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A study on bioaccumulation and translocation of toxic metals in different species of medicinal and aromatic plants

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Abstract:
The aim of this study was to evaluate, in a laboratory study, the accumulation of arsenic (As), cadmium (Cd), nickel (Ni) and lead (Pb) in the root, stem, leaves and flowers of some aromatic and medicinal plants grown on polluted soils. To carry out these experiments, the seeds of different plant species (*Mentha piperita*, *Sinapis alba*, *Satureja hortensis* and *Thymus serpyllum*) were planted in a mini-greenhouse, in universal soil (unpolluted). The seedlings thus obtained were transferred to pots containing soils polluted with metals (As, Cd, Ni and Pb) in different concentrations and combinations. The experiments were carried out over a period of three months. The concentration of metals in different plant organs (root, stem, leaves, flowers) was determined by inductively coupled plasma optical emission spectrometry. (ICP-OES). The accumulation of metals in plants was evaluated by calculating the translocation factor (TF) and the bioaccumulation factor (BCF).

Keywords: BCF, TF, aromatic plants, medicinal plants, ICP-EOS, toxic metals

1. INTRODUCTION

The continuous development of agriculture and industry has led to increasingly serious contamination of the environment with heavy metals. Environmental contamination, especially with heavy metals (such as Cd, Pb, As) that cannot be decomposed by soil microorganisms leads to negative effects on animal and plant organisms [1]. However, they are readily absorbed by plants and can adversely affect plant growth, even in trace amounts [2].

In plants, toxic metals produce nutritional imbalances, reduce the development of plant mass, produce changes in important physiological processes, such as photosynthesis, respiration and transpiration, and ultimately plant death [3]. As these toxic heavy metals accumulate in the food chain, they eventually threaten animal and human health [4]. Most studies have shown that excessive accumulation of heavy metals in the human body can cause cancer and damage to the liver, kidneys, spleen, bones and reproductive system [5].

Cadmium (Cd) is a non-essential element that affects seed germination rate and causes nutritional deficiencies and oxidative stress in plants, leading to stunted growth and even plant wilting [6]. Therefore, there is an urgent need to remediate heavy metal polluted land and reduce heavy metal enrichment in crop plants.

2. MATERIALS AND METHODS

2.1. Materials

Selected seeds of mint (*Mentha piperita*), mustard (*Sinapis alba*), thyme (*Satureja hortensis*) and wild thyme (*Thymus serpyllum*) were planted in mini-greenhouse, in an unpolluted soil (garden substrate). After the appearance of the seedlings, they were moved to pots containing soils contaminated with As, Cd, Ni, Pb in different combinations and concentrations. The pots with seedlings were moved to a greenhouse with an area of 6 m^2, with natural light for 12 hours/day; the plants were watered every day with tap water to maintain a constant humidity of the soil in which they were planted.

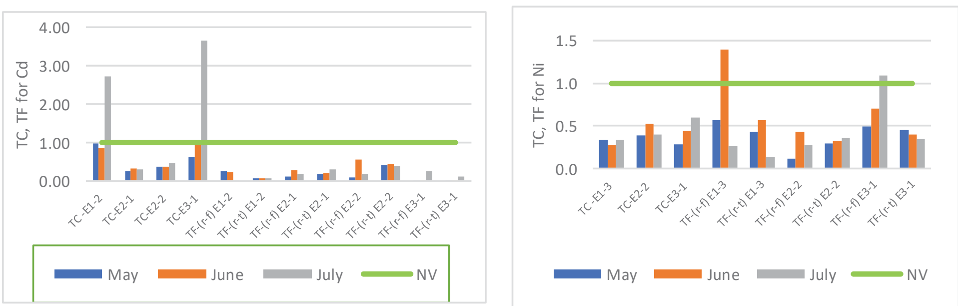
Plants subjected to stress with toxic metals were sampled after each month of the experiment, they were subjected to a digestion process in a microwave system (Milestone Ethos Up) in an acidic environment (mixture of HNO_3 and H_2O_2, ultrapure quality reagents).

2.2. Analysis methods

An optical emission spectrometer with inductively coupled plasma (ICP-EOS Perkin Elmer Avio 500) was used for the detection of the metals. A calibration curve was made in the range 100-500 μg/L using a certified reference material (CRM) with a concentration of 100 mg/L containing the four monitored metals.

3. RESULTS AND DISCUSSION

Bioaccumulation study of some toxic metals (As, Cd, Ni, Pb) in the root, respectively the stem and leaves of mint indicated that As was not found in any organ of the plant, Cd was mainly accumulated in the root (figure 1a), Ni accumulated both in the root and in the stem and leaves (TF 1.09 ÷ 1.39, figure 1b), Pb accumulated more in the root but with values of the transfer coefficient and subunit translocation index [7].



(a) (b)

Figure 1. Bioaccumulation and translocation indices for (a) Cd and (b) Ni in experimental tests on mint

Bioaccumulation study of some toxic metals (As, Cd, Ni, Pb) in aromatic mustard plants led to the following results:

With the exception of Ni, none of the studied metals reached the mustard seeds obtained at the end experiments.

The concentrations of Ni in the mustard seeds resulting from the tests combined with Ni reach values below the phytotoxic value of this metal (30 mg/kg). As remains predominantly in the root and is accidentally found in leaves or sheaths.

Cd is found both in the root and in all the aerial parts, including the grains. The transfer coefficients are high, indicating bioaccumulation in leaves and flowers, respectively TC=2.5 (leaves) and TC=6.7 (flowers).

Pb remains predominantly in the soil and does not bioaccumulate in the root or aerial parts [8].

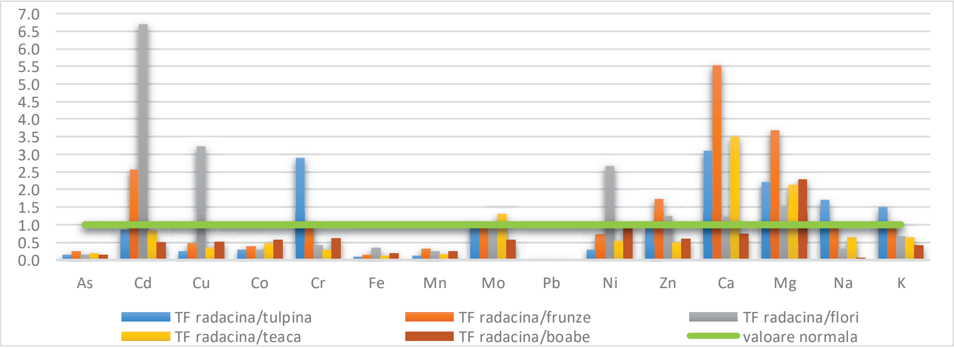


Figure 2. Transfer coefficients from the root to the aerial part in the As + Cd + Ni+ Pb test in the mustard experiment

The study of bioaccumulation and translocation from polluted soil with toxic metals (As, Cd, Ni, Pb) in wild thyme plants showed that for this plant As remains only in the soil, it is not extracted by the root of the plant.

Cd accumulates especially in the root and the stem, but it can also be found in the leaves in low concentrations (figure 3a).

Both Ni and Pb remain only in the root of the wild thyme plants. The bioaccumulation (BCF) and transfer (TF) indices from the root to the aerial parts of the plant indicate bioaccumulation (BCF>1) only for Cd and a transfer of this element from the root to the stem only if it was added in combination with As and Ni (figure 3b).

Ni and Pb do not bioaccumulate and do not transfer from the root to the stem and leaves.

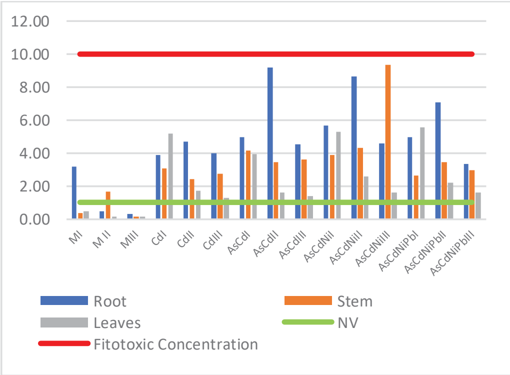


Figure 3a. Cd concentration in wild thyme

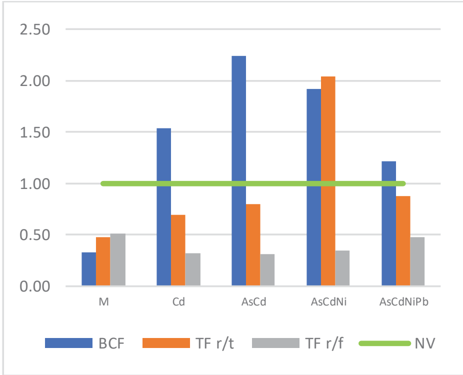


Figure 3b. BCF and TF for Cd in wild thyme

The study of bioaccumulation and translocation from a substrate polluted with toxic metals (As, Cd, Ni, Pb) in the aromatic thyme plant focused on the thyme root, stem, leaves and flowers.

The As accumulated only in the root. Cd accumulated both in the root and in the edible parts of the plant (stem, leaves, flowers) (figure 4a), in all experiments in which it was added exceeding the phytotoxic concentration (10 mg/kg). The Ni was transferred in higher concentrations in the root, but it also bioaccumulated in the other parts of the thyme, exceeding the normal value of this element in plants (5 mg/kg). Pb accumulated in the root and stem of thyme without exceeding the normal concentration of this element in plants (5 mg/kg).

The bioaccumulation (BCF) and transfer (TF) indices from the root to the aerial parts of the plant indicated bioaccumulation (BCF>1) only for cadmium (figure 4b) and a transfer of this element (TF>1) from the root to the leaves only in the experiment in which Cd was added in combination with As. Ni and Pb were not transferred from the root to the stem and leaves.

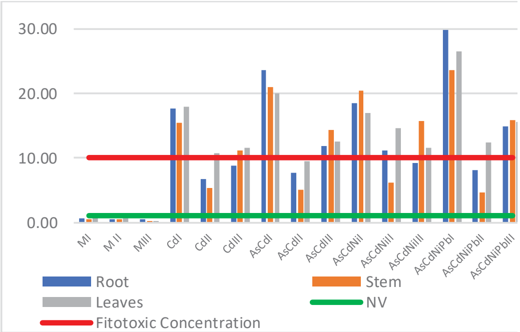


Figure 4a. Cd concentration in thyme

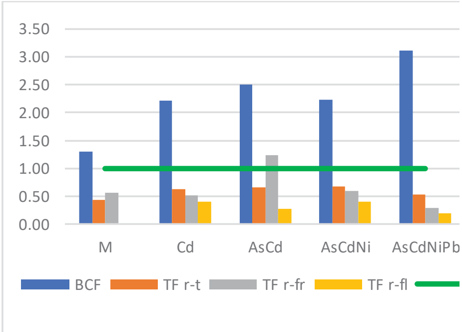


Figure 4b. BCF and TF for Cd in thyme

4. CONCLUSION

This study aimed to evaluate the bioaccumulation potential of some toxic metals in different species of medicinal and aromatic plants with the aim of highlighting the most suitable plant for the decontamination of polluted soils. Although all plant species were grown under the same conditions, they accumulated toxic metals differently in different component parts: mint accumulated Cd predominantly in the root and Ni both in the root and in the stem and leaves; mustard accumulated As in the root and Cd both in the root and in the aerial parts of the plant; wilde thyme accumulated Cd in the root and stem, Ni and Pb remaining only in the root; thyme accumulated Cd in the root and aerial parts and Ni in the root.

The accumulation of metals in plants is influenced by the concentration of metals in the soil, the presence of organic matter, but also by the antagonistic and competitive effects between metals. The high content of organic matter in the soil leads to the immobilization of metals in the soil and, consequently, a decrease in the bioavailability of metals for transfer and translocation in the plant.

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