.5		35		37.5		40		42.5	
	Probit	Model	Pro-bit	Mo-del	Probit	Mo-del	Probit	Mo-del	Probit	Mo-del
50	1,386*	1,101	180	172	34	27	4.7	4.2	2.5	2.6
60	3,827	2,202	258	297	75	40	6.3	5.4	2.7	2.9
70	11,466	5,379	379	597	175	66	9	7	3	3.3
80	42,088	18,945	601	1,598	482	135	13	11	3.4	3.8
90	251,600	163,008	1,131	4,306	1,932	455	22	24	4.1	5.1
R^2	0.631	0.588	0.964	0.772	0.693	0.710	0.886	0.803	0.943	0.904

*Values are rounded up or down.

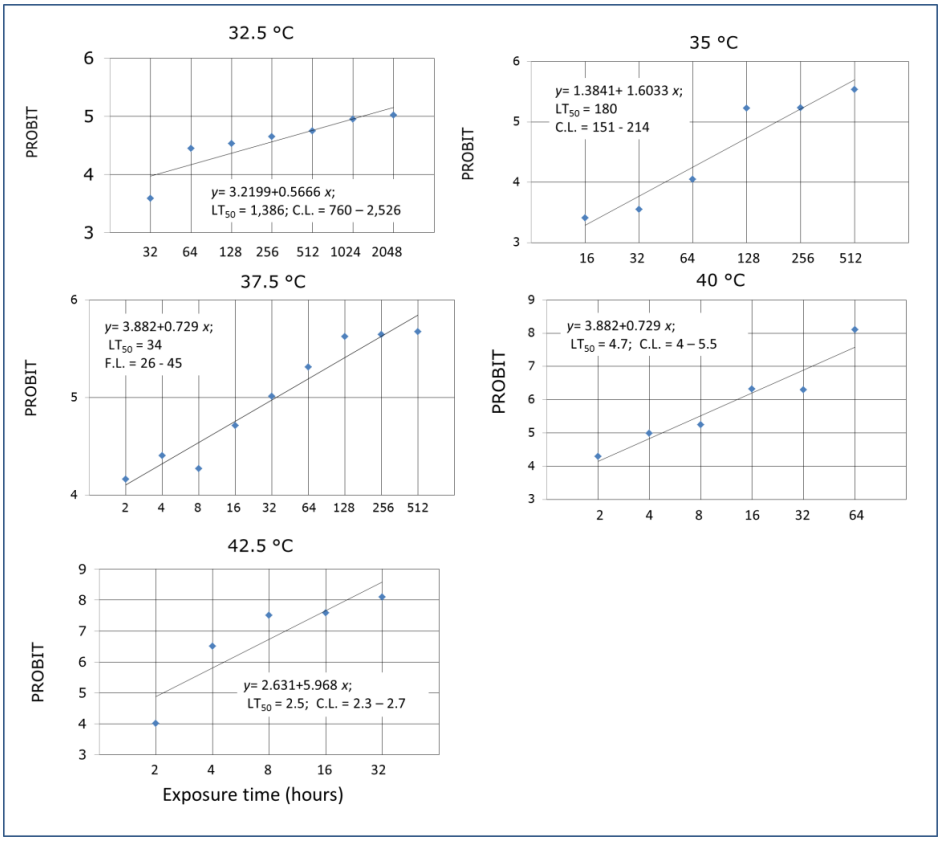


Fig. 1. Relation between exposure time and probit mortality of *Xiphinema index* in soil at 32.5, 35, 37.5, 40 and 42.5 °C; LT_{50} = Lethal time 50 (hours) (C.L.= confidence limit).

Conclusions. Nematode species investigated in this study showed to be very sensitive to temperature variations and, therefore, the dagger nematode *X. index* is expected to be heavily affected by global warming, as reducing its widespread and effects on grapewine.

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