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Variability in responses of soil nematodes to trace element contamination

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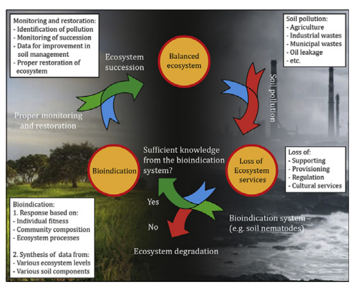
HIGHLIGHTS

- Responses of nematode genera were studied at several sites with industrial activity.
- Study brought new data of nematode genera reactions to heavy metal stress.
- Closely related nematodes showed different responses to the same pollutant.

GRAPHICAL ABSTRACT



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ABSTRACT

Free-living soil nematodes and plant parasites were previously repeatedly tested for their use as bioindicators of soil contamination. We investigated soil nematode communities from grasslands in four different industrial areas in Slovakia to estimate their responses to heavy metals. We considered differences or similarities in behavioural reactions of nematodes to different quantities of selected heavy metals in the soil. Using the CCA analysis and t-value biplot diagrams with van Dobben circles, we split individual nematode genera by their tolerance/intolerance to the particular heavy metal into several clusters. Our results showed that (a) representatives of nematode genera showed concurrently positive and negative associations with two or more heavy metals, (b) most nematode genera expressed a strong positive relation with Ni and to a lesser extend with Cr and Zn, (c) taxonomically closely related nematodes did not demonstrated similar responses to the same pollutant. We assume that nematode genera with a higher level of tolerance to trace elements should be prioritized in the heavy metal bioindication instead of sensitive species, due to their longer persistence in the stressed environment and better indicative ability. We pointed nematode genera, which according to received results may serve as suitable sentinels for specific soil pollutants.

1. Introduction

Belowground communities are an important natural resource with an immense, but largely unexplored biodiversity (Andre et al., 2001; Wheeler et al., 2004). The soil matrix represents a very complex and variable environment in physical, chemical and biological factors and thus, it may create myriads of distinct microhabitats. As a result, the soil organisms evolved strategies over time to optimize their growth and reproduction regard to specific local environmental conditions. Outside of environmental optima, or a tolerance range, the physiological, ecological or behavioural cycles and overall fitness of soil organisms might be negatively affected (Holt and Miller, 2011), which generally lead to significant changes in the population dynamic and alterations in the structure of their communities (Holt and Miller, 2011). As some faunal groups

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of the soil edaphon play an important role in soil processes and services, the changes in their communities (e.g. abundance, diversity) might be directly or indirectly responsible for the shifts in the food web and succession of the ecosystem (Wasilewska, 1995; Klironomos et al., 2000).

The soil contamination by trace elements is considered among others as important impulse to soil community changes. The responses of soil organisms to such environmental stress depend mainly on their tolerance and sensitivity. Numerous bioindicating organisms have the sufficient tolerance to one or few contaminants, and are able to answer effectively to the changing environmental conditions. However, in many cases there is a limitation of assessment to the broader range of disturbances, such as several trace elements, co-occurring in the environment (Holt and Miller, 2011). Consequently, the use of communities encompassing a broad range of environmental tolerances instead of single species tests seems to be more appropriate in the environmental bioindication as it has a higher potential to provide the more advanced insight into soil processes and services, in which the components of the community are involved (Ritz and Tradgill, 1999).

Since nematode communities are highly variable and relatively abundant in almost all terrestrial habitats, they offer an adequate bioindication capacity for the environmental assessment. Even though the evolution of bioindication concepts based on nematode life-history characteristics e.g. Maturity Index family (Bongers, 1990), or its updates (Ferris et al., 2001) has facilitated their studies as soil environment sentinels (Neher et al., 2005), there are still flaws due to lack of knowledge about specific responses of individual nematode genera to the environmental stress.

The aim of this study was to evaluate the responses of the individual nematode genera to different levels of trace elements in soil ecosystem, and to identify those nematode genera representatives appearing to be the best signals genera for particular metal(s).

2. Material and Methods

2.1. Site selection

We used the methodology of our previous researches, in which we evaluated the potential soil contamination by trace elements originating from various industrial emission deposits. In these studies, the following metallurgical factories were identified as main pollution sources: 1) Kovohuty Krompachy co. (48°55′19″ N 20°52′56″ E) with increased concentrations of As, Cd, Cu and Pb in the soil, 2) SMZ Jelšava co. (48°38′43″ N 20°13′13″ E) with higher levels of Cd and Pb, 3) OFZ Istebné co. (49°11′56″ N 19°13′33″ E) polluted with Cr, Cu, and Pb and 4) OFZ Istebné co. branch Široká (49°14′47″N 19°20′27″E), with mainly Cd contamination identified in their surroundings (Farkašová, 2009). Though some of these plants have already been closed (Kovohuty Krompachy co., OFZ Istebné co.), the trace element contamination of the surrounding areas due to lack of natural degradation or self-cleaning processes for trace elements persists even now (Fig. 1).

The Šarbov (49°25′15″ N, 21°37′48″ E), a human agglomeration free environment, belonging to the East Carpathian Biosphere Reserve, was used as a control site (Fig. 1).

2.2. Soil samples

For each studied area, four sampling sites located in the permanent grasslands were picked up and marked from 1 to 4, by the increasing distance from the pollution source, i.e. for Krompachy K1-K4, Jelšava J1-J4, Istebné I1-I4, and for Široká S1-S4. In each sampling site, four composite replicates were taken, each consisting from four pooled subsamples. Four replicates were also taken from the control area. This gave us totally 68 samples – 64 samples from 16 different polluted grassland sites and 4 samples from the potentially clean control site Šarbov. More details on the methodology see (Šalamún et al., 2011, 2012, 2014 and 2015).

2.3. Trace elements

A portion of each composite soil sample (300 g) was sifted through the 0.2 mm sieve to remove rocks and debris, and dried at a room temperature for 4 days. Trace elements (As, Cd, Cr, Cu Ni, Pb, Zn) were then analysed in the 5 g soil sample for their mobile concentrations obtained by the 0.05 mol/L EDTA extraction procedure (Sabienë et al., 2004). The determination of the actual

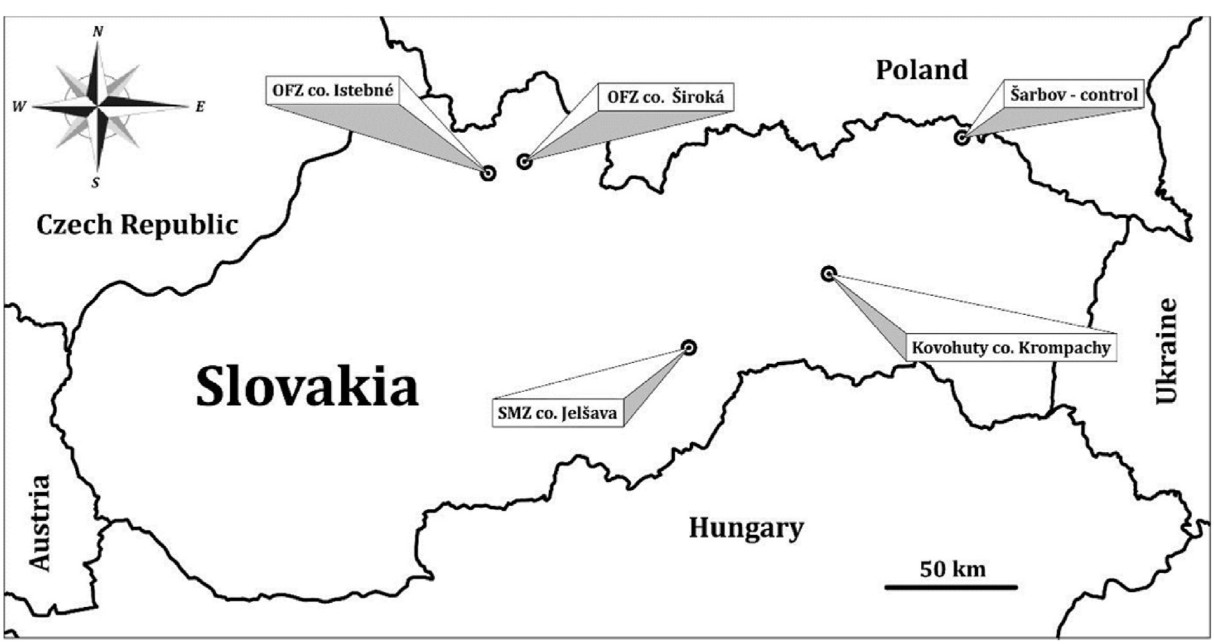

Fig. 1. Map of Slovakia with marked sampling areas – Krompachy, Istebné, Široká, Jelšava, and control area Šarbov.