EFFECTS OF *MELOIDOGYNE INCOGNITA* AND *ROTYLENCHULUS RENIFORMIS* ON GROWTH AND NUTRIENT CONTENT OF *VIGNA UNGUICULATA* AND *ZEA MAYS*

Terry-Ann P. Heffes,[1] Phyllis L. Coates-Beckford,[1] and Hilary Robotham[2]

Department of Botany[1] and Center for Nuclear Sciences,[2] University of the West Indies, Mona Campus, Kingston 7, Jamaica.

ABSTRACT

Heffes, T. P., P. L. Coates-Beckford, and H. Robotham. 1992. Effects of *Meloidogyne incognita* and *Rotylenchulus reniformis* on growth and nutrient content of *Vigna unguiculata* and *Zea mays*. Nematropica 22:139–148.

In a greenhouse experiment, seedlings of cowpea (*Vigna unguiculata* cv. Yvon Clay) and corn (*Zea mays* cv. X306B) were grown for 6 weeks in pots receiving initial inoculum (Pi) of 0, 100, 1 000, or 10 000 eggs of *Meloidogyne incognita* race 1 or immature, vermiform *Rotylenchulus reniformis* race A. Final nematode populations, plant growth, and concentrations of 11 plant nutrients within shoots and roots were measured. Each nematode reproduced on both hosts but final populations were larger on cowpea than on corn. Both nematodes stunted the growth of each host. Leaves of corn plants inoculated with 1 000 *M. incognita* eggs or with 10 000 vermiform *R. reniformis* showed symptoms of nutrient deficiency. For each host-parasite combination, there were more differences in nutrient concentrations in roots than in shoots, when infected and noninfected plants were compared. Specific effects of nematode parasitism on host nutrient concentrations differed with the host and the parasite. However, when affected, concentrations of potassium were always lower and those of aluminium and vanadium were always higher in nematode-infected than in noninfected plants. In most cases, nematode infection resulted in a decrease in the concentration of iron in roots and shoots.

Key words: corn, cowpea, macronutrient, *Meloidogyne incognita* race 1, micronutrient, pathogenicity, population development, *Rotylenchulus reniformis* race A, *Vigna unguiculata, Zea mays.*

RESUMEN

Heffes, T. P., P. L. Coates-Beckford y H. Robotham. 1992. Efectos de *Meloidogyne incognita* y *Rotylenchulus reniformis* sobre el crecimiento y contenido de nutrientes de *Vigna unguiculata* y *Zea mays*. Nematrópica 22:139–148.

En un ensayo de invernadero, plántulas de chícharo (*Vigna unguiculata* cv. Yvon Clay) y maíz (*Zea mays* cv. X306B) fueron inoculadas con una serie de 0, 100, 1 000 o 10 000 huevos de *Meloidogyne incognita* raza 1 o estadíos vermiformes inmaduros de *Rotylenchulus reniformis* raza A. Después de 6 semanas se midieron las poblaciones de nematodos, el crecimiento de las plantas y las concentraciones de 11 nutrientes in las raíces y hojas. Cada nematodo se reprodujo en ambos hospedadores y las poblaciones finales fueron mayores en maíz que en chícharo. Ambos nematodos causaron una reducción en el crecimiento de cada hospedador. Las hojas de las plantas de maíz inoculadas con 1 000 huevos de *M. incognita* o con 10 000 estadíos vermiformes de *R. reniformis* mostraron síntomas de deficiencia de nutrientes. Para cada combinación parásito-hospedador, las diferencias fueron más manifiestas en las concentraciones de nutrientes en las raíces que en el follaje cuando se compararon plantas infectadas con las no infectadas. Cuando afectadas por infección con nematodos, las concentraciones de potasio siempre fueron más bajas y las de aluminio y vanadio siempre más altas en plantas infectadas en comparación con las no infectadas. En la mayoría de los casos, la infección con nematodos resultó en una reducción de la concentración de hierro en las raíces y en el follaje.

Palabras clave: chícharo, desarrollo poblacional, macronutriente, maíz, *Meloidogyne incognita* raza 1, micronutriente, patogenicidad, *Rotylenchulus reniformis* raza A, *Vigna unguiculata, Zea mays.*

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp.] and corn (*Zea mays* L.) are grown on small farms throughout Jamaica. Corn is grown mainly for animal feed, and cowpea for human consumption. Each corn crop may require 90, 68, and 68 kg/ha of nitrogen, phosphate, and potash, respectively (27). Cowpea crops, however, are not usually fertilized. Two of the most frequently occurring nematodes in Jamaica, the root-knot nematode [*Meloidogyne incognita* (Kofoid & White) Chitwood] and the reniform nematode (*Rotylenchulus reniformis* Linford & Oliveira), parasitize both corn and cowpea in Jamaica (12). The root-knot nematode is pathogenic to both hosts (12,13) and the reniform nematode is known to be pathogenic to cowpea. The effects of the reniform nematode on Jamaican-grown corn cultivars are not known (12).

Parasitism by root-knot nematodes may affect the nutrient status of susceptible, tolerant, and resistant hosts (2,8,10,14,16,17,18,20,24). The following studies were carried out to examine reproduction by *M. incognita* and *R. reniformis* and their effects on cowpea and corn cultivars grown in Jamaica.

MATERIALS AND METHODS

Populations of *M. incognita* race 1 (9) and *R. reniformis* race A (4) were maintained on tomato (*Lycopersicon esculentum* Mill. cv. Rutgers) and pigeon pea [*Cajanus cajan* (L.) Millsp.], respectively, in a greenhouse. Inoculum of *M. incognita* consisted of eggs from tomato roots (19). Inoculum of *R. reniformis* consisted of immature, vermiform stages from pigeon pea rhizosphere soil (3). The methods used for evaluating the effects of nematodes on the growth and nutrient status of the plants were described in detail by Heffes *et al.* (10).

Two seeds of 'X306B' corn or 'Yvon Clay' cowpea were planted 1.5 cm deep in 2.5-cm-diam plastic pots containing 1 L of steam-sterilized sand. One seedling was removed from each pot after emergence. Seven days after planting, 10 randomly selected pots with each host were inoculated with 100, 1 000, or 10 000 eggs (Pi) of *M. incognita* by pouring 20-ml suspensions in a 2-cm-deep hole adjacent to the seedling. The hole was then filled with sterile sand. Six additional pots of each host were similarly inoculated with *R. reniformis*. Ten control pots for the *M. incognita* study received 20 ml of supernatant from centrifuged egg suspensions and six control pots in the *R. reniformis* study received tap water.

For each host inoculated with each nematode, six pots with each Pi were arranged in a completely randomized design in a greenhouse with a daytime temperature range of 28–30 C. For each host inoculated with *M. incognita*, the remaining four pots of the 10 inoculated at each Pi were randomly arranged in another group. Each pot was given 25 ml of Long Ashton nutrient solution (11) at the time of inoculation and thereafter once each week, until harvest, 6 weeks later.

For the groups with six replicates of each treatment, data taken for each plant included plant height at inoculation and harvest, number and area of leaves produced, oven-dry weights of shoots and roots (after 70 C for 5 days), and the number of root galls present. The number of egg masses on each root system were counted (10) only for the groups of *M. incognita*-inoculated pots with four replicates per treatment. Egg mass and gall production were rated by the indices 0, 1, 2, 3, 4, and 5, representing 0, 1–2, 3–10, 11–30, 31–100 and > 100 egg masses or galls per root system, respectively. Nematodes in the soil in each pot were extracted (3) and their populations were estimated (10).

Nutrient analyses were performed on the dry plant organs (10). Nitrogen was determined as nitrate in cowpea (7) and as ammonium in corn (26). Phosphorus was determined by the method of Rees and Sidrak (23). Potassium, magnesium, calcium, manganese, sodium, cobalt, iron, zinc, aluminium, and vanadium were determined by instrumental neutron activation analysis (1), as described by Heffes *et al.* (10).

Analyses of variance were performed on the data and treatment means were compared by the least significant difference test (LSD).

RESULTS

Nematode population development: Meloidogyne incognita and *R. reniformis* reproduced on cowpea and on corn but at each Pi the final soil population density (Pf) of each nematode was greater on cowpea than on corn (Table 1). For every host-parasite combination the greatest rate of population increase (Pf/Pi) occurred at Pi = 1 000. At Pi = 10 000, the Pf was smaller than the Pi in all instances except for cowpea inoculated with *R. reniformis*. In *M. incognita*-inoculated pots, the mean egg mass index was larger for cowpea than for corn at each Pi. For both hosts, indices were similar at Pi = 1 000 and 10 000 and greater than at Pi = 100.

Plant growth: Meloidogyne incognita and *R. reniformis* adversely affected most growth parameters of both hosts. The only exceptions were the number of leaves produced, the shoot/root weight ratio of corn when infected by either nematode, and that of cowpea when infected by *R. reniformis* (Table 1). Shoot lengths, leaf areas, and plant weights of inoculated plants always were suppressed at Pi = 10 000 and in most instances at Pi = 1 000. At Pi = 100, adverse effects were noted only for the dry shoot weight of *M. incognita*-infected corn, dry shoot weights of *R. reniformis*-infected cowpea and corn, and shoot length of *R. reniformis*-infected corn. In contrast, *M. incognita*-infected cowpea plants had larger leaf areas than the control plants at Pi = 100 and 1 000. Galls formed on the roots of *M. incognita*-infected plants at all Pis. The root-knot indices were greater for cowpea than for corn at each Pi (Table 1).

Nutrient content of cowpea: Plants infected with *M. incognita* showed nutrient concentrations different from those of the controls more frequently than did plants infected with *R. reniformis* (Tables 2 and 3). When compared with controls, nitrogen was significantly increased in cowpea shoots at *M. incognita* Pi = 100 and 1 000. In *M. incognita*-inoculated plants, at Pi = 1 000 and 10 000, shoot concentrations of phosphorus, calcium, magnesium, and aluminium exceeded concentrations in controls whereas sodium, iron, and zinc concentrations at Pi = 10 000 were significantly lower than in controls (Table 2). In shoots of *R. reniformis*-inoculated plants (Pi = 1 000 and 10 000), nitrogen concentrations exceeded those of controls, and potassium, sodium, and iron concentrations were negatively affected (Table 3).

In roots infected with *M. incognita* potassium and cobalt were the only elements unaffected by nematode parasitism (Table 2). Concentrations of iron were lower whereas those of eight of the remaining nine elements were higher at Pi = 10 000 than at Pi = 0; nitrogen, calcium, manganese, and aluminium concentrations were increased also at Pi = 1 000, and nitrogen at Pi = 100. In roots infected with *R. reniformis* (Pi = 10 000), concentrations of nitrogen, calcium, manganese, iron, and aluminium were

Table 1. Population development of *Meloidogyne incognita* race 1 and *Rotylenchulus reniformis* race A, and the responses of *Vigna unguiculata* and *Zea mays* grown for 6 weeks in soil infested at four initial densities of each nematode.

Pi[x]	Pf[x]	Egg mass index[y]	Root-knot index[y]	Shoot length (cm)[z]	Number of leaves	Leaf area (cm^2)	Dry shoot wt (mg)	Dry root wt (mg)	Shoot/root weight ratio
				V. unguiculata with *M. incognita*					
0	0	0	0	20	19	498	1 790	380	4.7
100	270**	3**	4**	20	20	710**	1 900	410	4.6
1 000	2 900**	4**	4**	22	19	713**	1 530*	540*	2.8*
10 000	7 400**	4**	4**	17*	19	442*	1 080*	620*	1.7*
				Z. mays with *M. incognita*					
0	0	0	0	23	10	629	2 675	1 064	2.5
100	100**	2*	2*	21	10	548	2 224*	956	2.3
1 000	1 100**	3**	3**	19*	10	459*	1 673*	770	2.2
10 000	4 200**	3**	3**	18*	10	405*	1 560*	685*	2.3
				V. unguiculata with *R. reniformis*					
0	0	–	–	21	15	221	810	270	3.0
100	230**	–	–	19	14	212	530*	250	2.1
1 000	3 150**	–	–	16*	14	178*	460*	220*	2.1
10 000	15 000**	–	–	15*	13	164*	390**	190*	2.1
				Z. mays with *R. reniformis*					
0	0	–	–	32	11	685	3 900	1 420	2.7
100	140**	–	–	26*	11	655	3 300*	1 330	2.5
1 000	2 000**	–	–	24*	11	611*	3 400*	1 180*	2.9
10 000	4 600**	–	–	23*	11	588*	2 500*	1 030*	2.4

Data are means of six replicates except for egg mass indices, which are means of four replicates.
*, ** = significantly different from the control at $P \leq 0.05$ and 0.01, respectively, by the LSD test.
[x]Pi = initial number of eggs or juveniles/pot; Pf = final number of vermiform nematodes/pot.
[y]Scale of 0–5 where 0 = 0, 1 = 1–2, 2 = 3–10, 3 = 11–30, 4 = 31–100 egg masses or galls/root system.
[z]Final height minus height at inoculation

Table 2. Nutrient content of shoots and roots of *Vigna unguiculata* and *Zea mays* after 6 weeks' growth in soil infested with *Meloidogyne incognita* race 1 at four initial nematode densities.

Initial number of	Macroelements (%)					Microelements (ppm)						
eggs/pot	N	P	K	Ca	Mg	Mn	Na[z]	Co	Fe[z]	Zn	Al[z]	V
					V. unguiculata - Shoots							
0	0.25	0.50	4.6	2.11	0.65	90	375	0.6	380	47	210	0.9
100	0.52**	0.58	4.8	2.10	0.73*	89	404	–	–	–	293*	2.0
1 000	0.50**	0.65*	4.9	2.36*	0.75*	101	362	–	–	–	275*	1.3
10 000	0.25	0.93*	4.5	2.75*	0.83**	105	260**	0.6	288*	37*	273*	1.9
					V. unguiculata - Roots							
0	0.17	0.58	3.0	1.58	1.80	104	110	4.0	380	67	60	23
100	0.33*	0.60	3.3	1.67	1.90	98	120	–	–	–	66	24
1 000	0).32*	0.62	3.3	1.94*	1.80	132**	140	–	–	–	80*	26
10 000	0.18	1.10**	3.2	2.11*	2.60*	160**	210*	5.0	320*	93*	123**	29*
					Z. mays - Shoots							
0	1.97	0.75	3.53	0.80	0.55	55	236	1.0	536	63	158	ND
100	1.86	0.74	3.07	0.87	0.52	58	239	–	–	–	151	ND
1 000	1.60*	0.54**	2.85**	0.63	0.39*	85**	450**	–	–	–	165	ND
10 000	1.54**	0.46**	2.64**	0.65	0.38**	93**	580**	1.0	313**	53*	151	ND
					Z. mays - Roots							
0	1.68	0.74	1.59	1.05	0.48	122	81	4.0	28	82	24	11
100	1.69	0.71	1.36	0.96	0.51	116	84	–	–	–	29	10
1 000	1.57*	0.52**	1.25**	0.70**	0.34**	200**	190**	–	–	–	26	15*
10 000	1.34*	0.42**	1.26**	0.76**	0.32**	251**	218**	6.0	24*	53*	26	14*

Data are means of six replicates.
ND = Not detectable.
*, ** = significantly different from the control at $P \leq 0.05$ and 0.01, respectively, by the LSD test.
[z]Root content = value × 100.

Table 3. Nutrient content of shoots and roots of *Vigna unguiculata* and *Zea mays* after 6 weeks' growth in soil infested with *Rotylenchulus reniformis* race A at four initial nematode densities.

Initial number of eggs/pot	Macroelements (%)					Microelements (ppm)						
	N	P	K	Ca	Mg	Mn	Na[z]	Co	Fe[z]	Zn	Al[z]	V
					V. unguiculata - Shoots							
0	2.76	0.26	3.79	1.93	0.40	90	334	0.6	487	85	124	ND
100	2.85	0.26	3.61	2.13	0.44	90	338	–	–	–	124	ND
1 000	3.42*	0.27	3.36*	2.09	0.39	86	190**	–	–	–	124	ND
10 000	3.15*	0.24	2.85**	2.26	0.39	84	150**	0.6	376**	79	125	ND
					V. unguiculata - Roots							
0	2.38	0.24	4.02	0.87	0.92	83	108	3.0	29	72	24	17
100	2.43	0.23	3.97	0.91	0.80	84	88	–	–	–	26	19
1 000	2.78*	0.24	3.53**	0.97	0.93	97**	65**	–	–	–	27	16
10 000	2.63*	0.24	3.08**	1.05*	0.90	96**	64**	4.0	35*	84	36**	19
					Z. mays - Shoots							
0	1.72	0.34	3.85	0.74	0.40	54	367	0.5	454	50	169	ND
100	1.73	0.33	3.76	0.68	0.37	57	364	–	–	–	183	ND
1 000	1.82	0.34	3.90	0.70	0.42	52	361	–	–	–	181	ND
10 000	1.77	0.35	3.44**	0.64	0.34*	51	365	0.4	353**	54	200	ND
					Z. mays - Roots							
0	1.29	0.25	1.81	0.01	0.44	103	110	4.0	29	65	26	9
100	1.27	0.23	1.69	1.01	0.47	106	95	–	–	–	54*	11
1 000	1.36*	0.26	1.70	0.97	0.35*	83	109	–	–	–	27	9
10 000	1.30	0.24	1.45**	0.89	0.33*	86	100	4.0	19**	69	30	9

Data are means of six replicates.
ND = Not detectable.
*, ** = significantly different from the control at $P \leq 0.05$ and 0.01, respectively, by the LSD test.
[z]Root content = value × 100.

increased compared to the controls (Table 3); nitrogen and manganese concentrations were increased also at Pi = 1 000. At Pi = 1 000 and 10 000, potassium and sodium concentrations were lower than in controls. The five remaining elements showed no significant difference in concentrations between infected and noninfected roots (Table 3).

Nutrient concentrations of corn: At Pis of 1 000 and 10 000, shoots of *M. incognita*-infected corn had lower concentrations of nitrogen, phosphorus, potassium, magnesium, iron, and zinc but higher concentrations of manganese and sodium than did controls (Table 2). Most effects on nutrient concentrations in roots were similar to those in shoots (Table 2).

In corn plants inoculated with *R. reniformis*, the concentrations of potassium, magnesium, and iron in shoots and roots were lower at Pi = 10 000 than at Pi = 0; root concentrations of magnesium were reduced also at Pi = 1 000. In contrast, the concentrations of nitrogen (at Pi = 1 000) and aluminium (at Pi = 100 significantly exceeded concentrations at Pi = 0 (Table 3).

Shoot/root ratios of nutrients: There were no significant differences for any element except sodium and zinc in *M. incognita*-infected cowpea, and iron in *R. reniformis*-infected corn (Table 4). The values for sodium and iron were lower and that of zinc higher than the control values.

Foliar symptoms of nutrient deficiency: Only shoots of corn inoculated with either nematode showed macroscopic symptoms of nutrient deficiency apart from stunting. At Pi = 1 000 and 10 000, the leaves developed chlorotic margins typical of potassium deficiency (15) and yellow streaks typical of magnesium deficiency (15) within 1 week of inoculation with *M. incognita*. Subsequently, a purple colour developed which spread from the margins to the midribs, typical of phosphorus deficiency (15). Plants infected with *R. reniformis* at Pi = 10 000 exhibited symptoms of potassium and magnesium deficiency within 6 weeks of inoculation.

DISCUSSION

Both cowpea and corn supported reproduction of *M. incognita* and *R. reniformis* but cowpea was a much better host for both nematodes. At high population densities, both nematodes were pathogenic to corn and cowpea resulting in stunting of shoots and roots. The large galls on cowpea caused root weights of infected plants to be greater than those of the controls. Pathogenic effects of both nematodes on corn were expressed within 6 weeks of inoculation by foliar nutrient deficiency symptoms.

Increases in the nutrient concentration of nematode-infected plants have been noted by other workers for nitrogen (10,25), calcium (8,10,16,17,18,20), magnesium (8,10), manganese (10,20), sodium (10,16,25), zinc (10), aluminium (10), and vanadium (10). Decreases have been observed for nitrogen (10,22), phosphorus (5,10), potassium (6,10,14,21), calcium (4,16,22,24,25), magnesium (10,14), manganese (10), sodium (10,16), iron (2,10,14), zinc (2,10,14,19), and cobalt (10). We observed a marked difference between the effects of parasitism by *M. incognita* on the nutrient status of cowpea and corn. Whenever *M. incognita* affected host nutrient status, similar responses in both hosts were noted only for iron and zinc in the shoots, and for manganese, sodium, iron, and vanadium in the roots (Table 2). For each host, there were more nematode-specific differences than similarities in effects on nutrient concentrations (Tables 2 and 3). These observations agree with those of Heffes *et al.* (10), where the effects of parasitism by *M. in-*

Table 4. Shoot/root ratios of nutrients in *Vigna unguiculata* and *Zea mays* after 6 weeks' growth in soil infested with *Meloidogyne incognita* race 1 or *Rotylenchulus reniformis* race A at four initial nematode densities.

Initial number of eggs or juveniles/pot	Shoot/Root ratio											
	Macroelements (%)					Microelements (ppm)						
	N	P	K	Ca	Mg	Mn	Na	Co	Fe	Zn	Al	V
	V. unguiculata with *M. incognita*											
0	1.47	0.86	1.53	1.34	0.36	0.86	0.34	0.15	0.08	0.07	0.04	0.04
100	1.57	0.97	1.45	1.26	0.38	0.90	0.35	–	–	–	0.04	0.08
1 000	1.56	1.05	1.48	1.21	0.42	0.78	0.29	–	–	–	0.03	0.05
10 000	1.39	0.86	1.41	1.30	0.32	0.68	0.12*	0.12	0.09	0.40*	0.02	0.06
	Z.mays with *M. incognita*											
0	1.17	1.01	2.22	0.76	1.15	0.45	0.03	0.15	0.19	0.77	0.07	–
100	1.10	1.04	2.26	0.90	1.02	0.50	0.03	–	–	–	0.05	–
1 000	1.02	1.04	2.28	0.90	1.15	0.43	0.02	–	–	–	0.06	–
10 000	1.15	1.10	2.10	0.85	1.19	0.37	0.03	0.17	0.13	1.00	0.06	–
	V. unguiculata with *R. reniformis*											
0	1.16	1.08	0.94	2.22	0.43	0.52	0.03	0.12	0.16	0.77	0.03	–
100	1.17	1.13	0.91	2.56	0.55	0.53	0.04	–	–	–	0.02	–
1 000	1.23	1.12	0.95	2.15	0.42	0.62	0.03	–	–	–	0.03	–
10 000	1.20	1.00	0.93	2.15	0.43	0.59	0.04	0.10	0.18	0.78	0.03	–
	Z. mays with *R. reniformis*											
0	1.33	1.36	2.03	0.73	0.91	1.08	0.31	0.20	0.17	1.18	0.05	–
100	1.36	1.43	2.26	0.67	0.79	1.07	0.43	–	–	–	0.05	–
1 000	1.34	1.31	2.50	0.72	1.20	0.89	0.29	–	–	–	0.05	–
10 000	1.36	1.45	2.86	0.72	1.03	0.98	0.23	0.15	0.11*	0.94	0.05	–

Data are means of six replicates.
* = significantly different from the control at $P \leq 0.05$ by the LSD test.

cognita on most nutrient concentrations in shoots and roots of *Amaranthus viridis* L. and *Hibiscus sabdariffa* L. showed no distinct pattern. However, a few consistencies are apparent in our results. Whenever affected, the concentrations of potassium in the present and in the previous study (10) were always lower and those of aluminium and vanadium were always higher in nematode-infected than in noninfected plants. In addition, iron concentrations in roots and shoots of *A. viridis* and *H. sabdariffa* cv. Red inoculated with 10 000 eggs of *M. incognita* were always lower than those in control plants (10). In the present study, iron concentrations, similarly, were reduced in the roots and in the shoots of cowpea and corn when inoculated with *M. incognita* and when inoculated with *R. reniformis* with only one exception: the concentration of iron in cowpea roots infected with *R. reniformis* was increased.

Although nematode reproduction on cowpea was greater than on corn, the uptake of most nutrients by cowpea roots did not appear to be affected severely and several nutrients were present in higher concentrations in infected than in noninfected plants. In contrast, the majority of nutrients in infected corn roots occurred in lower concentrations than in the controls; hence, nutrient uptake by corn may have been seriously hindered by nematode parasitism. Translocation of nutrients did not appear to be a factor limiting the growth of either host as there were few instances of significant differences in the shoot/root ratios of elements between infected and noninfected plants. Several factors other than nutrient uptake and translocation could be involved in adverse effects of nematode parasitism on cowpea, including water uptake, carbohydrate partitioning, and phytoalexin autotoxicity.

The initial Pis of both nematodes in this study were similar to those occurring in many tropical soils to which inorganic fertilizers can be added to improve crop growth. Our results confirm that nematodes may interfere with the efficient use of fertilizers by plants, be they dicotyledons or monocotyledons. In addition, the effects of nematode parasitism on nutrient content in general appear to be varied and not readily predictable.

ACKNOWLEDGEMENTS

We thank Professor G. H. Sidrak and the late Dr. L. B. Coke for their advice, and Mr. R. Rattray and Mr. W. Fielding for assistance with the nutrient and statistical analyses, respectively.

LITERATURE CITED

1. ANONYMOUS. 1983. Description and Safety Analysis for the SLOWPOKE-II Reactor. Atomic Energy Agency of Canada, Ltd.: Toronto. 400 pp.
2. BONETI, J. I. S., S. FERRAZ, J. M. BRAGA, and L. M. DE OLIVEIRA. 1982. Parasitism of *Meloidogyne exigua* in coffee seedlings. Effects on micronutrient absorption and seedling growth. Fitopatologia Brasilia 7:197–208.
3. CHRISTIE, J. R., and V. G. PERRY. 1951. Removing nematodes from soil. Proceedings of the Helminthological Society of Washington 18:106–108.
4. DASGUPTA, D. R., and A. R. SESHADRI. 1971. Races of the reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940. Indian Journal of Nematology 1:21–24.
5. DROPKIN, V. G., and R. C. KING. 1956. Studies on plant parasitic nematodes homogeneously labelled with radio-phosphorus. Experimental Parasitology 5:469–480.
6. FATEMY, F., and K. EVANS. 1986. Effects of *Globodera rostochiensis* and water stress on shoot and root growth and nutrient uptake of potatoes. Revue de Nématologie 9:181–184.
7. FAWCETT, G. S., and R. H. STOUGHTON. 1944. The Chemical Testing of Plant Nutrient Solutions. The Tintometer, Ltd.: Salisbury. 86 pp.

8. GOSWAMI, B. K., S. SINGH, and V. S. VERMA. 1976. Uptake and translocation of calcium and magnesium in tomato plants as influenced by infection with root-knot nematode *Meloidogyne incognita* and tobacco mosaic virus. Nematologica 22:116–117.
9. HARTMAN, K. M., and J. N. SASSER. 1985. Identification of *Meloidogyne* species on the basis of differential host test and perineal-pattern morphology. Pp. 66–77 *in* K. R. Barker, C. C. Carter, and J. N. Sasser, eds. An Advanced Treatise on *Meloidogyne*. Vol. 2: Methodology. Department of Plant Pathology, North Carolina State University, and U. S. Agency for International Development, Raleigh.
10. HEFFES, T. P., P. L. COATES-BECKFORD, and H. ROBOTHAM. 1991. Effects of *Meloidogyne incognita* on growth and nutrient content of *Amaranthus viridis* and two cultivars of *Hibiscus sabdariffa*. Nematropica 2:7–18.
11. HEWITT, E. J. 1952. Sand and Water Methods Used in the Study of Plant Nutrition. Commonwealth Agricultural Bureaux, London. 241 pp.
12. HUTTON, D. G., P. L. COATES-BECKFORD, and S. A. E. EASON-HEATH. 1982. Parasitic nematodes associated with various plant species in Jamaica, 1949-1981. Pp. 109-112 *in* Proceedings of the Third Research and Planning Conference on Root-knot Nematodes, *Meloidogyne* spp., International *Meloidogyne* Project, January 11-15, 1982, Panama City, Panama.
13. HUTTON, D. G., P. L. COATES-BECKFORD, and S. A. E. EASON-HEATH. 1983. Management of *Meloidogyne incognita* populations by crop rotation in a small-scale field trial and nematode pathogenic effects on selected cultivars. Nematropica 13:153–163.
14. IBRAHIM, I. K. A., M. A. REZK, and H. A. A. KHALIL. 1984. Effects of *Meloidogyne incognita, Fusarium oxysporum* and *F. vasinfectum* on plant growth and mineral content of cotton, (*Gossypium barbadense* L.). Nematologica 28:298.
15. ISHIZUKA, Y. 1971. Nutrient Deficiencies of Crops. ASPAC Food and Fertilizer Technology Center, Taipei. 112 pp.
16. JENKINS, W. R., and R. B. MALEK. 1966. The influence of nematodes on absorption and accumulation of nutrients in vetch. Soil Science 101:46–49.
17. MALEKEBERHAN, H., J. M. WEBSTER, R. C. BROOKE, J. M. D'AURIA, and M. CACKETTE. 1987. Effects of *Meloidogyne incognita* on plant nutrient concentration and its influence on the physiology of beans. Journal of Nematology 19:324–330.
18. MALEKEBERHAN, H., R. C. BROOKE, J. M. WEBSTER, and J. M. D'AURIA. 1985. The influence of *Meloidogyne incognita* on the growth, physiology and nutrient content of *Phaseolus vulgaris* (cultivar Topnotch Golden Wax). Physiological Plant Pathology 26:259–268.
19. McCLURE, M A., T. H. KRUK, and I. MISAGHI. 1973. A method of obtaining quantities of clean *Meloidogyne* eggs. Journal of Nematology 5:230.
20. NASR, T. A., I. K. A. IBRAHIM, E. M. EL-AZAB, and M. W. A. HASSAN. 1982. The effect of root-knot nematodes on the mineral, amino-acid and carbohydrate concentrations of almond and peach root-stock. Nematologica 26:133–138.
21. OTEIFA, B. A. 1952. Potassium nutrition of the host in relation to infection by a root-knot nematode, *Meloidogyne incognita*. Proceedings of the Helminthological Society of Washington 19:99–104.
22. OTEIFA, B. A., and D. M. ELGINDI. 1962. The influence of parasitic duration of *Meloidogyne javanica* (Treub) on host nutrient uptake. Nematologica 8:216–220.
23. REES, W. J., and G. H. SIDRAK. 1956. Plant nutrition of fly-ash. Plant and Soil 8:141–159.
24. SANTOS, J. M. D, S. FERRAZ, and L. M. DE OLIVEIRA. 1981. Absorption and translocation of nutrients in coffee plants parasitised by *Meloidogyne exigua*. Fitopatologia Brasilia 6:333–340.
25. SHAFIEE, M. F., and W. R. JENKINS. 1963. Host-parasite relationships of *Capsicum frutescens* and *Pratylenchus penetrans, Meloidogyne incognita acrita* and *Meloidogyne hapla*. Phytopathology 53:325–328.
26. TARAS, M. J. 1958 Nitrogen. Pp. 75–160 *in* D. F. Boltz, ed. Chemical Analysis, Volume 8. Colorimetric Determination of Nonmetals. Interscience Publishers, Inc.: New York.
27. THE JAMAICA FARMER'S GUIDE. 1988. Selecto Publications Ltd. and The Jamaica Agricultural Society, Kingston. 335 pp.

Received: *28.II.1992*
Recibido:

Accepted for publication: *16.VII.1992*
Aceptado para publicación: