IMPACT OF ORGANIC SOIL AMENDMENTS AND FUMIGATION ON PLANT-PARASITIC NEMATODES IN A SOUTHWEST FLORIDA VEGETABLE FIELD[†]

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ABSTRACT

McSorley, R., P. A. Stansly, J. W. Noling, T. A. Obreza, and J. M. Conner. 1997. Impact of organic soil amendments and fumigation on plant-parasitic nematodes in a southwest Florida vegetable field. Nematropica 27:181-189.

The effects of composted amendments and soil fumigation with methyl bromide/chloropicrin on plant-parasitic nematodes were examined in a three-year split-plot field experiment on tomato (*Lycopersicon esculentum*) in southwest Florida. Composted amendments included municipal solid waste, yard waste, and/or biosolids. Population densities of *Meloidogyne incognita* and root galling on tomato from this nematode were decreased ($P \leq 0.05$) by soil fumigation, but increased ($P \leq 0.10$) in response to compost amendment, with maximum levels in non-fumigated, compost-amended plots. Population densities of *Criconemoides* spp. and *Hemicycliophora* spp. were reduced by fumigation. Application of compost reduced population densities of *Hemicycliophora* spp. but did not affect *Criconemoides* spp. Numbers of *Paratrichodorus minor* were not affected by either treatment. Amendment with municipal solid waste compost was not an effective alternative to methyl bromide fumigation for management of the root-knot nematode in this site within the time-frame of the experiment.

Key words: compost, *Lycopersicon esculentum*, methyl bromide alternatives, nematodes, organic amendments, pest management, sustainable agriculture, tomato.

RESUMEN

McSorley, R., P. A. Stansly, J. W. Noling, T. A. Obreza y J. M. Conner. 1997. Impacto de enmiendas edaficas y de la fumigación, en los nematodos parasitadores de plantas en un campo de hortalizas del suroeste de la Florida. Nematropica 27:181-189.

Los efectos de la modificación con composta y de la fumigación del suelo con bromuro de metilo /cloropicrina en los nematodos parasitadores de plantas, fueron examinados en un experimento realizado por tres años, en un campo de tomate (*Lycopersicon esculentum*) con parcelas divididas, en el suroeste de la Florida. Las modificaciones con composta incluyeron, residuo sólido municipal, desperdicios de jardines caseros, y/o bioseólidos. Las densidades poblacionales de *Meloidogyne incognita* y el agallamiento de la raíz en el tomate producido por este nematodo, fueron disminuidos ($P \leq 0.05$) por la fumigación del suelo, pero incrementados ($P \leq 0.10$) en respuesta a la modificación con composta, con niveles máximos en las parcelas no fumigadas pero composta modificadas. Las densidades de poblacionales de *Criconemoides* spp. y *Hemicycliophora* spp. fueron reducidas por fumigación. La aplicación de composta redujo las densidades poblacionales de *Hemicycliophora* spp. pero no afectó a *Criconemoides* spp. Los números de *Paratrichodorus minor* no fueron afectados por ninguno de los tratamientos. La modificación con la composta de residuo sólido municipal, no resultó ser una alternativa eficiente a la fumigación con bromuro de metilo, para el control del nematodo agallador en este sitio en el marco de tiempo de este experimento.

[†] Florida Agricultural Experiment Station Journal Series No. R-05778.

Palabras claves: agricultura sostenible, alternativas al bromuro de metila, composta, control de plagas, *Lycopersicon esculentum*, al modificaciones orgánicas, nematodos, tomate.

INTRODUCTION

Plant-parasitic nematodes are damaging to many different vegetable crops (Netscher and Sikora, 1990; Potter and Olhof, 1993). Nematodes may be controlled on some high-value crops by fumigants such as methyl bromide, but if uses of this material become limited, it will be necessary to develop effective alternatives for nematode management (Noling and Becker, 1994). Non-chemical alternatives for pest management are particularly desirable for sustainable agricultural systems (Luna and House, 1990), and a number of non-chemical methods have been investigated for management of plant-parasitic nematodes (McSorley and Duncan, 1995; Trivedi and Barker, 1986). Nevertheless, there remains a need to compare the efficacy of these non-chemical alternatives with traditional practices such as fumigation with methyl bromide (McSorley, 1996).

Applications of various organic amendments have frequently been evaluated for nematode management (Muller and Gooch, 1982; Rodriguez-Kabana, 1986). However, the performance of organic amendments against nematodes has often been inconsistent, and their mechanisms of action are often unclear, lacking in documentation, and dependent on the composition of the many different materials available (Stirling, 1991). Interpretation of results is complicated because many amendments affect plant growth directly, even if nematode populations remain unaffected (McSorley and Gallaher, 1995). Recent work conducted in south Florida (Mannion *et al.*, 1994) suggests that despite some inconsistencies in performance, municipal solid waste amendments may be suppressive to the root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood. In Spain, municipal compost residues had some activity against *M. javanica* (Treub) Chitwood (Marull *et al.*, 1997), and raw sewage sludge affected *M. incognita* in greenhouse tests in Guadeloupe (Castagnone-Sereno and Kermarrec, 1991). The present study provided an opportunity to observe and compare the efficacy of amendment with solid waste compost and soil fumigation with methyl bromide for management of *M. incognita* and other plant-parasitic nematodes in a field experiment in southwest Florida.

MATERIALS AND METHODS

A field experiment was established in Sept. 1993 on Immokalee fine sand (95.8% sand, 2.2% silt, 2.0% clay) at the University of Florida Southwest Florida Research and Education Center in Immokalee (26.4°N, 81.5°W) in Collier County, Florida. Experimental design was a completely randomized split block replicated four times, with two levels of compost (present or absent) as main plots and two levels of fumigation (present or absent) as subplots. Main plots consisted of two pairs of raised beds, 73 m long and 0.8 m wide, with a spacing of 1.8 m between centers of adjacent beds and 3.6 m between pairs. Subplots consisted of one pair of beds, one of which was randomly selected for fumigation in each main plot. This design was maintained from 1993 to 1996, with the same beds receiving the same treatments each year.

Table 1. Compost applications to experimental plots in Immokalee, Florida, 1993-1996.

	Compost source		
	Reuter Recycling, Ft. Lauderdale, FL	Tampa, FL	Palm Beach County, FL
Description	Municipal solid waste	Dried, pelletized biosolids	Yard trimmings and biosolids
Date applied	Sept. 1993	Jan. 1995	Jan. 1996
Application rate (dry weight)	124 mt/ha	7 mt/ha	22 mt/ha
% C	37.0	30.0	35.0
% N	0.9	6.0	1.8
% P	0.3	3.0	1.1
% K	0.3	0.0	0.2
C:N ratio	41:1	5:1	19:1
% moisture at application	30.0	5.0	50.0

Composts consisting of municipal solid wastes, yard trimmings, and/or biosolids were applied prior to each growing season (Table 1). Different amendments were used each year, depending on availability. In each season, compost amendments were applied in a 1.0-m-wide band with a side-delivery compost spreader. Compost remained on the surface until the time of bed formation, when it was incorporated into the bed by rototilling to a depth of 15 cm. Fumigant treatments were applied at the time of bed formation each year: Jan. 1994, Jan. 1995, Feb. 1996. Fumigation treatments consisted of 248 kg/ha of a mixture of methyl bromide (67%) and chloropicrin (33%) injected to a depth of 10 cm from four chisels per bed, or a non-fumigated control. In either case, the bed was covered with black polyethylene mulch immediately after application.

At 14 to 28 days after fumigation and bedding, tomato (*Lycopersicon esculentum* Mill.) plants were transplanted 0.3 m apart into all beds. Cultivars and planting dates were: 'Sunbeam' on 28 Feb. 1994, and 'Agriset' on 19 Jan. 1995 and 26 Feb. 1996. Plots were fertilized as follows: in 1994, with 192, 64, and 192 kg/ha of N, P_2O_5, and K_2O for composted and 226, 176, and 248 kg/ha for non-composted plots; in 1995, with 64, 21, and 327 kg/ha for composted and 288, 289 and 328 kg/ha for non-composted plots; in 1996, with 213, 232, and 246 kg/ha for both composted and non-composted plots. Part of the fertilizer was applied to the beds before they were covered, and part was applied through the drip irrigation system used to water the plants. Different levels of inorganic fertilizer were applied to composted and non-composted plots in the first two years in an attempt to adjust available N, P, and K to comparable levels in both treatments, considering the different C:N ratios of the materials involved. This approach was abandoned in the third year because crop yields in the first two seasons were highly variable. Plots were harvested in June/July each year. Following the tomato crop, the site was planted until late autumn with sudangrass (*Sorghum sudanense* [Piper] Stapf) in 1994 and 1995 or browntop millet (*Panicum ramosum* L.) in 1996, followed by 'Gulf' annual ryegrass (*Lolium multiflorum* Lam.) in Nov. and Dec. of each year.

Galling from root-knot nematodes (*Meloidogyne* spp.) was observed in the site in 1994 and evaluated on 3 June 1994 by removing six tomato plants per subplot and rating them on a scale from 0 (no galling) to 10 (severe galling on dead plant) (Zeck, 1971). On 18 July 1995, 10 soil cores 2.5 cm in diameter × 20 cm deep were collected from each subplot and composited into a single soil sample. Samples were transported to the Citrus Research and Education Center in Lake Alfred, Florida, where a 100-cm^3 subsample was removed from each sample for Baermann extraction (Hooper, 1986) of nematodes.

In 1996, soil samples for nematode analysis were collected from each subplot (10 cores per subplot) on 8 March and 30 May. These samples were transported to the University of Florida in Gainesville for nematode extraction from 100-cm^3 subsamples using sieving and centrifugation (Jenkins, 1964). Additional subsamples (4 g each) were removed and heated at 500°C for 4 hours in a muffle furnance for determination of soil organic matter, and other subsamples were sent to J. Scott at the Gulf Coast Research and Education Center in Bradenton, Florida, for determination of soil pH and P, K, Ca, and Mg. On 29 May, five randomly chosen tomato plants were removed from each plot and root systems rated for galling on a 0 to 5 scale such that 0 = 0 galls, 1 = 1-2, 2 = 3-10, 3 = 11-30, 4 = 31-100, and 5 = >100 galls per root system (Taylor and Sasser, 1978).

Data were subjected to analysis of variance for the appropriate design (Freed *et al.*, 1991) to determine the effects of compost, fumigation, and their interaction. Nematode count data were transformed by $\log_{10}(x+1)$ prior to analysis of variance, but untransformed arithmetic means are presented in all tables and other presentations of results. Single degree of freedom orthogonal contrasts (Freed *et al.*, 1991) were used to compare fumigation effects within a compost level or to compare compost effects within a fumigation level.

RESULTS

In 1994, the effect of fumigation on root galling was significant ($P \leq 0.05$), but the effects of compost and the compost × fumigation interaction were not. Root galling in 1994 was much lower ($P \leq 0.05$) in fumigated subplots than in non-fumigated subplots (Table 2). Following harvest of the tomato crop in 1995, the effect of soil fumigation in reducing population levels of *M. incognita* was still evident, but amendment with compost resulted in the opposite trend (Table 3). A compost × fumigation interaction was present, and highest levels of *M. incognita* were found in non-fumigated plots with compost.

Numbers of *M. incognita* juveniles in soil were very low at the initial sampling in 1996. However, the efficacy of the soil fumigation in reducing population densities of *M. incognita* and other nematodes was already apparent, even in these low numbers (Table 4). *Meloidogyne incognita* was detected at this time only in non-fumigated plots with compost.

Near the end of the 1996 tomato crop, numbers of *M. incognita* reached high levels. Population densities of *M. incognita* were lower ($P \leq 0.05$) in fumigated plots, but numbers were more than twice as high ($P \leq 0.10$) in plots with compost than in those without compost (Table 5). Root gall ratings followed a similar pattern, with the most severe galling observed in non-fumigated plots with compost (Table 6). Several

Table 2. Effect of compost amendment and soil fumigation on root gall ratings, 3 June 1994.

	Root gall rating[y,z]		
Amendment	Fumigated	Not fumigated	Mean
Compost	0.5 aA	5.1 aB	2.8 a
No compost	0.1 aA	3.5 aB	1.8 a
Mean	0.3 A	4.3 B	

[y] Root galling rated on 0-10 scale where 0 = no galling and 10 = most severe (Zeck, 1971).
Means in columns (a,b) or in rows (A,B) followed by the same letter do not differ at $P \leq 0.05$.

other nematodes present in this site showed similar responses to fumigation but not to compost treatments. *Criconemoides* spp. were absent in fumigated plots, and *Hemicycliophora* spp. reached their highest levels in non-fumigated plots without compost (Table 5). *Paratrichodorus minor* was unaffected by either treatment (Table 5), as were *Pratylenchus* spp. which were present in low numbers (<1.0 per 100 cm^3 soil) on both sampling dates in 1996 (data not shown).

Crop yields were highly variable in this site, and no yield differences (at $P \leq 0.10$) with treatment were observed in any year. At the end of this experiment in 1996, soil organic matter was greater ($P \leq 0.05$) in plots amended with compost (mean = 1.57%) than in unamended plots (mean = 1.03%). Soil pH (mean = 7.31 in amended vs. 5.59 in unamended) and levels of the macronutrients P (106 mg/kg in amended vs. 43 mg/kg in unamended), K (21 mg/kg in amended vs. 8 mg/kg in unamended), Ca (781 mg/kg in amended vs. 321 mg/kg in unamended), and Mg (69 mg/kg in amended vs. 9 mg/kg in unamended) were also greater ($P \leq 0.05$) in plots amended with compost.

DISCUSSION

It is clear that the municipal solid waste compost used here was not an effective alternative to methyl bromide fumigation for nematode management during the three-year time-frame of this experiment. The data obtained in this study should add to the controversy concerning the reputed efficacy of organic amendments for nema-

Table 3. Effect of compost amendment and soil fumigation on post-harvest population densities of *Meloidogyne incognita*, 18 July 1995.

	Nematodes per 100 cm^3 soil[z]		
Amendment	Fumigated	Not fumigated	Mean
Compost	4.8 aA	52.5 aB	28.6 a
No compost	1.5 aA	2.8 bA	2.1 b
Mean	3.1 A	27.6 B	

[z] Means in columns (a,b) or in rows (A,B) followed by the same letter do not differ at $P \leq 0.05$.

Table 4. Effect of compost amendment and soil fumigation on population densities of plant-parasitic nematodes, 8 March 1996.

Amendment	Nematodes per 100 cm³ soil[y]		
	Fumigated	Not fumigated	Mean
		Criconemoides spp.	
Compost	0.5 aA	27.0 aB	13.8 a
No compost	0.8 aA	8.0 aB	4.4 a
Mean	0.6 A	17.5 B	
		Hemicycliophora spp.	
Compost	0.0 aA	1.5 aA	0.8 a
No compost	0.2 aA	2.2 aA	1.2 a
Mean	0.1 A	1.9 B	
		Meloidogyne incognita	
Compost	0.0 aA	2.0 aB	1.0 a[z]
No compost	0.0 aA	0.0 bA	0.0 b[z]
Mean	0.0 A[z]	1.0 B[z]	

[y] For each nematode, means in columns (a,b) or in rows (A,B) followed by the same letter do not differ at $P \leq 0.05$.

[z] $P \leq 0.10$ for these data.

tode management. For example, results obtained in the present field test differed from those obtained in greenhouse and microplot studies on the influence of organic amendments on *M. incognita* damage to tomato (Castagnone-Serreno and Kermarrec, 1991; Marull *et al.*, 1997). Although reductions in nematode numbers from use of amendments have been reported in many instances (Muller and Gooch, 1982; Rodriguez-Kabana, 1986), no effect on nematode population densities was obtained in other cases (McSorley and Gallaher, 1995), and root-knot nematode numbers were increased by compost amendment in the present study. The efficacy of an organic amendment against plant-parasitic nematodes depends on many different factors, including the nematode species present (McSorley and Gallaher, 1996), the chemical composition of the amendment (Mojtahedi *et al.*, 1993; Stirling, 1991) including its C:N ratio (Stirling, 1991), the length of time since application (McSorley and Gallaher, 1996), the other organisms present in the soil environment including those which degrade the amendment and those which feed on nematodes (Stirling, 1991), as well as other environmental factors and agricultural practices. Therefore it is extremely difficult to anticipate or generalize about the performance of specific amendments.

Organic amendments are a source of plant nutrients which may improve plant performance and complicate the inter-

Table 5. Effect of compost amendment and soil fumigation on population densities of plant-parasitic nematodes, 30 May 1996.

	Nematodes per 100 cm³ soil[y]		
Amendment	Fumigated	Not fumigated	Mean
	Criconemoides spp.		
Compost	0 aA	8 aB	4 a
No compost	0 aA	16 aB	8 a
Mean	0 A	12 B	
	Hemicycliophora spp.		
Compost	<1 aA	0 aA	<1 a
No compost	0 aA	8 bB	4 b
Mean	<1 A	4 B	
	Meloidogyne incognita		
Compost	459 aA	1633 aA	1046 a[z]
No compost	78 bA	852 aB	465 b[z]
Mean	267 A	1242 B	
	Paratrichodorus minor		
Compost	54 aA	27 aA	40 a
No compost	31 aA	49 aA	40 a
Mean	43 A	38 A	

[y] For each nematode, means in columns (a,b) or in rows (A,B) followed by the same letter do not differ at $P \leq 0.05$.

[z] $P \leq 0.10$ for these data.

pretation of nematode management experiments. In the present study, the compost amendments and the fertilizer applications used increased soil organic matter, pH, and soil nutrient levels in the compost-treated plots. Over the course of the study, the total amount of N applied to compost-treated plots was greater than that applied to non-amended plots. The more favorable pH levels achieved in amended plots may also have improved nutrient availability in amended plots. In addition, organic amendments also increase water-holding capacity of sandy soils (McSorley and Gallaher, 1995). These factors could have resulted in improved root growth, which could not be verified because no yield differences were found and no root samples were removed and weighed. Stimulation of root growth through N addition could provide more feeding sites for nematodes (Norton, 1978), and possibly lead to increases in galling and nematode num-

Table 6. Effect of compost amendment and soil fumigation on root gall ratings, 29 May 1996.

	Root gall rating[y,z]		
Amendment	Fumigated	Not fumigated	Mean
Compost	1.4 aA	4.9 aB	3.2 a
No compost	0.2 bA	3.6 bB	1.9 b
Mean	0.8 A	4.2 B	

[y] Root gall rating based on 0-5 scale: 0 = 0 galls; 1 = 1-2; 2 = 3-10; 4 = 31-100; 5 = >100 galls per root system (Taylor and Sasser, 1978).

[z] Means in columns (a,b) or in rows (A,B) followed by the same letter do not differ at $P \leq 0.01$.

bers. Nematode population increase with increased soil organic matter has been documented in an earlier study as well (O'Bannon, 1968). There is evidence that some organic amendments may be useful in improving plant tolerance to plant-parasitic nematodes (McSorley and Gallaher, 1995), but the extent to which improved plant growth may compensate for increased nematode populations is unknown and should require much additional research.

The many factors discussed above may affect the performance of the composts used here as well as amendments obtained from other sources, but at present the effects of any amendment should be considered unpredictable. Other alternatives to methyl bromide should be sought for short-term reductions of root-knot nematodes in sandy soils of South Florida. It is interesting to observe that densities of *M. incognita* declined between 18 July 1995 and 8 March 1996. During much of this time interval, sudangrass and ryegrass were planted on this site, and may have contributed to this decline. Hybrids of sudangrass with sorghum (*Sorghum bicolor* [L.] Moench) have been useful as rotation crops against *M. incognita* (McSorley, 1996; McSorley and Gallaher, 1991). The host status to *M. incognita* of sudangrass, browntop millet, annual ryregrass, and other cover crops to should be investigated to clarify this issue and to determine whether the planting of non-host cover crops could be more reliable than compost amendment for managing nematodes in this and other sites.

ACKNOWLEDGMENTS

The authors thank John J. Frederick for technical support, Nancy Sanders for manuscript preparation, and Jay W. Scott for analyses of soil pH and macronutrient levels.

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Received: *2.VI.1997*
Recibido:

Accepted for publication: *30.IX.1997*
Aceptado para publicación: