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The effects of vegetation cover on soil nematode communities in various biotopes disturbed by industrial emissions

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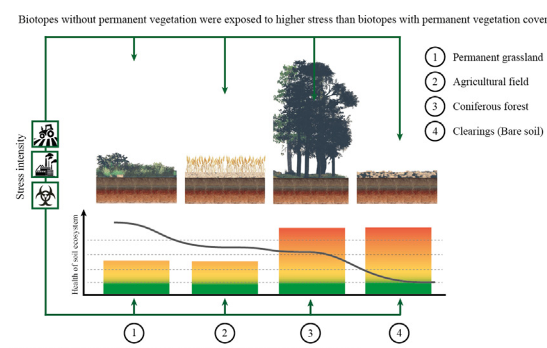
HIGHLIGHTS

- Interaction among ecosystem components may positively misrepresent the nematodes bioindication potential.
- Stress level increased in biotopes with disrupted phytocoenoses.
- Vegetation is able to buffer negative impacts of soil contamination.
- Biotopes with vegetation cover have higher resistance to stress as biotopes without vegetation.

GRAPHICAL ABSTRACT



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ABSTRACT

Better understanding of interactions among belowground and aboveground components in biotopes may improve our knowledge about soil ecosystem, and is necessary in environment assessment using indigenous soil organisms. In this study, we proposed that in disturbed biotopes, vegetation play important role in the buffering of contamination impact on soil communities and decrease the ecological pressure on soil biota. To assess the effects of these interactions we compared nematode communities, known for their bioindication abilities, from four types of disturbed and undisturbed biotopes (coniferous forest, permanent grassland, agricultural field, clearings), where the main stress agent was represented by long-term acidic industrial emissions containing heavy metals (As, Cd, Cu, and Pb). To understand the ecological interactions taking place in studied biotopes, we studied abiotic factors (soil properties) and biotic factors (vegetation, nematode communities). Except significant increase in metals total and mobile concentrations in disturbed biotopes soil, we found acidification of soil horizon, mainly in the clearings (pH = 3.68), due to SO_2 precipitation. These factors has caused in clearings degradation of native phytocoenoses and decrease in decomposition rate characterized by high amount of organic matter (C_{ox} = 4.29%). Nematodes reacts to these conditions by shifts in trophic structure (bacteriovores to fungal feeders), increase in c-p 2 genera (*Aphelenchoides*, *Acrobeloides*, and *Cephalobus*), absence of sensitive groups (c-p 3–5, omnivores, predators), and decrease in ecological indices (SI, MI, MI2–5, H′). Similar contamination was found in forest biotope, but the nematodes composition indicates more suitable conditions; more complex community structure (presence of sensitive trophic and higher c-p groups), higher abundance and indices values,

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comparable with less stressed field and grassland biotopes. As showed our results, the vegetation undoubtedly plays an important role not only as a resource of services indispensable for the ecosystem, but also as a significant buffer of negative impacts acting within.

1. Introduction

The aboveground and belowground components of ecosystems have traditionally been considered in isolation from each other (Wardle et al., 2004), but there is now increasing recognition of the interconnectivity of these two components and the fundamental role they play in belowground-aboveground feedbacks in controlling ecosystem processes and properties (Van Der Putten et al., 2001; Wardle et al., 2004). The producers (plants) provide resources to both i) decomposer system in a form of plant residues as a source of organic carbon required for its functioning (Neher and Campbell, 1994) and, ii) consumer systems directly bounded to the plants (plant feeders, parasites, pathogens, symbionts etc.). In turn, these systems indirectly regulate the aboveground vegetation communities (growth, composition, etc.) by organic matter mineralization (Wall et al., 2012) and complete the energy and nutrition cycles within the ecosystem.

By studying the changes in the belowground soil biota communities that are affected by disturbances, we can assess the deterioration of the soil environment. Soil nematodes can serve as a model subsystem for insight into the ecosystem processes as they are represented by wide variety of trophic preferences (plant feeders, omnivores, predators, fungal feeders, and bacterial feeders) and occupied important aspects of food web (Yeates et al., 1998). Furthermore, they are abundant, ubiquitous, and well adapted to a wide range of environmental conditions. They play important role in various soil processes, such as decomposition, nutrient cycling, and primary production by affecting the plant abundance, species diversity, and succession in natural vegetation (Wasilewska, 1995; Klironomos et al., 2000; Ferris et al., 2001; Reinhart et al., 2005; Kergunteuil et al., 2016). This represented a significant advance in interpreting the relationship between the ecology of nematode communities and soil functioning (Neher et al., 2012) and led to developing several indices for environment assessment e.g. Maturity, Structure and Enrichment indices (Bongers, 1990; Ferris et al., 2001). This facilitated indication of various changes in soil conditions caused by heavy metals contamination (Nagy, 1999; Rodríguez Martín et al., 2014), addition of inorganic and organic fertilizers (Widmer et al., 2002; Zhang et al., 2009; Wei et al., 2012), different farming practices (Neher, 1999; Panesar et al., 2000; Sánchez-Moreno et al., 2015) or use of pesticides (Ettema and Bongers, 1993; Yeates and Van Der Meulen, 1996). Despite this improvement in a soil assessment, the responses on environmental disturbances have had not been fully consistent and understand across qualitatively different ecosystems (Neher et al., 2005).

A better understanding of ecosystem functioning and ability to buffer the negative impacts of heavy metal contamination (Neher et al., 2013) could be obtain by more precise assessment strategies involving not only certain parts of ecosystem, but other important factors as well. One of a vital part of the ecosystem is vegetation, which is able to actively influence the ecosystem either directly or indirectly, by entering various soil processes. In addition to organic matter resource, vegetation affects various soil properties (porosity, bulk density, water retention, etc.) and thereby creates site-specific conditions (Wall et al., 2012). One of the ways that plants govern the soil biochemistry is through the quantity and chemistry of litter returned to soil (Berendse, 1998). Distribution, quality and concentration of litter appeared to be critical in organic matter availability and soil pH manipulation. As mobility of heavy metals is in soil mostly controlled by pH and organic matter, plant litter may play important role in restriction or bioavailability of heavy metals for soil organisms (Impellitteri et al., 2001).

In order to assess the relationship between the impact of heavy metal pollution and soil acidification on soil organisms, and the quality of the vegetation cover, we compared nematode community structure from different biotopes exposed for several decades to industrial emissions from a metallurgical plant Kovohuty Co., near Krompachy town, Slovakia, containing mainly As, Cu, Pb, and SO_2 (Hronec, 1996), with rather undisturbed biotopes. Investigated biotopes include coniferous forest, permanent grassland and agricultural field. Furthermore, we include barren soil, also known as clearings, as an original biotope in a degradation stage from stressed ecosystem. Our hypotheses were: (1) nematode communities' structure will depend not only on the intensity of soil acidification and metal contamination following the classic views on their reactions under environmental stress; (2) we expect lower range of changes in nematode communities' structure in disrupted biotopes with preserved vegetation; and (3) ability of vegetation to buffer contamination impact (acidification, high heavy metals mobility) on soil ecosystem.

2. Material and methods

2.1. Site selection

The terrestrial ecosystems in the surrounding of town Krompachy were for a long period of time (>50 years) exposed to industrial emission deposits originating from metallurgical plant Kovohuty Co., which contained various toxic heavy metals (As, Cu, and Pb) and SO_2. Though plant has been closed for several years, industrial pollution of the area mostly associated with increased content of As, Cd, Cu and Pb and soil acidification persists (Fargašová, 2009; Sabová and Valocká, 1996). Therefore, we choose the area of Krompachy, Slovakia, as stressed ecosystem and as a control, we used relatively undisturbed ecosystem in the Slovak Paradise National Park situated near Dedinky, Slovakia, where relatively unpolluted biotopes similar to stressed ones might be expected. Control and stressed ecosystem, were approximately 40 km apart.

2.2. Soil and vegetation samples

In each ecosystem, stressed and control respectively, three different biotopes were selected – i) forest – 60–70 year old, with conifers as the dominant vegetation; ii) grassland – permanent, mowed several times per year; iii) and grain field – with planted wheat (ca. one month old plants). As intense contamination significantly degraded some parts of the ecosystem and create biotope with very specific soil conditions we chose yet another biotope iv) clearings – composed mainly from bare soil with patches of resistant vegetation (Fig. 1).

The soil samples were taken by spade in two occasions (April and May 2014), according to the quadrat sampling method. In each biotope, 10 composite soil samples of weight approximately 3.0 kg of fresh soil were taken with distance at least 20 m among each sampling point in the biotope to prevent interferences among the samples, nematode communities respectively; each one was composed from four subsamples (ca. 0.75 kg) pooled together after taken from quadrat of size 1×1 m. For each soil composite sample, samples of plant tissues from nearest dominant plant were taken and divided into perennial (roots of herbs and wood of trees) and ephemeral (herb leaves and tree needles). In case of clearings biotope, both grass and tree samples were taken, where possible. Each sample (soil, plant tissues) was placed