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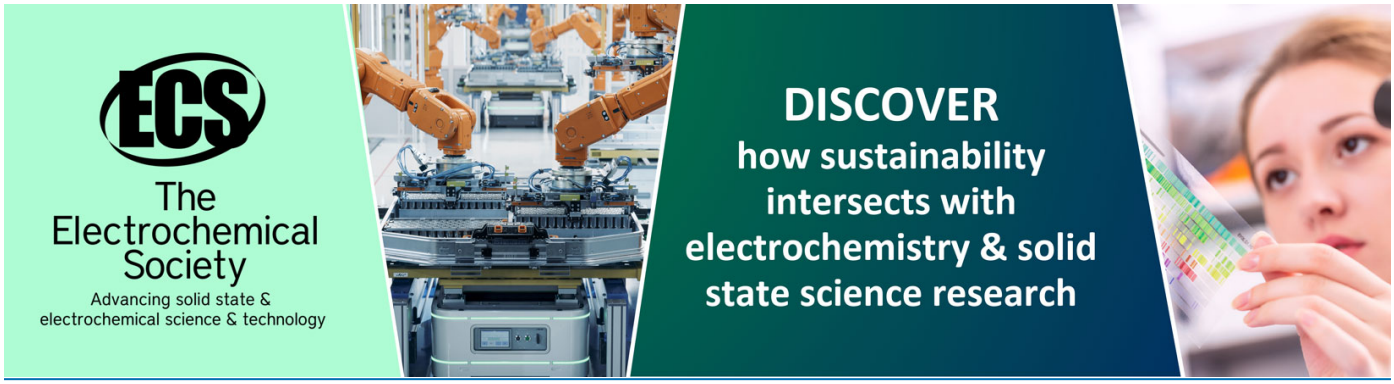

Role of growth regulators with anti-stress properties in overwintering and productivity of winter wheat

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Abstract. The paper states that study of the production process of winter wheat plants, including overwintering of plants. It showed that the plants treatment with biological products Albit and Moddus in the phase of 3-5 leaves had a positive effect on the studied parameters. The treatment with Albit increased the number of shoots and plant height, while Moddus increased the mass of plants and roots, the number of secondary roots and leaves, and the content of sugars and monosaccharides. The treatment with Moddus helped to preserve some overwintered plants by 6%, and Albit by 5% in comparison to untreated ones. The loss of sugars was insignificant, up to 5% for untreated plants, up to 4.6% when treated with Albit, and up to 3.8% when treated with Moddus. The sugar content in the tillering nodes was 16.2%, when treated with Albit was more by 10%. The sugar content in the tillering nodes was 16.2%, when treated with Moddus was by 21%, i.e., with an even more significant volume. The fully ripe grain had a high content of sugars and starch. The treatment with Albit promoted an increase in starch up to 16%, and with Moddus, an increase in sugars by 26%. The mass of a thousand grains and grain yield increased when treated with Albit and Moddus. The mass of 1000 seeds was equal to 2.5 g, the yield when treated with Albit by 16%, and it increased with Moddus by 20%.

1. Introduction

The cultivation of winter wheat and obtaining high yields is an integrated problem that includes some components [1, 2, 3].

The winter wheat is a cold-resistant crop. The first shoots appear in 7-9 days at a temperature of 14-16° C and sufficient soil moisture. A favorable calendar period for sowing wheat is the end of August and the beginning of September [4, 5]. In winter, with good hardening, wheat can withstand a drop in temperature at the depth of the tillering node to minus 16-18° C. The highly frost-resistant varieties it can withstand a drop in temperature to minus 20°C. However, only those plants that have grown well up to 2-4 shoots and have accumulated up to 30-35% of sugars in the tillering nodes are noted with high frost resistance. In winter, winter wheat freezes at minus 17-19° C without snow cover, it can withstand up to minus 25° C. In spring, when growth resumes for winter wheat, 12-15° C is favorable [4, 6, 7].

One of the promising, environmentally friendly methods to increase crop yields, preserve product quality, maintain soil fertility and clean the environment is the application of natural or synthetic biological products that in small doses, stimulate the growth and development of plants, help increase their resistance to diseases, pests and the formation of higher yields and quality products [8, 9, 10].

The biological product Albit stimulates plant resistance to abiotic stresses, associated with an increase in the formation of anti-stress proteins and components of the phytoimmunity system. There is an improvement in the quality of plant products, an increase in sugar content and the volume of nitrates after its application. Spraying with Albit increases drought resistance up to several months [11, 12].

The biological product Moddus increases the frost resistance while maintaining the potential biological yield of winter wheat. This is due to an increase in the volume of the root system, an increase in the concentration of sugars in the cell sap and the quality of overwintering. The qualitative and quantitative characteristics of the future harvest are improved [13, 14].

The aim of the research is to study the possibility of plant growth regulators with anti-stress properties to influence the metabolism and safety of plants during the wintering period and contribute to an increase in the productivity of winter wheat.

2. Materials and methods of research

In 2016-2020, experiments were carried out to study the effect of biological products Albit and Moddus on overwintering and productivity of winter wheat. Sowing was carried out in the generally accepted terms from the 25 of August till the 8 of September. Plants in the 3-5 leaves phase were sprayed with a knapsack sprayer. The consumption of solutions is 200 liters per hectare. A dose of preparations of Albit is 50 ml/ha, and a dose of preparations Moddus is 0.2 l/ha.

The meteo-climatic winter events of the region are severe, insufficient moisture supply and unstable temperature regime usually create tension for the normal autumn development of winter grain crops [1]. 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 [15, 16]. The meteorological events during the years of the research were contrasting, severe, but favorable.

The study of the autumn and spring content of sugars, the safety of plants by the spring when using the biological products Albit and Moddus were carried out in the crops of winter wheat varieties Svetoch on the experimental fields of the Agroecology laboratory of the Samara State Agrarian University. The area of sites was 1200 m^2. 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 [17, 18]. The soil of the experimental site is a typical medium-humus, medium-thick, heavy loamy chernozem, the pH reaction 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 [19]. The sowing of winter wheat was carried out in optimal agro-terms in the transverse direction to the variants of the main tillage with the DMC "Primera" seeder, with a seeding rate of 5.0 million germinating seeds/ha [20, 21].

The phases monitoring of the growth, development and quantitative results, as well as other related studies were carried out according to the methodology of the State Commission for Variety Testing of Agricultural Crops [2].

The Svetoch winter wheat crop has been included in the State Register of Breeding Achievements since 2005 in the Middle Volga region. It is a mid-season variety. The growing season is 308-329 days. The winter hardiness is increased. The mass of 1000 seeds is 38-43 g. The average yield in 2000-2010 in a competitive trial was 3.57 t/ha. The biological feature of the Svetoch cultivar is a fast rate of spring growth: its ability to form a productive ear under conditions of moisture deficit in the soil in the autumn period [7]. The estimation of sugars was carried out by a colorimetric method developed in the laboratory of biochemistry of the All-Russian Institute of Plant Genetic Resources (VIR). The method is based on changing the color of a copper glycerate solution at 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. Ermakov, 1987. The sugar content in the sample was estimated using a calibration curve constructed from glucose solutions of different concentrations from 0.5 to 10 mg. The content of sugars (%) was estimated by the formula $x = a \cdot V/10 \cdot н$, where a is sugar content in the sample (1 cm^3), mg; V is volume of the extract, cm^3; n is weight of the sample, g; 10 is conversion factor in milligrams and percent [4, 17].

The mathematical data processing was carried out applying the Excel computer software and the "Statistics software ".

3. Research results and discussions

Wheat plants overwinter better if they overwinter in the tillering phase (3-4-5 shoots). This requires 50-55 days of autumn vegetation with the sum of active temperatures (above + 5° C) 550-580° C [10].

Wheat culture has several stages of the development process. Each stage is characterized by the formation of a new organ, as well as morphological changes and development of the existing ones. So, in the autumn period there exist such stages of development as germination, shoots, the phase of the third leaf and tillering, in which aerial shoots are formed from the node located at the base of the main shoot [7].

The conditions of heat and moisture supply in the autumn growing season of the winter wheat that developed during the study period are presented in table 1.

Table 1. Conditions of heat and moisture supply and the duration of the autumn growing season of the winter wheat in the field experiment.

Year of study	Average air temperature, ° C	Average precipitation, mm	Duration, days
2016	14.0	166.5	43±0.8
2017	13.6	149.8	41±0.6
2018	14.5	54.6	47±0.8
2019	12.8	110.7	49±1.0
	Average long-term rate11.8 ° C	Average long-term rate 129.0 mm	V = 11 %

From the period of sowing to the period when the air temperature dropped to +5° C, the average temperature for all years exceeded the average long-term by 1-3.5%, and the amount of precipitation in different years fell both more to 29% and less from 14% to 42%. But, the accumulated moisture in the steam precursor made it possible for the seeds to germinate.

On average, during the study period, seedlings appeared on day 9, which is the norm for this region. The number of germinated seeds on the third day was 61%, and on the seventh day was 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 phase, the plants were treated with biostimulators Albit and Moddus. At the end of the autumn growing season, when the air temperature dropped to + 5 ° C, studies were carried out, the results of which are presented in table 2.

Table 2. Autumn vegetation of the winter wheat with the use of biostimulators, on average over 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
Plant height, cm	21.4±0.84	22.0±0.88	21.7±0.87	5.8
Plant weight, g/plant	3.52±0.16	3.68±0.18	3.71±0.17	8.4
Root mass, g	1.28±0.05	1.33±0.05	1.46±0.04	5.0
Number of secondary roots, un	3.8±0.17	4.5±0.19	5.2±0.20	7.3
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

The treatment with biological products promoted an increase in the duration of the autumn growing season by 1-2 days or 2-4.4%, an increase in the number of shoots and plant height by 4.5% and 3%, respectively. The weight of plants and roots also increased in comparison with plants not treated with biostimulators, up to 5.5% and up to 14%, respectively. The weight of plants and roots also increased in comparison with plants not treated with biostimulators up to 5.5% and up to 14%, respectively. The number of secondary roots and leaves on plants was also increased after treatment with growth regulators to 14 and 36%, respectively. The content of sugars and monosaccharides was increased in the treated plants to 25% and 20%, respectively.

So, the treatment of winter wheat plants with biological products in the 3-5 leaf phase had a positive effect on the studied parameters. The biological product Albit contributed to an increase in such indicators as the number of shoots and plant height. The biological product Moddus contributed to an increase in such indicators as the number the mass of plants and roots, the number of secondary roots and leaves, the content of sugars and monosaccharides.

According to meteorological events during the study period, the winter growing seasons were warmer than usual by 3-8° C with an excess of the average annual norm of precipitation, the height of the snow cover approximately corresponded to the average annual value. Weather events promoted good overwintering of winter crops and significantly replenished the reserves of productive moisture in the soil in the spring.

The peculiarity of wheat is the ability to bush. The appearance of sprouts on the sides and nodal roots begins after the opening of three to four leaves has occurred. The tillering node, which is located at a depth of 3 cm, is vital; when it dies off, the bush dies. With a decrease in air temperature, the tillering speed is noticeably reduced, and at + 2-4° C it completely stops. The autumn and spring tillering are typical for winter varieties.

The estimation results of the winter wheat plants in spring after overwintering are presented in table 3.

Table 3. Condition of plants in spring after overwintering and vegetation of winter wheat with the use of biostimulators, on average for the study period.

Studied parameter	Without treatment	Albit	Moddus	V, %
Number of overwintered plants, pcs	68.9	72.3	73.1	11.4
Sugar content in tillering nodes, %	16.2±0.7	17.8±0.7	22.8±0.8	9.2
Loss of sugars for overwintering wheat, %	5.0	4.6	3.8	5.6
Spring tillering - full ripeness, days	325	306	317	6.1
Sugar content in seeds, %	1.85±0.12	2.12±0.11	2.41±0.12	7.8
Starch content in seeds, %	55.7±1.5	64.5±1.6	63.1±1.6	8.6
Weight of 1000 seeds, g	27.6	29.9	30.1	12.1
Cereal yield, t/ha	3.21	3.73	3.86	8.1
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.				

The overwintering conditions for winter wheat plants during the study period were favorable, and therefore the number of overwintered plants turned out to be high. The sugar content in the tillering nodes turned out to be reduced in comparison with the autumn content, but biological products had a positive effect on the studied parameter. The biological product Albit contributed to an increase by 10%, and Moddus contributed to an increase by 21%. Meanwhile, losses for overwintering amounted to 5% in plants that had not been treated with biological products, treatment with Albit made it possible to reduce the loss of sugar content and keep it at the level of 4.6%, and treatment with Moddus only by 3.8%. So, as a result of overwintering, treatment with Moddus helped to preserve the number of winterized plants by 6%, and with Albit by 5%, in comparison with untreated ones. The loss of sugars

was insignificant, i.e., up to 5%. The loss of sugars was up to 4.6 when treated with Albit and up to 3.8% when treated with Moddus. The sugar content in the tillering nodes was 16.2%, when treated with Albit it was more by 10%. and an even more significant volume, i.e., by 21%, treated by Moddus.

The duration of the growing season of plants until the full ripeness of the cereal was 325 days, treatment with biological products affected their duration. The treatment with Albit reduced the duration by 15 days, and the treatment with Moddus reduced its duration to a lesser extent, by 8 days.

The content of sugars and starch in fully ripe grain was 1.85% and 55.7%, respectively. The treatment with biological products contributed to the increase in their content. Albit increased the sugar content by 15% and starch by 16%; Moddus increased it by 26% and 13%, respectively. So, in the cereal of full ripeness biochemical quality of such indicators as the content of sugars and starch was high. The treatment with Moddus promoted an increase in sugars by a higher value up to 26%, and with the treatment with Albit promoted an increase in starch up to 16%.

One can judge of the productivity of winter wheat plants by the mass of a thousand seeds and the cereal yield. On average, over the period of research, the mass of 1000 seeds 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 cereal 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 productivity of plants in terms of the mass of a thousand grains and grain yield increased when treated with biological products. The mass of 1000 seeds was equally by 2.5 g, the yield increased when treated with Albit by 16%, and treated with Moddus by 20%.

The content of sugars in the tillering nodes, the loss of sugars for overwintering and the safety of plants by spring and others, the characteristics of the homogeneity of the population were obtained to compare and evaluate the variants of the studied parameters of the vegetation of winter wheat. Variation indicators in all studies did not exceed 33%. Therefore, the totality can be considered homogeneous. The obtained value of the studied indicators was from 5% to 12%. It indicates that the fluctuations of the signs are small and of the average level and can be applied for these studies.

4. Conclusion

Seed shoots of the winter wheat appeared on the nineth day. The number of shoots on average was 418 pcs/ m^2, and the field germination was 83.6%. The weather conditions during the study period contributed to a good overwintering of winter crops and significantly replenished the reserves of productive moisture in the soil in the spring.

The treatment of winter wheat plants with biological products Albit and Moddus in the phase of 3-5 leaves had a positive effect on the studied parameters. The treatment with Albit increased the number of shoots and plant height, while Moddus increased the mass of plants and roots, the number of secondary roots and leaves, and the content of sugars and monosaccharides.

The treatment with Moddus helped to preserve the number of overwintered plants by 6%, and the treatment with Albit preserved it by 5%, in comparison with untreated ones. The loss of sugars was insignificant. It was up to 5% for untreated plants, up and it was up to 4.6% when treated with Albit, and up to 3.8% when treated with Moddus. The sugar content in the tillering nodes was 16.2%, when treated with Albit it was more by 10%, and treated with Moddus it was by an even more significant amount, i.e., by 21%

The fully ripe cereal had a high content of sugars and starch. The treatment with Albit promoted an increase in starch up to 16%. The treatment with Moddus promoted an increase in sugars by 26%.

The mass of 1000 seeds and sereal yield increased when processed with Albit and Moddus. The mass of 1000 grains was equal to 2.5 g, the yield increased when treated with Albit by 16%, and Moddus by 20%.

5. Practical significance of the conducted research

The use of growth regulators as antistress agents in the study of wintering and productivity of winter wheat showed that the treatment of winter wheat plants with biological products Albit and Moddus in the 3-5 leaf phase had a positive effect on the studied parameters.

The treatment with Albit increased the number of shoots and plant height, made it possible to maintain the number of overwintered plants by 5%, the sugar content in the tillering nodes was 10% higher in comparison with untreated ones, sugar losses were insignificant, up to 4.6%. The treatment with Albit contributed to the increase in starch up to 16%. The mass of 1000 seeds was equal to 2.5 g, the yield increased when treated with Albit by 16%, and Moddus by 20%.

The treatment with Moddus promoted an increase in the mass of plants and roots, the number of secondary roots and leaves, the content of sugars and monosaccharides. The Moddus treatment made it possible to preserve the number of overwintered plants by 6%, reduce sugar losses by 3.8%, increase the sugar of mature grains by 26%, the weight of 1000 grains by 2.5 g, and the yield by 20%.

The use of biological products in small volume at low cost and obtaining well-wintered plants from which a high yield with good quality can be obtained is a good alternative in replacing fertilizers that are harmful to the environment.

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