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Screening of a Granular Chelate of Metham-Zinc for Nematicidal Activity Using Citrus and Root-knot Nematodes

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Abstract: A granular formulation of a chelate of metham-zinc (CMZ) which liberates the biocidal methyl isothiocyanate was tested for nematicidal activity on *Tylenchulus semipenetrans* in a jar soil screening and on *Meloidogyne javanica* (greenhouse test) and *M. incognita* (field test) infecting tomato. Comparisons were made with 1,3-D in the jar and pot experiments. The CMZ caused only 3.9% mortality of citrus nematode juveniles at 1.0 μg a.i./g soil, but 95.4% mortality at 10.0 μg a.i./g and 100.0% at 100.0 μg a.i./g. CMZ at 10.0 and 100.0 μg a.i./g significantly reduced tomato root infections by *M. javanica* in the pot test relative to the untreated control. In the field test, CMZ (11.5 g a.i./m² calibration rate) reduced *M. incognita* populations in the zone of incorporation but not below it, thus failing to provide season-long control for tomato. This material has good nematicidal activity at 10 μg a.i./g or more, but its effectiveness in the field may be limited by its lack of movement.

Key words: chemical control, citrus nematode, *Lycopersicon esculentum, Meloidogyne incognita, Meloidogyne javanica,* methyl isothiocyanate, root-knot nematode, tomato, *Tylenchulus semipenetrans,* 1,3-dichloropropene.

Interest has increased recently in the use of methyl isothiocyanate (MIT) for controlling nematodes, weeds, and soil fungi (2,4,7). Currently available formulations are liquids containing metham-sodium which lend themselves to application through irrigation systems (2,4,7). A chelate of metham-zinc (CMZ) has been developed and formulated as a dry granule, which apparently releases MIT slowly when it is mixed into the soil. This study was made to determine the nematicidal activity of CMZ.

MATERIALS AND METHODS

The formulation of the chelate (Zetachron, State College, PA) is a fine granule containing 79% a.i. (metham-zinc) by weight (i.e., 21% moisture by weight; this can vary depending on the batch manufactured. Anhydrous CMZ is 76.5% metham by weight.).

Jar test: Using the technique of Moje et al. (6), 750 cm³ sandy clay loam soil (8% moisture by weight, 46% sand, 27% silt, 27% clay, 0.3% organic matter; pH 6.9) from a citrus orchard naturally infested with *Tylenchulus semipenetrans* Cobb was placed in each 1,000-cm³ glass jar. CMZ was placed in the center of the soil mass to provide concentrations of 0, 1, 10, or 100 μg a.i./g soil. The jar was sealed with a rubber-edged lid, and the chemical was mixed in the soil by tumbling 50 times. Similarly, 1,3-D was added to soil in the jar to provide concentrations of 1 or 10 μg a.i./g soil. The jars were arranged in a randomized complete block with five replicates on a laboratory bench at 25 C for 72 hours. Lids were removed to allow aeration of soil for 24 hours. A 50-cm³ soil sample was then processed using a modified Baermann funnel technique. The nematodes were counted 72 hours after placement on the funnels.

Greenhouse test: Aliquants of 3,750 cm³ loamy sand soil (8% moisture by weight, 88% sand, 2% silt, 10% clay, 0.2% organic matter; pH 7.9) naturally infested with 1,067 *Meloidogyne javanica* (Treub) Chitwood J2/50 cm³ soil were mixed by tumbling in a large plastic bag with CMZ to provide concentrations of 10 and 100 μg a.i./g of soil and placed in plastic pots. Ad-

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TABLE 1. Nematicidal effects of chemical treatments in jar tests using soil infested with *Tylenchulus semipenetrans* juveniles based on their ability to move through a Baermann funnel.

Treatment	Concentration (μg a.i./g soil)	Juveniles (no./50 cm³ soil)	Mortality (% of control)
Metham-zinc	1	1,682 a	3.9
	10	80 b	95.4
	100	0 b	100.0
1,3-D	1	1,573 a	10.1
	10	0 b	100.0
Control		1,750 a	

Means in column followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple-range test.

ditional pots were filled with the soil and injected with 1,3-D to provide concentrations of 10 and 100 μg a.i./g soil, but the chemical was not mixed with soil nor was a seal placed over the pot. Nontreated pots were set up for controls. All soil was kept moist but not wet for 7 days; at that time one 3-week-old susceptible tomato (*Lycopersicon esculentum* L. cv. Tropic) seedling was transplanted into each pot. Treatments were replicated five times in a randomized complete block arrangement on greenhouse benches. Fifty-three days after transplanting the roots were washed free of soil and rated for nematode galling (0 = no galls; 1 = 1–25% root system galled; 2 = 26–50% galled; 3 = 51–75% galled; 4 = 76–100% galled). Fresh roots were cut into 1-cm lengths and weighed. A 10-g subsample was macerated in 16% (v/v) Clorox (6.25% w/w NaOCl in an alkaline solution) to release nematode eggs for counting (3). Shoots and remaining roots were dried at 65 C for 72 hours in a forced-air oven to determine dry weight.

Field test: The site (University of California Kearney Agricultural Center, Parlier, CA) was infested with *Meloidogyne incognita* (Kofoid and White) Chitwood race 3 from cotton cultured for 3 years on susceptible tomato. The soil was a sandy loam (57% sand, 28% silt, 15% clay, 0.7% organic matter; pH 7.5). Tomato cultivar UC82B, susceptible to *M. incognita*, was direct seeded on 20 June in single rows. Standard local cultural production practices (1) were followed to develop the crop. Overhead sprinkler irrigations were applied daily for 15 days after planting to ensure seedling emergence and establishment. Thereafter, irrigation was applied at 2–3-day intervals for 15 days. Subsequently, furrow irrigation was applied every 10 days until fruit maturity (15 October). No rainfall occurred during the crop season, and soil temperatures at 15 cm deep ranged from 9 to 34 C maximum and 5 to 29 C minimum.

CMZ was applied 14 or 35 days before planting or at planting at a calibration rate of 11.5 g a.i./m² (equivalent to 115 kg a.i./ha overall rate) in a 0.30-m-wide band with a hand applicator. A rototiller was used for incorporating the material either 5 cm deep or 15–20 cm deep, depending on the treatment. Rows were reshaped with a tractor

TABLE 2. Effects of chemical treatments to soil in pot tests on *Meloidogyne javanica* infection of tomato and on tomato growth.

Treatment	Concentration (μg a.i./g soil)	*M. javanica* Eggs/g fresh root (× 10³)	*M. javanica* Root-gall index†	Tomato dry weight (g/plant) Shoots	Tomato dry weight (g/plant) Roots
Metham-zinc	10	1.46 b	1.0 c	37.4 a	3.5 a
	100	0.05 b	0.0 d	36.1 a	2.8 a
1,3-D	10	35.72 a	3.6 a	35.8 a	4.1 a
	100	29.74 a	3.0 b	34.1 a	4.4 a
Control		31.05 a	3.5 a	26.0 b	3.5 a

Means in columns followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple-range test.

† 0 = no galls, 1 = 1–25% root system galled, 2 = 26–50% galled, 3 = 51–75% galled, 4 = 76–100% galled.

drawn row shaper after application. The entire site was sprinkler irrigated with 2.5 cm water within a day of application.

The experimental design was a randomized complete block, replicated six times. Plots were three rows wide, with rows 0.76 m apart and 3.65 m long. A 2-m border of nontreated tomato surrounded each block.

Nematode population densities in soil were estimated from one soil sample composited from 10 cores (2.5 cm d × 40 cm deep) taken from the center row in each plot. Samples were taken immediately before treatment and 32 days and 98 days after planting. *M. incognita* J2 were extracted from 250 cm^3 soil by sieving through one 250-μm-pore sieve and two 45-μm-pore sieves, with all screenings extracted for 72 hours in a modified Baermann funnel-mist chamber.

Additional samples were taken 13 days after planting from the center row of plots treated 14 days before planting with CMZ incorporated 15–20 cm deep and from control plots. One sample was taken from each of four depths (0–15, 16–30, 31–45, and 46–60 cm). Each sample was composited from six 5-cm-d cores. In late season (day 99) 15 root systems per plot were indexed for galling using the root-knot galling index (0 = no galls; 1 = 1–25% root system galled; 2 = 26–50% galled; 3 = 51–75% galled; 4 = 76–100% galled).

Results and Discussion

Little mortality of *T. semipenetrans* juveniles occurred at 1 μg a.i./g 1,3-D and CMZ. CMZ at 10 and 100 μg a.i./g and 1,3-D at 10 μg a.i./g resulted in recovery of few nematodes (Table 1).

Results from the greenhouse test confirmed the activity of CMZ on nematodes (Table 2). Numbers of eggs of *M. javanica* and root galling were significantly suppressed by 10 μg a.i./g concentration in potted soil and almost completely suppressed at 100 μg a.i./g. The 1,3-D treatments were ineffective in these pot tests, which suggests that the testing procedure for this volatile fumigant was inappropriate. Significant increase in tomato plant

Table 3. Effects of chelate of metham-zinc (11.5 g a.i./m^2) application depths and times on control of *Meloidogyne incognita* and on tomato stand count in field plots.

Incorporation depth (cm)	Time of application	Stand count/ 3.5-m bed on day 27	*M. incognita* J2/250 cm^3 soil (0–40 cm)			*M. incognita* J2/250 cm^3 soil on day 13				Root-gall index on day 99†
			Pretreat	Day 32	Day 98	0–15 cm	15–30 cm	30–45 cm	45–60 cm	
5	14 days preplant	18.0 b	47.0 a	3.2 a	868.5 a					2.7 a
15–20	14 days preplant	16.7 b	9.2 a	3.3 a	436.2 a	0.5 b	15.3 a	71.8 a	38.0 a	2.0 a
15–20	35 days preplant	27.4 a	18.2 a	5.7 a	32.8 a					0.5 a
15–20	At plant	6.5 c	24.2 a	4.7 a	125.7 a					1.7 a
Control		16.2 b	11.0 a	3.5 a	445.7 a	5.8 a	27.3 a	177.3 a	63.3 a	1.8 a

Means in columns followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple-range test.
† 0 = no galls, 1 = 1–25% root system galled, 2 = 26–50% galled, 3 = 51–75% galled, 4 = 76–100% galled.

shoot weight, however, occurred with all treatments.

In the field test, CMZ was phytotoxic (based on stand count) to tomato when applied at planting (Table 3). Significant stand reductions occurred when CMZ was applied at planting but not when applied 14 or 35 days before planting. No treatment adequately controlled *M. incognita* in tomato. Nematode numbers assessed from soil samples taken 0–40 cm deep 32 and 98 days after planting and root galling at 99 days were not reduced by any treatment. Nematode numbers assessed from soil samples taken 13 days after planting, however, were significantly reduced at the 0–15-cm depth but not at lower depths in plots treated with CMZ incorporated 15–20 cm deep 14 days before planting (Table 3).

Our results show that CMZ is nematicidal to *T. semipenetrans* and *M. javanica* at or above 10 μg a.i./g soil in a restricted environment condition (jar or pot test). When incorporated into tomato rows in the field, this material reduced *M. incognita*, but only in the zone of incorporation. The concentration in this zone was approximately 80 μg a.i./g; therefore, nematicidal activity was expected. According to the manufacturer (Zetachron, pers. comm.), the chelate slowly releases the biologically active methyl isothiocyanate (MIT) that is liberated from the metham zinc. MIT has limited fumigant action and a high affinity for the soil water phase (2,5,8); therefore, distributing effective concentrations into soil below 15–20 cm would be dependent largely on movement with water through repeated irrigations. Deep mechanical incorporation of CMZ is generally impractical; therefore, this material may have greater potential for controlling weed seeds or pathogens of shallow-rooted crops than for controlling root-knot and other nematodes that are distributed deeper in the soil profile.

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