The influence of growth regulators on the productivity of the sunflower under cultivation by innovative technologies in the southern chernozem of the Volgograd areas

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Abstract. The article presents the results of three-year observations of the sunflower growth and development in two innovative systems of sunflower cultivation: Clearfield and Express Sun and the use of two growth regulators - IzagriBor and Fertigrain in the subzone of southern chernozems of the Volgograd region. It was found in laboratory studies that the positive influence of the studied growth regulators is already manifested during the period of seed germination. The plant growth and development regulator Fertigrain had a positive influence on the length of roots and seedlings. IzagriBor was less effective. The advantages obtained during the seeds germination then affect both the studied hybrids field germination and the yield. On average, over three-years-long observations, the Clearfield sunflower cultivation system (ES-Novomis hybrid + Eurolighting herbicide) turned out to be the most efficient. When cultivating sunflower by using this system, an average of 2.53 t/ha of oilseeds was obtained in three years, which is 9.7% more than the Express Sun system with the same combination of factors studied. Fertigrain was found to be the most effective regulator of plant growth and development. Its use increased yields in the Clearfield system by 15.0% and in the Express Sun system by 12.4% compared to the control.

1. Introduction
Sunflower occupies a special place among oilseeds in the Nizhneje Povolzhje region. In the Volgograd region, sunflower is the main oilseed crop. The Volgograd region ranks fourth in the Russian Federation in terms of sunflower production [4,7]. In favorable weather years, the gross harvest of sunflower oilseeds in the Volgograd region reaches 1 million tons and more. In ordinary years, the gross harvest is reduced to 750-780 thousand tons. The average yield of sunflower in the Volgograd region in recent years ranges from 1.36 to 1.57 t/ha. Advanced farms receive 2.5-2.6 t/ha. While the biological potential of cultivated varieties and hybrids is -3.5-4.5 t/ha. This fact makes agricultural producers look for ways to increase the yield of this important oilseed crop in specific farm conditions. One of the factors for increasing yields is the use of innovative cultivation technologies and the use of effective plant growth and development regulators. The main goal of our research was to increase the yield of sunflower hybrids when cultivating it in innovative systems through the use of plant growth and development regulators in the subzone of southern chestnut soils of the Volgograd region.

2. Materials and methods
The objects of the research in our experiment were two systems of sunflower cultivation in the subzone of southern chestnut soils of the Volgograd region: 1. Clearfield system 2. Express Sun system and two regulators of plant growth and development: 1. IzagriBor, 2. Fertigrain.
A two-factor field experiment was laid in the farm Tkachenko V.A. Elansky district of the Volgograd region in 2018 - 2020. The setting-up of the experiments and all the necessary observations and research were carried out according to B.A. Dospekhova’s method of field experiment (1985). The field experiment included two factors:
Factor A - innovative systems: 1. Clearfield system - (hybrid ES-Novomis + herbicide Eurolighting). 2. System Express Sun - (hybrid ES-Arcadia SU + herbicide Express). Factor B - Regulators of plant growth and development: 1. Control without the use of growth regulators. 2. IzagriBor – 1 l/t of seeds before sowing + 1 l/ha in the phase of the anthodium formation beginning. 3. Fertigrain – 1 l/t of seeds before sowing + 1 l/ha in the phase of the anthodium formation beginning. The experiment was repeated three times, the registration plot area was 120 m².

The agrotechnics in the experiment included chisel processing of PCHN-2.3 by 0.22-0.25 m, since, in the opinion of many researchers, in this zone it is the best one for sunflower planting, [1,4,5]. In the spring, surface harrowing and two cultivations were carried out by using the KPU-8 to the depth of 0.06 m. In all the years of observations, due to the cold and protracted spring, the sunflower was sown on May 15 and 18 and 25, respectively, with an MS-8 precision seeder with a seeding rate of 50 thousand viable seeds per hectare.

In the phase of three leaves, sunflower was treated with herbicides by using an OP-2000 sprayer with a working solution flow rate of 150 l/ha. Harvesting was carried out according to the plots of the experiment as the seeds ripen with the Dobrynya 1500 combine.

It should be noted that 2018 turned out to be quite wet, especially in the second half of summer. During the growing season of sunflower hybrids, 296 mm of moisture fell out, which is slightly more than long-term indicators, and in 2019 only 225.8 mm of precipitation fell out, but they fell more evenly. The driest year was 2020. There was little precipitation, only 217 mm, and they were distributed extremely unevenly. So in June, precipitation fell out by 3.2 times and in July, 6.3 times less than the average long-term indicators, this naturally affected the yield of hybrids.

3. Research results
As our laboratory studies showed, the growth regulators influence begins to manifest itself even at the stage of seed germination (Table 1).

| Hybrid          | The length of underground seedlings, m control | IsagriBor | Fertigrain | The length of roots, m control | IsagriBor | Fertigrain |
|-----------------|-----------------------------------------------|-----------|------------|--------------------------------|-----------|------------|
| ES-Novomis     | 0.043                                         | 0.052     | 0.054      | 0.034                          | 0.037     | 0.043      |
| ES-Arkadia SU   | 0.041                                         | 0.049     | 0.052      | 0.032                          | 0.034     | 0.038      |

The most pronounced stimulating effect on both hybrids was the growth regulator Fertigrain. In this variant, the length of the seedlings was 0.011-0.013 m longer than in the control ones. In terms of roots length, the advantage was slightly less - 0.007-0.010 m. Of the hybrids taken for the study, in the length of seedlings and roots, ES-Novomis had a slight advantage. A more powerful development of roots at the hybrids development first stage subsequently affected the field germination and safety of plants for harvesting (Table 2).

| Innovative system | Growth regulator | Sprouting, thousand/ha | Ground germination capacity, % | Plants before harvesting, thousand/ha | Percent alive, % |
|-------------------|------------------|------------------------|-------------------------------|---------------------------------------|-----------------|
| Clearfield        | Control          | 36.4                   | 72.9                          | 35.7                                  | 98.2            |
|                   | IsagriBor        | 38.1                   | 76.1                          | 37.6                                  | 98.6            |
|                   | Fertigrain       | 38.3                   | 76.6                          | 38.1                                  | 99.6            |
| Express Sun       | Control          | 36.0                   | 71.9                          | 35.2                                  | 97.9            |
|                   | IsagriBor        | 37.1                   | 74.1                          | 36.4                                  | 98.3            |
|                   | Fertigrain       | 37.8                   | 75.5                          | 37.5                                  | 99.1            |

From the data in Table 2, it can be seen that the hybrids field germination on average for three years was not very high 71.9-76.6%. This is due to the fact that during all the years of observations, the spring was cold and not sufficiently wet. It should be noted that the Clearfield system had some advantage in terms of field germination. In the control variant, the Novomis hybrid had a field germination rate of 1.0% higher than the Express hybrid.
The growth regulators influence on the hybrids field germination was more noticeable. Thus, in the Clearfield system, the hybrid field germination increased by 3.7% from the use of Fertigrain in comparison with the control one. In the Express Sun system, this pattern was fully confirmed, but the indicators were slightly less only by 3.6%.

It should be noted that the preparation IzagriBor also increased field germination in both hybrids in comparison with the control one, but slightly inferior in this indicator to the growth regulator Fertigrain. As for the safety of sunflower plants for harvesting, it was on average very high for three years and did not fall below 97.9% in the control one. In our opinion, this is due to the fact that inter-row weeding was not carried out in the tested cultivation systems of sunflower. This contributed to the high preservation of plants. Growth regulators slightly increased plant safety, but this advantage was insignificant, only 1.4-1.9%. Most of the plants were preserved for harvesting on the variant with the use of the Fertigrain preparation in the Clearfield system -38.1 thousand/ha, which is 2.4 thousand more than in the control one and by 0.5 thousand more than on the variant with IsagriBor. In the Express Sun sunflower cultivation system, the same pattern was noted, but the number of preserved plants in all variants was slightly less. Many researchers consider growth regulators and other biological products to be elements of biological agriculture and indicate their effectiveness not only on sunflower crops, but also on crops of other agricultural crops [7, 8, 9, 10].

All this, naturally, affected the structure of the hybrids crop and yields (Table 3).

### Table 3. Influence of growth regulators on the sunflower harvest structure in innovative cultivation systems (on average over three years).

| Innovative system | Growth regulator | Amount of plants, thousand/ha | Amount of achenes in 1 anthodium, pcs | Mass of 1000 achenes, g | Mass of 1 achen in 1 anthodium | Hybrids biological crop capacity, thousand/ha |
|-------------------|------------------|-----------------------------|---------------------------------|-----------------|-----------------------------|-----------------------------------|
| Clearfield        | Control          | 35.7                        | 1104                            | 58.6            | 64.7                        | 2.31                               |
|                   | IsagriBor        | 37.6                        | 1092                            | 59.7            | 65.2                        | 2.45                               |
|                   | Fertigrain       | 38.1                        | 1107                            | 61.5            | 68.1                        | 2.59                               |
| Express Sun       | Control          | 35.2                        | 1138                            | 52.6            | 59.9                        | 2.11                               |
|                   | IsagriBor        | 36.4                        | 1141                            | 53.7            | 61.3                        | 2.23                               |
|                   | Fertigrain       | 37.5                        | 1159                            | 54.5            | 63.2                        | 2.37                               |

Analyzing the data in Table 3, it should be noted that the ES Novomis hybrid had larger achenes than the ES Arkady SU hybrid. Both tested growth regulators had a positive influence on the increase in the weight of 1000 achenes and the weight of seeds from the anthodium. However, it should be noted that these indicators were more effectively influenced by the preparation Fertigrain. In the Clearfield system on this variant, the weight of achenes in one anthodium increased on average over the observation years by 3.4 g as compared to the control and by 2.9 g as compared to the IsagriBor preparation.

### Table 4. Influence of the studied factors on the sunflower hybrids yield in innovative technologies.

| Innovative system | Growth regulator | 2018 | 2019 | 2020 | average |
|-------------------|------------------|------|------|------|---------|
| Clearfield        | Control          | 2.21 | 2.35 | 2.20 | 2.25    |
|                   | IsagriBor        | 2.34 | 2.64 | 2.28 | 2.42    |
|                   | Fertigrain       | 2.45 | 2.76 | 2.38 | 2.53    |
| Express Sun       | Control          | 2.06 | 2.20 | 1.90 | 2.05    |
|                   | IsagriBor        | 2.28 | 2.28 | 1.98 | 2.18    |
|                   | Fertigrain       | 2.34 | 2.50 | 2.10 | 2.31    |

A number of authors point out the positive influence of the studied factors on the yield structure in their studies [5, 7]. In the Express Sun cultivation system, the same pattern was noted, although all elements of the yield structure were noticeably worse here. The advantages noted here then affected the economic productivity of the tested hybrids (Table 4).

The data in Table 4 show that the highest yield in both sunflower cultivation systems was in 2019, and the lowest one was in 2020. So, if in 2019 the yield according to the variants of the experiment ranged
from 2.20-2.35 t/ha on the control one to 2.50-276 t/ha on the best options, then in 2020 the yield varied on the same options from 1.90 -2.20 t/ha up to 2.10- 2.38 t/ha.

Hybrid yields in 2018 were higher than in 2020 but significantly lower than in 2019. On average, over the years of observations in terms of yield, the advantage was for Clearfield system. Here, the yield according to the variants of the experiment varied from 2.25 t/ha to 2.53 t/ha, while in the Express Sun system the yield varied from 2.05 to 2.31 t/ha or 8.9-8.7%, respectively, less. The highest yield, on average over the years of observation, was obtained in the Clearfield system by using Fertigrain - 2.53 t/ha. The record yield on this option was achieved in 2019 and amounted to 2.76 t/ha, which is 10.4% more than on a similar option in the Express Sun system. The lowest yield, on average, over three years of observations, was obtained in the Express Sun system under control - 1.90 t/ha. Fertigrain proved to be the most effective growth regulator. In the Clearfield sunflower cultivation system, the yield increased by 15.0% in relation to the control one, and in the Express Sun system it increased by 12.4%.

The effectiveness of the IsagriBor preparation turned out to be slightly lower. From its use, the yield in relation to the control, on average over the years of observation, increased in the Clearfield system by 7.6%, and in the Express Sun system only by 6.3%. Since the costs of seeds processing before sowing and plants during the growing season with regulators of plant growth and development are not large, from an economic point of view, their use is quite justified (Table 5).

### Table 5. Growth regulators influence on economic indicators of sunflower hybrids cultivation by using innovative technologies on average for 2018-2020.

| Innovative system | Growth regulator | Crop capacity, t/ha | Gross product value, rub/ha | Production costs, rub/ha | Production on costs, l thousand rub | Estimated profit, Rub/thous and | Profitability level, % |
|-------------------|------------------|---------------------|----------------------------|-------------------------|-----------------------------------|-------------------------------|------------------------|
| Clearfield        | Control          | 2.25                | 67500                      | 11820                   | 5253                              | 55680                         | 471.1                  |
|                   | IsagriBor        | 2.42                | 72600                      | 12352                   | 5104                              | 60248                         | 487.7                  |
|                   | Fertigrain       | 2.53                | 75900                      | 12148                   | 4801                              | 63752                         | 524.8                  |
|                   | Control          | 2.05                | 56400                      | 11426                   | 6077                              | 44974                         | 393.6                  |
|                   | IsagriBor        | 2.18                | 65400                      | 12264                   | 5625                              | 53136                         | 433.2                  |
|                   | Fertigrain       | 2.31                | 69300                      | 12133                   | 5252                              | 57167                         | 471.2                  |

Analyzing the data in Table 5, it should be noted that all economic indicators turned out to be slightly better in the Clearfield system. Here we had the lowest one ton of seeds cost, the highest estimated profit per ton and the highest profitability of sunflower production. In this sunflower production system, the profitability for the variants of the experiment ranged from 471.1% in the control one to 524.8% in the variant with the Fertigrain preparation. In the Express Sun sunflower cultivation system, the profitability was slightly lower and varied from 393.6 to 471.2%. Of the plant growth and development regulators, Fertigrain turned out to be the most effective. Its advantage over IsagriBor in terms of sunflower production profitability by systems was 37.1-38.0%.

### 4. Conclusion

Therefore, on the basis of the carried out three-year studies, it can be concluded that on the southern chestnut soils of the Volgograd region, when cultivating sunflower, the Clearfield system for chisel tillage with seeds and crops processing by Fertigrain at the rate of 1 l/t of seeds before sowing and 1 l/ha in the of the anthodium, formation beginning phase. This allows to steadily obtain more than 2.5 t/ha of oilseeds and significantly increase the sunflower production profitability.

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