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Plant-Parasitic Nematode Communities in Dogwood, Maple, and Peach Nurseries in Tennessee[1]

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Abstract: Nursery blocks (48 dogwood, 27 red maple, and 17 peach) distributed among 20 Tennessee nurseries were sampled for nematodes in March, July, and October 1981. Plant-parasitic nematodes were extracted from soil, counted by genera, and identified to species after fixation. A total of 57 species in 24 genera were found, with 1–16 species occurring in a site. The species most commonly detected were *Paratylenchus projectus* and *Xiphinema americanum,* which were found in 88% and 78% of the sites, respectively. Relationships existed between distribution and densities of some species present in more than 10% of the sites and certain soil factors (pH, bulk density, texture, and organic matter content). Plant-parasitic nematode community diversity was related to tree age, percentage of weed ground cover, and number of weed species. Site similarities in community ordinations were dependent on the individual nurseries sampled, tree age, and soil type, but clusters of sites of similar tree ages and soil types were not exclusive.
Key words: *Cornus florida, Acer rubrum, Prunus persica,* community ordination.

Plant-parasitic nematodes are not known to cause serious problems in ornamental tree nurseries, perhaps because of the difficulty of quantifying growth or quality losses in woody plants. Nonetheless, several plant-parasitic species are known to damage peach trees (*Prunus persica* L.) either directly or through disease interactions (23). Comparatively less is known about nematode pathogenicity on dogwood (*Cornus florida* (L.) *Batsch*) or red maple (*Acer rubrum* L., hereafter referred to as maple). Few host–parasite relationships have been demonstrated with dogwood or maple (10,18) although known nematode parasites have been reported as occurring in association with each (7,17). The transfer of soil with balled and burlapped trees raises the question of whether nematode parasites of other economically important crops may be introduced into previously uninfested areas through transplanting (20). Likewise, endoparasitic species may be transferred in the absence of soil on bare-root stock (12).

Little is known about plant-parasitic nematode communities in nurseries. An investigation was warranted in Tennessee because of the high economic value of nursery crops (2), and because both known and potential nematode pathogens of nursery crops occur in Tennessee (4,20). Dogwood, maple, and peach are among the most economically important nursery trees produced in Tennessee. Characterization of the plant-parasitic nematode communities comprised three specific objectives: 1) to identify the species of plant-parasitic nematodes present; 2) to quantify the nematode community diversity; and 3) to determine the relative importance of some floristic and edaphic factors in the distribution of nematode species.

Materials and Methods

Sites of ca. 30 m^2 in 92 nursery blocks from 20 Tennessee nurseries were sampled. The 48 dogwood and 27 maple sites were each grouped in three age classes (1–2, 3–5, and 10+ years), and the 17 peach sites contained only 1–2-year-old trees. Samples were taken in March, July, and October 1981. Methods used for nematode assay, soil analyses (pH, bulk density, texture, and organic matter), and weed determinations were reported previously (13). Plant-parasitic nematodes extracted from soil samples (9) were identified to genus, then hand-picked from the extracts, killed and fixed in hot 4% formalin, processed to glycerin (19), mounted, and identified to species. Each sample containing *Meloidogyne* sp. juveniles was potted with a tomato plant (*Lycopersicon esculentum* Mill. 'Rutgers') to obtain adult females for species

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identification (21). Soil from samples containing *Heterodera* sp. juveniles was processed to extract cysts (8).

Species diversity (H′) was computed for each site on each sampling date with the Shannon-Weiner formula as modified by Lloyd et al. (11):

$$H' = \frac{c}{n}(N \log_{10}N - \Sigma n_i \log_{10} n_i),$$

where c = log base conversion factor (= 1); N = total number of individuals; and n_i = number of individuals per species.

Correlation coefficients among nematode species densities, nematode diversity, floristic, and edaphic factors were calculated and were significant at $P < 0.05$ unless otherwise noted. Correlation analysis of nematode densities was restricted to those species found in 10% or more of the sites sampled. Correlation coefficients for species in the Tylenchidae were calculated for data collected in July only. These species were counted as one group on all three sampling dates, and one-fourth of the total individuals collected in July were handpicked and identified to species. The proportion of Tylenchidae represented by genera considered fungivorous was subtracted from the total, and the remaining number allocated to separate plant-parasitic species based on the proportions they represented. Plant-parasitic nematode communities were compared by a two-dimensional community ordination method (3).

Results

Both bulk densities and organic matter contents of the nursery soils were within narrow ranges. Bulk densities were between 1.07 and 2.07 g/cm³ (mean 1.49 ± 0.20), and organic matter ranged from 0.64 to 2.79% (mean 1.60 ± 0.55). Soil pH ranged from 4.3 to 7.3. Percentages of sand, silt, and clay were highly variable, but 58 (63%) of the sites were in the silt loam soil textural class: 17 were loams, 10 silty clay loams, 4 clay loams, 2 sandy loams, and 1 sandy clay loam. No significant correlations were detected among the soil variables.

There was a strong positive correlation between percentage of weed cover in a sample site and number of weed species present ($r = +0.81, P < 0.01$) and between both weed measurements and tree age ($r = +0.60$ and $+0.71$, respectively, $P < 0.01$).

Plant-parasitic nematodes occurred in every site. Specific identities, frequency of occurrence, plant association, and mean densities were determined for each species (Table 1). A total of 57 species in 24 genera were identified, with 1–16 species occurring in a site. Five *Filenchus* and two *Tylenchus* species were not named but were separated into numbered taxa based on morphological characters. One *Gracilacus* species, one *Paratylenchus* species, and two *Hemicycliophora* species were undescribed and were designated by numbers. Including those not named, 13 species were found in one site each, 22 occurred in more than 10% of the sites, and only 5 species were found in more than 25% of the sites. The most common species were *Paratylenchus projectus* (88% of the sites), *Xiphinema americanum* (78%), *Helicotylenchus pseudorobustus* (53%), *Filenchus cylindricus* (50%), and *Tylenchus davainei* (36%). The 22 species present in more than 10% of the sites were generally equally distributed among dogwood, maple, and peach sites. Seven of the thirteen species found only once were in maple sites.

Selected species occurring in more than 10% of the sites: Mean populations of *Coslenchus costatus* were highest in dogwood sites, at 164/200 cm³ soil compared with 87 for maple and 55 for peach. This species was found in sites with a pH of 4.5–6.0, most often in sites with a pH of 5.0–5.4; densities were negatively correlated with pH ($r = -0.31$, Table 2).

Of the Tylenchidae identified to species and included as plant parasites, *Filenchus cylindricus, F. parvissimus, Tylenchus arcuatus,* and *T. davainei* all occurred in more than 10% of the sites. Densities of *F. cylindricus, F. parvissimus,* and *T. davainei* were correlated with sand content and the latter two with silt content of soil (Table 3). Densities of *T. arcuatus* and *F. parvissimus* were positively correlated with percentage of weed cover and with tree age (Table 4).

Gracilacus aculenta was found in eight dogwood and five maple sites, but in no peach site. Densities of *G. aculenta* were positively correlated with tree age (Table 4).

TABLE 1. Frequency and density of plant-parasitic nematodes in 92 dogwood, maple, and peach nursery sites in Tennessee.

Species	Frequency	Mean density/200 cm³			Sites*		
		March	July	October			
Aglenchus agricola (de Man) Meyl	4	46	50	34	D	M	
Aorolaimus helicus Sher	4	15	7	10	D		
Basiria sp. Siddiqi	4	21	28	36	D	M	P
Cephalenchus sp.	1	226	896	874		M	
Coslenchus costatus (de Man) Siddiqi	19	77	169	89	D	M	P
Criconemella macrodora (Taylor) Luc & Raski	2	2	0	0	D		
Criconemella xenoplax (Raski) Luc & Raski	11	3	3	13	D	M	P
Filenchus cylindricus (Thorne & Malek)†	46		121		D	M	P
F. parvissimus (Thorne & Malek)†	11		87		D	M	P
F. plattensis (Thorne & Malek)†	8		51		D	M	P
Gracilacus aculenta (Brown) Raski	13	26	86	65	D	M	
Helicotylenchus canadensis Waseem	1	6	0	2		M	
H. crassatus Anderson	1	4	4	0	D		
H. dihystera (Cobb) Sher	17	22	25	93	D		
H. paraplatyurus Siddiqi	14	15	10	12	D	M	P
H. platyurus Perry in Perry, Darling & Thorne	1	2	0	0	D		P
H. pseudorobustus (Steiner) Golden	49	36	34	15	D	M	P
H. vulgaris Yuen	1	0	5	13		M	
Heterodera glycines Ichinohe	1	0	2	0	D		
H. lespedezae Golden & Cobb	2	2	3	0	D	M	
H. schachtii Schmidt	1	2	0	0	D		
H. trifolii Goffart	4	7	4	1	D	M	P
Hoplolaimus galeatus (Cobb) Filipjev & Schuurmans Stekhoven	13	10	4	3	D	M	P
Malenchus sp. Andrassy	28	68	64	70	D	M	P
Meloidogyne hapla Chitwood	21	20	7	45	D	M	P
M. incognita (Kofoid & White) Chitwood	1	0	0	92	D		
Merlinius brevidens (Allen) Siddiqi	10	20	8	14	D	M	
Nothocriconema demani (Micoletzky) de Grisse & Loof	1	0	3	10		M	
N. mutabile (Taylor) de Grisse & Loof	4	7	5	24		M	P
Paratrichodorus minor (Colbran) Siddiqi	7	1	8	20	D	M	
Paratylenchus projectus Jenkins	81	136	185	165	D	M	P
P. tenuicaudatus Wu	8	157	131	212	D	M	P
Pratylenchus crenatus Loof	2	9	9	3	D		P
P. hexincisus Taylor & Jenkins	1	10	0	14		M	
P. neglectus (Rensch) Filipjev & Schuurmans Stekhoven	2	10	2	9	D	M	
P. penetrans Steiner in Sherbakoff & Stanley	5	14	8	13	D	M	P
P. scribneri Steiner in Sherbakoff & Stanley	10	16	3	6	D	M	P
P. vulnus Allen & Jensen	8	20	14	29	D	M	
P. zeae Graham	6	16	3	3	D	M	P
Pseudhalenchus sp. Tarjan	11	30	5	81	D	M	P
Quinisulcius curvus (Williams) Siddiqi	4	24	17	5	D	M	
Tylenchorhynchus claytoni Steiner	14	59	94	89	D	M	P
T. maximus Allen	5	37	36	14	D	M	P
Tylenchus arcuatus Siddiqi	10		52		D	M	P
T. davainei Bastian	33		80		D	M	P
Xiphinema americanum Cobb	72	27	9	33	D	M	P

* Sites: D = dogwood, M = red maple, P = peach.
† These species fit the generic circumscription of *Filenchus* (= *Lelenchus*) as proposed by Andrássy (1).

Correlations were found between *Helicotylenchus dihystera* densities and soil bulk density ($r = +0.38$) and between *H. pseudorobustus* and clay content (Table 3) and tree age (Table 4). Both species attained their highest densities in sites with a pH of 4.5–4.9 (Table 2). Two or three species of *Helicotylenchus* were commonly present in the same site.

Densities of *Hoplolaimus galeatus* were

TABLE 2. Mean density per 200 cm^3 soil of seven plant-parasitic nematode species in 92 dogwood, maple, and peach nursery sites in Tennessee by soil pH class.

Species	Soil pH class						
	<4.5	4.5–4.9	5.0–5.4	5.5–5.9	6.0–6.4	6.5–6.9	>6.9
Coslenchus costatus	0	287	85	53	0	0	0
Helicotylenchus dihystera	5	215	11	11	10	0	0
H. pseudorobustus	2	66	12	6	14	20	33
Hoplolaimus galeatus	0	6	6	7	3	1	0
Meloidogyne hapla	6	19	48	8	1	0	5
Tylenchorhynchus claytoni	4	151	83	51	33	1	0
Xiphinema americanum	102	21	21	13	10	21	9

generally low, but they were higher in sites with a pH of 4.5–5.9 than in those with a higher pH (Table 2) and were positively correlated with percentage of soil organic matter ($r = +0.33$).

Densities of *Meloidogyne hapla* juveniles were higher in dogwood (19/200 cm^3 soil) and maple (42) than in peach (4) sites. In all sites, juveniles were more abundant in March and October than in July (Table 1) and their densities were positively correlated with tree age (Table 4). Densities were highest in soils with a pH of 5.0–5.4 (Table 2).

Paratylenchus projectus was the species most frequently identified. Its mean density was 162/200 cm^3 soil, with a range of 2 to 5,043. Adult females were rare in March and only slightly more common in July and October; the ratio of adults to juveniles in July was about 1:100. Densities of *P. projectus* were positively correlated with percentage of weed cover, number of weed species, and tree age (Table 4).

Tylenchorhynchus claytoni occurred in one peach, seven maple, and six dogwood sites. Its highest density of 1,072/200 cm^3 soil was in the peach site in the October sample. This species occurred most frequently and in highest densities in soils with a pH of 4.5–4.9 (Table 2).

Xiphinema americanum was the only species of this genus found in the nurseries and was the second most frequently extracted plant parasitic species. Densities were positively correlated with tree age (Table 4) and weakly negatively with pH ($r = -0.19$) (Table 2).

Diversity of plant-parasitic nematodes: Diversity as measured by H′ ranged from 0.00 to 0.88. Mean sample diversities were higher for maple sites than for dogwood or peach (Fig. 1).

Diversity of plant parasites (H′) was positively correlated with tree age in dogwood but not in maple sites (Fig. 2) and, weakly, with percentage of weed cover ($r = +0.17$) and number of weed species ($r = +0.23$) for all sites (Table 5). Analysis of variance in H′ revealed significant effects from nursery, tree species, and tree age.

Ordination of sites: Ordination was performed for all sites together and then separately for each tree species. In the overall ordination, the low reference site for the X-axis (the site with the least similarity to

TABLE 3. Relationship of soil particle size to densities of five plant-parasitic nematode species in Tennessee tree nursery sites.

Species	Number of sites	Correlated variable	r*
Filenchus cylindricus	46	% sand	+0.26
F. parvissimus	11	% sand	−0.63
		% silt	+0.48
Helicotylenchus pseudorobustus	49	% clay	−0.18
Paratylenchus projectus	81	% sand	−0.18
		% silt	+0.22
Tylenchus davainei	33	% sand	−0.24
		% silt	+0.30

* Correlation coefficient at $P < 0.05$.

TABLE 4. Mean densities per 200 cm³ of seven plant-parasitic nematode species and correlations between densities and tree age, percentage of weed ground cover, and number of weed species in 92 dogwood, maple, and peach tree nursery sites in Tennessee.

Species	Tree age (years)			Correlated variable		
	1–2	3–5	>10	Tree age	% weed ground cover	Number weed species
Filenchus parvissimus	56	104	314	+0.42*	+0.53	+0.29
Gracilacus aculenta	8	15	175	+0.36	NS	NS
Helicotylenchus pseudorobustus	16	19	92	+0.41	NS	NS
Meloidogyne hapla	33	92	109	+0.52	NS	NS
Paratylenchus projectus	65	205	382	+0.28	+0.29	+0.34
Tylenchus arcuatus	32	44	67	+0.53	+0.69	NS
Xiphinema americanum	13	55	20	+0.42	NS	NS

* $P < 0.05$ for all significant correlations.

all other sites) was one that contained a single species. The higher reference site for the X-axis (the site most dissimilar to the low site) had five species, all of which occurred frequently. Sites within a nursery were in many cases separated by 1.6–11.3 km but were often closely spaced on the ordination (Fig. 3). Sites with similar age trees or soil types also clustered within the ordination plane, but the clusters were not exclusive (Fig. 4). These observations were confirmed by analysis of variance in location of sites on the X-axis, but attempts to refine the clusters by eliminating sites of poor fit on the X-axis were unsuccessful. A relatively strong correlation existed between percentage of clay and X-axis location ($r = +0.46$, $P < 0.01$).

As in the overall ordination, ordination of the dogwood and maple sites separately reflected similarities among sites within nurseries, tree age classes, and soil types. The dogwood ordination showing sites containing trees 10+ years old is illustrated (Fig. 4).

The peach site ordination (not shown) was dependent on the fumigation history of the site. Four sites had been fumigated

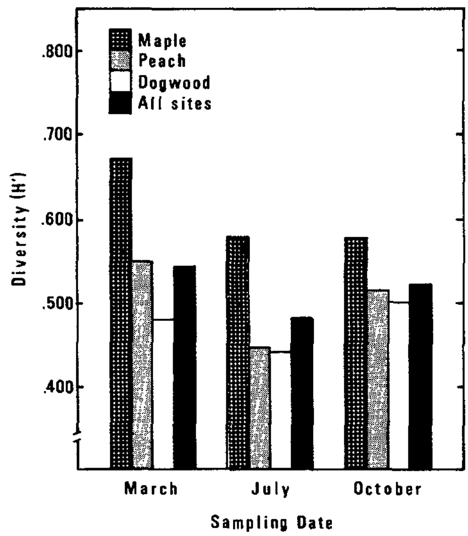

FIG. 1. Plant-parasitic nematode community diversity in 92 red maple, dogwood, and peach nursery sites in Tennessee on three sampling dates.

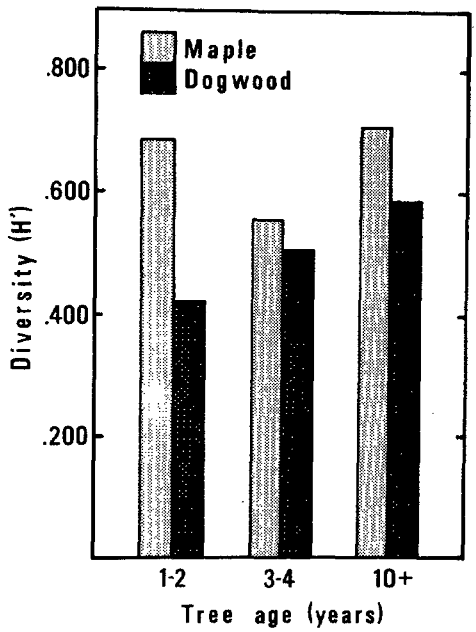

FIG. 2. Effect of tree age on plant-parasitic nematode community diversity in 75 dogwood and red maple nursery sites in Tennessee with trees of three age classes.

TABLE 5. Relationship between plant-parasitic nematode community diversity (H') and weeds in 92 dogwood, maple, and peach nursery sites in Tennessee.

% weed ground cover	H'	Number weed species	H'
0	0.48	0	0.46
1–20	0.52	1–3	0.47
21–40	0.50	4–6	0.52
41–60	0.62	7–9	0.55
61–80	0.58	10–12	0.55
81–100	0.57	13–16	0.64

with methyl bromide in the previous 5 years, and two of these sites were reference sites for the ordination axes. The remaining sites did not cluster according to any of the other variables measured.

DISCUSSION

Communities of plant-parasitic nematodes in nurseries are qualitatively and quantitatively diverse. How the nematodes biologically affected the trees was not considered in this study; however, the economic value (e.g., interstate marketing) of the trees can be affected simply by the presence of certain species, such as *Xiphinema americanum* as a vector of certain peach viruses. Species and community level analyses were used to determine some of the factors that affect plant-parasitic nematode communities.

Community diversity (H') bore no significant relationship to the edaphic factors; however, some soil characteristics were correlated with densities of several nematode species. In general, nematode densities were highest in the 4.5–5.9 pH range, but distributions were not limited to this range, except in the case of *Coslenchus costatus.* Norton et al. (15) and Norton and Hoffman (16) found positive correlations between *Helicotylenchus pseudorobustus* densities and pH in Iowa soybean fields at pH 6.0–8.0 and woodlands at pH 4.5–7.9. In both cases, the highest nematode densities occurred at the highest pH. Although *H. pseudorobustus* was found in 53% of the sites in our study, including some in every pH class, its highest density was in soils in the 4.5–4.9 pH range. A negative correlation of pH with densities of *X. americanum* was found in soybean fields (15), but in woodlands the correlation was positive (16). In

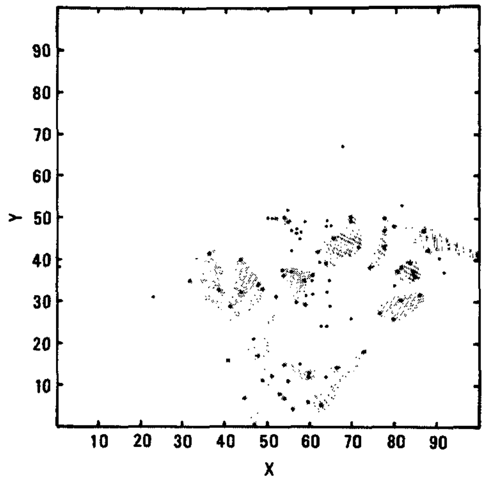

FIG. 3. Ordination of 92 dogwood, maple, and peach tree nursery sites in Tennessee based on plant-parasitic nematode communities. Shaded areas include sites within individual nurseries; those outside shaded clusters were not located close to other sites within the same nursery.

our study, the highest densities of *X. americanum* were found in soils with a pH below 4.5. Norton et al. (15) also found a negative correlation between *Hoplolaimus galeatus* densities and pH in soybean fields, similar to our findings.

Most of the nematode species present in more than 10% of the nursery sites exhibited peak populations at pH 4.5–5.9, which is the optimum range for nutrition of many native Tennessee plants as well as the most

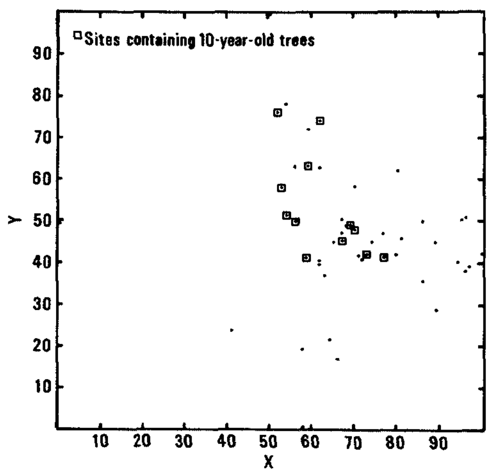

FIG. 4. Ordination of 48 dogwood nursery sites in Tennessee based on plant-parasitic nematode communities.

common range for soils in the state. Therefore, any effect of pH on nematode density is probably indirect through its influence on host plant(s). Burns (6) and Brzeski and Dowe (5) reached similar conclusions in their studies.

Correlations were found between sand, silt, or clay content of soil and densities of several nematode species, but densities of these species were not related to soil textural classes. Norton et al. (15) found higher densities of *Tylenchus* spp. in certain soil types, but no correlation with percentages of sand, silt, or clay. Wallace (22) and Norton (14) both suggested that soil factors other than soil type were more important in determining nematode species distribution. In our nurseries, soil textural class seemed an unimportant factor in influencing species occurrence or density, but certain correlations suggested that a factor related to particle size was important in some cases. Unfortunately, bulk density measurements were narrow in range, and the two weak correlations between species densities and soil bulk density do not lend themselves to valid speculation.

The floristic factors—tree species, tree age, percentage of weed ground cover, and number of weed species—are interrelated in the nurseries and difficult to consider as separate factors affecting nematode communities (13). The effect of tree species on plant-parasitic species diversity may be explained by differences in site management; peach sites are managed intensively because plant uniformity and sanitation are critical to the economic value of peach trees but of less importance to dogwood and maple. The positive correlations among tree age and weed factors suggest that sites containing older trees are managed even less intensively. As expected, diversity of plant-parasitic species was positively correlated with tree age and weed factors; however, H′ was high even in the absence of weeds and in the intensively managed peach sites. Coupled with the observation that none of the plant parasites occurring in more than 10% of the sites was limited in distribution to any tree species, the high diversity indicates communities of polyphagous nematode species whose host ranges include dogwood, maple, and peach trees.

Densities of several nematode species were positively correlated with tree age and one or both weed factors, further reflecting the nematodes' wide host ranges. However, no correlations existed with weed factors for *G. aculenta, H. pseudorobustus, M. hapla,* and *X. americanum,* and, although a significant correlation is not intended to imply cause and effect, the positive correlations between these species' densities and tree age suggests that these are parasites of dogwood and maple.

The community ordinations provided only slight additional information beyond the correlation analyses. In the overall ordination, clustering in one quadrant toward the upper half of the X-axis and the lower half of the Y-axis reflects the greater similarity of all sites to the more diverse communities of plant parasites in the reference sites. Similarity among plant-parasitic nematode communities in nurseries was often dependent on the individual nursery in which sites were physically located, a relationship that was found both in analysis of diversity (H′) values and in the ordinations. Such similarity might be expected if the sites were geographically close together, but many sites which clustered in the ordination were separated by up to 11.3 km, and, conversely, individual nurseries geographically close together were not closely spaced in the ordination plane. Some of the nursery effect may be attributed to distribution of nematodes in soil on equipment or the roots of transplants. Tree age and soil type also affected community similarity, but the clusters of sites of similar age trees and similar soil types were not discrete. Fumigation history was the only differentiating factor among peach sites, suggesting that site management practices rather than tree age may be important factors governing similarity of plant-parasitic nematode communities.

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