Efficiency of growth regulators with anti-stress properties in agricultural technology of winter wheat in the Middle Volga region

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Abstract. The use of growth regulators with anti-stress properties Albit and Moddus was studied during winter wheat cultivation in the conditions of the Middle Volga region. During the study period, the effectiveness of biological products was high; in the autumn period, treatment with biological products allowed winter wheat plants to overwinter with less losses, to reduce the duration from germination to autumn tillering, to increase the number of shoots, the weight of plants and roots, the number of leaves and sugar content. The biostimulator Moddus has shown the effectiveness of action at the heading stage on such parameters as the content of sugars, starch and fibre in the leaves; at the stage of grain full ripeness – sugar, starch and fibre content in grain, yielding ability and realization of the yield potential. The antistressant Albit showed great efficiency by influencing such indicators as the duration of growing season, the weight of 1000 grains, the value of the activities of α-amylase, β-amylase and α + β-amylase.

1. Introduction
Obtaining high yields of agricultural crops consists of many tasks that include many components. Winter wheat is very demanding for fallow predecessors, they effect presence of moisture and nutrients in the soil at sowing period, friendly appearance and development of seedlings, phytosanitary crops state, yield and grain quality. Pure fallow in the areas with insufficient and unstable moisture is the most reliable predecessor, provides the best moisture in the soil, obtaining good shoots, under conditions of agriculture biologization [1, 2].

Winter wheat is a cold-resistant crop. Grain germinates at 1-2°C, and assimilation processes begin at 3-4°C, the optimum temperature is 12-15°C. At the temperature of 14-16°C and sufficient soil moisture, the first shoots appear in 7–9 days. In winter, winter wheat freezes with a lack of sugars in the tillering nodes and minus 17-19°C without snow cover, with which it can withstand up to minus 25°C. In spring, when growth resumes for winter wheat, 12-15°C is favorable. Winter wheat demanding on moisture during the entire growing season [3, 4].

One of the promising and environmentally friendly methods of increasing crop yields, maintaining product quality, soil fertility and clean environment is the use of biological products that, in small doses, stimulate plants growth and development, higher yields formation and products quality.

The preparation Albit stimulates plant resistance to abiotic stresses, which is associated with an increase in formation of anti-stress proteins and phytoimmunity in cells. High efficiency of its action in conditions of severe drought was noted, there was an improvement in grown plants quality, an increase in sugar content, a decrease in acidity and nitrates amount.
Moddus increases frost resistance by increasing root system volume, sugars concentration in the cell sap, overwintering quality, low temperatures resistance.

The research purpose is to treat winter wheat plants with growth regulators with anti-stress properties and to study their use effectiveness on the vegetation indicators.

2. Materials and methods of research

The experiments were carried out in 2016-2020 with the purpose to study the effect of biological products Albit and Moddus with anti-stress properties on winter wheat plants growth and development. The following experimental options were used: no treatment, the first autumn treatment with Albit and Moddus, the second spring treatment with biological products. The plants were sprayed with a shoulder sprayer. Consumption of solutions: 200 l/ha. Preparations doses: Albit – 50 ml/ha, Moddus – 0.2 l/ha. In the spring, in the beginning of heading stage of cereal crops in all options of the experiment, the herbicide Prima was applied against annual dicotyledonous weeds at a dose of 500 ml/ha. After the treatment with the herbicide, at the beginning of heading stage, the crops were treated for the second time, the plants were triple selected for the research, according to the experimental scheme.

Inhibition of crops and stress changes in plants, including lightening of leaf color and appearance of insignificant dark spots, were visually determined [5, 6]. On the third day after the herbicide treatment, the plants were sprayed with biostimulants Albit and Moddus.

The growth regulator Albit contains natural microbial polymer poly-beta-hydroxybutyric acid, which is similar in structure and functions to humates, isolated from soil bacteria, terpene acids, a balanced set of macro- and microelements, etc. Albit is a biological product of complex action, combining properties of plant growth regulator, antistressant, micronutrient fertilizer and biofungicide. The main purpose of this biological product is to stimulate growth and yield increase. Spraying of winter wheat plants is carried out twice, in the autumn in the first half of the growing season at the stage of 3-5 leaves, and in the second spring, combining with herbicide treatment.

Spraying plants with Moddus is carried out twice: the first time – at the beginning of the autumn vegetation, the second time – during the spring aftergrowing. It is used to improve the yield and quality of grain, faster and more active development of the root system and strengthen the stem tissue, withstand adverse weather conditions. Getting on plants, it is absorbed internally and inhibits the formation of the gibberellin hormone at the points of active growth, which ensures the formation of stronger stem tissues and increases sugars in plants; increases quality and productivity of the products obtained.

Meteo-climatic winter conditions of the region are difficult, insufficient moisture supply and unstable temperature regime usually create tension for the normal autumn development of winter grain crops [7]. Therefore, it is important to understand in what state the plants will enter a state of dormancy and subsequently emerge from it in the spring [8]. Meteorological conditions during the years of the research were contrasting, difficult, but favorable.

The study effectiveness of using biological products Albit and Moddus was carried out in the crops of the winter wheat variety Svetoch on the experimental fields of the Agroecology laboratory of Samara State Agrarian University. The area of the plots was 1200 m², the experiments were repeated three times. The relief of the experimental field is leveled; there are old forest belts along the northern and southern borders of the experimental field [9, 10].

The soil of the experimental field is a typical medium-humus, medium-thick, heavy loamy chernozem, the pH response of the environment is close to neutral and with an average humus content. The content of easily hydrolyzable nitrogen, mobile phosphorus, and exchangeable potassium in the 0-30 cm soil layer is increased or high [11, 12]. Sowing of winter wheat was carried out in optimal agricultural terms with a seeding rate of 5.0 million germinating seeds/ha [13, 14].

All observations on the growth stages, development and quantitative results, as well as other accompanying studies were carried out according to the methodology of the State Commission for Variety Testing of Agricultural Crops [15, 16].

The winter wheat variety Svetoch has been included in the State Register of Breeding Achievements since 2005 in the Middle Volga region. It is mid-season variety. The growing season is 308-329 days
with increased winter hardiness. Plant height is 69-94 cm. The weight of 1000 grains is 38-43 g. The average yield in 2000-2010 in a competitive trial was 3.57 t/ha. The biological feature of the variety Svetoch is a fast rate of spring growth, its ability to form a productive head under conditions of moisture deficit in the soil in the autumn period [17–19].

The determination of sugars content was carried out by a colorimetric method developed in the biochemistry laboratory of the Institute of Plant Industry, which is based on changing the color of a copper glycerate solution when boiling it with sugar extracts in an acidic medium to determine the total amount of mono- and disaccharides and without adding hydrochloric acid to determine reducing sugars according to A.I. Ermakova, 1987. The sugar content in the sample was determined using a calibration curve constructed from glucose solutions of different concentrations from 0.5 to 10 mg. The sugars amount (%) was determined by the formula: \( x = a \cdot V / 10 \cdot n \), where \( a \) is the sugar content in the sample (1 cm\(^3\)), mg; \( V \) is the extract volume, cm\(^3\); \( n \) is the weight of the sample, g; 10 – conversion factor in milligrams and in percent [11]. The starch content was determined as described in [14, 20] using sulfosalicylic acid.

Mathematical processing of the data was carried out using the Excel software package and the “Statistics software package”.

3. Research results and discussion

On average, during the study period, seedlings appeared on the ninth day, which is the norm for this region. The number of germinated seeds on the third day was 61%, and on the seventh day – 76%. Thus, the average number of seedlings was 418 un/m\(^2\), and the field germination rate was 83.6%.

In the 3-5 leaf stage, the plants were treated with biostimulants Albit and Moddus. The studies were carried out at the end of the autumn vegetation, when the air temperature dropped to +5°C, the results of them are presented in Table 1.

**Table 1. Autumn vegetation of winter wheat with the use of biostimulants, on average for the study period**

| Studied parameter                          | Without treatment | Albit       | Moddus      | V, % |
|-------------------------------------------|-------------------|-------------|-------------|------|
| Seedlings – autumn tillering, days        | 45±1.2            | 46±1.4      | 47±1.0      | 6.6  |
| Number of shoots, un                      | 4.4±0.13          | 4.6±0.12    | 4.5±0.11    | 7.3  |
| Weight of plants, g/plant                 | 3.52±0.16         | 3.68±0.18   | 3.71±0.17   | 8.4  |
| Weight of roots, g                        | 1.28±0.05         | 1.33±0.05   | 1.46±0.04   | 5.0  |
| Number of leaves, un                      | 8.2±0.46          | 9.8±0.48    | 10.5±0.45   | 12.2 |
| Sugar content, %                          | 21.2±0.97         | 22.4±0.88   | 26.6±0.89   | 10.2 |
| Monosaccharide content, %                 | 4.0±0.12          | 4.3±0.12    | 4.8±0.11    | 8.4  |

Biological treatment of winter wheat plants in the 3-5 leaf period had a positive effect on the studied parameters. The preparation Albit contributed to an increase in such indicators as number of shoots, and Moddus – weight of plants and roots, number of leaves, content of sugars and monosaccharides. As a result of overwintering, treatment with Moddus made it possible to preserve the number of overwintered plants by 6%, and with Albit by 5%, in comparison with untreated plants. Sugar content in the tillering nodes was 16.2%, when treated with Albit it was more by 10%, and with Moddus by an even more significant amount – 21%.

The duration of plants vegetation until full grain ripeness was 325 days, treatment with the preparations affected their duration. Treatment with Albit reduced the duration by 15 days, and with Moddus to a lesser extent – by 8 days.

The assessment results of the winter wheat plants’ state in the spring after overwintering are presented in Table 2.
Table 2. The state of plants in the spring after overwintering and vegetation of winter wheat with the use of biostimulants, on average for the study period; the difference is significant at $P = 0.05$

| Studied parameter             | Without treatment | Albit     | Moddus       | V, % |
|-------------------------------|-------------------|-----------|--------------|------|
|                               | one treatment     | two       | one treatment| two  |     |
|                               | (autumn)          | treatments| (autumn,     | treatments|   |   |
|                               |                   | (spring)  | spring)      |       |   |   |
| Sugar in leaves, %            | 12.3±1.2          | 13.4±1.3  | 13.9±1.3     | 14.5±1.4| 15.2±1.2 | 6.9 |
| Starch in leaves, %           | 0.014±            | 0.017±    | 0.020±       | 0.018± | 0.023±0.03 | 7.6 |
| Fibre in leaves, %            | 18.4              | 18.8      | 19.6         | 19.1  | 19.9  | 8.9 |

Heading stage

| Vegetation duration, days     | 325               | 306       | 300          | 317   | 310   | 7.2 |
| Weight of 1000 grains, g      | 27.6              | 29.9      | 31.6         | 30.1  | 32.3  | 10.1 |
| Sugar in grain, %             | 1.85±0.12         | 2.12±0.11 | 2.34±0.12    | 2.41±0.13 | 2.49±0.14 | 8.2 |
| Starch in grain, %            | 55.7±1.5          | 63.1±1.6  | 66.6±0.14    | 64.51±1.6 | 67.1±0.17 | 8.8 |
| $\alpha$-amylase activity, mg/g meal·min | 18.9±1.2 | 20.5±1.1  | 21.2±1.2     | 19.4±1.3 | 20.3±1.2 | 5.7 |
| $\beta$-amylase activity, mg/g meal·min | 186.2±4.2 | 198.9±2.4 | 204.7±2.3    | 181.4±4.2 | 200.3±3.3 | 6.2 |
| $\alpha+\beta$-amylase activity, mg/g meal·min | 204.7±3.2 | 218.6±3.1 | 224.9±4.1    | 201.8±4.0 | 220.7±3.5 | 7.1 |
| Fibre, %                      | 1.9               | 2.0       | 2.2          | 2.1   | 2.3   | 11.7 |
| Grain yield, t/ha             | 3.21              | 3.73      | 3.80         | 3.86  | 3.92  | 12.1 |
| Realizing yield potential, %  | 82.8              | 84.7      | 86.8         | 89.0  | 91.2  | 8.7 |

2017 HCP$_{05}$ = 0.28 t/ha; 2018 HCP$_{05}$ = 1.8 t/ha; 2019 HCP$_{05}$ = 1.7 t/ha; 2020 HCP$_{05}$ = 1.58 t/ha;

In the heading period, such indicators as content of sugar, starch and fibre in the leaves were investigated. Compared to untreated crops, the first treatment increased the values of indicators to 9-18%, and the second to 13-23%, and the biostimulator Moddus exceeded the effect of Albit up to 9%.

In the stage of full grain ripeness, the indicators of sugar, starch and fibre content were also investigated. In comparison with untreated crops, the first treatment increased the indicators values to 15-30%, and the second to 26-34%, and the biostimulator Moddus exceeded the effect of Albit by up to 7%.

Thus, the content of sugar, starch and fibre increased from the tillering to the full grain ripeness period. Treatments with biological products had a positive effect on the values of these indicators; their content increased to 18%, and the second treatment was to a greater extent compared to the spring one up to 30%, Moddus treatments exceeded the effect of Albit up to 9%.

The amidolytic enzymes are $\alpha$-amylase and $\beta$-amylase and $\alpha+\beta$-amylase. The values of these enzymes’ activities increased after the first treatment by 3-9%, after the second by 7-12%, and the treatment with Albit exceeded the effect of Moddus by 4%.

The productivity of winter wheat plants can be judged by the weight of a thousand grains and the grain yield. On average, over the research period, the weight of 1000 grains was at the level of 27.6 g. The treatment with biological products had the same effect on this indicator, increased its weight by 2.5 g. The grain yield over the years of study averaged 3.21 t/ha, treatment with biological products contributed to an increase in this indicator, Albit – by 16%, Moddus – by 20%. Thus, the plants’ productivity in terms of the weight of 1000 grains and grain yield increased when treated with biological products. The weight of 1000 grains was equally by 2.5 g, the yield increased when treated with Albit by 16%, and with Moddus by 20%.
The vegetation duration until the full grain ripeness of untreated crops was 325 days, after the autumn treatment, the duration was reduced by 8 days, and after the spring – by 12 days, and the treatment with Albit shortened the growing season by 4 days, compared with the use of Moddus.

The best options for realizing the yield potential were the options with single and double treatment with biostimulator Moddus up to 91%. To a lesser extent, the yield potential was realized with Albit up to 87%. A comprehensive assessment of changes in the studied indicators values made it possible to highlight the best options among them.

In comparison with untreated crops, single and double treatment with biological products increased the values of the studied parameters. The biostimulator Moddus surpassed the effect of Albit in terms such indicators as content of sugar, starch and fibre in the leaves, in the grain full ripeness period – weight of 1000 grains, yield and realization of yield potential increased when treated with Albit to a lesser extent, compared with Moddus.

Treatments with Albit exceeded the effect of Moddus up to 4%, in terms of such indicators as activity of α-amylase, β-amylase and α + β-amylase, as well as the duration of the growing season until the grain is fully ripe.

For comparison and assessment of the studied parameters options of winter wheat vegetation, homogeneity characteristics of the collection were obtained. Coefficients of variation in all studies did not exceed 33%. Therefore, the collection can be considered homogeneous. The obtained value of the studied indicators is from 5% to 12%, which indicates that the fluctuations of the signs are small and are of the average level and can be applied for these studies.

The high efficiency of biological products is due to the creation of more favorable conditions and the implementation of the internal direction of metabolic processes for winter wheat plants growth and development. So, in the autumn period, the effectiveness of biological products action was reflected in such parameters as duration of the period from germination to autumn tillering, number of shoots, weight of plants and roots, number of leaves and content of sugars, and the loss of overwintered plants were smaller. During the spring-summer growing season in the heading period, content of sugars, starch and fibre in the leaves was higher when biological products were used, and the Moddus effect was more effective. At the full grain ripeness stage, the use of Moddus was more effective on such indicators as content of sugar, starch, fibre in the grain, yield and realization of the yield potential. The antistress agent Albit showed great efficiency by influencing such parameters as duration of the growing season, weight of 1000 grains, value of the activities of α-amylase, β-amylase and α + β-amylase.

4. Conclusion
One of the promising, environmentally friendly methods of increasing crop yields and product quality, maintaining soil fertility and environmental cleanliness is using biological products that, in small doses, stimulate growth and development of plants. To study the effectiveness of growth regulators with anti-stress properties in the agricultural technology of winter wheat, biological products Albit and Moddus were used.

In the autumn period, treatment with biological products allowed winter wheat plants to overwinter with less losses, the effectiveness of the biological products was high, this provided an increase in the values of such parameters as duration of the period from germination to autumn tillering, number of shoots, weight of plants and roots, number of leaves and content of sugars.

The influence of the biological product Moddus was more effective during the spring-summer growing season in the heading period on such parameters as content of sugars, starch and fibre in the leaves. At the stage of full grain ripeness: content of sugar, starch, fibre in the grain, yield and realization of yield potential. The antistressant Albit showed great efficiency by influencing such indicators as duration of the growing season, weight of 1000 grains, the activities value of α-amylase, β-amylase and α + β-amylase.
5. Practical significance of the conducted research
To stimulate plants’ growth and development, formation of higher yields and quality products, the use of biological products is effective. Application of drugs is an environmentally friendly method of plant growth and development management

The effectiveness of growth regulators with anti-stress properties in the agricultural technology of winter wheat in the Middle Volga region was shown using the preparations Albit and Moddus. During the study period, the effectiveness of biological products action was high; in the autumn period, treatment with biological products allowed winter wheat plants to overwinter with less losses, to reduce the duration of the period from germination to autumn tillering, to increase the number of shoots, the weight of plants and roots, the number of leaves and the content of sugars. The biostimulant Moddus has shown the effectiveness of action in the heading period on such parameters as content of sugars, starch and fibre in the leaves. At the stage of full grain ripeness – content of sugar, starch, fibre in the grain, yield and realization of yield potential of. The antistressant Albit showed great efficiency by influencing such indicators as duration of the growing season, weight of 1000 grains, the activities value of α-amylase, β-amylase and α + β-amylase.

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