SHORT-TERM EFFECTS OF CATTLE GRAZING ON NEMATODE COMMUNITIES IN FLORIDA PASTURES[†]

R. McSorley and J. J. Frederick

Department of Entomology, P.O. Box 110620, University of Florida, Gainesville, FL 32611-0620, U.S.A.

ABSTRACT

McSorley, R., and J. J. Frederick. 2000. Short-term effects of cattle grazing on nematode communities in Florida pastures. Nematropica 30:211-221.

Effects of cattle population density on nematode community structure were evaluated in a rotational grazing study involving 16 experimental pastures (each 20-32 ha in size) at a cattle ranch in south-central Florida. Summer pastures were grazed from Apr./May to Oct./Nov. and winter pastures from Oct./Nov. to Apr./May. Experimental design was a split-plot, with two pasture locations (winter, summer) as main plots and four cattle densities (0, 15, 20, or 35 cow-calf pairs per pasture) as subplots. With a few exceptions, population densities of most nematode genera in winter and summer pastures were similar ($P > 0.10$). Cattle density had relatively little effect on population levels of individual nematode genera or on indices of nematode community structure. Of the more than 50 nematode genera found at this site, *Monhystera* populations were affected most frequently by the short-term (6-7 months) grazing, but the nature of the responses were inconsistent. Nematode community data showed strong seasonal trends, with many genera more abundant in autumn than in spring samples ($P \leq 0.05$). In this study, seasonal effects greatly overshadowed any minor effects of cattle grazing on the soil nematode community.

Key words: bioindicator, ecological indices, grazing intensity, nematode community, soil ecology, sustainable agriculture, trophic groups.

RESUMEN

McSorley, R., y J. J.Frederick. 2000. Efectos a corto plazo del pastoreo de ganado en las comunidades de nematodos en los pastos de la Florida. Nematropica 30:211-221.

Los efectos de la densidad poblacional del ganado en la estructura de la comunidad de nematodos, fueron evaluados en un estudio de pastoreo rotacional, en 16 pastos experimentales (20-32 ha cada uno), en un rancho de ganado en el centro-sur de la Florida. Los pastos de verano, fueron pastoreados en Abril/Mayo y Oct./Nov. y los de invierno en Oct./Nov.y Abril/Mayo. El diseño experimental fue de parcela dividida, con dos localidades de pasto (invierno y verano) como parcelas principales y cuatro densidades de ganado (0, 15, 20 ó 35 pares por pasto) como subparcelas. Con unas pocas excepciones, las densidades poblacionales de la mayoría de los generos de nematodos en los pastos de invierno y verano fueron similares ($P > 0.10$). La densidad del ganado tuvo un efecto relativamente menor en los niveles poblacionales de los generos individuales de nematodos o en los índices de la estructura de la comunidad de nematodos. De los más de 50 generos de nematodos encontrados en este sitio, las poblaciones de *Monhystera* fueron afectadas más frecuentemente por el pastoreo a corto plazo (6-7 meses), pero la naturaleza de las respuestas fue muy inconsistente. Los datos de la comunidad de nematodo mostraron una fuerte influencia estacional, muchos generos fueron más abundantes en las muestras de otoño que en las de primavera ($P \leq 0.05$). En este estudio los efectos de estación, ensombrecieron grandemente cualquiera de los efectos menores del pastoreo de ganado, en la comunidad de nematodos del suelo.

[†]Florida Agricultural Experiment Station Journal Series No. R-07622.

Palabras claves: bioindicador, índices ecológicos, intensidad del pastoreo, comunidad de nematodo, ecología del suelo, agricultura sostenible, grupos tróficos.

INTRODUCTION

Grasslands and pastures contain a rich nematode fauna that is the subject of many community studies (de Goede and Bongers, 1998). While nematode communities associated with pastures and grasslands have been examined most extensively in northern Europe (de Goede and Bongers, 1998; Wasilewska, 1997), New Zealand (Yeates, 1981; 1982; 1984), and the western United States (Ingham and Detling, 1984; Todd, 1996), relatively few studies have been conducted in tropical and subtropical locations. The influence of plant species composition on soil nematode communities in temperate systems is well known (Wasilewska, 1997; Yeates, 1981), and appears to be of major importance in subtropical systems as well (McSorley, 1997a). Seasonal climatic fluctuations, particularly in rainfall and soil moisture, also exert important effects on nematode communities in tropical and subtropical systems (McSorley, 1997a, b; Powers and McSorley, 1994).

Grazing is an integral part of most pasture ecosystems, and can influence below ground communities through effects on the plant, through effects on litter quality, and through the deposition of nutrients (Bardgett *et al.*, 1998). Nutrient enrichment may have a particularly important influence on soil nematode communities (Wasilewska, 1989). For instance, experimental addition of nitrogen affected nematode community structure in a Kansas prairie, increasing herbivore and bacterivore levels while decreasing omnivores and predators (Todd, 1996). The objective of the present study was to determine the effects of grazing intensity by cattle on the nematode community in a subtropical pasture in Florida.

MATERIALS AND METHODS

The study was conducted in a series of pastures located at the MacArthur Agro-Ecology Research Center at Buck Island Ranch in Highlands County, Florida. (27°9'N, 81°11'W). A total of 16 experimental pastures, ranging in size from 20 to 32 ha, were established at two locations on the ranch. The pasture site intended for cattle grazing during the summer months consisted of a large bahiagrass (*Paspalum notatum*) pasture subdivided into eight experimental units. The winter pasture location was somewhat wetter and generally less suitable for summer grazing. This site contained small amounts of some native grasses mixed with bahiagrass, and was similarly divided into eight experimental pastures. The distance between the summer and winter pasture locations was about 0.5 to 1.0 km, and the soil type at both locations was similar (Pineda fine sand; 89-90% sand, 4-5% silt, 6% clay). Soil organic matter (0 to 20 cm deep) averaged 12.3% in the summer pasture location and 26.6% in the winter pasture location.

In 1998, a rotational grazing study was initiated involving four different cattle densities as treatments: 0, 15, 20, or 35 cow-calf pairs per pasture. Each of these cattle densities was replicated twice at each pasture location. The experimental design was therefore a split-plot, with pasture locations (winter or summer) as main plots and cattle densities as subplots. Cattle were first moved into the winter pastures in October 1998. In April 1999, they were transferred from the winter to the summer pastures, where they were kept until November 1999. A temporary shelter and water for the cattle were provided at a similar position within each plot when cattle were present.

Soil samples for nematode analysis were collected on 13 May 1998, 7 October 1998, 15 April 1999, and 23 November 1999. Each sample consisted of six soil cores (2.5 cm diameter × 20 cm deep) collected systematically from a 10-m × 10-m area within the pasture. This 10-m × 10-m area within each pasture was located about 50m from the point where shelter and water were provided. The soil cores comprising a sample were placed in a plastic bag, mixed, and stored at 10°C for 2 to 3 days before nematode extraction. A 100-cm^3 subsample was removed from each sample, suspended in 1.7 liters of water, and nematodes were removed by sieving and centrifugation (Jenkins, 1964). Extracted nematodes were identified to genus in most cases (except for Rhabditidae, Tylenchidae, and some Neotylenchidae) and counted on an inverted microscope.

Based on recent literature (McSorley and Frederick, 1999; Yeates *et al.*, 1993), nematodes were assigned to five trophic groups: bacterivores, fungivores, herbivores, omnivores, or predators. Several indices of nematode community structure were also calculated for each sample, including diversity at the genus level and at the trophic group level, calculated as $1/\lambda$, where λ is Simpson's index (Porazinska, 1998; Simpson, 1949); maturity index (MI) and plant-parasite index (PPI) as defined by Bongers (1990); $\sum$MI as refined by Yeates (1994); F/B, the ratio of fungivores to bacterivores; and (F + B)/PP, the ratio of fungivore and bacterivore decomposers to plant parasites (Wasilewska, 1994). Effects of pasture location, cattle density, and their interaction on nematode numbers and community structure were determined by analysis of variance, followed by mean separation by the Student-Neuman-Keul's test where appropriate (Freed *et al.*, 1991). Although regression analysis is usually recommended for quantitative variables (Mihail and Niblack, 1991), our objective was not to develop regression equations relating nematode levels to cattle densities (the number of levels was limited). The densities chosen were somewhat arbitrary, and represented levels near those likely to be used in practice (15 or 20 cow-calf pairs per pasture), an excessive level (35 per pasture), and an ungrazed control (0 per pasture). Seasonal effects were assessed by single degree of freedom orthogonal contrasts (Freed *et al.*, 1991) between spring-collected and autumn-collected data from each year.

RESULTS AND DISCUSSION

Soil moisture did not differ ($P > 0.10$) between summer and winter pasture locations on any sampling date. Soil moisture across sites averaged 34-38% on all sampling dates except 15 April 1999, when it averaged 21%.

A wide variety of nematode genera were found in the experimental site (Table 1), although individual samples contained, on average, only 24.0-29.4 taxa (Table 2). Many genera of bacterivores were present, and total bacterivore numbers (Table 1) included occasional specimens of *Aphanolaimus*, *Cryptonchus*, *Diploscapter*, *Euteratocephalus*, *Rhabdolaimus*, and *Turbatrix*, as well as those Araeolaimida, Chromadorida, Monhysterida, and Rhabditida that could not be identified to family or genus. In addition to the genera shown (Table 1), fungivore totals included a single *Eutylenchus* and a few Neoty-

Table 1. Nematode population densities on four sampling dates in pasture sites in south-central Florida, 1998-1999.

Nematode taxon	c-p value[w]	Nematodes per 100 cm^3 soil			
		13 May 1998	7 Oct. 1998	15 Apr. 1999	23 Nov. 1999
Bacterivores					
Acrobeles	2	1.1[x]	2.1	1.9	11.2
Acrobeloides	2	133.2	246.6*[y]	56.5	167.3**
Alaimus	4	0.3	0.7	2.2	1.2
Bunonema	1	0.4	4.9*	0.4	5.0
Cephalobus	2	8.4	3.5	1.0	1.8
Cervidellus	2	0.7	1.4	1.2	27.0
Chronogaster	3	16.0	21.1	3.3	13.8**
Eucephalobus	2	49.9	189.5**	18.2	76.1**
Monhystera	1	22.9	43.5*	12.6	38.8**
Panagrolaimus	1	0.6	3.2*	0.6	2.8
Plectus	2	8.9	16.6*	3.1	9.7*
Prismatolaimus	3	3.4	7.2*	0.9	11.4**
Rhabditidae	1	15.2	52.2**	10.9	86.4**
Teratocephalus	3	14.4	21.6*	9.9	15.1
Wilsonema	2	10.2	28.0**	5.2	32.8**
Zeldia	2	0.2	1.4*	1.3	2.4
Total bacterivores[z]		289.0	648.4**	130.4	503.4**
Fungivores					
Aphelenchoides	2	109.2	160.8	31.1	160.9**
Aphelenchus	2	0.1	1.6**	0.4	3.3*
Ecphyadophora	2	23.8	19.1	29.9	26.6
Nothotylenchus	2	9.4	22.7**	9.9	8.1
Psilenchus	2	0.4	1.3	2.9	3.6
Tylencholaimellus	4	2.2	12.1**	5.1	1.2*
Tylenchidae	2	192.9	498.8**	284.4	383.4
Fung. Dorylaimida	4	0.5	2.4	0.5	0.8
Total fungivores[z]		338.5	719.4**	364.3	587.9*
Herbivores					
Criconema	3	5.6	0	5.2	33.1*
Criconemella	3	11.1	56.9**	28.4	68.8
Gracilacus	2	5.1	3.2	42.0	24.6

Table 1. (Continued) Nematode population densities on four sampling dates in pasture sites in south-central Florida, 1998-1999.

Nematode taxon	c-p value[w]	Nematodes per 100 cm^3 soil			
		13 May 1998	7 Oct. 1998	15 Apr. 1999	23 Nov. 1999
Helicotylenchus	3	42.4	175.3*	203.3	87.6
Hemicriconemoides	3	16.2	10.1	83.2	103.4
Hemicycliophora	3	15.1	16.3	20.8	5.8
Meloidogyne	3	2.6	4.6	0.9	2.0
Paratrichodorus	4	3.9	3.4	0.7	3.9
Paratylenchus	2	0	57.7	86.3	115.9
Pratylenchus	3	0.2	0.5	0.1	5.9
Tylenchorhynchus	3	115.1	250.0*	82.1	100.9
Tylenchulus	3	95.4	46.0	107.5	166.6
Total herbivores		312.8	624.1**	660.3	718.6
Omnivores					
Aporcelaimellus	5	0.2	1.4	0.6	0.3
Eudorylaimus	4	1.8	16.1**	4.2	1.6
Mesodorylaimus	4	0.6	1.3	0.2	0.2
Total omnivores[z]		4.3	20.5**	5.4	2.7
Predators					
Iotonchus	4	0.9	0	1.3	0.2
Mononchus	4	1.2	1.9	0.4	0.5
Nygolaimus	5	0.1	3.9**	3.6	0.8
Tripyla	3	2.0	1.2	0.6	1.7
Total predators[z]		5.5	9.1	6.2	4.3

[W]From Bongers (1990), for calculation of maturity index.
[X]Data are means of 16 replications (pooled across pasture locations and cattle densities).
[Y]*,**indicate significant difference from the other sampling date in the same calendar year at $P \leq 0.05$ and $P \leq 0.01$ respectively.
[Z]Totals include uncommon taxa not shown in table (see text).

lenchidae; fungivorous Dorylaimida consisted of *Leptonchus* and *Tylencholaimus*, and Tylenchidae consisted mostly of *Filenchus*. Although the food habits of many Tylenchidae are unclear, Florida populations of *Filenchus* behaved as fungivores in a recent study (McSorley and Frederick, 1999) Omnivore totals also included *Actinolaimus* and Dorylaimida that could not be further identified. Total predators included a few specimens of Diplogasteridae, *Miconchus*, *Seinura*, and *Tobrilus*, along with the other genera of predators shown (Table 1).

Table 2. Indices of nematode community structure on four sampling dates in pasture sites in south-central Florida, 1998-1999.

Index measured	13 May 1998	7 Oct. 1998	15 Apr. 1999	23 Nov. 1999
Nematodes per 100 cm^3	962.0[y]	2034.7**[z]	1173.5	1829.3*
% bacterivores	29.6	31.5	12.2	29.3**
% fungivores	33.0	34.4	34.0	33.8
% herbivores	35.2	31.9	51.9	35.7*
% omnivores	0.4	1.0	0.5	0.2
% predators	0.5	0.5	0.7	0.2
Genera per 100 cm^3	24.0	29.4**	25.8	27.7
Genus diversity	6.95	6.41	4.96	7.51**
Trophic diversity	2.74	2.74	2.26	2.76**
MI	2.04	2.04	2.08	1.94
PPI	3.00	2.96	2.88	2.91
∑MI	2.35	2.31	2.46	2.26
F/B	1.27	1.21	3.35	1.32**
(B + F)/PP	2.32	2.76	1.58	2.35

[y]Data are means of 16 replications (pooled across pasture locations and cattle densities).
[z]*,**indicate significant difference from the other sampling date in the same calendar year at $P \leq 0.05$ and $P \leq 0.01$ respectively.

When data were pooled across pasture locations and cattle densities, nematode numbers showed consistent seasonal trends (Table 1). When nematode numbers in spring (April/May) were contrasted with those in autumn (Oct./Nov.), total numbers of bacterivores and fungivores were more abundant ($P \leq 0.05$) in autumn of each year. Total herbivores and omnivores were more abundant in autumn than in spring of 1998 ($P \leq 0.01$), but not in 1999. Increased numbers of some nematode groups in autumn probably result from the active period of crop growth due to summer rains. Seasonal effects on nematode community indices were less consistent, except in total nematode numbers (Table 2).

Effect of Pasture Location: The nematode faunae of summer and winter pastures were remarkably similar. Instances in which differences between pasture locations occurred in nematode numbers or community indices are summarized in Table 3. *Hemicriconemoides* was more abundant ($P \leq 0.10$) in summer than in winter pasture locations on two different sampling dates. Interestingly, *Ecphyadophora* was more abundant in summer pastures in May 1998 but in winter pastures in Nov. 1999 (Table 3).

Effect of Cattle Density. Cattle density had few significant effects ($P \leq 0.10$) on nematode genera or community structure (Table 4). Although significant effects on maturity index were observed on two different sampling dates, the effects were inconsistent (Table 4). However, the low maturity index on 23 November was likely influenced by the high numbers of Rhabditidae (low c-p value) present in the zero-density treatment on that date.

Table 3. Summary of parameters for which a significant difference (P ≤ 0.10) between summer and winter pasture locations was observed.

Parameter evaluated	Sampling date	Pasture location	
		Summer	Winter
Criconemella per 100 cm^3	13 May 1998	20.2	2.0*
Ecphyadophora per 100 cm^3	"	35.0	12.5@
Helicotylenchus per 100 cm^3	"	56.6	28.2**
Hemicriconemoides per 100 cm^3	"	23.4	9.0@
Aporcelaimellus per 100 cm^3	7 Oct. 1998	2.5	0.2@
Nygolaimus per 100 cm^3	"	5.4	2.4@
Prismatolaimus per 100 cm^3	"	10.5	3.9@
Psilenchus per 100 cm^3	"	2.6	0*
Rhabditidae per 100 cm^3	"	60.4	44.0@
Tripyla per 100 cm^3	"	2.4	0.1@
Zeldia per 100 cm^3	"	2.2	0.5@
% bacterivores	"	35.6	27.8**
% omnivores	"	1.3	0.6@
Hemicriconemoides per 100 cm^3	15 April 1999	163.8	2.6@
Tylenchorhynchus per 100 cm^3	"	141.5	22.6**
Wilsonema per 100 cm^3	"	6.4	4.0@
Omnivores per 100 cm^3	"	6.2	4.5@
PPI	"	2.99	2.78*
MI	"	2.11	2.04@
Ecphyadophora per 100 cm^3	23 Nov. 1999	7.8	45.5**
Nothotylenchus per 100 cm^3	"	10.9	5.2@
% bacterivores	"	35.9	22.6@
Trophic diversity	"	2.92	2.53*

Data are means of eight replications (pooled across cattle densities).
*,**Mean in winter pasture differs from that in summer pasture at $P \leq 0.05$ or $P \leq 0.01$, respectively.
@ Mean in winter pasture differs from that in summer pasture at $P \leq 0.10$.

Location × Cattle Density Interactions: The effect of cattle density on population levels of *Monhystera* and *Prismatolaimus* varied with pasture location (Table 5). In April 1999, when cattle grazing on the winter pastures had just been completed, *Monhystera* numbers in winter pastures were lower ($P \leq 0.05$) in the lower-density cattle treatments than in the higher-density cattle treatments. No effects were observed in the summer pastures, which had not been grazed in the preceeding months. In November 1999, numbers of *Monhystera* and *Prismatolaimus* in the summer pastures, which had just been grazed, were greatest in the zero-cattle-density control

Table 4. Summary of parameters for which a significant (P ≤ 0.10) effect of cattle density was observed.

Parameter evaluated	Sampling date	Cow-calf pairs per pasture			
		0	15	20	35
Wilsonema per 100 cm^3	15 April 1999	4.2 b	4.2 b	2.0 b	10.2 a
% fungivores	"	44.3 a	43.8 a	21.2 b	26.6 ab
% herbivores	"	44.7 bc	35.5 c	68.6 a	59.0 ab
Trophic diversity	"	2.06 b	2.81 a	1.90 b	2.28 ab
MI	"	2.06 b	2.04 b	2.16 a	2.05 b
Rhabditidae per 100 cm^3 23	Nov. 1999	186.0 a	35.8 b	83.2 ab	40.5 b
MI	"	1.87 b	1.99 a	1.96 a	1.94 a

Data are means of four replications (pooled across pasture location). Means in rows followed by the same letter do not differ at P ≤ 0.10, according to Student-Neuman-Keul's test.

treatment. Numbers in the winter pastures, which had not been grazed since April, were unaffected in November.

On both sampling dates, results (Table 5) were consistent with the timing of the rotational grazing. Responses ($P \leq 0.10$) of *Monhystera* or *Prismatolaimus* to grazing occurred only in pastures that had been grazed during the months prior to sampling. Winter pastures were grazed for six months prior to 15 April, when cattle were moved from the winter to the summer pastures, where they remained until late November. Responses of *Monhystera* to grazing in the winter pastures, observed in April, were no longer evident in these pastures in November following seven months without grazing. Although *Monhystera* populations responded to grazing, the nature of the response was inconsistent, as shown by opposite trends in the data for 15 April in winter pastures and 23 November in summer pastures. Both soil moisture and *Monhystera* numbers were much lower in April than in November.

Overview: Although data were not collected on vegetation biomass, visual differences were evident among the pastures. Grass was closely cropped in pastures with the highest cattle density, reached ca. one meter tall in the ungrazed pastures, and was patchy in height at the intermediate cattle densities. In addition, moderate populations of dog fennel (*Eupatorium capillifolium*) developed in the ungrazed summer pastures.

Despite visible differences in vegetation, few effects of short-term (6-7 months) grazing on nematode genera or community structure were noted. However, more detailed studies involving multiple seasons and multiple locations would be needed to reach a more definitive conclusion about the effects of rotational grazing on nematodes. Possibly more effect on the nematode community might be observed if pastures were grazed continuously, but this is an unsound management practice that does not allow the grass to recover from grazing.

In temperate systems, deposition of manure during grazing stimulated populations of bacterivorous nematodes, particularly *Rhabditis* and *Panagrolaimus* (Wasilewska, 1989; 1998). Of the nematode parameters measured here, the best

Table 5. Nematode population densities for which a significant ($P \leq 0.10$) pasture location × cattle density interaction was observed.

			Nematodes per 100 cm^3 soil			ANOVA effects		
Nematodes	Sampling date	Cow-calf pairs per pasture	Summer pastures	Winter pastures	Mean	Pasture	Cattle	P × C
Monhystera	15 Apr. 1999	0	3.5 a	2.0 c	2.7 b	P ≤ 0.05	P ≤ 0.01	P ≤ 0.05
		15	6.0 a	8.5 c	7.2 b			
		20	7.5 a	34.5 a	21.0 a			
		35	15.5 a	23.5 b	19.5 a			
		Mean	8.1 A	17.1 B				
Monhystera	23 Nov. 1999	0	61.5 a	26.0 a	43.8	ns	ns	P ≤ 0.10
		15	36.0 b	39.0 a	37.5			
		20	26.5 b	56.0 a	41.2			
		35	26.5 b	38.5 a	32.5			
		Mean	37.6	39.9				
Prismatolaimus	23 Nov. 1999	0	13.5 a	6.0 a	9.8	ns	ns	P ≤ 0.10
		15	12.5 a	11.5 a	12.0			
		20	6.5 b	22.0 a	14.2			
		35	4.5 b	14.5 a	9.5			
		Mean	9.2	13.5				

Means followed by the same letters in columns (small letters) or in rows (capital levels) do not differ at P value shown under ANOVA effects, according to the Student-Neuman-Keul's test.

potential bioindicator of cattle density effects appeared to be population levels of *Monhystera*. In some sites, however, *Monhystera* may not be present in sufficient numbers to make meaningful observations. The current study sites were rather wet pastures with unusually high organic matter content and good water holding capacity, where *Monhystera* consistently comprised 1-2% of the soil nematode community. In other sites in Florida, where soil organic matter and water holding capacity are typically quite low, *Monhystera* was not as abundant as in the current study, or was represented by only a few specimens (McSorley, 1993; 1997a; Porazinska *et al.*, 1998; 1999).

Although examination of seasonal effects was not an initial objective of the current study, strong seasonal differences between spring and autumn samples were evident, both in a baseline year when grazing had not yet occurred (1998) and in a year in which sampling followed grazing periods (1999). That seasonal trends should overshadow effects from grazing is probably not surprising, given that plant species and seasonal climatic fluctuations are known to be the major influences on nematode population size and community structure in subtropical pasture systems (McSorley, 1997a, b; Powers and McSorley, 1994). In subtropical systems, fluctuations in rainfall (McSorley, 1997b; Powers and McSorley, 1994) or irrigation levels (Porazinska *et al.*, 1998) may be important contributors to seasonal trends. One of the challenges in the reliable use of nematodes as bioindicators of environmental parameters remains the difficulty in distinguishing responses to the desired environmental parameter, particularly if that parameter is overwhelmed by the most dominant physical and biological effects that shape nematode community structure.

ACKNOWLEDGMENTS

The authors thank Joseph Mullanack for technical assistance, Nancy Sanders for manuscript preparation, the Archbold Biological Station's MacArthur Agro-Ecology Research Center (MAERC) for access to Buck Island Ranch, and Gene Lollis and the MAERC staff for maintenance of the experimental pastures and grazing management. This work has supported in part by grant no. 97-35108-5125 from the USDA/NRICGP Agricultural Systems program.

LITERATURE CITED

BARDGETT, R. D., D. A. WARDLE, and G. W. YEATES. 1998. Linking above-ground and below-ground interactions: how plant responses to foliar herbivory influence soil organisms. Soil Biology and Biochemistry 30:1867-1878.

BONGERS, T. 1990. The maturity index: an ecological measure of environmental disturbance based on nematode species composition. Oecologia 83:14-19.

DE GOEDE, R. G. M., and T. BONGERS, eds. 1998. Nematode communities of northern temperate grassland ecosystems. Focus Verlag, Giessen, Germany.

FREED, R., S. P. EISENSMITH, S. GOETZ, D. REICOSKY, V. W. SMAIL, and P. WOHLBERG. 1991. User's guide to MSTAT-C. Michigan State University, East Lansing, MI, U.S.A.

INGHAM, R. E., and J. K. DETLING. 1984. Plant-herbivore interactions in a North American mixed-grass prairie. III. Soil nematode populations and root biomass on *Cynomys ludovicianus* colonies and adjacent uncolonized areas. Oecologia 63:307-313.

JENKINS, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48:692.

MCSORLEY, R. 1993. Short-term effects of fire on the nematode community in a pine forest. Pedobiologia 37:39-48.

MCSORLEY, R. 1997a. Relationship of crop and rainfall to soil nematode community structure in perennial agroecosystems. Applied Soil Ecology 6:147-159.

MCSORLEY, R. 1997b. Correlation of nematode densities and rainfall in a Florida pasture. Soil and

Crop Science Society of Florida Proceedings 56:55-57.

MCSORLEY, R., and J. J. FREDERICK. 1999. Nematode population fluctuations during decomposition of specific organic amendments. Journal of Nematology 31:37-44.

MIHAIL, J. D., and T. L. NIBLACK. 1991. Comparison of treatment means: a statistical fantasy. Supplement to the Journal of Nematology 23:557-563.

PORAZINSKA, D. L. 1998. Nematode communities as indicators of agricultural management practices. Ph.D. dissertation, University of Florida, Gainesville, FL, U.S.A.

PORAZINSKA, D. L., R. MCSORLEY, L. W. DUNCAN, J. H. GRAHAM, T. A. WHEATON, and L. R. PARSONS. 1998. Nematode community composition under various irrigation schemes in a citrus soil ecosystem. Journal of Nematology 30:170-178.

PORAZINSKA, D. L., L. W. DUNCAN, R. MCSORLEY, and J. H. GRAHAM. 1999. Nematode communities as indicators of status and processes of a soil ecosystem influenced by agricultural management practices. Applied Soil Ecology 13:69-86.

POWERS, L. E., and R. MCSORLEY. 1994. Soil nematode community structure in two tropical pastures. Nematropica 24:133-141.

SIMPSON, E. H. 1949. Measurement of diversity. Nature 163: 688.

TODD, T. C. 1996. Effects of management practices on nematode community structure in tallgrass prairie. Applied Soil Ecology 3:235-246.

WASILEWSKA, L. 1989. Impact of human activities on nematode communities in terrestrial ecosystems. Pp. 123-132 *in* M. Clarholm, and L. Bergstrom, eds. Ecology of Arable Land. Kluwer Academic Publishers, Dordrecht, the Netherlands.

WASILEWSKA, L. 1994. The effect of age of meadows on succession and diversity in soil nematode communities. Pedobiologia 38:1-11.

WASILEWSKA, L. 1997. The relationship between the diversity of soil nematode communities and the plant species richness of meadows. Ekologia Polska 45:719-732.

WASILEWSKA, L. 1998. Changes in the proportions of groups of bacterivorous soil nematodes with different life strategies in relation to environmental conditions. Applied Soil Ecology 9:215-220.

YEATES, G. W. 1981. Populations of nematode genera in soils under pasture. IV. Seasonal dynamics at five North Island sites. New Zealand Journal of Agricultural Research 24:107-121.

YEATES, G. W. 1982. Variation of pasture nematode populations over thirty-six months in a summer dry silt loam. Pedobiologia 24:329-346.

YEATES, G. W. 1984. Variation of pasture nematode populations over thirty-six months in a summer moist silt loam. Pedobiologia 27:207-219.

YEATES, G. W. 1994. Modification and qualification of the nematode maturity index. Pedobiologia 38:97-101.

YEATES, G. W., T. BONGERS, R. G. M. de GOEDE, D. W. FRECKMAN, and S. GEORGIEVA. 1993. Feeding habits in soil nematode families and genera - an outline for soil ecologists. Journal of Nematology 25:315-331.

Received: *12.VII.2000*

Recibido:

Accepted for publication: *8.VIII.2000*

Aceptado para publicación:

BLANK PAGE USED IN PAGE COUNT