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# Effect of seed treatment by selenium and silicon on the absorption of heavy metals by barley plants under soil drought

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## Abstract

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Vegetative experiments were carried out to study the effect of pre-sowing seed treatment with selenium and silicon on the barley culture, the "Reliable" variety under conditions of optimal and insufficient soil humidity. In vegetative experiments were investigated the effect of short-term drying of the soil, which was established by stopping the watering of the sixth stage of organogenesis. Certain regularities are the uptake of barley of individual heavy metals, depending on the conditions of humidification and pre-sowing seed treatment of the seeds with selenium and silicon. The relationship of cadmium, lead, zinc, copper and chromium accumulation in the basic and by-products is established, depending on the conditions of barley cultivation and the method of seed treatment with silicon and selenium.

*Keywords:* barley; selenium; silicon; heavy metals; pre-sowing seed treatment; drought; pre-sowing seed treatment (PST)

## Introduction

Dry years have repeatedly fallen to the share of Russia. And each time this disaster left behind a significant damage caused not only to nature, but also to man. The drought destroyed the large share of the potential crop yield, which in turn led to a shortage of food raw materials and, as a result, to tangible financial losses. In recent years, due to global warming, the negative effects of drought are increasingly observed and cover more and more regions.

Just do not forget that the population of the planet is steadily growing, and therefore requires more and more food resources. One of the leading groups of crops that are preferred for growing is cereals, which include a range of important plants, such as wheat, barley, oats, triticale, etc. (Yakovlev, 2015). In order to reduce crop losses after exposure to plants, it is necessary to ensure optimal mineral nutrition (Kurnosova et al., 2017; Vernichenko & Yakovlev, 2014).

Also, in the era of such a strong technological progress, a person does not cease to contact with the environmental conditions, and often, his work has a rather detrimental effect on nature. Soil, water, air – everything is contaminated with heavy metals (Balakhnina & Nadezhkina, 2017). Researching the reactions of plants to stressful situations that periodically arise during the growing season is necessary to develop ways to reduce their negative impact (Osipova et al., 2015).

This problem is addressed by many scientists from different countries. For example, colleagues from China (Zhu

& Gong, 2014) in their studies noted that the use of silicon increased the yield of the studied crops, reduced the loss of water from leaves and increased photosynthetic enzymatic activity. Experiments with cucumber and the use of silicon in drought conditions conducted by researchers from Bulgaria have shown that this element not only improves water exchange by reducing transpiration and increasing the efficiency of water use, but also reduces the content of free Proline in tissues (Harizanova, 2017; Harizanova & Koleva-Valkova, 2019). They also found in other studies that silicon increases the consumption of phosphorus and potassium in the aboveground parts of plants (Kozarov et al., 2019). Colleagues from Japan (Hasanuzzaman & Fujita, 2011) in experiments with rapeseed seedlings found that their preliminary treatment with selenium in the conditions of artificially created drought increased the resistance of plants to oxidative stress due to the stimulation of antioxidant defence systems.

In order to find possible ways to reduce the level of stress, researches have been conducted to study actions involving the treatment of seeds by selenium and silicon under conditions of plant resistance to changes in environmental conditions and the accumulation of plant groups of metals.

## Materials and Methods

In 2017 and 2018 years to solve the tasks vegetative experiments were carried out at the Department of Agronomic, Biological Chemistry and Radiology of the Russian State Agrarian University – Moscow “Timiryazev” Agricultural Academy (Russia) to study the effect of pre-sowing seed treatment (PST) by selenium and silicon on the quality of the harvest of barley plants of the “Reliable” variety under optimal and insufficient soil moisture. This variety was developed by the Nemchinovka Research Institute of Agriculture (Moscow region), and was included in the state register in 2017 year. The experiments were carried out on sod-podzolic heavy loamy soil brought from Dolgoprudnaya agrochemical experimental station (Moscow region), which was characterized by the following agrochemical indicators: humus content – 2.2%, $pH_{KCl}$ – 4.5; hydrolytic acidity – 4.20 mgeq/100 g of soil; the amount of absorbed bases – 12.0 mEq/100 g of soil; degree of saturation with bases – 74%. The provision of soil with exchange potassium (according to Kirsanov) was at the level of Class II, mobile phosphorus (according to Kirsanov) of Class III, the total content of selenium in the soil was 64.3 μg/kg (Kidin, 2008).

When filling jars, with a capacity of 5 kg of soil, NPK were additionally introduced at a dose of 150, 100, 100 mg/kg, respectively, and the soil was produced by a full dose of lime, calculated from the hydrolytic acidity value (Zhurbitsky, 1968). The effect of a short-term soil drought was studied in vegetative experiments. It was created by discontinuation irrigation at the sixth stage of organogenesis (in the phase of entering the tube). According to the literature, plants in this phase of development are very sensitive to stress (Seregina, 2011). When the soil moisture reached a level of stable wilting (14% field capacity), watering was resumed until the end of the growing season.

The scheme of the experiment included variants with pre-sowing seed treatment (PST) of Se and Si and their mixture, by wetting with the appropriate solutions (5% by weight of seeds) in the norm of 2.5 and 50 g of element per hectare of seeds, respectively. Trace elements were used in the form of solutions of $Na_2SeO_3$ and $Na_2SiO_3 \cdot 9H_2O$ salts, and the seeds were treated with distilled water as a control. The content of cadmium, lead, zinc, copper and chromium was determined in accordance with the guidelines for the determination of heavy metals in plants (Kuznetsov, 1992). The analysis was carried out on a atomic absorption spectrophotometer AA – 7000 “Shimadzu”.

## Results

Studies have shown that the drought created at the time of planting a tube significantly affected the grain yield, since in this period of time the formation of barley harvest elements took place. Thus, on average over 2 years, the weight of the grain during soil drought was reduced by more than 2 times compared with the control variant. At the same time, the lack of moisture during the growing season had practically no effect on the accumulation of straw mass of the experimental culture.

PST Se and Si significantly reduced the negative impact of soil drought on the formation of barley grain. As a result, yield losses from moisture deficit were significantly reduced, while the greatest protective effect from water stress was observed when seed was treated simultaneously with selenium and silicon (Lapushkina, 2018).

In this publication, special attention was paid to the influence of the studied elements on the accumulation by the barley plants of a number of heavy metals, which affect its nutritional and feed value. According to the results of the experiments, it was found that the soil drought in the phase of the beginning of the release into the tube significantly affects the content in the grain and straw of barley individual heavy metals. It is especially noticeable that water deficiency contributes to the accumulation of Cd, Zn, Cu and Cr in the vegetative organs of barley, and this pattern was observed in all variants of experiments (Table 1).

**Table 1. The effect of Se and Si on the content of heavy metals in the straw of barley plants under different growing conditions, mg/kg, on average, for 2017-2018**

| Moisturizing conditions | PST | Cd | Pb | Zn | Cu | Cr |
|---|---|---|---|---|---|---|
| Control | $H_2O$ | 0.46 | 5.0 | 16.2 | 3.3 | 1.9 |
| | Se | 0.50 | 4.7 | 15.0 | 3.1 | 1.7 |
| | Si | 0.60 | 5.5 | 18.9 | 3.6 | 2.2 |
| | Se+Si | 0.50 | 6.1 | 13.0 | 2.9 | 2.4 |
| Disadvantage | $H_2O$ | 0.59 | 5.7 | 23.3 | 5.0 | 3.6 |
| | Se | 0.68 | 6.5 | 24.1 | 4.6 | 3.1 |
| | Si | 0.85 | 6.1 | 24.6 | 5.5 | 3.6 |
| | Se+Si | 0.69 | 5.9 | 19.5 | 4.4 | 3.1 |

Pre-sowing treatment of barley seeds with selenium increased the content of cadmium in straw, both under optimal moisture and drought, and increased the accumulation of lead plants in vegetative organs only with a deficit of moisture. When considering the content of chromium in the straw of barley, it can be noted that seed treatment with selenium contributed to a decrease in the accumulation of chromium under all growing conditions.

When growing barley both in the control variant and in the soil with a lack of moisture, the pre-sowing treatment of seeds with silicon promoted the accumulation of cadmium in straw, and in the latter case this increase was especially noticeable. The increase in the concentration of this element occurred by 29% and 45%, respectively, relative to the treatment of seeds with water. Seed treatment with silicon stimulated the accumulation of almost all studied heavy metals in straw of barley, but the most noticeable effect (except cadmium) was established for zinc with optimal irrigation. The use of silicon only made it possible to slightly increase the concentration of zinc and copper in the straw of barley. These patterns are observed both under optimal conditions and under the influence of water stress.

Under optimal irrigation conditions, seed treatment at the same time with selenium and silicon increased plumbum accumulation in plants by 22%. But with constant watering joint PST the studied elements led to the accumulation of chromium by 25%, and during drought, on the contrary, decreased its concentration by 14% relative to PST water.

Considering the effect of soil drought on the accumulation of the studied heavy metals in grain (Table 2), it should be noted that the overall level of their content in the reproductive organs was in all cases less than in the straw.

Barley plants subjected to water stress, in almost all cases, accumulated less heavy metals than plants grown with optimal watering. But this pattern does not obey the nature of the accumulation of zinc in the grain and in the straw. Its concentration increases with a lack of moisture, apparently, this is due to the physiological role of this element, affecting the drought resistance of plants. The accumulated soil drought did not have a significant effect on the accumulation of Cr in the barley grain.

Unlike straw, the use of Se and Si contributed to a decrease in the accumulation of cadmium in the grain. This may indicate that the elements under study interfere with the movement of cadmium into the ear, retaining it in the vegetative mass of the plant, and contribute to the production of cleaner marketable products.

**Table 2. The effect of Se and Si on the content of heavy metals in the grain of barley plants under various growing conditions, mg / kg, on average for 2017-2018**

| Moisturizing conditions | PST | Cd | Pb | Zn | Cu | Cr |
|---|---|---|---|---|---|---|
| Control | $H_2O$ | 0.40 | 3.0 | 25.6 | 5.2 | 2.9 |
| | Se | 0.20 | 3.2 | 26.6 | 5.1 | 3.1 |
| | Si | 0.28 | 3.4 | 29.9 | 5.8 | 2.4 |
| | Se+Si | 0.24 | 3.6 | 22.7 | 4.9 | 2.4 |
| Disadvantage | $H_2O$ | 0.29 | 2.6 | 31.3 | 3.1 | 2.9 |
| | Se | 0.28 | 2.6 | 34.0 | 4.2 | 3.1 |
| | Si | 0.21 | 2.8 | 28.0 | 3.9 | 3.2 |
| | Se+Si | 0.21 | 2.6 | 26.3 | 2.7 | 3.3 |

## Discussion

Analyzing the effect of selenium on the accumulation of the studied heavy metals in the grain harvest (Table 2), it is necessary to note a significant decrease (2 times) under its influence the cadmium content during optimal irrigation and the absence of this effect during the drought tested by plants. When drought suffered PST Se caused an increase in the content of barley grain copper by 38%. Under other growing conditions, the use of selenium did not have a noticeable effect on the accumulation of heavy metals in the grain.

Our research has shown that with sufficient soil moistening, the use of silicon made it possible to somewhat increase the content of zinc and copper in the barley grain. Unlike lead, cadmium and chromium, zinc and copper are trace elements essential and indispensable in plant nutrition. Therefore, their accumulation in the plant can, under certain conditions and acceptable concentrations, play a positive role in the formation of the crop and its quality.

With sufficient moisture, seed treatment with selenium and silicon, both individually and together, led to an accumulation of plumbum in the grain. The maximum content was noted in the variant with the combined use of Se and Si – 20% higher relative to the control variant. Under the conditions of drought exposure, there was no difference between the individual variants of the experience in lead content in barley grain.

Sharing PST Se and Si in all growing conditions, led to a decrease in the amount of zinc and copper in comparison with treatment with water. Under conditions of moisture deficiency in the soil, the use of selenium with silicon contributed to an increase in the chromium content in the grain.

Figure 1 presents a comparison of the content of heavy metals relative to the control variant of seed treatment, namely distilled water, with timely watering.

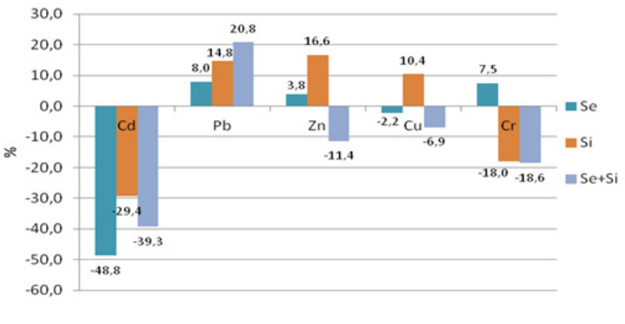


**Fig. 1. Influence PST selenium and silicon on the content of the studied heavy metals in barley grain**

As can be seen, the use of separate selenium and together with silicon contributed to the decrease in the content of cadmium by 48.8 and 39.3%, respectively. Also, seed treatment with both silicon and the amount of selenium and silicon reduced the chromium concentration by 18.0 and 18.6%. But these same methods of treatment contributed to the accumulation of lead by 14.8 and 20.8%.

Figure 2 presents data on the content of a number of heavy metals in barley grain relative to the control variant of seed treatment with moisture deficiencies.

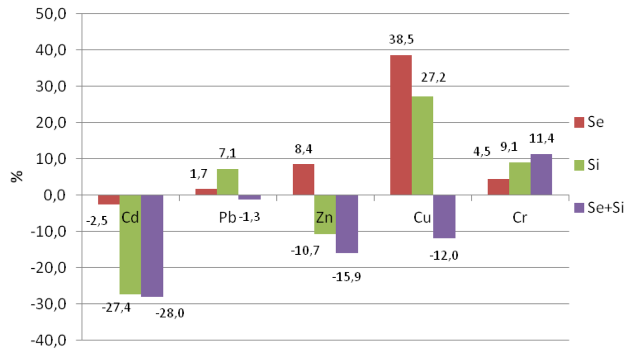


**Fig. 2. Influence PST selenium and silicon on the content of the studied heavy metals in barley grain under conditions of soil moisture deficiency**

So, PST silicon, both separately and together with selenium, reduced the concentration of cadmium by 27.4 and 28.0%, zinc by 10.7 and 15.9%, respectively. But, separate use of selenium and silicon, on the contrary, could increase the concentration of copper in the grain by 38.5 and 27.2%.

## Conclusion

Thus, it is possible to note some regularity in the absorption of individual heavy metals by barley plants, depending on the conditions of wetting and the pre-sowing treatment of seeds with selenium and silicon. All PST contributed to the accumulation of cadmium in straw, thereby preventing it from accumulating in the grain. In the case of plumbum, only joint treatment with selenium and silicon with optimal irrigation led to an increase in its content both in straw and in grain. The accumulation of zinc and copper in primary and secondary products is interrelated with both the growing conditions and seed treatment only with silicon and silicon with selenium. In the chromium absorption by plants in the control variant, an inverse relationship is observed: selenium reduces its concentration in straw, but increases it in grain, while silicon and silicon with selenium, on the contrary, prevent the metal from entering the grain, retaining it in straw.

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