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STUDY ON PHYTO-EXTRACTION BALANCE OF ZN, CD AND PB FROM MINE-WASTE POLLUTED SOILS BY USING *FESTUCA ARUNDINACEA* AND *LOLIUM PERENNE* SPECIES

STUDIUL BILANTULUI FITOEXTRACTIV AL ZN, CD SI PB DIN SOLURI POLUATE CU STERIL DE MINA IN CAZUL UTILIZARII SPECIILOR DE FESTUCA ARUNDINACEA SI LOLIUM PERENE

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Through the cultivation of tall fescue (Festuca arundinacea) and of perennial ryegrass for two years on a chernozem type of soil, in the Banat's plain area we investigated the phyto-extraction potential of Zn, Cd and Pb. In the experimental plot it has been incorporated a quantity of 20 kg of mine-waste per square meter, in a mass ratio of 1:2,5. The mine-waste polluting "contribution" was of 1209 mg Zn / kg d.s., 4.70 mg Cd / kg d.s. and 188.2 mg Pb / kg d.s. The metals content in the soil was determined at the two moments of biomass harvesting, and through balance calculations we could establish the phyto-extraction efficiency of the two forage-grasses species. The obtained results indicate that Festuca arundinacea has an average phyto-extraction yield of 50% for Zn and Cd in the soil; in the case of an ionic excess of 3,5 to 4 times, the phyto-extraction efficiency is reduced, more obvious in the case of Pb (lead) ions. The species Lolium perenne registers a yield of almost 92% in the process of phyto-extraction of Zn. The yield values for Cd si Pb are lower, but comparable with the control plot. Unlike Festuca arundinacea, the Lollium perenne species tolerates better the Cd and Pb ionic excess.
Keywords: tall fescue, perennial ryegrass, phyto-extraction, zinc (Zn), cadmium (Cd), lead (Pb)

Introduction

The studies on the phytoremediation of polluted soils have revealed plant species or specific biocoenoses which possess an increased potential of adaptation to metals polluting the soil, such as Zn, Cd, Cu, Ni etc.

These plants can be found together forming very well adapted ecotypes or endemic phytocoenosis. The degree of adaptation to metal ions excess has two physiological and morphological sources. The first adaptation form may arise from

the specific self-protecting mechanisms of the radicular system, which reduces the absorption of toxic metals in the radicular cells. Despite having a reduced potential for phyto-extraction, these species can be used in the phytoremediation process as soil-stabilizers against the wind-generated erosion occurring at the surface of the mine-waste pile. Based on this, these species are very important in the early stages of the primary ecological succession for the gain of biomass incorporated in the mine-waste.

The second adaptation form is that of hyper-accumulating plants which, lacking the self-protection mechanism of the rhizosphere, posses cellular detoxification mechanisms with the purpose of protecting the plant from the large amounts of metals bio-accumulated in the aerial tissues.

Biomass production per surface unit is a biological factor which restricts the phyto-extraction efficiency. Thus, it has been observed that the extraction of 400 kg of metals / ha / year would require a biomass production of 100 tones of green mass / ha / year. Nevertheless, plant species with metals hyperextraction and hyperaccumulation potential have a slow growth and a reduced biomass yield per hectare. Therefore, in the phyto-extraction and phytoremediation research it is still imperative to establish technologies for cultivating species with both an elevated phyto-extraction potential and with large biomass yield, which in the end would allow achieving high phyto-extraction efficiency.

The goal of this research was the analysis of the phyto-extraction potential of the species Festuca arundinacea – tall fescue, and Lolium perenne – perennial ryegrass.

Materials and Methods

In the research plots of the disciplines of Fodder Cultures and Ecology from the USAMVB Timişoara in the last two years it has been tested the Zn, Cd and Pb phyto-extraction potential of the species Festuca arundinacea and Lolium perenne.

The plots surface was 3 sq m. The experimental plot contained 20 kg of mine-waste per square meter; the mine-waste originated from the Copper Exploitation Factory in Moldova Nouă, Caraş-Severin County. The chemical composition of the mine-waste was as follows: Cu – 669 mg / kg d.s., Zn – 610 mg / kg d.s., Mn – 676 mg / kg d.s., Cd – 2,76 mg / kg d.s. and Pb – 10 mg / kg d.s. The mine-waste bedding thickness per surface unit was about 8 cm, and through agro technical processing was incorporated at a depth of about 20 cm, resulting in a final mass ratio between mine-waste and soil of 1: 2,5.

In the first year we cultivated tall fescue, and in the second year the perennial ryegrass. Before each sowing we determined the Zn, Cd and Pb content in the soil, determining the polluting “contribution” of the mine-waste. The analysis of metal quantity accumulated in the plants was made through two harvests. At the last mowing, the average sample also contained samples from the radicular system. Through balance calculations we could establish the metal quantity extracted each year by the two fodder plant species; in the end we also determined the phyto-

extraction efficiency. The chemical analyses have been performed through spectrophotometry in the Technological Research Platform of USAMVB Timişoara.

Results and Discussion

In Table 1 there are presented the results of the phyto-extraction of metals from the soil, through cultivation of the species Festuca arundinacea.

Table 1

Metal phyto-extraction balance for the species Festuca arundinacea

Metal pollutants	Regulated maximum limit of heavy metals in soil	Control parcel					Experimental parcel				
		Amount of metals at the beginning of the experiment (mg / kg d.s.)	Extracted amount (mg / kg d.s.)			Phyto-extraction efficiency (%)	Amount of metals at the beginning of the experiment (mg / kg d.s.)	Extracted amount (mg / kg d.s.)			Phyto-extraction efficiency, (%)
			I-st harvest	II-nd harvest	Total			I-st harvest	II-nd harvest	Total	
Zn	300	67,80	20,04	19,26	39,30	57,96	1209.0	214.50	290.40	504.90	41.76
Cd	3	0,90	0,31	0,46	0,77	85,55	4.70	Sld	0.55	0.55	11.70
Pb	50	30,00	2,31	3,11	5,42	18,06	188.20	2.46	5.44	7.90	4.19

It can be ascertained that the soil form the control plot had a metal concentration bellow the maximum regulated limit. In the experimental plot, the maximum level was exceeded by 4 times by Zn, 1,5 times by Cd and over 3,7 times by Pb.

In the case of cultivating tall fescue on a soil with moderate metal quantities, the plants of this species register high Cd phyto-extraction efficiency, followed by Zn, whereas Pb phyto-extraction efficiency is 2-4 times smaller.

On the plot with polluted soil there have been recorded massive Zn bioaccumulations at both harvests: 10-12 times more Zn compared to the control plot. From the analysis of the phyto-extraction balance results that the best efficiency is achieved, in order, by Zn, Cd, and Pb. Therefore, in conditions of excessive Zn, Cd and Pb concentrations in the soil, the tall fescue plants extract Zn ions best; this means tall fescue possesses a good tolerance capacity for this metal's toxicity. The Cd and Pb phyto-extraction efficiency has lower values, similar to the control plot.

The results of metals bioaccumulation through the cultivation of perennial ryegrass (Lolium perenne) are presented in Tabel 2.

Table 2

Metal phyto-extraction balance for the species Lolium perenne

Metal pollutants	Regulated maximum limit of heavy metals in soil	Control parcel					Experimental parcel				
		Amount of metals at the beginning of the experiment (mg / kg d.s.)	Extracted amount (mg / kg d.s.)			Phyto-extraction efficiency (%)	Amount of metals at the beginning of the experiment (mg / kg d.s.)	Extracted amount (mg / kg d.s.)			Phyto-extraction efficiency (%)
			I-st harvest	II-nd harvest	Total			I-st harvest	II-nd harvest	Total	
Zn	300	28,50	22,34	16,96	39,30	+ 100	704,1	273,21	371,51	644,72	91,56
Cd	3	0,13	0,36	0,41	0,77	+ 100	4,15	0,10	0,63	0,73	17,60
Pb	50	24,58	1,07	3,33	4,40	17,90	180,3	12,03	11,84	23,87	13,23

It can be ascertained that on the soil from the control plot, the ryegrass extracts the entire Zn and Cd quantities, whereas the Pb extracted quantity is only 18%.

In the case of the plot with mine-waste, the quantities of studied metals were 24 times higher for Zn, 31,9 times higher for Cd and 7,33 times higher for Pb. In these conditions the ryegrass extracts significant quantities of Zn and Pb and smaller quantities of Cd, at both harvests. Thus, the total amount of extracted Zn was 16,4 times higher and the amount on Pb only 5,42 times higher. Moreover, in the case of Pb ionic excess of over 3 times above the regulated limits, the plants of Lollium perenne achieved lower phyto-extraction efficiency compared to the control plot. This result indicates that the species Lollium perenne has a lower tolerance capacity for this metal's toxicity.

A totally different situation can be observed in the bioaccumulation and tolerance capacity for zinc (Zn). Whereas on soils with normal zinc concentrations the ryegrass performs a total extraction, in the case of a ionic concentration of about 2,5 times above the regulated values, this species reaches a high phyto-extraction efficiency, of almost 92%.

Comparing the results of the two plant species, it can be ascertained that Lollium perenne achieves a Zn phyto-extraction efficiency 2,9 times higher than Festuca arundinacea. In the case of Pb ions, both species have a smaller tolerance capacity, which decreases proportionally with concentration growth, more obviously at tall fescue.

In the case of a mix of mine-waste (from copper mine-waste) with chernozem type soil in a mass-ratio of 1:2,5, after which the Zn, Cd and Pb levels grew by 2,34, 1,88 and 3,6 times respectively, the species Lolium perenne records a Zn phtyto-extraction efficiency of almost 92%. The Cd and Pb phyto-extraction levels are smaller, but comparable with the ones from the control plot. This means that, unlike the species Festuca arundinacea , the Lolium perenne species has a better tolerance for the Cd and Pb ions excess.

We emphasize that in both plant species the biomass production per hectare was normal, typical for the pedological and climatic conditions from the experiment's ecological area.

Conclusions

1. *Festuca arundinacea* has, on average, a Zn and Cd phyto-extraction efficiency of 50%. In the conditions of an ionic excess of over 3.5 – 4 times, the phyto-extraction of the three metals is decreased, more obviously in the case of Pb.
2. From the soils with small Zn and Cd concentrations the perennial ryegrass (*Lolium perenne*) extracts these ions totally. In the case of a Zn concentration 2.34 times higher than the regulated maximum, the species *Lolium perenne* records a Zn phyto-extraction efficiency of 92%, which proves a very good tolerance for this metal.
3. Compared to *Festuca arundinacea*, at values 1.88 times bigger than the regulated maximum for Cd and 3,6 times for Pb, the species *Lolium perenne* tolerates better these metals excess.

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