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The effect of soil disturbance in a spruce forest on the abundance of nematode trophic groups

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Summary. Changes in the soil nematode fauna of a natural spruce forest caused by the laying of a gas pipeline was studied in the Moscow region. In the disturbed soil there was a significant reduction in nematode abundance, with fewer saprophagous, bacteriophagous and omnivores present. These changes were correlated with mixing of the soil horizons, change of vegetation and a reduction in organic matter.
Key words: trophic groups, nematodes, distribution, soil disturbance.

Nematodes constitute a major component of the soil fauna and are the most numerous and diverse group among all metazoan soil-inhabiting invertebrates. Formation, structure and development of nematode communities depend on different soil properties and processes. The nematofauna is responsive to changes in soil texture, chemical composition and vegetation, and abundance of nematode trophic groups are bioindicators of environmental disturbance. An investigation was undertaken of the effect of disturbances, caused by a gas pipeline, on the nematofauna of a spruce forest with the results reported here.

MATERIALS AND METHODS

The investigation was done in part of a 110 years old spruce forest on the Experimental Farm "Michailovsky" in the Podolsky district of the Moscow region, where, in 1962 and in 1983, gas pipelines were laid. Soil samples were collected from the two areas in the spruce forest where the plant and soil cover had 33 and 12 years of recovery to natural vegetation and from the undisturbed part of the forest.

Soil in the undisturbed part of the forest is a podzolic loam. The upper horizon has a high abundance of organic matter (23.1%), nitrogen and potassium (40 and 30 mg/100 g soil, respectively) and a pH of 4.4 and a humus content of *c.* 6.6%. The soil profile consists of the following horizons: O (0-3 cm), A (3-10 cm), AE (10-13 cm), E (13-22 cm), EB (22-46 cm) and B (46-70 cm). The dominant tree species is *Picea abies* L. with occasional *Populus tremula* L., *Betula pubescens* L., *Sorbus aucuparia* L. and *Quercus robur* L., and the undergrowth, which is sparse, consists mainly of *Oxalis acetosella* L. and *Convallaria majalis* L. and moss.

The profile of the disturbed sites consists of a developing humus horizon (Ad/AB 0-10 cm) above a mixture of the natural soil layers and parent clay material. On the basis of the humus content this mixed soil can be divided into two horizons, ABg and Bg, consisting of several subhorizons with different coloration and degree of gley process. The pH in the humus layer and the Bg horizon were 5.5 and 6.0, respectively, with low levels of nitrogen and phosphorus. The mean humus content in the upper horizon of the site disturbed in 1983 was 0.95% and for the site disturbed in 1962 was 1.9%; total organic content of the upper horizons at these two sites were 13.5% and 15%, respectively. Tree species growing at these sites were *P. abies*, *B. pubescens* and *P. tremula*. The site disturbed in 1983 is somewhat waterlogged with undergrowth species comprising *Carex* spp., *Deschampsia caespitosa* P.B., *Alopecurus pratensis* L., *Festuca pratensis* L., *Poa pratensis* L., *P. annua* L., *Matricaria inodora* L., *Ajuga repens* L., *Alchemilla vulgaris* L., *Melampyrum nemorosum* L., and *Ranunculus* spp. The undergrowth of the more elevated site which had been disturbed 33 years previously consisted mainly of the following graminaceous plants: *F. pratensis*, *A. pratensis*, *P. pratensis*, and *P. annua*.

The stepped diagonal and random sampling strategies described by Metlitskii & Matveeva (1975) were used. At each site an area of 10 x 30 m was delimitated and from each horizon 10-15 sub-sample cores were collected and combined to provide a sample of *c.* 1 kg and this was repeated to provide 3-4 replicate samples from each horizon, at each of the sites.

Nematodes were extracted by a decanting and sieving method with final separation overnight in a Baermann funnel (Flegg, 1967), then fixed in hot 4% formalin and processed and mounted in anhydrous glycerine on glass microscope slides by the method of Seinhorst (1959). Nematodes, contained in 100 cm^3 soil, from each sample were identified and counted and classified to the main trophic groups following the classifications of Paramonov (1962) and Hănél (1995a&b, 1996): saprophages/bacteriophages, omnivores, mycophages, phytophages (plant-parasitic nematodes), and predators.

RESULTS

The occurrence and abundance of the trophic groups are given in Tables 1, 2 and 3. The saprophage/bacteriophage nematodes present at each site included representatives of the families Cephalobidae and Rhabditidae; omnivores were mostly represented by Dorylaimida (*Prodorylaimus* spp., *Mesodorylaimus* spp., *Dorylaimus* spp., *Eudorylaimus* spp., *Belondira* spp., *Discolaimoides* spp., *Labronema* spp., and *Aporcelaimus* spp.) and to a lesser extent by Chromadorida; predators were mostly Mononchidae; phytophages mainly were *Helicotylenchus* spp., *Pratylenchus* spp. and *Paratylenchus* spp.; and mycophages were represented by *Tylenchus* spp., the most abundant, and *Aphelenchus* species.

Nematodes were most abundant in the upper organic horizons of all sites, especially in the litter of undisturbed spruce forest, and significantly exceeded nematode densities in the inorganic soil layers (Tables 1, 2 & 3). Saprophages/bacteriophages were dominant in the upper layers of the undisturbed podzolic soil (in litter O and horizon A). Among them Rhabditidae were dominant in each of the soil horizons from the site disturbed in 1983 and in the lower part of the humus horizon and in the mineral horizons of the site disturbed in 1962 and the undisturbed site (Tables 1, 2 & 3). Cephalobidae has the largest population in litter of undisturbed site (416 specimens/100 cm^3 soil).

In the deeper horizons of the undisturbed site the abundance of saprophages/bacteriophages decreased considerably, being supplanted by phytophages whose percentage increased from 5 to 6.7% in the horizons O and A and to 70.3% in horizon B, at a depth of 46 to 70 cm, where the largest biomass of tree and shrub roots were present. Omnivores were also rather numerous, with 34.5 to 39% abundance in the soil at 0-13 cm depth. Predatory nematodes were insignificant, with 1 to 4% being present in the upper horizons and virtually absent in the lower horizons. The principal biomass of mycophages (187 individuals/100 cm^3 soil) was present in the litter layer and decreased with soil depth (1 to 2 specimens/100 g soil at 46 to 70 cm depth; Table 1).

There were fewer nematodes in the disturbed sites than in the undisturbed site, mainly because of an apparent decrease in the saprophages/bateriophages nematodes. Omnivores were dominant at all sites (29 to 75% of total nematodes; Tables 2 & 3). Our observations revealed that parasitic nematodes increased in number in the upper soil horizons at the disturbed sites (50-111 individuals/100 cm^3 soil, representing a total abundance of 11-24%) and decreased in the lower horizons (4 to 9 individuals/100 cm^3 soil) compared with the undisturbed site (17 to 68 and 26 to 58 individuals/100 cm^3 soil in the upper and the lower horizons, respectively; Tables 1, 2 & 3).

The abundance of predatory nematodes in the site disturbed in 1983 was significantly more as compared with the site disturbed in 1962 and the undisturbed site, which had similar abundances of these nematodes, which indicates the time required for the re-establishment of community stability. Conversely, mycophages were observed to have reacted negatively to disturbance and were much fewer in the upper horizons at the site disturbed in 1983 as compared to the other two sites. There was also a general decline in nematode numbers with depth of soil horizon at each site.

DISCUSSION

Our study revealed that disturbance of soil and plant cover in a spruce forest resulted in a significant reduction in total numbers of nematodes, which is mainly due to a decrease of saprophages/bacteriophages. This is associated with the removal of the naturally accumulating organic horizon which has an abundance of undecomposed and partially decomposed organic material and humus. A similar negative effect was observed with mycophages, but their restoration of abundance was more rapid, and these nematode communities had already achieved their former levels at the site disturbed in 1962. Ruess (1995) also noted a significant decrease in nematode numbers at the sites with greatest damage to the trees compared to uninjured spruce forest.

Hănél (1995a) reported that at a heavily disturbed spruce forest a decrease in mycophages abundance was associated with the mycorhizal activity in the soil. This author also reported a decrease in omniphages abundance, but in our study a similar decrease was not apparent. This discrepancy may

Table 1. Abundance of ecological nematode groups. Undisturbed spruce forest.

Ecological groups of nematodes	Horizon O, 0-3 cm		Horizons A-AE, 3-13 cm		Horizons E-EB, 13-46 cm		Horizon B, 46-70 cm	
	Specimens/ 100 cm^3 soil	%	Specimens/ 100 cm^3 soil	%	Specimens/ 100 cm^3 soil	%	Specimens/ 100 cm^3 soil	%
Saprophages/bacteriophages								
Rhabditidae	148±13	10.8	96±11	37.2	12±3	11.6	4±2	10.8
Cephalobidae	416±21	30.5	32±5	12.4	3±1	3.0	3±1.5	8.1
Sum number	564±34	41.3	128±17	49.6	15±4	14.6	7±3.5	18.9
Omnivores	532±30	39.0	89±23	34.5	18±4	17.5	3±1.5	6.8
Predators	14±3	1.0	10±3	4.0	1±0.5	0.9	–	–
Phytophages	68±9	5.0	17±6	6.7	58±10	56.3	26±10	70.3
Mycophages	187±15	13.7	14±4	5.0	11±5	10.7	2±1	4.0
Total abundance	1365±85	100	258±24	100	103±10	100	38	100

Table 2. Abundance of ecological nematode groups in soil disturbance (1962) in a spruce forest.

Ecological groups of nematodes	Horizon Ad, 0-5 cm		Horizon AB, 5-10 cm		Horizon Bg1, 10-30 cm		Horizon Bg2, 30-75 cm	
	Specimens/ 100 cm^3 soil	%	Specimens/ 100 cm^3 soil	%	Specimens/ 100 cm^3 soil	%	Specimens/ 100 cm^3 soil	%
Saprophages/bacteriophages								
Rhabditidae	35±10	7.8	29±3	6.7	–	–	6±3	12.0
Cephalobidae	53±19	11.8	24±1	5.7	–	–	2±1	4.0
Sum number	88±29	19.6	53±4	12.4	–	–	8±4	16.0
Omnivores	130±26	29.0	176±29	41.6	48±6	73.8	30±9	60.0
Predators	20±9	4.4	21±6	5.0	4±2	6.2	1±0.5	2
Phytophages	50±8	11.0	102±18	24.0	9±5	13.8	9±3	18.0
Mycophages	162±10	36.0	72±3	17.0	4±2	6.2	2±1	4.0
Total abundance	450±45	100	424±52	100	65±1	100	50±12	100

Table 3. Abundance of ecological nematode groups in soil disturbance (1983) in a spruce forest.

Ecological groups of nematodes	Horizon Ad, 0-3 cm		Horizon AB, 3-10 cm		Horizons Bg1-Bg2, 10-30 cm	
	Specimens/ 100 cm^3 soil	%	Specimens/ 100 cm^3 soil	%	Specimens/ 100 cm^3 soil	%
Saprophages/bacteriophages						
Rhabditidae	50±20	10.2	68±9	10.1	2±1	14.3
Cephalobidae	25±10	5.1	7±1	1.0	1±1	7.1
Sum number	75±30	15.3	75±10	11.1	3±2	21.4
Omnivores	172±24	35.0	502±42	75.0	6±1	42.9
Predators	96±21	19.5	6±2	0.9	–	–
Phytophages	111±10	22.6	80±21	12.0	4±1	28.6
Mycophages	37±12	7.6	7±1	1.0	1±0.5	7.1
Total abundance	491±13	100	670±69	100	14±4	100

result from the disturbance in Hănĕl's study being caused by chemical pollution whereas in our study it was a physical/mechanical disturbance of the biotope. We also observed that omnivores were most tolerant of successional change and these nematodes were most abundant in the disturbed sites.

Comparison of the nematofauna of the undisturbed forest with that disturbed in 1962 and in 1983 and in the process of restoration revealed a significant increase in predaceous and phytophagous nematodes. Most of these nematodes were present in the upper soil horizons and the increase in phytophages is probably correlated with the presence of grass roots in these horizons at the disturbed sites. Hănĕl (1995a) also noted increased numbers of predaceous and phytophages in young spruce forests as compared with older forests and that ground cover was more dense in the young as compared to the older forests. This author also suggested that a decrease in predaceous nematodes in the older, more established, forests was associated with their sensitivity to acid substrates, as reported by Szczygiel (1971) and Winiszewska-Slipinska & Skwierscz (1987), to the chemical composition of the humus as reported by Arpin *et al.* (1988) or to the presence of other naturally occurring chemicals present in spruce forest soils.

A sharp decline in nematode abundance with depth at the two disturbed sites examined in our study could be correlated with changes in humus and root content. However, it was probably caused by mechanical compaction of the soil during pipe-laying and intermixing of the soil horizons with parent sub-soil clay material. Such changes would result in decreased pore space and aeration in the soil which would adversely affect the viability and survival of soil-inhabiting nematodes.

The maximum numbers of nematodes at each site occurred in the upper organic and humus horizons, and the composition of these trophic communities differed from those present in the lower, mineral soil horizons. De Goude *et al.* (1993) and Ruess (1995) reported similar differences and Wasilewska (1970, 1971) associated such changes with humus content and vegetation, i.e. plant root density. In our study maximum numbers of saprophages/bacteriophages (especially Cephalobidae), omnivores and mycophages were present in the forest litter layer which is probably the most favourable trophic and living condition for these groups. De Goude *et al.* (1993) reported that different stages of decomposition of organic materials could result in different nematode communities and a similar observation was made in our study. The dominant role of Cephalobidae in the forest litter and upper humus horizon, which are characterised by differentially decomposing materials, reflects the different feeding sources of these nematodes. Possibly, representatives of the Cephalobidae prefer a saprophytic medium as a food source (saprophytes) whereas the Rhabditidae utilise the bacterial mass of humus and mineral horizons (bacteriopahes). Further investigation is required as such feeding strategies would necessitate a clear distinction to be made between these two trophic groups.

The structure of nematode fauna is considerably affected by soil disturbance and takes several years to be fully restored to equilibrium. Changes in the relative abundance of the trophic groups has considerable potential for utilisation as bioindicators of the rate of change occurring after soil disturbance of natural habitats.

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Романенко Е. Н., Гельцер Ю. Г., Романенко Н. Д. Воздействие антропогенного перемешивания почвы на встречаемость трофических групп нематод.
Резюме. Были исследованы изменения в фауне почвенных нематод естественного елового леса, вызванные прокладкой газопровода в Московской области. В нарушенных почвах наблюдалось значительное снижение обилия нематод, заметное уменьшение числа нематод - бактерио- и сапрофагов, а также всеядных. Эти изменения коррелировали со степенью перемешивания почвенных горизонтов, сменой растительного покрова и понижением запасов органических веществ.