NEMATOPHAGOUS FUNGI FROM AGRICULTURAL SOILS OF CENTRAL AMERICA

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ABSTRACT

Persmark, L., N. Marban-Mendoza, and H.-B. Jansson. 1995. Nematophagous fungi from agricultural soils of Central America. Nematropica 25:117-124.

Seventeen agricultural soils from Costa Rica, Nicaragua and Panama were surveyed for fungi attacking vermiform nematodes and 13 species of nematode-trapping fungi were found. The most commonly detected fungus was *Stylopage* sp., found in 12 soils. Six endoparasitic species, the most common of which was *Catenaria anguillulae*, were observed in 11 soils. The soils contained between 1 and 10 fungal species, and the number of specimens varied from 0.1 to 5.1/g soil. The total number of nematodes varied from 0.9 to 25.5/g soil. There was a correlation between the number of nematodes and the number of specimens of nematophagous fungi found in 1 g of soil ($r = 0.78$; $P \leq 0.001$). There was also a correlation between the number of nematodes/g soil and the number of species of nematophagous fungi per soil sample ($r = 0.81$; $P \leq 0.001$).

Key words: biological control, geographical distribution, nematode, nematode-trapping fungi, survey.

RESUMEN

Persmark, L., N. Marban-Mendoza y H.-B. Jansson. 1995. Hongos nematófagos en suelos agrícolas de América Central. Nematropica 25:117-124.

Diecisiete suelos agrícolas de Costa Rica, Nicaragua y Panamá fueron estudiados. El balance total arrojó 13 especies de hongos nematófagos depredadores, y correspondió a las especies de *Stylopage* sp. ser las más comúnmente encontradas en 12 suelos. Se encontraron seis especies endoparasiticas, siendo la más comun *Catenaria anguillulae*, observada en 11 suelos. Los suelos contuvieron entre uno y diez especies y el número de especímenes encontrados osciló de menos de 0.1 a 5.1/g de suelo. El número total de nematodos también varió de 0.9 a 25.5/g de suelo. Hubo correlación entre los números de nematodos/g y la cantidad de hongos nematófagos, expresados como número de especimenes/g de suelo ($r = 0.78$; $P \leq 0.001$). También hubo correlación entre los números de nematodos/g de suelo y los números de especies de hongos nematófagos por muestra de suelo ($r = 0.81$; $P \leq 0.001$).

Palabras claves: control biológico, distribución geológico, nematodo, hongos, reconocer.

INTRODUCTION

Several agricultural soils in Central America have developed an apparent suppressiveness to some plant diseases. Microbial factors, such as viruses, bacteria or fungi, are probably involved in soil suppression, but the mechanisms are not yet fully understood (14). Several examples of soil suppressiveness, mainly to fungal diseases, have been described in natural soils (2) but nematode-suppressive soils also exist (20,21).

To find suitable antagonists to specific nematodes, it is necessary to investigate soils in which a natural suppression of these nematodes may occur. Several types of microorganisms may be involved and

the nematophagous fungi may constitute a major cause of the suppressiveness. These fungi are ubiquitous soil inhabitants and several hundred species have been described (9). Nematode-trapping (predatory) fungi appear to have little host specificity and can also live at varying degrees of saprophytism in soil. Endoparasitic nematophagous fungi generally have a higher host specificity and are obligate parasites of vermiform nematodes (4). Fungi attacking nematode cysts and eggs (13) are not covered in this study.

Investigations of nematode-trapping and endoparasitic fungi from tropical areas are few in number. In Central and South America, 4 such surveys have been performed (1,6,11,16). In the present investigation, a number of agricultural soils from different elevations in Nicaragua, Costa Rica, and Panama were surveyed for the presence of nematophagous fungi.

MATERIALS AND METHODS

Soil: The agricultural soils sampled from Nicaragua, Costa Rica, and Panama exhibited various degrees of suppressiveness, based on reports from local scientists and farmers. The soil samples, taken from the upper 10 cm preferably containing rhizosphere soil and roots, were kept cool or refrigerated until processed up to 2 months after sampling. Soil analyses were conducted for pH (water solution) and organic matter content.

Designations and locations of the soils: Nicaragua: N1, Masatepe, coffee plantation infested with *Meloidogyne* sp.; N2, Masatepe, coffee farm infested with *Meloidogyne* sp.; N3, San Pedro, tomato field; N4, Las Playitas, chinampa-like soil; N5, Valle de Sebaco Research Station, soybean field infested with *Meloidogyne* sp., treated with nematicide; and N6, Tamarindos Research Station, soil infested with *Meloidogyne* sp.

Costa Rica: CR1, Centro Agronomica Tropical de Investigacion y Enseñanza (CATIE), soil infested with *Meloidogyne* sp.; and CR2, CATIE, chinampa-like soil.

Panama: P1, Alange Research station, tomato field infested with *Meloidogyne* sp.; P2, Jarquin, watermelon field infested with *Meloidogyne* sp.; P3, Guarumal, rice field; P4, Guarumal, rice field infested with *Meloidogyne* sp., nematicide treated; P5, Boquete, tomato field; P6, Santuario, tomato field infested with *Meloidogyne* sp.; P7, Cerro Punta Experimental Station, potato field; P8, Cerro Punta Experimental Station, potato field infested with *Globodera* sp.; and P9, Cerro Punta Experimental Station, potato field infested with *Globodera* sp.

Nematodes and endoparasitic fungi: Nematodes were extracted with both the Seinhorst elutriator (18,19) and mistifier methods (17). Total numbers of nematodes were counted and presented as numbers per g soil (wet weight). The extracted nematodes were suspended in 3 ml of water and poured onto 1.5% water agar plates. After 3 days, excess water was evaporated in the air flow of a laminar flow cabinet, and after another 3 and 10 days, the nematodes were observed at 25× magnification for the occurrence of endoparasitic fungi (15). The nematodes infected with endoparasitic fungi were not identified since they were almost completely digested.

Nematode-trapping fungi: Nematode-trapping fungi were observed using the sprinkled plate method (9). One g of soil was spread on water agar plates baited with 1 000 specimens of the bacterivorous nematode, *Panagrellus redivivus*, grown axenically as described previously (10). Ten replicates per soil were evaluated. The fungi were isolated and grown on diluted

corn meal agar (CMA 1:10) and identities were determined mainly using the keys by Cooke and Godfrey (3) and DeHoog (5).

RESULTS

The following 13 species of nematode trapping fungi were found: *Stylopage* sp., *Acaulopage pectospora* Drechsler, *Dactylaria sclerohypha* Drechsler, *Dactylella leptospora* Drechsler, *Monacrosporium eudermatum* (Drechsler) Subram., *M. ellipsosporum* (Preuss) R. C. Cooke & C. H. Dickenson, *M. candidum* (Nees:Fr) Xing-Z. Liu & K.-Q. Zhang, *M. haptotylum* (Drechsler) Xing-Z. Liu & K.-Q. Zhang, *Arthrobotrys conoides* Drechsler, *A. kirgizica* (Soprunov) ex Soprunov, *A. musiformis* Drechsler, *A. oligospora* Fres., and *A. oviformis* Soprunov. Six species of endoparasites were found: *Catenaria anguillulae* Sorokin, *Myzocytium* sp., *Drechmeria coniospora* (Drechsler) W. Gams & H.-B. Jansson, *Harposporium anguillulae* Lohde, *Hirsutella rhossiliensis* Minter & Brady, and *Verticillium balanoides* (Drechsler) Dowsett *et al.*

The presence of nematophagous fungi was low except in soils from high elevations of Panama (P5-P9) and soil N1 from Nicaragua (Table 1). The most commonly observed nematode trapping species was *Stylopage* sp., which was found in 12 of the soils and often with a high frequency of occurrence (Table 2). In soils N2, N4, N5, N6, and P4 this was almost the only nem-

Table 1. Soil characteristics, nematode numbers, and numbers of nematophagous fungi in agricultural soils of Central America.

Soil	Elevation (m)	Organic matter (%)	pH	Nematodes per g soil[y]	Number of nematophagous fungi[z]
N1	450	3.9	6.2	7.3	7
N2	450	1.9	6.3	8.7	2
N3	30	17.4	6.7	3.6	2
N4	550	11.9	6.7	2.7	2
N5	600	1.4	6.9	2.8	2
N6	600	11.2	7.4	1.5	2
CR1	1070	16.4	5.3	6.0	3
CR2	950	3.7	3.4	2.3	4
P1	50	18.7	5.3	2.3	3
P2	50	5.1	5.0	2.2	2
P3	20	7.0	6.0	1.7	4
P4	20	8.0	5.9	0.9	1
P5	1000	24.1	5.4	6.9	6
P6	1200	21.5	5.8	25.2	10
P7	1890	9.0	5.6	14.5	8
P8	1900	9.8	5.0	3.9	7
P9	2100	10.6	5.1	25.5	9

[y]Wet soil weights; extracted using the mistifier method.
[z]Number of species recovered with the sprinkled plate method and on extracted nematodes.

Table 2. Species of nematophagous fungi found in Central American agricultural soils.

Soil	Nematode-trapping species[v]	Infection structure[w]	Frequency[x]	Endoparasitic species[y]	Infection structure[w]	Frequency
N1	*Stylopage* sp.	AH	100	*Catenaria anguillulae*	Z	ND[z]
	Dactylaria sclerohypha	RK	20	*Harposporium anguillulae*	I	10
	Monacrosporium sp.	AN	10			
	Arthrobotrys musiformis	AN	10			
N2	*Stylopage* sp.	AH	100			
	Arthrobotrys sp.	AN	10			
N3	*Monacrosporium* sp.	AN	10	*C. anguillulae*	Z	ND
N4	*Stylopage* sp.	AH	90			
	Monacrosporium sp.	AN	10			
N5	*Stylopage* sp.	AH	70	*C. anguillulae*	Z	ND
N6	*Stylopage* sp.	AH	20	*C. anguillulae*	Z	ND
CR1	*Monacrosporium* sp.	AN	50	*C. anguillulae*	Z	ND
	A. musiformis	AN	10			
CR2	*Acaulopage pectospora*	AB	30	*C. anguillulae*	Z	ND
	A. musiformis	AN	50	*H. anguillulae*	I	ND
P1	*Stylopage* sp.	AH	50	*C. anguillulae*	Z	ND
	Monacrosporium eudermatum	AN	50			
P2	*Dactylella leptospora*	RK	20			
	Monacrosporium sp.	AN	10			
P3	*Stylopage* sp.	AH	100	*C. anguillulae*	Z	10
	A. pectospora	AB	40			
	M. eudermatum	AN	20			
P4	*Stylopage* sp.	AH	80			
P5	*Stylopage* sp.	AH	90	*C. anguillulae*	Z	ND
	Monacrosporium sp.	AN	10	*Hirsutella rhossiliensis*	A	10
	A. musiformis	AN	90			
	Arthrobotrys oligospora	AN	10			
P6	*Stylopage* sp.	AH	90	*C. anguillulae*	Z	ND

[v]Nematode-trapping species detected using the sprinkled plate method with 10 replicate plates containing one g soil.

[w]Infection structure: AH = adhesive hyphae, RK = non-constricting rings and adhesive knobs, AN = adhesive networks, AK = adhesive knobs, AB = adhesive branches, Z = zoospores, I = ingested non-adhesive spores, A = adhesive spores.

[x]Percent of sprinkled plates on which the species were found out of 10 sprinkled plates each containing one g soil.

[y]Endoparasitic fungi found either on sprinkled plates or on the extracted nematodes.

[z]ND = not determined since these species were found only on the extracted nematodes.

Table 2. (Continued) Species of nematophagous fungi found in Central American agricultural soils.

Soil	Nematode-trapping species[v]	Infection structure[w]	Frequency[x]	Endoparasitic species[y]	Infection structure[w]	Frequency
	Monacrosporium candidum	RK	100	*H. anguillulae*	I	10
	Monacrosporium ellipsosporum	AK	90	*Verticillium balanoides*	A	40
	A. oligospora	AN	80	*H. rhossiliensis*	A	ND[z]
	Arthrobotrys oviformis	AN	10			
	A. musiformis	AN	80			
P7	*Stylopage* sp.	AH	20	*C. anguillulae*	Z	ND
	Arthrobotrys conoides	AN	40	*Drechmeria coniospora*	A	30
	A. musiformis	AN	100	*H. anguillulae*	I	20
	A. oligospora	AN	70			
P8	*Stylopage* sp.	AH	20	*V. balanoides*	A	10
	Monacrosporium haptotylum	RK	40	*H. rhossiliensis*	A	ND
	A. conoides	AN	50			
	A. musiformis	AN	60			
	A. oligospora	AN	90			
P9	*M. ellipsosporum*	AK	100	*C. anguillulae*	Z	ND
	M. eudermatum	AN	10	*Myzocytium sp.*	Z	20
	Arthrobotrys kirgizica	AN	20	*H. anguillulae*	I	10
	A. musiformis	AN	10			
	A. oligospora	AN	80			

[v]Nematode-trapping species detected using the sprinkled plate method with 10 replicate plates containing one g soil.

[w]Infection structure: AII = adhesive hyphae, RK = non-constricting rings and adhesive knobs, AN = adhesive networks, AK = adhesive knobs, AB = adhesive branches, Z = zoospores, I = ingested non-adhesive spores, A = adhesive spores.

[x]Percent of sprinkled plates on which the species were found out of 10 sprinkled plates each containing one g soil.

[y]Endoparasitic fungi found either on sprinkled plates or on the extracted nematodes.

[z]ND = not determined since these species were found only on the extracted nematodes.

atophagous fungus found. *Arthrobotrys musiformis* was also common and was isolated from 8 soils, and frequently in the soils of high elevations in Panama. Network forming species of the genus *Monacrosporium* were especially common at lower elevations, and this genus was encountered in 9 soils. All unidentified isolates of *Monacrosporium* were network-forming species (Table 2). The endoparasitic fungus *C. anguillulae* was found in 11 soils.

The highest number of species of nematophagous fungi was found in soil P6, which contained 10 species. This soil also had a high density of nematodes (Table 1). In P4 only one species was found, *Stylopage*

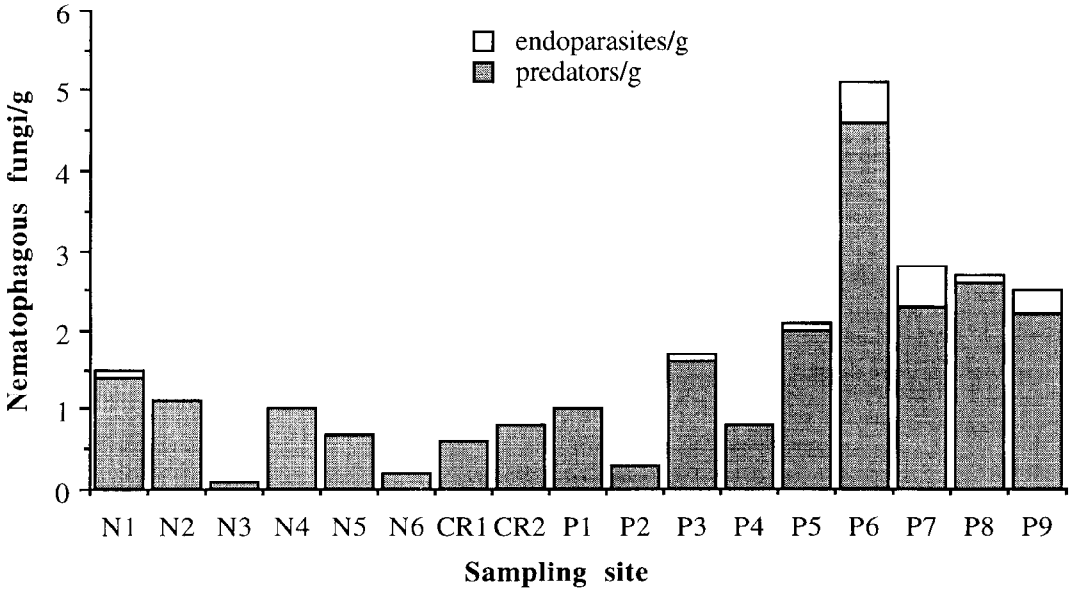

Fig. 1. Specimens of nematophagous fungi/g soil found with the sprinkled plate technique. Data are average of 10 replicate plates each containing 1 g soil from each sampling site. See text and Table 1 for descriptions of sampling sites.

sp. (Table 2). The number of specimens in the soils investigated varied from 0.1/g to 5.1/g soil (Fig. 1).

The nematode numbers were very low, with many soils containing less than 1 specimen/g soil. Soils from high elevations of Panama (P5-P9) contained higher numbers of nematodes and up to 25.5 nematodes/g soil were found in tomato and potato fields infested with *Meloidogyne* spp. and *Globodera* spp., respectively (Table 1). A positive correlation ($r = 0.78$; $P \leq 0.001$) was found between the number of nematodes/g and the number of nematophagous fungi recovered in 1 gram of soil (Fig. 2). There was also a positive correlation between the number of nematodes/g and the total number of species of nematophagous fungi recovered ($r = 0.81$; $P \leq 0.001$). There was no correlation between soil organic matter content and the number of nematophagous fungi, or between soil pH and number of nematophagous fungi.

DISCUSSION

In the soils at higher elevations of Panama, 1 500-2 000 m above sea level, both the species frequency and density of nematophagous fungi were higher than in the soils from areas at lower elevations. The nematode numbers also were higher in these soils. The cooler climate at higher elevations might favor these organisms. We only sampled the top 10 cm of soil, and at the lower elevations, the soil temperature in the top soil layer might get too high both for the nematodes and the nematophagous fungi. Therefore, sampling soil from the 20-30 cm horizon might have been more efficient.

Stylopage sp., followed by *Arthrobotrys musiformis*, was the most common nematode-trapping species observed. Rubner (16) also found *A. musiformis* quite frequently in a survey of Ecuadorian soils. Other common fungi in her study were

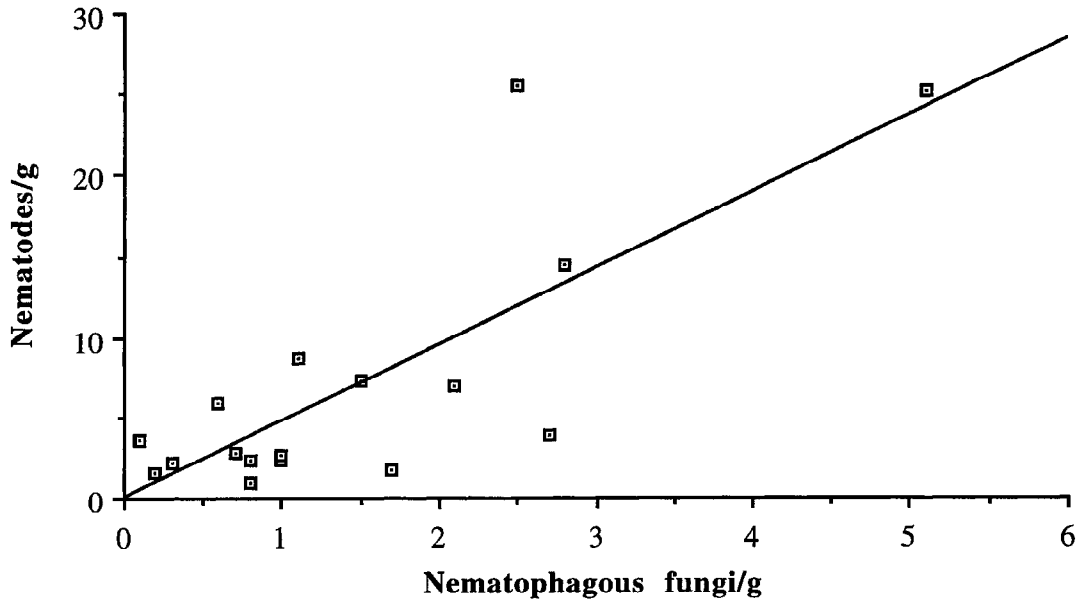

Fig. 2. Correlation ($r = 0.78$; $P \leq 0.001$) between total number of nematodes/g and number of specimens of nematophagous fungi/g soil in agricultural soils of Central America.

network-forming *Monacrosporium* species. We also found these to be common, and they were observed in 9 soils, generally from the lower elevations. *Catenaria anguillulae* was the most common endoparasite, and this zoospore-forming species might be favored by the tropical climate with high humidity and daily rain.

Although a range in suppressiveness of the surveyed soils to nematodes was reported by local observers, we found no correlation between reported soil suppressiveness and the amount of nematophagous fungi or the occurrence of any particular species. We found a positive correlation between the numbers of nematodes and both the amount of fungi and the number of species detected in the soil. Mahoney and Strongman (12) also found that increased species richness was positively correlated with increased numbers of nematodes close to piles of manure. Gray (7) found that the presence of obligate nematode endoparasitic fungi was associated with high nematode densities. Generally the soils sampled in Central America had a composition of species of nematophagous fungi similar to those found in surveys of Europe and North America (8).

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