MANAGEMENT OF *MELOIDOGYNE INCOGNITA* POPULATIONS BY CROP ROTATION IN A SMALL-SCALE FIELD TRIAL AND NEMATODE PATHOGENIC EFFECTS ON SELECTED CULTIVARS

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ABSTRACT

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The density of field populations of the root-knot nematode, *Meloidogyne incognita* Race 1, was suppressed and maintained at a low level for 3 yr in a small-scale crop rotation trial. The cropping sequence from mid-August, 1978, to early January, 1982, was: a 3:1 mixture of red and white sorrel (*Hibiscus sabdariffa*); a 5-wk weed fallow; cassava (*Manihot esculenta*); a 1- and 3-mo weed and clean fallow, respectively; chinese cabbage (*Brassica chinensis*); maize (*Zea mays*); red kidney beans (*Phaseolus vulgaris*); a mixed crop of cowpeas (*Vigna unguiculata*) and callaloo (*Amaranthus viridis*); and finally, red sorrel. The density of *Pratylenchus* sp. increased in cassava and maize rhizosphere soil while those of *Helicotylenchus* sp. and *Rotylenchulus reniformis* increased in maize and cowpea rhizosphere soil. *Tylenchorhynchus* sp. density increased during the cultivation of red kidney beans and callaloo intercropped with cowpeas. Roots of the first crop of red sorrel and maize yielded large numbers of *M. incognita* and *Pratylenchus* sp., respectively. In a greenhouse test, *M. incognita* infested all cultivars grown in the field trial but callaloo and white sorrel appeared to be less suitable hosts of the nematode than the other test plants. The root-knot nematode adversely affected growth of all greenhouse-grown crops, except cassava.
Additional key words: Nematode population changes, cropping system, greenhouse tests.

RESUMEN

Hutton, D.G., Phyllis L. Coates-Beckford, and Sharon A.E. Eason-Heath. 1983. Manejo de las poblaciones de *Meloidogyne incognita* mediante la rotación de cosechas en pruebas de campo de menor escala y efectos patógenicos del nematodo en cultivares selectos. Nematropica 13:163-153.

La densidad de las poblaciones del nematodo de los nódulos de las raices, *Meloidogyne incognita* race 1, fue suprimida y mantenida a un nivel bajo por tres años en pruebas de campo de menor escala de rotación de cosechas. La sequencia de cosechas desde mediados de Agosto de 1978 hasta principios de Enero de 1982, fue: una

mezcla 3:1 de serení rojo y blanco (*Hibiscus sabdariffa*); barbecho de hierbas de 5 semanas; yuca (*Manihot esculenta*); 1 y 3 meses de hierbas y barbecho limpio respectivamente; col china (*Brassica chinensis*); maíz (*Zea mays*); frijol colorado (*Phaseolus vulgaris*); una mezcla de frijol de vaca (*Vigna unguiculata*) y bledo (*Amaranthus viridis*); y por último serení rojo. La densidad de *Pratylenchus* sp. aumentó en el suelo del area radicular de la yuca y el maíz mientras que el *Helicotylenchus* sp. y el *Rotylenchulus reniformis* aumentaron en el suelo del area radicular del maíz y el frijol de vaca. La densidad de *Tylenchorhynchus* sp. aumentó durante el cultivo de frijol colorado y el bledo intercalado con el frijol de vaca. Las raices de la primera cosecha de serení rojo y maíz produjeron conteos altos de *M. incognita* y *Pratylenchus* sp. respectivamente. En una prueba de invernadero, *M. incognita* infestó todos los cultivares usados en la prueba de campo, pero el bledo y el serení blanco mostraron ser huespedes menos apropiados del nematodo que el resto de las plantas probadas. El nematodo de los nódulos de las raices afectó adversamente el crecimiento de todas las cosechas en el invernadero con excepcion de la yuca.
Palabras claves adicionales: Cambios en la población de nematodos, rotación de cosechas, pruebas de invernadero.

INTRODUCTION

Species of root-knot nematodes, *Meloidogyne* Goeldi, are considered to be among the top five major pathogens affecting both quality and quantity of world food supply (7). In Jamaica, these nematodes were found associated with approximately 85% of 140 economic and other plant species surveyed (2). *Meloidogyne incognita* (Kofoid and White) Chitwood represents approximately 64% of the root-knot nematode populations occurring in tropical countries (8) and appears to be the most common and most important species in Jamaica (1).

Lamberti (3) has suggested that the use of chemicals is likely to be the main method of controlling root-knot nematodes since the wide polyphagy of the more important species precludes the use of other control measures. However, alternative methods of control are desirable in Jamaica because of the high cost and unavailability of suitable chemicals and applicators. Crop rotation was one alternative practice followed by farmers worldwide long before its significance as a nematode control measure was recognized (4, 6). By this method, the population of a particular nematode species may be reduced by planting a non-host or poor host before an economically valuable but susceptible host (6).

In this trial we have attempted to devise a three-year crop rotation scheme for the control of *M. incognita* in a region of Jamaica where the size of many farms ranges from 0.25-2.00 ha.

MATERIALS AND METHODS

Field trial

The experiment was conducted from August, 1978, to January, 1982, on a 0.1 ha field located at Tamarind Farm Prison, Spanish Town, Jamaica, at an elevation of 15 m above sea level. The yearly average rainfall and mean air temperature recorded for the 3 years was 59.4 mm and 26.1C, respectively. Monthly average rainfall ranged from 0.0 mm in January to 123.0 mm in September and mean temperature from 23.7C in January to 27.7C in September. The soil type was Caymanas clay loam (13% sand, 67% silt, 20% clay).

The field was cropped to okra, *Abelmoschus esculentus* (L.) Moench before the start of the trial in order to increase the density of soil populations of *M. incognita* (2). Crops commonly grown in the region were selected for the trial. They were: callaloo (*Amaranthus viridis* L.); cassava, a mixture of accession nos. C5, 30, and 69 (*Manihot esculenta* Crantz); chinese cabbage cv. Santoh Round Leaved (*Brassica chinensis* L.); maize cv. MB-2 (*Zea mays* L.); cowpeas cv. African Red (*Vigna unguiculata* [L.] Walp.); red kidney beans cv. California Light Red (*Phaseolus vulgaris* L.); sorrel cvs. Red and White (*Hibiscus sabdariffa* L.); and tomatoes cv. Walter (*Lycopersicon esculentum* Mill). The growing period for each crop was chosen to avoid or minimize the damage caused not only by *M. incognita,* but also by other endemic plant pathogens known to be active at particular seasons, to avoid excessive depletion of essential minerals from the soil, and also to fit in with traditional farming practices. The cropping sequences were as shown in Table 1. Seeds of red and white sorrel were mixed inadvertently, approximately 3:1, respectively, at sowing in August, 1978. Cowpeas and callaloo were intercropped from June to August, 1981. All other cultivars were grown singly. Tomatoes were planted in late March, 1980, after cassava had been harvested. However, the seeds were not viable and a fallow was substituted.

Table 1. Sequence and growth period of crops selected for a rotation trial at Spanish Town for control of *Meloidogyne incognita.*

Crop	Growth period	No. plants/ha
Sorrel cvs. Red and White	Mid-Aug 1978 - early Feb 1979	35,800
Clean fallow	Early Feb 1979 - mid-Mar 1979	—
Cassava	Mid-Mar 1979 - late Mar 1980	8,970
Weed fallow	Late Mar 1980 - early May 1980	—
Clean fallow	Early May 1980 - mid Jul 1980	—
Chinese cabbage	Mid-Jul 1980 - late Sep. 1980	43,000
Maize	Late Sep. 1980 - late Jan 1981	35,000
Red kidney beans	Late Jan 1981 - late Apr 1981	63,800
Cowpeas	Early May 1981	13,500
and	and - mid Aug 1981	and
Callaloo	Mid Jun 1981	20,000
Sorrel cv. Red	Mid Aug 1981 - late Jan 1982	35,800

Samples of four to 10 randomly selected units, each comprising 20-30 g of roots and approximately 1,000 cm^3 of rhizosphere soil, were taken at a depth of 10-20 cm at various time intervals during crop growth. Nematodes were extracted from roots by chopping 10g in 150 ml water in a blender for 40 sec and screening the suspension through 20-, 60-, and 325-mesh sieves. The residue on the 325-mesh sieve was collected in water and the filtrate was passed through and the residue collected from the 325-mesh sieve six more times. Nematodes were extracted from a 150 cm^3 soil sample aliquant by the method of Whitehead and Hemming (12). The final suspensions from the root and soil samples were reduced to 100 ml from which at least a 10-ml aliquant was removed for counting and identifying nematodes.

The field was weeded regularly by hand to remove probable alternate hosts of the plant-parasitic nematodes present. Irrigation was utilized after the harvest of each crop and at dry periods during crop growth. Plants were given NPK fertilizers at the rates recommended by the Agricultural Chemistry Division, Ministry of Agriculture.

Greenhouse trial

A complementary greenhouse test was conducted to verify the host status of each test crop plant and to investigate the pathogenic effects of *M. incognita* Race 1. Each cultivar, except cassava, was grown from seed. Cassava was grown from 15-cm long cuttings. All cultivars were grown in 18 15-cm diam plastic pots containing 2,000 cm^3 steam-sterilized soil. When the plants were established, the soil in each of six pots was inoculated with 4.0g of tomato roots infested with Race 1 of *M. incognita.* Soil in each of an additional six pots received 0.5g of infested roots. There was an average of 64 galls/g on the infested roots used as inoculum. The remaining six pots were controls. Infested roots were selected as inoculum rather than nematode eggs or second-stage juveniles in order to simulate conditions in the field. The pots for each cultivar were arranged on a greenhouse bench in a randomized complete-block design.

The plant cover of chinese cabbage and the heights of the remaining cultivars were recorded at inoculation and after growth for 3 and 6 wk. At 6 wk, shoots were cut at soil level, except for cassava where only the leaves were harvested. The roots were washed free of soil and the degree of galling determined. Nematodes were extracted from root systems of only those treatments which had a mean root-knot index of less than 1.5. Shoots and roots were dried in an oven at 80C for 10 days, then weighed. Dry weights of pods were recorded for red kidney beans. The data were analysed statistically to detect any significant effects of *M. incognita* on plant growth.

RESULTS AND DISCUSSIONS

Table 2 shows the mean soil and root populations of nematodes and the mean root-knot indices estimated at the time of harvest of each crop. Red and white sorrel cultivars, grown for the first 6 mo. of the trial, showed differences in their response to root-knot nematode infestation. At harvest, red sorrel had a galling index of 3.3, indicating that this plant was a good host of the nematode, whereas that of white sorrel was 0.6, suggesting that it was a less suitable host. No galls were detected on the roots of the second red sorrel crop which commenced the second cycle of the 3-yr crop rotation scheme. Chinese cabbage was the only other plant which developed galls and the mean root-knot index at harvest was 0.2. Large numbers of *M. incognita* were recovered from the roots of the first crop of red sorrel only. White sorrel, cassava, and chinese cabbage yielded few root-knot nematodes and were the only other crops from which *M. incognita* was recovered. (Table 2).

At harvest, the final density of *M. incognita* in the rhizosphere soil of the first crop of sorrel showed little change from the initial density. After the subsequent 5 wk of fallow, no root-knot nematodes were detected in the soil samples. At harvest of the second crop, cassava, the density of *M. incognita* in the soil was low, it decreased during the subsequent 4 mo of fallow, and it remained at a low level for the duration of the trial (Table 2).

The greenhouse trial showed that all crops selected for the rotation experiment were hosts of *M. incognita* Race 1 (Table 3). However, callaloo and white sorrel each scored a root-knot index of only 1.2 at the higher infestation level tested, suggesting that they were poor hosts of the nematode. Extraction of *M. incognita* from both of these plant species yielded less than 20 nematodes/g fresh wt. of roots when soil was inoculated with either 0.5g or 4.0g of infested roots/pot. All other test cultivars showed severe galling at the higher level of infestation but the degree of galling varied at the lower level. When soil was inoculated with 0.5g of infested roots/pot, maize and red sorrel scored galling indices of 1.8 and 1.5, respectively. Cassava, chinese cabbage, cowpeas, and red kidney beans scored indices between 2.5 and 3.8. Tomato, the most susceptible plant tested, scored an index of 4.0 and, at the higher level of infestation, 83% of the plants died before the end of the test. These results indicated that the field-grown plants could have been severely galled if the initial population of *M. incognita* in the soil had been at a high level when susceptible crops were planted. Thus, the rotation of good and poor hosts and fallow periods appeared to control *M. incognita* in the field.

The greenhouse test also showed that *M. incognita* adversely affected plant growth (Table 3). Plant cover of chinese cabbage and the heights

Table 2. Soil and root populations of five nematode species and root-knot index at harvest of various crops grown for three years in a rotation trial.

			Mean no. of nematodes/100 cm³ soil and per g roots[v]											
			MELI		PRATY		TYLEN		ROTY		HELIC			
Crop	MON[w]	SAM[x]	S	R	S	R	S	R	S	R	S	R	PLANTS[y]	RKI[z]
Okra	0	10	45	350	4	0	3	0	1	0	3	0	50	4.0
Red sorrel	6	10	50	280	0	0	0	0	0	0	0	0	80	3.3
White sorrel	6	4	60	25	0	0	0	0	0	0	0	0	41	0.6
Clean fallow	7	4	0	—	12	—	10	—	3	—	11	—	—	—
Cassava	19	8	15	2	40	13	0	0	4	2	4	2	40	0.0
Weed fallow	21	—	—	—	—	—	—	—	—	—	—	—	—	—
Clean fallow	23	5	2	—	16	—	24	—	0	—	2	—	—	—
Chinese cabbage	25	9	0	10	5	1	21	0	2	0	0	0	69	0.2
Maize	29	10	3	0	85	105	0	0	18	0	39	0	50	0.0
Red kidney beans	32	10	0	0	7	6	67	0	0	4	1	0	60	0.0
Cowpeas	36	5	18	0	18	0	53	0	31	0	30	0	50	0.0
Callaloo	36	4	7	0	7	0	97	0	0	0	0	0	50	0.0
Red sorrel	41	10	9	0	1	0	57	0	1	0	0	0	50	0.0

[v]MELI = *Meloidogyne incognita*; PRATY = *Pratylenchus* sp.; TYLEN = *Tylenchorhynchus* sp.; ROTY = *Rotylenchulus reniformis*; HELIC = *Helicotylenchus* sp.; S = soil; R = roots.

[w]MON = Months from start of trial

[x]SAM = Number of samples

[y]PLANTS = Number of plants examined for root-knot

[z]RKI = Mean root-knot index, such that 0, 1, 2, 3, 4 = 0%, 1-25%, 26-50%, 51-75%, 76-100%, respectively, of the root system galled.

Table 3. Growth and root-knot index of nine cultivars grown in soil inoculated with *Meloidogyne incognita*-infested tomato roots in a greenhouse test.

Cultivar	No. days between planting and inoculation	Wt(g) of inoculum/ 2,000 cm^3 soil	Plant height or cover[x] (cm)[y]		Dry wt(g) at 6 wk[y]			Root-knot[z] index
			3 wk	6 wk	Shoot	Root	Pod	
Callaloo	30	0.0	19.7a	35.2a	4.7a	2.87a	—	0.0a
		0.5	18.9a	38.8a	4.3a	2.02b	—	1.0b
		4.0	15.0a	29.6a	2.8b	1.28c	—	1.2b
Cassava - mixture of accessions Nos. C5, 30 and 69	38	0.0	22.8a	25.3a	2.1a	0.82a	—	0.0a
		0.5	21.2a	23.3a	2.0a	0.80a	—	3.2b
		4.0	22.7a	24.5a	1.4a	0.65a	—	3.4b
Chinese cabbage cv. Santoh Round Leaved	18	0.0	29.7a	35.4a	3.9a	0.47a	—	0.0a
		0.5	26.0ab	27.2a	2.8ab	0.42a	—	2.5b
		4.0	23.5b	24.7a	1.5b	0.25a	—	4.0c
Maize cv. MB-2	11	0.0	42.3a	85.7a	12.4a	2.54a	—	0.0a
		0.5	43.5a	79.5a	11.8ab	2.62a	—	1.8b
		4.0	44.0a	86.2a	10.1b	3.21a	—	4.0c

Table 3. Growth and root-knot index of nine cultivars grown in soil inoculated with *Meloidogyne incognita*-infested tomato roots in a greenhouse test (continued).

Cultivar	No. days between planting and inoculation	Wt(g) of inoculum/ 2,000 cm³ soil	Plant height or cover[x] (cm)[y]		Dry wt(g) at 6 wk[y]			Root-knot[z] index
			3 wk	6 wk	Shoot	Root	Pod	
Cowpeas cv. African Red	11	0.0	28.3a	82.2a	3.8a	0.91a	—	0.0a
		0.5	27.5a	62.3b	3.4b	0.97a	—	3.5b
		4.0	25.3a	50.3b	2.2b	0.87a	—	4.0c
Red kidney beans cv	11	0.0	51.8a	—	1.6a	0.85a	5.8a	0.0a
California Light		0.5	50.3a	—	1.1b	0.83a	5.3a	3.8b
Red		4.0	60.3a	—	1.1b	0.70a	4.6b	4.0b
Sorrel cv. Red	18	0.0	16.8a	26.4a	0.7a	0.18a	—	0.0a
		0.5	15.5ab	18.3b	0.4b	0.14ab	—	1.5b
		4.0	13.9b	17.5b	0.3b	0.11b	—	3.8c
Sorrel cv. White	18	0.0	26.5a	40.5a	2.7a	1.00a	—	0.0a
		0.5	27.5a	43.5a	2.5a	0.87a	—	1.0b
		4.0	20.3b	29.8b	1.2b	0.35b	—	1.2b
Tomato cv. Walter	18	0.0	20.3a	56.9a	3.1a	0.45a	—	0.0a
		0.5	18.3a	39.5b	1.3b	0.55a	—	4.0b
		4.0	9.2b	4.0c	0.1c	0.01b	—	4.0b

[x]Maximum horizontal distance covered by leaves measured for Chinese cabbage.

[y]Each value is the mean of six observations; column means followed by unlike letters are significantly different ($P<0.05$) according to Duncan's Multiple Range Test. There were no significant differences in height for any cultivar at inoculation.

[z]0, 1, 2, 3, 4, = 0%, 1-25%, 26-50%, 51-75%, 76-100%, respectively, of root system galled.

of red and white sorrel and tomatoes grown in soil inoculated with 4.0g infested roots/pot, were significantly less than those of control plants as early as 3 wk after inoculation. By 6 wk, red sorrel and tomato plants grown at the lower infestation level, as well as cowpeas at both infestation levels, were significantly shorter than control plants. The heights of the remaining cultivars were not affected by the nematode, but shoots of callaloo and maize at the higher level of infestation and red kidney beans at both infestation levels had significantly lower dry weights than control plants (Table 3). Dry root weights of callaloo at both infestation levels and of red and white sorrel and tomato at the higher level of infestation were significantly less than the control weights. Dry pod weights of red kidney beans grown at the higher infestation level were significantly less than those from uninfested plants and those receiving a lower level of inoculum. Cassava was the only plant on which *M. incognita* had no measurable pathogenic effects during the test period. Although good hosts, such as maize and red sorrel, and poor ones, such as callaloo and white sorrel, developed few galls at some of the inoculum levels tested, plant growth was nevertheless suppressed (Table 3).

Samples taken from the soil at the experimental site before the start of the field trial showed that other plant-parasitic nematodes present in low density were species of *Pratylenchus* Filipjev, *Helicotylenchus* Steiner, *Tylenchorhynchus* Cobb and *Rotylenchulus reinformis* Linford and Oliveira with a mean of <5 nematodes/100 cm^3 of soil for each sp. Populations of these nematodes fluctuated with the rotation of the crops (Table 2). Numbers of *Pratylenchus* sp./100 cm^3 of soil increased markedly during the growth of cassava and maize but declined to a low level on the remaining crops. This nematode was present in the roots of chinese cabbage, red kidney beans, cassava, and maize. Numbers of *Tylenchorhynchus* sp./100 cm^3 of soil were low for the first 19 mo of the trial, increased during the subsequent 4 mo fallow, remained at the same level during the growth of chinese cabbage, declined under maize, increased markedly on the subsequent red kidney bean crop, and remained high for the final 8 mo of the trial. Soil population densities of *R. reniformis* and *Helicotylenchus* were low for the first 25 mo of the trial until maize was grown. Table 2 shows that they increased on this crop, declined on the subsequent red kidney bean crop, increased again on cowpeas, but declined on callaloo and on the final crop, red sorrel. Both species were present in low numbers in the roots of cassava, and *R. reniformis* was also present in the roots of red kidney beans.

Other plant-parasitic nematodes not detected in the initial soil samples were extracted during the trial. They were: species of *Aphelenchus* Bastian (5 and 10 nematodes/100 cm^3 of cassava and maize rhizosphere soil, respectively); *Hoplolaimus* Daday (1 nematode/100 cm^3 of cassava and cowpea rhizosphere soil each); and *Criconemoides* Taylor, *Xiphinema* Cobb, *Ditylenchus* Filipjev, and *Tylenchus* Bastian (1, 1, 1, and 5 nematodes/100 cm^3 of maize rhizosphere soil, respectively).

Although there may have been interspecific competition between some nematode species for feeding sites, the control of *M. incognita* observed in this trial may not have been due mainly to this factor. Studies of the interactions between *M. incognita* and *R. reniformis* by Singh (9) and by Thomas and Clark (11), and *M. incognita* and *P. brachyurus* (Godfrey) Filipjev and Stekhoven by Ogbuji (5) showed that the activities of the root-knot nematode were not affected by the presence of the other nematode species. However, the final population densities of juveniles of *M. incognita* were reduced by *R. reniformis* only when fields were infested with low levels of both species (10). Nevertheless, the cropping system used in this trial reduced *M. incognita* populations by causing this species to reach a low level before planting susceptible crops which were good hosts of the nematode.

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