Spring wheat yield (Triticum aestivum L.) when applying selenium fertilizers in extreme growing conditions

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Abstract. To study the effect of sodium Selenite application different methods on the yield of spring wheat varieties, depending on the conditions of water supply, a series of vegetation experiments in accordance with the methodology were carried out. The object of the study is spring wheat of the Zlata variety (Triticum aestivum L.). It was found that the effect of selenium on the yield of wheat of the Zlata variety depended on the method of its application and the conditions of water supply. With optimal water supply, the positive effect of selenium on the yield of spring wheat plants was revealed with both methods of applying sodium selenite. It was found that in conditions of drought, the positive effect of selenium was obtained with both methods of using sodium selenite. The greatest efficiency of selenium is obtained in foliar processing of plants. The increase in grain weight in this variant was 1.4 times. The increase in the share of the agronomic significant part of the wheat crop yield to 36% is shown, which indicates the decrease in the negative effect of drought on the formation of spring wheat yield when using foliar processing of plants.

1. Introduction
The Non-Black Earth zone has relatively favorable climatic conditions. Nevertheless, agricultural plants cultivated in these areas have a moisture deficit in some years. Water deficit causes not only a sharp decrease in productivity, but also complete destruction of the plant organism. Insufficient moisturizing in the critical period of plant development is especially dangerous [1].

The deficit of soil moisture in grain crops causes inhibition of ear formation processes and accumulation of dry matter by it. At the same time, the processes of formation of floral rudiments and vegetation cone growth are inhibited [2, 3, 4].

In conditions of lack of soil moisture for plant organisms, a long withering established. At the given type of fading in all parts of a plant loss of turgor and dehydration occurs, speed of photosynthesis decreases, processes of formation of chlorophyll, transport of electrons and photophosphorylation are broken. Besides, changes in hormonal status of plants are observed, growth and generative development are suppressed [5].
The effect of drought on plants is manifested in the form of disturbances of energy processes, water regime, as well as such metabolic processes as protein biosynthesis, respiration rate and photosynthesis [6].

Spring wheat is cultivated mainly in areas with continental climate and belongs to cold resistant plants. Vegetable seedlings may appear at 5-7 °C, but the most optimal temperature for seed germination is 12-15 °C. Optimal air temperature during filling and maturing of grain is 22-25 °C [7].

Spring wheat is a crop that is resistant to high temperatures, especially with normal soil moisture supply. Water shortage is observed if the moisture stock in the meter layer in the spring period is less than 100 mm, and with a stock of less than 60 mm there is a significant decrease in yield. The critical period of water absorption is the phase of thawing - outlet into the tube [8].

Selenium is one of the components of antioxidant plant protection. At biochemical level selenium reduces the intensity of peroxidation of membrane lipids by inhibiting superoxide dismutase [9].

A number of studies found a relationship between the application of selenium and the accumulation of amino acid proline in the leaves. Proline, participating in protective processes, slows down the outflow of assimilates from the leaves and activates hydrolytic enzymes. The dependence of the concentration of proline on the application of selenium is associated with the regulation of carbohydrate metabolism, which can reduce the water potential of the leaves and restore the functioning of the root system. This process is one of the mechanisms of protective action of selenium in conditions of oxidative stress caused by many adverse factors [10].

In this regard, our study was aimed at studying spring wheat yield when sodium selenite is used in extreme conditions of cultivation (under insufficient and excessive water supply).

2. Materials and methods

The object of research is spring wheat of Zlata variety (Triticum aestivum L.).

To study the influence of different methods of application of sodium selenite on the yield of spring wheat of Zlata variety depending on the conditions of water supply, a series of vegetation experiments (No. 1 and No. 2) was carried out in the vegetation house of the Department of Agronomic, Biological Chemistry and Radiology of the Russian State Agrarian University - Moscow Timiryazev Agricultural Academy according to the methodology [8].

The soil typical of urban soil from the training and experimentation area of the department of the Russian State Agrarian University - Moscow Timiryazev Agricultural Academy was used for studies. The determination of agrochemical indicators of soil was carried out by conventional methods [8]: the humus content of Tyurin was 1.5% (State Standard 26213-91), pH_{KCl} = 5.7 (State Standard 2648-85), hydrolytic acidity of the soil is 1.2 mg-eq/100 g of soil (State Standard 26212-91), the sum of the absorbed bases by Kappen-Gilkowitz is 24.3 mg-eq/100 g of soil (State Standard 27821-88), the content of alkaline hydrolyzable nitrogen by Cornfield is 82 mg/kg of soil (State Standard 26107-84), the content of phosphorus and potassium by Kirsanov 180 and 150 mg/kg of soil respectively (State Standard 54650-2011). The soil is slightly acidic, class of mobile forms of phosphorus and potassium - V.

The level of mineral nutrition in all variants of the experience was created by applying ammonium nitrate (NH₄NO₃), ammonophos (NH₄H₂PO₄) and potassium chloride (KCl) in the bookmark experience. NPK doses were based on 100 mg/kg of soil for each element.

Sodium selenite (Na₂SeO₃) was used as a selenium-containing compound. This substance is a derivative of selenium acid and is a white amorphous powder easily soluble in water with selenium content of 45.2% [7].

Two methods of sodium selenite application were studied in the studies: seed treatment before sowing and foliar treatment of plants. Seed treatment before sowing was carried out by soaking the seeds a few hours before sowing in 0.01% (0.1 g/l) solution of sodium selenite taken in the amount of 5% of the grain weight. At foliar treatment of plants the same solution of salt was used, which was treated in the phase of 5 sheets (before the phase of entering the tube). No sodium selenite was used in the control versions of plants.
In experiments No. 1, 2 we modeled optimal, insufficient and excessive water supply conditions. The optimal regime of soil moisture for plants was created by watering vessels by weight up to 60% of the full moisture capacity.

In the experiment No. 1, to study the influence of selenium on spring wheat yield under drought conditions, plants were grown in Mitcherlich's vessels with pallets of 6 kg of soil. Drought of "northern type" was modeled by stopping irrigation of plants before the VI stage of organogenesis. The duration of the drought was 7 days. After the onset of moisture in the soil steady withering (40% of the full moisture capacity) was resumed irrigation.

In the experiment No. 2, the effect of sodium selenite on spring wheat yield under flooded conditions was studied. Plants were grown in Wagner’s vessels with capacity of 6 kg. The duration of flooding was 10 days. For this purpose, the vessels were flooded so that the water level was above the soil surface, and after the end of stress water was drained and gradually returned to normal watering.

We sowed 40 spring wheat seeds in each vessel. During the thawing phase, up to 20 plants per vessel were thinned. Harvesting was carried out in the phase of full ripening.

Reliability of the data obtained in the course of the experiment was determined with the help of mathematical processing by one-factor method of dispersion analysis [8].

3. Results and discussion

The results of the research on the influence of sodium selenite on the yield of spring wheat of Zlata variety under conditions of insufficient soil moisture in experiment No. 1 are presented in Table 1.

Table 1. Yields of spring wheat selection lines at different methods of sodium selenite treatment in conditions of drought (experiment No. 1).

| Selenium application       | Water supply conditions  | Weight, g/vessel |
|----------------------------|--------------------------|------------------|
| Control                    |                          | 13.0 4.7 18.5    |
| Seed treatment before sowing| Optimum water supply     | 15.6 3.9 18.0    |
| Foliar treatment of plants |                          | 13.2 3.9 18.7    |
| LSD05                      |                          | 0.6 0.2 0.8      |
| Control                    |                          | 8.6 3.7 14.0     |
| Seed treatment before sowing| Inadequate water supply | 10.7 3.8 16.8    |
| Foliar treatment of plants |                          | 12.2 4.3 17.5    |
| LSD05                      |                          | 0.6 0.2 0.8      |

As the results of studies have shown, in the experience No. 1 in the conditions of optimal water supply, the greatest effect on the yield of spring wheat of Zlata variety was obtained by using seed treatment before sowing, while foliar treatment of vegetative plants did not lead to a reliable increase. Grain mass gain from seed treatment with sodium selenite before sowing was 15.6%. On the contrary, the mass of floors decreased in comparison with the control version. No reliable changes in straw weight were obtained under these conditions.

In dry conditions, the effectiveness of selenium is shown regardless of the method of application. So, at treatment of seeds before sowing the weight of grain has increased on 24%, and at foliar treatment of vegetative plants in 1.4 times. In addition, there is a reliable increase in the mass of straw by 14% and 25%, respectively.

In assessing the effect of various methods of treatment of sodium selenite on the yield of spring wheat in drought conditions, the effect of this trace element on the structure of the crop was also studied. Obtained data are given in Table 2.
From Table 2 you can see that different methods of selenium treatment have ambiguous influence on the structure of spring wheat harvest. Under optimal water supply conditions, foliar treatment of plants and seed treatment before sowing spring wheat contributed to an increase in the mass fraction of grain up to 37% to 42%, respectively, compared with the option without selenium. At application of seed treatment before sowing the decrease of the share of floor and straw is shown, that testifies to the increase of agronomically significant part of the harvest and improvement of the wheat harvest structure.

**Table 2.** Spring wheat yield structure of Zlata variety in the application of sodium selenite in various ways in conditions of insufficient moisture (experience No. 1).

| Selenium application          | Water supply conditions | Yield structure, % | Weight of the above-ground part of plants, g/vessel |
|------------------------------|-------------------------|-------------------|-----------------------------------------------|
| Control                      |                         | 36 13 51          | 36.2                                          |
| Seed treatment before sowing | Optimum water supply    | 42 10 48          | 37.5                                          |
| Foliar treatment of plants   |                         | 37 11 52          | 35.8                                          |
| Control                      |                         | 32 14 53          | 26.3                                          |
| Seed treatment before sowing | Inadequate water supply | 34 12 54          | 31.3                                          |
| Foliar treatment of plants   |                         | 36 13 51          | 34.0                                          |

In the conditions of drought in the control version of the reduction of above-ground mass of plants from 36.2 g/vessel with optimal water supply to 26.3 g/vessel in the drought. Application of selenium in these conditions leads to an increase in the weight of the above-ground mass of plants, especially in foliar treatment of plants from 26.3 g/vessel to 34 g/vessel, compared with the control. In these conditions the increase in the share of grain in the structure of the crop when both methods of application of selenium is showed. This indicates the decrease in the negative effect of drought on the mass of aboveground plants of spring wheat.

In the experiment No. 2 on study of influence of selenium on formation of spring wheat yield of Zlata variety in conditions of excessive humidification there is a sharp decrease of grain mass in all variants of experiment in comparison with plants, grown in optimal conditions of water supply (Table 3).

**Table 3.** Yield of spring wheat breeding lines at different methods of sodium selenite treatment in conditions with flooding (experience No. 2).

| Selenium application          | Water supply conditions | Weight, g/vessel |
|------------------------------|-------------------------|-----------------|
| Control                      |                         | 8.6 3.4 13.5    |
| Seed treatment before sowing | Optimum water supply    | 9.3 3.0 13.9    |
| Foliar treatment of plants   |                         | 10.3 3.4 16.0   |
| LSD₀.₀₅                      |                         | 0.5 0.2 0.6     |
| Control                      |                         | 2.1 1.0 12.2    |
| Seed treatment before sowing | Inadequate water supply | 3.5 1.2 13.5    |
| Foliar treatment of plants   |                         | 4.4 1.4 10.6    |
| LSD₀.₀₅                      |                         | 0.4 0.2 0.7     |
The mass of grain decreased by more than 4 times in comparison with the variant with optimal water supply. The use of selenium in these conditions contributed to reducing the negative effect of excessive flooding on the formation of wheat plants yield. Grain mass gain during seed treatment before sowing sodium selenite was 10.8%, at foliar treatment of plants 19.8% in comparison with the variant without sodium selenite.

The results of studies on the effect of sodium selenite on the structure of spring wheat yield under conditions of excessive moisture in experiment No. 2 are presented in Table 4.

**Table 4. Structure of spring wheat yield at application of sodium selenite in different ways under conditions of excessive humidification (experiment No. 2).**

| Selenium application | Water supply conditions | Yield structure, % | Weight of the above-ground part of plants, g/vessel |
|----------------------|-------------------------|--------------------|---------------------------------------------------|
| Control              |                         | Grain  | Chaff  | Straw  | 25.5  |
| Seed treatment       | Optimum water supply    | 34     | 13     | 53     |       |
| before sowing        |                         | 36     | 11     | 53     | 26.2  |
| Foliar treatment of plants | Inadequate water supply | 35     | 12     | 54     | 29.7  |
| Control              |                         | 14     | 6      | 80     | 15.3  |
| Seed treatment       |                         | 19     | 7      | 74     | 18.2  |
| before sowing        |                         | 27     | 9      | 65     | 16.4  |

In the conditions of flooding, a sharp decrease in the weight of the above-ground part of plants up to 15.3 g against 25.5 g with optimal water supply in the control version was established. The favorable effect of sodium selenite on the increase in the mass of the above-ground part of plants and the share of grain in the structure of the crop with both methods of its application is shown. The weight of the above-ground part of plants increased to a greater extent with the application of seed treatment before sowing by 19% compared to control without selenium. But the effect of selenium on the fraction of grain manifested itself to a greater extent in the foliar treatment of plants. In this case, the share of grain increases to 27% compared with the control without selenium, and the share of straw decreases to 65% compared with the option without selenium.

### 4. Conclusion

As the result of the research on the impact of different methods of sodium selenite processing on the yield of spring wheat of Zlata variety, the following conclusions can be drawn:

1. The effectiveness of the selenium influence on the spring wheat yield depends on the method of sodium selenite application and water supply conditions.
2. At optimal water supply, a positive effect of selenium on the yield of spring wheat plants in both methods of application of sodium selenite revealed. The increase of grain share in the structure of above-ground part of plants is shown.
3. The positive effect of selenium in drought conditions was found out at both methods of application of sodium selenite. The highest efficiency of selenium was obtained at foliar treatment of plants. The increase in mass of grain in this variant was 1.4 times. The increase in the share of agronomic significant part of the yield of wheat plants up to 36% was shown, which indicates the decrease in the negative effect of drought on the formation of spring wheat yield when using foliar treatment of plants.
4. It is established that in the conditions of excessive water supply there was a sharp decline in the yield of plants more than 4 times compared with the optimal water supply of plants. The decrease in
structure of a crop as the result of strong decrease in a mass share of grain to 14% in comparison with an optimum water supply was received.

5. The use of sodium selenite in conditions of excess water supply shows the increase in the mass of grain in both methods of treatment of selenium. It testifies to decrease of negative effect of excess moisture in soil on formation of plants yield. The increase of a share of grain in structure of above-ground weight of plants at processing of seeds before sowing to 19%, and at foliar processing of plants to 27% against 14% in control without selenium was revealed.

References
[1] Aristarkhov A N, Busygin A S and Yakovleva T A 2018 Selenium deficiency in soils and plants of the North-Eastern Non-Chernozem region as an indicator of the need to use selenium fertilizers Int. Agricultural J. 1 31-36
[2] Voronov S I, Pleskachev Yu N and Ilyashenko P V 2020 Fundamentals of production of high-quality winter wheat grain Fertility 2(113) 64-66
[3] Voronov S I, Pleskachev Yu N and Chernomorov G V 2020 Productivity of winter wheat depending on leaf application of CAS and growth regulators Problems of Agro-Industrial Complex Development in the Region 1(41)19-22
[4] Pleskachev Yu N, Voronov S I and Grabov R S 2020 Improvement of the system of basic tillage in the cultivation of spring barley Proc. of the Nizhevolzhsky Agricultuniversity Complex: Science and Higher Professional Education 1(57) 88-95
[5] Baraboy V A 2004 Biological functions. metabolism and mechanism of action of selenium Advances in Modern Biology 2 157-168
[6] Seregina I I 2018 Zinc, Selenium and Growth Regulators in Agrocenosis (Moscow: Agrorus) p 208
[7] Genkel P A 1982 Physiology of Heat and Drought Resistance of Plants (Moscow: Nauka) p 279
[8] Golubkina N A, Kekina E G, Molchanova A V, Antoshkina M S, Nadezhkin S M and Soldatenko A V 2018 Plant Antioxidants and Methods of Their Determination (Moscow: Federal Scientific Center of Vegetable Growing) p 66
[9] Koshkin E I 2010 Physiology of Stability of Agricultural Crops (Moscow: Bustard) p 638
[10] Posypanov G S et al 2017 Crop Production (Moscow: KolosS) p 612