Temperature-enhanced efficacy of methyl isothiocyanate for soilborne pests control

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Soil solarization has been reported as an effective practice for the control of soilborne pests, pathogens and weeds near the soil surface in warm, sunny climates. Integration of soil solarization with fumigation may make it possible to effectively control pests, pathogens and weeds at a reduced fumigtion rate as solar heat weakens soilborne pests. Using reduced fumigant dosage not only lowers the costs of production, but also reduces the risk of environmental contamination. Therefore, this practice is compatible with the principle of integrated pest management (IPM).

We investigated the relationships among temperature, fumigant application rate and efficacy of methyl isothiocyanate (MITC) for control of citrus nematode (*Tylenchulus semipenetrans*) juveniles, barnyard grass and *Fusarium oxysporum* under well-controlled environments. We used MITC as an example. Results from this study are useful for optimizing MITC application rate for pest control under solarized conditions.

The soil was an Arlington sandy loam. Fresh soil taken from the field was passed through a 2-mm sieve and stored in room temperature before use. Technical standard of MITC (99%) was purchased from Chem Service (Bellefonte, NJ). The chemical was dissolved in ultra pure water just before use.

The citrus nematodes were obtained from a naturally infested orchard at the University of California, Riverside Citrus Research Center. Infested citrus roots were cut into approximately 1-cm pieces and placed onto a Baermann funnel in a mist chamber for 48 h at 24 ^{o}C for extracting the second-stage juveniles of the citrus nematodes. The population was adjusted to approximately 1500 nematodes per ml solution for the study.

The fungus used in this study was *Fusarium oxysporum f. sp. cysts* isolated from Heterodera schachtii cysts in a diseased field at the University of California Agricultural Operations at Riverside. The fungi were proliferated on potato dextrose agar (PDA) and then transferred onto sterilized millet seeds. The seeds were then dried in the hood under sterile conditions for 24 h and stored in a clean plastic bag at 5 ^{o}C.

The weed seeds used in this study were barnyard grass seeds (*Echinochloa crus-galli*), which were purchased from the Valley Seed Service in Fresno, CA. The seeds were tested in petri dishes to give a germination rate > 99% at 22 ^{o}C.

The nematodes (in 0.5 ml solution), fungi (on 30 millet seeds), or weed seeds (50 seeds) were mixed with 50.0 g (dry weight) of soil in 165-ml jars and pre-incubated for 24 h at room temperature before fumigation. The soil had been brought to the desired soil water content of 6.3% by weight, which is approximately 60% of field capacity.

Samples were spiked with MITC at different application rates. The respective rates were selected based on the sensitivity of the pests or weed to MITC to obtain relatively smooth response curves. The jars were capped immediately with aluminum seal and Teflon-faced butyl rubber septa, producing a gas-tight system. The capped jars were then transferred into temperature-controlled rooms or incubators at 20, 30, and 40 ^{o}C, with temperature variation less than 0.5 ^{o}C. The experiments for nematode, fungus and weed treatments were carried out separately because large number of samples was required in each experiment. Control samples (no MITC applied) were included in each experiment. At selected time intervals, samples were taken for analyzing MITC concentrations and the mortality rates of the nematode, fungus or weed. For nematode bioassay, the Baermann funnel method was used to extract nematodes from the soil for 5 days and then the nematode population was enumerated using a dissecting microscope. For fungi and weed bioassay, the soil was sieved to recover the seeds. Ten millet seeds were selected from each sample and transferred into a PDA growth medium in a sterile petri dish at 22 ^{o}C. The white restricted colonies of *Fusarium o. cysts* developed around the seeds, which later turned pinkish, were counted after 4 days. Thirty weed seeds were picked up and transferred into a petri dish in which a moist germination blotter had been placed. The seeds were allowed to germinate in the petri dish for 10 days at 22 ^{o}C and the germinated seeds were counted.

Results are shown in Table 1 in which the efficacy of MITC for control of nematodes, fungi or weeds at different temperatures and MITC concentrations is expressed by T_{50}, the time required for 50% kill. Without fumigation, the viability of the nematode and fungus was not significantly affected by temperature between 20 and 30 ^{o}C. However, at 40 ^{o}C it took 4.3 and 95.5 h to kill 50% of the nematodes and fungi, respectively (Table 1). This suggests that soil solarization could provide effective control of the nematode and fungus in the field near the soil surface as temperature under the tarp could reach as high as 50 to 70 ^{o}C. The effect of temperature on the viability of the weed is less significant between 20 and 40 ^{o}C (Table 1), although the germination of the weed seeds was delayed from 1 to 3 days at 40 ^{o}C compared to those at 20 and 30 ^{o}C. With fumigation, the viability of the nematode, fungus and weed decreased significantly with increasing temperature between 20 and 40 ^{o}C (Table 1). The T_{50} values for the fungus decreased from 31 h at 20 ^{o}C to 15.5 h at 30 ^{o}C at an initial concentration of 6.80 mg kg^{-1} (Table 1), although temperature alone did not significantly affect the viability of the fungus within this temperature range. Similar results were observed for the nematode and weed at all concentration levels. This indicates that MITC becomes more effective at 30 ^{o}C than at 20 ^{o}C. The T_{50} values further decreased significantly when temperature increased from 30 to 40 ^{o}C. These results clearly suggest that the activity of MITC against soilborne nematodes, fungi and weeds is enhanced at elevated temperature. Increased MITC activity allows to use reduced fumigation rate for adequate control of soilborne nematodes, fungi and weeds. Thus, this study provides the basis for integrating soil solarization with fumigation at a reduced application rate. Such integration will reduce the use of fumigants, improve fumigant efficacy, reduce environmental contamination and lead to the adoption of non-chemical pest management practices such as soil solarization.

Table 1. Values of T_{50} (h) for MITC to kill nematodes, fungi and weeds at different concentrations and temperatures in Arlington sandy loam

	Temperature (^{o}C)		
Concentration	20	30	40
(mg kg^{-1})	Nematode (*Tylenchulus semipenetrans*)		
0	NA*	NA	4.3
0.52	8.8	4.3	3.0
1.26	5.4	4.4	3.0
2.37	5.4	3.2	3.0
	Fungus(*Fusarium o. cysts*)		
0	NA	NA	95.5
3.02	NA	NA	63.9
4.53	NA	NA	25.8
6.80	31.0	15.5	4.0
9.82	25.2	13.8	3.9
	Weed (*Echinochloa crus-galli*)		
0	NA	NA	NA
3.89	68.5	17.9	8.7
5.83	8.4	4.8	2.7
8.74	4.4	2.9	0.8
12.95	2.6	1.2	0.5

*NA: Not affected.