The effect of growth regulators with retardant properties on the growth and development of winter wheat

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Abstract. The article presents the results of experiments to study the reaction of winter soft wheat of the Nemchinovskaya 17 variety to growth regulators with retardant properties. It was found that the use of growth regulators at the end of the tillering-exit phase into the tube reduced the height of plants by an average of 0.115 m compared to the control without treatment, where the height of plants was on average 0.813 m. According to the results of observations, a differentiated reaction of the tested winter wheat to lodging was established when using the studied growth regulators. In plants treated with Reggi and Messidor growth regulators, lodging was not observed and ranged from 4.4 to 5 points of lodging on the control without treatment – 3 points. The tested plant growth regulators have a significant impact on the yield of winter wheat of the studied variety and the formation of its structural elements. The increase in yield according to the variants of the experiment was about 4.1-6.1 t/ha depending on the type of drug. The highest yield increases were obtained with the use of Reggi at a dose of 1.5 l/ha.

1. Introduction

It is known that grain is the most important part of the world agricultural economy. The level of its production ensures food security and well-being of the country, as well as the ability to increase the economic and political importance of the state in the world community [1].

Grain is a universal product. It occupies the first place in the human diet and is an indispensable food for animals. In recent years, the area of grain sowing in the world has stabilized and amounts to 777-788 million hectares. It should be noted that China, Russia and the United States occupy 50% of the total area of cultivated grain in the world [2].

In Europe and the USA, winter wheat occupies the main areas of sowing, and in the Russian Federation and Canada, spring wheat prevails [3].

Wheat is one of the most ancient crops on the globe. In Europe and Asia, it began to be cultivated in prehistoric times. The latest research shows that over 6.5 thousand years ago wheat was known in Iraq, Egypt and Asia Minor, it was sown for 6 thousand years BC, for 3 thousand years BC wheat was sown...
in China, Turkmenistan, Georgia, Armenia and Azerbaijan, and traces of its culture in the IV millennium BC [4].

Winter wheat is one of the most important, most valuable and high-yielding grain crops. Its value lies in the fact that the grain is characterized by a high content of protein (16%) and carbohydrates (80%), along with spring wheat, it is widely used in the baking, pasta, confectionery industry [5, 6].

To form a higher grain yield, a number of measures and methods of caring for winter wheat crops should be applied, which are aimed at creating conditions that ensure better plant safety in the autumn-winter and spring-summer periods. In the system of measures for growing high-quality winter wheat crops, complex plant protection is an obligatory link. It provides reliable prevention of crop losses from pests, diseases and weeds at minimal cost [7].

Also, plant protection measures include one of the most effective methods – this is the method of combating the lodging of grain crops [8, 9, 10].

According to numerous scientific research and practice data, their correct use on positively responding varieties (relatively unstable to lodging) allows you to get an increase in the grain yield of 2.5-6 centners per hectare. The effect of these drugs is associated not only with the shortening of the lower internodes and an increase in the mechanical strength of the stem, but also with physiological changes that cause an increase in the drought resistance of plants, the content of chlorophyll in the leaves, a balanced intake of nutrients, and a more powerful development of the root system [11, 12].

The use of growth regulators with retardant properties is one of the important factors of grain production intensification. At present and in the future, growth regulators will become increasingly important not only for increasing the resistance of plants to lodging, but also for purposeful management of physiological metabolic processes for crop formation [13, 14].

Currently, significant progress is being observed in understanding the mechanism of action of the components of the hormonal regulation system, in the interaction of genetic and hormonal regulation of plant development. The emergence of new tools, such as synthetic growth regulators that interrupt the biosynthesis of individual hormones, combined with the use of plants that carry a mutation in the pathway of hormone biosynthesis or the transmission of a hormonal signal, has determined strategic achievements in the field of genetic control of plant development. Thus, having studied the nature of phytohormones-plant growth inhibitors, scientists hastened to synthesize artificial analogues [15].

2. Materials and methods

The research was carried out in 2013-2017 on the basis of the field experimental station of the Federal Research Center “Nemchinovskaya”.

The field experimental station of the Federal Research Center "Nemchinovskaya" is located in the usual conditions of the non-Chernozem zone for the central region of the Russian Federation.

The climate of the Moscow region is moderately continental. During the year, westerly and southwesterly winds prevail, which carry a lot of Atlantic air. The annual arrival of total solar radiation is approximately 87 kcal/cm² in the form of scattered solar radiation.

The air temperature in the territory of the Moscow region is quite uniform, especially in the early winter period. The average monthly temperature in the coldest month decreases down to -10 and -11 °C. Low negative air temperatures cause almost annual freezing of soils in winter up to 60-70 cm. In July, the average monthly air temperature is 17-18 °C. The duration of the period with positive temperatures is 206-216 days (Figure 1).
Figure 1. The dynamics of the temperature regime for the period 2013-2017, taking into account the average long-term temperature values.

The Moscow region belongs to the zone of moderate humidification. The average annual precipitation is 550-660 millimeters. Two-thirds of the precipitation in the year falls in the form of rain. The entire area of the region during the entire growing season has a moisture index of approximately or even more than one.

Stable snow cover is established only at the end of November, but in recent years mainly by the third decade of December. The height of the snow cover by the end of winter reaches 30-45 cm in protected areas. According to the average annual data, temporary freezing of soils in the region occurs in October, stable freezing at the border of the second and third decades of November-November 15-20. In December, the freezing depth is 30-40 cm, in February and in March it reaches 50-80 cm. By the third decade of April, the soil completely thaws. The duration of stable permafrost of soils is 150-160 days.

The object of research was winter wheat, varieties Nemchinovskaya 17. In all experiments, sowing was carried out on pure vapors at the optimal time for this crop.

The soil of the experimental site is sod-podzolic, medium loamy. The thickness of the arable layer is 0.25-0.27 m.

During the 5 growing seasons of 2013-2017, small-scale field experiments were conducted to select the most effective drug with retardant properties. Two Reggi retardants, Messidor with different doses of treatments were used as test drugs, the CeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCeCe Ce

3. Results and discussion
One of the properties of retardants is the inhibition of plant growth due to the reduction of the length of internodes. Of course, retardants ensure the synchronicity of tillering, and by reducing the growth of the
lower internodes, the resistance of plants to lodging increases. According to the latest data, retardants do not inhibit the growth of all shoots on the plant, but only the central one, thereby ensuring the formation of an aligned productive stem in the future. But in addition to the above, retardants have a significant impact on numerous indicators of the physiological and biochemical vital activity of plants, in particular on the processes of photosynthesis.

Under the influence of retardants, the leaf surface area of plants increases significantly (on average by 25-40%) and the content of chlorophyll increases (on average by 10-35%). The grains treated with the preparations stop growing upwards, but at the same time their root system becomes more developed, and the ears add significantly in weight.

According to the results of our research, the use of various growth regulators with retardant properties provided a significant reduction in plant height during the entire growing season on the Nemchinovskaya 17 winter wheat variety. On average, over 5 years, the use of growth regulators at the end of the tillering-exit into the tube phase reduced the height of plants by an average of 0.115 m compared to the control without treatment, where the height of plants averaged 0.813 m (0.636...0.976 m) (Table 1).

### Table 1. Effect of plant growth regulators with retardant properties on plant height for 2013-2017.

| Experience options                           | 2013  | 2014  | 2015  | 2016  | 2017  | Yield, t/ha m | Difference +/-  
|---------------------------------------------|-------|-------|-------|-------|-------|---------------|----------------|
| Control without processing                  | 0.829 | 0.762 | 0.862 | 0.636 | 0.976 | 0.813         |                |
| CeCeCe-750, water-soluble concentrate (WC) (standard) - 1.5 l/ha | 0.765 | 0.698 | 0.757 | 0.485 | 0.936 | 0.728         | -0.084         |
| Reggi, WC - 1.0 l/ha                         | 0.769 | 0.729 | 0.760 | -     | -     | -             |                |
| Reggi, WC - 1.5 l/ha                         | 0.698 | 0.679 | 0.710 | 0.504 | 0.725 | 0.725         | -0.088         |
| Messidor, concentrate of suspension (CS) – 1.0 l/ha | 0.744 | 0.678 | 0.713 | -     | -     | -             |                |
| Messidor, CS – 1.5 l/ha                      | 0.675 | 0.701 | 0.694 | 0.594 | 0.794 | 0.794         | -0.019         |

In our studies, the use of Reggi, Messidor, CeCeCe-750 growth regulators (standard) provided a significant decrease in plant height during the entire research period (Figure 2).

In the research work, preparations with concentrations (concentration range) recommended by manufacturers for processing winter wheat were taken - these are Reggi and Missidor (0.1 l/ha and 1.5 l/ha) to determine the effect of retardant properties on the growth and development of the plant. During the entire research period, it was revealed that lower concentrations (in this case 0.1 l/ha) of the tested drugs still have an effect on plant growth, but significantly worse compared to the same drugs with a concentration of 1.5 l/ha. Thus, when treating plants with Reggi and Messidor preparations at a dose of 0.1 l/ha, there was a slight shortening of the stem by 0.085 m (average height 0.728 m) and 0.094 m (average height 0.719 m in comparison with Reggi and Messidor at a dose of 1.5 l/ha, where a decrease in plant growth by 0.150 m (0.663 m) and 0.121 m (0.692 m), respectively, was observed for the control without treatment. Having traced the dynamics of the effect on the height of the stem of winter wheat, it can be seen that treatment with preparations with a concentration of 1.0 l/ha has a weak effect on reducing the growth process of winter wheat. The main indicator of the effectiveness of the growth regulator is the yield.
Figure 2. Dynamics of growth of winter wheat plants of the Nemchinovskaya 17 variety when using growth regulator preparations for 2013-2017, cm.

When analyzing the results of studies of Reggi and Messidor growth regulators at a concentration of 1.0 l/ha compared to the same drugs, but with a higher concentration (1.5 l/ha), on average, less by 0.1 t/ha. It is the yield that allows us to identify the influence of growth regulators with optimal concentrations on the growth and development of winter wheat plants (Table 2).

Table 2. Indicators of plant height, yield and lodging for 2013-2017.

| Experience options                      | Plant height, m | Yield, t/ha | Culture Lodging Points |
|-----------------------------------------|-----------------|-------------|------------------------|
|                                        | Plant height, m | Yield, t/ha | Culture Lodging Points |
| Control without processing              | 0.813           | 4.170       | 3                      |
| CeCeCe-750, WC (standard)               | 0.728           | 4.800       | 4.4                    |
| Reggi, WC - 1.0 l/ha                   | 0.753           | 5.200       | 4.6                    |
| Reggi, WC - 1.5 l/ha                   | 0.663           | 5.340       | 4.8                    |
| Messidor, CS - 1.0 l/ha                | 0.719           | 5.100       | 5                      |
| Messidor, CS - 1.5 l/ha                | 0.692           | 5.180       | 5                      |

According to the results of studies for the period 2013-2017, in 2016, drugs with doses that had a more effective effect on winter wheat of the Nemchinovskaya 17 variety were left for further testing. The drugs Reggi and Messidor at a dose of 1.0 l/ha were completely excluded from the experiments.

In the winter wheat variety Nemchinovskaya 17, on average, over five years, when using growth regulators at the end of the tillering phase and the beginning of entering the tube, a decrease in plant height (difference) was observed from 0.085 m to 0.150 m compared to the control, where the plant height was 0.813 m.
The results of our research showed that the yield of the Nemchinovskaya 17 winter wheat variety significantly depended on weather conditions and, accordingly, on the level of moisture availability of the growing season and the temperature regime.

In different years of moisture availability, the Nemchinovskaya 17 variety had a different reaction to the use of Reggi and Messidor growth regulators, in most cases, the increase or decrease in yield was not statistically significant. In the highly humidified in 2017, the Reggi growth regulator and Messidor were less effective than in 2013-2016, which is due to low insolation, low temperature conditions (compared to the average annual norm) and abundant precipitation during its use. The yield of winter wheat with Reggi and Messidor treatments was 4.7 t/ha each, which is 0.3 t/ha lower than the standard (CeCeCe-750), but higher by 1.2 t/ha to the control.

The highest yield was recorded in 2014 on winter wheat with Reggi treatment and amounted to 6.1 t/ha, which is 1.8 t/ha more than the control. The drug Messidor showed weaker and the yield this year was 5.9 t/ha compared to the control - 4.3 t/ha. In the spring-summer period of 2014, the weather conditions were with a high temperature regime and a large deficit of precipitation, including during the period of processing by the growth regulators of the crop itself (Figure 3).

There was no significant increase in yield when using the Reggi and Messidor growth regulator in 2013, the maximum difference was observed on the Messidor preparation and amounted to 0.74 t/ha (yield – 5.82 t/ha) in comparison with the control one.

**Figure 3.** Grain yield of the Nemchinovskaya 17 winter wheat variety when treated with growth regulators in the tillering phase-the beginning of entering the tube.

**4. Conclusion**

As the result of the conducted studies of growth regulator preparations with retardant properties, a different reaction of the Nemchinovskaya 17 winter wheat variety was revealed.

According to the results of observations, a differentiated reaction of the tested winter wheat to lodging was established when using the studied growth regulators. In plants treated with Reggi and Messidor growth regulators, lodging was not observed and ranged from 4.4 to 5 points of lodging on the control without treatment – 3 points.

The tested plant growth regulators have a significant impact on the yield of winter wheat of the studied variety and the formation of its structural elements. The increase in yield according to the variants of the experiment was about 4.1-6.1 t/ha. Depending on the type of drug. The highest yield increases were obtained when using Reggi at a dose of 1.5 l/ha, the yield increase was 6.1 t/ha against
the control without treatment - 4.3 t/ha. A higher yield was formed as a result of the formation of a larger number of productive shoots, higher water content and grain weight.

Thus, the treatment of winter wheat plants with the tested growth regulators contributes to an increase in the yield of the Nemchinovskaya 17 winter wheat variety even under unfavorable climatic conditions.

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