The effect of silicon humic preparation on the biometrics of spring wheat germinated under stress

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Abstract. Fluctuation of climatic conditions negatively affects the yield of farmers. To compensate for stress factors, various preparations are used, humic and silicon-containing preparations have been widely introduced. The silicon-humic preparation BoHum-K, obtained on the basis of a humic preparation and amorphous silicon oxide, is being tested at VNIIMZ. The studies were carried out with BoHum-K containing various amounts of SiO₂. A laboratory experiment was carried out on wheat grown under simulated abiotic stresses. The preparation was used for pre-sowing seed treatment and spraying of seedlings. The obtained data on the biometrics of seedlings indicated that the use of a silicon humic preparation reduced the negative impact of simulated stresses. When treating seeds before sowing, the greatest increase in biometric indicators was noted with the use of BoHum-K with a silicon oxide content of 0.5% when simulating a decrease in temperature after sowing: the average length of the seedling increased by 10.1%, the raw weight by 14.3%, dry weight - by 10.9% compared with the control variant. When applying the spraying technique, depending on the simulated stress, the leaders were BoHum-K [0.1%] and BoHum-K [0.5%], the biomass increments were up to 20.0%. In general, according to the experiment, the increase in the biomass of seedlings from spraying wheat with BoHum-K [0.5%] averaged 12.7%, from seed soaking - 8.9%, which indicates the advantage of non-root treatment.

1. Introduction
The instability of climatic conditions in many regions of the Russian Federation, associated with sharp fluctuations in temperature, heavy precipitation or, conversely, droughts, leads to a negative impact on the growth and development of agricultural plants, thereby reducing their productivity [1]. Farmers, in turn, are trying to reduce the negative impact of abiotic factors by using various immunostimulating and anti-stress preparations. The use of liquid preparations is possible not only in advance, preventing stress, but also after the negative impact that has occurred.

VNIIMZ (branch of FRC V.V. Dokuchaev Soil Science Institute) has been conducting research in the field of obtaining, testing and introducing liquid preparations for crop production for the past two decades. In the institute arsenal there are preparations of microbiological, biogenic and humic nature, work is underway to strengthen their composition and quality characteristics. One of these work directions is the creation of a new liquid-phase silicon humic preparation. The expected positive results are associated with its complex of active substances - humic substances and silicon. Humic substances facilitate the transport of micro- and macronutrients, inclusion in the plant lipid metabolism, adaptation of plants to various stress factors [2, 3]. Silicon increases the resistance of plants to adverse environmental factors, improves plant nutrition conditions, influences many
physiological and biochemical processes, participates in the optimization of transport and redistribution of substances inside the plant [4, 5].

One of the developed and undergoing primary testing is a silicon humic preparation obtained on the basis of the humic biological agent BoHum (humic substances of at least 7 g/l, dry matter – at least 20 g/l) developed in the biotechnology department of VNIIMZ, amorphous silicon oxide was used as a silicon source under the trademark Kovelos (Ecosilicon LLC). Amorphous silicon particles have a micron size and a complex spatial structure that creates a huge specific surface area, therefore it is able to impart new characteristics to various compositions, materials, products without changing their chemical properties, for example, to be a carrier of active substances. The manufacturing of a silicon humic preparation was carried out by introducing an amorphous silicon oxide at the normalization stage, with further mixing of the mixture for 30 minutes. After that, the mixture was kept for 7 days to complete the transformation processes. The disadvantage of amorphous silicon is poor solubility, so the resulting silicon humic preparation had a suspended solid, which requires mixing before use. The resulting preparation was designated as BoHum-K.

The approbation of amorphous silicon oxide Kovelos is presented in the scientific literature quite informatively and on various media [6, 7]. Laboratory experiments conducted in VNIIMZ with spring wheat germinated under conditions of abiotic stress showed good responsiveness of plants to pre-sowing treatment of wheat seeds with Kovelos solutions. The greatest effect was obtained from the use of a 0.5% solution when simulating an acute lack of soil moisture [8].

The humic preparation BoHum is undergoing extensive testing on various agricultural crops, including spring wheat. According to laboratory experience, two concentrations of BoHum were identified, contributing to a statistically significant increase in the biometric indicators of seedlings. Further field tests showed high efficiency of pre-sowing seed treatment with a solution containing 0.01% humic acids – the increase in grain yield was 12.9% [9].

The resulting silicon humic preparation will combine the functions of its basic active substances (humic substances and silicon), and as a result of the synergistic effect will enhance their effectiveness.

The high efficiency of such preparations can be viewed on the example of a concentrated humic fertilizer with a high silicon content presented on the market - Edal KS (Vacuum Components LLC, city of Ryazan, RF), recommended for pre-sowing treatment of seeds, planting material and fertilizing during the growing season of all agricultural and flower-decorative crops. This fertilizer was widely tested in subsidiary farms of the Federal Penitentiary Service of Russia in the Ryazan region in 2018-2019 and high yield increases were obtained for: winter wheat - 4.5-10.6 c/ha, barley - up to 10.2 c/ha, corn for grain - 4.2-4.9 c/ha, sugar beet - 49.0-78.0 c/ha, carrot - 30.0-80.0 c/ha, etc. [10].

The purpose of the research was to study the effect of the silicon humic preparation BoHum-K on the biometric parameters of wheat grown under abiotic stress.

2. Materials and methods
The studies were carried out with the BoHum-K preparation with the following content of amorphous silicon – 0.1 %, 0.5 %, 2.5 %, 5.0 %, which practically corresponded to the same concentration of silicon oxide in the resulting preparations. When choosing concentrations, we were guided by the recommendations of the manufacturer of Kovelos, as well as data from the scientific literature on the use of silicon-containing preparations.

Evaluation of the effectiveness of the new silicon humic preparation was carried out in a laboratory experiment by modeling stress conditions for spring wheat plants of the Irgina variety. Sod-podzolic soil with agrochemical characteristics - pH - 4.31; P2O5 – 192.1; K2O – 156.2 mg/kg of soil, humus – 2.83 %, dried to air-dried basis, sieved, placed in plastic containers at 150 g and moistened to 70 % of the SFMC (smallest field moisture capacity). Spring wheat seeds were sown in three rows of 7 seeds. The preparation was used for soaking seeds before planting and spraying plants during vegetation (germination phase) after simulated stresses. The seeds were treated with a solution at a working concentration of 1:100, spraying - 1:300 (recommended norms when using BoHum). The control was
a variant with water treatment of wheat. There were also options with seed growth without any stress (ambient temperature 20-22°C, soil moisture - 70% of SFMC). Cultivation was carried out for 2 weeks, regular watering was carried out to maintain the desired moisture, the repetition of the experiment was threefold.

The following stress factors were modeled: low temperature (up to 7°C, soil moisture – 70% of SFMC) after sowing, temperature drop (up to 7°C, soil moisture – 70% of SFMC) in the germination phase, excessive humidity (140% of SFMC, ambient temperature 20-22°C), acute lack of soil moisture (10% of SFMC, ambient temperature 20-22°C). Temperature drop was provided by placing containers in a refrigerated heating circulator, excessive moisture - by additional watering, acute lack of moisture - by stopping watering.

The effectiveness was evaluated by determining the length of seedlings, raw and dry biomass of plants. Statistical processing was carried out by calculating the arithmetic mean values of the indicators (sample size n = 63), followed by a one-factor analysis of variance with the LSD calculation at a 5% significance level.

3. Results and discussion
The analysis of the obtained data indicated the negative impact of simulated stress abiotic factors on the growth of wheat seedlings, which was expressed in a decrease in biometric indicators. The exception was a block with excessive soil moisture imitation – due to maintaining a temperature of 20-22°C, an increase in the length and raw weight of wheat seedlings was noted, while the dry biomass changed less significantly, which indicated the formation of longer and weaker plants prone to lodging.

Pre-sowing treatment of spring wheat seeds with a silicon-containing preparation to varying degrees reduced the negative impact of simulated stresses, which affected the development of wheat seedlings. The greatest increase in the length and biomass of seedlings relative to the variant with water treatment was noted from BoHum -K with a SiO₂ content of 0.5% (Table 1). When using high seedlings. The greatest increase in the length and biomass of seedlings relative to the variant with degrees reduced the negative impact of simulated stresses, which affected the development of wheat.

The best responsiveness of plants to the use of BoHum -K [0.5%] when soaking seeds was noted by stopping watering.

The effectiveness was evaluated by determining the length of seedlings, raw and dry biomass of plants. Statistical processing was carried out by calculating the arithmetic mean values of the indicators (sample size n = 63), followed by a one-factor analysis of variance with the LSD calculation at a 5% significance level.

Table 1. Biometric indicators of seedlings during pre-sowing treatment of spring wheat seeds with a silicon humic preparation.

| [C] | Average length of 1 seedling, cm | Average raw weight of 1 seedling, x10⁻³ g | Average dry weight of 1 seedling, x10⁻³ g |
|-----|---------------------------------|------------------------------------------|----------------------------------------|
| water | 19.9 | 17.6 | 19.5 | 18.0 | 22.4 | 92.8 | 78.4 | 83.6 | 87.1 | 104.6 | 11.8 | 10.1 | 10.5 | 10.7 | 10.8 |
| 0,1% | 20.3 | 19.1 | 19.8 | 19.0 | 23.1 | 98.0 | 88.4 | 87.8 | 90.6 | 111.2 | 12.9 | 11.2 | 11.6 | 11.1 | 11.8 |
| 0,5% | 20.8 | 19.4 | 20.6 | 19.0 | 23.5 | 99.2 | 89.6 | 89.1 | 91.8 | 112.0 | 12.7 | 11.2 | 12.0 | 11.2 | 12.0 |
| 2,5% | 20.7 | 19.0 | 20.3 | 18.5 | 21.6 | 98.1 | 88.2 | 87.7 | 90.7 | 107.1 | 12.2 | 11.3 | 11.5 | 10.8 | 11.7 |
| 5,0% | 20.4 | 19.2 | 20.1 | 18.7 | 21.9 | 93.4 | 88.7 | 87.2 | 90.2 | 99.5 | 11.8 | 11.1 | 10.8 | 11.0 | 10.5 |
| LSD₉₅ | 1.02 | 0.95 | 0.98 | 0.86 | 1.06 | 4.25 | 3.87 | 4.21 | 4.32 | 5.21 | 0.57 | 0.54 | 0.61 | 0.50 | 0.47 |

Note: without - growing plants without stressful conditions; t.sow – growing plants with a decrease in temperature after sowing; t.germ. – cultivation of plants with a decrease in temperature after germination; dry -
cultivation of plants with an acute lack of soil moisture; moist. – cultivation of plants with excessive soil moisture.

Spraying of wheat seedlings after the acute phase of simulated abiotic stresses with a silicon humic preparation in all the studied concentrations of silicon oxide also contributed to an increase in biometric indicators, but there was no clear leader, unlike the use of the preparation for seed treatment (Table 2). It should be noted that the greatest increases in the raw and dry biomass of seedlings were noted when using the preparation in conditions of acute lack of soil moisture. In this case, the BoHum-K preparation with a silicon oxide content of 0.1% – 20.0% and 17.5%, respectively, was in the lead, compared with the control, the BoHum-K variant had similar values [0.5%]. In the conditions of high humidity modeling, the maximum was observed in the variant with spraying with BoHum-K [0.5%] - the increase in the raw weight was 14.0%, dry weight - 12.2%.

**Table 2. Biometric indicators of seedlings during non-root treatment of spring wheat with a silicon humic preparation.**

| [C]  | Average length of 1 seedling, cm | Average raw weight of 1 seedling, x10^{-3} g | Average dry weight of 1 seedling, x10^{-3} g |
|------|--------------------------------|---------------------------------------------|---------------------------------------------|
|      | without t.germ. | dry | moist. | without t.germ. | dry | moist. | without t.germ. | dry | moist. |
| water | 19.6  | 20.3 | 17.9 | 20.8 | 83.7 | 82.8 | 82.7 | 91.6 | 10.1 | 9.3 | 10.6 | 9.9 |
| 0,1%  | 19.9  | 22.7 | 18.9 | 20.7 | 86.7 | 100.3 | 92.4 | 97.3 | 10.5 | 10.8 | 11.8 | 10.7 |
| 0,5%  | 20.1  | 21.9 | 18.4 | 21.1 | 87.9 | 97.6 | 91.3 | 104.4 | 10.8 | 10.4 | 11.5 | 11.1 |
| 2,5%  | 20.3  | 21.5 | 18.2 | 21.2 | 89.9 | 97.7 | 90.7 | 97.6 | 11.7 | 10.7 | 11.5 | 10.6 |
| 5,0%  | 21.2  | 22.6 | 18.4 | 21.1 | 92.9 | 101.0 | 90.3 | 103.2 | 11.5 | 11.0 | 11.4 | 11.1 |
| LSD_{0.05} | 0.97  | 0.95 | 0.84 | 1.04 | 3.96 | 4.86 | 4.23 | 5.07 | 0.43 | 0.51 | 0.54 | 0.48 |

Note: see table 1

Under stress-free conditions, a gradual increase in all biometric indicators was observed with an increase in the concentration of the silicon humic preparation used for spraying seedlings, and nearly the maximum increase was obtained from BoHum-K [5%] and amounted to 10.9% of the raw weight, 14.2% of the dry weight. With a decrease in temperature after germination, ambiguous results were obtained – a positive effect was revealed when using a silicon-containing preparation with both a minimum and maximum concentration of silicon oxide.

In general, according to the results of the study, the advantage of spraying seedlings before soaking of seeds was revealed, expressed in a higher frequency and a significant reliable increase in biometric indicators of wheat seedlings. Despite the fact that soaking of seeds affects germination and the formation of more powerful seedlings capable of resisting the external effects of abiotic stresses, when modeling the studied abiotic stresses, the use of spraying at the time of a strong negative influence was targeted and timely, plants received support in the form of nutrients, physiologically active substances. This is because in case of direct contact with the leaf surface, the components of the silicon-containing preparation are immediately included in the physiological and biochemical processes of plants aimed at removing the negative effects of stress and activating plant growth and development.

**4. Conclusion**

Thus, the positive effect of the obtained silicon humic preparation BoHum-K on wheat plants was revealed. The effect of its use was expressed in an increase in the biometric indicators of wheat seedlings, which indirectly indicates a decrease in the negative impact of abiotic stresses on plants. The conducted studies allowed to establish the optimal concentration of silicon oxide in the preparation - 0.5%, the greatest responsiveness of plants was obtained from the use of the preparation for non-root treatment of seedlings. The increase in the biomass of seedlings from spraying wheat with BoHum-K [0.5%] averaged 12.7%, from soaking of seeds - 8.9% compared to the option with water treatment.
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