Journal of Nematology 35(3):289–293. 2003.

Effect of Compost and Manure Soil Amendments on Nematodes and on Yields of Potato and Barley: A 7-Year Study

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Abstract: A 7-year study located in Prince Edward Island, Canada, examined the influence of compost and manure on crop yield and nematode populations. The compost used in this study consisted of cull waste potatoes, sawdust, and beef manure in a 3:3:1 ratio, respectively. No plant-parasitic nematodes were detected in samples collected from windrow compost piles at 5- and 30-cm depths prior to application on field plots. Low population densities of bacterial-feeding nematodes were recovered from compost windrows at the 5-cm depth. Field plots of potato (*Solanum tuberosum* cv. Kennebec) received compost applied at 16 metric tonnes per hectare, or beef manure applied at 12 metric tonnes per hectare. An adjacent trial with barley (*Hordeum vulgare* cv. Mic Mac) received only the compost treatment. In both trials the experimental design was a complete randomized block with four replicates. Data averaged over seven growing seasons indicated that population levels of root-lesion nematodes (primarily *Pratylenchus penetrans*) were higher in root-zone soil in potato plots treated with either compost or manure compared to the untreated control plots. The soil amendments did not affect root-knot nematode (*Meloidogyne hapla*) population densities in the potato plots, but clover-cyst nematodes (*Heterodera trifolii*) were more numerous in the root-zone soils of barley treated with compost compared to the untreated plots. Numbers of bacterial-feeding nematodes (primarily *Diplogaster lheritieri*) were greater in soil in potato plots treated with manure and in soil around barley roots than in untreated plots. Total yields of potato tubers averaged over seven growing seasons increased by 27% in the plots treated with either compost or manure. Grain yields of barley also were increased by 12% when compost was applied. These results indicated that organic amendments increased crop yields, but the impacts on different nematode species varied and usually increased soil population levels.

Key words: bacterial-feeding nematodes, barley, beef manure, clover cyst nematode, compost, cull potato, *Diplogaster lheritieri, Heterodera trifolii,* potato, root-knot nematode, root-lesion nematode, sawdust.

During the period from 1994 to 1999, the average annual production of potatoes on Prince Edward Island was 1,300,000 metric tonnes (Prince Edward Island Department of Agriculture and Forestry, 2000). Stringent quality control measures usually result in about 25% of the potato crop being discarded as cull potatoes. Because culls left on the surface subsequently serve as the foci of diseases, most are buried, though some of the material is fed to livestock. However, it has been suggested that burial of culls may lead to groundwater pollution, a major concern because this province is wholly dependent on groundwater as its water source.

Composting is an alternative to cull burial and serves to "break down" potatoes without creating the environmental problems associated with other disposal methods that may allow soluble potato residues to move down through the soil. Composted potatoes may be used as an agricultural amendment, adding nutrients to the soil and reducing the requirements for applied inorganic fertilizer. Other composted materials such as yard waste have enhanced the organic matter and water-holding capacity of soil and, subsequently, led to increased crop yields (Gallaher and McSorley, 1994; Kostewicz, 1993). Various reports also have indicated that certain organic amendments and mulches have reduced population levels of plant-parasitic nematodes (Rodríguez-Kábana, 1986; Trivedi and Barker, 1986). Lazarovits et al. (1999) found that soybean or meat bone meal virtually eliminated populations of root-lesion and root-knot nematodes 2 weeks after application to commercial potato fields in Ontario. However, the effect of added compost and other amendments is variable and often conflicting. For example, McSorley and Gallaher (1995) found that yard-waste compost (leaves, branches, grass clippings) had little effect on either the population densities of *Pratylenchus* spp. and *Meloidogyne incognita* or the yields of a variety of vegetable crops in north Florida. In contrast, numbers of *Pratylenchus* spp. were reduced in the third year of a 3-year trial with sweet corn (*Zea maize*), and yields were increased in every year of the study (McSorley and Gallaher, 1996).

The objectives of this project were to assess the impact of spring-applied compost and manure treatments on the survival of plant-parasitic and bacterial-feeding nematodes, and on the subsequent yields in potato and barley crops receiving these soil amendments.

Materials and Methods

The field trial was conducted from 1992 to 1998 on private land near the Harrington Farm of the Agriculture and Agri-Food Canada Crops and Livestock Research Centre on Prince Edward Island. The soil type was a fine sandy loam with 60% sand, 29% silt, 11% clay, 2.8% organic matter, and a pH range of 5.2 to 6.2.

In spring 1992 the site, consisting primarily of timothy (*Phleum pratense*) with some red clover (*Trifolium pratense*) from 1989 to 1991, was mouldboard plowed 20 cm deep, tandem disc harrowed, and S-tine harrowed 15 cm deep. Individual plots, 7.6 × 3.6 m, were planted in late May to potato (*Solanum tuberosum* cv. Kennebec) or barley (*Hordeum vulgare* cv. Micmac) in rows 0.9 m

Received for publication 8 October 2001.
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This paper was edited by Patricia Timper.

and 9.5 cm apart, respectively. In the same general area from 1993 to 1998, the same procedures were followed and potato and barley were rotated with red clover and potato, respectively, which are common crop sequences in the province. In each year, recommended cultural and fertilizer practices were followed (Atlantic Canada Potato Guide, 1993; Atlantic Provinces Field Crop Guide, 1991).

The experimental design in each year for either the potato or barley crop was a randomized complete block with four replicates per treatment. There were two treatments in the barley plots, the untreated control and compost applied at 16 metric tonnes/ha. The same treatments, as well as a third treatment of manure applied at 12 metric tonnes/ha, were applied to the potato plots.

The compost consisted primarily of cull potatoes, sawdust, and beef manure in a 3:3:1 ratio, respectively, and the materials were mixed and passed through a manure spreader. In each year composting was carried out from May to October in windrows approximately 3.0 to 3.5 m wide at the base and 1.2 m high. After the temperature in the windrows had risen to 50 °C, the piles were turned as necessary to maintain the composting process. The windrows were then left to cool. Approximately 1 week before planting, compost or beef manure was applied to the experimental plots.

In August of each year, samples for nematode analyses were collected from the windrows with a 2.5-cm-diam. soil probe. Ten composite samples made up of 15 cores each were taken at depths of 0 to 5 cm or 25 to 30 cm. Soil nematode populations also were measured in each plot from a composite sample of 10 cores, 2.5-cm-diam. and 20-cm-deep, taken from the outside rows of the potato plots and randomly in the rows from the barley plots about 1 week prior to harvest. A 50-g subsample from each windrow or plot composite sample was placed in a modified Baermann funnel (Barker, 1985) at 22 °C. Nematodes in roots removed from the field soil were assayed by placing 10 g of fresh roots from each sample in a mist chamber (Hooper, 1986) at 22 °C. After 7 days, nematodes that had emerged from the samples were counted with a stereomicroscope (×80) and individual specimens were observed with the oil immersion lens (×1000) and identified to species. The processed soil and root samples were then dried for 48 hours at 100 °C and the data recorded as numbers of nematodes per kilogram of dry soil or per gram of dry root.

Potato tuber yields were determined from the two inside rows in late September. Tubers were mechanically sized into Canada No. 1 (58–88 mm diam.), and total yields were determined (Atlantic Canada Potato Guide, 1993). Barley grain yields were estimated from the center six rows of each plot in early August of each year except 1996 using the methodology of Sylvester-Bradley et al. (1985).

Nematode data were transformed to $\log_{10}(X + 1)$ for analyses of variance (Genstat, v.5, Clarendon Press, Oxford, UK) (Snedecor and Cochran, 1989) and assessed for the effects of amendments on nematode populations. Duncan's multiple-range test (SAS Institute Inc., Cary, NC) was used for comparisons among treatment means. Error variances were homogenous and years were treated as fixed effects for the combined-year analyses of variance (Steel and Torrie, 1960). The same statistical analyses were applied for analyses of crop yield data.

Results

The high temperatures, which often reached 55 °C near the centers of the windrow compost piles, were lethal to all plant-parasitic nematode species. A few bacterial-feeding nematodes were present in the 0 to 5-cm depth where the temperature ranges were lower (20–35 °C). The dominant bacterial-feeding nematode species was *Diplogaster lheritieri.*

The most frequent plant-parasitic nematode species detected in the potato and barley plots was the root-lesion nematode, *Pratylenchus penetrans* (Table 1). Other plant-parasitic nematodes (*Pratylenchus crenatus, Merlinius* spp., *Tylenchorhynchus* spp., and *Helicotylenchus* spp.) were detected in low numbers in soil (<500 nematodes/kg of dry soil). Numerous bacterial-feeding nematodes were recovered from root-zone soil, and

TABLE 1. Effect of compost and manure treatments on nematodes in potato and barley averaged over 7 years.

	Number of nematodes[a]			
	Potato		Barley	
Treatment	per kg soil	per g root	per kg soil	per g root
Root-lesion nematodes[b]				
Check	2,880a[c]	3,240	2,040	1,550
Compost	5,250b	3,090	2,290	1,700
Manure	5,890b	4,270	—[d]	—
Root-knot nematodes[e]				
Check	1,410	190	—	—
Compost	1,050	210	—	—
Manure	1,290	160	—	—
Clover-cyst nematodes[f]				
Check	590	—	600a	—
Compost	480	—	1,780b	—
Manure	510	—	—	—
Bacterial feeding nematodes[g]				
Check	6,760a	1,450	4,680	270a
Compost	8,320ab	1,290	6,610	490b
Manure	12,300b	1,260	—	—

[a] Samples collected 1 week before harvest.
[b] Primarily *Pratylenchus penetrans.*
[c] Back-transformed mean; means in a column followed by the same letter are not different ($P = 0.05$) according to Duncan's multiple-range test. Letters omitted if there is no significant difference.
[d] No treatment or plant is not a host for the nematode species.
[e] *Meloidogyne hapla* second-stage juveniles.
[f] *Heterodera trifolii* second-stage juveniles.
[g] Primarily *Diplogaster lheritieri.*

again the dominant species was identified as *Diplogaster lheritieri* (Table 1).

The population levels of *P. penetrans* averaged over the 7-year study were higher ($P = 0.01$) in potato soil in the compost-(5,250/kg soil) and manure-treated plots (5,890/kg soil) than in the untreated plots (2,880/kg soil) (Table 1). There was no interaction between year and treatment on densities of *P. penetrans* in soil or roots of potato. The yearly population data for root lesion nematode in potatoes are shown in Figure 1A,B. Soil amendments did not affect *M. hapla* populations in potatoes or *P. pentrans* populations in barley (Table 1); however, *H. trifolii* juveniles were more numerous ($P = 0.01$) in the soil of barley plots treated with potato compost (1,780/kg soil) than in the untreated plots (600/kg soil). The numbers of bacterial-feeding nematodes were higher ($P = 0.05$) in soil around potato roots in manure-treated plots (12,300/kg soil) as compared to untreated plots (6,760/kg soil). The same trend was also present on the root surfaces of barley, though the counts were lower (270/g of root in the untreated plots and 490/g of root in the compost-treated plots). There was a significant ($P = 0.05$) year by treatment interaction for bacterial-feeding nematodes in potato soil but not in potato roots. The yearly population data for bacterial-feeding nematodes are shown in Figure 1C,D.

Averaged over 7 years, total tuber yields were approximately 27% higher ($P = 0.01$) in treated plots than in untreated plots, and yields of Canada No. 1 tubers (57 to 89-mm diam.) were approximately 10% higher ($P = 0.05$) in compost-treated plots than in untreated plots (Table 2). There was a significant ($P = 0.05$) year by treatment interaction for total tuber yield, but not for marketable tuber yield. Averaged over 6 years, grain yields in barley were about 12% greater ($P = 0.01$) in compost-treated plots than in untreated plots. There was also a significant ($P = 0.05$) year by treatment interaction for barley grain yield. The total tuber yield, Canada No. 1 tuber yield, and barley grain yield in each year are shown in Figure 2A–C, respectively.

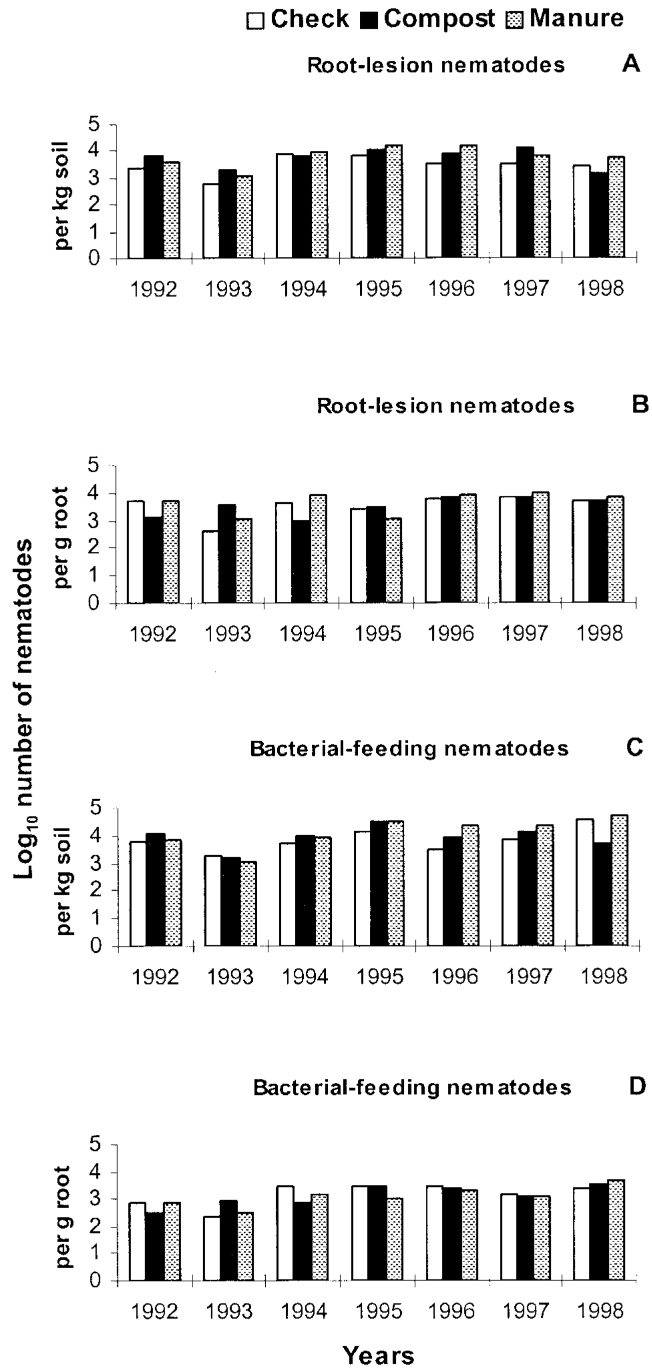

Fig. 1. Effect of compost and manure treatments on nematodes in potatoes over a 7-year period. Data averaged over 7 years from soil samples collected 1 week prior to harvest indicated that root-lesion nematode populations were greater ($P = 0.01$) in plots treated with compost or manure than in untreated plots (A). Bacterial-feeding nematode populations were also greater ($P = 0.05$) in manure-treated plots (C).

Discussion

The dominant bacterial-feeding nematode species, *Diplogaster lheritieri,* is common in the rhizosphere of potato roots on Prince Edward Island and is known to disperse plant-growth promoting bacteria (Kimpinski and Sturz, 1996). The dominant plant-parasitic nematode species detected in the potato and barley plots, *Pratylenchus penetrans,* as well as the northern root-knot nematode *Meloidogyne hapla* were the only plant-parasitic nematode species that were present at levels above the damage threshold for potatoes (Kimpinski and McRae, 1988; Olthof and Potter, 1972).

In these studies, both compost and manure treatments were associated with higher population densities of *P. penetrans* in potato soil, in marked contrast to the results of several previous studies. For example, Rodríguez-Kábana (1986), Trivedi and Barker ((1986), Akhtar and Alam (1993), and Akhtar (2000) indicated that organic amendments usually decreased nematode populations, and suggested the addition of waste materials from animals and plants to field soil might be an

TABLE 2. Effect of compost and manure treatments on tuber yields in potato and compost treatment on grain yields in barley averaged over 7 and 6 years, respectively.

Treatment	Potato: Total yield (tonnes/ha)	Potato: Canada No. 1[a] (tonnes/ha)	Barley: Grain yield (tonnes/ha)
Check	35.0a[b]	22.3a	3.25a
Compost	44.4b	25.0b	3.65b
Manure	44.3b	23.9ab	—[c]

[a] 57-mm to 89-mm diam.
[b] Means in a column followed by the same letter are not different ($P = 0.05$) according to Duncan's multiple-range test.
[c] No treatment.

environmentally friendly way to control plant-parasitic nematodes. In a similar microplot study, the application of mushroom compost reduced potato early dying disease through the suppression of *P. penetrans* populations (LaMondia et al., 1999). However, McSorley and Gallaher (1995) found that yard-waste compost did not affect *Pratylenchus* spp. Perhaps the greater number of *P. penetrans* in the amended soil in this study was due to increases in soil moisture and better development of potato roots, which provided more resources for the nematode population.

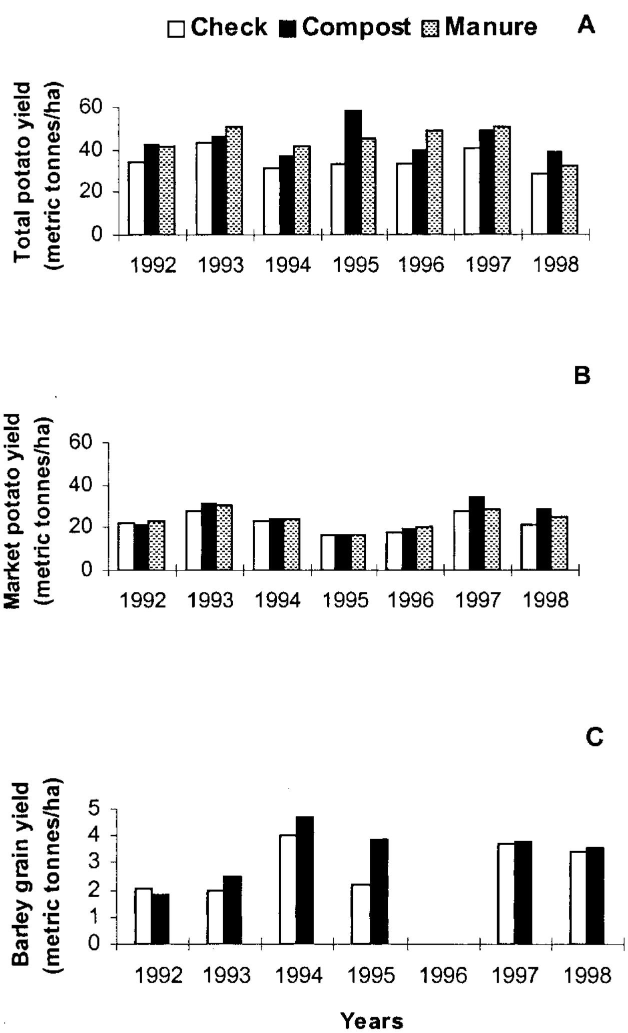

FIG. 2. Effect of compost and manure treatments on yields over a 7-year period. Data averaged over 7 years indicated that total potato tuber yields (A) were greater ($P = 0.01$) in treated plots than in untreated plots. Marketable potato tuber (57–89-mm diam.) yields (B) and barley grain yields (C) were also greater ($P = 0.05$ and $P = 0.01$, respectively) in compost-treated plots.

Compost and manure amendments did not affect the population levels of *M. hapla,* and these results are in agreement with Bélair and Tremblay (1995) who showed that chitin-urea amendments did not suppress root-knot nematodes in mineral soils. However, in a one-season field trial, a compost of cattle manure and leaves reduced *M. incognita* populations in chickpeas (*Cicer arietinum*) by about 90% (Akhtar, 2000). Similarly, seed crop meals usually reduced populations of *M. chitwoodi* on tomato (*Lycopersicon esculentum*) grown in the greenhouse (Hafez and Sundararaj, 1999), and soil amendments consisting primarily of pomace and chicken litter reduced numbers of *M. javinca* in microplot experiments (Marull et al., 1997). In a potato field trial, rapeseed (*Brassica napus*) amendments suppressed populations of *M. chitwoodi* (Mojtahedi et al., 1993). In contrast, Sotomayor et al. (1999) found that yard-waste compost increased populations of *Meloidogyne arenaria.*

We found that the compost amendments in the barley plots increased *H. trifolii* juvenile nematode populations. This species parasitized the preceding red clover crop, but not barley. The compost treatment may have stimulated egg hatching. Increased egg hatching of this species was observed previously on Prince Edward Island (Kunelius et al., 1988) and was attributed to increased aeration in conventionally tilled soil compared to no-till soil.

In the present study we found that the numbers of bacterial-feeding nematodes in soil around potato roots increased when manure was applied, and this is in agreement with the findings of McSorley and Frederick (1999). In that investigation, crop residue amendments increased bacterial-feeding nematode populations in the greenhouse, an effect that persisted approximately 4 months after application.

The improved yields in potato and barley plots where compost or manure was applied were expected responses to additions of organic matter to soil and agreed with previous studies (Akhtar, 2000; Akhtar and Alam, 1993; LaMondia et al., 1999; Marull et al., 1997; McSorley and Gallaher, 1996, 1997; Power and Papendick, 1985). Even so, such beneficial results are not guaranteed. For example, chitin-urea amendments to mineral soils did not affect fruit weights of tomatoes (Bélair and Tremblay, 1995), and the application of soybean meal as well as meat and bone meal caused phytotoxicity in potato (Lazarovits et al., 1999).

Our conclusion based on this long-term study supports that of McSorley et al. (1997) that the effect of any amendment on plant-parasitic nematode populations is unpredictable. Although there is general agreement that organic amendments supply nutrients to plants and improve yields, the effect on nematodes can vary with the nematode species, type of amendment and its by-products, and length of time after application (McSorley and Gallaher, 1996, 1997). Furthermore, they suggested that cultivar choice of the host crop was more important than the application of yard-waste amendments for management of root-knot nematodes. They also questioned the efficacy of organic soil amendments for nematode management, and they inferred that the impact of these treatments could differ depending on whether the experiments were conducted in the greenhouse, in microplots, or in the field (McSorley et al., 1997). We also tend to favor the practical view of Whitehead (1998), who stated that even when organic amendments appear to have a negative effect on plant-parasitic nematodes, the large amounts needed for effective control make their use feasible only for small areas of land. Nevertheless, because organic amendments usually increase crop yields, enhance soil health, and add to the biodiversity of soil flora and fauna, further research on soil amendments that appear to have nematostatic and nematicidal properties should be pursued.

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