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Effects of Perennial Peanut (*Arachis glabrata*) Ground Cover on Nematode Communities in Citrus[1]

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Abstract: The effects of perennial peanut (*Arachis glabrata*) ground cover on the nematode community in a citrus orchard were examined. Samples were taken from two different ground cover treatments (perennial peanut or bare ground) at each of three distances from the tree trunk. Richness, measured as total numbers of nematode genera per sample, and total numbers of nematodes were greatest in the perennial peanut treatment ($P < 0.05$). Abundance of many genera of bacterivores, fungivores, and omnivores were increased by the perennial peanut ground cover. Total numbers of plant parasites were greater in perennial peanut treatments on three of the five sampling dates ($P < 0.05$), mainly due to trends in numbers of *Mesocriconema*. Distance from a tree trunk and the interaction of ground cover treatments and proximity to a tree trunk were most influential for *Belonolaimus* and *Hoplolaimus*. Although differences among treatments were observed for nematode genera and trophic groups, ecological indices were not consistently sensitive to treatments. Among several ecological indices evaluated, richness was most often affected by ground cover treatment.

Key words: Arachis glabrata, Belonolaimus, citrus, ecological indices, *Hoplolaimus, Mesocriconema* nematode community, perennial peanut, plant-parasitic nematodes.

The soils in some of the citrus-producing counties in Florida are primarily sandy soils (> 95% sand) with little organic matter (Brown et al., 1991). Porous soils, combined with irrigation and high seasonal rainfall, can lead to the leaching of fertilizer and herbicide, depriving the crop of the full benefits of these inputs. With increased concerns about profitability, environmental health, and crop sustainability, citrus growers in Florida are modifying traditional management practices. As a result, many citrus growers are using ground covers in their orchards rather than the previous standard of disked or herbicide-treated, weed-free rows. In addition to reducing amounts of agricultural inputs lost through leaching, ground covers also prevent soil erosion, increase soil organic matter, and may reduce the overall amount of inputs necessary to maintain crop productivity (Powers and McSorley, 2000).

One potential ground cover for Florida citrus is a rhizomatous perennial peanut, *Arachis glabrata* Benth., a relative of the cultivated edible peanut (*A. hypogaea* L.). Because perennial peanut is a legume, nitrogen availability is increased by fixation of atmospheric nitrogen and decomposition of mowed peanut clippings. Once established, perennial peanut competes well with native grasses, does not require additional fertilizer, and allows growers to reduce fertilizer applications by up to 40% (Rouse and Mullahey, 1997). Furthermore, perennial peanut is not known to be an important host to economically damaging pathogens and pests, including nematodes (French et al., 1993).

As with any agricultural management practice, the establishment of a perennial peanut ground cover likely affects the soil fauna, including nematodes. Since the development of the maturity index (MI) (Bongers, 1990), interest has increased in the use of nematode communities to reflect various degrees of environmental disturbance incurred by agricultural management practices (McSorley, 1997; Neher, 1999; Porazinska et al., 1999; Yeates and Bird, 1994; Yeates et al., 1993). The composition of the plant community has a major effect on the structure of the associated soil nematode community (Wardle et al., 2001; Wasilewska, 1995; Wasilewska, 1997a). Studies of herbaceous ground covers are of particular importance to growers because composition of vegetation directly affects abundance of plant-parasitic nematodes. Indirect influences of the plant community on bacterivores and other nematode trophic groups also must be considered because nematodes function in nutrient cycling and other soil processes (Freckman, 1988).

The purpose of this study was to compare nematode community structure between herbicide-managed rows and rows with perennial peanut as a ground cover in a citrus orchard. This was accomplished both by examination of the effects on individual nematode genera and measures of community structure, at different distances from a citrus tree trunk.

Materials and Methods

The experiment was conducted in a young citrus orchard at the University of Florida Citrus Research and Education Center in Lake Alfred, Florida (28° 5.4′ N, 81° 43.5′W). The soil was characterized as Astatula fine sand, with a composition of 95% sand, 4% silt, and 1% clay, and a pH of 6. In March 1996, rhizomes of perennial peanut (*Arachis glabrata*) were planted among 4-year-old trees. In May 1997, these trees were removed and replaced with young 'Mid Sweet' orange trees (*Citrus sinensis* [L.] Osbeck) on 'Rough Lemon' rootstock

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(*Citrus jambhiri* Lush). A total of 180 trees were planted in nine rows of 20 trees/row, with 8 m between rows and 3 m between trees. From these, 10 plots of 5 trees each were selected for use in this experiment.

The main treatments examined in this experiment were (i) bare soil within tree rows, about 100 cm on either side of the trunks, maintained with herbicides glyphosate and gluphosinate, and (ii) perennial peanut within and between rows. Within the main treatments, three different locations around the tree were studied—at 30 cm, 60 cm, and 90 cm from the tree trunk. Soil habitat in the bare-ground treatment can be classified as primarily citrus habitat and trace amounts of native vegetation with decreasing amounts of citrus root material as distance from the tree trunk increased, although the 90-cm distance had considerably more perennial peanut and weed roots present because this distance is near the edge of the bare-ground area. In the perennial peanut treatment, ratios of citrus roots to perennial peanut and (or) miscellaneous weed roots decreased with increased distance from a tree trunk. The two main ground cover treatments were replicated five times in a randomized complete-block design.

Soil samples for nematode analysis were taken on five different dates between 4 February 2000 and 22 January 2001. On each sampling date, a total of 30 samples were collected (2 ground cover treatments × 3 distances from trunk × 5 replications). Each sample consisted of two cores taken from each of the five trees in a plot at the specified distance from the trunk. The two cores per tree were removed at opposite ends of the appropriate distance diameter initially running in an east-west direction. The sampling axis was rotated approximately 45° for each sampling date to prevent the removal of roots from the same area on consecutive dates. Cores measured 2 cm in diam. and 30 cm deep. Samples were stored at 7 °C for no longer than 1 week after collection. Nematodes were extracted from 100 cm^3 of well-mixed soil using a modified sieving and centrifugation method (Jenkins, 1964). Nematodes were counted using an inverted microscope and identified to genus, except for Rhabditidae and some individuals of Tylenchidae and Neotylenchidae.

Nematodes were assigned to one of five trophic groups: bacterivores, fungivores, herbivores, omnivores, or predators (McSorley and Frederick, 1999; Yeates et al., 1993). Indices of nematode community structure were calculated for each sample, including richness, determined as the total number of different genera per sample; dominance at the genus level and at the trophic level, determined in each case as Simpson's index, λ (Simpson, 1949); diversity at the genus level and the trophic group level, calculated as $1/\lambda$ (Freckman and Ettema, 1993; Ludwig and Reynolds, 1988); MI, the total maturity index including plant parasites (Bongers and Bongers, 1998; Yeates, 1994); F/B, the ratio of fungivores to bacterivores (Freckman and Ettema, 1993); F/(F+B), the ratio of fungivores to total decomposers (Neher and Campbell, 1994); and (F+B)/PP, the ratio of fungivore and bacterivore decomposers to plant parasites (Wasilewska, 1997b). Data from each sampling date were subjected to a 2 × 3 factorial analysis of variance (ANOVA) with 2 ground covers × 3 distances from tree, using MSTAT-C software (Freed et al., 1991). Effects of ground cover (C) are summarized by sampling date for all data. Data for which significant effects of distance (D) or C×D interaction were observed consistently are summarized by sampling date.

Results

A total of 51 genera were identified from five sampling dates. The most frequently observed nematode taxa and their average populations for bare ground (herbicide-treated) and perennial peanut ground cover treatments are shown (Table 1). Other genera found sporadically during the study included *Alaimus* de Man, 1880, unidentified Cephalobidae, *Diploscapter* Cobb, 1913, *Monhystera* Bastian, 1865, and unidentified Rhabditida (bacterivores); unidentified Neotylenchidae and *Neotylenchus* Steiner, 1931 (fungivores); *Mesodorylaimus* Andrássy, 1959 (omnivore); *Caloosia* Siddiqui and Goodey, 1964, and *Helicotylenchus* Steiner, 1945 (plant parasites); *Carcharolaimus* Thorne, 1939, *Iotonchus* Cobb, 1916, *Miconchus* Andrássy, 1958, and *Nygolaimus* Cobb, 1913 (predators). Infrequent genera included *Bunonema* Jagerskiold, 1905, *Chiloplacus* Thorne, 1937, *Chronogaster* Cobb, 1913, *Panagrolaimus* Fuch, 1930, and *Teratocephalus* de Man, 1876 (bacterivores); *Tylencholaimellus* Cobb, 1915 and *Tylencholaimus* de Man, 1976 (fungivores); *Aporcelaimus* Thorne & Swanger, 1936, *Laevides* (synonym: *Nygolaimus,* Cobb), *Paraxonchium* Krall, 1958, *Pungentus* Thorne & Swanger, 1936, and *Thonus* Thorne (omnivores); *Hemicycliophora* de Man, 1921 and *Longidorus* Micoletzky, 1922 (plant parasites); *Cobbonchus* Andrássy, 1958 and *Mylodiscus* Thorne, 1939 (predators). Counts of these taxa were summed by their respective trophic groups (bacterivores, fungivores, omnivores, plant parasites, and predators) and were included in total and community measures.

On every sampling date, many nematode genera were more abundant in soil from the perennial peanut than bare-ground treatment (Table 1). Numbers of total nematodes, total bacterivores, Rhabditidae, *Aphelenchoides,* and *Mesocriconema* were greater in perennial peanut than bare-ground treatments on all sampling dates. For other nematodes, results varied with sampling date. For example, numbers of *Acrobeles* were greater ($P < 0.05$) under perennial peanut than bare ground on the last three sampling dates, whereas on the first two dates no effect of ground cover treatment was observed (Table 1). Similar patterns were observed

TABLE 1. Effects of ground-cover treatments on nematode numbers per 100 cm^3 soil by sampling date, 2000–2001.

Nematode taxon	4 February		15 May		7 August		31 October		22 January	
	BG[1]	PNUT[1]	BG	PNUT	BG	PNUT	BG	PNUT	BG	PNUT
Bacterivores										
Acrobeles	15.8[2]	19.6	19.1	30.7	40.4	64.9**[3]	38.9	103.3*	32.1	88.1**
Acrobeloides	12.9	27.1*	21.8	67.1**	21.7	44.7	15.1	59.7**	12.9	59.5**
Cephalobus	12.1	6.4*	6.0	14.5**	17.1	23.6	18.9	27.4*	28.6	40.2**
Cervidellus	2.2	3.6	0.8	6.3**	1.4	8.1**	7.7	15.0*	3.4	16.8**
Eucephalobus	4.3	9.5*	3.1	11.6*	5.4	33.7**	5.2	38.8**	9.9	17.7
Plectus	1.4	1.9	0.7	1.1	1.5	4.8**	2.3	4.7	2.7	4.9**
Prismatolaimus	2.7	1.9	1.8	4.9	6.1	8.6	8.6	11.5	10.2	11.5
Rhabditidae	10.0	34.7**	5.2	45.0**	4.3	33.6**	11.5	76.5**	8.0	67.7**
Wilsonema	2.8	2.3	0.1	11.5*	3.5	8.9*	10.3	10.3	6.3	11.3
Zeldia	1.3	9.2	12.9	15.1	11.5	11.3	10.6	17.8**	9.7	17.1
Total Bacterivores	77.9	117.7**	74.7	212.5**	125.5	256.5**	140.0	382.9*	128.7	345.3**
Fungivores										
Aphelenchoides	1.9	4.5*	0.7	13.1**	2.1	22.3**	3.9	11.9*	0.1	7.5**
Aphelenchus	12.9	13.1	28.0	39.3	19.6	35.5	23.7	35.6**	26.8	45.1**
Filenchus	3.6	3.9	2.5	4.9	2.6	4.5	1.9	6.7*	1.2	2.5
Nothotylenchus	2.4	3.8	3.1	6.3	2.3	6.1	1.9	6.8**	0.5	2.3
Tylenchidae	0.3	0.2	0.1	0.1	0.1	0.0	11.3	10.5	9.3	15.3*
Tylenchus	1.8	2.5	1.3	4.1	5.6	9.8*	3.7	7.5	1.2	4.7**
Total Fungivores	24.5	29.7	36.5	68.3	32.3	78.4*	47.5	78.9[4]	40.7	78.1**
Omnivores										
Aporcelaimellus	3.5	4.6	3.8	12.3**	4.9	11.1*	4.3	12.2	5.2	18.3*
Eudorylaimus	3.9	4.2	2.8	3.3	7.9	11.4	3.5	4.6	2.1	3.7
Total Omnivores	8.1	10.3	7.5	16.9*	13.0	24.2*	9.0	18.6	7.9	23.8*
Plant parasites										
Belonolaimus	1.9	3.4	5.8	6.1	12.1	5.5	2.6	5.4	3.0	6.5
Hoplolaimus	9.5	13.1	9.9	19.1	10.1	19.0	7.2	11.9	6.1	16.2
Meloidogyne	3.4	1.9	2.9	3.9	2.6	4.1	1.7	6.7	11.7	2.8
Mesocriconema	34.6	64.0*	15.3	68.1*	11.1	53.5**	9.9	42.9**	9.0	51.4**
Pratylenchus	2.2	2.0	0.1	2.2	1.8	2.7	2.5	5.7	2.1	6.2
Tylenchulus	6.6	2.6*	5.8	3.1	0.1	0.1	0.3	5.1	3.0	0.4
Xiphinema	1.5	0.4	0.4	0.1	2.8	0.7**	2.7	0.3	2.7	0.3
Total plant parasites	62.2	88.1*	42.3	103.9*	45.0	86.7	27.5	78.4*	37.7	83.9
Predators										
Mononchus	1.6	0.6	0.9	0.2	3.0	2.5	1.1	1.5	0.1	0.5
Total predators	3.7	3.4	2.3	1.9	4.8	5.3	3.4	6.0	0.9	2.7
Total nematodes	182.1	256.4**	166.6	410.5**	222.1	456.2*	229.5	567.1*	217.1	234.6**

[1] Abbreviations for main treatments: BG = bare ground resulting from herbicide spray; PNUT = perennial peanut ground cover.
[2] Values are means of 15 samples.
[3] *, **indicate significant difference between BG and PNUT at $P < 0.05$ and $P < 0.01$, respectively.
[4] Significance at $P < 0.06$.

for a variety of nematode taxa, especially among bacterivore genera (Table 1). *Aporcelaimellus* and total omnivores were more abundant under perennial peanut than bare ground on three sampling dates.

In addition to ground-cover treatment effects, many nematode taxa also were affected by distance from a tree trunk. Effects of ground-cover treatment, distance from a tree trunk, and interactions of ground cover and distance are shown for those taxa and community indices for which significant effects were observed on two or more sampling dates (Figs. 1–3, Table 2). Effects of distance on total numbers of bacterivores, predators, and total nematodes were significant ($P < 0.05$), generally on spring-to-fall sampling dates (Fig. 1).

Total bacterivores were affected ($P < 0.05$) by distance in spring and summer, with greater population densities of nematodes at sampling distances nearer than farther from a tree trunk (Fig. 1). Individual bacterivore genera exhibiting these results were *Acrobeles* and *Cephalobus* (Fig. 2). *Acrobeles* was greatly affected by distance in May and August ($P < 0.01$), with greater numbers near than far from a tree trunk under both ground-cover treatments (Fig. 2). By fall, several bacterivores had increased to attain similar abundance at all distances from the trunk (Fig. 2).

Total omnivores were not influenced by distance from a tree trunk, and no interactions between ground cover and distance were observed. Generally, total fungivores were not affected by sampling distance, but *Aphelenchus* was influenced ($P < 0.05$) by proximity to a tree trunk under both ground-cover treatments, especially during May (Fig. 3).

Despite the fact that total plant parasites were influenced by ground-cover treatments, *Mesocriconema* was

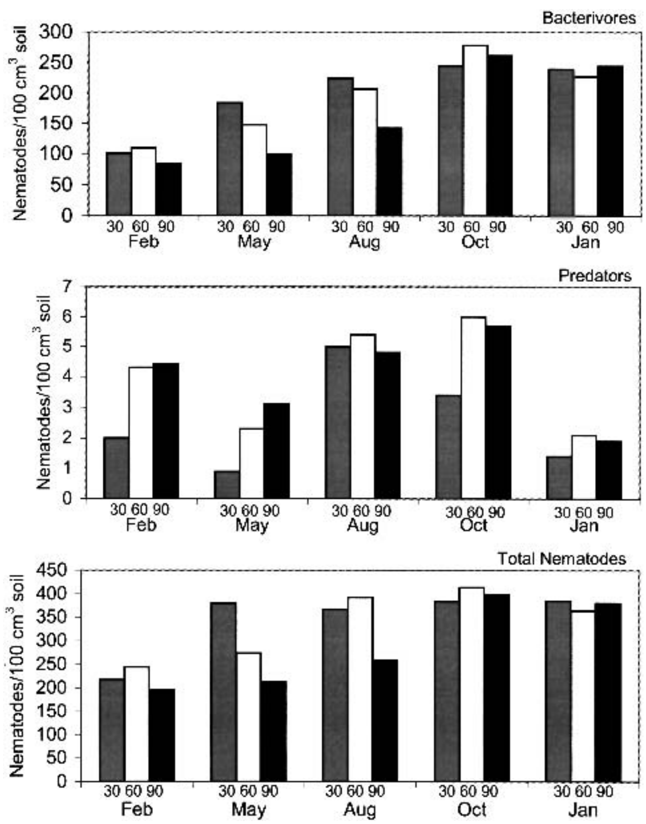

FIG. 1. Effect of distance from tree trunk (30, 60, 90 cm) on numbers of bacterivores, predators, and total nematodes by sampling date, 2000–2001. Effect of distance significant ($P < 0.05$) in May and August for bacterivores, May and October for predators, and May and August for total nematodes.

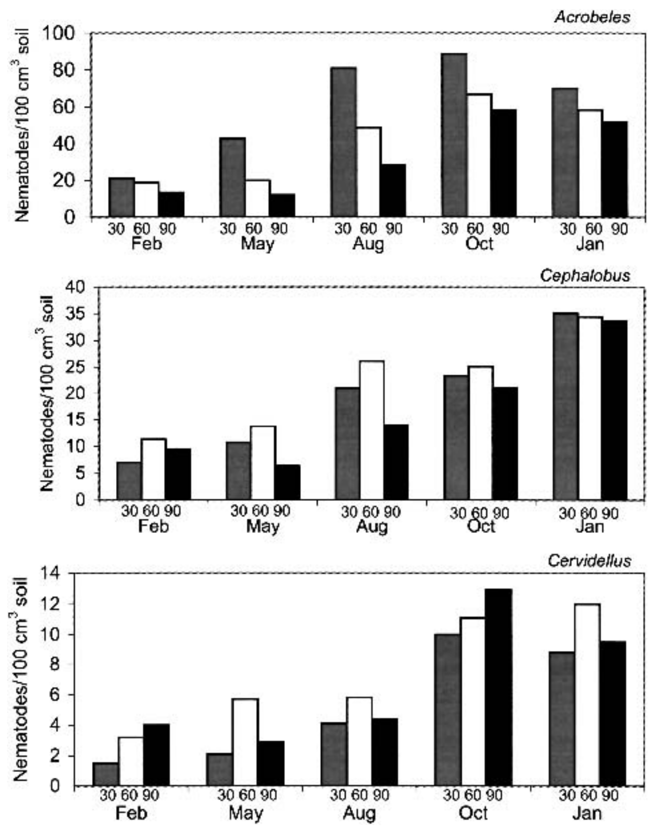

FIG. 2. Effect of distance from tree trunk (30, 60, 90 cm) on numbers of the bacterivores *Acrobeles, Cephalobus,* and *Cervidellus* by sampling date, 2000-2001. Effect of distance significant ($P < 0.05$) in May, August, and October for *Acrobeles,* May and August for *Cephalobus,* and February and May for *Cervidellus.*

the only genus affected by ground cover on each date throughout the course of the experiment ($P < 0.05$). Several important plant-parasitic nematodes were affected by distance from a tree trunk or ground cover by distance interactions. Numbers of *Belonolaimus* were greatest ($P < 0.05$) at the 30-cm sampling distance in the spring and summer under both ground-cover treatments (Fig. 3). *Hoplolaimus* was influenced by proximity to a tree trunk, but the interaction was significant ($P < 0.05$), with highest populations at 90 cm from a tree trunk in the bare-ground treatment and 30 cm from a tree trunk in the perennial peanut treatment (Table 2). *Pratylenchus* was also influenced by the interaction between ground cover and distance treatments, but oppositely from *Hoplolaimus.* Numbers of *Pratylenchus* were greatest ($P < 0.05$) at sampling distances proximate to a tree trunk in bare ground and farther from a tree trunk in soil with perennial peanut ground cover in the summer and second winter of the experiment (Table 2).

Although numbers of individual genera and total nematodes were greater consistently in the perennial peanut treatment than in bare ground, many of the community measures were not influenced by contrasting ground-cover regimes (Table 3). For percentages of bacterivores, fungivores, and predators, and the F/B ratio, differences ($P < 0.05$) between ground-cover treatments occurred only in the fall (Table 3.) Of the ecological indices evaluated, nematode taxa richness was the only one affected by ground cover on more than one sampling date. In the latter portion of the growing season, richness was always greater ($P < 0.10$) under perennial peanut than bare ground (Table 3). Effects of distance from a tree trunk and the ground cover by distance interaction were most evident for (F+B)/PP ratio, diversity, and MI (Table 4). Diversity was greatest ($P < 0.05$) at the 90-cm sampling distance under both ground-cover treatments (Table 4). Values for MI were higher at the 90-cm sampling distance ($P < 0.05$) for both ground-cover treatments, although the bare-ground treatment usually had greater MI values than perennial peanut (Table 4). Interaction effects between distance from a tree trunk and ground-cover treatments were most important for the (F+B)/PP ratio, with greatest values at the 30-cm sampling distance under bare ground (Table 4).

Discussion

Greater total nematode numbers in soil with perennial peanut ground cover compared to bare ground was

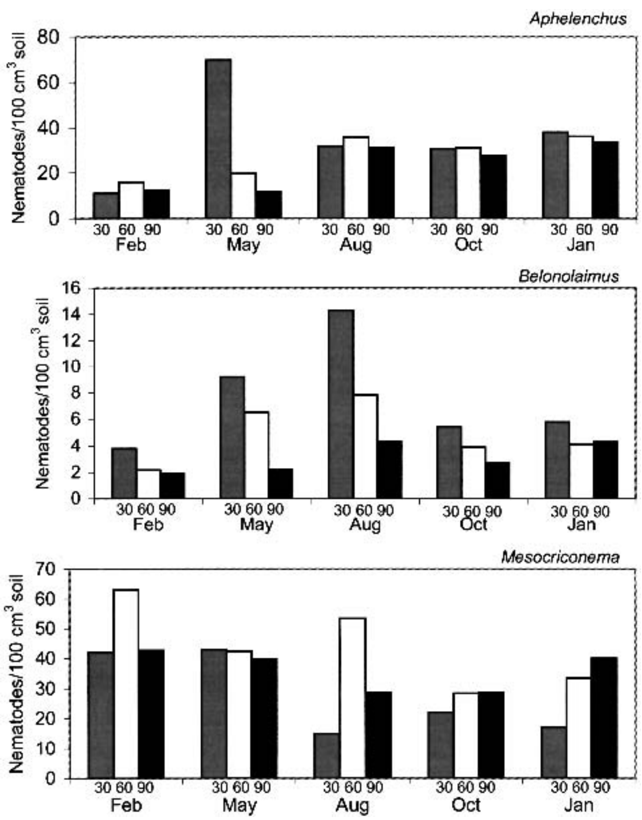

FIG. 3. Effect of distance from tree trunk (30, 60, 90 cm) on numbers of *Aphelenchus, Belonolaimus,* and *Mesocriconema* by sampling date, 2000-2001. Effect of distance significant ($P < 0.05$) for *Aphelenchus* and *Belonolaimus* in May and August, and for *Mesocriconema* in August and January.

expected, despite the fact that differences were not uniform across trophic groups. Most bacterivore genera benefited from the presence of ground cover, resulting in greater numbers of bacterivores under the perennial peanut ground cover, where both citrus and perennial peanut roots may exist, than under the bare-ground treatment, where primarily citrus roots are present. Increased amounts of vegetation provide an increase in the amount of organic matter available for decomposition, which directly affects numbers of bacteria involved in decomposition. Conversely, sparse ground cover or weed-free ground treatments, which provide low amounts of organic matter available for decomposition, diminish feeding opportunities for bacterivores and result in reduced numbers than where ground cover is present.

Despite the increased vegetation and decomposition potential, total numbers of fungivores were affected by the perennial peanut treatments less than bacterivores. Differences between ground-cover treatments were not apparent for fungivores until the summer, but then these differences persisted through the remainder of the experiment. Number of fungivores tends to increase later than bacterivores in ecological succession (Wasilewska and Bienkowski, 1985), which would explain why a difference in fungivore numbers between treatments was not observed during the first two sampling dates.

The effects of perennial peanut ground cover on plant-parasitic nematodes varied with proximity to a tree trunk. Two of the more important plant-parasitic genera to citrus growers are *Belonolaimus* and *Pratylenchus* (Duncan and Cohn, 1990). For *Belonolaimus,* proximity to the tree trunk was most important in determining the population distribution. Because numbers of *Belonolaimus* were generally greatest at the 30-cm sampling distance, management practices aimed at reducing numbers of *Belonolaimus* might be more efficient at distances nearer to the citrus tree trunk. Although perennial peanut reduced *Pratylenchus* abundance close to a tree trunk and increased numbers farther from a trunk on some sampling dates, overall numbers of *Pratylenchus* present were generally few on most sampling dates, making interpretation difficult. Results from *Hoplolaimus* were more complicated than those for other plant-parasitic genera, although this genus is not recognized as a major concern in citrus agroecosystems (Duncan and Cohn, 1990). Distance from a tree trunk affected *Hoplolaimus* abundance on three sampling dates, and the difference was most marked in the perennial peanut between the 30-cm sampling distance and the other two distances. One possible explanation for the apparent concentration of *Hoplolaimus* near a tree trunk (where perennial peanut was killed by herbicide) may be that perennial peanut provides an unfavorable environment for members of this genus. Another possible explanation is that *Hoplolaimus* may prefer the increased moisture and shade provided by dead perennial peanut residues immediately surrounding a tree trunk. However, populations of *Hoplolaimus* were greater at the 90-cm distance under the bare-ground treatment. This does not support the earlier speculation that perennial peanut provides an unfavorable habitat for *Hoplolaimus* because the boundary of the herbicide spray occurred approximately 100 cm from the tree trunk, where perennial peanut and miscellaneous weeds were located. A confounding issue is that the herbicide spray used to maintain a weed-free environment under the tree was often not as effective toward the boundaries of the spray zone as it was immediately under the tree. Perennial peanut and Florida pusley (*Richardia scabra* L.) were often observed growing in varying densities near the edge of the herbicide spray, perhaps providing better feeding opportunities for *Hoplolaimus* than in a citrus-only environment. Many grasses are good hosts for *Hoplolaimus* (Christie, 1959; Williams, 1973), and, in this site, bahiagrass (*Paspalum notatum* Flüggé) grew in close association with perennial peanut. Results from nematode assays conducted in Florida suggest that *Hoplolaimus* can persist on bahiagrass, sometimes in large numbers (Crow, pers. comm.).

Apart from richness, indices of nematode community structure were less helpful than abundance of indi-

TABLE 2. Effects of ground cover and distance from tree trunk on nematode numbers per 100 cm^3 of soil, 2000–2001.

Nematode	Sampling date	Distance from tree (cm)	Nematodes per 100 cm^3 soil		ANOVA		
			BG[1]	PNUT[1]	C[2]	D[2]	CxD[2]
Total plant parasites	4 Feb. 00	30	44.4[3]	107.8	**[4]	ns	*
		60	74.2	94.6			
		90	68.0	61.8			
	31 Oct. 00	30	19.6	102.4	*	ns	*
		60	31.6	71.6			
		90	31.2	61.2			
Hoplolaimus	15 May 00	30	7.2	49.0	ns	**	**
		60	7.4	4.2			
		90	15.0	4.2			
	31 Oct. 00	30	4.8	27.6	ns	*	**
		60	7.0	4.8			
		90	9.8	3.4			
	22 Jan. 01	30	2.8	28.8	ns	**	**
		60	7.0	9.6			
		90	8.4	10.2			
Pratylenchus	7 Aug. 00	30	4.4	2.0	ns	ns	*
		60	0.8	2.6			
		90	0.2	3.6			
	22 Jan. 01	30	3.4	3.0	ns	ns	**
		60	1.8	8.6			
		90	1.0	7.0			

[1] Abbreviations for treatments: BG = bare ground resulting from herbicide; PNUT = perennial peanut ground cover.
[2] Abbreviations for analysis of variance (ANOVA) effects: C = grond cover; D = distance from tree; CxD = interaction between ground cover and distance.
[3] Data are means 5 replications.
[4] *, ** indicate significant at $P < 0.05$ and $P < 0.01$, respectively; ns = not significant at $P < 0.10$.

vidual nematode genera in interpreting effects of ground-cover treatments. The increase in overall numbers of nematodes under perennial peanut does help to explain the differences in richness among ground-cover treatments from late summer through the second winter. The greater food source and food web base offered by a more abundant rhizosphere could accommodate greater richness (more genera present) as well as greater abundance in the nematode community. Maturity index (MI) values tended to be reduced under perennial peanut compared to bare ground, and therefore did not convey the increased nematode richness and numbers under perennial peanut. Numbers of both bacterivores (colonizers with low cp values used in calculating MI) and omnivores (persisters with high cp values) increased in soil with perennial peanut, but because numbers of bacterivores always exceeded omnivores, the mathematical result was to shift MI to lower values as bacterivores increased. In the spring and summer, greater MI values at the 90-cm distance for both

TABLE 3. Effects of ground-cover treatments on nematode community measures and ecological indices by sampling date, 2000–2001.

Indices[1]	4 February		15 May		7 August		31 October		22 January	
	BG[2]	PNUT[2]	BG	PNUT	BG	PNUT	BG	PNUT	BG	PNUT
% bacterivores	43[3]	45	46	51	54	57	61	68*[4]	61	64
% fungivores	14	12	17	16	14	17	21	14*	19	15
% omnivores	5	4	5	5	6	5	4	3	4	4
% plant parasites	33	34	28	25	22	18	12	14	16	16
% predators	2	1	2	1	3	1	2	1*	1	0
Richness	25	24	23	25	26	28**	27	30[5]	23	29**
F/B	0.335	0.262	0.423	0.318	0.277	0.309	0.351	0.212*	0.318	0.235
F/(F+B)	0.239	0.201	0.328	0.243	0.205	0.234	0.253	0.171	0.240	0.184
(F+B)/PP	1.960	1.906	3.581	3.360	4.121	4.698	9.103	7.115	7.405	5.317
Dominance	0.094	0.127	0.122	0.111	0.091	0.089	0.085	0.097	0.104	0.095
Diversity	11.8	8.8	9.6	9.1	12.1	11.6	12.6	10.6	9.8	10.6
Maturity index	2.392	2.293	2.388	2.251	2.417	2.245*	2.231	2.117	2.251	2.163

[1] Ecological indices as defined by various authors: F/B, ratio of fungivores (F) to bacterivores (B) (Freckman and Ettema, 1993); F/(F+B) (Neher and Campbell, 1994); (F+B)/PP, ratio of F+B to plant parasites (PP) (Wasilewska, 1997b); dominance (Simpson, 1949); diversity (Ludwig and Reynolds, 1988); maturity index (Bongers and Bongers, 1998). Richness = number of taxa per sample.
[2] Abbreviations for ground-cover treatments: BG = bare ground resulting from herbicide spray; PNUT = perennial peanut.
[3] Values are means of 15 samples.
[4] *, ** indicate significant difference betweeen BG and PNUT at $P < 0.05$ and $P < 0.01$, respectively; ns = not significant at $P \leq 0.10$.
[5] Significance at $P < 0.06$.

TABLE 4. Effects of ground cover and distance from tree trunk on ecological indices, 2000–2001.

Ecological index[1]	Sampling date	Distance from tree (cm)	Index value		ANOVA		
			BG[2]	PNUT[2]	C[3]	D[3]	CxD[3]
(F+B)/PP	4 Feb. 00	30	2.70[4]	1.41	ns	ns	**[5]
		60	1.63	2.22			
		90	1.55	2.09			
	15 May 00	30	7.08	2.95	ns	*	**
		60	1.86	4.81			
		90	1.80	2.32			
	31 Oct. 00	30	14.56	4.45	ns	ns	**
		60	6.20	7.43			
		90	6.55	9.46			
Diversity	31 Oct. 00	30	9.63	10.42	ns	**	*
		60	13.60	10.68			
		90	14.67	10.65			
	22 Jan. 01	30	8.29	11.11	ns	ns	*
		60	9.91	10.68			
		90	11.33	10.09			
Maturity index	15 May 00	30	2.17	2.20	ns	**	*
		60	2.48	2.16			
		90	2.51	2.39			
	31 Oct. 00	30	2.18	2.20	ns	ns	*
		60	2.26	2.09			
		90	2.25	2.06			

[1] Ecological indices as defined by various authors: (F+B)/PP, ratio of fungivores and bacterivores to plant parasites (Wasilewska, 1997b); diversity (Ludwig and Reynolds, 1988); maturity index (Bongers and Bongers, 1998).
[2] Abbreviations for treatments: BG = bare ground resulting from herbicide; PNUT = perennial peanut ground cover.
[3] Abbreviations for analysis of variance (ANOVA) effects: C = ground cover; D = distance from tree; CxD = interaction between ground cover and distance.
[4] Data are means of 5 replications.
[5] *, ** indicate significance at $P < 0.05$ and $P < 0.01$, respectively, ns = not significant at $P < 0.10$.

treatments may be attributed to the larger populations of plant-parasitic nematodes (higher cp values), mainly *Mesocriconema,* associated with perennial peanut treatment. Use of herbicide spray in both treatments was probably the greatest source of disturbance between both ground-cover treatments. Because the 90-cm sampling distance was near the edge of the herbicide spray zone in the bare-ground treatment, negative impacts to nematode communities were probably diluted at this distance. The impacts of the herbicide spray were probably compromised on the other sampling dates by seasonal effects (good growing conditions for plants/weeds later in the year) and temporal lags in nematode population growth (effects of winter). Measures for nematode diversity on the sampling dates occurring in the summer and fall are most likely an effect of seasonal growth peaks for perennial peanut and other weeds present in the orchard.

In summary, this study illustrates the importance of ground cover and its management on many different members of the nematode community associated with citrus. Presence of a ground cover increased number of nematode taxa present as well as abundance of many nematode genera. While effects may not be evident immediately after such management practices are initiated (Porazinska, 1998), such effects became evident through time and may have important implications in the conservation of nematode biodiversity and in the management of plant-parasitic nematodes in citrus.

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