Evaluation of the effectiveness of using microfertilizers and biologic drug to increase the yield of new soybean varieties

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Abstract. The area of soybean acreage in the Russian Federation is growing rapidly, including due to new soybean-growing regions. Over the past 20 years, production has increased by 2.9 times. However, the progress of soybean production is not as fast as national demand. To obtain high and high-quality yields, it is necessary to develop new technologies for soybean cultivation, which include solving the problem of optimizing the conditions of external resources by using minimized doses of mineral nutrition and sparing methods of application. It was found that complex pre-sowing treatment of seeds of new varieties of soybean Zusha and Osmon, containing fungicidal pickling in a tank mixture with an amino acid stimulator 14 days before sowing and inoculation on the day of sowing, caused the formation of a larger number of active nitrogen-fixing nodules on the roots, an increase in the yield of soybean and, as a rule, the highest collection of raw protein from 1 hectare compared to sowing untreated seeds. The economic effect of combining chemical and biological drugs at the stage of pre-sowing seed treatment is expressed in this case in an increase in the quantity and quality of yield and low production costs, which are characterized, among other things, by the low cost of minimized doses of implemented drugs. This agricultural method can be recommended for the production of soybean seeds of new varieties of Zusha and Osmon as an element of biologization in already proven modern technologies.

1. Introduction

On the background of circulating energy and economic crises in Russia in particular and the world in general, the research of technologies or individual agricultural methods for obtaining an environmentally safe final product of the crop production industry that meets the needs of humanity in quantitative and qualitative terms, in conditions of minimal energy resources and protection of surrounding agrocenoses is updated [1]. One of the cardinal ways to implement this direction is to create modern (high-tech) science-based systems of adaptive agricultural production with the most important elements of intensification of biological parameters aimed at increasing the productive part of the crop not only in quantitative but also in qualitative terms [2].

Soybean is a very interesting and significant crop in crop production, as soybean is highly profitable and promising from the point of view of a number of valuable economic characteristics: high plasticity in relation to growing areas, waste-free processing, multidisciplinary use of the final product, a source of high-grade protein as a natural biological nutrition corrector, an economically profitable crop even with a yield of more than 1.0 t/ha [3].

Interest in growing soybeans from producers of crop products is growing. Soybean crops are expanding every year (table 1, [4]). An important role in the spread of this crop on the territory of
Russia is played by the orientation of the country’s leadership to meet the needs of the population with its own soy products.

**Table 1.** Structure of soybean acreage in the Russian Federation (in farms of all categories).

| Acreage, thousand ha | 2000 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|----------------------|------|------|------|------|------|------|------|------|
| The total cultivated area | 84670 | 77854 | 78635 | 79312 | 80049 | 79634 | 79881 | 79629.7 |
| Oil crops, including: | 5489\(^{a}\) | 11211/\(^{b}\) | 11517/\(^{b}\) | 12320/\(^{b}\) | 12630/\(^{b}\) | 13941/\(^{b}\) | 14615/\(^{b}\) | 14317.3/\(^{b}\) |
| Soybean | 6.48\(^{b}\) | 14.40 | 14.65 | 15.53 | 15.78 | 17.51 | 18.30 | 17.98 |
| Soybean | 421\(^{a}\) | 2012/\(^{b}\) | 2131/\(^{b}\) | 2237/\(^{b}\) | 2636/\(^{b}\) | 2949/\(^{b}\) | 3079/\(^{b}\) | 2832.7/\(^{b}\) |

\(^{a}\) thousand ha
\(^{b}\) In % of the total sown area.

The main leap in the growth of soybean acreage occurred in 2017, by 2020 the acreage increased by 673% compared to 2000 and by 141% over the past 6 years.

In addition to the increase in acreage, there was a noticeable structural adjustment by region. The main soybean growing regions are the Far East, the Central black earth region, and the Amur region. The share of CBER in the structure of acreage increases every year and makes up a third of the total area.

**Table 2.** Gross soybean grain harvest in the Russian Federation (in farms of all categories).

| Gross harvest | 2009-2013\(^{a}\) | In average for 2009-2013\(^{a}\) | 2014\(^{b}\) | 2015\(^{b}\) | 2016\(^{b}\) | 2017\(^{b}\) | 2018\(^{b}\) | 2019\(^{b}\) |
|---------------|----------------|-----------------|------|------|------|------|------|------|
| Grain, million tons, including | 83.1 | 105.2 | 104.7 | 120.7 | 135.5 | 113.3 | 121.2 |
| Oil crops, million tons, including | 10.9 | 12.9 | 13.9 | 16.3 | 16.5 | 19.5 | 22.8 |
| Soybean, million tons | 1477 | 2371 | 2716 | 3143 | 3622 | 4027 | 4344 |

\(^{a}\) On average for the year in the initially credited weight.
\(^{b}\) In weight after completion.

Analysis of the gross soybean grain harvest by country (table 2) and yield by year (figure 1) is guaranteed to show a certain growth in the soybean industry [5].

The growth of crop yields has a direct significant impact on the growth of gross crop harvest data collection (the correlation coefficient is close to 1) [6].

Nevertheless, the progress of soybean production is not as fast as national demand. We have all the potential and resources to not only fully meet our own national needs, but also produce products for import (however, data for 2018 show that the increase in imports of plant products was 1.9% compared to 2010 [7]).
To do this, we need to equip technologically the industry and bring it to a higher level, which will significantly improve the economy and increase profits. A new approach to the development and creation, followed by the introduction of agricultural technologies with elements of biologization, will now allow obtaining environmentally stable products with minimized costs due to resource conservation while preserving soil fertility.

2. Materials and methods
The research was carried out within the framework of state task No. 0466-2019-0001.

The objects of the study were soybean plants and seeds of a new early-maturing variety of indeterminate development type Osmon (in the state register of the Russian Federation since 2018) and a medium-early variety Zusha of semi-determinant development type (since 2015). The region of admission for both varieties: Central Black earth (5 zone of zoning of varieties) [8].

The experimental technology included pre-sowing treatment of seeds with a fungicidal Scarlet, ME disinfectant (0.4 l/t) + amino acid biostimulant Biostim Start (1.0 l/ha) in advance of sowing; inoculation with microbiological drugs Rizoform (3.0 l/t) + stabilizer-adhesive Static (0.85 l/t) on the day of sowing. All used drugs of national production of the company “Shchelkovo Agrochim”, characterized by minimized doses of application per 1 processed unit [9]. The agricultural methods used for applying microbimineral complexes in the experimental technology are characterized by efficiency, environmental friendliness and maximum effectiveness, which corresponds to the conditions of organic farming.

The volume of water for making working solutions of drugs is 10 liters per one ton of seeds.

During the vegetation calculations of germination were conducted (seedling phase at the stage of forming an embryonic stem leaves, nodes, internodes of stem and ramification), the number and quality of nodules on the root system (in the budding phase at the stage of completion of formation of all organs of the inflorescence). The yield of peas is taken into account separately in the phase of full ripeness. Yield data is given to standard humidity and 100% purity.

3. Results
Soybean plants have a very high need for food elements from external resources after the emergence of seedlings.

Molybdenum and boron affect the development of the soybean symbiotic apparatus. Therefore, before inoculation of soybean seeds with Rizoform, 14 days before sowing, pre-sowing treatment of the planting material was carried out with an amino acid biostimulant, including one containing molybdenum (0.01 %) and boron (0.1 %). The drug Biostim Start is a stimulator of germination and development of the root system, as in addition to the above microelements it also contains phosphorus oxide (5 %), this element is necessary for soybean plants during the period from germination to ramification.
Complex pre-sowing treatment of soybean seeds Zusha and Osmon increased field germination by 3.8 and 5.1%, respectively.

The use of a liquid Rizoform inoculant containing a strain of specialized soybean bacterium Bradyhizobium japonicum 2-3 x 109 CFU/ml in complex pre-sowing treatment, together with a Static stabilizer-adhesive, is intended for effective formation of a symbiotic apparatus and providing soybean plants with nutrition with biological nitrogen. In the soil of the experimental site, at the time of the experiments, as a result of systematic cultivation of the host plant, a large local population of the corresponding nodule bacteria was formed, which is confirmed by the formation of nodules on the roots of control plants, even though the precursor was bare fallow (table 3). Despite this, inoculation with Rizoform increased the level of nodule formation by 55-117% in the Osmon variety and by 117-280% in the Zusha variety compared to the control. The studied varieties of soybeans differ in the degree of symbiotic apparatus activity. The Zusha variety formed more nodules (14-20 pieces per 1 plant) than the Osmon variety (13-15 pieces per 1 plant).

Table 3. Influence of the use of complex pre-sowing treatment of soybean seeds on the formation of a symbiotic apparatus on soybean roots.

| Variant                              | Average number of nodules for 4 replications, PCs/plant (seed formation phase) |
|--------------------------------------|--------------------------------------------------------------------------------|
|                                      | Replications       | Average | Characteristic |
|                                      | I     | II    | III   | IV    |          |
| Zusha variety                        |      |       |       |       |          |
| Control                              | 6     | 3     | 1     | 5     | 7.5      | Small, medium |
| Complex pre-sowing treatment         | 17    | 14    | 14    | 20    | 16.3     | Large |
| Osmon variety                        |       |       |       |       |          |
| Control                              | 11    | 8     | 5     | 12    | 9        | Medium |
| Complex pre-sowing treatment         | 15    | 13    | 14    | 14    | 14       | Massive |

In both varieties, nodule bacteria formed large nodules, which, in turn, fix more intensively and effectively atmospheric nitrogen in the process of symbiosis and accumulate it more in soybean plants. During the budding phase, at the stage of completion of the formation of all inflorescence organs, the nodules were active, as evidenced by the presence of a pinkish spot inside containing the pigment legoglobin.

The factors studied in the experiment affected the yield of different soybean varieties (table 4). The maximum yield was observed in the variants of the experiment with the use of complex pre-sowing treatment of seeds in both varieties. The yield increase to the control in the experimental version was 1.0 and 1.2 C/ha (3.2 and 3.4%), respectively, for Zusha and Osmon varieties.

The Zusha variety exceeds the Osmon variety (37.5-38.0 %) in whole protein content (38.5-39.2 %).

Table 4. Quantitative and qualitative parameters of soybean yield depending on the use of microfertilizers and biologic drugs.

| Variant | Soybean yield, C/ha | The whole protein content |
|---------|---------------------|--------------------------|
|         | Zusha variety       | Osmon variety            | Zusha variety increase in control | Osmon variety increase in control |
|         |                     |                          | % increase in control | % increase in control |
| Control | -                   | -                        | 38.5 | -        |
| Experiment | 1.0      | 1.2                     | 39.2 | 0.7      |
|          |                     |                         | 38.0 | 0.5      |
The content of whole protein in the Zusha soybean seed crop was higher in the variant with complex pre-sowing treatment by 0.7%, and the collection of whole protein – by 70.2 kg/ha in comparison with the control (without treatment) variant. This pattern was also observed in the Osmon variety: the whole protein content is 0.5% higher, and the whole protein collection is 63.5 kg/ha.

4. Discussion
The effectiveness of legume-nodule bacteria symbiosis is mainly determined by the conditions of nutrition of the host plant. However, after the invasion of nodule bacteria into the host plant tissue, the development of the latter is determined, among other things, by the action of external factors. The presence or absence of a particular nutritional element may be the determining factor for the entire infectious process [10-13]. Therefore, additional microelements in the form of Biostim Start in the pre-sowing treatment of seeds activated the activity of nodule bacteria, as molybdenum mediated electron transfer in enzymatic redox reactions, and cobalt – as an antioxidant of legoglobin. The amino acid biostimulant also intensified the germination and development of soybean seedlings, which contributed to the formation of a more powerful root system (active strains of nodule bacteria are usually formed on large skeletal roots), even against the background of the use of a chemical fungicide due to the content of phosphorus oxide in its composition.

Complex pre-sowing treatment of soybean seeds, containing fungicidal pickling in a tank mixture with an amino acid stimulator 14 days before sowing and on the day of sowing inoculation, initiated:
- providing plants with nitrogen in an accessible ammonium form during the growing season, especially during the phases of flowering and filling of beans;
- enriching the soil with more accessible forms of nitrogen for subsequent crop rotation;
- increasing the productive part of the soybean crop in quantitative and qualitative terms.

Thus, the agricultural method presented in the research can be recommended for the production of soybean seeds of new varieties of Zusha and Osmon as an element of biologization in already tested modern technologies. The economic effect of combining chemical and biological drugs at the stage of pre-sowing seed treatment is expressed in this case in an increase in the quantity and quality of yield and low production costs, which are characterized, among other things, by the low cost of minimized doses of implemented drugs.

5. Summary
Complex pre-sowing treatment of soybean seeds, containing fungicidal pickling in combination with an amino acid stimulator 14 days before sowing and inoculation on the day of sowing, led to the formation of a larger number of active nitrogen-fixing nodules on the roots, an increase in soybean yield, and, as a rule, the largest collection of whole protein from 1 hectare compared to sowing untreated seeds.

The effect of a combination of drugs for pre-sowing seed treatment in a specific dose had an ambiguous effect on different varieties of soybean, so we can conclude that the dose of drugs should be selected, taking into account the varietal characteristics and growing conditions of the crop vegetation.

6. References
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