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PAPER

DYNAMICS OF SOME HEAVY METALS IN THE GROWTH PHASES OF INDIGOFERA TINCTORIA

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Abstract

The article considers the history of studying heavy metals in meadow-oasis soils and heavy metals in the plant Indigofera tinctoria, a legume (Febaceae) grown on newly developed saline meadow soils of the Fergana region, dynamics, significance, permissible standard concentrations. metals are discussed. In particular, the amount of heavy metals in soil samples of the study area and plant samples taken in the flowering, bean and maturity phases of the plant Indigofera tinctoria is determined. The amount of heavy metals chromium (Cr), cobalt (Co), nickel (Ni), zinc (Zn) in the soil and the plant Indigofera tinctoria is determined, as well as the established permissible norm of heavy metals in plant products. limits.

Key words: indigofera tinctoria, flowering phase, bean phase, maturity phase, inductively coupled plasma mass spectrometer ICP-MS (Nexion 2000), dynamics of chromium, cobalt, nickel, zinc, heavy metals, permissible standard concentrations.

INTRODUCTION

Soil, considered the main part of nature, has a very complex chemical composition and can become contaminated over time and distance. Heavy metals accumulate in the soil over a certain period of time, i.e. until they reach an equilibrium state. In this case, the chain of actions in the ecosystem can be closed or open. It is known that soil is a complex polyfunctional polydisperse system. Most heavy metals are absorbed mainly through the solid and liquid phases of the soil.

Plants also accumulate heavy metals in different quantities and in different parts. Of course, this is influenced by many factors, such as the type of plant, growth and development phases, soil environment, properties, etc.

Efficient use of mineral fertilizers is also important in agriculture. The use of mineral and organic fertilizers is a source of heavy metals. In particular, the use of unreasonably high doses of phosphorus fertilizers, especially their long-term

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use, contributes to the accumulation of heavy metals in the soil and their inclusion in food chains, which is harmful to human and animal health.

LITERATURE ANALYSIS

Muhammad Aslam Khoso, Altaf Hussain Nizamani, Hussain Saleem (Pakistan, 2021) Significant progress has been made in identifying heavy and toxic elements in food products that affect human and animal health. In this work, the laser induced breakdown spectroscopy (LIBS) method was used. Soil samples taken from the right bank of the Indus River in the Sindh province of Pakistan were studied. Spectroscopic analysis of transition lines revealed various toxic and nutritious elements in the soil. In particular, the emission spectra of elements such as titanium (Ti), manganese (Mn), aluminum (Al), chromium (Cr), nickel (Ni), cobalt (Co), zinc (Zn) were studied [1]. Zeeshan Ahmed et al. (Pakistan, 2022) identified a number of plant species that could be considered as indicators of mineralization, especially coal, chromite and marble, in the Khyber Pakhtunkhwa province of northern Pakistan. It was observed that most of the indicators belonged to the families Poaceae, Amaranthaceae, Compositae and Lamiaceae. The dominance of a few specific families was due to their longevity and ability to absorb some heavy metals present in the sediments. Several recent studies were conducted on the vegetation around chromite deposits in northern Pakistan. They identified 32 medicinal and fodder plants associated with cadmium (Cd) and lead (Pb) accumulation [2].

Chemical Fertilizers, Pesticides, and Animal Feed in Agriculture Abdur Rashid, Brian J. Schutte, April Ulery, Michael K. Deyholos, Sum Sanogo, Eric A. Lenhoff, and Leslie Becklar (New Mexico, USA, 2023) Heavy Metal Pollution of Croplands The use of fertilizers and composts, as well as irrigation, has revealed the biological availability of heavy metals in the soil solution and the factors influencing their absorption, migration, bioaccumulation in plant organs, and the direct effect of heavy elements on physiological, biochemical, and molecular processes in plants. studied [3].

Zimi Zhukowska-Wiezek and Danuta Nokowski conducted studies on the classification of heavy metals in soils depending on their pollution potential. V.A. Bolshakov, T.I. Borisichkina, N.M. Krasova also classified soils by the mobile form of heavy metals in them [4]. There are many problems associated with heavy metals, and the most relevant solutions are: methods for quick and easy detection of heavy metals; determining their permissible concentrations; classifying it, i.e. the soil, depending on the quantity and quality of its content, choosing plant species by this feature, etc. The research of a number of scientists in this area deserves attention, including M.A. Glazovskaya, I.G. Vazhenin, N.G. Zirin, A.I. Obukhova, T.A. Abdrakhmonov, G. Yuldasheva, M. Isagalieva and others [4]. V.A. Bolshakov, T.I. Borisichkina, N.M. Krasova (1992) grouped soils by the mobile form of heavy metals in them.

METHODS

The object of the study is the plant Indigofera tinctoria L. (belongs to the legume family), grown in the climatic conditions of newly developed saline meadow soils of the Fergana region (Dangara District Multidisciplinary Technical College). Field and laboratory studies were carried out using standard methods generally accepted in soil science: stationary, Dokuchaev's soil section method, chemical-analytical and biogeochemical analyses using the methods described in the book «Руководства по химическому анализу почвы» by E. Arinushkina. The amount of heavy metals in the soil and samples of Indigofera tinctoria L. plants taken as the object of the study was determined using the method of mass spectrometry with inductively coupled plasma ICP-MS (Nexion 2000).

RESULTS

The processes of migration and accumulation of chemical elements in soil and plants are interdependent. Each plant species has the ability to selectively absorb chemical elements from the soil in accordance with its life form and its needs. But in this complex physiological process, the composition and quantity of chemical elements in the soil are important. Satisfaction of the plant's need for a particular chemical element depends on its quantity in the soil. According to the results of our research, the amount of heavy metals in samples of newly developed saline meadow soil (section 1/D) of the Dangara district of the Fergana region is as follows

(Table 1):

Table 1

1/D cross section. Heavy metal content in newly reclaimed saline meadow soils (mg/kg)

Soil layer depth, sm	Chemical elements			
	Cr	**Co**	**Ni**	**Zn**
0-30	1,433	0,277	1,197	2,218
30-48	1,741	0,286	1,035	1,917
48-74	7,448	0,378	1,294	2,981
74-100	1,181	0,207	0,672	1,295

Permissible concentrations of heavy metals in soils vary, for example, chromium (Cr) 50 mg/kg, nickel (Ni) 45 mg/kg, zinc (Zn) 150 mg/kg (according to A.I. Obukhov, 1988), cobalt (Co), equal to 50 mg/kg (according to Kloske), is given in scientific sources [5]. Based on the above, the newly reclaimed saline meadow soils we studied are not contaminated with these heavy metals.

According to the results of our research, the amount of heavy metals in the Indigofera tinctoria L. plant grown in a field with newly reclaimed saline meadow soil (2022) is as follows (Table 2):

Table 2

The amount of heavy metals in the development phases of the plant *Indigofera tinctoria*, mg/kg

Indigofera tinctoria L. plant		Heavy elements			
Phases of development	Plant organs	Cr	Co	Ni	Zn
Flowered	Root	6,9	0,7	8,3	0,378
	Stem	6,7	0,6	6,8	0,475
	Leaf	4,8	0,6	4,7	0,441
Legumes	Root	4,7	0,6	6,8	2,99
	Stem	3,4	<0,01	5,7	3,14
	Leaf	4,6	<0,01	4,8	4,51
	Bean	3,8	<0,01	6,5	5,49
Matured	Root	0,31	0,7	5,1	2,78
	Stem	0,21	0,4	4,1	2,71
	Leaf	0,42	0,9	3,9	4,98
	Seed	0,22	0,5	5,3	4,53

The amount of heavy metals in the flowering phase of Indigofera tinctoria L. increases in the following order: In the root: Co → Zn → Cr → Ni; In the stem: Co → Zn → Cr → Ni; In the leaf: Co → Zn → Ni → Cr.

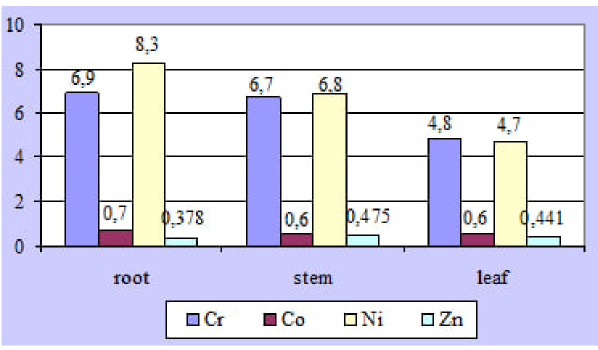


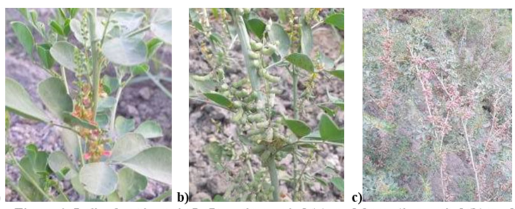
Figure 1. Dynamics of heavy metals in the flowering phase of Indigofera tinctoria, mg/kg It is seen that chromium (Cr), cobalt (Co) and nickel (Ni) in the root of Indigofera tinctoria in the flowering phase are 6.9, respectively; The highest concentration is from 0.7 to 8.3 mg/kg, while zinc (Zn) is most common in its stem, i.e. 0.475 mg/kg. Also, the smallest amount of these heavy metals is Zn in the roots of Indigofera tinctoria, which is 0.378 mg / kg.

The amount of heavy metals in the bean phase of Indigofera tinctoria L. increases in the order Co → Zn → Cr → Ni in the root, stem, leaf and in the order Co → Cr → Zn → Ni in the bean: (Table 2)

As a result, the amount of Cr, Co and Ni in the bean phase of Indigofera tinctoria is 4.7, respectively; 0.6; At a concentration of 6.8 mg/kg in the roots, Zn in the pods was 5.49 mg/kg.

Figure 2. The amount of heavy metals in the bean phase of the Indigofera tinctoria plant, mg/kg The content of heavy metals in the mature phase of the Indigofera tinctoria L. plant increases in the order Cr → Co → Zn → Ni in the root, stem and seed (grain), and in the order Cr → Co → Ni → Zinc in the leaf: (Table 2)

Figure 3. The amount of heavy metals in the mature phase of the Indigofera tinctoria plant, mg/kg It is seen that in the mature phase of the Indigofera tinctoria plant, its leaves contain 0.42 of the heavy metals chromium, cobalt and zinc respectively; 0.9; is 4.98 mg/kg. And nickel in its grain is the most 5.3 mg/kg.



a) b) c)

Figure 4. *Indigofera tinctoria L.* flowering period (a), pod formation period (b), pod maturation period (c)

Chromium (Cr) is an element necessary for the normal development and vital functions of plants. It is known from the literature that at relatively low concentrations, i.e. all chromium compounds with a fraction higher than 3 mg/kg, have a toxic effect on living organisms. As a result of our studies, the amount of chromium in all vegetative organs of the Indigofera tinctoria plant in the flowering and bean formation phase exceeds the norm by 1.13-2.3 times. This means that the green masses of the Indigofera tinctoria plant in the flowering and bean formation phase can have a toxic effect on livestock [7].

Plants contain an average of 2 · 10-5 percentage or 0.2 mg/kg of dry weight of cobalt (Co). This element is more essential for leguminous crops and ensures the growth of nodule bacteria. Vitamin B12 contains a lot of Co. This vitamin is synthesized only by bacteroids. It is involved in the fixation of molecular nitrogen. Co affects nitrogen absorption and increases the amount of chlorophyll [5; 8]. The permissible level of cobalt in plants is an average of 0.4 mg/kg. As a result of our studies, only the stem of the mature phase of the Indigofera tinctoria plant is at the standard level, and the stem, leaf and pods of the pod phase are 40 times less. However, in the organs of the flowering and maturity phases, it exceeds the permissible norm by 1.25-2.25 times. Therefore, vitamin B12 accumulates in the organs in large quantities during these periods. As a result, it is possible to fix nitrogen. More nitrogen is absorbed, which leads to an increase in the amount of chlorophyll [7].

The role of nickel (Ni) in organisms has not yet been sufficiently studied, but its amounts have already been determined. For example, its amount in plants is 5 · 10-5 percentage or 0.5 mg/kg, in animals – 1 · 10-6percentage, and in humans - 1-2 · 10-6percentage. At the same time, there are plants that accumulate nickel. If the amount of nickel in the soil exceeds 18-40 mg/kg, this slows down plant growth. For plants, the amount of nickel is harmful if it exceeds 3 mg/kg [7]. It has been established that the amount of nickel in the organs of the Indigofera tinctoria plant at all stages of development exceeds the permissible norm by 1.3-2.8 times.

Like all elements, zinc (Zn) enters plants mainly in the form of a cation (Zn2+). In the above-ground part of leguminous plants, zinc is 15-60 mg/kg of dry weight. It accumulates especially in young plant organs. [6]. It is known from the literature that the permissible norm of zinc in plants is on average 75 mg/kg [7]. The amount of zinc in all organs of the Indigofera tinctoria plant in the development phases is 14 to 198 times less than PRL.

According to V. G. Mineev (1990), a comparison of the permissible standards for the content of chemical elements in plant products [5] with the plant Indigofera tinctoria L. is presented in Table 3 below.

Table 3

Standard limits of heavy metals in the plant *Indigofera tinctoria L.*, mg/kg (according to V.G. Mineev)

Indigofera tinctoria L.		Heavy elements			
Phases of development	Plant organs	Cr *PC 0,2 - 1,0	Co PC 0,3 - 0,5	Ni PC 0,4 – 3	Zn PC 15 – 150
Flowered	Root	6,9	0,7	8,3	0,378
	Stem	6,7	0,6	6,8	0,475
	Leaf	4,8	0,6	4,7	0,441
Legumes	Root	4,7	0,6	6,8	2,99
	Stem	3,4	<0,01	5,7	3,14
	Leaf	4,6	<0,01	4,8	4,51
	bean	3,8	<0,01	6,5	5,49
Matured	Root	0,31	0,7	5,1	2,78
	Stem	0,21	0,4	4,1	2,71
	Leaf	0,42	0,9	3,9	4,98
	seed	0,22	0,5	5,3	4,53

* - PC - is the permissible concentration

The limit of zinc content in plants recommended by the World Health Organization (WHO) is 50 mg/kg, and nickel - 1.5 mg/kg. From this table it is clear that the amounts of PC (permissible concentration) of the heavy element zinc (Zn) in the organs of the flowering, bean and maturity phases of the Indigofera tinctoria plant are at a normal level. When comparing the results of our studies with the data of V. G. Mineev (1990), the amounts of PC of heavy elements in the Indigofera tinctoria plant are 6.9 times higher than Cr in the root in the flowering phase, Ni - 2.8 times, Co - 2.25 times in the leaf of the mature phase is increased from the normal level, but only the amount of Zn in these organs is normal.

DISCUSSION

Newly developed saline meadow soils of the Fergana region (Dangara District Multidisciplinary Technical University) are not contaminated with heavy metals Cr, Co, Ni, Zn.The content of chromium (Cr) in the organs of Indigofera tinctoria L. in the mature phase, the content of cobalt (Co) in the stems, leaves and pods at the bean stage, as well as the content of zinc (Zn) in all organs at the development stage. Indigofera tinctoria L., grown on newly developed saline meadow soils, it was found that the amount of metallic iron is at the standard level, as well as the amount of chromium (Cr) in all organs of Indigofera tinctoria in the flowering and warping phases, the amount of cobalt. (Co) in the organs of the flowering and maturity phases, and the amount of nickel (Ni) in all organs of the development phase of Indigofera tinctoria exceeded the PC norm.

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