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Curative and Residual Efficacy of Injection Applications of Avermectins for Control of Plant-parasitic Nematodes on Banana[1]

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Abstract: Studies were conducted to determine the curative and residual efficacy of avermectins at controlling plant-parasitic nematodes when injected into the pseudostem of banana, *Musa acuminata* cv. Cavendish. In addition, we determined the lowest concentration of avermectins that provided satisfactory efficacy as protectants when injected into banana pseudostems. Experiments were conducted with a root-knot nematode, *Meloidogyne javanica,* and the burrowing nematode, *Radopholus similis.* Injections (1 ml) of ≥100 µg a.i./plant of abamectin into pseudostems were effective at controlling *M. javanica* and *R. similis,* and were comparable to control achieved with a conventional chemical nematicide, fenamiphos, in a protectant assay. Abamectin injections of 250 and 500 µg a.i./plant were effective at reducing nematode infections 28 to 56 days after inoculation. Abamectin was more effective than ivermectin at controlling nematodes after nematode populations were established in banana roots. Injections of between 100 and 1,000 µg a.i./plant were effective at controlling nematodes for at least 56 days after treatment. These studies confirmed earlier results and demonstrated that abamectin has potential for controlling nematode parasites on banana when injected into the pseudostem.

Key words: abamectin, avermectins, banana, efficacy, fenamiphos, ivermectin, *Meloidogyne javanica, Musa acuminata,* nematicide, nematode, *Radopholus similis.*

The burrowing nematode, *Radopholus similis* (Cobb) Thorne, is one of the most important biotic factors affecting banana (*Musa acuminata* Colla) production worldwide (Gowen and Quénéhervé, 1990; Pinochet, 1977; Sarah, 1989; Vilardebo, 1971). Feeding on the cortical parenchyma of root tissue results in severe root necrosis that subsequently reduces anchorage of the root system and uptake of water and nutrients. Feeding damage from *R. similis* also increases disease incidence of Panama disease, hastening the decline of the plants.

Root-knot nematodes, *Meloidogyne* spp., are the most economically important nematode parasites worldwide and attack a broad range of crops. These nematodes are considered to be minor pests of full-grown bananas in the tropics (Blake, 1972; Gowen and Quénéhervé, 1990; Vilardebo, 1971) but may be important parasites of banana in subtropical areas where bananas are grown under suboptimal conditions (Sikora and Schlosser, 1973; Vovlas et al., 1993).

Currently, nematode control on banana relies primarily on the use of soil-applied chemical nematicides and fumigants. In many parts of the topics, e.g., Africa, nematicides are applied three times per year based on calendar dates to maintain low populations of *R. similis* (Quénéhervé, 1993). Continuous use of conventional soil-applied nematicides (e.g., organophosphate and carbamate compounds) for nematode control has been a serious concern in most banana-producing countries with regard to environmental and worker safety, residue tolerances, and ground water contamination. For these reasons, safer alternative methods for nematode control on banana are needed to reduce risks to humans and the environment.

Avermectins are 16-membered macrocyclic lactones that were isolated as fermentation products from the soil microorganism, *Streptomyces avermitilis* MA-4680 (NRRL 8165) (Campbell, 1989). The anthelmintic, insecticidal, and acaricidal activity of the avermectins is well known (Campbell,

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1989; Dybas, 1989; Jansson and Dybas, 1997; Lasota and Dybas, 1991; Shoop et al., 1995). Several researchers have shown that root-dip, bulb-dip, and soil applications of avermectins were effective at controlling plant-parasitic nematodes on certain crops (Blackburn et al., 1996; Cayrol et al., 1993; Garabedian and Van Gundy, 1983; Nordmeyer and Dickson, 1985; Putter et al., 1981; Roberts and Matthews, 1995; Sasser et al., 1982; Stretton et al., 1987). However, use rates needed to achieve satisfactory control were cost-prohibitive. Because avermectins are highly toxic to nematode parasites of animals and plants (Campbell, 1989; Putter et al., 1981; Stretton et al., 1987), studies have focused on discovering other applications for these compounds for control of plant-parasitic nematodes.

Recent studies showed that two avermectin compounds, abamectin and emamectin benzoate, had potential for controlling two parasitic nematodes on banana, *R. similis,* and a root-knot nematode, *Meloidogyne javanica* (Treub) Chitwood. Abamectin, the major avermectin fermentation component of *S. avermitilis,* was shown to be more effective than emamectin benzoate when applied as a root dip or when injected into the pseudostem of banana (Jansson and Rabatin, 1998). Pseudostem injections of ⩾125 µg a.i./plant were effective at protecting plants from both nematodes, and pseudostem-injection applications were more effective than root-dip applications at protecting banana plants from these nematodes. Injection of avermectins into plants was reportedly effective at controlling southern root-knot nematode, *M. incognita* (Kofoid & White) Chitwood, on tomato (Jutsum, 1988) and elm leaf beetle, *Pyrrhalta luteola* Müller, on Siberian elm (Harrell and Pierce, 1994). The present studies were conducted to determine the curative and residual activity of abamectin at controlling *M. javanica* and *R. similis* on banana when injected into pseudostems. Additional studies were conducted to determine the minimum effective concentration of abamectin needed to protect plants from these two nematodes when injected into the pseudostem. Finally, we compared the effectiveness of ivermectin, a derivative of abamectin that has been commercialized worldwide for control of nematode parasites of animals (Shoop et al., 1995), with abamectin for controlling these nematodes when injected into the pseudostem.

Materials and Methods

Nematode cultures: Nematodes used in these studies were cultured in vivo in a glasshouse. *Radopholus similis* was obtained from the USDA, ARS, Nematology Laboratory, BARC West, Beltsville, Maryland. This culture was maintained on 'Cavendish' banana (12–24 weeks old) grown in a soil:sand:peat (3:2:1) mixture in large tubs (150 liters) in a glasshouse maintained under a 14:10 (L:D) photophase with day and night temperatures between 26.1 ± 0.2°C and 14.4 ± 0.2°C, respectively, and 53.7 ± 1.2% RH. Soil temperatures were maintained continuously at approximately 22.8 ± 0.2°C. Additional cultures were maintained on monoxenic carrot discs (Moody et al., 1973) held in a controlled-environment chamber set at 12:12 (L:D) and 26.0 ± 0.3°C. Nematodes from these cultures were used only to supplement those extracted from the glasshouse culture when additional inoculum was required. *Meloidogyne javanica* was maintained on 'Rutgers' tomato grown in tubs (150 liters) in the glasshouse (Jansson and Rabatin, in press). Soil temperatures for the *M. javanica* culture were maintained at 28.3 ± 0.2°C by placing tubs on benches equipped with heating coils.

Minimum effective concentration experiments: Avermectins were applied to 3- to 4-month-old 'Cavendish' banana plants grown in 12.5-cm-diam. pots in a sand:soil mix (1:1) in a controlled environment glasshouse as described above. Plants were grown in the glasshouse for 3 months, and shoots were approximately 30 cm tall when the experiments were initiated.

Two studies were conducted to determine the minimum effective concentration of abamectin at controlling disease symptoms associated with *M. javanica* and *R. similis.* In both studies, five concentrations (10, 50, 100, 250, and 500 µg a.i./ml) of abamectin

(Merck, Whitehouse Station, NJ) were prepared by diluting a 1% soluble liquid (SL) formulation of abamectin in deionized water containing 100 µl/liter of Triton X-155 (Sigma Chemical, St. Louis, MO). Test concentrations were then applied in combination with 0.0625% solution of a nonionic surfactant, LeafAct 80A (Pure Gro, West Sacramento, CA). One-milliliter treatments were injected immediately above and into the center of the pseudostem at the first leaf axil with a 10-ml syringe (model no. 9604, Becton Dickinson, Rutherford, NJ). Abamectin treatments were compared with plants that were treated with fenamiphos (250 mg a.i./pot [0.4 kg a.i./ha]) (Nemacur 15 G, Bayer, Kansas City, MO) incorporated into the sand:soil mixture of 12.5-cm-diam. pots before transplanting bananas, and with untreated control plants. The rate of fenamiphos used was approximately 10% of that used in commercial plantations (Gowen and Quénéhervé, 1990).

Meloidogyne javanica eggs were collected from the roots of severely galled tomato stock plants by shaking roots vigorously in a 1% NaOCl solution for 4 minutes (Hussey and Barker, 1973). Egg suspensions were poured through nested 60-, 325-, and 500-mesh sieves (250-, 44- and 26-µm pores, respectively). Eggs were collected from the 26-µm screen after rinsing in tap water to remove NaOCl, then resuspended in water. Egg density was calibrated by counting numbers of eggs in 1-ml aliquots of the suspension. This aqueous suspension was then pipetted into openings on the soil surface of each potted banana plant 24 hours after treatment to achieve a density of 7,000 eggs per pot.

Vermiform stages of *R. similis* were extracted from the roots of banana plants used to culture this nematode and from monoxenic carrot disks over a 48-hour period using Baermann trays (Jansson and Rabatin, in press). Nematode suspensions were concentrated by allowing nematodes to settle and then removing surface water volumes by aspiration. The remaining suspension was mechanically stirred and aliquots (1 ml) were removed; nematodes were counted under a dissecting microscope. Approximately 700 vermiform nematodes were then dispensed around the base of each banana plant 24 hours after treatment. Pots were maintained in a controlled-environment glasshouse as described previously. Treatments were arranged in a completely randomized design with ten (*R. similis*) or six (*M. javanica*) replications.

Egg counts and root damage from *M. javanica* were assessed 28 days after treatment by washing roots thoroughly in water and visually inspecting roots for the presence of galls using a rating system from 0 to 10, where 0 = complete and healthy root system with no infection; 1 = very few small galls visible; 2 = small root galls more numerous and easily visible; 3 = numerous small galls, some of which have grown together, but root function is not seriously impaired, and so on up to 10 = death of plant and roots (Zeck, 1971). The entire root system of each plant was then excised into pieces (2.5–5.0 cm) and placed in a jar along with a 1% NaOCl solution (200 ml). The jar was shaken thoroughly for 4 minutes to dislodge eggs. The egg suspension was then poured through three nested screens to collect eggs as described above. Eggs were suspended in water and aliquots were removed to count eggs under a dissecting microscope as described above.

Numbers of *R. similis* in root tissue were assessed 28 days after treatment using methods similar to those described by Hooper (1986). Roots were washed and macerated in water in a blender. Each root system was then placed in individual Baermann trays; nematodes were collected from trays after 24 hours. Nematode suspensions were allowed to settle overnight and then concentrated to a volume of 100 ml. Several aliquots (1 ml) were then removed, diluted, and the number of nematodes counted under a dissecting microscope. The mean nematode count per aliquot was then used to calculate the number of nematodes extracted per plant.

Currative efficacy experiments: Two studies (one per nematode species) were conducted to assess the effectiveness of abamec-

tin at eradicating established infections of both nematodes. Banana was inoculated with each nematode species as described above and then treated with abamectin 28 days (approximately one life cycle) or 56 days (approximately two life cycles) after inoculation. Four concentrations (10, 125, 250, and 500 µg a.i./ml) of abamectin were prepared as described above and injected (1 ml) into the pseudostem on these two dates. Injection treatments of abamectin were compared with applications of fenamiphos (250 mg a.i./pot [0.4 kg a.i./ha]) incorporated into the soil, and with untreated plants as described above. Plants were held in a controlled-environment glasshouse, as described above, in a completely randomized design with ten (*R. similis*) or eight (*M. javanica*) replications. Nematode counts and gall damage were assessed 28 days after treatment. All other methods were similar to those described above.

An additional experiment was conducted to compare the curative efficacy of abamectin with that of ivermectin at controlling *R. similis*. Four concentrations (10, 125, 250, and 500 µg a.i./ml) of each compound were injected (1 ml) 28 days after inoculation. Ivermectin concentrations were prepared from a 1% SL formulation. All other methods were similar to those described above.

Residual efficacy experiments: Two studies (one per nematode species) were conducted to assess the residual effectiveness of abamectin at protecting banana plants from both nematodes. Two concentrations (100 and 1,000 µg a.i./ml) of abamectin were prepared and injected (1 ml) into banana as described above. Banana was then inoculated with each nematode species 1, 14, and 28 days after treatment. Injection treatments of abamectin were compared with applications of fenamiphos (250 mg a.i./pot [0.4 kg a.i./ha]) incorporated into the soil, and with untreated plants. Plants were inoculated with about 900 *R. similis* 1 day after treatment and with 1,000 *R. similis* 14 and 28 days after treatment. Plants were inoculated with approximately 4,400, 6,000, and 6,750 eggs of *M. javanica* per pot 1, 14, and 28 days after treatment, respectively. In both studies, plants were held in a controlled-environment glasshouse in a completely randomized design with eight (*R. similis*) or six (*M. javanica*) replications. Nematode counts and gall damage were assessed 28 days after inoculation using methods described above. All other methods were similar to those described above.

Data analysis: Data were analyzed using least squares analysis of variance and regression techniques (Zar, 1984). Gall damage ratings, *M. javanica* egg counts, and *R. similis* nematode counts were natural log (*ln*) or square root-transformed to normalize error variance. Means were separated with the Waller-Duncan *K*-ratio *t*-test (Waller and Duncan, 1969). Square-root or *ln*-transformed nematode counts, egg counts, or gall ratings were regressed on dose or *ln*-transformed dose of abamectin to generate dose response models from the experiments. Parameter estimates were compared among regression models, where appropriate, by a general linear test (Neter and Wasserman, 1974).

Results and Discussion

Minimum effective concentration experiments: Pseudostem injections of abamectin were effective at controlling *R. similis* and *M. javanica* (Table 1), which concurs with a similar study (Jansson and Rabatin, in press). For *R. similis*, numbers of nematodes extracted decreased with an increase in the dose of abamectin injected into banana (square-root[nematode count] = 15.62 − 2.39*ln*[dose + 1]; F = 63.2; df = 2,67; $P < 0.0001$; $R^2 = 0.65$). In general, reductions in the numbers of *R. similis* and disease symptoms associated with *M. javanica* were greatest on plants that received between 100 and 500 µg of abamectin and declined significantly on plants that received <100 µg of abamectin. Control of *R. similis* with fenamiphos (250 mg a.i./pot) was superior to all abamectin treatments, except for plants that received the highest dose (500 µg a.i./plant), which produced control comparable to fenamiphos. For *M. incognita*, numbers of eggs extracted also decreased with an in-

TABLE 1. Effectiveness of pseudostem injections of different dosages of abamectin at controlling *Radopholus similis* and *Meloidogyne javanica* on banana.

Treatment	Dosage (μg a.i./plant)	*R. similis* per plant	*M. javanica* eggs per plant	Gall rating per plant[a]
Abamectin 1% SL	10	56 ± 12 b	1,450 ± 613 b	1.0 ± 0.1 a
Abamectin 1% SL	50	58 ± 20 b	417 ± 70 c	0.3 ± 0.2 b
Abamectin 1% SL	100	20 ± 8 c	417 ± 126 c	0.0 ± 0.0 c
Abamectin 1% SL	250	20 ± 8 c	17 ± 16 d	0.0 ± 0.0 c
Abamectin 1% SL	500	18 ± 10 cd	33 ± 33 d	0.0 ± 0.0 c
Fenamiphos 15 G	250[b]	0 ± 0 d	0 ± 0 d	0.0 ± 0.0 c
Untreated control	—	334 ± 43 a	2,417 ± 658 a	1.2 ± 0.3 a

Numbers are means ± SE. Means in a column followed by the same letter do not differ by the Waller-Duncan *K*-ratio *t*-test (*K*-ratio = 100).

[a] Galls were rated on a scale from 0 (none) to 10 (severe, with plant death).

[b] Milligrams a.i. applied per pot.

crease in the dose of abamectin injected into banana (ln[egg count + 1] = 7.45 − 0.026[dose]; F = 74.4; df = 3,38; $P < 0.0001$; $R^2 = 0.85$). Gall ratings also decreased with an increase in the dose injected into plants (ln[gall + 1] = 0.712 − 0.0076[dose]; F = 23.1; df = 4,37; $P < 0.0001$; $R^2 = 0.71$). Counts of *M. javanica* eggs were lower on plants that received 250 to 500 μg of abamectin and on those that were treated with fenamiphos than on plants receiving all other treatments (Table 1). Egg numbers increased significantly on plants that received <250 μg of abamectin. Gall ratings were lowest on plants that received ≥100 μg of abamectin and on those treated with fenamiphos than on all other plants, albeit gall ratings were generally lower than expected. Collectively, these data showed that injections of 250 to 500 μg of abamectin per plant resulted in satisfactory control of both nematodes that was comparable or nearly comparable to control achieved with fenamiphos.

Curative efficacy experiments: Injections of abamectin were also effective at controlling *R. similis* 28 to 56 days after inoculation (Table 2). *Radoholus similis* counts decreased with an increase in the dose of abamectin injected 28 days (square-root[nematode count] = 24.19 − 3.28 ln[dose + 1]; F = 30.0; df = 2,45; $P < 0.0001$; $R^2 = 0.57$) or 56 days after inoculation (square-root[nematode count] = 15.10 − 0.017[dose]; F = 11.3; df = 2,45; $P < 0.0001$; $R^2 = 0.33$). Nematode control was comparable among plants that received 250 to 500 μg of abamectin and those that received fenamiphos when injections were made 28 days after inoculation; nematode control on plants that received 500 μg abamectin was comparable to that on fenamiphos-treated plants when injections were made 56 days after inoculation.

Injections of abamectin 28 to 56 days after inoculation were also effective at reducing counts of *M. javanica* eggs, but this nematode was not controlled as effectively as *R. similis* in this assay. None of the abamectin treatments were as effective as soil-applied treatments of fenamiphos at reducing egg counts (Table 2). Egg counts decreased with an increase in the dose of abamectin injected 28 days after inoculation (ln[egg count] = 9.14 − 0.182 ln[dose + 1]; F = 59.9; df = 2.27; $P < 0.0001$; $R^2 = 0.82$). When injections were made 56 days after inoculation, egg counts did not decrease on plants that received between 10 and 250 μg of abamectin; however, egg counts were 4.9 to 5.3-fold lower on plants that received 500 μg of abamectin than on those that received between 10 and 250 μg of abamectin and on untreated plants (Table 2).

Gall rating data were more difficult to interpret because some galls had already formed before treatments were applied. When injections were made 28 days after inoculation, gall ratings decreased with an increase in the dose of abamectin injected (square-root[gall rating] = 2.25 − 0.002[dose]; F = 66.0; df = 2,45; $P = 0.0001$; $R^2 = 0.75$). Gall ratings were lowest on plants that received 500 μg of abamectin and on those

TABLE 2. Effectiveness of pseudostem injections of different dosages of abamectin at controlling *Radopholus similis* and *Meloidogyne javanica* on banana when injected 28 or 56 days after inoculation.

Treatment	Dosage (µg a.i./plant)	*R. similis*/plant		*M. javanica* eggs/plant		Gall rating/plant[a]	
		28 days	56 days	28 days	56 days	28 days	56 days
Abamectin 1% SL	10	205 ± 44 b	133 ± 20 b	7,620 ± 1,344 a	73,555 ± 8,994 a	5.1 ± 0.3 a	6.5 ± 0.1 a
Abamectin 1% SL	125	122 ± 41 bc	160 ± 24 b	3,640 ± 668 b	72,111 ± 7,530 a	4.5 ± 0.4 a	6.7 ± 0.2 ab
Abamectin 1% SL	250	26 ± 9 cd	73 ± 20 bc	4,380 ± 473 b	74,333 ± 11,446 a	2.0 ± 0.2 b	6.1 ± 0.3 b
Abamectin 1% SL	500	90 ± 73 cd	43 ± 18 cd	2,780 ± 607 b	14,125 ± 1,925 b	1.6 ± 0.3 bc	5.4 ± 0.5 c
Fenamiphos 15 G	250[b]	5 ± 3 d	5 ± 3 d	870 ± 106 c	3,622 ± 1,365 c	1.4 ± 0.3 c	5.3 ± 0.5 c
Nontreated control	—	808 ± 195 a	665 ± 226 a	8,580 ± 749 a	69,889 ± 8,664 a	5.0 ± 0.3 a	6.8 ± 0.1 a

Means in a column followed by the same letter do not differ by the Waller-Duncan *K*-ratio *t*-test (*K*-ratio = 100).
[a] Galls were rated on a scale from 0 (none) to 10 (severe, with plant death).
[b] Milligrams a.i. applied per pot.

that received fenamiphos 28 days after inoculation (Table 2). Gall ratings were considerably higher when treatments were applied 56 days after inoculation. At this time, approximately two generations of root-knot nematodes had colonized and galled cortical tissue. Nonetheless, trends in the data were comparable with those for applications made 28 days after inoculation. Collectively, these data demonstrate that shoot injections of abamectin have potential for controlling existing infestations of *R. similis* and suppressing existing infestations of *M. javanica.*

Counts of *R. similis* decreased with an increase in the dose of abamectin and ivermectin injected into plants (abamectin: square-root[nematode count] = 15.26 − 0.056[dose]; ivermectin: square-root [nematode count] = 15.26 − 0.010[dose]; F = 17.4; df = 5,104; $P < 0.0001$; $R^2 = 0.46$) (Table 3). Slopes differed ($P = 0.0001$) between the two compounds: the slope for abamectin was markedly steeper than that for ivermectin, indicating that abamectin was more effective than ivermectin at controlling established infestations of *R. similis* on banana at the dosages tested. Control achieved with injections of 250 and 500 µg/plant of abamectin was comparable to that achieved with fenamiphos, which concurs with earlier results (Table 3). Abamectin was more effective than emamectin benzoate at

TABLE 3. Effectiveness of pseudostem injections of different dosages of abamectin and ivermectin at controlling *Radopholus similis* on banana when injected 28 days after inoculation.

Treatment	Dosage (µg a.i./plant)	*R. similis* per plant
Abamectin 1% SL	10	212 ± 73 de
Ivermectin 1% SL	10	332 ± 6 ab
Abamectin 1% SL	125	110 ± 54 ef
Ivermectin 1% SL	125	208 ± 77 cde
Abamectin 1% SL	250	30 ± 13 fg
Ivermectin 1% SL	250	196 ± 46 de
Abamectin 1% SL	500	8 ± 4 fg
Ivermectin 1%SL	500	148 ± 46 de
Fenamiphos 15 G	250[a]	0 ± 0 g
Nontreated control	—	392 ± 86 a

Nematode numbers are means ± SEM. Means followed by the same letter do not differ by the Waller-Duncan *K*-ratio *t*-test (*K*-ratio = 100).
[a] Milligrams a.i. applied per pot.

controlling nematodes on banana (Jansson and Rabatin, in press). Abamectin is slightly more potent than ivermectin to most nematode parasites of animals (Shoop et al., 1995). Abamectin is also more potent than ivermectin or emamectin benzoate to *R. similis* in contact toxicity assay (R. Jansson and S. Rabatin, unpubl.). The higher toxicity of abamectin to *R. similis* helps, in part, to account for its superior efficacy compared with ivermectin and emamectin benzoate when injected into banana plants.

Residual efficacy experiments: Pseudostem injections of abamectin were effective at protecting banana plants from both nematode species even when plants were infected up to 28 days after treatment (Table 4). Nematode counts and gall ratings did not differ among plants that received 100 and 1,000 µg of abamectin and those treated with fenamiphos (250 mg a.i./pot) on all but one inoculation date. Thus, injections of as little as 100 µg of abamectin provided residual control for at least 28 days. Considering that plants were evaluated 28 days after infestation, residual control of both nematodes was achieved for 56 days after treatment, the maximum interval that plants were maintained in the glasshouse.

These data concur with those from Jansson and Rabatin (in press) and show that injection applications of avermectins have potential for controlling nematode parasites on banana. Satisfactory protectant, curative, and residual control was demonstrated when 100 to 500 µg of abamectin was injected into plants. Additionally, control achieved with injection of abamectin was comparable to that achieved with a soil-incorporated application of a chemical standard, fenamiphos. Currently, control of *R. similis* and other nematodes in intensively grown banana plantations relies on the use of high rates (5 to 20 kg a.i./ha) (Hague and Gowen, 1987) of organophosphate and carbamate insecticides/nematicides broadcast over the soil surface. When used in banana plantations, these products pose significant risks to workers, applicators, consumers, and the environment, and are expected to receive increased scrutiny from regulatory agencies worldwide. For these reasons, the banana industry is actively striving to identify safer alternatives for control-

TABLE 4. Residual efficacy of pseudostem injections of different dosages of abamectin at controlling *Radopholus similis* and *Meloidogyne javanica* on banana.

Treatment	Dosage (µg a.i./plant)	Day after treatment[a]		
		1	14	28
		R. similis per plant		
Abamectin 1% SL	100	10 ± 8 b	5 ± 3 b	30 ± 12 b
Abamectin 1% SL	1,000	0 ± 0 b	0 ± 0 b	15 ± 7 bc
Fenamiphos 15 G	250[b]	0 ± 0 b	0 ± 0 b	3 ± 3 c
Nontreated control	—	570 ± 161 a	115 ± 11 a	193 ± 43 a
		M. javanica eggs per plant		
Abamectin 1% SL	100	50 ± 25 b	0 ± 0 b	0 ± 0 b
Abamectin 1% SL	1,000	27 ± 18 b	0 ± 0 b	0 ± 0 b
Fenamiphos 15 G	250[b]	0 ± 0 b	0 ± 0 b	0 ± 0 b
Nontreated control	—	1,487 ± 508 a	110 ± 28 a	107 ± 39 a
		Gall rating per plant[c]		
Abamectin 1% SL	100	0.0 ± 0.0 b	0.3 ± 0.2 b	0.3 ± 0.2 b
Abamectin 1% SL	1,000	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 b
Fenamiphos 15 G	250[b]	0.0 ± 0.0 b	0.0 ± 0.0 b	0.2 ± 0.2 b
Nontreated control	—	0.7 ± 0.2 a	1.0 ± 0.4 a	1.3 ± 0.2 a

Numbers are means ± SEM. Means in a column followed by the same letter do not differ by the Waller-Duncan *K*-ratio *t*-test (*K*-ratio = 100).

[a] Day after application that plants were infested with nematodes; plants were evaluated 28 days after inoculation.

[b] Milligrams a.i. applied per pot.

[c] Galls were rated on a scale from 0 (none) to 10 (severe, with plant death).

ling nematodes. The present studies support the need to conduct field studies to assess the potential of injection applications of abamectin into banana for nematode control.

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