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Effect of Agricultural Management on Nematode Communities in a Mediterranean Agroecosystem

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Abstract: The effects of agricultural management on the soil nematode community were investigated in a field study at depths of 0 to 10 cm and 10 to 20 cm during a peanut (*Arachis hypogaea*) growing season in Israel. Nineteen nematode families and 23 genera were observed. Rhabditidae, *Cephalobus, Eucephalobus, Aphelenchus, Aphelenchoides, Tetylenchus, Tylenchus, Dorylaimus,* and *Discolaimus* were the dominant family and genera. Ecological measures of soil nematode community structure, diversity, and maturity indices were assessed and compared between the managed (by fertilization, irrigation, and pesticide application) and unmanaged fields. The total number of nematodes at a 10-cm depth during peanut-sowing, mid-season, and harvest periods was higher in the treated (managed) plot than in the control (unmanaged) plot. Bacterivores and fungivores were the most abundant trophic groups in both plots and both depths. The relative abundance of each group averaged 60.8 to 67.3% and 11.5 to 19.6% of the nematode community, respectively. Plant parasites and omnivores-predators at the 0 to 10-cm depth were much less abundant than any other two groups in our experimental plots. During the growing season, except the harvest period, populations of plant parasites and omnivores-predators at the 10 to 20-cm depth were lower in the treated plot than in the control plot. Maturity index (MI), plant-parasite index (PPI), and ratio of fungivores and bacterivores to plant parasites (WI) were found to be more sensitive indicators than other ecological indices for assessing the response of nematode communities to agricultural management in an Israeli agroecosystem.
Key words: agricultural management, agroecosystem, diversity, maturity index, nematode communities, peanut.

In agroecosystems, agricultural management practices affect native soil biota through cultivation, irrigation, and application of agrochemicals (Yeates and Bird, 1994). Soil is a critical component in the structure and function of agroecosystems, and the condition of the soil biological communities is important to both the structure and function of soils. An indicator of soil biological conditions would help measure the current status of vital ecological processes in soil as well as changes in function over time. Because indices of nematode community structure can reflect changes in soil conditions, they show promise for monitoring the ecological condition of soils (Neher and Campbell, 1994).

Nematodes play a significant role in the decomposition of soil organic matter, mineralization of plant nutrients, and nutrient cycling (Griffiths, 1994, Ingham et al., 1985). Because nematodes are ubiquitous and occupy important positions in the detritus food web (Freckman, 1988; Ingham et al., 1985; Sohlenius et al., 1987), they can be used as sensitive indicators of ecosystem change (Bongers, 1990; Freckman and Ettema, 1993; Wardle et al., 1995). Analysis of the trophic structure of nematode communities can help determine soil food web structure and function (Parmelee, 1995).

The objectives of this investigation were to: (i) describe the nematode community structure; (ii) determine the effect of agricultural management on nematode communities; and (iii) evaluate several ecological indices used for assessing the nematode community in an Israeli agroecosystem.

Materials and Methods

The field work in this study was conducted at the Ramat Hakovesh Kibbutz (32°10′N, 34°50′E), approximately 4 km north of Kfar-Saba. The area has a Mediterranean climate. Annual mean temperature is 21 °C. Minimum and maximum monthly means are 14 °C and 30 °C in January and June, respectively. Average annual rainfall is 600 mm, and annual evaporation is 1,500 mm. The soil at the study site is a light sandy soil that is suitable for growing potatoes, peanuts, and carrots (Liang et al., 1999). The selected study site was a peanut (*Arachis hypogaea*) field that was planted on 13 May 1998. The previous crop at the same site was potato. The experiment was conducted in two adjacent fields, with seven sample dates, each at two depths and five replicates (7 dates × 2 depths × 2 fields × 5 replicates). The treated field was managed by fertilization, irrigation, and application of pesticides, whereas the control plot did not receive any of these treatments in the peanut growing season. The weeds were controlled by hand in the control field, which was 2,000 m^2.

Soil samples from depths of 0 to 10 cm and 10 to 20 cm were collected between April and September 1998. The first and last sample dates were 22 April (pre-plant period) and 16 September 1998 (post-harvest period), respectively, with five intermediate sample dates during the peanut growing season (13 May, planting period; 14 June, post-planting period; 8 July, mid-growing period; 5 August, pre-harvesting period; and 31 August, harvesting period). Each soil sample comprised 5 cores (5-cm diam.), which were mixed and composited; subsamples were taken from each such bulk sample for estimation of nematode population and soil chemistry. The samples were protected against overheating and were

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processed immediately. Soil moisture was determined gravimetrically from samples dried at 105 °C for 48 hours. Soil organic matter (AFDM = ash-free dry mass) content was determined from dried soil burned in a muffle furnace at 490 °C for 8 hours.

Nematodes were extracted from 100-g subsamples with a Baermann funnel apparatus (Cairns, 1960). This procedure depends on active nematode movement. The size of the nematode population presented here refers to the number per 100 g dry soil. The nematodes were counted and preserved in formalin (Maggenti, 1981). An arbitrarily selected sample of the total organisms was identified to genus level, if possible, with an inverted compound microscope. The classification of trophic groups was based on known feeding habitats or stoma and esophageal morphology as follows: (1) bacterivores; (2) fungivores; (3) plant parasites; and (4) omnivores-predators (Steinberger and Sarig, 1993; Yardim and Edwards, 1998; Yeates et al., 1993).

The nematode community was analyzed using the following approaches: (1) absolute abundance of individuals per 100 g dry soil; (2) trophic structure; (3) ratio of fungivores and bacterivores to plant parasites (WI), WI = (FF + BF)/PP (Wasilewska, 1994); (4) fungivores/bacterivores ratio (F/B), lower ratios being associated with higher rates of decomposition and nutrient turnover (Twinn, 1974); (5) trophic diversity (T), which describes the diversity of functional groups, where $T = 1/\sum Pi^2$, in which Pi is the proportion of each trophic group i in the nematode community (Heip et al., 1988); (6) genus dominance (I_g), where $I_g = \sum Pi^2$, in which Pi is the proportion of the *i*th genus in the sample (McSorley and Frederick, 1996); (7) Simpson diversity (S_g), which gives more weight to common genera, with $S_g = 1/\sum Pi^2$ (Freckman and Ettema, 1993); (8) Shannon index (H′), a species diversity measure, which gives more weight to rare species, $H' = -\sum Pi(\ln Pi)$, where Pi is the proportion of each taxon in the total population; (9) maturity index (MI); and (10) plant-parasite index (PPI), which measure disturbances, with a lower value indicating a more disturbed environment, which could be the result of any abiotic and (or) human activity (Bongers, 1990; Freckman and Ettema, 1993). All data were subjected to analysis of variance (ANOVA). Differences with $p < 0.05$ were considered significant.

Results

Soil moisture: Differences in percentage soil moisture (SM) were observed among sampling dates and depths, whereas no difference was found between the treated and control plots. During the peanut-sowing (13 May 1998) and mid-season (8 July 1998) periods, the SM values at both depths were higher in the treated than in the control plot, and the SM values in both plots were lower at the 0 to 10-cm than at the 10 to 20-cm depth (Fig. 1).

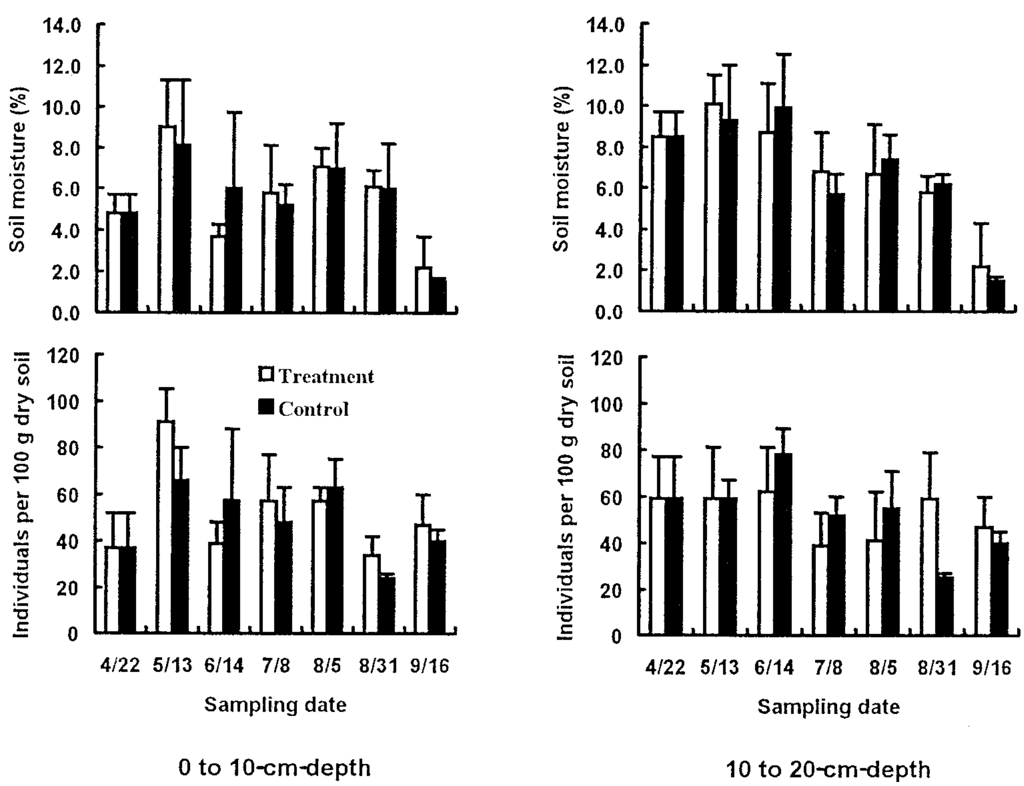

FIG. 1. Soil moisture and total number of nematodes at 0 to 10- and 10 to 20-cm soil depth in treated (□) and control (■) peanut plots during one growing season.

TABLE 1. Mean number of nematodes on three sampling dates in two treatments and soil depths during a peanut growing season in a field in Israel.

		13 May 1998				8 July 1998				31 August 1998			
		Treated		Control		Treated		Control		Treated		Control	
Genus/family	c-p[a]	0–10	10–20	0–10	10–20	0–10	10–20	0–10	10–20	0–10	10–20	0–10	10–20
Bacterivores		74[b]	47	33	39	31	34	28	24	25	13	15	41
Acrobeles	2	1	3	1	5	0	1	0	3	3	4	0	6
Acrobeloides	2	0	4	1	1	3	0	2	2	0	0	1	0
Alaimus	4	0	0	0	0	0	0	0	0	1	0	0	0
Cephalobus	2	19	6	11	9	10	13	15	9	11	2	3	7
Cervidellus	2	1	0	1	4	0	1	0	0	0	0	0	1
Chiloplacus	2	2	0	0	0	0	0	0	0	0	1	1	3
Diplogaster	1	3	2	0	0	0	2	0	0	0	1	0	2
Diploscapteridae	1	0	0	0	0	0	1	1	0	0	0	0	0
Eucephalobus	2	0	3	0	0	4	5	3	4	7	4	5	13
Monhysteridae	1	0	0	0	0	0	2	0	1	1	1	0	0
Plectus	2	18	4	6	1	0	0	1	1	0	0	0	0
Rhabditidae	1	27	23	13	19	14	9	6	4	2	0	4	9
Wilsonema	2	3	2	0	0	0	0	0	0	0	0	1	0
Fungivores		5	9	18	10	7	8	6	8	4	5	8	7
Aphelenchoides	2	0	8	5	0	2	6	1	1	0	2	2	0
Aphelenchus	2	5	1	11	10	5	2	5	6	3	3	6	7
Ditylenchus	2	0	0	0	0	0	0	0	1	1	0	0	0
Leptonchus	4	0	0	2	0	0	0	0	0	0	0	0	0
Plant-parasites		12	4	6	1	17	6	7	4	4	3	1	1
Heterodera	3	0	0	0	0	0	0	0	0	0	0	0	0
Pratylenchus	3	0	0	0	0	0	2	0	3	0	0	0	0
Trichodorus	4	2	0	0	0	2	1	1	0	0	0	0	0
Tylenchidae	2	0	1	2	0	0	0	0	0	0	0	0	0
Tylenchorhynchus	3	10	3	4	1	15	3	6	1	4	3	1	1
Omnivores-predators		0	7	2	9	2	0	1	3	1	3	2	9
Discolaimidae	4	0	7	2	4	2	0	1	2	0	1	0	1
Dorylaimidae	4	0	0	0	5	0	0	0	1	1	2	1	5
Monochus	4	0	0	0	0	0	0	0	0	0	0	0	2
Nygolaimus	5	0	0	0	0	0	0	0	0	0	0	1	1

[c] Taxa are classified by trophic groups and their respective c-p value according to Bongers (1990).
[d] Individuals per 100 g dry soil.

Nematode community structure: Nineteen nematode families and 23 genera were identified (Table 1). Rhabditidae, *Cephalobus, Eucephalobus, Aphelenchus,* and *Aphelenchoides,* were the dominant family/genera. Differences in the families of *Tylenchidae* and *Dorylaimidae* were found between fields and depths. Numbers of *Acrobeles* and *Discolaimidae* differed between depths and sampling dates. *Aphelenchus* exhibited a significant difference between fields (Table 2).

The total number of nematodes ranged from 17 to 104 individuals/100 g dry soil in the study period. The total number of nematodes at 0 to 10-cm depth in the treated plot reached a maximum (91 ± 14) during peanut planting (13 May 1998), and the minimum (34 ± 8) was found during harvest (31 August 1998) (Fig. 1). A significant difference in the total number of nematodes was found among sampling dates (Table 2).

Bacterivores were the most abundant group in this study. At planting and harvest, populations of bacterivores at both depths were higher in the treated than in the control plot. The maximum number (74 ± 10) of fungivores at 0 to 10 cm in the control plot was observed at planting (Table 1). The populations of fungi-

TABLE 2. Univariate analysis of variance (ANOVA) for soil nematodes and ecological indices on seven sampling dates in two peanut fields at two soil depths.

Index	Date (*F*)	Field (*F*)	Depth (*F*)
Abundance[a]	10.36**[a]	0.46 ns	0.93 ns
Trophic structure[b]			
BF	10.08**	1.03 ns	0.14 ns
FF	1.70 ns	3.96*	0.88 ns
PP	6.85**	32.54**	19.51**
OP	5.46**	6.45*	38.13**
WI[c]	12.59**	24.53**	9.27*
F/B[d]	1.13	1.13 ns	0.30 ns
S_g[e]	7.49**	0.14 ns	5.43 ns
H′[f]	7.04**	0.40 ns	6.74*
MI[g]	17.55**	24.52**	40.12**

[a] Absolute abundance per 100 g dry soil.
[b] Trophic structure: BF, Bacterivores; FF, Fungivores; PP, Plant-parasites; OP, Omnivores-predators.
[c] WI, (BF + FF)/PP.
[d] F/B (fungal feeders/bacterial feeders).
[e] Sg, Simpson genus diversity ($S_g = 1/\sum Pi^2$).
[f] H′, Shannon index ($H' = -\sum Pi(\ln Pi)$).
[g] MI, maturity index,

$$[MI = \sum_{i=1}^{n} v(i) \cdot f(i)].$$

* = $p < 0.05$; ** $p < 0.01$; ns = not significant.

vores at 10 to 20 cm in both plots fluctuated slightly throughout the study period. Plant parasites and omnivores-predators at 0 to 10 cm were much lower than any other two groups in our experimental plots, During the growing season, populations of plant parasites at both depths were higher in the treated than in the control plot, whereas populations of omnivores-predators at 10 to 20 cm were lower in the treated than in the control plot (Table 1). Differences in the plant-parasite and omnivore-predator groups were found between plots, depth, and sampling dates (Table 2).

Ecological indices of the nematode community: The ratio of bacterivores and fungivores to plant parasites (WI) at both depths was lower in the treated than in the control plot (Fig. 2). Differences in WI were found between plots, depths, and sampling dates (Table 2).

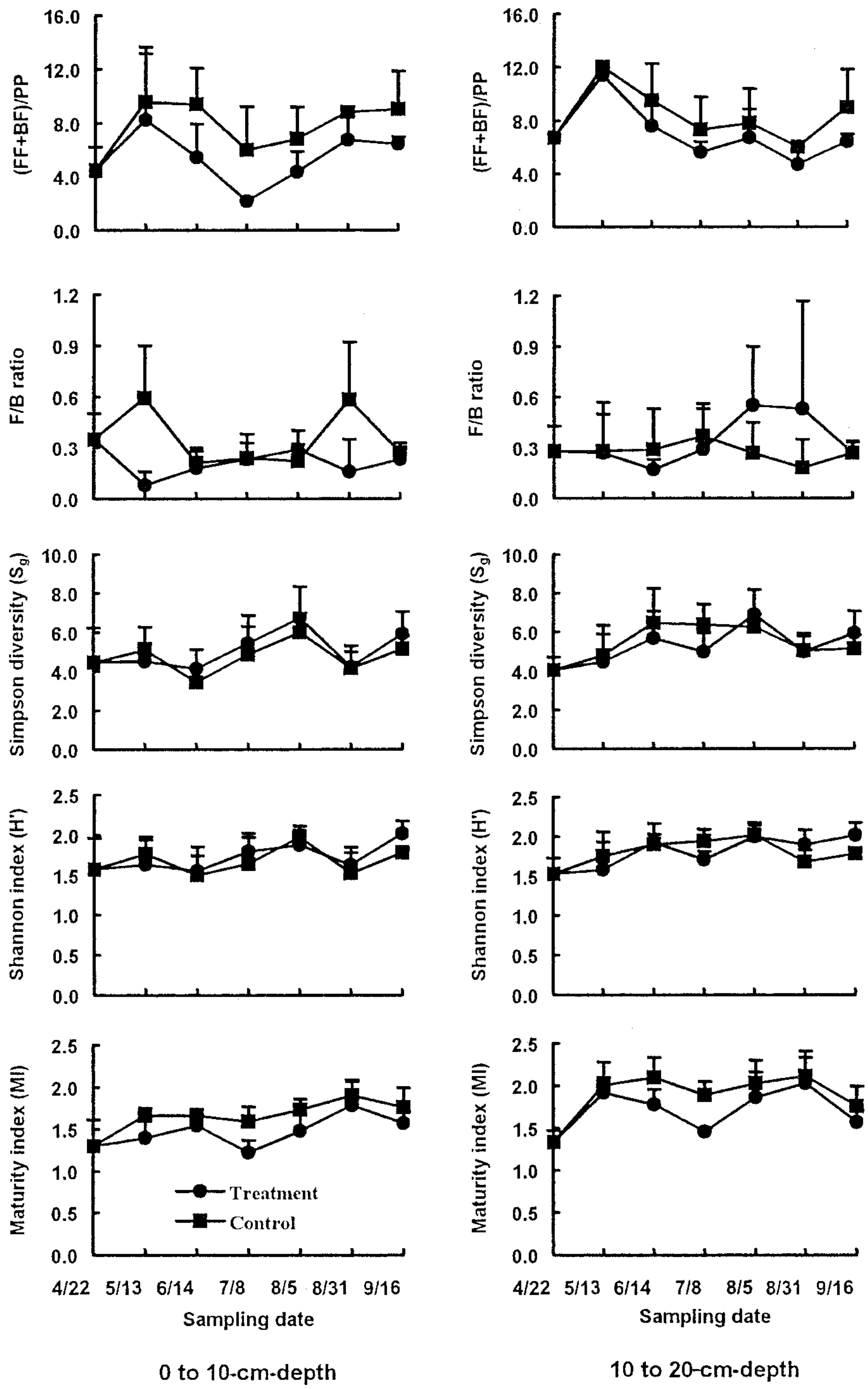

FIG. 2. Variation of ecological indices at 0 to 10- and 10 to 20-cm soil depth in treated (□) and control (■) peanut plots during one growing season. Vertical bars indicate standard deviations.

The ratio of fungivores to bacterivores (F/B) (Fig. 2) in our study site was less than 1.0 in both plots and both depths. The mean values of the F/B ratio of the treated plot at 0 to 10 cm exhibited a minimum value (0.08 ± 0.08) at planting. The F/B ratio of the treated plot at 10 to 20 cm reached a peak (0.55 ± 0.35) during the pre-harvesting period (5 August 1998) (Fig. 2). No significant differences in the F/B ratio were found between plots, depths, and sampling dates.

The values of Simpson's diversity (S_g) at 0 to 10 cm exhibited a similar trend during the study period. A maximum value (6.71 ± 1.64) of S_g in the treatment at 0 to 10 cm was found during the pre-harvesting period (Fig. 2). No differences in the index of S_g were found between plots and depths.

The Shannon index (H′) fluctuated slightly in both plots and both depths during the study period (Fig. 2). Differences in the index of H′ were found between depths and sampling dates (Table 2).

The values of MI at both depths were lower in the treated than in the control plot during the growing season (Fig. 2). Differences were found between fields, depths, and sampling dates (Table 2).

Discussion

Agricultural management practices such as tillage, fertilization, irrigation, and pesticide application cause a disturbance of the soil ecosystem (Bongers et al., 1997) and affect the soil nematode community structure (Freckman and Ettema, 1993; Porazinska and Coleman, 1995; Yardim and Edwards, 1998; Yeates and Bird, 1994). Although the total number of nematodes was not found to differ significantly between the treated and control plots, trophic groups such as fungivores, plant parasites, and omnivores-predators exhibited significant treatment effects during the study period.

The total number of nematodes in our experimental plots (51 individuals/100 g dry soil) was lower than those observed in Michigan (1,048) (Freckman and Ettema, 1993), Georgia (390 to 6,920) (Porazinska and Coleman, 1995), and South Australia (314 to 8,054) (Yeates and Bird, 1994). Bacterivores and fungivores were the most abundant trophic groups in both plots and both depths, averaging 64.7% and 11.8% of the nematode community, respectively. These proportions appear typical compared with those of some other agricultural sites (Freckman and Ettema, 1993; McSorley and Frederick, 1996, Porazinska and Coleman, 1995). Omnivores-predators were the least abundant group in our experimental plots (5.9%). The results of our investigation are similar to the findings of Yardim and Edwards (1998). This demonstrates that the densities of omnivores-predators may be decreased by agricultural management practices during the growing season.

The number of nematode taxa in our experimental plots (about 20) was less than in Swedish arable cropping systems (Sohlenius et al., 1987) and Michigan agroecosystems (Freckman and Ettema, 1993) and similar to that reported by Porazinska and Coleman (1995). *Cephalobidae* and *Rhabditidae* were the most abundant families in this study. These results are highly comparable to those in the Georgia site (Porazinska and Coleman, 1995).

The mean value of WI in our experimental site was 7.11, which is comparable to the range (1.01 to 8.80) of mean values observed by McSorley and Frederick (1996) for a soybean field. The F/B ratio in this study (0.30) was similar to those in other studies (Freckman and Ettema, 1993; Porazinska and Coleman, 1995).

The Shannon index (H′) gives more weight to rare species, and a higher index indicates greater diversity. The mean value of H′ in our experimental plots was 1.75, which is lower than that obtained by Freckman and Ettema (1993) and similar to those observed by Liang et al. (1999) at the same experimental site.

The maturity index (MI), a measure based on the composition of the nematode community, can reflect the degree of disturbance of the soil ecosystem as described by Bongers (1990) and Bongers et al. (1997). In their studies, Bongers et al. (1997) reported that MI decreases with increasing nutrient status.

In conclusion, significant time effects were found in most of the indices in our study during the study period. There were significant treatment effects in the plant-parasite group and the omnivore-predator group. Significant effects also were found in the ecological indices of MI and WI. Among the several ecological indices examined, MI and WI were the most sensitive indicators of treatment in Israeli agroecosystems. Agricultural management affects soil nematode communities during the peanut growing season by causing a significant increase in the plant-parasite population in comparison with the control plots and other trophic groups. Such patterns need to be taken into consideration for future land use.

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