CULTURAL PRACTICES IMPROVE CROP TOLERANCE TO NEMATODES†

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ABSTRACT

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The effects of organic amendments and crop establishment on nematode densities and yields of susceptible vegetable crops were determined in sites infested with *Meloidogyne incognita* race 1, *Paratrichodorus minor, Pratylenchus* spp., and *Criconemella* spp. Separate experiments were conducted with yellow squash (*Cucurbita pepo*) and okra (*Hibiscus esculentus*). In each test, the design was a split plot, involving three compost treatments as main plots (269 mt/ha of a yard waste compost applied to the soil surface as a mulch, 269 mt/ha of compost incorporated into the soil, and an unamended control) and two methods of crop establishment as subplots (transplanted 3-week-old seedlings or direct seeding). Final densities (Pf) of *Paratrichodorus minor* and *Pratylenchus* spp. were low ($\leq 14/100$ cm^3 soil) but were affected by compost treatments in some instances. Pf of *M. incognita* was high ($\geq 270/100$ cm^3 soil) in all squash plots, and all plants were heavily galled (> 100 galls/root system), but *M. incognita* was not affected by any treatment. However, yield of squash was increased by 38% when transplants were used instead of direct seeding, and by 155% when incorporated compost was used as compared to the unamended control. Maximum yield of okra was obtained from transplants in plots amended with incorporated compost. Results illustrate the potential for use of these cultural practices to improve performance of susceptible crops grown in nematode-infested sites.

Key words: crop establishment, *Cucurbita pepo,* cultural practices, *Hibiscus esculentus, Meloidogyne incognita,* mulch, nematodes, okra, organic amendments, root-knot nematodes, squash, sustainable agriculture, tolerance.

RESUMEN

McSorley, R. y R. N. Gallaher. 1995. Prácticas culturales para mejorar la tolerancia de cultivos a nematodos. Nematrópica 25:53-60.

Los efectos de enmiendas orgánicas y el establecimiento de los cultivos sobre las densidades poblacionales de nematodos y producción de cultivos susceptibles, se determinó en sitios infestados con *Meloidogyne incognita* raza 1, *Paratrichodorus minor, Pratylenchus* spp. y *Criconemella* spp. Experimentos independientes se llevaron a cabo con calabaza amarilla (*Cucurbita pepo*) y okra (*Hibiscus esculentus*). En cada ensayo, el diseño fue de parcela divididas involucrando a tres tratamientos compuestos como ensayos principales (269 mt/ha de una composta de residuos aplicado sobre la superficie como mulch, 269 mt/ha incorporada en el suelo y un testigo sin enmienda), dos métodos de establecimiento de cultivo como subparcelas (transplante de plántulas de tres semanas o siembra directa). Las densidades finales (Pf) de *Paratrichodorus minor* y *Pratylenchus* spp. fueron bajas ($< 14/100$ cm^3 de suelo) y fueron afectados en algún momento por las compostas. Los valores Pf para *M. incognita* fueron altos ($< 270/100$ cm^3 de suelo) en todas las parcelas de calabaza las plantas mostraron fuerte agallamiento radical (> 100 agallas/raíz), por lo que *M. incognita* no fue afectada por ningún tratamiento. Sin embargo, la producción de calabaza se incrementó 38% cuando se transplantó en lugar de sembrarse directamente y 155% cuando se le incorporó composta. La máxima producción de okra se logró

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transplantando en las parcelas enmendadas con incorporación de compostas. Los resultados ilustran el uso potencial de estas prácticas culturales para mejorar la producción de cultivos susceptibles sembrados en suelos infestados de nematodos.

Palabras clave: calabaza, *Cucurbita pepo*, cultura práctica, enmiendas organicas, *Hibiscus esculentus*, *Meloidogyne incognita*, nematodo, nematodos de las agallas, okra, tolerancia.

INTRODUCTION

Tolerance, or the limitation of plant damage despite the presence of potentially damaging levels of plant-parasitic nematodes, is a particularly useful characteristic of some plant cultivars (1,15). Tolerance also depends on the dynamics of the nematode pest (15), and since many environmental factors influence both plant growth and nematode dynamics, relationships between crop damage and nematode density are also influenced by environmental factors (10,11). If the influence of environment on plant damage is important, then it may be possible to manipulate environmental factors so that crops with little or no inherent resistance or tolerance could show improved growth, despite nematode infestation.

Addition of organic amendments is one of many cultural practices which can improve crop performance (8,13). Organic amendments have been studied extensively as nematode management tools (12,16,17,19), since nematode population densities may be reduced in some cases. Addition of organic amendments may improve crop growth by increasing tolerance to nematodes (19). Watson (20) observed the benefits of mulching on plant growth, even when plants were heavily infected with *Meloidogyne* spp. Many other cultural practices are available which can be used to help alleviate damage in infected plants (19). For example, the use of transplants rather than direct seeding could provide a crop with a larger root system early in the season, making it less vulnerable to nematode damage and improving plant establishment. The use of organic amendments for management of nematode damage is a particularly attractive option because large amounts of organic waste products may be available from urban areas (4,8).

Our objective is to improve the performance of vegetable crops which are highly susceptible to *Meloidogyne* spp., even when these crops are grown in infested sites. The specific objectives of these experiments were to examine the effects of an organic amendment (yard waste compost) and crop establishment methods on nematode densities and yields of squash (*Cucurbita pepo* L.) and okra (*Hibiscus esculentus* L.) in sites infested with *Meloidogyne incognita* (Kofoid and White) Chitwood (race 1) and other plant-parasitic nematodes.

MATERIAL AND METHODS

Two separate experiments, one with yellow squash and the other with okra, were conducted at the University of Florida Green Acres Agronomy Research Farm in Alachua County. The soil was an Arredondo fine sand with 92% sand, 4% silt, 4% clay, pH = 5.4, and 1.8% organic matter. The site was planted to crimson clover (*Trifolium incarnatum* L.) during the winter of 1993-94 until February 1994.

A yard waste compost obtained from Wood Resource Recovery of Gainesville, Florida, was applied to the site in March 1994. The compost consisted of four- to six-month-old yard waste such as sticks, leaves, grass clippings, limbs, and other wood fragments, all < 2.5 cm in length. At the time of application, the compost consisted of about 50% dry weight (498 g dry matter/kg of fresh material). The dry matter consisted of 592 g organic matter per kg, with pH = 7.5, and 313.0 g C/kg and 9.1 g N/kg for a C:N ratio of approximately 34: 1. The dry compost also contained 34.1 g Ca, 1.9 g Mg, 2.9 g K, 1.8 g P, 18.0 mg Cu, 1825 mg Fe, 188 mg Mn, and 118 mg Zn/kg. Before application of compost, all plots were fertilized with 145 kg N, 5 kg P, and 100 kg K/ha, a standard practice for vegetable production in north Florida (6). The following three compost treatments were applied individually to plots 3.0 m wide × 4.5 m long: 269 mt/ha of fresh compost applied to the soil surface as a mulch; 269 mt/ha of fresh compost applied to the soil surface and then incorporated by rototilling; and an unamended rototilled control.

In the squash and okra experiments, which were conducted in adjacent sites, each of the main plots was split at planting on 12 April, when two different methods of crop establishment were used. Seeds of the yellow squash cv. Dixie or the okra cv. Clemson Spineless were planted 10 cm apart in half of each plot (2 rows, 4.5 m long), and seedlings were thinned to 30 cm apart one week later. On 12 April, 3-week-old seedlings of the same cultivars were transplanted 30 cm apart into the other half of each plot. The design of each experiment was a split plot, with two crop establishment methods split on three compost treatments, and all combinations were replicated four times. Crops were irrigated as needed, but no pesticides or additional fertilizers were applied. Squash was harvested 12 times between 9 May and 20 June. Okra was harvested 7 times between 27 May and 5 July.

All subplots in both experiments were sampled at planting for initial (Pi) nematode densities and on 30 June for final densities (Pf). Each soil sample consisted of six cores 2.5-cm-diam × 20 cm deep collected within plant rows in a systematic pattern and mixed thoroughly. A 100-cm^3 subsample was removed for nematode extraction using a modified sieving and centrifugation procedure (7). Following the final harvest of each crop, 5 root systems were removed from each plot and rated for galling on a scale of 0 to 5, where 0 = 0 galls and 5 = > 100 galls per root system (18). Data were analyzed using analysis of variance (ANOVA) for a split-plot design (3), followed by Duncan's multiple-range test to compare means of main effects (if no interaction) or means within treatment combinations (if interaction was significant).

RESULTS

No differences ($P > 0.10$) with treatment were observed among Pi of any plant-parasitic nematode in either test. Across treatments, Pi of *M. incognita* averaged 10/100 cm^3 soil in the squash test and 11/100 cm^3 soil in the okra test. Pf of *M. incognita* following squash was high (≥ 270/100 cm^3) but not affected by compost treatment or crop establishment method (Table 1). Densities of *M. incognita* following okra were not affected by compost treatment but were lower ($P \leq 0.10$) following direct-seeded than following transplanted okra. After the final harvest, all plants in both the okra and squash tests were heavily galled with uniform gall ratings of 5.

Pi of *Criconemella* spp. (primarily *C. ornata* [Raski] Luc and Raski with some *C. sphaerocephala* [Taylor] Luc and Raski) averaged 27/100 cm^3 at the squash site and 58/100 cm^3 at the okra site. Final den-

Table 1. Effect of yard waste compost treatment and crop establishment method on final population densities of *Meloidogyne incognita* on squash and okra, 30 June 1994.

Compost treatment	Compost amount (mt/ha)	Nematodes per 100 cm^3 soil: Squash Transplanted	Squash Seeded	Squash Mean	Okra Transplanted	Okra Seeded	Okra Mean
Incorporated	269	416	303	360	330	94	212
Mulch	269	270	362	316	276	206	241
Control	0	460	340	400	106	110	108
Mean	—	382	335		237	137*	

*Mean values between crop establishment methods differ at $P \leq 0.10$. No differences among compost treatments at $P \leq 0.10$.

sities were not affected ($P > 0.10$) by compost treatment or crop establishment method (Table 2).

Paratrichodorus minor (Colbran) Siddiqi was present in both tests with Pi averaging 4/100 cm^3 in the squash test and 5/100 cm^3 in the okra test. Pf of *P. minor* was < 9/100 cm^3 soil in all plots of both tests. Pf of *P. minor* was reduced ($P \leq 0.05$) from 7.2/100 cm^3 in control plots to 1.0/100 cm^3 soil following incorporation of compost in the squash test, but Pf was not affected by compost treatments in the okra test or by crop establishment method in either test.

Pi of *Pratylenchus* spp. (mainly *P. scribneri* Steiner) averaged 4/100 cm^3 in the squash test and 14/100 cm^3 in the okra test. Final densities were < 5/100 cm^3 soil on squash and < 15/100 cm^3 soil on okra but were lower ($P \leq 0.05$) in the incorporated compost treatment than in the control in both squash (1.4 vs. 4.1/100 cm^3) and okra (4.4 vs. 12.4/100 cm^3). Pf was lower ($P \leq 0.05$) on direct-seeded than on

Table 2. Effect of yard waste compost treatment and crop establishment method on final population densities of *Criconemella* spp. on squash and okra, 30 June 1994.

Compost treatment	Compost amount (mt/ha)	Nematodes per 100 cm^3 soil[z]: Squash Transplanted	Squash Seeded	Squash Mean	Okra Transplanted	Okra Seeded	Okra Mean
Incorporated	269	118	79	98	93	160	126
Mulch	269	44	70	57	290	218	254
Control	0	114	223	168	341	371	356
Mean	—	92	124		241	250	

[z]No differences among compost treatments or between crop establishment methods at $P \leq 0.10$.

Table 3. Effect of yard waste compost treatment and crop establishment method on total squash yield, 1994.

Compost treatment	Compost amount (mt/ha)	Total yield (kg/ha)[z]		
		Transplanted	Seeded	Mean
Incorporated	269	18 900	15 300	17 100 a
Mulch	269	14 800	9 800	12 300 ab
Control	0	8 100	5 200	6 700 b
Mean	—	13 900	10 100	

[z]Total of 12 harvests. Mean values among compost treatments not followed by the same letter differ at $P \leq 0.05$.
*Mean values between crop establishment methods differ at $P \leq 0.05$.

transplanted okra (5.3 vs. 9.2/100 cm^3 soil).

Total yield of yellow squash was improved by compost incorporation and by use of transplants rather than direct seeding (Table 3). Transplanted squash yielded 38% more than direct-seeded squash, and the yield of plants in plots treated with incorporated compost was 155% greater than the average yield without compost.

Analysis of total okra yield data revealed an interaction ($P \leq 0.10$) between compost treatment and crop establishment method (Table 4). Yield was greatest in plots receiving incorporated compost and transplanted seedlings. Yield of direct-seeded okra was very low.

DISCUSSION

Root-knot nematode numbers were high in these sites, and likely, accounted for the poor performance of okra. The heavy infestation of *M. incognita* resulted in death of some seedlings (which showed

Table 4. Effect of yard waste compost treatment and crop establishment method on total okra yield, 1994.

Compost treatment	Compost amount (mt/ha)	Total yield (kg/ha)[z]		
		Transplanted	Seeded	Mean
Incorporated	269	2 270 a	340 a *	1 310
Mulch	269	450 b	30 a ns	240
Control	0	610 b	40 a ns	330
Mean	—	1 110	140	

[z]Total of 7 harvests. Within a crop establishment method (column), mean values among compost treatments not followed by the same letter differ at $P \leq 0.10$.
*Values between crop establishment methods differ at $P \leq 0.05$; ns = values between crop establishment methods do not differ ($P \leq 0.10$).

gall ratings = 5) and stunted, low yielding plants, particularly among those which were direct-seeded. Damage from cutworms was also observed, particularly when the compost was used as a mulch, although no systematic data on cutworm damage were collected. It is possible that the lower Pf of *M. incognita* on direct-seeded vs. transplanted okra resulted from the smaller root systems (fewer feeding sites) on the stunted, direct-seeded plants. Although compost treatments reduced densities of *P. minor* and *Pratylenchus* spp. in some instances, any implications on plant performance appear unlikely. Densities of both nematodes were low, and while threshold densities of these nematodes on squash and okra are unknown, the numbers found here were below thresholds reported on other crops (14). Severe damage to yellow squash was reported following a Pi of 627 *P. minor*/100 cm^3 (9), far in excess of the numbers observed here.

Meloidogyne incognita is a problem on squash and okra (9), but okra yields were improved by incorporating compost and by using 3-week-old seedlings instead of direct seeding. Squash was also severely infected, with severe galling and similarly high Pf (ca. 300-400 second-stage juveniles/100 cm^3 soil) in all treatments. Despite the high nematode numbers, yield of squash in response to several treatment combinations exceeded the average reported for marketed squash for the state (12 983 kg/ha) and for the north central region of the state (9 408 kg/ha) for the 1992-93 season (2). The yield of transplanted squash with incorporated compost was 3.6 times greater than the yield of the unamended, direct-seeded control.

Use of transplants and compost both improved plant performance despite large numbers of root-knot nematodes which were unaffected by treatment The addition of yard waste compost has been particularly beneficial in enriching the organic matter of nutrient-poor sandy soils in Florida (4,8). Increased soil organic matter improves cation exchange capacity, water-holding capacity, and crop nutrition (4). Use of a similar compost in a corn (*Zea mays* L.) field resulted in 40-75% more storage of soil water than in an unamended control, with resultant yield increases of 38-45% (5).

In the present study as well as in others, it is difficult to ascertain whether the principal benefit of the compost was to improve water-holding capacity, increase soil organic matter, increase soil fertility, improve soil structure, or some other factor. Much additional research and sophisticated experimentation is needed to separate the relative contributions of these factors to crop growth, and results would probably vary from case to case. The potential of a compost or other amendments to provide additional crop nutrients is particularly variable. For example, the compost application in the present study apparently adds a large amount of N to the sites, most of which is immobilized in the compost and unavailable to the crops. A compost with a high C:N ratio (e.g. 34:1 here) can even immobilize soil N and may result in N deficiency (4).

While it is encouraging that plant tolerance and performance can be improved even if nematode densities are not reduced, much work is needed to optimize cultural methods for enhancing plant performance under such conditions. Our results show an almost complete spectrum of crop performance, from above-average squash yield in some treatments to death of some plants in direct-seeded okra plots. The application rates for yard waste compost in these and related studies (4,5,8) are very high. Effective use of this material will depend on several factors, such as supply and quality control, ability to deliver large quantities of material to the field, and avoidance of negative effects like providing habitat for cutworms in mulch, immobilization of N by materials with high C:N ratios, or accumulation of heavy metals or other toxic materials (4,8). The head-start provided by use of transplants was beneficial but depends on availability and production sites for transplants. Much additional research is needed to develop and perfect these methods and to integrate their use with other practices which improve plant health and tolerance to nematodes. Furthermore, these methods for managing plant tolerance could be combined with other options available (10,19) for reducing nematode population densities as well.

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