Effects of Dosage Sequence on the Efficacy of Nonfumigant Nematicides, Plantain Yields, and Nematode Seasonal Fluctuations as influenced by Rainfall

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Abstract: Four nonfumigant nematicides applied three times during the wet season were used to study dosage sequence and nematicide effectiveness. Control of *Helicotylenchus multicinctus* (Cobb) Thorne and *Meloidogyne javanica* (Treub) Chitwood increased plantain (*Musa* AAB) yields. The nematicide (aldicarb, carbofuran, oxamyl, and miral) performance and yield response varied with dosage sequences. Applications of 2, 3, and 2 g ai/tree in March, July, and October (sequence I), respectively, gave greater control of *M. javanica* than did applications of 3, 2, and 2 g ai/tree in March, June, and September (sequence II), respectively. However, the high initial dose sequence was effective against *H. multicinctus*. Persistence of the different nematicides differed over the 14-month experimental period. Miral, aldicarb, and carbofuran were the most effective treatments against either species by the end of the wet and dry seasons. Dry season residual nematode populations were significantly lower in nematicide treated than in control plots. Yield increases over controls were 96.9, 90.1, 78.4, and 70.1% for carbofuran applied by sequence II, aldicarb by II and I, and oxamyl by II, respectively. Nematode populations directly fluctuated with rainfall and dropped to low (*H. multicinctus*) or to undetectable (*M. javanica* juveniles) levels during the dry season. Of the two nematodes studied, the more serious pest to plantain was *H. multicinctus;* it was tolerant to drought and survived the dry season in untreated soils. *Key words:* chemical control, *Musa* AAB, spiral nematode, root-knot nematode, nematode-rainfall-dose interrelationships, population dynamics, survival.

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Plantain (*Musa acuminata* Colla X *M. balbisiana* Colla, AAB), an important food and commercial crop in the tropics, is seriously damaged by several nematodes such as *Radopholus similis* (Cobb) Thorne, *Helicotylenchus multicinctus* (Cobb) Golden, *Meloidogyne javanica* (Treub) Chitwood, and *M. incognita* (Kofoid & White) Chitwood (1,6,9). Because of the lack of nematode resistant *Musa* spp., fumigant or nonfumigant nematicides are the most effective methods of nematode control (4,5,7,9,10,12). It has been shown that soil treatment with either carbofuran or oxamyl at 3 g ai/tree followed by another 1.2 g ai/tree 4 months later reduces damage caused by *H. multicinctus* and *M. javanica* to established plantains (3). Other studies have shown that nematode soil population levels are interrelated with rainfall patterns in the tropics (3,6,8). Timely nematicide applications during the wet season should lower population levels and give continuous protection to long-term plantain stands. As rainfall patterns will influence the effectiveness of nematicides, appropriate dosage and application sequence designs are essential for meaningful nematode control.

The objectives of this study were to evaluate further the efficacy of nonfumigant nematicides on nematode parasites of plantain and to determine 1) the effects of two application sequences on the efficacy of the nematicides, 2) the correlations between rainfall patterns and nematode population levels, and 3) the treatment effect on nematode population survival through the dry season.

MATERIALS AND METHODS

The studies were conducted in an 8-month-old plantain (cv. Orishele) plantation heavily infested with *H. multicinctus* and *M. javanica*. The top soil was a loamy sand (82% sand, 11.6% silt, 6.5% clay), pH 6.9, 2.4% organic matter, and the following exchangeable cations per gram of soil: 1,320 μg Ca, 6 μg Mg, 1 μg Mn, 120 μg K, and 20 μg Na. The nonfumigant nematicides—aldicarb, carbofuran, miral, and oxamyl—were incorporated into the soil within a 0.75-m radius of each tree. A total of 7 g ai/tree was applied between March and October in three applications using two different sequence patterns. In sequence I, nematicides were applied at 2, 3, and 2 g ai/tree in March, July, and October, respectively; in sequence II, nematicides were applied at 3, 2, and 2 g ai/tree in March, June, and September, respectively. The experi-

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ment was a completely randomized design with six replications of one tree each and the untreated controls. The trees were grown under natural rainfall conditions without supplemental irrigation, and the harvest was made in the dry season.

Nematode numbers in the soil were determined monthly throughout the experiment. Three soil cores, 2.5 cm d × 20 cm long, were collected within the treated area of each tree. The cores were combined and three 120-cm^3 subsamples used for assay. Root samples (100 g/tree) were collected for nematode extraction in July and December 1979 and in March 1980. Nematodes were extracted from soil and root samples by the modified Baermann technique (13) and concentrated by the settling-siphon method (2). Trunk circumference 1 m above the soil surface, plant height, number of leaves, and suckers were recorded at the beginning of the experiment and at harvest. The number of fruits per bunch and bunch weights were recorded at harvest. The experiment was continued into the dry season after harvest to determine nematode population carry-over; it was terminated in the beginning of the next wet season. Data were subjected to regression b values, analysis of variance, and Duncan's multiple-range test (11).

RESULTS

Nematodes in soil: The numbers of nematodes in the treated areas were generally below levels in untreated areas, though in a few instances numbers from low populations tended to increase to above untreated (Figs. 1, 2, 3, 4). In comparing the nematode species-dosage response relations, numbers of *H. multicinctus* declined with sequence I (Fig. 1) slower than with sequence II (Fig. 2), while *M. javanica* was controlled better with aldicarb, carbofuran, and miral applied by sequence I (Fig. 3) than with sequence II (Fig. 4) as expressed by b values (Table 1).

Population data (Figs. 1, 2, 3, 4) and b values (Table 1) show the gradual effectiveness of the four nematicides during the experiment. Oxamyl treatment resulted in the earliest marked reduction in both nematode species during the wet season. However, it had a less prolonged effect during the dry season, and high numbers of both nematode species carried over into the next growing season (Figs. 1, 2, 4). Conversely, miral treatments applied by sequence I and II were slower to act against both species (Figs. 1, 4), but by the end of the wet season (late November 1979), it had provided a high degree of control (Table 1) which extended into the dry season. Aldicarb applied by

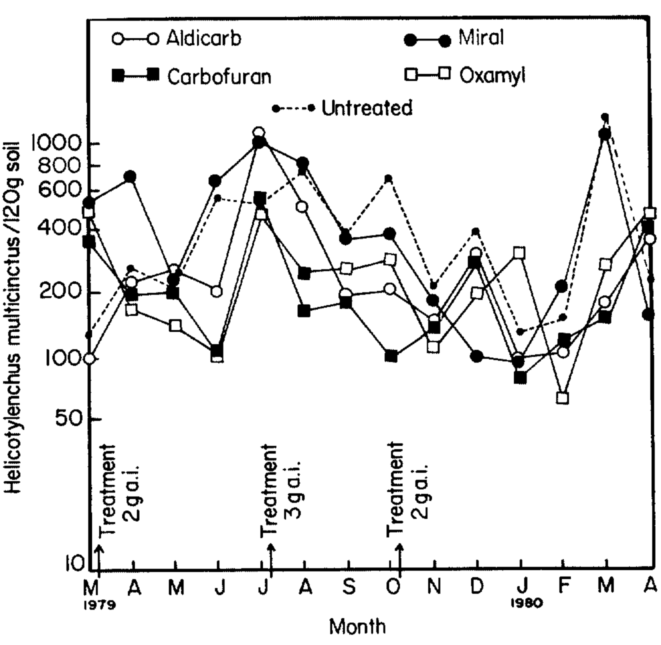

Fig. 1. Fluctuations of *Helicotylenchus multicinctus* populations in soil with application sequence I (2, 3, and 2 g ai/tree in March, July, and October) of nonfumigant nematicides and time.

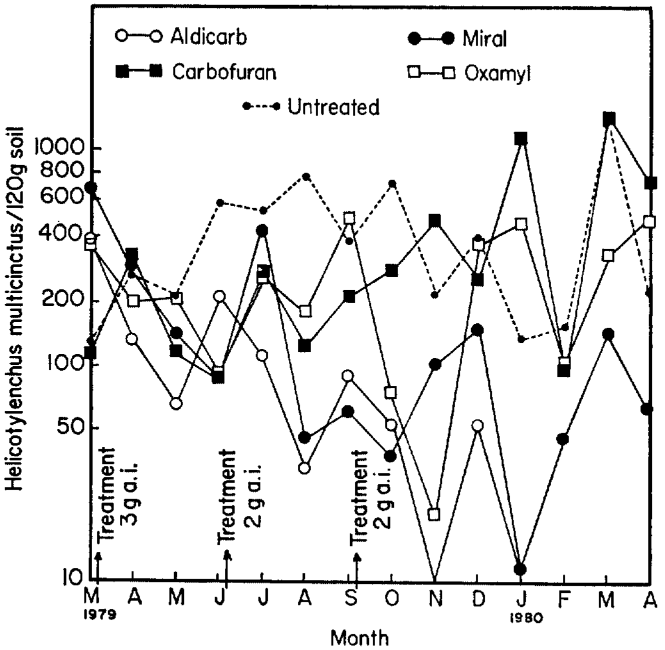

Fig. 2. Fluctuations of *Helicotylenchus multicinctus* populations in soil with application sequence II (3, 2, and 2 g ai/tree in March, June, and September) of nonfumigant nematicides and time.

sequence II gave a consistant pattern of control during the wet season, especially against *H. multicinctus* (Fig. 2); populations continued to decline during the dry season and by the end of the experiment (April 1980), neither nematode species was detected in treated soils (Figs. 2, 4). Carbofuran controlled nematodes satisfactorily in the wet season but was less deterimental to *H. multicinctus* than to *M. javanica* in the

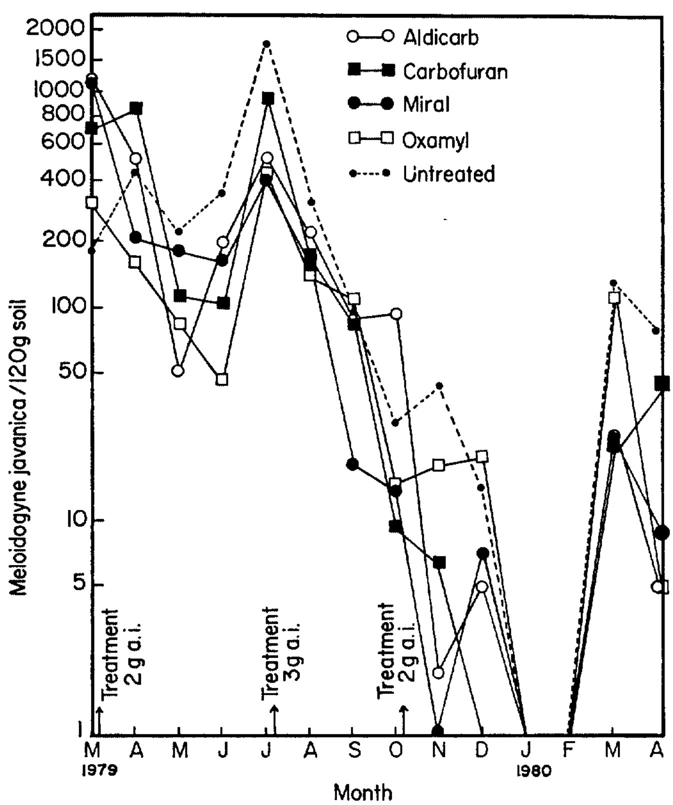

Fig. 3. Fluctuations of *Meloidogyne javanica* populations in soil with application sequence I (2, 3, and 2 g ai/tree in March, July, and October) of nonfumigant nematicides and time.

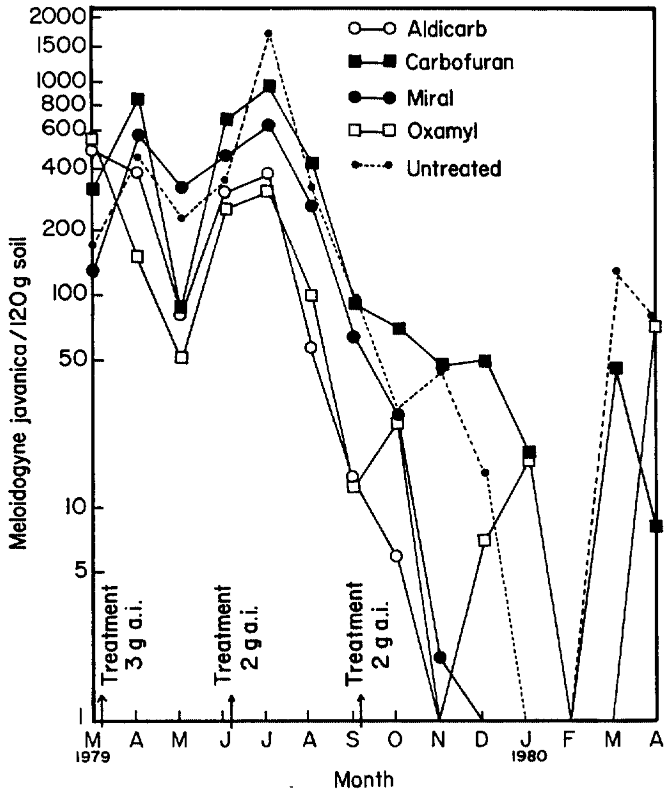

Fig. 4

Fig. 4. Fluctuations of *Meloidogyne javanica* populations in soil with application sequence II (3, 2, and 2 g ai/tree in March, June, and September) of nonfumigant nematicides and time.

dry season (Figs. 2, 4). The regression b values indicate that by the end of the two seasons the most effective treatment against either nematode population was miral followed by aldicarb or carbofuran (Table 1).

Nematodes in roots: Numbers of nematodes in roots in the middle (July) and at the end (December) of the wet season were depressed by sequence II in most cases, but most nematicides in sequence I had sustained significantly higher population densities than in untreated plots (Table 2). Numbers of *M. javanica* juveniles recovered from roots declined from the high obtained

Table 1. Regression b values of *Helicotylenchus multicinctus* and *Meloidogyne javanica* numbers in soil at the middle (b_1) and end (b_2) of the experiment as influenced by nematicide treatments.*

Nematicide (7 g ai/tree) and application sequence†	*H. multicinctus*		*M. javanica*	
	b_1 (after 8 intervals)	b_2 (after 13 intervals)	b_1 (after 8 intervals)	b_2 (after 13 intervals)
Aldicarb 15% G (I)	+27.2	−9.9	−110.1	−51.6
Aldicarb 15% G (II)	−36.3	−21.1	−58.0	−32.2
Carbofuran 10% G (I)	−20.8	−6.5	−86.3	−51.9
Carbofuran 10% G (II)	+10.8	+64.3	−48.5	−51.5
Miral 10% G (I)	−4.7	−25.4	−110.7	−51.0
Miral 10% G (II)	−71.0	−28.7	−38.0	−39.1
Oxamyl 10% G (I)	−5.0	−1.7	−22.2	−18.2
Oxamyl 10% G (II)	−10.2	+8.4	−49.2	−25.7
Control	+75.7	+16.7	−12.5	−41.5

*b_1, March 1979 to October 1979; b_2, March 1979 to March 1980.

†Sequence I = 2, 3, and 2 g ai/tree in March, July, and October; Sequence II = 3, 2, and 2 g ai/tree in March, June, and September.

Table 2. Effect of nematicide application sequence on numbers of *Helicotylenchus multicinctus* and *Meloidogyne javanica* juveniles per 100 g of plantain roots.*

Nematicide (7 g ai/tree) and application sequence†	Number of nematodes					
	July 1979		December 1979		March 1980	
	H. multicinctus	*M. javanica*	*H. multicinctus*	*M. javanica*	*H. multicinctus*	*M. javanica*
Aldicarb 15% G (I)	812 c	254 b	42 a	0	205 a	0
Aldicarb 15% G (II)	109 a	23 a	0 a	0	195 a	0
Carbofuran 10% G (I)	1112 c	208 b	7 a	4	68 a	0
Carbofuran 10% G (II)	245 a	78 a	401 c	0	45 a	0
Miral 10% G (I)	1461 d	41 a	217 b	0	80 a	0
Miral 10% G (II)	491 b	249 b	72 a	0	325 b	0
Oxamyl 10% G (I)	208 a	35 a	23 a	0	11 a	0
Oxamyl 10% G (II)	23 a	28 a	126 b	21	568 c	0
Control	322 b	278 b	14 a	0	900 d	30

*Means of six replications. Means followed by the same letters are not significantly different according to Duncan's multiple-range test ($P = 0.05$).

†Sequence I = 2, 3, and 2 g ai/tree in March, July, and October; sequence II = 3, 2, and 2 g ai/tree in March, June, and September.

in July to very low in December and none in March. *H. multicinctus* root population was highest in July and greatly reduced in December and March in areas treated by sequence I, but populations in areas treated by sequence II were generally uniform for the three sampling dates.

Soil and root populations of *H. multicinctus* and *M. javanica* appeared to be rhythmically ascending or descending with rainfall fluctuations (Fig. 5). There were significant positive correlations between population levels of *M. javanica* (untreated plots) and total or average daily rainfall, but not number of rain days. *H. multicinctus* populations appeared to be less sensitive than *M. javanica* populations to rainfall, since all correlations were not significant.

Yield: Plant height increase, leaves per tree, and fingers per bunch were not significantly affected by most treatments, but tree circumference increase, number of suckers per tree, and bunch weight showed favorable responses to treatments (Table 3). All treatments, except miral II, significantly increased bunch weight and, similarly, the number of suckers per tree. The effect of sequence I or II on bunch yield was only significant with aldicarb and carbofuran (Table 3). Yields from oxamyl and miral treated areas were significantly greater than from untreated controls, but there were no differences between the two sequences of application. Yield increases over controls were 96.9, 90.1, 78.4, and 70.1% for carbofuran II, aldicarb II, aldicarb I, and oxamyl II, respectively.

DISCUSSION

The results showed differences in the efficacy of nonfumigant nematicides against *H. multicinctus* and *M. javanica* infesting plantains when applied in two different dosage sequences. Sequence II appeared better in controlling *H. multicinctus* and improving yields, whereas sequence I was more effective against *M. javanica.* These findings appear to correspond to rainfall intervals and magnitude and biological interrelationships with nematode species in the agroecosystem. Rainfall has appeared to variably influence population dynamics which might in turn have interacted with the performance of the nematicides by determining the dose variability required for suppression of a certain nematode species. With *M. javanica* responsive to the heavy rainfall of June, July, and August, a second treatment at the higher rate of 3 g ai/tree in July (sequence I) was necessary to achieve control, in contrast to the second treatment of 2 g ai/tree in June (sequence II) which was insufficient. Being less influenced by rainfall, *H. multicinctus* was better controlled by a higher initial dose (3 g ai/tree) at the onset of the rains (sequence II) than by an initial low dose (sequence I).

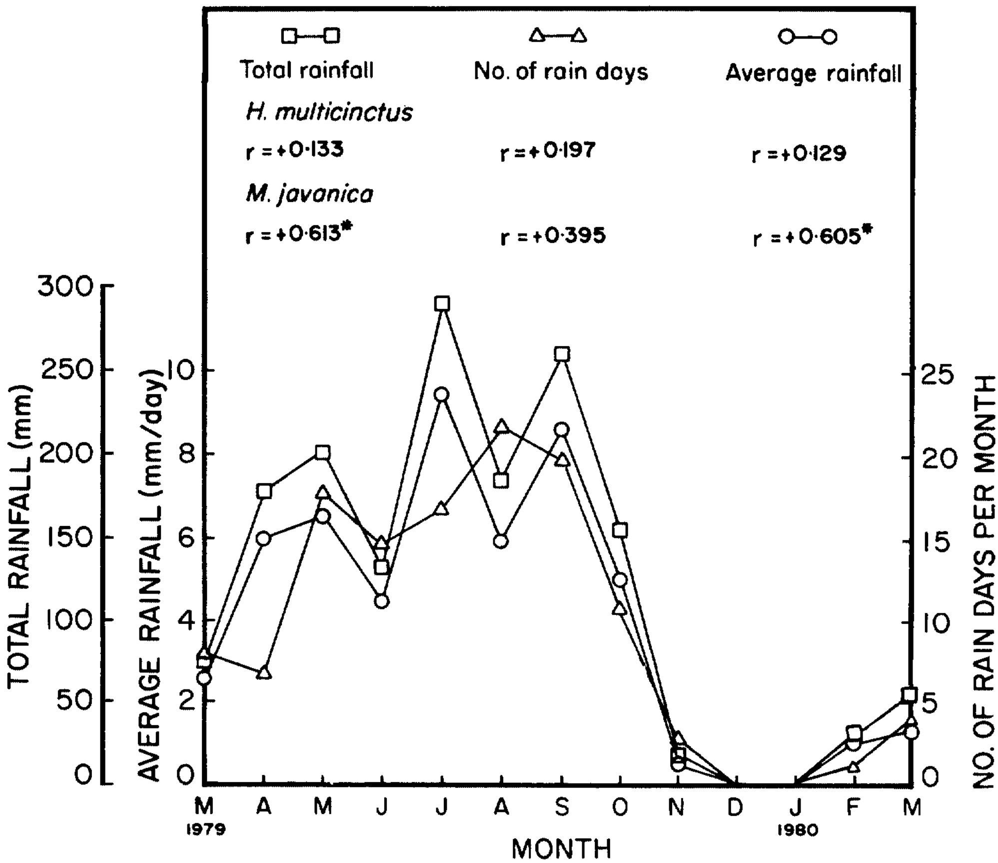

Fig. 5. Rainfall records and abiotic regulation of *Helicotylenchus multicinctus* and *Meloidogyne javanica* populations in untreated soils. An * indicates a significant correlation of a nematode species with total rainfall, average rainfall, or number of rain days per month in untreated soils.

Table 3. Influence of application sequence on efficacy of nematicide treatments on plantain growth and marketable fruits.*

Nematicide (7 g ai/tree) and application sequence†	Height increase‡ (cm)	Circumference increase‡ (cm)	Leaves per tree (No.)	Suckers per tree (No.)	Fingers per bunch (No.)	Bunch weight (kg)	Yield increase over untreated (%)
Aldicarb 15% G (I)	185.4 b	22.6 b	12.3 a	6.6 b	50.5 a	17.3 b	178.4
Aldicarb 15% G (II)	172.5 a	22.2 b	12.3 a	6.8 b	51.8 b	18.5 c	190.1
Carbofuran 10% G (I)	154.2 a	21.0 b	12.7 a	8.3 c	49.6 a	15.3 b	157.7
Carbofuran 10% G (II)	166.6 a	23.0 b	12.6 a	8.0 c	49.8 a	19.1 c	196.9
Miral 10% G (I)	162.0 a	19.8 b	13.5 b	5.8 b	53.3 b	14.0 b	144.3
Miral 10% G (II)	150.5 a	19.3 a	12.7 a	5.7 a	47.8 a	15.1 b	155.7
Oxamyl 10% G (I)	187.0 b	24.5 c	11.2 a	7.0 b	47.3 a	14.6 b	150.1
Oxamyl 10% G (II)	197.6 b	24.0 b	13.0 b	7.2 b	54.2 b	16.5 b	170.1
Control	158.8 a	14.8 a	12.5 a	4.3 a	44.6 a	9.7 a	100.0

*Means of six replications of one tree each. Means followed by the same letters are not significantly different according to Duncan's multiple-range test ($P = 0.05$).

†Sequence I = 2, 3, and 2 g ai/tree in March, July, and October; sequence II = 3, 2, and 2 g ai/tree in March, June, and September.

‡Height or circumference increase represents the difference in the measurements taken at the beginning of the trial and at harvest.

The observations show that in either sequence, the final dose of 2 g ai/tree was useful in maintaining nematicidal suppression into the dry season when nematode populations are lowest. This continued suppression apparently helped minimize injury caused by *H. multicinctus* persisting in soils and roots during the dry season and produced a minimal nematode carryover into the next growing season.

The comparative behavior of the two nematode species shows that *H. multicinctus* is probably of greater importance to plantains than *M. javanica*. *H. multicinctus* was observed to survive and even maintain high populations in very dry soils, while *M. javanica* declined to undetectable levels in soils and roots of the host, as reported earlier (3,6,8). These findings suggest that multiple application sequences should be aimed at *H. multicinctus* rather than at *M. javanica* and that rainfall patterns should be considered in designing control strategies.

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