Management of *Meloidogyne javanica, M. arenaria,* and *M. incognita* on Flue-Cured Tobacco with Organophosphate, Carbamate, and Avermectin Nematicides

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ABSTRACT

Nordmeyer, D., and Dickson, D. W. 1985. Management of *Meloidogyne javanica, M. arenaria,* and *M. incognita* on flue-cured tobacco with organophosphate, carbamate, and avermectin nematicides. Plant Disease 69:67-69.

The differential sensitivity of *Meloidogyne javanica, M. arenaria,* or *M. incognita* to nonfumigant nematicides was evaluated on tobacco grown in microplots inoculated with 64 nematode eggs and/or infective second-stage juveniles per 100 cm^3 of soil. Ethoprop, aldicarb, fenamiphos, oxamyl, and carbofuran applied at an overall rate of 6.7 kg a.i./ha, and avermectin B_1 at a rate of 0.17 kg a.i./ha increased yields of tobacco infected with *M. incognita.* Carbofuran did not increase yields of *M. arenaria*-infected plants. Neither carbofuran nor avermectin B_1 increased yields of *M. javanica*-infected plants. All nematicides except avermectin B_1 decreased the number of nematodes in the soil as well as the root-gall index at the end of the season. *M. javanica* and *M. arenaria* reproduced faster than *M. incognita* during the first part of the growing season.

Additional key words: *Nicotiana tabacum,* root-knot nematodes

Differences in the sensitivity among species of root-knot nematodes to nonfumigant nematicides have been observed in the field and under controlled conditions (3,15). Differential sensitivity to nematicides has also been reported for free-living nematodes (4,11). *Meloidogyne javanica* (Treub) Chitwood, *M. arenaria* (Neal) Chitwood, and *M. incognita* (Kofoid & White) Chitwood are limiting factors in Florida tobacco production. Nematicides have not always given consistent control of the three species (6,14,18,19). This study was conducted on tobacco to compare the differential sensitivity of *M. javanica, M. arenaria,* or *M. incognita* to five widely used nonfumigant nematicides, ethoprop, fenamiphos, aldicarb, oxamyl, carbofuran, and one experimental compound, avermectin B_1, and to determine their effectiveness in increasing tobacco yields.

MATERIALS AND METHODS

The experiment was conducted in 76-cm-diameter microplots enclosed with fiberglass and open at the bottom (10). The microplot soil consisted of an Arredondo fine sand (93.2% sand, 4.3% silt, and 2.5% clay; pH 5.8, 1.5% organic matter) treated with 1,200 kg/ha of methyl bromide 2 mo before planting. The microplots were 1.2–1.5 m apart and the area between the plots was kept fallow during the growing season. The entire microplot area was bordered by tobacco. No plant-parasitic nematodes were detected when the microplots were sampled before planting.

M. incognita, M. arenaria, and *M. javanica* were cultured in the greenhouse on tomato (*Lycopersicon esculentum* Mill. 'Rutgers'). Eggs used as inoculum were extracted from tomato roots with 0.5% sodium hypochlorite (8). Each microplot was inoculated with an initial density of 64 eggs and/or infective second-stage juveniles per 100 cm^3 of soil. The inocula were placed in 54 uniformly spaced holes divided evenly to provide depths of 7, 14, and 23 cm.

Ethoprop (10G), fenamiphos (15G), aldicarb (10G), oxamyl (2L), carbofuran (10G), and avermectin B_1 (0.3G) (Merck, Sharp, & Dohme L-676-863) were evaluated. Avermectin B_1 was applied overall at 0.17 kg a.i./ha; other nematicides were applied overall at 6.7 kg a.i./ha. The nematicides were applied by shaker jar with a screened lid and incorporated into the top 8 cm of soil, except for avermectin B_1, which was incorporated into the top 13 cm of soil because of its relative immobility in soil.

Nematodes were added to the soil on two consecutive days followed by the nematicide application on the third day. Two plants of the root-knot-nematode-susceptible tobacco (*Nicotiana tabacum* L. 'McNair 944') were transplanted 25 cm apart in each microplot on the fourth day. Each treatment was replicated seven times in a randomized complete-block design. About 400 spores of the endomycorrhizal fungus *Glomus microcarpum* Tull. & Tull. were added to each microplot at planting. Fertilizer applications to simulate field conditions were used. The microplots were weeded and irrigated and the plants sprayed for insect control as needed. Axillary and terminal buds of tobacco were removed as necessary. Soil samples were taken with a 2.5-cm cone-shaped auger for nematode analysis 7, 11, and 15 wk after planting. Soil (250 cm^3) was processed by a modified centrifugation-flotation technique (9). Mature tobacco leaves were harvested, flue-cured, and weighed seven times during the growing season. Immediately after the final harvest, a root-gall index was made, where 0 = no visible galls, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, and 4 = more than 75% of the tobacco root system galled.

Nematode counts of the soil samples converted to $\log_{10}(x + 1)$ were analyzed by Duncan's new multiple range test if the attained significance level of the F test from an analysis of variance was $P \leq 0.05$.

Table 1. Effects of nematicides on the yield of tobacco cultivar McNair 944 infected with three *Meloidogyne* species

Treatment	Rate (kg a.i./ha)	Yield (g cured weight/plot)[y]		
		M. javanica	*M. arenaria*	*M. incognita*
Fenamiphos	6.7	81.5 a[z]	81.8 a	84.0 a
Aldicarb	6.7	82.4 a	80.3 ab	80.1 a
Ethoprop	6.7	80.1 a	80.2 ab	80.2 a
Oxamyl	6.7	77.4 a	74.4 ab	76.7 a
Avermectin B_1	0.17	61.4 b(a)	75.2 ab(a)	78.2 a(b)
Carbofuran	6.7	65.6 b(a)	72.2 bc(ab)	75.5 a(b)
Control	···	65.6 b	64.9 c	66.2 b

[y] Numbers are means of seven replicates.

[z] Means with the same letter are not significantly different ($P = 0.05$). Letters in parentheses indicate differences among nematode species receiving the same nematicide treatment according to Duncan's new multiple range test.

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Table 2. Effects of nematicides and soil populations of three *Meloidogyne* species 7, 11, and 15 wk after planting

Treatment	Rate (kg a.i./ha)	Soil population (weeks after planting)[y]								
		M. javanica			*M. arenaria*			*M. incognita*		
		7	11	15	7	11	15	7	11	15
Fenamiphos	6.7	0.10 d[z]	1.19 b	0.32 c	0.35 c	1.27 cd	0.62 b	0.33 cd	0.97 b	0.81 b
Aldicarb	6.7	0.00 d	0.78 b	0.50 c	0.00 d	0.49 c	0.61 d	0.00 d	0.47 b	0.90 b
Ethoprop	6.7	0.00 d	0.97 b	0.35 c	0.13 cd	1.00 cd	0.73 b	0.13 cd	1.08 b	1.03 b
Oxamyl	6.7	0.13 d	0.86 b	1.08 bc	0.27 c	1.14 cd	0.61 b	0.23 c	1.09 b	1.50 b
Carbofuran	6.7	0.62 c	2.25 a	1.87 b	0.95 b	1.87 b	1.53 b	0.78 a	2.38 a	2.65 a
Avermectin B_1	0.17	1.90 a	3.03 a	2.91 a	1.61 a(b)	2.85 a	3.21 a	0.44 b(c)	2.13 a	2.73 a
Control	···	1.51 b(a)	2.33 a	3.13 a	1.61 a(a)	3.23 a	3.06 a	0.88 a(b)	2.55 a	3.63 a

[y] Numbers are means of seven replicates; data transformed to $\log_{10}(x + 1)$ nematodes per 250 cm^3 of soil.
[z] Means with the same letter are not significantly different ($P = 0.05$). Letters in parentheses indicate differences among nematode species receiving the same nematicide treatment according to Duncan's new multiple range test.

Table 3. Effects of nematicides on the gall index of tobacco plants infected with three *Meloidogyne* species

Treatment	Rate (kg a.i./ha)	Gall index[y]		
		M. javanica	*M. arenaria*	*M. incognita*
Fenamiphos	6.7	1.8 d[z]	1.6 d	1.9 d
Aldicarb	6.7	1.9 d	1.5 d	2.3 cd
Oxamyl	6.7	2.0 cd	2.4 b	2.9 bc
Ethoprop	6.7	2.4 b	2.2 c	3.1 b
Carbofuran	6.7	3.3 ab	3.4 ab	3.5 ab
Avermectin B_1	0.17	3.6 a	4.0 a	3.3 ab
Control	···	4.0 a	4.0 a	4.0 a

[y] Root-knot gall index: 0 = no visible galls, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, and 4 = >75% of tobacco root system galled.
[z] Means with the same letter are not significantly different ($P = 0.05$) according to Duncan's new multiple range test.

RESULTS

Yield of tobacco plants infected with *M. arenaria* was not increased by carbofuran. Yield of tobacco plants infected with *M. javanica* was not increased by applications of either carbofuran or avermectin B_1 ($P = 0.05$) (Table 1). Fenamiphos, aldicarb, ethoprop, and oxamyl were equally effective in all treatments. Carbofuran increased tobacco yields only in plots infested with *M. incognita*.

All nematicides except avermectin B_1 decreased the number of *M. javanica* and *M. arenaria* juveniles in the soil. Neither carbofuran nor avermectin B_1 decreased the number of juveniles of *M. incognita* in soil (Table 2). Larger numbers of *M. javanica* and *M. arenaria* than *M. incognita* were found in the control plots 7 wk after treatment, whereas no population differences among species existed 15 wk after inoculation. Similar results were also found in plots treated with avermectin B_1. For all other treatments, no differences in nematode numbers could be shown among species.

Gall indices were not significantly different among species ($P = 0.05$) (Table 3). Fenamiphos, aldicarb, and oxamyl notably reduced galling, whereas gall indices in plots treated with carbofuran and avermectin B_1 were not significantly different from those in untreated plots. Ethoprop was intermediate in effectiveness.

DISCUSSION

Differences in the efficacy of various nematicides on root-knot nematodes on tobacco have been explained to be caused by differing reproductive rates among root-knot nematode species (3). In field and greenhouse studies, *M. javanica* and *M. arenaria* have been reported to be more damaging than *M. incognita* on susceptible tobacco cultivars (1–3). In our study, however, no significant differences in yields were observed in the untreated tobacco plots infected with either species, although soil populations of *M. javanica* and *M. arenaria* were greater than those of *M. incognita* 7 wk after planting. The small differences in yields among plots containing the three species may be attributed to the relatively low initial populations (P_is) of nematodes used as well as the environmental conditions during the experiment. The maximum-minimum mean soil temperatures at a depth of 10 cm under centipedegrass sod for the 3.5 mo of the experiment were 25.6–21.9, 28.6–25.0, 31.9–28.6, and 32.1–28.8 C. The tobacco was not stressed by other competitive soil microorganisms, weeds, or drought. Yet, in past microplot experiments conducted in Florida, *M. javanica* reduced tobacco leaf yield at relatively low P_is compared with tobacco plants infected with the same levels of *M. incognita* (1). In greenhouse experiments, Paez et al (16) and Lopez-Chaves et al (12) did not find differences in the yield of susceptible tobacco cultivars infected with either *M. javanica* or *M. incognita*. Differences in populations of these two species and environmental conditions may account for these discrepancies.

Carbofuran and avermectin B_1 were less effective than the other nematicides against *M. javanica*. Carbofuran also appeared slightly less effective against *M. arenaria* than the other nematicides. In general, carbofuran has been shown to be less active against root-knot nematodes than against other nematode species (5,15,17) in Florida. Avermectin B_1, a very potent nematicide under controlled conditions (7,20), showed comparatively low activity in the field, but the compound was evaluated at about a 40-fold lower rate than the other nematicides. This agrees with other observations of this compound on tobacco, tomato, corn, soybean, and peanut (J. R. Rich, A. J. Overman, R. A. Kinloch, and D. W. Dickson, *personal communications*). In this study, the compound did not show activity against *M. javanica*. There was a significant yield increase, however, in *M. incognita* plots treated with avermectin B_1, which agrees with findings of Sasser et al (20) and Garabedian and Van Gundy (7). It has been reported that ethoprop was less effective against *M. arenaria* than *M. incognita* (3); however, in our experiment, the compound was equally effective against the three root-knot nematode species.

Greater differences in nematicide susceptibility between *Aphelenchus avenae* and *Panagrellus redivivus* were found with the relatively weak nematicide phorate than with the much more effective aldicarb (4,11). Similar differences in susceptibility for phorate and aldicarb were shown between *M. javanica* and *M. incognita* concerning hatching and migration (13).

These findings and our own studies suggest that more potent nematicides may be so effective that differences in nematicide susceptibility between closely related nematodes are not easily recognized. Differences in efficacy often may go undetected in the field, especially where differences in susceptibility may be marginal. This leads to the conclusion that differential effectiveness of nematicidal compounds on closely related nematode species is more likely to be detected where less effective nematicides are used or where effective ones lose their

potency because of absorption, leaching, or conversion into less nematicidal products. Research on the differential drug sensitivity among different species of plant-parasitic nematodes is still rudimentary and deserves further investigation.

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