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ASSESSMENT OF THE INTENSITY OF ACCUMULATION OF LEAD AND CADMIUM IN LEAVES AND SEEDS WHEN USING DIFFERENT TYPES OF FERTILIZERS

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Abstract

The intensity of accumulation of heavy metals in the leaf mass and seeds of milk thistle with mineral and organic fertilizers was studied. The obtained research results showed a certain influence of fertilizer on the coefficient of accumulation of heavy metals (lead, cadmium) in the leaf mass and seeds of milk thistle grown in the field crop rotations of the Forest-Steppe of the Right Bank.

It was investigated that the highest coefficient of accumulation of lead and cadmium in leaf mass and seeds of milk thistle was observed for fertilization with mineral fertilizers, and relatively lower for organic thistle. When fertilizing the plant with mineral fertilizers, the lowest level of lead accumulation was observed with the use of simple phosphate and a mixture of fertilizers (simple superphosphate, ammonium nitrate, potassium chloride). When fertilized with organic fertilizers, a low coefficient of accumulation of lead and cadmium in the leaf mass and seeds of milk thistle was observed after green fertilizers (mustard) and the four-year-old precursor of alfalfa, and when foliar fertilizer was used, phosphorus chelate.The highest efficiency in reducing the accumulation coefficient of lead and cadmium in the leaf mass and seeds of milk thistle in the agricultural lands of the right-bank forest-steppe of Ukraine of all studied fertilization options was observed when the plant was grown after green fertilizers (mustard) and perennial legumes (4-year-old predecessor of alfalfa sowing).

Keywords: milk thistle, cadmium, lead, leaf mass, seeds, concentration, mineral fertilizers, organic fertilizers

Introduction

Milk thistle (Sílybum Mariánum) is deservedly recognized as a popular plant, because it is actually used for over 2000 years. The plant is native to the Mediterranean region and a member of the Asteraceae plant family. This healing herb gets its name from the milky-white liquid that runs off of the plant's leaves when they're crushed. The actual leaves of the plant also have a spotted white pattern that makes them look as if they've been dunked in milk. It's also known as St. Mary's thistle, holy thistle and silybum [9, 16].

Due to its unique properties, milk thistle is widely used in medicine, pharmacology, animal husbandry, crop production and food industry, as it contains biologically active substances that are useful for the work of all internal organs. Almost the whole plant can be used for medicinal purposes, but the greatest value belongs to its seeds, which contain silymarin [8, 19].

Silymarin, a mixture of flavanoid complexes, is the active component that protects liver and kidney cells from toxic effects of drugs, including chemotherapy. There is strong preclinical evidence for silymarin's hepatoprotective and anticarcinogenic effects, including inhibition of cancer cell growth in human prostate, skin, breast, and cervical cells. Milk thistle is considered safe and well-tolerated [15]. Silymarin has hepatoprotective, anti-inflammatory, anticancer, immunomodulatory, antidiabetic and cardioprotective activity, and its antioxidant action increases the body's resistance to various negative environmental factors [2, 6].

The seeds contain fatty and essential oils, resins, histamine, flavonoids, as well as macro-and micronutrients [10]. The composition of the seeds of milk thistle also includes a significant amount of B vitamins; vitamins K, A, E; macronutrients (mg/g): potassium – 9.2; calcium – 16.6; magnesium – 4.2; iron – 0.08 and trace elements (mg/g): manganese – 0.1; copper – 1.16; zinc – 0.71; chromium – 0.15; selenium – 22.9; iodine – 0.09; boron – 22.4 [12].

Products of processing of seeds of a milk thistle (oil, meal) are useful not only as a medicine and preventive measure for a human body, but also for animals. The meal obtained after squeezing the oil is a valuable feed with a high content of fats and phytolignals, the aboveground part of milk thistle plants in the budding phase can be used as a fodder plant, which significantly expands the range of its use in the national economy [11, 20].

For the Milk thistle, the use of fertilizers contributes to the significant development of the plant. The use of mineral fertilizers significantly affects the productivity of milk thistle, the quality and environmental safety of its raw materials. Milk thistle belongs to plants with an extended period of consumption of elements of mineral nutrition. Excess nitrogen nutrition is not desirable for her, since it leads to a delay in the growing season, and also worsens the medicinal properties of its raw materials. From production and economic considerations, the most reasonable fertilization rate should be considered the introduction of $N_{60}P_{60}K_{60}$, however, scientifically grounded and experimentally proven optimal rates for fertilizing milk thistle plants, after which the medicinal properties of the plant will not deteriorate, have not been studied [14].

Today, one of the directions of fertilization of agricultural crops is the introduction of their newest types: chelate-based mineral fertilizers, microfertilizers, complex organo-mineral fertilizers, plant growth stimulants, and others [5, 21]. At the same time, mineral fertilizer can help increase the level of various toxicants in the soil, in particular heavy metals, which can affect the quality and safety of grown raw materials [3, 7, 17-18].

The study of the adaptation of certain species of medicinal plants growing near potential sources of heavy metals makes it possible to determine the level of transport through the soil to medicinal plants of these toxicants and to determine the level of their biological resistance to contamination. Due to this, it is possible to establish the feasibility of using such medicinal plants to increase or correlate the body's resistance to the effects of negative environmental factors. [1, 4, 13]. Since heavy metals from medicinal raw materials enter medicinal products, and then enter the human body, the use of medicinal plants collected in areas with a high content of heavy metals can threaten human health, creating a negative impact on the functioning of internal organs and physiological processes of the body as a whole [19]. Based on this, there is a need for constant monitoring of the safety of this raw material.

Materials and Methods

The study of the influence of mineral, organic and microfertilizers on productivity, chemical composition and safety of raw milk thistle raw materials was carried out according to the scheme, which included three scientific experiments according to the defined research scheme. The first experiment included five options for growing milk thistle, in particular, the first – without fertilizer, the second – fertilizer with ammonium nitrate (N_{60}), the third – potassium chloride fertilizer (K_{60}), the fourth – simple superphosphate fertilizer (P_{60}), the fifth – $N_{60}P_{60}K_{60}$. The second scientific experiment also covered five options for growing milk thistle: the first – without fertilizer, the second – sugar beet lime sludge compost (6 t/ha), the third – humus fertilizer (20 t/ha), the fourth – green manure (mustard), fifth – four-year predecessor (alfalfa sowing). The third scientific experiment included four options for growing milk thistle, namely: the first – without fertilizer, the second – phosphorus-chelate fertilizer (0.9 l/ha), the third – potassium-chelate fertilizer (0.9 l/ha), the fourth – use of growth concentrate (0.5 l/ha).

Results and Discussion

The obtained research results showed a certain effect of fertilizer on the accumulation coefficient of heavy metals (Pb and Cd) in the leaf mass and seeds of milk thistle grown in the field crop rotations of the Forest-Steppe of the Right Bank (table 1).

Table 1

Coefficient of Pb accumulation in milk thistle when using different types of fertilizers

Experiment options	Accumulation factor, average for options	
	Leaf mass	Seeds
Ammonium nitrate (N_{60})	4.63	1.6
Potassium chloride (K_{60})	4.88	1.5
Superphosphate simple (P_{60})	4.76	1.5
$N_{60}P_{60}K_{60}$	4.0	1.4
Humus, 20 t/ha	3.6	1.3
Sugar beet lime sludge compost, 6 t/ha	3.9	1.4
Green manure (mustard)	2.8	1.2
4-year-old predecessor (alfalfa sowing)	2.8	0.41
Phosphorus-chelate, 0,9 l/ha	4.5	1.18
Potassium-chelate, 0,9 l/ha	5.7	1.03
Growth-concentrate, 0,5 l/ha	5.1	1.46

Thus, the coefficient of accumulation of lead in the leaf mass for fertilization with mineral fertilizers, ammonium nitrate, potassium chloride, double superphosphate and a mixture of fertilizers ranged from 4.0 to 4.88, which averaged 4.56. The lowest lead accumulation coefficient, which was 4.0 in the leaf mass of milk thistle, was observed for its fertilization with a mixture of nitrogen nitrate, potassium chloride and simple superphosphate, respectively ($N_{60}K_{60}P_{60}$) in milk thistle seeds. The lowest coefficient of accumulation of lead in the seeds of milk thistle was also observed with a complex fertilizer with a mixture of ammonium nitrate, potassium chloride and simple superphosphate and was 1.4.

The difference between the coefficient of accumulation of lead in the leaf mass and the seeds of milk thistle for fertilization with mineral fertilizers was also revealed. Thus, when fertilizing milk thistle with ammonium nitrate, potassium chloride, simple superphosphate and a mixture of these mineral fertilizers, the coefficient of accumulation of lead in the seeds was lower by 2.89 times, 3.25, 3.17 and 2.85 times, respectively. When fertilizing milk thistle with humus, sugar beet lime sludge compost and the use of green manure (mustard) and four-year predecessor (alfalfa sowing), the coefficient of accumulation of lead in the leaf mass ranged from 2.8 to 3.6, which averaged 3.2. The lowest coefficient of accumulation of lead, which was 2.8 among organic fertilizers, was observed for the four-year predecessor – alfalfa sowing. In the seeds of milk thistle with organic fertilizer, the coefficient of accumulation of lead ranged from 0.41 to 1.4, which averaged 1.07. The lowest coefficient of accumulation of lead in the seeds of milk thistle was also observed when growing it after a four-year predecessor (alfalfa sowing).

Comparing the coefficient of accumulation of lead in the production of milk thistle with organic fertilizer, it should be noted that the use of humus, sugar beet lime sludge compost, green manure (mustard) and four-year predecessor (alfalfa sowing) this figure was lower in seeds compared to leaf mass 2.33 times, 2.78 times and 6.8 times, respectively.

With surface (leaf) fertilization of milk thistle with phosphorus-chelate, potassium-chelate and growth-concentrate, the coefficient of accumulation of lead in the leaf mass ranged from 3.2 to 5.7, which averaged 4.4. The lowest coefficient of accumulation of lead in the leaf mass of milk thistle was observed for growth-concentrate fertilizer.

Characterizing the coefficient of accumulation of lead in the seeds of milk thistle with foliar fertilizer, it should be noted that this figure ranged from 1.03 to 1.18, which averaged 1.17. The lowest coefficient of accumulation of lead in the seeds of milk thistle with its foliar fertilizer was observed with the use of potassium chelate and growth concentrate. When using as fertilizer milk thistle phosphorus-chelate, potassium-chelate and growth concentrate, the coefficient of accumulation of lead in the seeds was lower by 3.81 times, 5.53, 3.49 and 3.1 times, respectively, compared to the leaf mass.

Characterizing the coefficient of accumulation of cadmium with milk thistle for fertilization with mineral and organic fertilizers, it is also necessary to note a certain tendency to increase and decrease this indicator (table 2).

Table 2

Coefficient of Cd accumulation in milk thistle when using different types of fertilizers

Experiment options	Accumulation factor, average for options	
	Leaf mass	Seeds
Ammonium nitrate (N_{60})	24.0	6.0
Potassium chloride (K_{60})	17.0	5.2
Superphosphate simple (P_{60})	13.6	5.3
$N_{60}P_{60}K_{60}$	15.0	4.8
Humus, 20 t/ha	10.8	4.0
Sugar beet lime sludge compost, 6 t/ha	11.6	6.9
Green manure (mustard)	10	3.7
4-year-old predecessor (alfalfa sowing)	10.5	2.0
Phosphorus-chelate, 0,9 l/ha	16.8	3.3
Potassium-chelate, 0,9 l/ha	18.2	3.2
Growth-concentrate, 0,5 l/ha	19.7	4.1

Analyzing the results of research, it should be noted that when used as fertilizer milk thistle spotted mineral fertilizers (ammonium nitrate, potassium chloride, superphosphate) and their mixtures per hectare in the active raw material N_{60}, K_{60}, P_{60}, respectively, the accumulation coefficient of cadmium in the leaf from 13.6 to 24.0, which averaged 19.9 The lowest cadmium accumulation coefficient – 13.6 was observed in the leaf mass of milk thistle when using simple superphosphate.

In the seeds of milk thistle when using mineral fertilizers, the accumulation coefficient of cadmium ranged from 4.8 to 6.0, which averaged 5.32. The lowest coefficient of accumulation of cadmium in the seeds of milk thistle was observed for its fertilizer mixture (ammonium nitrate, potassium chloride, superphosphate).

Along with this, it should be noted that the coefficient of cadmium accumulation in the leaf of milk thistle for fertilization with humus, sugar beet lime sludge compost, green manure (mustard) on the four-year predecessor (alfalfa sowing) ranged from 10 to 11.6, which averaged 10.7. The lowest coefficient of cadmium accumulation in the leaf mass under organic fertilizer was observed after the use of green manure and four-year predecessor of alfalfa sowing.

At the same time, it should be noted that in the seeds of milk thistle the accumulation coefficient was also 2.7 times lower than with humus fertilizer, 1.7 times lower than sugar beet lime sludge compost, 2.7 times lower than green manure and 5.2 times lower than its 4-year predecessor (alfalfa sowing).

Analysis of the coefficient of cadmium accumulation in the leaf mass of milk thistle for fertilization with microfertilizers (phosphorus-chelate, potassium-chelate, growth-concentrate) was in the range of 16.8-19.7, which averaged 18.2. The lowest coefficient of cadmium accumulation in the leaf mass of milk thistle was observed for itsfertilizer with phosphorus-chelate.

In the seeds of milk thistle with the use of microfertilizers, the accumulation coefficient of cadmium ranged from 3.2 to 4.1, which averaged 3.5. The lowest coefficient of cadmium accumulation in the seeds of milk thistle was found when using potassium-chelate for its fertilizer. The accumulation coefficient of cadmium in milk thistle seeds was also the lowest for fertilizer with phosphorus-chelate 5.1 times, potassium-chelate – 5.6 times and growth-concentrate – 5.6 times compared to the leaf mass.

Conclusion

The analysis of the obtained research results showed that the highest coefficient of accumulation of lead and cadmium in the leaf mass and seeds of milk thistle is observed for the use of mineral fertilizers, relatively lower – when using organic fertilizers. Among mineral fertilizers, the lowest level of lead accumulation was observed when using superphosphate simple and a mixture of fertilizers (simple superphosphate, ammonium nitrate, potassium chloride). When using organic fertilizers, the lowest coefficient of accumulation of lead and cadmium in the leaf mass and seeds of milk thistle was observed after green fertilizers (mustard) and four-year predecessor (alfalfa sowing), and when using foliar fertilizer – phosphorus-chelate.

Among all the studied fertilizer variants, the highest efficiency in reducing the accumulation of lead and cadmium in the leaf mass and seeds of milk thistle in the agricultural lands of the right-bank Forest-Steppe of Ukraine was observed for growing this crop after green fertilizers (mustard) and perennial legumes (4-year-old predecessor of alfalfa sowing).

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