NEMATODE POPULATION DYNAMICS IN MUNICIPAL SOLID WASTE–AMENDED SOIL DURING TOMATO AND SQUASH CULTIVATION†

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ABSTRACT

Mannion, C. M., B. Schaffer, M. Ozores-Hampton, H. H. Bryan, and R. McSorley. 1994. Nematode population dynamics in municipal solid waste-amended soil during tomato and squash cultivation. Nematropica 24:17–24.

The influence of amending soil with municipal solid waste (MSW) materials on nematode populations in tomato and squash fields in southern Florida was examined. The MSW materials included Daorganite produced from heat-treated sewage sludge, Agrisoil compost (composted yard and house trash), and Eweson Compost (a combination of composted house and yard trash and sewage sludge). Tomato and squash were planted as rotation crops in soils amended with the MSW materials. The experiment was repeated on a different site the following year. Nematodes found in the soil included *Criconemella onoensis, Helicotylenchus dihystera, Rotylenchulus reniformis, Meloidogyne incognita, Pratylenchus* spp., *Quinisulcius acutus, Tylenchus* spp., *Ditylenchus* spp., *Rhabditida* (primarily *Rhabditis* spp.), Dorylaimida (primarily *Eudorylaimus* spp.) and Aphelenchida. There were few consistent effects of MSW treatments on nematode populations. The plant-parasitic nematodes, as a group, were not affected by MSW treatment. In both years, however, the final populations of juvenile *Meloidogyne incognita* in squash were significantly greater in the control than in the compost treatments. These data indicate that the incorporation of these MSW materials may have a negative impact on populations of *M. incognita.*

Keywords: compost, municipal solid waste, nematode suppression, population dynamics, organic amendments.

RESUMEN

Manion, C. M., B. Schaffer, M. Ozores-Hampton, H. H. Bryan y R. McSorley. 1994. Dinámica poblacional de nematodos en suelos enmendados con desechos sólidos municipales en cultivos de tomate y calabaza. Nematrópica 24:17–24.

Se estudió el efecto de enmiendas edáficas a base de desechos sólidos municipales (DSM) en la población de nematodos de tomate y calabaza en el sur de Florida. Estos DSM incluyen a productos como la Daorganita (lodos de drenaje tratados con calor), composta 'Agrisoil', composta de basura casera y de jardín, composta 'Eweson' y una combinacion de las compostas de basura casera, jardín y lodos de drenaje. Los tomates y calabazas fueron sembrados como rotación de cultivos en suelos en-

† Florida Agricultural Experimental Station Journal Series No R-03411. This study was supported by grants from the Florida Center for Solid and Hazardous Waste Management, The Charles Lindbergh Fund, and the Rare Fruit and Vegetable Council of Broward County, Florida. Present address of C. M. Mannion is Rohn and Hass Inc., 1205 Newton Drive, Tifton, GA 31794.

mendados con productos derivados de DSM. El experimento se repitió en un sitio diferente al año siguiente. Los nematodos encontrados en el suelo fueron: *Criconemella onoensis, Helicotylenchus dihystera, Rotylenchulus reniformis, Meloidogyne incognita, Pratylenchus* spp., *Quinsulcius acutus, Tylenchus* spp., *Ditylenchus* spp., Rhabditida (antes *Rhabditis* spp.), Dorylaimida (antes *Eudorylaimus* spp.) y Aphelenchida. Hubo pocos efectos consistentes de los tratamientos de DSM sobre las poblaciones de nematodos. Los fitonematodos como grupo no fueron afectados por los tratamientos de DSM en los dos años, sin embargo, la población final de juveniles de *M. incognita* en calabaza fue significativamente mayor en el testigo que en los tratamientos con compostas. Los datos indican que la incorporación de productos DSM podrían ocasionar un impacto negativo en la población de *M. incognita*.

Palabras clave: composta, desechos sólidos municipales, supresión de nematodos, dinámica poblacional, enmiendas orgánicas.

INTRODUCTION

The addition of organic amendments to soil is a common means of improving soil fertility and structure, especially in subsistence farming. In many cases, yields are increased, presumably due to improved soil structure or added crop nutrients (2, 7, 15). In some cases, the benefits of adding organic material or residues to the soil can be attributed to a decrease in the populations of soil pathogens (9).

Many types of soil amendments have been tested as a means of managing nematodes in field soils (15). In different experiments, nematode populations have been positively or negatively correlated with organic matter content (16). Organic amendments such as oil cake, sawdust, compost, green manure, and chicken manure have reduced nematode populations (15). Less commonly used organic amendments include urban compost and sewage.

The influence of amending soil with sewage sludge on crop growth and productivity has been extensively studied. Incorporation of sewage sludge into the soil improved growth and yield of several vegetable crops (2,6,7,20,21). Recently, composts derived from house and yard trash have become available on a large commercial scale. The effects of these composts on crop growth and yield have been tested on tomato and squash in southern Florida (17). The effects of municipal solid waste (MSW) materials on nematode populations, however, are not well known.

Vegetable crops in southern Florida are grown on soils of the Krome very gravelly loam series (loamy-skeletal, hyperthermic lithic Rendol) (12). These soils have an alkaline pH (7.2–7.6) and are low in fertility and organic matter content (2,12). Amending these soils with MSW materials can improve soil water- and nutrient-holding capacity which may also affect nematode populations. Presumably, improved soil water- and nutrient-holding capacity could also reduce the rates of pesticide application. Improvements in soil structure and plant nutrition, and the production of breakdown products with nematicidal properties may reduce nematode populations. Also, the addition of organic matter is thought to allow nematode antagonists to compete with other soil organisms and attack nematodes (15).

The objectives of this study were to determine the effects of amending calcareous soil with three MSW materials on soil nematode populations in fields planted with tomato *Lycopersicon esculentum* Mill. and squash, *Cucurbita maxima* Duch. ex Lam.

Table 1. Planting, harvest, and soil sampling dates.

Year	Crop	Planting date	Harvest dates	Initial soil sample date	Final soil sample date
1991	Tomato	14 Feb.	9-16 May	22 Jan.	20 Jun.
	Squash	3 Oct.	1-26 Nov.	18 Oct.	2 Dec.
1992	Tomato	25 Jan.	1-20 May	3 Dec.	14 Apr.
	Squash	21 May	11-30 Jun.	27 May	5 Jul.

MATERIALS AND METHODS

The three MSW materials evaluated in this study included Daorganite (a heat-treated sewage sludge produced by Metro Dade County and distributed by South Dade Soil and Water Conservation District), Agrisoil Compost (composed of processed yard and house trash produced by Agripost, Inc., Miami, Florida), and Eweson Compost (a combination of house trash and sewage sludge distributed by Bedminster Bioconversions, Inc., Cherry Hill, New Jersey). These products were tested as soil amendments for cultivation of tomato cv. Sunny and squash cv. Dixie at the Tropical Research and Education Center, Homestead, Dade County, Florida.

Each of the three MSW materials was incorporated into the soil at the rates recommended by the producers which were 16 MT/ha for Daorganite [3.2:1.7:0.1 (N:P:K)], 48 MT/ha for Agrisoil [0.5:0.2:0.3 (N:P:K)], 24 MT/ha for Eweson compost [1.2:1.0:0.6 (N:P:K)], and no MSW material for the control treatment. The materials were applied one time prior to planting tomato in a 45-cm-wide strip with a steel belt distributor (Kennco Manufacturing, Inc., Ruskin, Florida) and rototilled 10 cm deep into the bed. The MSW materials were applied 2–4 weeks before planting.

For each treatment (three MSW materials and the control), two rates of irrigation were established (low: 1.25 L/min/30 m; high: 3.78 L/min/30 m). The high rate of irrigation was a typical irrigation rate used for commercial tomato and squash production in southern Florida. Irrigation was supplied by a drip-irrigation system. Each treatment was replicated 4 times in a 2 × 4 factorial (2 irrigation rates and 4 treatments) experimental design for each of 2 years.

1991: Three-week-old tomato plants grown from seed in flats were transplanted to polyethylene covered beds with 0.5 m between plants and 1.8 m between rows. Treatment rows were 6 m long. After summer fallow, squash was planted on the same beds following the tomato crop. Squash was direct-seeded in two rows on each bed with 0.4 m between rows and 0.4 m between planting holes within a row. Each planting hole contained two plants. See Table 1 for planting and harvest dates. No pesticides were applied to the soil on either crop during the growing season. Fertilizer programs for tomato and squash have been described in detail elsewhere (17).

1992: Tomato followed by squash was planted at a new site at the Tropical Research and Education Center (Table 1). Cultural procedures for both crops (*i.e.*, irrigation, mulching, and fertilizer applications) were similar to those in 1991 as described elsewhere, and detailed yield data are available from both vegetable crops, in both years (17).

Sampling and nematode extraction: Soil samples were collected and processed for nematodes approximately at the time of planting and harvest for both crops, both years (Table 1). Six soil sample units (approximately 200 cm^3 soil/sample unit) were taken from each treatment row and consolidated into one sample. Sample units were collected approximately 15 cm deep with a hand-held trowel. The unusually shallow nature of the soil limits depth of sampling and root penetration (4,12). Each composite soil sample was thoroughly mixed and passed through a 4.0-mm sieve to remove rock. The nematodes were removed from four 100-cm^3 soil subsamples through a combination sieving and centrifugal process as modified by McSorley and Parrado (13,14). All nematodes present in the soil sample were identified and quantified. Nematodes were categorized into the following groups: plant parasites, fungivores, rhabditids, and dorylaimids. Fungivores included those nematodes such as *Tylenchus* spp., *Ditylenchus* spp., and Aphelenchida, which are also recognized as facultative root feeders (19). Four of the most common plant parasites were identified to species.

Data analysis: Nematode counts were transformed to $\log_{10}(X + 1)$ prior to statistical analysis. Transformed data were subjected to two-way analysis of variance using SuperANOVA (1). If there was no significant interaction ($P \leq 0.05$) between treatment (MSW material or control) and irrigation rate, irrigation treatments within each MSW treatment were combined and subjected to a one-way analysis of variance. When significant treatment effects were detected ($P \leq 0.05$), means were separated using Fisher's protected least significant difference (FLSD) (1).

RESULTS AND DISCUSSION

Nematodes found in the soil included *Criconemella onoensis* (Luc) Luc & Raski, *Helicotylenchus dihystera* (Cobb) Sher, *Rotylenchulus reniformis* Linford & Oliveira, *Meloidogyne incognita* (Kofoid & White) Chitwood, *Pratylenchus* spp., *Quinisulcius acutus* (Allen) Siddiqi, *Tylenchus* spp., *Ditylenchus* spp., Rhabditida (primarily *Rhabditis* spp.), Dorylaimida (primarily *Eudorylaimus* spp.), and Aphelenchida. With a few exceptions, there were no interactions between MSW treatment and irrigation rate.

In some instances, initial nematode populations (P_i) were below detectable levels, but in three of four crops, final nematode densities (P_f) increased over P_i (Table 2). The exception was the 1992 squash crop, in which P_f was less than P_i for many treatments. It is likely that high rainfall during June 1992 affected the P_f in squash. An average of 334.5 mm rain fell in June 1992. The average rainfall for June 1991, was 190.7 mm, and the average rainfall for the same month for the past 6 years was 221.6 mm. Squash is susceptible to many pathogens that require high moisture and humidity. This large amount of precipitation presumably caused the majority of squash plants to die before all harvests were completed. When moisture becomes excessive, nematode numbers often decline (16). Also, the premature death of the plant roots likely reduced feeding sites for plant parasites.

Most nematodes were not affected by MSW treatments. Rhabditida showed few significant ($P \leq 0.05$) effects from treatment, and these were inconsistent (Table 2). The fungivores (*Tylenchus* spp., *Ditylenchus* spp., and Aphelenchida) remained at low levels (< 20 nematodes/100 cm^3 soil) during both seasons and were not affected by treatment (data not shown). Populations of Dorylaimida (primarily *Eudorylaimus* spp.) were not affected by the soil amendments in 1991 nor in the tomato crop in 1992 (data not shown). However, in the 1992 squash crop, the mean P_f of 2.7 Dorylaimida/100 cm^3 soil in the control treatment was greater ($P \leq 0.05$) than mean P_f (≤ 0.4 Dorylaimida/100 cm^3 soil) from soil amended with any of the MSW treatments.

Helicotylenchus dihystera was the most abundant nematode at both sites. With the exception of a MSW treatment × irrigation rate interaction observed in tomato in 1992, no significant ($P \leq 0.05$) effects of treatment on *H. dihystera* densities were observed (Table 2). *Criconemella onoensis* was relatively common (mean densities up to 88.5/100 cm^3 soil) in the site used in 1991, but had low population densities (< 2/100 cm^3 soil) in the 1992 site. No significant ($P \leq 0.05$) effects from MSW treatment were observed in either season (data not shown). *Quinisulcius acutus* was found occasionally but was not affected by treatment. Densities of *R. reniformis* were relatively low in both seasons, and except for a significant ($P \leq 0.05$) MSW treatment × irrigation interaction in tomato in 1991, were not affected by treatment (Table 2).

Densities of *M. incognita* juveniles in soil were below detectable levels initially in both sites, but increased on the susceptible vegetable crops (Table 2). Due to low initial numbers, serious plant damage from root-knot nematodes was not observed and root-gall indices were generally low and inconsistent (data not shown). Nevertheless, in both seasons, final densities of juveniles in soil during the second vegetable crop (squash) were suppressed by each of the MSW treatments (Table 2).

Overall, there were few consistent effects due to amending soil with MSW materials on nematode populations in the soil. In most cases, irrigation rate in conjunction with MSW materials did not affect nematode populations. Moisture may have affected final nematode populations in squash due to the unusually large amount of rainfall in June 1992.

Ozores-Hampton *et al.* (17) determined that the rates of Eweson and Agrisoil Composts were too low to obtain consistant plant growth and yield responses. As a result of this work, the producers of these composts are currently recommending higher application rates (B. Schaffer, personal communication). Therefore, the compost rates used in the current study may have been too low to afford any consistent effects on nematode population dynamics. For example, we would expect nematodes such as Rhabditida, which are involved in the decomposition process, to be consistently affected by compost treatments.

Based on previous observations, Hunt *et al.* (11) predicted that compost applications of 55 to 100 MT/ha could suppress *B. longicaudatus* populations. This prediction was in agreement with the response of *Helicotylenchus* spp. populations in oat and sorghum field plots amended with compost where Hunt (10) found lower rates of composted municipal refuse (8, 16, and 32 MT/ha) suppressed these nematode populations.

Amending soil with Daorganite improved tomato and squash growth and yield (17). These effects were attributed to increased nitrogen content of the soil because Daorganite contains approxi-

Table 2. Initial (P_i) and final populations (P_f) of nematodes per 100 cm^3 soil from tomato and squash amended with three municipal solid waste composts.

	1991				1992			
	Tomato		Squash		Tomato		Squash	
Treatment	P_i	P_f	P_i	P_f	P_i	P_f	P_i	P_f
				Rhabditida spp.				
Daorganite	6	3*	6	29	2	13	8	1
Eweson compost	3	11	11	53	1	34	22	2
Agrisoil	2	5*	13	30	1	81*	16	2
Control	9	19	11	58	1	23	19	3
				Rotylenchulus reniformis				
Daorganite	0	6*/5[z]	1	12	0	6	4	3
Eweson compost	0	6*/3	1	15	0	7	2	3
Agrisoil	0	27*/1	1	4	<1	12	2	2
Control	0	109/3	1	10	0	6	4	2
				Helicotylenchus dihystera				
Daorganite	3	16	11	72	2	4/<1[z]	95	52
Eweson compost	1	7	11	48	2	2/3	58	39
Agrisoil	2	14	9	79	2	2/2	69	63
Control	2	13	4	59	2	2/2	48	51
				Meloidogyne incognita				
Daorganite	0	1	<1	12*	0	3	5	1*
Eweson compost	0	1	<1	9*	0	4	3	1*
Agrisoil	0	<1	0	10*	0	4	9	1*
Control	0	3	<1	57	0	5	32	11

[y] Unless noted otherwise, data are means of four replications, pooled across two irrigation levels (eight plots).
[z] A significant ($P < 0.05$) interaction between treatment and irrigation rate exists. Data are means of 4 replications of low irrigation rate/high irrigation rate. Low irrigation rate = 1.25 liters/min/30 m; high rate = 3.78 liters/min/30 m. Asterisk indicates mean is significantly different from control ($P < 0.05$; FLSD).

mately twice the percentage of nitrogen as Eweson Compost and about three times the percentage of nitrogen as Agrisoil Compost. Increased nitrogen can result in increased nematode populations, presumably by providing more feeding sites through stimulation of root growth. Conversely, ammonia produced from decomposition of organic nitrogen has been suggested to reduce nematode populations (22). Heald and Burton (8) found that organic nitrogen in the form of activated sewage sludge reduced numbers of *B. longicaudatus* and *Hypsoperine graminis* Sledge & Golden on turf more effectively than inorganic nitrogen. Galling of tomatoes was reduced also by sludge additives, possibly resulting from toxicity of chemicals released during incubation of the sludge (5). However, no obvious effects on nematode population dynamics were observed here, which could be attributed to an increase in nitrogen by application of Daorganite.

Although incorporation of organic materials into the soil can change the abiotic and biotic qualities of the soil and introduce elements or toxins which can be detrimental to nematode populations, a period of incubation is required to obtain the best control from organic amendments (16). The incubation period differs with the material being added to the field and may be especially important in crops with a relatively short growing season. Additionally, the effects of repeated application or long-term use of MSW materials would likely affect nematode populations differently than short-term application as in this study.

In spite of inconsistent results, there was some indication that *M. incognita*, which is considered one of the most important plant parasites of vegetables in the tropics and subtropics, was suppressed in soils amended with the MSW materials. In both 1991 and 1992, populations of root-knot nematodes rose more dramatically in the control plots than in the plots amended with the MSW materials. In other studies, organic amendments incorporated into the soil have reduced root-knot nematode densities (15). Castagnone-Sereno and Kermarrec (3) observed antagonistic effects of raw sewage sludge on infection of tomato by *M. incognita* in greenhouse pot experiments. They reported suppressed invasion of tomato roots by *M. incognita* juveniles and a significant reduction in egg mass production by females and eggs per egg mass when sludge was mixed with the soil. Although these results are encouraging, continued research on the effects of these products on root-knot nematode are necessary.

Suppression of plant-parasitic nematodes by a variety of organic soil amendments has been demonstrated in many studies (15). The agronomic benefits such as improved soil structure and addition of supplemental nutrients have also been well documented. Studies on the effects of MSW materials on nematode populations, however, are lacking and more work is needed. The greatest potential commercial use of MSW is as agricultural compost (18). A better understanding of the effects of MSW materials on nematode populations may facilitate its potential use in management of these pest species.

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Received: / *Recibido:* *18.XII.1993*

Accepted for publication: / *Aceptado para publicación:* *15.I.1994*