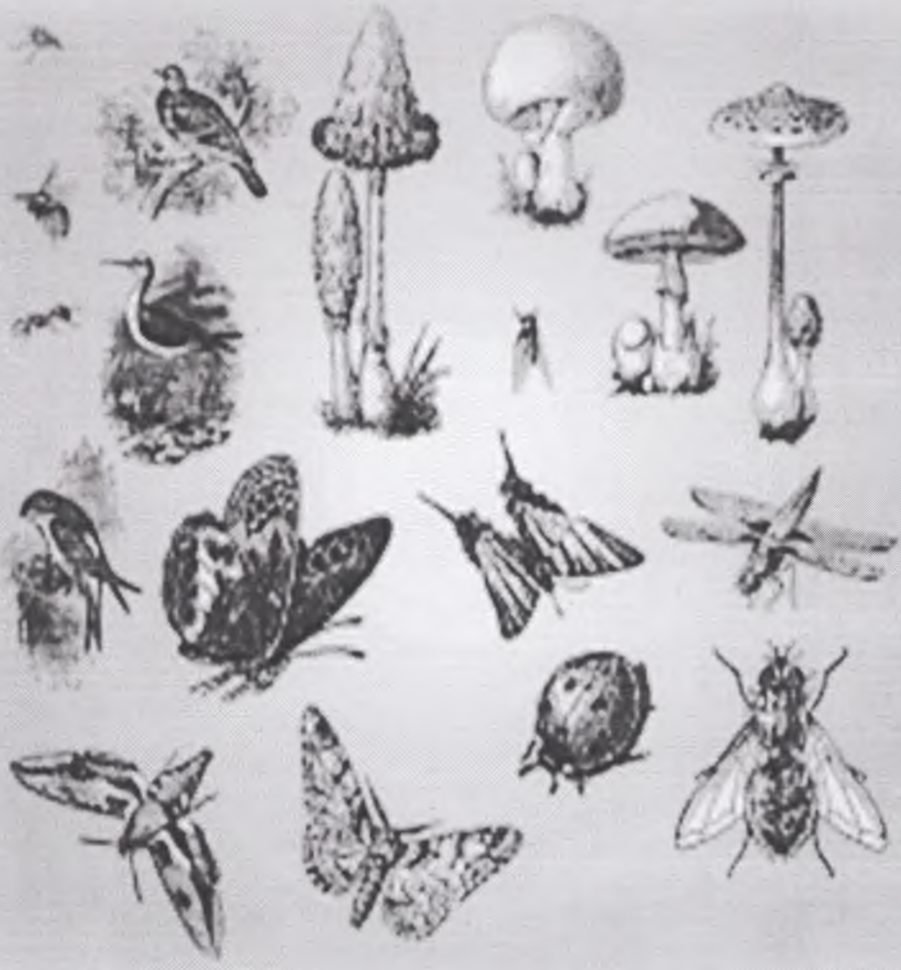
UKRAINIAN JOURNAL OF ECOLOGY



2018, 8(2)

JOURNAL OF BIOLOGY
FOUNDED IN 2011

Research Notes

Review article

Since April 2018 Journal changed the editorial policy and starts to be published exclusively in English, and changed its main site into www.ujecology.com

Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2018, 8(2), 294-300 doi: 10.15421/2018_341

ORIGINAL ARTICLE *UDC 631.453:633.31/.37*

Effect of bean perennial plants growing on soil heavy metal concentrations

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Received: 20.02.2018. Accepted: 07.04.2018

The results of researching the effectiveness of growing legumes perennial plants as natural constraints of heavy metals in the soil, in particular lead, cadmium, copper and zinc, as well as the change in the concentration of heavy metals in the soil and the total index of soil contamination by heavy metals have been presented. It was ascertained that during the two-year growth of legumes perennial plants in the soil decreased the concentration of lead by 3.4-74.6%, cadmium - by 16.7-96.7%, copper - by 1.5-11.8%, zinc - by 27.5-69.2%. The highest efficiency of reducing the concentration of lead, cadmium, copper and zinc in the soil was observed because of growing Onobrychis arenaria. During the four-year-long growth of legumes, perennial plants in the soil a decrease in lead concentration has been revealed by 39.0–74.6%, cadmium - by 96.7–98.3%, copper - by 94.1–98.5%, zinc by 73.6–90.1%. The highest efficiency of reducing the concentration of lead in the soil was observed while cultivating Onobrychis arenaria, cadmium, copper and zinc - Alfalfa lucerne, Onobrychis arenaria, Lotus corniculatus and galega oritntalis.
Key words: bean perennial grasses; heavy metals; pollution; concentration.

Introduction

Heavy metals include chemical elements with an atomic mass more than 40 and a density more than 5 g / cm^3, which have properties of metals (Sauve et al., 2000). The notion of "heavy metals" conventional, because this group includes copper, zinc and other elements that have a positive biological significance, they are called trace elements, but when they are accumulated above the permissible limit, they can be toxic and activate or, conversely, block biochemical processes in living organisms. Of particular concern are heavy metals, in particular Zn, Cu, Pb and Cd (Yang et al., 2002, 2004).

It is known that heavy metals in the soil may be in various forms of solubility and mobility, namely: insoluble, which are part of the soil minerals; exchanges that are in a dynamic equilibrium with the ions of the metal in the soil solution; actuated and soluble forms. Between them there is not only a close relationship, but also the possible transformation of some forms into others. Actuated metal forms can be accumulated in the soil in large concentrations what causes their toxicity for both soil biota and plants (Grodzinska et al., 2001, Hall et al., 2002).

Thus, it has been determined that lead and copper, in comparison with other heavy metals, are less mobile and are mainly accumulated in the upper horizons of the soil (Harris et al., 2001; He et al., 2005).

Important factors influencing the mobility of Zn in soils are the content of clay minerals in them and the pH value. With increasing pH the element passes into organic complexes and binds to the soil. The mobility of cadmium in the soil depends on the environment and oxidation-reducing potential. Cadmium contamination of soil cover is considered one of the most dangerous ecological phenomena, since it is accumulated in plants above the norms, even with low soil contamination (Kirkham et al., 2006, Kosobrukhov et al., 2004).

It is also necessary to take into account that plants absorb different metals in different ways, for example, lead, even in high concentrations in the soil, is in weakly soluble compounds and therefore its level in the plant will be less (Proctor et al., 2009; Souza et al. 2003).

Zinc is highly accumulated by plants and contained in them; copper, and cadmium are weakly accumulated and strongly held; lead is weakly accumulated and poorly kept in plants (Stolt et al., 2003; Wójcik et al., 2005).

To estimate soil contamination, the technogenic concentration coefficient K_c is used, which characterizes the ratio of the real content of a chemical element in the soil C_a to the background content of the same element of C_ϕ in the environment. The value of K_c indicates the activity of leaching processes (K_c <1) and the accumulation (K_c > 1) of chemical elements in the soil (Conn et al., 2010; Davis et al., 2007).

The results of studies on the influence of heavy metals on clover plants showed that the content of heavy metals in plant material exceeds the limit-permissible concentrations, which indicates a high level of accumulation of metal ions. During the studied period, the intensity of accumulation of Zn ions in plants decreases, while for Cu the coefficient of biological absorption increases. This can be explained by the process of adaptation of trifolium pratense to the conditions of growth, and, as a consequence, an increase in the level of biological resistance of the plants to contamination. The property of the clover to accumulate heavy metals can be used as one of the methods of phyto monitoring and phytoremediation of the environment (Foyer et al., 2005; Gechev et al., 2002).

The urgency of the question of shaping the degree of soil contamination by heavy metals is determined by the fact that they enter the human body, mainly from plant food, the accumulation of these elements in it occurs mainly through the soil. Heavy metals out of a human body are exterminated very slowly and capable of accumulation in the kidneys and the liver, taking into consideration that plant products, even from slightly polluted areas, can cause the cumulate effect - a gradual increase in the content of heavy metals in the human body. Therefore, determining the concentration of heavy metals in soils becomes important (Clemens et al., 2006; Cobbett et al., 2000).

Material and methodology of researches

Field research was conducted in the conditions of the scientifically-research enterprise "Agronomic" of Vinnytsia National Agrarian University. The effectiveness of reducing heavy metals by growing six types of legumes of perennial plants: alfalfa lucerne (*Medicago sativa*), red clover (*Trifolium pratense* L.), esophagus (*Onobrychis arenaria* L.), yellow sweetclover (*Melilotus albus* L.), leguminosae (*Lotus corniculatus* L.) and eastern galega (*Galega oritntalis* L.). Bean perennial plants were sown in 2013 in a non-obtrusive way in the early spring. Before planting on the experimental plot, the soil was calcined to bring the reaction of the soil solution to a neutral pH of 7.0.

The soil on the experimental plot is gray forest, medium-grained. The agrochemical composition of the soil of the experimental site is characterized by the following indicators: humus content – 2.0%, nitrogen easily hydrolyzed (according to Cornfield) – 13.3 mg / 100 g soil - low, mobile phosphorus (according to Chirikov) – 39.0 mg / 100 g soil - very high, exchangeable potassium (according to Chirikov) – 6.4 mg / 100 g soil - medium, calcium – 12.6 mg / 100 g soil - sufficient, hydrolytic acidity 0.53 mg equivalents / 100 g soil, reaction of soil solution pH 7.0 - neutral.

Repeated trials have been conducted four times. The accounting area of each plot area is 50 m2, the total area of the plot is 70 m2. Variants in the experiment are systematically placed in 6 blocks.

Laboratory research was carried out in certified and accredited laboratories: Testing center of Vinnitsa branch of the State Institution «State Crop Protection» of the Institute of Soil Conservation of Ukraine of the Ministry of Agrarian Policy and Food of Ukraine and the Scientific and Measuring Agrochemical Laboratory of the Department of Environment and Environmental Protection of Vinnytsia National Agrarian University of the Ministry of Agrarian Policy and Food of Ukraine and the Ministry of Education and Science of Ukraine.

The concentration of heavy metals such as lead (Pd), cadmium (Cd), copper (Cu) and zinc (Zn) by atomic absorption method was determined in the soil (DSTU 4770.1:2007). Sampling of soil was carried out by «envelope method». The tests were carried out prior to the cultivation of herbs, before growing herbs after liming the soil, after two and four years of herb cultivation. The obtained parameters of the concentration of heavy metals were compared with the maximum permissible concentrations of heavy metals in Ukraine.

Results of research and their discussion

Before sowing herbs, the concentration of lead in the soil was 1.7 mg / kg of soil. An increase in the concentration of lead in the soil to 5.9 mg / kg is due to the introduction of limestone material - defecet, as well as preliminary introduction of mineral fertilizers into the experimental site.

Two years of cultivation of *Onobrychis arenaria* contributes to a decrease in the concentration of lead in the soil by 74.6%, *Lotus corniculatus* - by 61.0%, *Trifolium pratense* - by 49.2%, *Melilotus albus* - by 39.0%, Alfalfa lucerne - by 3.4 % At the same time, the concentration of lead in the soil after two years of growth of *Galega oritntalis* has not changed (Table 1).

The maximum permissible concentration of lead in the soil is 6.0 mg / kg. Two-year cultivation of *Onobrychis arenaria* allows to reduce the concentration of lead in the soil by 75.0% less than MAC, *Lotus corniculanus* - by 61.7%, *Trifolium pratense* - by 50.0%, *Melilotus albus* - by 40.0%, *Alfalfa lucerne* - by 5.0% and *Galega oritntalis* - 1.7% less than MAC.

Table 1. Concentration of heavy metals in the soil after the growth of legumes perennial grasses, mg / kg

A kind of legumes of perennial herbs	Year of plants vegetation	Lead	Cadmium	Copper	Zinc
Before growing herbs	×	1.7	0.08	5.4	6.0
Before growing herbs after liming the soil	×	5.9	0.60	6.8	9.1
Alfalfa lucerne	2	5.7	0.05	6.8	9.1
	4	3.6	0.02	0.1	1.1
Trifolium pratense	2	3.0	0.03	6.7	6.6
Onobrychis arenaria	2	1.5	0.02	6.0	2.8
	4	1.5	0.01	0.4	2.4
Melilotus albus	2	3.6	0.60	6.4	4.3
Lotus corniculanus.	2	2.3	0.50	6.6	4.0
	4	3.4	0.01	0.2	0.9
Galega oritntalis	2	5.9	0.60	6.5	5.4
	4	2.6	0.01	0.1	1.1

The concentration of lead in the soil after two years of growing legumes perennial grasses was 1.5 - 5.9 mg / kg. The smallest concentration of lead was in the soil after growing *Onobrychis arenaria* - 1.5 mg / kg. The cultivation of a hare catcher leads to a concentration of lead in the soil by 34.8% higher than in the soil after the growth of Onobrychis arenaria, trifolium pratense - by 50.0%, Melilotus albus - by 58.4%, Alfalfa lucerne - by 73.7%, and Galega oritntalis - at 74,6% higher than after cultivating onobrychis arenaria.

Two-year cultivation Onobrychis arenaria helps to reduce the concentration of cadmium in soil by 96.7%, Trifolium pratense - by 95.0%, Alfalfa lucerne - by 91.7%, Lotus corniculatus - by 16.7%. At the same time, the growth of Melilotus albus and Galega oritntalis does not change the concentration of cadmium in the soil compared with the period before the cultivation of herbs.

The maximum permissible concentration of cadmium in the soil is 0.70 mg / kg. The cultivation of Onobrychis arenaria makes it possible to reduce the concentration of cadmium in the soil by 97.2% less than the MPC, Ttrifolium pratense - by 95.7%, Alfalfa lucerne - by 92.9%, Lotus corniculanus - by 28.6%, the Melilotus albus and Galega oritntalis - by 14,3% less than the maximum permissible concentration.

Concentration of cadmium in the soil after the growth of legumes perennial grasses was 0.02 - 0.60 mg / kg. The lowest concentration of cadmium in the soil was detected after the growth of the sainfoin, by 33.3% higher - after the growth of Trifolium pratense, by 60.0% - after Alfalfa lucerne, 96.0% - Lotus corniculanus and 96.7% higher - after Galega oritntalis and Melilotus albus.

After two years of cultivation of the espresso, the concentration of copper in the soil decreased by 11.8%, Melilotus albus - by 5.9%, Galega oritntalis - by 4.4%, Lotus corniculanus- by 3.0%, and Tritolium pratense by 1.5% less, compared to the soil before growing legumes perennial grasses.

Compared with the maximum permissible concentration of copper in the soil - 3.0 mg / kg, the soil after the cultivation of all beans perennial grasses had an exceeded permissible levels for copper. In particular, after cultivation of sauerkraut - by 50.0%, Melilotus albus - by 53.1%, Galega oritntalis - by 53.9%, Lotus corniculanus - by 54.6%, Tritolium pratense - by 55.2%, and Alfalfa lucerne - 55.9% higher than the MPC.

Concentration of copper in the soil after growing legumes perennial plants was 6.0 - 6.8 mg / kg. Copper in the soil at the same time is a trace element and a toxic heavy metal. The lowest concentration of copper in the soil was established after growing Lotus corniculanus - 6.0 mg / kg. A 6.3% higher concentration of copper was found in the soil after the growth of melilotus albus, 7.7% higher - after galega oritntalis L., 9.1% - lotus corniculanus, 10.5% - trifolium pratense and 11.8% - after growing alfalfa lucerne.

Two-year cultivation of onobrychis arenaria resulted in a decrease in the concentration of zinc in the soil by 69.2% compared with the period before the cultivation of herbs. Growth of Lotus corniculanus - by 56,0%, melilotus albus - by 52,8%, galega oritntalis - by 40,7%, tritolium pratense - by 27,5% reduced the concentration of zinc. At the same time, the concentration of zinc in the soil after growing alfalfa did not change compared with the period before the cultivation of herbs.

Concentration of zinc in the soil after growing legumes perennial grasses was 2.8 - 9.1 mg / kg with MAC 23.0 mg / kg. The lowest concentration of zinc in comparison with the maximum permissible concentration was found in the soil after growing the sainfoin, which was 12.2% of the MPC, after the growth of Lotus corniculanus - 17.4%, melilotus albus - 18.7%, galega oritntalis - 23, 5%, trifolium pratense - 28.7%, and alfalfa lucerne - 39.6% of the value of the MPC.

The lowest concentration of zinc in the soil was observed after growing onobrychis arenaria - 2.8 mg / kg. A higher concentration of 30% was detected in the soil after the growth of Lotus corniculanus, 34.9% after a melilotus albus, 48.2% for galega oritntalis, 57.6% for trifolium pratense and 69.2% higher after growing alfalfa lucerne.

Summing up the results of studying the effects of biennial bean perennial plants on the concentration of heavy metals in the soil, it should be noted: the biennial cultivation of onobrychis arenaria mainly reduces the concentration of lead, cadmium, copper and zinc; the least reduces the concentration in the soil of Alfalfa lucerne and Galega oritntalis; cadmium - melilotus albus and galega oritntalis; copper - alfalfa lucerne and trifolium pratense; zinc - Aalfalfa lucerne; reducing the concentration of lead in the soil after two years of growing legumes perennial plants occurs in the following sequence (from the largest to the smallest): Alfalfa lucerne, Trifolium pratense, Onobrychis arenaria, Melilotus albus, Lotus corniculanus, Galega oritntalis; cadmium concentration: Alfalfa lucerne, Trifolium pratense, Onobrychis arenaria, Melilotus albus, Lotus corniculanus, Galega oritntalis; concentrations of copper: Alfalfa lucerne, Trifolium pratense, Onobrychis arenaria, Melilotus albus, Lotus corniculanus, and Galega oritntalis; zinc concentration: Alfalfa lucerne, Trifolium pratense, Onobrychis arenaria, Melilotus albus, Lotus corniculanus, and Galega oritntalis.

After four years of vegetation of onobrychis arenaria the concentration of lead in the soil decreased by 74.6%, galega oritntalis - by 55.9%, lotus corniculanus - by 42.3%, alfalfa lucerne - by 39.0%.

The concentration of lead in the soil after the growing of onobrychis arenaria was 75.0% lower than the MPC, after Galega oritntalis - by 56.7%, Lotus corniculanus - by 43.3%, Alfalfa lucerne - by 40.0% lower than the MPC.

The actual concentration of lead in the soil after the cultivation of onobrychis arenaria was the lowest and was 1.5 mg / kg, after Galega oritntalis - 42.3% higher, after Lotus corniculanus - 55.9% and after Alfalfa lucerne - 58.3% more.

In the four years of vegetation, the eastern concentration of lead in the soil in the soil, compared with the two-year cultivation decreased by 55.9%, and the alfalfa lucerne - by 36.9%. At the same time, the concentration of lead in the soil after four years of growing onobrychis arenaria did not change, compared with the two-year term, and after the growth of lotus corniculanus - increased by 32.4%.

The four-year cultivation of onobrychis arenaria, the hare catcher and Galega oritntalis reduces the concentration of cadmium in the soil by 98.3%, and the alfalfa of the seedlings - by 96.7%.

Cultivation of Onobrychis arenaria, Lotus corniculanus and Galega oritntalis reduced the concentration of cadmium in the soil to a level of 1,4% of its maximum permissible concentration, and alfalfa lucerne - up to 2.9% of the MPC.

The lowest concentration of cadmium in the soil was established after the growth of onobrychis arenaria, the Lotus corniculanus and galega oritntalis - 0,01 mg / kg, and after the alfalfa of the sowing - by 50,0% higher - 0,02 mg / kg.
The four-year cultivation of Alfalfa lucerne and Galega oritntal is reduces the concentration of copper in the soil by 98.5%, Lotus corniculanus- by 97.1%, and Onobrychis arenaria - by 94.1%.
Concerning the maximum permissible concentration of copper in the soil, the cultivation of alfalfa of the seed and galega oritntalis reduces its concentration by 96.7% relative to the MPC, Lotus corniculanus- by 93.3%, onobrychis arenaria - by 86.7% less than the MPC.
The actual concentration of copper in the soil after the cultivation of alfalfa and Galega orientalis was 0.1 mg / kg, after raising Lotus corniculanus- by 50.0% higher, Onobrychis arenaria - by 86.7% higher.
Compared to the two-year cultivation of Alfalfa lucerne and Galega oritntalis, their four-year cultivation reduces the concentration of copper in the soil by 98.5%, Lotus corniculanus- by 97.0%, sauerkraut - by 93.3%.
For four years, the growth of the Lotus corniculanusconcentration of zinc in the soil has decreased by 90.1%, galega oritntalis and alfalfa lucerne - by 87.9%, onobrychis arenaria - by 73.6%.
Concentration of zinc in the soil after the growth of Lotus corniculanuswas 96.1% lower than the MPC, alfalfa and galega oritntalis - 95.2%, and onobrychis arenaria - by 89.6% lower than the MPC.
The actual concentration of zinc in the soil after the growth of lotus corniculanus was 0.9 mg / kg, after sowing alfalfa lucerne and galega oritntalis was 18.2% higher, after onobrychis arenaria- 62.5% higher.
In the four years of cultivating alfalfa lucerne, compared with the two-year period, zinc concentrations in the soil decreased by 87.9%, galega oritntalis - by 79.6%, lotus corniculanus - by 77.5%, and onobrychis arenaria - by 14.3%.
Summarizing the results of studies on the effects of four-year-old bean perennial grasses on the concentration of heavy metals in the soil, it should be noted: the growth of the removal of heavy metals from the soil compared to the two-year cultivation date: the lead - in 1.6-2.3 times; cadmium - in 2-60 times; copper - in 15-68 times; zinc - in 1.2-8.3 times; the cultivation of Onobrychis arenaria contributes to the largest removal of lead and cadmium from the soil, but the smallest - copper and zinc; the cultivation of Aalfalfa lucerne contributes to the largest removal from the soil of copper, but the smallest - lead and cadmium; the cultivation of Galega oritntalis helps the largest removal of cadmium and copper from the soil; the cultivation of a hare catcher leads to the largest withdrawal of cadmium and zinc from the soil; an increase in the length of the growth of galega oritntalis milk helps to significantly accelerate the removal of lead and cadmium from the soil; Alfalfa lucerne - copper and zinc; Lotus corniculanus - cadmium, copper and zinc. These grasses belong to the group of durable, therefore their positive effect on the soil manifests itself after prolonged cultivation. At the same time, the long-term cultivation of a hare catcher leads to an increase in the concentration of lead in the soil, and Onobrychis arenaria - reduces the concentration of copper, zinc and cadmium in the soil less intensively, since the espresso belongs to the annual herbs, which at four years of age are suppressed, liquefied and fall from the grass.
The ratio of the actual concentration of heavy metal in the soil to the maximum permissible concentration of this element is determined by the coefficient of concentration, calculated by the formula:
$K_c = C / MAC$, where: K_c - coefficient of concentration of heavy metal in the soil; C - actual concentration of heavy metal in the soil, mg / kg; MAC - the maximum permissible concentration of heavy metal in soil, mg / kg.
The smaller the concentration ratio of heavy metals in the soil, the better conditions are for the cultivation of agricultural plants. At the same time, the concentration factor of less than one indicates the safe environmental conditions of the soil.
The concentration of lead in the soil to the grass seed was 0.29. The liming of the soil resulted in an increase in the concentration of lead by 70.7% to a value of 0.99 (Table 2).

Table 2. Coefficient of concentration of heavy metals in the soil after the cultivation of legumes perennial plants

A kind of legumes of perennial herbs	Year of plants vegetation	Lead	Cadmium	Copper	Zinc	Total pollution indicator
Before growing herbs	×	0.29	0.12	1.80	0.26	- 0.53
Before growing herbs after liming the soil	×	0.99	0.86	2.27	0.40	1.52
Alfalfa lucerne	2	0.95	0.08	2.27	0.40	0.70
	4	0.60	0.03	0.04	0.05	- 2.28
Trifolium pratense	2	0.50	0.05	2.24	0.29	0.08
Onobrychis arenaria	2	0.25	0.03	2.00	0.13	- 0.59
	4	0.25	0.02	0.14	0.11	- 2.48
Melilotus albus	2	0.60	0.86	2.14	0.19	0.79
Lotus corniculanus	2	0.39	0.72	2.20	0.18	0.49
	4	0.57	0.02	0.07	0.04	- 2.30
Galega oritntalis	2	0.99	0.86	2.17	0.24	1.26
	4	0.44	0.02	0.04	0.05	- 2.45

The two-year cultivation of onobrychis arenaria decreased the concentration of lead in the soil by 74.8%, the lotus corniculanus - by 60.6%, trifolium pratense - by 49.5%, melilotus albus - by 39.4%, the alfalfa lucerne by sowing - by 4.0 %, and after raising galega oritntalis it did not change.
The lowest concentration of lead concentrations in the soil was after the cultivation of onobrychis arenaria - 0,25, after lotus corniculanus - by 35.9% higher, trifolium pratense - by 50.0%, melilotus albus - by 58,3%, alfalfa lucerne - by 73.7%, and after cultivation of galega oritntalis - by 74.8% higher than after cultivating the onobrychis arenaria.
Before the growth of grasses, the coefficient of cadmium concentration in the soil was 0.86. After two years of cultivation of the sainfoin, it decreased by 96.5%, trifolium pratense - by 94.2%, alfalfa lucerne - by 90.7%, lotus corniculanus- by 16.3%. After growing melilotus albus and galega oritntalis - it has not changed.
The lowest coefficient of cadmium concentration in the soil was after the cultivation of onobrychis arenaria - 0.03. After cultivating trifolium pratense, it was 40.0% higher, alfalfa lucerne - 62.5%, Lotus corniculanus - 95.8%, galega oritntalis and melilotus albus - 96.5% higher.
By growing bean perennial grasses, the concentration of copper in the soil was 2.27. After two years of growing the sainfoin, it decreased by 11.9%, melilotus albus - by 5.7%, galega oritntalis by 4.4%, lotus corniculanus - by 3.1%, trifolium pratense by 1.3%, and after the cultivation of alfalfa lucerne - has not changed.
The lowest coefficient of copper concentration in the soil was after the cultivation of onobrychis arenaria - 2.00, after the growth of melilotus albus - by 6.6% higher, galega oritntalis - by 7.8%, Lotus corniculanus - by 9.1%, trifolium pratense - on 10.7%, alfalfa lucerne - 11.9% higher.
By growing legumes of perennial grasses the concentration of zinc was 0.40. The two-year cultivation of the onobrychis arenaria reduces the concentration of zinc in the soil by 67.5%, Lotus corniculanus - by 55.0%, melilotus albus - by 52.5%, galega oritntalis - by 40.0%, trifolium pratense - by 27.5 % and alfalfa lucerne does not change the magnitude of the concentration of zinc in the soil.
The smallest concentration of zinc in the soil was after the growth of onobrychis arenaria - 0,13. After cultivating Lotus corniculanus - by 27.8% higher, melilotus albus - by 31.6%, galega oritntalis - by 45.8%, trifolium pratense - by 55.2%, and alfalfa lucerne - by 67.5% higher.
The four-year cultivation of the onobrychis arenaria reduces the concentration of lead in the soil by 74.8%, galega oritntalis - by 55.6%, Lotus corniculanus - by 42.4%, alfalfa lucerne - by 39.4%.
The lowest coefficient of lead concentration was in the soil after the growth of onobrychis arenaria - 0,25, after galega oritntalis - by 43,2%, Lotus corniculanus - by 56,1%, the alfalfa lucerne - by 58,3% higher.
In the four years of vegetation, the eastern chicken, compared to a two-year-old vegetation, decreased the concentration of lead in soil by 55.6%, alfalfa lucerne - by 36.9%. After growing onobrychis arenaria - it did not change, and after the growth of lotus corniculanus- grew by 31,6%.
Four-year cultivation of alfalfa lucerne reduces the concentration of cadmium in the soil by 96.5%, the remaining herbs - by 97.7%.
The lowest coefficient of cadmium concentration in the soil was after the growth of onobrychis arenaria, Lotus corniculanus and galega oritntalis - 0,02, and after alfalfa lucerne - by 33,3% higher.
The four-year-old growth of galega oritntalis, compared to the two-year old, reduces the coefficient of cadmium concentration in the soil by 97.7%, lotus corniculanus- by 97.2%, alfalfa lucerne - by 62.5%, and onobrychis arenaria - by 33.3%.
In the four years of vegetation of alfalfa lucerne and galega oritntalis, the eastern concentration of copper in the soil decreases by 98.2%, Lotus corniculanus - by 96.9%, the onobrychis arenaria - by 93.8%.
The lowest coefficient of copper concentration in the soil was after the cultivation of alfalfa lucerne and galega oritntalis - 0,04. After Lotus corniculanus - by 42.9%, onobrychis arenaria - by 71.4% higher.
In the four-year period, the cultivation of alfalfa lucerne and galega oritntalis, compared with the two-year old, the copper concentration in the soil decreased by 98.2%, lotus corniculanus- by 96.8%, and onobrychis arenaria - by 93.0%.
The four-year cultivating of Lotus corniculanus reduces the concentration of zinc in the soil by 90.0%, alfalfa lucerne and galega oritntalis - by 87.5%, onobrychis arenaria - by 72.5%.
The lowest concentration of zinc in the soil was after the growth of lotus corniculanus- 0.04, after the alfalfa lucerne and galega oritntalis - by 20.0%, onobrychis arenaria - by 63.6% more.
In the four years of vegetation, compared to the two-year period, the zinc concentration in the soil after the cultivation of alfalfa lucerne decreased by 87.5%, galega oritntalis - by 79.2%, lotus corniculanus- by 77.8%, and onobrychis arenaria - by 15,4%.
Summing up the results of studying the effect of growing perennial plants on the concentration of heavy metals in the soil, it should be noted: liming of the soil causes an increase in the concentration of lead in the soil by 70.7%, cadmium - by 86.0%, copper - by 20.7 % and zinc - by 35.0%; The two-year cultivation of the onobrychis arenaria provides the lowest coefficient of lead concentration - 0,25, cadmium - 0,03, copper - 2,00 and zinc - 0,13; Four-year-old bean perennial grasses promote more intensive removal from the soil of heavy metals than biennial.
Since the soil is contaminated simultaneously with several heavy metals (lead, cadmium, copper and zinc), it is necessary for him to calculate the total pollution index, which takes into account the complex influence of all heavy metals on the ecological state of the soil environment:
$Zs = (K_{c1} + K_{c2} + K_{c3} + K_{c4}) - (n - 1)$, where: Z_c - the total index of soil pollution; K_c - heavy metal concentration factor; n - the number of heavy metals taken into account.
The total indicator of soil contamination to grass seed was minus 0.53. After liming, it has grown to 1.52, indicating that the liming of the soil is a powerful factor in total soil contamination by heavy metals.

Two-year-old bean perennial herbs have reduced the total soil contamination of heavy metals. In particular, after cultivating Onobrychis arenaria, it decreased by 2.11, after the growth of Trifolium pretense - by 1.44, Lotus corniculanus - by 1.03, Alfalfa lucerne - by 0.82, and Galega oritntalis - by 0.26.
The lowest aggregate soil contamination index was after the cultivation of onobrychis arenaria- minus 0.59. After growing the Trifolium pratense - 0,67 higher, Lotus corniculanus - on 1,08, Alfalfa lucerne - 1,29, Galega oritntalis - 1,85 higher.
During four years of growing the sailfish, the total amount of soil contamination by heavy metals has decreased by 4, after Galega oritntalis - by 3.97, Lotus corniculanus - by 3.82, Alfalfa lucerne - by 3.80.
The lowest aggregate index of soil contamination by heavy metals for four years of growing herbs was after Onobrychis arenaria - minus 2.48. At 0.03 less, after growing Galega oritntalis, by 0.18 - after Lotus corniculanus, by 0.20 less - after Alfalfa lucerne.
The largest decrease in the total soil contamination index for four-year grass cultivation, compared with biennials, was detected after the growth of Galega oritntalis - by 3.71. After cultivating Alfalfa lucerne - by 2.98, Lotus corniculanus - by 2.79, Onobrychis arenaria - by 1.89.
Summarizing the results of studies on the effect of growing legumes perennial grasses on the magnitude of the total index of soil contamination by heavy metals, it should be noted: for the two-year cultivation of legumes perennial grasses, the most positive integrated effect on the ecological state of the soil is provided by Onobrychis arenaria, as well as Trifolium pretense. The complex positive effect of long-standing grass beans on the ecological state of the soil during the two years of vegetation decreases in the following order: Onobrychis arenaria - Trifolium pratense - Beaked alfalfa - Alfalfa lucerne - Melilotus albus - Ggalega oritntalis; four-year-old bean perennial herb cultivation has a significantly greater positive effect on the ecological state of the soil; for such a period of growing of grasses, all kinds of investigated plants carry approximately the same total impact on the reduction of heavy metals in the soil; the total reduction of heavy metals in the soil decreases in the following sequence of legumes perennial grasses: Onobrychis arenaria - Galega oritntalis - Lotus corniculanus - Alfalfa lucerne.

Conclusions

For two years of growing legumes perennial plants a decrease in lead concentration of the soil was revealed by 3.4-74.6%, cadmium - by 16.7-96.7%, copper - by 1.5-11.8%, zinc - by 27.5-69.2%. The highest efficiency of reducing the concentration of lead, cadmium, copper and zinc in the soil was observed while growing onobrychis arenaria. The lowest efficiency of reducing the concentration of lead in the soil was observed while cultivating Galega oritntalis and Alfalfa lucerne, cadmium - Melilotus albus and Galega oritntalis, copper - Alfalfa lucerne and Lotus corniculanus, zinc - Alfalfa lucerne.
During the four-year-long growth of legumes perennial plants in the soil a decrease in lead concentration revealed by 39.0-74.6%, cadmium - by 96.7-98.3%, copper - by 94.1-98.5%, and zinc by 73.6-90.1%. The highest efficiency of reducing the concentration of lead in the soil was observed while cultivating Onobrychis arenaria, cadmium, copper and zinc - Alfalfa lucerne, Onobrychis arenaria, Lotus corniculanus and Galega oritntalis.
The smallest indicator of total soil contamination by heavy metals during two- and four-year grass cultivation, respectively, minus 0.59 and minus 2.48, was observed while cultivating Onobrychis arenaria. The largest indicator of total soil contamination by heavy metals during the two-year-old grass growing - 1.26 was observed while growing Galega oritntalis, and the four-year-old minus 2.28 Alfalfa lucerne.

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Citation:
Razanov, S.F., Tkachuk, O.P., Mazur, V.A., Didur, I.M. (2018). Effect of bean perennial plants growing on soil heavy metal concentrationsts. Ukrainian Journal of Ecology, 8(2), 294–300.