RELATIVE LETHAL DOSE, A TIME-TEMPERATURE MODEL FOR RELATING SOIL SOLARIZATION EFFICACY AND TREATMENT DURATION FOR NEMATODE CONTROL

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Much of the previous soil solarization research has involved efficacy assessments of soilborne pest population control correlated with crop growth, development and or yield responses. Much less research has been committed to quantitative assessments of cumulative impacts of sublethal temperatures within ambient environments. For example, Heald and Robinson (1987), using the concept of a death map, were able to show a close relationship between maximum daily temperature and mortality of soil populations of Rotylenchulus reniformis. This paper reflects yet another approach in developing a predictive system to assess nematode mortality and to signal an appropriate soil solarization termination period in the field. The objectives were a) to quantify the effects of temperature and exposure time on the root galling response of cucumber to the southern root knot nematode, *Meloidogyne* incognita; b) to test a predictive model, based on relative lethal dose (RLD), describing thermal induced mortality of M. incognita as a cumulative summary (chronology) of sublethal temperature stresses

MATERIALS & METHODS

Two series of laboratory experiments were conducted to evaluate thermal sensitivity of M. incognita In all laboratory studies, hot water baths were used to determine the lethal time-temperature relations of the southern root-knot nematode, Meloidgyne incognita Eggs and juveniles, collected from greenhouse tomato culture, were exposed for various periods in water baths maintained at constant or increasing temperatures between 25-55°C. Pyrex test tubes (20 X 150 mm) containing 3.5 ml of water were preheated by immersion in a thermostatically controlled water bath. After reaching the appropriate temperature, 1.5 ml of nematode inoculum (2000-35,000 eggs + juveniles/ml) were introduced into the preheated test tubes. During the course of each experiment at least five replicate tubes were removed from the water bath for each sampling interval and immediately transferred to another water bath of iced tap water (20°C). Sampling intervals were generally one minute increments and bracketed on anticipated thermal death times reported from previous research. After cooling heat treated eggs and juveniles were poured from the test tubes into a 1.25 cm deep planting holes within individual cells (4.75 cm x 4.75 cm) of a plastic transplant tray. A single cucumber seed was placed in each cell over the inoculum and covered with soil. Seed germination generally required 2-3 days. Nematode kill was exclusively assessed by monitoring subsequent galling of cucumber roots 45 days post planting.

In a second series of experiments, eggs and juveniles of M. incognita were subjected to a treatment regime of increasing temperatures. Prior to introduction of nematodes, water bath temperatures were stabilized at temperatures of either 38, 39,40,41,42,43,44,45,46, or 47°C. Immediately after introduction of the nematodes into the Preheated test tubes. the water bath temperature setting was dialed up to a new maximum temperature set point of either 50° or 55°C. Ensuing bath water temperatures increased over the next 20-25 minutes as an allometric function of time and temperature. As in previous experiments, replicate tubes were removed from the water bath at minute intervals, cooled and then transferred to soil within cells of the transplant trays. In this way nematodes could be subjected to a diverse family of heat treatment regimes of variable temperature and times of exposure, all of which, ultimately capable of providing a cumulatively lethal dose. An added benefit of such a treatment regime was that it resembled, in a chronologically compressed fashion, typical soil heat up curves within a solarized environment.

To examine the functional response of root galling with that of thermal stress history, a physiological time- degree minute model was used as a means of integrating temperature and time of exposure into a single dosage (CxT) predictor variable. Nematode degree minutes were calculated as area under curve (AUQ for single minute intervals. As with other AUC models, degree minutes for each heat treatment regime were then represented as the partial sum of average temperature at each minute interval midpoint In addition to the AUC model, relative lethal dose was also used to relate thermal induced mortality of *M.incognita* eggs and juveniles as a cumulative summary (chronology) of sublethal temperature stresses. RID

is simply defined as the single minute proportion of the total elapsed time required to kill *M. incognita* eggs and juveniles at a specified temperature. RLD is algebraically defined as the inverse of the thermal death time function. The partial sum of RLD over time provides a useful method for predicting times of thermal induced mortality

RESULTS

Root galling response was adequately described by a negative exponential function between time and constant temperature (fig. 1). Given the nonlinearity of the thermal death time function (fig. 1), separate and unique root gall response curves developed with the AUC model for each heat treatment regime (fig.2). Disparity between curves was inversely related to initial temperature setting of the water bath before dialing up to the higher equilibrated temperature setting of either 50° or 55°C. As initial temperature setting of the water bath increased, significantly fewer degree minutes were required to achieve an equivalent reduction of root galling between heat treatment regimes. Irrespective of water bath starting or ending temperatures (heat treatment regime), reductions in root gall response was well defined as a sigmoidal function with that of the partial sums of relative lethal dose (figs. 3). As predicted by model theory, root gall response converged toward zero as the partial sum of relative lethal dose approached 1. The points of inflection of the sigmoidal curves is also suggestive of the heat sensitivity distribution of individuals within the population of nematodes evaluated. The low level incidence and severity of galling when RLD exceeds the lethal dose equivalent value of 1, suggests a small but significant heat tolerant segment of the nematode population. Study results suggest potential for selection pressures towards heat tolerant individuals.

DISCUSSION

Work in our laboratory has focused on quantifying the thermal sensitivity of the southern root-knot nematode, *M. incognita*, to different temperatures and durations of exposure. This work has shown that the time required to kill *M. incognita* decreases with temperature, such that at temperatures above 48°C only a few minutes is required. More importantly, our work has shown that combinations of sublethal doses can be cumulatively additive in producing a lethal effect if individual doses (CxT) can be weighted accordingly. Use of the AUC degree minute model did not prove to be globally useful as a predictor of thermal induced mortality because it failed to account for the differential thermal sensitivity of nematodes. In essence, a myriad of permutations or combinations of time and temperature are possible which will produce equivalent degree minute accumulations (AUC) but have significantly different end results. To be useful the model must embody a weighting or scaling factor which characterizes thermal sensitivity and differential impacts of sublethal temperature per unit time. Without differential weighting, the AUC model merely summarizes physiologic time and not thermal induced stresses In contrast, use of relative lethal dose standardized comparisons between treatments by accounting for a heat quality factor for continuous exposures to sublethal temperatures. Use of RID allowed integration of both temperature and time of exposure into formulation of a multiple point predictor model. The ability to sum partial lethal doses over time in an ambient environment provided a useful and precise method for predicting times of thermal induced mortality.

Clearly more research is needed demonstrating soil solarization broadspectrum pest control efficacy, consistency, and economic practicality within the context of an IPM program. The element of risk and grower uncertainty must also be scientifically addressed and some type of bioassay or simple and effective monitoring system developed to assure growers that a suitable and efficacious solarization period has been achieved prior to tarp removal and crop planting. Although the relative lethal dose model may contribute towards this goal, field validation is still required for ambient environments undergoing solarization processes. We do however believe that the information required to predict when death occurs to the nematode in soil after being subjected to regimes of sublethal temperatures is now available. Hopefully this information can be made useful in grower management decisions determining efficacy and when the solarization treatment period can be reliably discontinued in the field.

LITERATURE CITED

Heald, C.M. and A.F. Robinson. 1987. Effects of soil solarization on Rotylenchulus reniformis in the Lower Rio Grande Valley of Texas. Journal of Nematology 19:93-103.

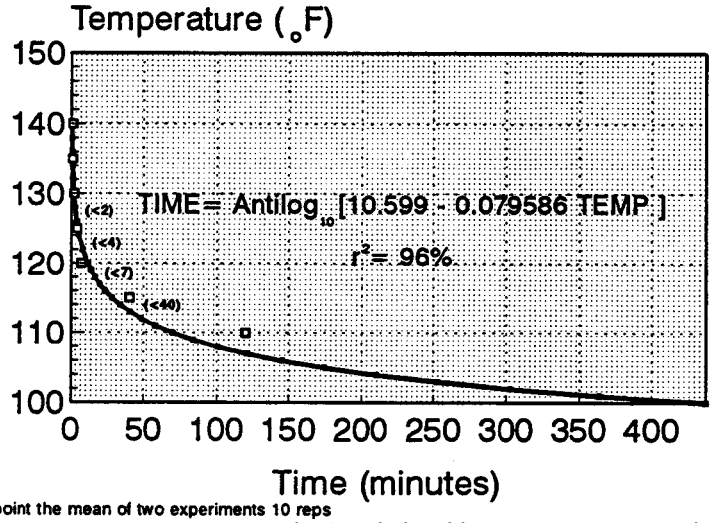


Fig. 2 Relationship Between Degree Minute and Root Gall Index
For 38 C, 43 C, and 47 C Bath Heat Up Treatment Regimes

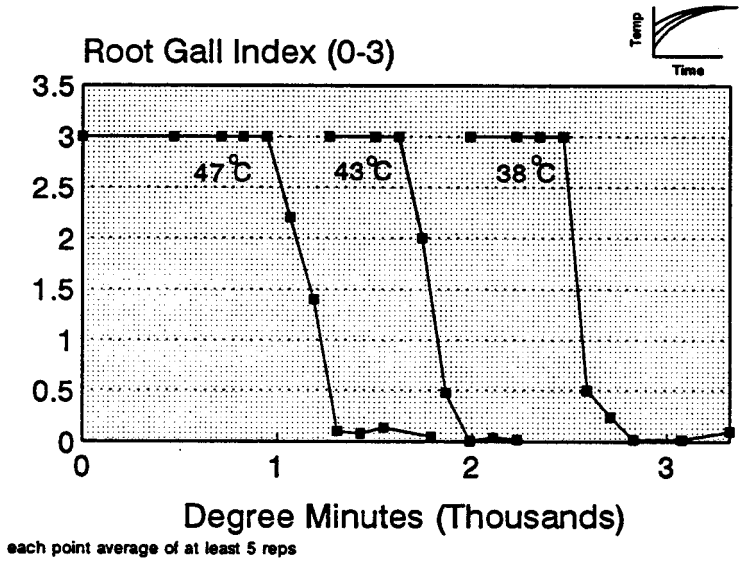
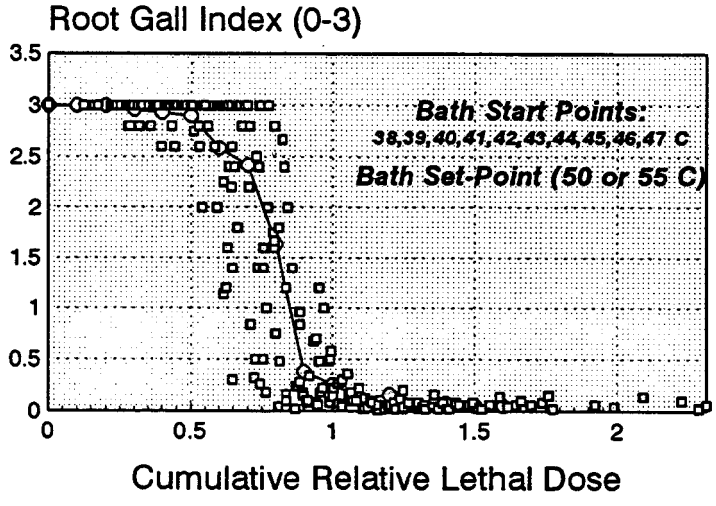


Fig. 3 Relationship between Galling Response & Cumulative Relative Lethal Dose for Bath Experiments
May 16, 22. 23. 1997 (38 C- 47C)



General Conclusions / Speculations

- Root Galling Response adequately described by negative exponential function between Time and constant Temperature
- Use of Degree Minute Model NOT Globally useful
- Use of Relative Lethal Dose standardized comparisons between treatments by accounting for a 'heat quality' factor for continuous exposures to sublethal temperatures
- Model validation is required for ambient environments undergoing solarization processes.
- Study results suggest potential for selection pressures towards 'heat tolerant' individuals

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