DOSE-DEPENDENT TOXIC EFFECTS OF SELENIUM ON FAUNAL ELEMENTS OF SOIL FOOD WEB

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ABSTRACT

Selenium effects were investigated in the framework of a long-term agricultural experiment exposed to an artificial pollution in 1991. Samples were taken from the soil of sunflower in 1998. Soil zoological part of the study was carried out at two levels. Field work focussed on the coenoses of free-living terrestrial nematodes. Ecological measures, such as genus richness, Maturity Index, Structure Index and feeding group distribution values were recorded. The results revealed dose-dependent toxic effects of Selenium, with differences in sensitivity related to feeding types and life strategies of nematode taxa. In the laboratory, potworm (Enchytraeus albidus) tests were performed according to international standards. Target parameters of the tests were mortality and reproduction. Even concentrations below or around the present threshold level resulted in toxic effects for Enchytraeus.

Key-words: Selenium, Soil contamination, Nematodes, Enchytraeus

INTRODUCTION

Average concentration of the selenium in soils ranges from 0,1-2 $mg \cdot kg^{-1}$ (Kádár, 1999). In spite of this, attention towards physiological and environmental effects of Se increasing considerably. The explanation for this can be found in the ambivalent character of this element. On the one hand, Se is an essential microelement for crops, animals and man. On the other hand, however, it can act as a harmful and persistent environmental pollutant in biotic systems. In terrestrial systems, Se also shows alternate characters. Among acidic, reductive, organic soil conditions its uptake is blocked due to its presence in the elementary form and as selenide (Se^{2-}) ions, while in alcalic, well aerated oxydative soils the easily available selenite (SeO_3^{2-}) and selenate (SeO_4^{2-}) forms dominate (Kádár 1999). Although considerable amount of information is available on Se effects on living organisms in general (Gissel-Nielsen et al. 1984, Csathó 1994, Lin 2004, Zhenli 2005, Helinä 2005) little is known on the impact of this element on soil fauna (Fischer and Koszorus 1992, Nagy 1999, Bakonyi et al. 2003).
Free-living nematodes are widely usable indicators of various environmental disturbances (Bongers, 1990, Samoiloff, 1987). Some toxic effects of heavy metal and microelement contamination (including Se-pollution) have been studied in the framework of the same experiment (Nagy, 1999, Bakonyi et al., 2003).
Although the application of Enchytraeids in soil toxicological tests goes back to several decades (Weuffen 1968), the standardized procedures for these worms became more spread based on the work of Römbke and Moser (2002). To achieve a better compara-

bility of test results, Römbke and Moser (1999) worked out test protocol, the so-called *Enchytraeus* Reproduction Test (ERT).
Our aim was to explore effects on increasing Se doses on two important components of soil fauna groups and see whether coensis- and single-species level survey techniques lead to comparable conclusions on dose-dependent effects.

MATERIAL AND METHODS

Soil samples were taken on 30. 06. 1998. in the experimental field of Research Institute for Soil Science and Agrochemistry at Nagyhörcsök, on the North-western edge of the Great Plane, in Hungary, from the soil of sunflower (*Helianthus annuus* L., cv. Viki). *Se* was mixed to soil in April, 1991 in form of Na_2SeO_3. Original nominal *Se* concentration values were: 10 $mg \cdot kg^{-1}$, 30 $mg \cdot kg^{-1}$, 90 $mg \cdot kg^{-1}$ and 270 $mg \cdot kg^{-1}$. Soil of the experimental field is a calcareous loamy chernozem, with pH(H_2O): 7.6, humus content: 3.1. Selenium concentrations from samples were measured with the following techniques: „total" as extracted with ccHNO_3+ccH_2O_2 solution (Talajvizsgálati szabvány 1998) and „available" as extracted with NH_4-acetat+EDTA solution (Lakanen and Erviö 1971), respectively.
Nematological analyses were performed immediately after sampling, focussing on the coenoses of free-living terrestrial nematodes. Samples were extracted with Cobb's sieves, according to s'Jacob and van Bezooijen (1984) subsequently fixed in formaline. Sample processing involved identification of at least 150 nematodes, possibly to genus level.
Measures, such as nematode density, genus richness, Maturity Index (Bongers, 1990), Structure Index (Ferris et al, 2001) and feeding type distribution (Yeates et al, 1993) were recorded. Data were tested for significant differences with one-way ANOVA (density and genus richness) and Pearson χ^2 test (feeding group distribution).
Enchytraeus tests were performed on stored and re-wetted soil in between January 2000 and April 2000, based on the requirements of ERT. Test endpoints were mortality and reproductivity. Results were evaluated with Statistica 5.0 and ToxRat 2.08 Light softwares.

RESULTS AND DISCUSSION

„Total" and „available" *Se* concentration values for the subsequent contamination levels were 2.33, 7.25, 17.18, 70.47 $mg \cdot kg^{-1}$ and 1.02, 2.09, 7.05, 28.12 $mg \cdot kg^{-1}$, respectively. In control samples, both values were below the detection limits of 0.6 $mg \cdot kg^{-1}$ and 0.12 $mg \cdot kg^{-1}$, respectively.
Table 1. shows nematological values measured in plots of increasing *Se* concentrations and control. It is clear that the two highest pollution levels decrease all the values to a significant extent (in cases where significance could be tested). Moreover, certain values were not even calculable for plots of the highest *Se*-dose, due to the low number of nematodes found in total. On the other hand, the index values showed a slight increase as a response to the lowest Se dose, compared to the control.

Pollution level	0	1	2	3	4
Density	1275(±1104)	1160 (±587)	954 (±861)	422.5(±370)*	20.0(±3.5)**
Richness	19.0 (±2.8)	16.5 (±2.1)	16.0 (±2.8)	2.5 (±2.1)*	3.0 (±1.4)*
MI values	2.4 (±0.1)	2.51 (±0.06)	2.16 (±0.04)	1.99 (±0.08)	n.c.
SI values	52.68 (±7.8)	56.93 (±3.6)	28.58 (±9.4)	9.12 (±0.8)*	n.c.

Table 1.: Nematological values (± STD).
n.c.: not calculable
n.s.: non significant difference
* P<0.05
** P<0.01

Nematode feeding group distribution values showed significant differences between the "available" *Se* dose of 2.09 mg·kg^{-1} (p<0.05) and 7.05 mg·kg^{-1} (p<0.001), respectively, while in the plots of the maximum *Se* dose this value was not calculable.

Figure 1. shows that significant mortality effect was found in the case of "available" *Se* at a rate of 7.05 ("total" 17.18) mg·kg^{-1} and it decreased reproduction at 2.09 mg·kg^{-1} "available" ("total" 7.25) *Se*. Soils of *Se*-contaminated plots showed significant differences both in terms of mortality (F=18,4; p<0,001) and reproductivity (F=21,6; p<0,001) reflecting the increasing Se-doses.

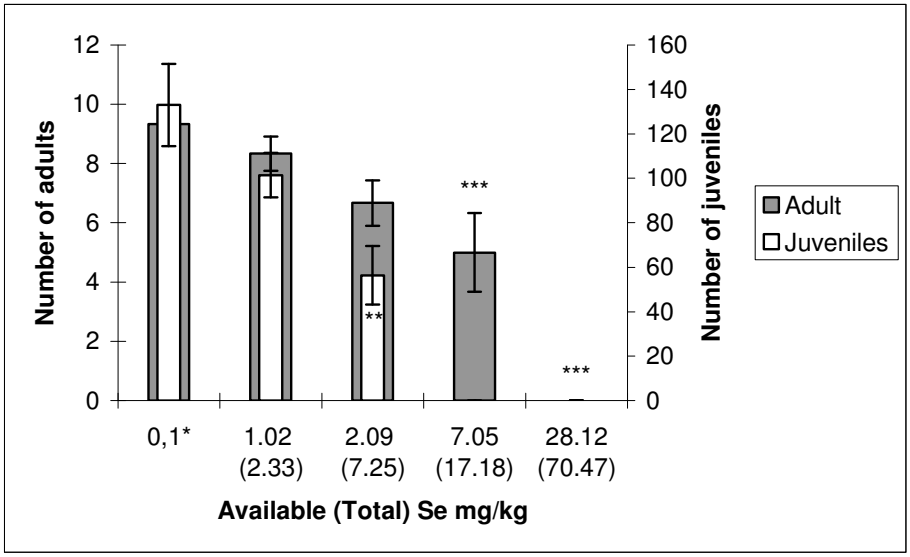

Fig. 1. Average abundance of *E. albidus* adults and juveniles per pot with the increasing Se concentrations.Bars represent ±SD. Total Se values are in parentheses.
* concentration in the control soil.
Significance levels: ** p<0.01, *** p<0.001

CONCLUSIONS

Nematode density and genus richness show a clear dose dependence. The fact that in the lowest Se dose some values show a slight, although statistically non-significant increase compared to the control indicates the positive effect of this treatment, probably due to a microelement completion effect (Nagy, 1999).

In the case of E. albidus reproduction is a more sensitive measure of enhancing Se concentration than mortality. This was the case in other experiments as well (Dodard 2003, Römbke 2003).

Even concentrations below or around the present threshold level determinated by the Hungarian law in Magyar Közlöny (2000) resulted in toxic effects for *Enchytraeus*.

Our results show the dose dependent effects both in the coenosis and the species level study, with *Enchytraeus* reproduction being the most sensitive parameter apparently.

Regarding Se effects, the above data give a warning on possible contaminant character of a plant microelement that is in low concentrations an essential factor of plant-, animal and human nutrition.

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