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Factors affecting bioaccumulation of heavy metals in the earthworm genus *Aporrectodea* Örley, 1881 in croplands

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Abstract:

Heavy metal bioaccumulation in earthworms can be used as an ecological indicator for heavy metal contamination in soils. In this study, the levels of Pb and Cd were analyzed in the body tissues of two endogeic earthworm species, *Aporrectodea caliginosa* and *A. rosea*, collected from three agricultural soils (turnip cabbage, beet, and fallow). At each system, soil samples for earthworm hand-sorting (quadrats of 50 × 50 × 25 cm) and analyses of organic matter and metal contents together with those of edible parts of agricultural plants were randomly collected at each field. The amounts of heavy metals were measured using flame atomic absorption spectrophotometry, organic matter content by loss on ignition (at 550 ºC for 4h) and soil Ca concentrations by Systronics Flame Photometer. The results showed that *A. caliginosa* was the dominant species in the turnip cabbage cropland, whereas *A. rosea* was dominant in the beet farmland; however, in the fallow system, both species had similar densities. The concentrations of Cd and Pb in earthworms were higher in the croplands than in the fallow. The concentrations of both Cd and Pb were significantly higher in the *A. caliginosa* specimens collected from the turnip cabbage and fallow lands, than in the soil samples from the same sites. By contrast, no significant differences were observed in the metal accumulations of the earthworm species collected from the fallow, although higher levels of Pb and Cd were measured in *A. rosea* and *A. caliginosa*, respectively. In addition, we found that the Pb concentration in earthworms was negatively correlated to calcium concentration in the soils, whereas the significant increase in organic matter contents observed in the soils with turnip cabbage (compared to the fallow) led to a higher accumulation of Cd in *A. rosea*; the opposite trend was observed for Pb accumulation in *A. caliginosa*. These results suggest that crop identity, calcium concentrations and organic matter contents play a key role in the uptake of heavy metals by earthworms.

Keywords: *Aporrectodea caliginosa*; *A. rosea*; Pb; Cd; Calcium; Organic matter

Introduction

Metal pollution is putting both terrestrial and aquatic ecosystems at risk. Cadmium (Cd) and lead (Pb), two non-essential metals, are particularly found in areas under irrigation with wastewater; both pollutants can put human health in danger. The bioavailability of metals cannot be measured directly using chemical analyses and hence, living organisms are used to accurately determine their bioavailability (Lanno and McCarty 1997). Depending on soil availability and their susceptibility and ability to accumulate metals, living organisms are used as bioindicators. The presence of a storage detoxification system has been demonstrated in a number of earthworm species (Cancio et al. 1995). Earthworms are also able to avoid unfavorable environments thanks to the numerous chemo-receptors located in their prostomium. Many studies have indicated low elimination rates of some metals by some earthworm species; for example, Cd (Spurgeon and Hopkin 1999), Cr (Van Gestel et al. 1993), and Pb (Spurgeon and Hopkin 1999), which makes them suitable candidates to assess soil contamination. Toxicity tests using earthworms is a well-developed tool for studying the bioavailability and acute toxicity of soil contaminants (Edwards and Bohlen 1996) in polluted field soils.

Materials and Methods

The experimental samples were collected from three farms in the South of Tehran Province: (1) turnips, (2) beet and (3) fallow. These small agricultural lands (approximately 1 km² surface area) had similar climatic conditions, soil type and were irrigated by various urban and industrial wastewater without any previous chemical treatment (Fig.1).

All collected samples (soils, plants and earthworms) were collected in clean tubes to digest for metal assessment (Fig. 2).

Fig. 1. Preparation of samples for metals analysis

Fig. 2. Sampling in the studied area

Results and Discussion

At sites 1 and 2, *A. caliginosa* and *A. rosea* were the dominant earthworm species, respectively, while at site 3 neither species were dominant. A negative relationship between Cd concentration and organic matter was found in the case of *A. caliginosa* from site 1, which. In a previous study conducted by Corp and Morgan (1991), organic matter was found to account for most Cd variation of *Lumbricus rubellus* in-tissue concentration. Ma et al. (1983), investigating *A. caliginosa* and *L. rubellus*, reported a significant contribution of organic matter to the accumulation of Cd. However, Tischer (2009) suggested that organic matter is of less importance in the uptake of Cd and Pb.

The other endogeic earthworm *A. rosea* from site 2 accumulated a higher Cd concentration compared to the same species at site 3. This could be associated with certain variability in feeding preferences within species belonging to the same ecological group. Although they are mainly considered mineral soil dwellers, most members of all ecological groups utilize surface litter as an N and C source (Curry and Schmidt 2007).

Therefore, the presence of plants may play an important role in the regulation of metal accumulation in earthworms.

Pb concentration was higher in *A. rosea*, while Cd concentration was higher in *A. caliginosa*, confirming previous findings (Latif et al. 2013) showing higher levels of Cd in the tissues of *A. caliginosa* than *Octolasion lacteum* and *A. rosea (*Fig. 3). Therefore, *A. caliginosa* appears as a better bioindicator candidate for Cd than *A. rosea*.

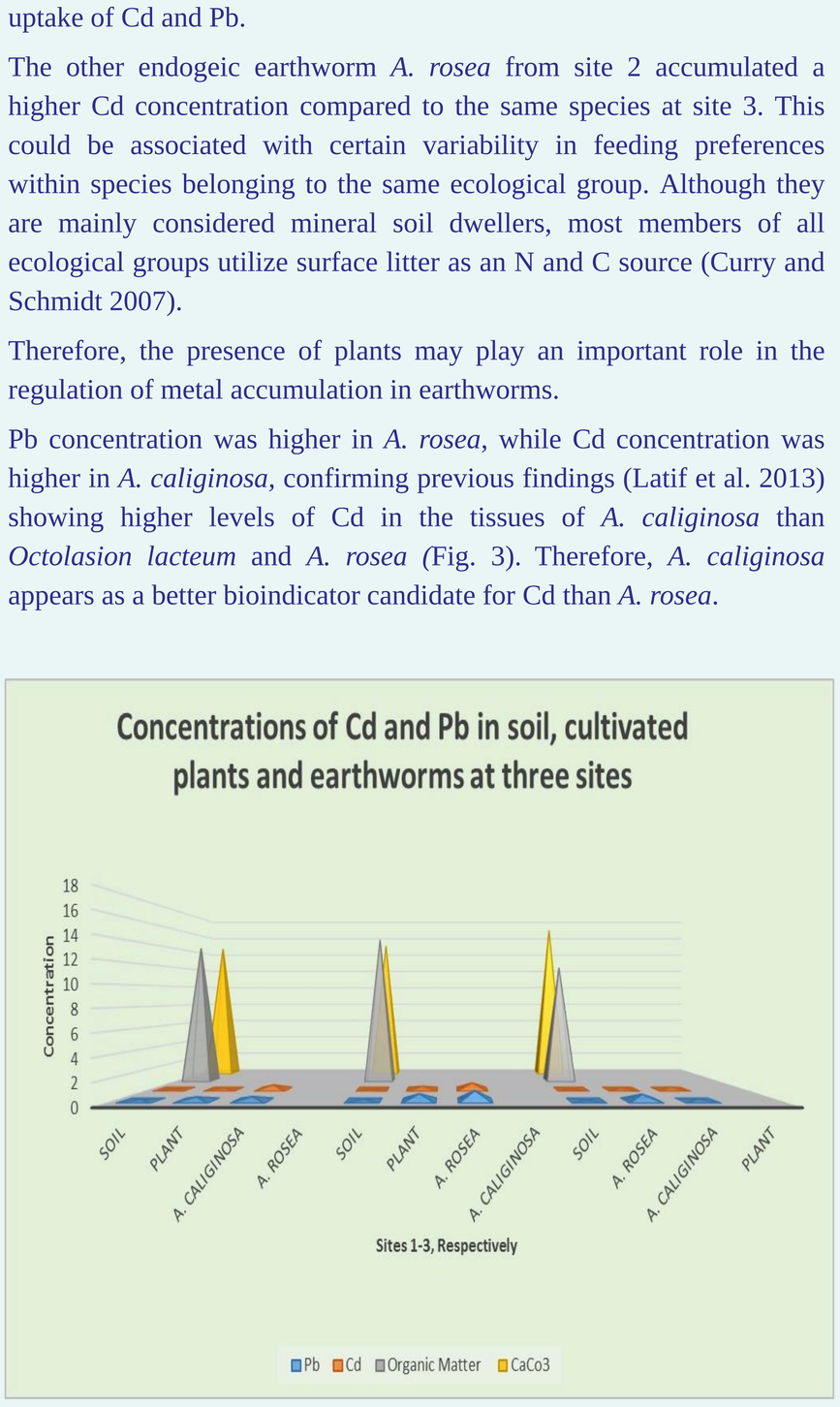

Fig. 3. Concentrations of Cd and Pb

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