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BIOLOGICAL FEATURES OF ARSENIC TRANSLOCATION IN CROPS DEPENDING ON FERTILIZER

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The process of arsenic translocation into agricultural crops were investigated. It allowed to define the dependence typical for all studied crops - wheat, rape, soya. The biggest amount of the element was concentrated in the plant rootage, the smallest one was in the generative organs (seed). The fertilizers greatly influenced the As-translocation into the plants. In this case we can clearly see the direct dependence between their amount and volume of arsenic accumulation by the plants.

Arsenic, mineral, organic manures, translocation, agricultural crops.

The plants' absorption of chemicals is the process which is regulated by the organism dependng on the structure and chemical components of cell membranes.

The plant cell membranes are active biocatalysts which provide the directed transport of substances. Chemicals can be transported by the apoplastic and symplastic pathways. The apoplastic pathway is provided to the cell membrane available space due to diffusion and water flow with dissolved substances. This way some random and useless for normal metabolism elements can pass to the plant. The probability of chemical absorption into the plant increases with the increase of their content in the soil solution. Symplastic pathway is optional as the transport of the chemicals takes place in in symplast between cells through plasmodesmata. Chemicals mainly pass in the vegetative parts of plants by the apoplastic transport, while the symplastic transport is common for reproductive organs. The biological filter of symplast protects the plant from the uncontrolled chemicel accumulation. That is the reason why the highest level of chemical substances is mainly observed in the root system of plants, and the lowest level is in stems and leaves, seeds and root crops. Represented by the xylem and the phloem the conducting system of plants provides different routes for metabolites. The chemical substances can pass through the xylem by the apoplastic transport to the plant's organs, and the concentration of elements depends on the xylem vessels amount as well as on the concentration of chemicals in the solution which is in the vessels. According to Y. Alekseiev (1987) the critical arsenic concentration in plants, which reduces its performance by 10%, is 20 mg / kg of dry matter [1,3].

The aim of the research is to explore the processes of arsenic translocation in crops under the influence of organic and mineral fertilizers.

Research materials and methods. The process of arsenic translocation from soil to plants was studied under the conditions of field experiments at the Institute of Agroecology of UAAS. The three-field crop rotation is the following: spring wheat - spring rapeseed - soy. The soil is gray sandy clay loam forest soil. General agriculture cultivation is common for a given soil-climatic zones. The scheme of the experiment was supposed to study these systems fertilization:

- spring wheat: control (without fertilizers); $N_{150}P_{100}K_{100}$; $N_{75}P_{50}K_{50}$ + sideline products + green manure; $N_{10}P_{10}K_{10}$ + sideline products + green manure; organic fertilizers;

- spring rapeseed: control (without fertilizers); $N_{120}P_{100}K_{90}$; $N_{60}P_{30}K_{45}$ + sideline products + green manure; $N_{20}P_{10}K_{10}$ + ssideline products + green manure; organic fertilizers;

– soy: control (without fertilizers); 2) $N_{40}P_{60}K_{60}$; $N_{20}P_{30}K_{30}$ + sideline products + green manure; $N_{10}P_{10}K_{10}$ + sideline products + green manure; organic fertilizers;

Plant samples were taken in the phase of full ripeness, analyzed the underground and above-ground vegetative organs (root, stem, leaves) and generative organs (grain). Soil samples were taken simultaneously with plant samples from 0-20 cm layer. Sampling of soil and plants was performed according to conventional methods.

The arsenic determination in the plant samples was performed after the prior ashing of plant material with the means of photocolorimetric method [ТУ У6- 14005076.041-2000].

The research results. It is known that the fertilizers significantly affect the admission process of the nutrients and toxic elements from the soil to the plant organs. The investigation of the effect of different combinations of mineral and organic fertilizers, which were carried on the gray forest soils, showed a significant influence on the process of translocation and redistribution of arsenic in the crops.

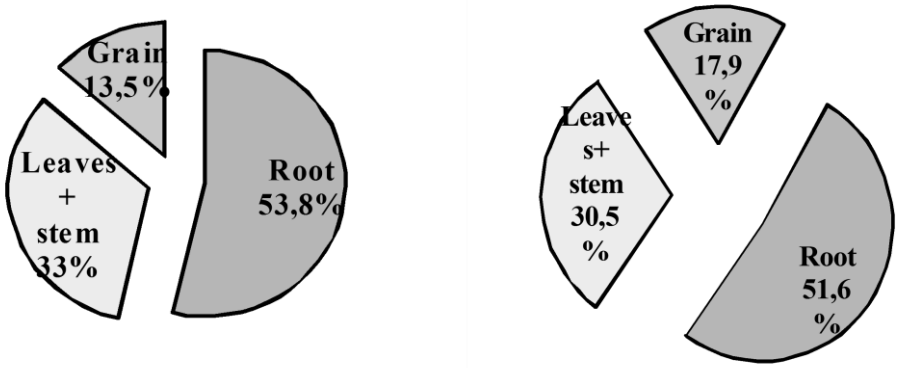
The results of the studies of the arsenic distribution in organs of spring wheat showed that the fertilizers increased translocation activity from the soil. While using the mineral fertilization system (by introducing the maximum dose of fertilizers $N_{150}P_{100}K_{100}$) the arsenic content in the spring wheat roots was 4,9 mg/kg compared to 2,8 mg/kg on the control (no fertilizer). The high content of arsenic was observed in aboveground vegetative and generative organs of wheat. It was 2,9 mg/kg in the leaves and stems, and 1,7 mg/kg in grains compared to 1,7 i 0,7 mg/kg on the control (no fertilizer).

While using the organic and mineral fertilization system ($N_{75}P_{50}K_{50}$ and $N_{10}P_{10}K_{10}$ against a background of green manures) led to the As transition activity reduction from soil to plants, and the content of the element in the root system decreased to 3,9 and 3,2 mg/kg. In the embodiments of the application of mineral fertilizers doses $N_{75}P_{50}K_{50}$ i $N_{10}P_{10}K_{10}$ compatible with the organic content of the element in the leaves and stems were only 2,3 i 1,9 mg/kg, and

1,2 or <0,05 mg/kg in grain.

Thus, the studies have shown that the high doses of fertilizers ($N_{150}P_{100}K_{100}$) stimulated the arsenic absorption in the wheat plants under the influence of the relative content, and the level of arsenic in the grain increased from 13.5% to 17.9%. At the same time the number of elements in the root system and aboveground vegetative organs of wheat decreased, so the fertilizers slightly decreased the protective ability of the root system of wheat plants against the arsenic contamination of the generative organs (picture 1).

The highest capacity for accumulation of arsenic in both underground and overground in the vegetative mass was observed at the spring rapeseed. While using the fertilizers ($N_{120}P_{60}K_{90}$) the arsenic content in the roots increased from 2,1 mg/kg on the control (no fertilizer) to 8,3 mg/kg. The maximum arsenic accumulation in vegetative organs and grain was also observed with the introduction of high doses of fertilizers ($N_{120}P_{60}K_{90}$), the arsenic accumulation increased from 1,3 and 0,6 to 6,1 and 2,1 mg/kg. In general, the use of the high doses of the fertilizers resulted in the higher As content in the root system in 4,0 times, the leaves and stems in 4,7, corn in 3,5. The use of organic and mineral fertilizers helped reduce arsenic transport to plants. So, when making the moderate doses of fertilizers ($N_{60}P_{30}K_{45}$ і $N_{20}P_{10}K_{10}$) the content of arsenic significantly decreased compared to the control (no fertilizer) and was <0,05 mg/kg.



A **B**

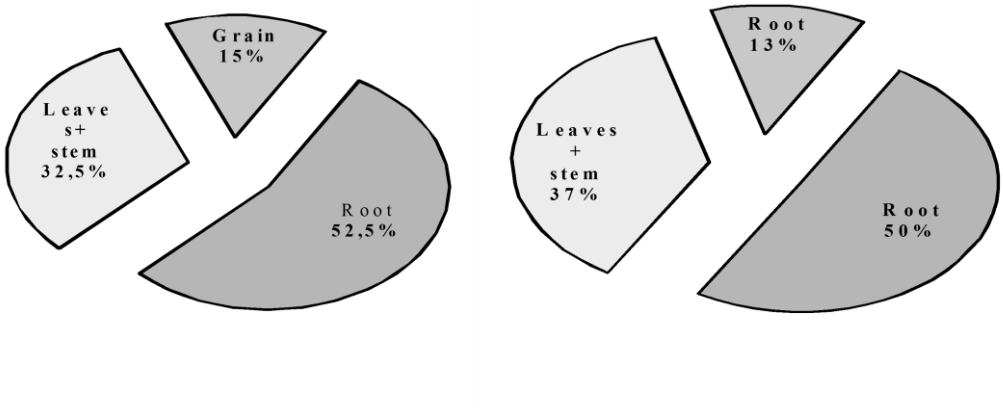
Picture 1. Fertilizers' effect on arsenic distribution in the organs of spring wheat:
A – control (no fertilizer); B – $N_{150}P_{100}K_{100}$

The studying of the fertilizers impact on the As redistribution in the organs of the spring rapeseed showed that the element accumulation in overground vegetative mass is activated under their influence, which is needed to be taken into consideration when using rape to feed farm animals. The As content in the leaves and stems increased from 32,5% to 37,0%, while there was the element decrease in the root system and grain (picture 2).

The soy showed the lowest ability to accumulate arsenic among all the crops that were studied. As was seen only in trace amounts in the grain regardless to the doses of the mineral fertilizers. This is very important because

soy is used for the dietary and baby food manufacture.

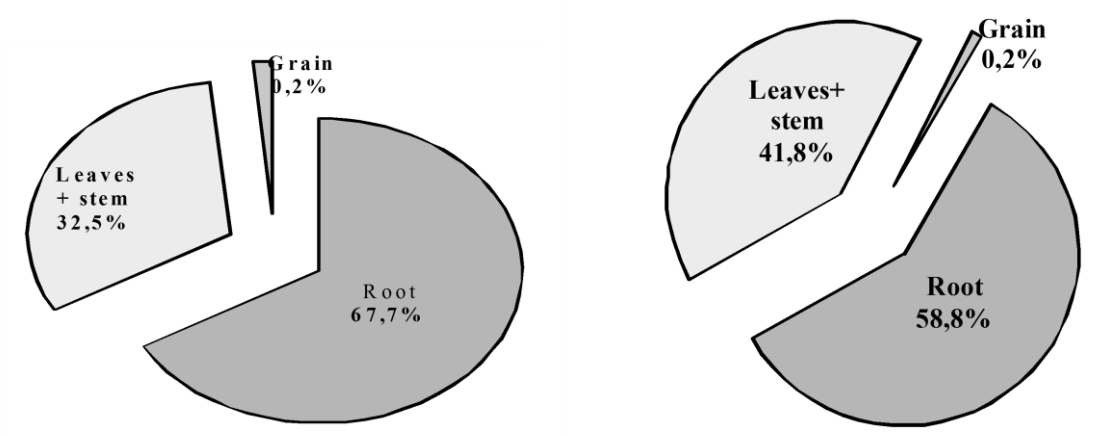
The results of studies of the fertilizers' effect on the element translocation have shown that the content of arsenic in making maximum dose of fertilizers $N_{40}P_{60}K_{60}$ in the soy root system increased in 0,57 times, in 1,3 times in the overground vegetative mass compared to the control (no fertilizer) (picture 3).



A **B**

Picture 2. Fertilizers' effect on arsenic distribution in the organs of spring rapeseed
A – control (no fertilizer), B – $N_{120}P_{60}K_{90}$

The use of organic-mineral fertilization reduced the arsenic transition activity to the soy plants. While using the fertilizers $N_{10}P_{10}K_{10}$ compared to green manure the element content in the vegetative and generative organs of the culture decreased to the trace amounts. The usage of the $N_{40}P_{60}K_{60}$ decreased the protective function of the root system and allowed the accumulation of arsenic in the overground vegetative mass, so that its amount in the leaves and stems increased from 32,5 to 41% (picture 3).



A **B**

Picture 3. Fertilizers' effect on arsenic distribution in the organs of soy
A – control (no fertilizer), B – $N_{40}P_{60}K_{60}$

The studies on the cereal, legume and oil crops (wheat, spring rape and soy) have shown the absolute correlation between the accumulation of arsenic by plants and the use of the mineral and organic fertilizers. In the ecotoxicological research the biological absorption coefficient is used to characterize the process and to show the intensity of the chemical absorption by a plant [2]. The research has found that the arsenic absorption coefficient varied from 0,01 to 0,94, and it was dependent on the crop, plant organs and systems of fertilization (table).

So the studies of the arsenic translocation process in crops have revealed the common dependence of all studied cultures - wheat, rapeseed and soy. The largest number of arsenic was seen in the root system of plants due to their protective function against the toxic substances, and the lowest was in the generative organs (grain). The fertilizers significantly influenced the As translocation in the plants, so that a direct correlation between the number and amount of the arsenic accumulation was observed.

Fertilizers' influence on the arsenic absorption coefficient

Variants	Biological absorption coefficient		
	root	leaves+stem	grain
Spring wheat			
Control (no fertilizer)	0,80	0,49	0,20
$N_{150}P_{100}K_{100}$	0,91	0,54	0,31
$N_{75}P_{50}K_{50}$ sideline products + green manure	0,87	0,51	0,27
$N_{10}P_{10}K_{10}$ + sideline products + green manure	0,94	0,56	< 0,02
Spring rapeseed			
Control (no fertilizer)	0,70	0,43	0,20
$N_{120}P_{60}K_{90}$	0,87	0,64	0,22
$N_{60}P_{30}K_{45}$ sideline products + green manure	0,76	0,40	< 0,01
$N_{20}P_{10}K_{10}$ + sideline products + green manure	0,62	0,38	< 0,01
Soy			
Control (no fertilizer)	0,70	0,33	< 0,02
$N_{40}P_{60}K_{60}$	0,75	0,52	< 0,01
$N_{20}P_{30}K_{30}$ sideline products + green manure	0,75	0,47	< 0,01
$N_{10}P_{10}K_{10}$ sideline products + green manure	< 0,02	<0,02	< 0,02

Conclusion

The studies on the cereal, legume and oil crops (wheat, spring rape and soy) have shown the absolute correlation between the plants' arsenic accumulation and the use of the fertilizers. The greatest ability to accumulate arsenic was observed at the spring rapeseed. According to the results the biological absorption coefficient of the arsenic increased from 0,01 to 0,94,

depending on the crop and fertilization systems.

References

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Досліджено процеси транслокації миш'яку у сільськогосподарські культури, що дозволило виявити залежності, характерні для всіх культур, що вивчалися – пшениці, ріпаку, сої. Найбільша кількість елемента концентрувалася у кореневій системі рослин, найменша – у генеративних органах (зерні). Добрива істотно впливали на транслокацію As у рослини, при цьому простежувалася пряма залежність між їх кількістю та розмірами нагромадження миш'яку рослинами.

Миш'як, мінеральні, органічні добрива, транслокація, сільськогосподарські культури.

Исследованы процессы транслокации мышьяка в сельскохозяйственные культуры, что позволило установить зависимость, которая является характерной для всех изученных культур – пшеницы, рапса, сои. Наибольшее количество элемента накапливалось в корневой системе растений, наименьшее – в генеративных органах (семенах). Удобрения влияют на транслокацию As в растениях, при этом прослеживается прямая зависимость между их количеством и размерами накопления мышьяка растениями.

Мышьяк, минеральные, органические удобрения, транслокация, сельскохозяйственные культуры.