Combined use of microbiological preparations and Nano Silicon in oats cultivation

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Abstract. The article presents the results of the studies on the combined use of microbiological preparations and NanoSilicon in oat cultivation. Biological products (Fungilex, Bactophosphine, Extrasol, Fitosporine) were used for presowing seed treatment, NanoSilicon – for leaf treatment. Presowing seed treatment with Fitosporine, Bactophosphine, and Extrasol increased the height of oat plants and changed the panicle length: the height of oat plants after seed treatment with Extrasol was 6.3 cm or 8.3% higher than the control one, with Fitosporine – 5.9 cm or 7.7% higher. Fungilex seed treatment reduced oat height by 6.5 cm, or by 8.5%. Bactophosphine seed treatment did not affect the plant height. While the combined use of seed bacterization and treatment with NanoSilicon decreased the height of oat plants by 1.6-18.7 cm, or by 2.1-22.6%, the stimulating effect of the combined use of Fungilex and NanoSilicon on the growth and height of plants was observed. Seed bacterization with biological products increased the yield of oats. It was greatest when using Extrasol for seed treatment and amounted to 25.9 c/ha, which was 7.0 c/ha higher than in the control option. The leaf treatment with NanoSilicon increased the yield by 2.6-5.4 c/ha. Combined treatment of oat plants with NanoSilicon and Extrasol reduced the yield by 1.6 c/ha. The combined presowing seed treatment with biological products and leaf treatment with NanoSilicon increased the yield of oats by 2.7-5.9 kg/ha compared to the control option due to an increase in the number and weight of grains in the panicle. The highest yield – 26.7 c/ha was obtained when treating seeds with Fungilex and leaves with NanoSilicon (7.8 c/ha or 37.0% higher than in the control option).

1. Introduction

The role of microorganisms for plants is crucial. Microbial-plant interactions provide efficient nutrition, growth and development of plants, increase productivity of agrophytocenosis, the yield and quality of crops [1-5]. The use of microbial preparations based on useful soil microorganisms which populate the plant rhizosphere, produce physiologically active compounds that increase the root system power, optimize mineral nutrition, and phytohormones, antibiotic compounds. They protect roots from damage caused by phytopathogens [3-8]. Environmentally-friendly microbiological preparations reduce the need for mineral fertilizers and pesticides, increase plant resistance to biotic and abiotic stresses, and increase the yield [6-13].

Silicon deficiency is one of the limiting factors in the development of plants. The silicon nutrition increases the efficiency of photosynthesis, productivity, and resistance to stresses. Silicon improves the consumption of phosphorus, nitrogen, and potassium, stimulates growth processes, accumulates in conducting vessels and increases the mechanical strength of tissues [14].

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In Russia, the NanoSilicon mineral product with a high content of biologically active silicon has been developed for presowing seed treatment and spraying plants during the growing season. NanoSilicon contains silicon, iron, copper, zinc, and boron. Particles are less than 0.5 microns, which allows the plant absorbing them directly at the cellular level [14-17].

The purpose of the research is to study the effect of presowing seed treatment with microbiological preparations and leaf treatment with NanoSilicon on the growth and development of oat plants and the yield.

2. Materials and method

The object was oat variety Jacob. For seed treatment, Fungilex, Fitospore, Bactophosphine, Extrasol and NanoSilicon were applied.

Fungilex is a broad-spectrum biofungicide that contains living cells and spores of Bacillus subtilis LZ 12 with a living cell titer of more than 2.5x10^9 CFU /ml and products of their metabolism (phyto-hormones, biofungicides, antibiotics) [1,5].

Phytosporine was produced on the basis of Bacillus subtilis 26D with a titer of at least 1x10^9 spores and cells in 1 g, it has an inhibitory effect on pathogens of plants – fungi and bacteria [1,5].

Bactophosphine is a biological product based on the bacteria Bacillus megaterium LZ (a titer of 1x10^9 CFU / ml) and microbial metabolites [1,5].

Extrasol is produced on the basis of Bacillus subtilis Ch-13, the concentration is not less than 1x10^8 CFU/ml. Extrasol improves the supply of nutrients to plants, accelerates plant development, and inhibits the development of phytopathogenic microorganisms [1,5].

NanoSilicon is a Russian silicon fertilizer that contains silicon (50%), iron (6%), copper (1.0%), zinc (0.5%), and boron (0.5%).

Presowing seed treatment: oat seeds were soaked for 2 hours in solutions of the preparations at the rate of 10 l/t of seeds. Oats seeds soaked in water were used as control ones. Doses for the preparation of 10 l were as follows: Fungilex –1.0 l, Fitospore –150 g, Bactophosphine –1.0 l, Extrasol –1.0 l.

The treatment of oat plants with NanoSilicon was carried out in the shooting phase (dose 100 g/ha) by spraying with an aqueous solution. The control plants were sprayed with water. The flow rate of the working solution was 300 l/ha. The experiment was conducted on the territory of the Botanical garden of Voronezh State Agrarian University. The experiment was conducted six times. The location of plots was systematic, the plot area was 1.0 m². The experiment was two-factor: factor A – presowing treatment; factor B – foliar feeding. Harvesting was carried out in the phase of full ripeness.

3. Results and discussion

The effect of presowing seed treatment with biological products in combination with leaf treatment with NanoSilicon on the morphological indicators of oats was studied. Table 1 presents data on the height of plants and the length of the panicle depending on the type of biological product used for seed treatment.

The effect of seed bacterization on the height of oat plants was revealed. The result depended on the type of a preparation. The height of oat plants after seed treatment with Extrasol was higher than the control one by 6.3 cm, or 8.3%, with Fitospore - by 5.9 cm, or 7.7%. Fungilex seed treatment reduced the height by 6.5 cm, or 8.5%. Bactophosphine seed treatment did not affect the plant height.

Leaf treatment with Nanosilicon in the bumping phase in combination with seed treatment with Bactophosphite, Extrasol, Fitospore decreased the plant height by 1.6-18.7 cm. The most noticeable decrease in the height (18.7 cm or 22.6%) was due to the seed treatment with Extrasol and NanoSilicon. Fungilex treatment decreased the height, and when combined with Nanosilicon, the plant height increased by 10.4 cm, or 14.9%.

Presowing seed treatment with Fungilex and Extrasol reduced the panicle length by 1.1 cm, or 7.6% compared to the control one, and the use of Bactophosphine and Fitospore increased the panicle length by 2.4 cm (16.7%) and 3.3 cm (22.9%), respectively. The use of NanoSilicon for treating leaves after seed bacterization with Bactophosphine and Fitosporin had an inhibitory effect and de-
creased the length of the panicle by 3.4 cm (20.2%) and 3.3 cm (18.6%), respectively. The combined use of Fungilex and Extrasol with NanoSilicon did not affect the panicle length. The use of NanoSilicon as a growth inhibitor can be one of the ways to solve the problem of stem lodging [9].

**Table 1.** Plant height and panicle length depending on the use of microbiological preparations and NanoSilicon, cm

| Presowing seed treatment | Leaf treatment | plant height, cm | panicle length, cm |
|-------------------------|----------------|-----------------|-------------------|
|                         | control        | NanoSilicon     | control           | NanoSilicon     |
| Control                 | 76.4           | 74.8            | 14.4              | 13.4            |
| Fungilex                | 69.9           | 80.3            | 13.3              | 13.3            |
| Bactophosphine          | 76.5           | 71.9            | 16.8              | 13.4            |
| Extrasol                | 82.7           | 64.0            | 13.3              | 13.3            |
| Fitosporine             | 82.3           | 72.4            | 17.7              | 14.4            |

The number of grains in the panicle did not change when treating seeds with Fungilex, and increased when treating seeds with Bactophosphine, Fitosporine by 3.7 pcs. (9.3%) and Extrasol- by 4.4 pcs. (11.1%) (Table 2).

**Table 2.** Number and weight of grains in the oat panicle depending on the presowing seed treatment and leaf treatment

| Presowing seed treatment | Leaf treatment | the number of grains, pcs. | grain weight, g | weight of 1000 grains, g |
|-------------------------|----------------|----------------------------|-----------------|--------------------------|
|                         | control        | NanoSilicon                | control         | NanoSilicon              |
| Control                 | 39.6           | 43.8                       | 1.21            | 1.36                     | 30.6                      | 31.1                      |
| Fungilex                | 39.6           | 47.1                       | 1.23            | 1.71                     | 31.1                      | 36.3                      |
| Bactophosphine          | 43.3           | 33.3                       | 1.25            | 1.44                     | 28.9                      | 43.2                      |
| Extrasol                | 44.0           | 40.6                       | 1.41            | 1.49                     | 32.0                      | 36.7                      |
| Fitosporine             | 43.3           | 40.5                       | 1.34            | 1.61                     | 30.9                      | 39.8                      |

The combined use of NanoSilicon and Bactophosphine, Fitosporine and Extrasol decreased the number of grains in the panicle by 6.5-23.1%. Leaf treatment with Nano-Silicon increased the number of grains by 10.6%, and in combination with Fungilex- by 18.9%.

It was established that seed treatment with the biological products increased the mass of grains, the most pronounced stimulating effect was achieved when applying Extasol- 16.5%. The treatment of leaves with NanoSilicon positively affected the mass of grains in the panicle, increasing it when treating seeds with Fungilex, Bactophosphine, Fitosporine and Extrasol by 5.6-39.0%, respectively.

The mass of 1000 grains is an important indicator of oat grain quality. The largest mass of 1000 grains (32.0 g) was achieved when treating seeds with Extrasol. The indicator was exceeded by 1.4 g (4.6%). When treating seeds with Fungilex, the weight of 1000 grains was 31.1 g, which is higher than the control by 0.5 g (1.6%). The weight of 1000 grains after treating with Bactophosphine was less than the control one by 1.7 g (5.5%). The leaf treatment with Nanosilicon increased the mass of 1000 grains by 0.5-14.3 g (1.7-49.5%).

It was established that presowing seed treatment with Bactophosphine, Fitosporine, and Fungilex increased the yield by 0.1, 2.5, 2.4 c/ha, respectively. The maximum effect was achieved when applying Extrasol - 7.0 c/ha or 37.0% (Table 3).
Table 3. The oats yield depending on the pre-sowing seed treatment and leaf treatment, c/ha

| Presowing seed treatment | Leaf treatment                        |
|-------------------------|---------------------------------------|
|                         | Control  | NanoSilicon |
| Control                 | 18.9     | 22.0        |
| Fungilex                | 21.3     | 26.7        |
| Bactophosphine          | 19.0     | 21.6        |
| Extrasol                | 25.9     | 24.3        |
| Fitosporin              | 21.4     | 24.8        |

The use of Nanosilicon for leaf treatment increased the yield by 2.6-5.4 c/ha, except for the option with Extrasol. The combined use of Nanosilicon with Fungilex and Fitosporine increased the yield by 25.3%, 13.7%, 15.9%, respectively. Leaf treatment with Nanosilicon without seed bacterization increased the yield by 3.1 c/ha, or 16.4%. Extrasol seed treatment in combination with Nanosilicon reduced the yield by 1.6 c/ha (6.2%).

It was revealed that the combined treatment with Fungilex and NanoSilicium significantly exceeded the sum of the yield increments obtained from each individual treatment. It was established that an increase in the yield when treating with Fungilex was 2.4 c/ha, when treating with NanoSilicon – 3.1 c/ha, the sum of the increments from individual applications of these methods was 5.5 c/ha, while when combined, an increase in the oat yield was 7.8 c/ha. Thus, the yield increase due to the synergy of NanoSilicon and Fungilex was 2.3 kg/ha. Synergism was manifested with the combined use of Nanosilicon and Fitosporine (0.3 c/ha).

Conclusion

• The stimulating effect of presowing seed treatment is evident at the early stages of plant development. Presowing seed treatment with Fungilex, Fitosporine, Bactophosphine, and Extrasol increases the height of oat plants, but the length of the panicle formed at later stages, remains the same or decreases.
• The retardant effect in the shooting phase when treating with NanoSilicium was identified. It manifests as a decrease in the plant height and the panicle length.
• Presowing seed treatment with Fungilex, Bactophosphine, Extrasol and Fitosporine increased the yield by 2.6-5.4 c/ha due to an increase in the number and weight of grains in the panicle.
• Plant treatment plants in the shooting phase with NanoSilicon increases the yield by 2.7-7.8 c/ha due to an increase in the mass of 1000 grains. By reducing the height of plants, NanoSilicon contributed to the development of a more optimal plant habit, which improved the outflow of plastic substances into seeds.
• The combined use of Bactophosphite, Extrasol, Fitosporine and NanoSilicon inhibits the plant growth. The data obtained allow considering the possibility of using NanoSilicon in oat cultivation as a growth inhibitor and one of the ways to solve the problem of stem lodging.

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