Effect of Aldicarb, Ethoprop, and Carbofuran on Control of Coffee Root-knot Nematode, *Meloidogyne exigua*[1]

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Abstract: Egg hatch of *Meloidogyne exigua* was significantly inhibited in 14 days pretreatment with aldicarb, ethoprop, or carbofuran at concentrations higher than 0.1 μg/ml; these eggs were found to delay hatch in 19 days posttreatment in ethoprop. Aldicarb and carbofuran solutions at concentrations greater than 0.1 μg/ml significantly decreased the motility and the life span of the second-stage juveniles; aldicarb was more toxic than carbofuran to the nematode. In a field test, aldicarb (Temik 10G), ethoprop (Mocap 10G), and carbofuran (Furadan 5G and Furadan Liquid 350F) significantly decreased *M. exigua* populations. *Key words: Coffea arabica,* chemical control, hatching, motility, mortality, nematicides.

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Meloidogyne exigua Goeldi, 1887 is widely distributed in coffee plantations in Brazil. According to the estimation of the International Meloidogyne Project, the average annual loss of coffee yield caused by *Meloidogyne* spp. in Brazil is 24% (6). Some *Coffea* spp. are resistant to *M. exigua* (2), but *C. arabica,* the most economically important species of coffee in Brazil, is susceptible. The purposes of this work were to study the sensitivity of *M. exigua* egg hatch, juvenile motility and mortality to nematicides, and to evaluate the efficacy of these nematicides for control of nematodes in coffee plantations.

MATERIALS AND METHODS

Chemical preparations: Solutions of test chemicals (aldicarb, carbofuran, and ethoprop) were prepared from the commercial product as previously described (3). The solutions were adjusted to 1,000 μg/ml and stored for up to 1 week at 4 C. At the time of use, stock solutions were diluted with distilled water to 0.1, 1, 10, 50, 100, and 500 μg/ml.

Test nematodes: M. exigua was isolated from infected coffee roots and maintained on tomato plants (*Lycopersicon esculentum* Mill. cv. Santa Cruz) under greenhouse conditions.

Egg hatch test: Egg masses were picked from infected tomato roots and stored for up to 4 days at 4 C before testing. They were placed on two layers of tissue paper supported by 20-mesh plastic screen in a 26-ml petri dish containing 10 ml of the test solution described above. The egg masses were pretreated in the chemical solutions for 14 days and then posttreated in distilled water for 19 days at 25 C, with daily changes of fresh solution or water. In pretreatment, egg masses in distilled water without chemical solution served as controls. Each treatment was replicated five times with eight egg masses per repli-

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cation. Egg hatch was determined by counting the second-stage juveniles that migrated into each petri dish.

Motility test: Juveniles were collected from the egg masses, incubated in Baermann funnels for 24 hours, and tested immediately. Nematode motility was tested by using the Moje technique (4) in which the juveniles were exposed to 7 ml of chemical solution (aldicarb or carbofuran at 0.1, 1, or 10 μg/ml) in a 15-ml bottle for 24 hours at room temperature (23–28 C). The mouth of the bottle was covered with two layers of tissue paper and then turned upside down in a 24-ml petri dish containing 12 ml of the same test chemical solution for another 24 hours. Motility was expressed in percent (the number of juveniles that migrated into each petri dish divided by the total number of juveniles exposed to the test chemical). The juveniles in distilled water served as the control. Each treatment was replicated six times.

Mortality test: Within 24 hours after egg hatch, juveniles were exposed to 10 ml of test chemical solution (aldicarb or carbofuran) at 0.1, 1, 10, or 50 μg/ml in a 24-ml petri dish at 25 C; they were changed daily with fresh solution. Juveniles in distilled water served as the control. Each treatment was replicated three times and each replication contained 100 ± 19 nematodes. Juveniles were observed daily, and those showing no movement and straight body form were considered dead. The treatment continued until the day that 95% mortality was attained.

Field test: A field test was conducted in a 5-ha plantation containing 10,000 15-year-old *Coffea arabica* L. cv. Mundo Novo trees heavily infected with *M. exigua.* The soil was a 'cerrado' type containing 41.5% sand, 7.2% silt, 47.2% clay, and 4.1% organic matter (pH = 5.3). The commercial products (Temik 10G, Mocap 10G, Furadan 5G, and Furadan Liquid 350F) were applied at 1, 2, 4, and 6 g a.i./tree, respectively. Nematicides were incorporated into the top 5–10 cm of soil in a 1-m area surrounding the tree trunk. Nontreated trees served as controls. The treatments were arranged in randomized blocks with six replications. Nematode populations (eggs and juveniles) in roots were assayed 45, 80, and 363 days after chemical treatment.

RESULTS

Egg hatch: Egg hatch was inhibited in the 14-day pretreatment by aldicarb, ethoprop, or carbofuran at concentrations higher than 0.1 μg/ml (Table 1). Aldicarb and ethoprop were more inhibitive than carbofuran to egg hatch, but there was no difference between aldicarb and ethoprop.

Hatch of eggs held in distilled water following the 14-day treatment with ethoprop was delayed (Fig. 1). Also, aldicarb or carbofuran at the dosages higher than 10 μg/ml and ethoprop at concentrations higher than 1 μg/ml decreased the total number of juveniles hatched from eggs exposed to posttreatments (Table 1).

Motlity test: Nematode motility was reduced in aldicarb and carbofuran concentrations higher than 0.1 μg/ml (Fig. 2). The juvenile's motility decreased as aldi-

Table 1. Number of juveniles from eight egg masses of *Meloidogyne exigua* treated with three nematicides for 14 days and then transferred to distilled water for 19 days.

Treatments	Rate (μg/ml)	Number of juveniles: 14 days in chemical solution	Number of juveniles: 14 days in chemical solution and 19 days in distilled water
Untreated control		429 a*	620 ab
Aldicarb	0.1	281 bcd	605 ab
	1	241 cd	733 a
	10	123 ef	242 de
	50	36 g	ND
	100	12 g	67 f
	500	6 g	198 ef
Ethoprop	0.1	339 b	540 ab
	1	212 d	412 cd
	10	58 fg	271 de
	50	30 g	326 dc
	100	12 g	163 ef
	500	13 g	154 ef
Carbofuran	0.1	318 b	524 bc
	1	298 bc	605 ab
	10	238 cd	411 cd
	50	281 d	393 cd
	100	204 de	314 de
	500	46 g	387 cd

*Different letters in the same column indicate significant difference in Duncan's multiple-range test ($P = 0.05$).

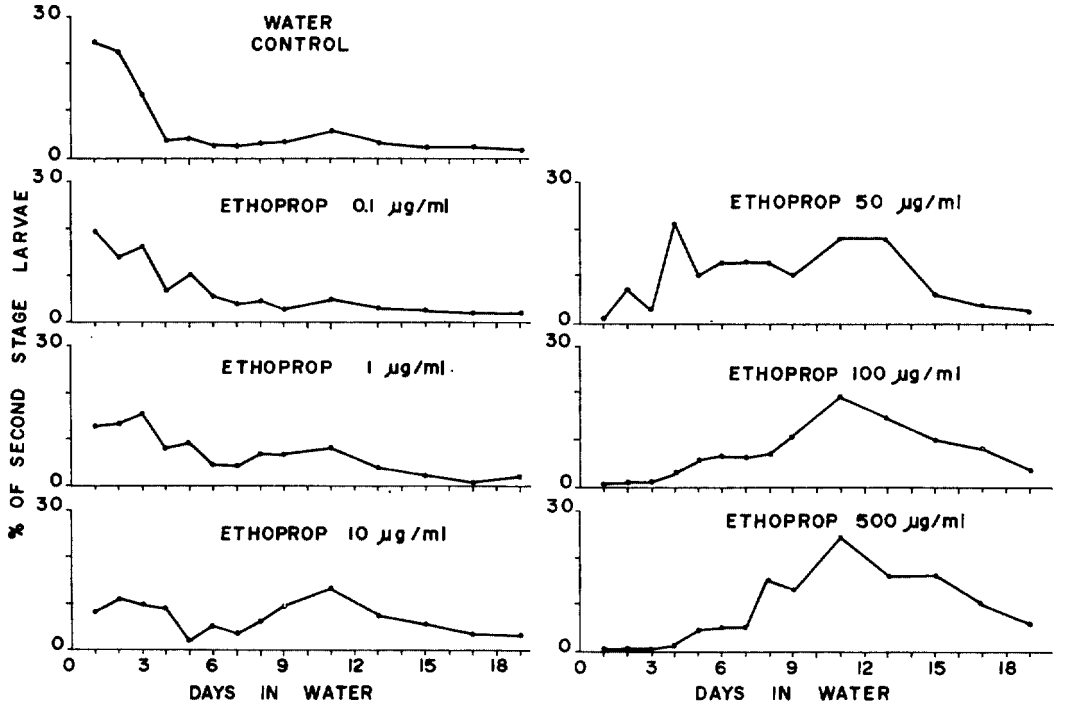

Fig. 1. Percentages of egg hatch from eight egg masses of *Meloidogyne exigua* held in distilled water for 19 days, after 14-day treatment with ethoprop.

carb concentrations increased. There was no difference in juvenile motility between 0.1 and 1 µg/ml carbofuran. Juvenile motility was reduced more in aldicarb at 1 and 10 µg/ml than in carbofuran at similar concentrations.

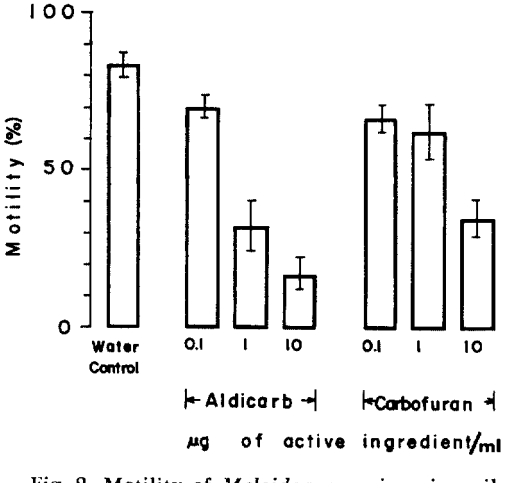

Fig. 2. Motility of *Meloidogyne exigua* juveniles treated with aldicarb and carbofuran at 0.1, 1, and 10 µg/ml for 24 hours and then allowed to migrate through two layers of tissue paper in the same concentrations for another 24 hours. The bars indicate variability ($P = 0.05$).

Mortality test: Aldicarb and carbofuran decreased the life span of the tested juveniles (Table 2). Aldicarb was more toxic than carbofuran to the nematodes; neither chemical caused morphological aberrations like wrinkling, shortening, or swelling of the body shape as reported in *Tylenchulus semipenetrans* (3), *Ditylenchus dipsaci,* and *Pratylenchus penetrans* (1).

Field test: Nematode populations were reduced 30–80% at 45 and 80 days after treatment (Table 3). Nematode populations were lower in roots of trees treated with $\geq$ 2 g carbofuran (Furadan 5G), $\geq$ 4 g aldicarb, and $\geq$ 4 g ethoprop per tree than in controls 363 days after treatment. At that time, the nematode population in roots of trees treated with Furadan Liquid 350F were not different from controls.

DISCUSSION

Aldicarb and carbofuran inhibited egg hatch at dosages higher than 0.1 µg/ml and were lethal at concentrations higher than 10 µg/ml (Table 1). Also, the second-stage juveniles were sensitive in motion and in death to concentrations of aldicarb and carbofuran $\geq$ 0.1 µg/ml (Fig. 2 and Table

Table 2. Mortality day of second-stage juvenile of *Meloidogyne exigua* treated with aldicarb and carbofuran solutions.

	Water control	Aldicarb (μg/ml)				Carbofuran (μg/ml)			
		0.1	1.0	10	50	0.1	1.0	10	50
LD_{50}	14.9 a*	8.3 c	3.3 g	0.8 h	0.5 h	9.2 b	7.5 d	5.1 e	4.0 f
LD_{95}	17.6 a	15.6 bc	5.2 f	3.1 g	1.9 h	16.5 b	15.3 c	8.0 d	6.8 e

*Different letters in the same row indicate significant difference in Duncan's multiple-range test ($P = 0.05$).

Table 3. *Meloidogyne exigua* populations in *Coffea arabica* L. cv. Mundo Novo treated with nematicides.

Treatment	Rate (g ai/tree)	No. of nematodes/g of roots		
		Days after treatment		
		45	80	363
Untreated control		135	411.7	216.7
Aldicarb 10G	1	96.2*	244.3**	245.7
Aldicarb 10G	2	103.2	136.3**	175.0
Aldicarb 10G	4	97.9*	134.0**	96.3**
Aldicarb 10G	6	62.9**	78.7**	107.0**
Ethoprop 10G	1	100.6	208.3**	156.7
Ethoprop 10G	2	115.6	181.3**	175.3
Ethoprop 10G	4	86.9**	136.3**	115.7*
Ethoprop 10G	6	62.9**	69.7**	95.7**
Carbofuran 5G	1	73.3**	290.3**	160.9
Carbofuran 5G	2	48.9**	116.1**	106.5**
Carbofuran 5G	4	37.2**	139.9**	100.9**
Carbofuran 5G	6	32.8**	154.4**	134.0*
Carbofuran 350F	1	74.0**	285.2**	189.5
Carbofuran 350F	2	68.2**	177.4**	231.4
Carbofuran 350F	4	61.8**	202.5**	241.5
Carbofuran 350F	6	67.5**	221.9**	182.4

* and ** = significantly different from untreated control ($P = 0.05$) and ($P = 0.01$), respectively.

2). The second-stage juveniles were more sensitive than eggs to both chemicals.

There were more second-stage juveniles of *M. exigua* in soil during the wet season (November–April) than during the dry season (May–October) in this region (personal observation). Therefore, the time to apply nematicides in coffee plantations for optimum nematode control appears to be in October–November because of adequate soil moisture, temperature, and sensitive target.

In laboratory tests, aldicarb showed greater effects than carbofuran on egg hatch and juvenile motility and mortality (Table 1 and 2, Fig. 2), but the results from the field test (Table 3) showed no statistical difference between the Temik 10G and Furadan 5G treatments. However, the degradation of aldicarb in soil might be more rapid than that of carbofuran (5). Hence, the lack of statistical difference for the two chemicals may be attributed to the difference in persistence of both chemicals in soil and perhaps in the plant tissue. Liquid form of carbofuran showed its effectiveness against *M. exigua* population in the field at 45 and 80 days after treatment. The nematode population increased again at 363 days after treatment, probably because of being leached by rains.

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