NUKLEONIKA 2005;50(Supplement 1):S59–S61

Platinum bioaccumulation by mustard plants (*Sinapis alba* L.)

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Abstract The ability of hydroponically cultivated Indian mustard plants (*Sinapis alba* L.) to accumulate platinum was investigated. The Pt-bioaccumulation in leaves, stem and shoots of plants growing for 2 and 4 weeks at Pt-concentration of 50 and 500 μg/L was compared. The relation between dry and fresh weight was also estimated. Adsorptive stripping voltammetry (AdSV) and mass spectrometry with inductively coupled plasma (ICP-MS) were applied for determination of Pt. Increasing Pt-concentration from 50 to 500 μg/L in the medium causes: (1) reduction of the root tissue hydration level at unchanged modification in aboveground parts of the plants and (2) decrease of the Pt transfer factor (TF) for roots and increase for leaves and stem. Duration of the culture influenced on Pt-accumulation in roots and in aboveground organs of mustard plants. Transfer factor for Pt between 560 and 1600 makes Indian mustard plants one at Pt-hyper-accumulators. Distribution of Pt-bioaccumulation in the plant organs may be useful for biomonitoring of platinum in the environment.

Key words bioaccumulation of Pt • biomonitoring • bioremediation • mustard plants • platinum

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Received: 2 August 2005
Accepted: 23 August 2005

Introduction

In the recent years, a new source of platinum release into environment has come about through the use of platinum in catalytic converters. The concentration of this element typically ranges from 300 to 1000 $\mu g \cdot g^{-1}$ [6]. Platinum is a potential marker for traffic [8]. The increased use of platinum group elements (PGEs) in automobile catalyst converters and their emission into environment has led to a concern over environmental and particularly biological accumulation [1]. Samples from plants are useful for the investigation of the impact of platinum because the contaminated plants are found both in urban and rural environments and are at the base of the food chain. Indian mustard plants belongs to the group of Pt-accumulators [3] that fix platinum mainly in roots. From the reason of soil decontamination it is very important to know how: (1) the time of plant cultivation, and (2) concentration of platinum in the medium, influence Pt-bioaccumulation in aboveground and underground organs of plants.

Experimental

The Indian mustard plants (25 to 120 plant samples) were grown in hydroponic cultures in greenhouse for 2 and 4 weeks. Platinum was added to the nutrient solution in the form of $[Pt(NH_3)_4](NO_3)_2$ in concentration of 50 and 500 μg/L. The reagents, apparatus, plant

Table 1. Mean ratio of dry weight to fresh weight [%] of mustard plant organs, depending on Pt-concentration in culture (mean ± $t_{95\%}$ SD)

Pt-concentration in medium [μg/L]	Time of plant cultivating [weeks]	Mean ratio of dry weight to fresh weight [%]		
		Leaves	Stem	Roots
50	4	9.44 ± 0.28	5.15 ± 0.04	3.92 ± 0.71
500	4	13.82 ± 4.00	6.73 ± 1.86	7.41 ± 0.24

cultivation, samples pretreatment, microwave decomposition of the sample, voltammetric determination and ICP-MS determination are described by Kowalska *et al*. [3].

Results

It can be concluded that phytoextraction of platinum by mustard plants may be useful for bioremediation of soils, since the mass of the aboveground parts of plants was much greater than the mass of the roots.

The increase of Pt-concentration in medium from 50 to 500 μg/L does not exert any effect on dry to fresh weight ratio in the aboveground organs of mustard plants but strongly influences this ratio calculated for the roots (Table 1). The dry to fresh weight ratio in roots was two-fold greater at 500 than at 50 Pt μg/L in medium.

TF of platinum was dependent on the time of plant cultivation and on Pt-concentration in medium (Table 2). The highest TF was observed in the case of roots of mustard plants and it decreased after longer plant cultivation as the result of further platinum transport from roots to stem and leaves. The translocation of Pt from roots to aboveground parts of plants was greater at 500 Pt μg/L than at 50 μg/L.

After a two week culture using a 500 Pt μg/L medium, the plants accumulated platinum mainly in roots (Table 3). After next two weeks of culture the per cent distribution of platinum in their organs changed, i.e. the level of Pt was reduced in the roots and increased in the aboveground parts of the plants (stem and leaves). The plants growing for 4 weeks at 50 Pt μg/L had different distribution of Pt than the plants growing at 500 Pt μg/L.

Discussion and conclusions

Previous studies showed that the most od PGEs are accumulated in roots and only a small fraction is metabolised and transported to leaves [4, 5]. In this study, the highest transfer factor was also obtained for Pt in roots of Indian mustard plants (Table 2). The TF between 560 and 1600 makes Indian mustard plant one at the Pt hyperaccumulators. High bioaccumulation of platinum was also observed in roots of *Lolium multiflorum* [5] and in cucumber [7]. In the case of roots, more platinum appeared in the fraction containing water-soluble low molecular mass material of water hyacinths treated with cis platinum $[Pt(NH_3)_2]\ Cl_2$ [2]. From this point of view, the observed decrease of Pt-concentration in roots of mustard plants as the effect of growth of Pt-concentration from 50 to 500 μg/L, may be caused by a decreased root tissue hydration (Table 1). It may be an effect of increasing synthesis of lignin and suberin [5].

Higher transfer of platinum to leaves and stem, observed in Indian mustard plants (Tables 2 and 3), under influence of increased Pt-concentration (from 50 to 500 Pt μg/L) and time of cultivation (from 2 to 4

Table 2. Transfer factor (TF) of platinum from medium to organs of mustard plants depending on plant age and Pt-concentration in medium (mean ± $t_{95\%}$ SD)

Pt-concentration in medium [μg/L]	Time of plant cultivating [weeks]	Transfer factor of Pt		
		Leaves/medium	Stem/medium	Roots/medium
500	2	45.4 ± 0.48	65.2 ± 0.33	1592.2 ± 27.15
500	4	55.6 ± 4.64	61.6 ± 4.47	564.7 ± 5.00
50	4	29.2 ± 0.37	46.4 ± 0.45	921.0 ± 5.67

Table 3. Pt-distribution among leaves, stem and roots in mustard plants depending on age of plants and Pt-concentration in medium (mean ± $t_{95\%}$ SD)

Pt-concentration in medium [μg/L]	Time of plant cultivating [weeks]	Percentage distribution of platinum		
		Leaves	Stem	Roots
500	2	8.0 ± 0.4	5.3 ± 0.2	86.6 ± 2.3
500	4	30.1 ± 1.4	23.0 ± 1.0	46.9 ± 2.3
50	4	14.8 ± 0.1	18.5 ± 0.01	66.7 ± 3.8

weeks), may be result of metabolism or only transport of platinum to be stored in the leaves. The most of platinum in leaves is insoluble and is bound by α-cellulose of cell walls as well as by soluble pectins, proteins and aminoacids [2]. The binding of platinum to carbohydrates, such as sugar alcohols, sugar acids or oligosaccharides in the low molecular mass range was assumed [9].

The proved ability of Indian mustard plants for phytoextraction of the soil platinum points to the possibility to utilise this plant in the soil bioremediation. Greater mass of aboveground parts of this plant than mass of roots makes Indian mustard plants more useful for bioremediation especially of the soils strongly contaminated with platinum. Distribution patterns of the accumulated Pt in Indian mustard organs may be useful for monitoring of platinum in environment.

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