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THE YIELD AND QUALITY OF SUNFLOWER SEEDS DEPEND ON THE PRE-SOWING TREATMENT OF THE SEEDS AND EXTRA-ROOT NUTRIENTS

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The article presents the results of two-year studies on the effect of different options of pre-sowing treatment of seeds with various combinations of bacterial, mycorrhizal preparations and growth stimulators based on humic substances, and foliar fertilizing with various combinations of growth stimulators and complex water-soluble fertilizers on seed yield, oil content and collection from 1 hectare of crops high oil sunflower hybrid Aurora AM. The research was conducted during 2022 and 2023 on the basis of LLC "Alliance Agro" located in the Pyryatinsky district of the Poltava region. The technology of sunflower cultivation, with the exception of the investigated issues, was generally accepted for the research area. The yield results showed a significant positive effect of pre-sowing seed treatment. On average, by years and variants of foliar fertilizing, the highest yield of sunflower seeds was in the variant of pre-sowing treatment of seeds with a mixture of Micofrend, BlackJack and "PMK-U" drugs - 2.66 tons/hectare, which is by 0.3 tons/hectare (12.7 %) is higher than on the control version. The advantage of this option in terms of seed yield was noted in the weather conditions of both years. In 2022 and 2023, it was 2.37 and 2.94 tons/hectare, respectively, which is 0.27 and 0.32 tons/hectare higher than in the NIR05 control – 0.06 and 0.09 tons/hectare. In general, according to the experiment, due to the optimization of pre-sowing seed treatment and foliar fertilization, the yield of sunflower seeds on average in two years was increased by 0.45 tons/hectare or almost 20.0%, which indicates the need to pay more attention to pre-sowing seed treatment and foliar feeding. The largest collection of oil in an average of two years - 1,417 tons/hectare was obtained in the variant of pre-sowing treatment of seeds with a mixture of Micofrend, Blackjack and "PMK-U" and carrying out two foliar fertilizing with a mixture of the Blackjack growth stimulator with the formulations of the complex fertilizer Jiva MIX recommended for a specific period of plant growth. Compared to the control, the increase in the indicator was 0.271 tons/hectare or almost 24.0%. According to years of research, the highest oil collection from 1 hectare was also in this variant. In contrast to the seed yield, the oil collection in the variants of three foliar top dressings was somewhat lower than after two top dressings. This trend is associated with a decrease in the oil content in the seeds after the third foliar feeding, while the yield did not increase significantly. Pre-sowing treatment of seeds with a mixture of all drugs provided both the highest seed yield and the highest oil content in seeds, which is why its greater effect on oil collection from 1 hectare than on seed yield is associated with this. Thus, in this variant, compared to the control, the seed yield increased by 12.7% on average over the years and foliar fertilization, while the oil yield from 1 hectare increased by 16.2%. Like the seed yield, the oil yield from 1 hectare underwent greater changes under the influence of weather conditions, while their influence was somewhat less than that of the seed yield. Thus, the range of seed yield variation under the influence of weather conditions was 24.0% (2.25 tons/hectare in 2022 and

2.79 tons/hectare in 2023), and oil yield from 1 hectare was 19, 7% (1.166 tons/hectare in 2022 and 1.396 tons/hectare in 2023). A somewhat smaller influence of the weather conditions of the year on the collection of oil from 1 hectare is due to the lower content of oil in the seeds in the sunflower of 2023, which is more favorable for plants.

***Key words**: sunflower, yield, seed quality, oil collection from 1 hectare, growth stimulants, bacterial preparations, complex fertilizers*

УРОЖАЙНІСТЬ ТА ЯКІСТЬ НАСІННЯ СОНЯШНИКУ ЗАЛЕЖНО ВІД ПЕРЕДПОСІВНОЇ ОБРОБКИ НАСІННЯ ТА ПОЗАКОРЕНЕВИХ ПІДЖИВЛЕНЬ

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У статті представлені результати дворічних досліджень щодо впливу різних варіантів передпосівної обробки насіння різними сполученнями бактеріального, мікоризоутворюючого препаратів і стимулятору росту на основі гумусових речовин, та позакореневих підживлень різними сполученнями стимуляторів росту і комплексних водорозчинних добрив на врожайність насіння, вміст та збір олії з 1 га посівів високоолійного гібриду соняшнику Аврора АМ. Дослідження проводили впродовж 2022 і 2023 рр. на базі ТОВ «Альянс Агро» розміщеного в Пирятинському районі Полтавської області. Технологія вирощування соняшнику, за виключенням досліджуваних питань, була загальноприйнятою для району досліджень. Результати врожайності показали істотний позитивний вплив передпосівної обробки насіння. У середньому за роками та варіантами позакореневих підживлень, найвища врожайність насіння соняшнику була у варіанті передпосівної обробки насіння сумішшю препаратів Мікофренду, БлекДжеку і «ПМК-У» – 2,66 т/га, що на 0,3 т/га (12,7 %) вище, ніж на контрольному варіанті. Перевага цього варіанту за врожайністю насіння відмічалася в погодних умовах обох років. У 2022 і 2023 рр. вона становила 2,37 і 2,94 т/га відповідно, що на 0,27 і 0,32 т/га вище, ніж на контролі за $НІР_{05}$ – 0,06 і 0,09 т/га. У цілому по досліду, за рахунок оптимізації передпосівної обробки насіння та позакореневих підживлень, урожайність насіння соняшнику в середньому за два роки вдалося підвищити на 0,45 т/га або майже на 20,0 %, що свідчить про необхідність приділяти більше уваги передпосівній обробці насіння та позакореневим підживленням. Найбільший збір олії у середньому за два роки – 1,417 т/га отримали у варіанті передпосівної обробки насіння сумішшю Мікофренду, БлекДжеку і «ПМК-У» і проведення двох позакореневих підживлень сумішшю стимулятора росту БлекДжеку з рекомендованими для конкретного періоду росту рослин формуляціями комплексного добрива Jiva MIX. Порівняно з контролем приріст показника становив 0,271 т/га або майже 24,0 %. По роках досліджень найвищий збір олії з 1 га був також у цьому варіанті. На відміну від урожайності насіння, збір олії на варіантах проведення трьох позакореневих підживлень був дещо менший, ніж після двох підживлень. Така тенденція пов'язана зі зменшенням вмісту олії в насінні після проведення третього позакореневого підживлення при тому, що врожайність істотно не зростала. Передпосівна обробка насіння сумішшю всіх препаратів забезпечувала отримання як найвищої врожайності насіння, так і вищого вмісту олії в насінні, саме з цим пов'язаний більший її вплив за збір олії з 1 га, ніж на врожай-

ність насіння. Так, у цьому варіанті, врожайність насіння порівняно з контролем у середньому за роками та позакореневими підживленнями зростала на 12,7 %, тоді як збір олії з 1 га – на 16,2 %. Як і врожайність насіння, збір олії з 1 га більших змін зазнавав за впливу погодних умов при цьому їх вплив був дещо менший, ніж на врожайність насіння. Так, діапазон розбіжності врожайності насіння за впливу погодних умов становив 24,0 % (2,25 т/га – в 2022 р. і 2,79 т/га – у 2023 р.), а збору олії з 1 га – 19,7 % (1,166 т/га в 2022 р. і 1,396 т/га – в 2023 р.). Дещо менший вплив погодних умов року на збір олії з 1 га зумовлений меншим вмістом олії в насінні в більш сприятливому для рослин соняшнику 2023 р.

Ключові слова: *соняшник, врожайність, якість насіння, збір олії з 1 га, стимулятори росту, бактеріальні препарати, комплексні добрива.*

Ukraine is one of the countries characterized by a high potential for the development of agriculture, therefore plant growing has acquired a special status of the national economy, in which the oil industry occupies a leading position. Sunflower is the leading oilseed crop, the share of which in the structure of the sown areas of oilseed crops exceeds 90%. The annual cultivated area of sunflower in Ukraine reaches 5.0 million hectares and more, and oil production exceeds 10.0 million tons (Shcatula Y., 2021). Since it is not rational to further expand the sunflower acreage, increasing the gross production of sunflower seeds should be based primarily on increasing the yield level of the crop due to increasing the adaptability of the sunflower agrobiocenosis (Tkalich I., 2012).

It is possible to successfully solve the issue of increasing the production of sunflower seeds due to the development and implementation of modern cultivation technologies capable of increasing the level of disclosure of the genetic potential of the crop's seed productivity. It is practically impossible to achieve this without scientifically based application of modern types of fertilizers, growth stimulants, bacterial preparations, etc. (Cricta F., 2023).

Nowadays, when growing sunflowers, more and more attention is paid to complex water-soluble fertilizers, growth stimulants, fungal and bacterial preparations. The practical interest in preparations based on beneficial bacteria is due to the fact that they are created on the basis of microorganisms isolated from natural biocenoses, that is, they are environmentally friendly and do not pollute the environment. A significant part of these preparations are created on the basis of microorganisms capable of converting insoluble phosphorus compounds into forms accessible to plants, fixing atmospheric nitrogen, stimulating plant growth, and increasing their resistance to pests and diseases (Volkogon V.V., et al., 2011).

In order to effectively use the genetic potential of modern high-yielding varieties and the available agricultural resources of the cultivation area, it is important to develop and implement modern, adaptive sunflower cultivation technologies. At the same time, an important condition is the improvement of cultivation technology, in particular pre-sowing treatment of seeds and foliar fertilizing of crops with the involvement of innovative preparations with different bases. Only comprehensive improvement of the elements of the nutrition system can be an effective measure to increase the yield and quality of sunflower seeds.

Bacterial preparations based on phosphate-mobilizing microorganisms are characterized by antibiotic action and contribute to the reduction of plant morbidity. Unlike nitrogen fixers, they are less demanding on abiotic factors and soil acidity, but require a sufficient amount of organic matter in it (Grinyk I. V., et al., 2011).

Due to the use of effective compositions of bacterial preparations, the bacteria of

which are able to fix nitrogen and mobilize phosphorus, it is possible to increase the yield of seeds by 20-25%, significantly reduce the prevalence of diseases, and also significantly improve soil fertility (Vlasyuk O. S., 2020). An important aspect of the use of these drugs is also increasing the resistance of plants to adverse weather conditions, reducing phytotoxic effects.

The development of modern technologies for growing sunflowers will make it possible to use the potential of this crop more widely, and the use of innovative bacterial and mycorrhizal preparations, as well as modern ecological growth stimulators, will contribute to reducing the chemical load on ecosystems, without reducing the yield of sunflower seeds. That is why the use of biological products should be considered not as a separate direction, but as an integral part of modern adaptive cultivation technologies.

Along with pre-sowing seed treatment, an important source of revealing the genetic potential of sunflower productivity is foliar feeding, which allows solving the issue of element deficiencies at virtually any time of plant growth and development, and also helps to overcome various types of stress (Kovalenko O. A., 2019; Oad R. K. , et al., 2018; Palamarchuk V.D., et al., 2022). An important advantage of foliar fertilizing is the avoidance of chemical and biological soil binding of the elements of mineral nutrition necessary for plants (Palamarchuk V. D., 2020; Kovalenko O., et al., 2021; Jabeen, N., 2012).

Field crops show different fastidiousness to the elements of mineral nutrition. At the same time, both their deficiency and excess can cause a negative reaction of plants not only because of their toxicity, but also because of blocking the supply of other necessary elements to plants (Hamaiunova V. V., et al., 2018; Kovalenko O. A., et al., 2022 ; Palamarchuk V.D., et al., 2021).

The level and rate of absorption of nutrients through the leaves is much higher than through the roots, but the leaves are not able to "transfer" the necessary amount of elements that the plant needs the most to the plant. In particular, phosphorus, potassium, and calcium cannot be absorbed by plants in significant quantities through the leaf surface, but the need for micro- and mesoelements can be fully met through foliar fertilization (Mazur V. A., et al., 2020).

In stressful weather conditions (high temperatures, long droughts), farmers increasingly use anti-stress, stimulating drugs, including those based on humates, which increase the resistance of plants to a complex of adverse growing factors (Palamarchuk V. D., et al., 2021).

Growth stimulators activate the main life processes of plants, increase the resistance of plants to damage by diseases and pests. Pre-sowing treatment of seeds with growth stimulants helps to level the toxic effect of poisoners, without reducing their protective effect. The sowing qualities of the seeds are also improved, due to which its field germination increases (Bahan A. V., et al., 2020).

It has been proven that the use of growth stimulants based on humic substances for pre-sowing treatment of seeds stimulates their germination, as a result of which the field germination of seeds increases, more synchronous growth and development of plants is ensured. Foliar fertilization with growth stimulators of this group activates physiological processes in plants, eliminates the consequences of stress, as a result of which the reduction of plants decreases, their productivity increases during the growing season (Marenych M. M., et al., 2016).

In recent times, some material has been accumulated regarding the influence of pre-sowing seed treatment and foliar fertilization of field crops, including sunflower, with modern preparations with different active bases on growth and development, yield

and seed quality, but the issue is far from fully resolved. In particular, there is a lack of data on the complex effect of pre-sowing seed treatment with a mixture of drugs with different directions of action in a complex with foliar feeding in different phenological phases, combinations of growth stimulants with complex water-soluble fertilizers on the level of yield and quality of sunflower seeds under different weather conditions. Research on the effectiveness of pre-sowing treatment of seeds with mycorrhiza-forming drugs is also of great interest, since sunflower is classified as a crop that forms a powerful mycorrhiza, while mycorrhiza, like phosphate-mobilizing and nitrogen-fixing bacteria, is an alternative to mineral fertilizers and can partially replace them without reducing seed yield.

The purpose of the research was to determine the complex effect of pre-sowing seed treatment and foliar fertilization with various combinations of preparations on the yield and quality of sunflower seeds in the conditions of the Eastern Forest Steppe of Ukraine.

Research materials and methods. The research was conducted during 2022 and 2023 on the basis of LLC "Alliance Agro" located in the Pyryatinsky district of the Poltava region. The technology of sunflower cultivation, with the exception of the investigated issues, was generally accepted for the research area. The predecessor of sunflower was steamed wheat under which $N_{90}P_{30}K_{30}$ was applied. Immediately after harvesting the predecessor, the area was disked twice, and after two weeks plowing was carried out to a depth of 25–27 cm.

100 kg/hectare of ammophos was applied for pre-sowing cultivation, and 100 kg/hectare of ammonium nitrate during sowing. Sowing in 2022 and 2023 was carried out on May 7 and 11, respectively. The method of sowing is wide-row with 70 cm between rows, the seed sowing rate is 60,000 seeds/hectare, the depth of seed wrapping is 5–6 cm.

Along with carrying out the planned variants of foliar fertilizing with growth stimulants and complex water-soluble fertilizers, urea and magnesium sulfate were added to their tank mixtures in doses of 10 and 5 kg/hectare, respectively.

A new, high-oil sunflower hybrid AURORA AM of the selection of AF NPP AGROMYR LLC was chosen for research, which is included in the register of plant varieties suitable for distribution in Ukraine in 2021.

To solve the tasks, a two-factor experiment using the method of split plots was laid out. The plots of the first order (factor A) were six variants of pre-sowing seed treatment: 1 – control (water treatment); 2 – treatment with the mycorrhizal drug Mycofrend; 3 – treatment with growth stimulator based on humates by BlackJack; 4 – treatment with the bacterial preparation "PMK-U"; 5 – processing with a mixture of Mikofrend with "PMK-U"; 6 – treatment with a mixture of Micofrend, Blackjack and PMK-U. The plots of the second order (factor B) were seven variants of foliar fertilization: I – control; II – Blackjack + *Jiva MIX*$_{(10\text{-}30\text{-}10)}$ during the 12th-13th microphases; III – *Alhum Plus* + *Jiva MIX*$_{(10\text{-}30\text{-}10)}$ during the 12th-13th microphases; IV – Blackjack + *Jiva MIX* $_{(10\text{-}30\text{-}10)}$ during the 12th-13th microphases and Blackjack + *Jiva MIX*$_{(20\text{-}20\text{-}20)}$ during the 35th-37th microphases; V – *Alhum Plus* + *Jiva MIX*$_{(10\text{-}30\text{-}10)}$ during microphases 12-13 and *Alhum Plus* + *Jiva MIX*$_{(20\text{-}20\text{-}20)}$ during microphases 35-37; VI – Blackjack + *Jiva MIX*$_{(10\text{-}30\text{-}10)}$ during the 12th-13th microphases, Blackjack + *Jiva MIX* $_{(20\text{-}20\text{-}20)}$ during the 35th-37th microphases and Blackjack + Jiva MIX$_{(10\text{-}5\ \text{-}40)}$ during the 51st-53rd microphases; VII – *Alhum Plus* + *Jiva MIX*$_{(10\text{-}30\text{-}10)}$ during 12-13 microphases, *Alhum Plus* + *Jiva MIX*$_{(20\text{-}20\text{-}20)}$ during 35-37 microphases and *Alhum Plus* + *Jiva MIX*$_{(10\text{-}5\text{-}\ 40)}$ during 51-53 microphases. The total number of options in the experiment is 42. The area of the sowing and accounting plots of the experiment was

105 and 84 m2, respectively.

The active basis of Mycofriend is a complex of mycorrhizal fungi of the genus Glomus; rhizospheric microorganisms that enhance mycorrhizal formation: *Trichoderma harzianum, Pseudomonas fluorescens, Streptomyces sp.,* as well as agronomically valuable microorganisms, namely: phosphate-mobilizing bacteria and bacteria with fungicidal and bactericidal properties - *Bacillus subtilis, Bacillus megaterium var. phosphaticum, Bacillus muciloginosus, Enterobacter sp*. Sunflower seeds were treated with this drug in a dose of 7.0 kg/t.

The bacterial preparation "PMK-U" is designed to improve the nutrition and protection of a wide range of crops. Its active basis is nitrogen-fixing bacteria *Azotobacter chroococcum, Pseudomonas* and a complex of probiotics to neutralize phytopathogens - *Lactobacillus casei, Lactococcus lactris, Saccharomices cerevisiae*. Sunflower seeds were treated with this drug in a dose of 0.3 l/hectare.

Blackjack growth stimulator is a highly concentrated suspension based on humic acids, fulvic acids, ulmic acids, humin, micro and trace elements. It is intended for root and foliar feeding of field crops. Unlike humates, which contain only two fractions of humic substances - humic and fulvic acids and have an alkaline reaction, BlackJack contains all four fractions of humic substances and has an acidic reaction. In the conducted experiment, sunflower seeds were treated with this drug at a dose of 6.0 l/t. A single dose of foliar feeding with BlackJack is 2.0 l/hectare.

Liquid highly concentrated plant growth stimulator *ALHUM PLUS* contains seaweed extract (180 g/l), amino acids (20 g/l), phytohormones (13 mg/l), fullerene (1.2 g/l), alginic acid (20 g/l), potassium humate (50 g/l), as well as a balanced content of macro- and microelements. The density of the drug is 1.17 g/cm^3, the pH is 8.0-10.0. A single dose of foliar feeding is 2.0 l/hectare.

Complex water-soluble *Jiva MIX* fertilizers with a balanced content of macro- and microelements in chelated form are intended for foliar fertilization of field crops. There are three brands of these fertilizers on the market: *Jiva MIX* (20-20-20), *Jiva MIX* (10-30-10) and *Jiva MIX* (10-5-40). The brand of fertilizer with more phosphorus - $N_{10}P_{30}K_{10}$ - is usually used for the first top dressing, the brand with the same content of macroelements - $N_{20}P_{20}K_{20}$ is mostly used during the period of active plant growth, and the brand with the highest potassium content - $N_{10}P_5K_{40}$ - for late foliar top dressings, in order to improve the quality of products. A single dose of foliar fertilization is 3.0 kg/hectare.

The establishment of the experiment, the accompanying observations, records and analyzes were carried out according to the generally accepted method of conducting field research (Rozhkov A. A., 2016). The variance analysis was carried out in the Microsoft Excel software package based on the methods of B.A. Dospekhov.

Research results. All agricultural crops are grown with one goal - to obtain a harvest of the main and secondary products. The main products of sunflower are seeds, which are used mainly as raw materials for the production of edible oil. The yield of sunflower seeds depends on the complex influence of the elements of cultivation technology, while the greatest influence is exerted by the nutrition system, the components of which include pre-sowing seed treatment and foliar fertilization.

In any case, it is possible to make certain recommendations for the production of a certain element or elements of cultivation technology based only on the level of productivity. And indeed, only on the basis of, for example, the larger area of the leaf surface of the crops, the height of the plants, or the number of seeds in the sunflower basket, one cannot give preference to any option, since it may not necessarily be better in terms of seed yield. This is precisely the case with other biometric and structural

indicators, which can characterize the impact of a certain option only in a certain range of the evaluation plane. And only after recording the yield can one draw specific conclusions about the agronomic feasibility of using a specific option or options.

In the conducted experiment, the harvest was harvested with a Claas combine equipped with a universal harvester adapted for harvesting sunflowers. In order to obtain more accurate yield results, despite the fact that the area of the accounting plot was not large (84.0 m^2), the seeds were collected on the way to the bunker, in bags fixed on the open bottom of the conveyor. After harvesting the accounting plot, seed samples were taken to determine its moisture content and quality indicators.

As we predicted, the results of the yield of sunflower seeds showed a significant positive effect of the studied variants of pre-sowing seed treatment. On average, by year and variant of foliar feeding, the highest yield of sunflower seeds was in the variant of pre-sowing treatment of seeds with a mixture of all studied drugs - 2.66 tons/hectare, which is 0.3 tons/hectare higher than in the control variant of this factor (Table. 1).

Table 1

Yield of sunflower seeds under the combined effect of pre-sowing seed treatment and foliar fertilization, tons/hectare

Option of feeding (factor B)	Option of pre-sowing seed treatment (factor A)						Average	Rank group
	1*	2	3	4	5	6		
2022 year								
I	2,03	2,16	2,20	2,07	2,18	2,23	*2,15*	●
II	2,11	2,22	2,30	2,15	2,27	2,39	*2,24*	●●
III	2,07	2,24	2,25	2,11	2,24	2,32	*2,21*	●
IV	2,15	2,30	2,37	2,22	2,34	2,44	*2,30*	●●
V	2,10	2,27	2,32	2,17	2,30	2,37	*2,26*	●●
VI	2,16	2,33	2,40	2,28	2,39	2,45	*2,34*	●●
VII	2,10	2,29	2,35	2,19	2,33	2,39	*2,28*	●●
Average	*2,10*	*2,26*	*2,31*	*2,17*	*2,29*	*2,37*	2,25	
Rank group	●	●●●	●●●●	●●	●●●	●●●●		
NIR_{05} of the main effect A – 0.06 tons/hectare; NIR_{05} of the main effect B – 0.09 tons/hectare; NIR_{05} of partial comparisons A – 0.09 tons/hectare; NIR_{05} of partial comparisons B – 0.11 tons/hectare								
2023 year								
I	2,54	2,67	2,63	2,60	2,71	2,78	*2,66*	●
II	2,61	2,77	2,74	2,69	2,82	2,93	*2,76*	●
III	2,59	2,70	2,74	2,72	2,80	2,87	*2,74*	●
IV	2,67	2,85	2,83	2,78	2,91	3,01	*2,84*	●●
V	2,62	2,81	2,80	2,75	2,84	2,96	*2,80*	●●
VI	2,70	2,90	2,90	2,83	2,99	3,03	*2,89*	●●
VII	2,64	2,85	2,82	2,78	2,86	2,97	*2,82*	●●
Average	*2,62*	*2,79*	*2,78*	*2,74*	*2,85*	*2,94*	2,79	
Rank group	●	●●	●●	●●	●●●	●●●●		
NIR_{05} of the main effect A – 0.09 tons/hectare; NIR_{05} of the main effect B – 0.12 tons/hectare; NIR_{05} of partial comparisons A – 0.12 tons/hectare; NIR_{05} of partial comparisons B – 0.13 tons/hectare								

Average for 2022 and 2023 years							
I	2,29	2,42	2,42	2,34	2,45	2,51	*2,41*
II	2,36	2,50	2,52	2,42	2,55	2,66	*2,50*
III	2,33	2,47	2,50	2,42	2,52	2,60	*2,47*
IV	2,41	2,56	2,60	2,50	2,63	2,73	*2,57*
V	2,36	2,54	2,56	2,46	2,57	2,67	*2,53*
VI	2,43	2,62	2,65	2,56	2,69	2,74	*2,62*
VII	2,37	2,57	2,59	2,49	2,60	2,68	*2,55*
Average	*2,36*	*2,53*	*2,55*	*2,46*	*2,57*	*2,66*	2,52

*Note: * – the content of variants of factors A and B is given in the item – Materials and methods of research. ** – rank groups of indicators of the main effects of factors according to Duncan's statistical criterion*

The advantage of this option in terms of seed yield was noted in the weather conditions of both years. In particular, in 2022 and 2023, it was 2.37 and 2.94 tons/hectare, respectively, which is 0.27 and 0.32 tons/hectare higher than in the control according to NIR05 – 0.06 and 0.09 t /Hectare.

In the conducted experiment, all options for pre-sowing treatment of seeds provided a significant increase in seed yield compared to the control option, therefore, in order to compare them with each other, a statistical analysis was carried out based on Duncan's rank criterion, which makes it possible to distribute the obtained indicators by statistically homogeneous rank groups.

As a result of this analysis, a significant advantage of the sixth variant of factor A was established both compared to the control and compared to other variants of this factor. In 2022, only in the third option (pre-sowing treatment of seeds with the growth stimulator BlackJack), the seed yield was at the same level as the sixth option - 2.31 tons/hectare. Under favorable weather conditions in 2023, the seed yield of Aurora AM sunflower hybrid in the sixth variant of factor A significantly exceeded all other variants. According to the statistical analysis using the rank criterion, the seed yield in this variant (2.94 tons/hectare) was included in the fourth rank group, the others - in the lower groups.

In contrast to 2022, in 2023, the fifth variant of factor A showed higher efficiency - pre-sowing treatment with a mixture of Micofrendu and PMK-U preparations. On average, according to the options of foliar fertilizing, the seed yield in this option belonged to the third ranking group, that is, it significantly exceeded all other options, except for the sixth option.

The high efficiency of pre-sowing treatment of seeds with a mixture of drugs selected for research is logically explained by the different direction of their action, due to which many processes are activated, which cannot be achieved using any one drug. So, Mycofriend mycorrhizal agent contains special types of fungi that form arbuscular mycorrhizae on plant roots. In addition, it includes a number of types of phosphate-mobilizing bacteria (*Bacillus megaterium var. phosphaticum, Bacillus muciloginosus, Enterobacter sp.*), which convert large reserves of insoluble phosphorus into forms available to plants. As a result, plant nutrition is significantly improved. The main component of the bacterial preparation "PMK-U" is nitrogen-fixing bacteria *Azotobacter chroococcum* and a complex of probiotics *Lactobacillus casei, Lactococcus lactris, Saccharomices cerevisiae,* which reduce the risk of plant damage by diseases. Blackjack, the only humate-based growth stimulator of its kind, activates hormonal and enzymatic processes, ensuring better development of the root system and plants as a whole.

It is this multidirectional effect of the researched drugs in the complex that ensures a significantly higher yield compared to both the control and other variants of the experiment. Their application one by one also contributed to obtaining a higher yield compared to the control, but its increase was significantly smaller compared to the option of their combined application.

The difference between the seed yield indicators under the influence of the investigated variants of foliar fertilization was somewhat smaller than under the influence of pre-sowing seed treatment (on average, over the years, the largest difference under the influence of pre-sowing seed treatment was 0.30 tons/hectare, and under the influence of foliar fertilization - 0.21 tons/hectare), however, they also significantly influenced the change of this indicator.

On average for years and variants of pre-sowing seed treatment, the highest yield was formed in the variant of carrying out three foliar fertilizing with a mixture of the Black Jack growth stimulator and the complex water-soluble fertilizer *Jiva MIX* – 2.62 tons/hectare. The increase in the indicator compared to the control of factor B was 0.21 tons/hectare or almost 9.0%. At the same time, both in 2022 and 2023, the seed yield in this variant was at the same statistical level as in the variants of carrying out two foliar feedings and three feedings with a mixture of growth stimulator *ALHUM PLUS* with complex water-soluble fertilizer *Jiva MIX*.

In the experiments, the interaction of the studied factors was noted, which was manifested in the increase in the influence of the studied variants of foliar fertilization against the background of pre-sowing treatment of seeds with a mixture of all studied drugs. Thus, in 2022 and 2023, under the control of factor A, due to foliar fertilization, the yield of sunflower seeds increased by 0.13 and 0.16 tons/hectare, respectively, and against the background of pre-sowing treatment of seeds with three preparations - by 0.22 and 0.25 tons/hectare.

The weather conditions of the research years were quite contrasting both in terms of temperature and rainfall, so it is quite natural that they had the greatest imact on the variability of yield. Under their influence, seed yield varied from 2.25 to 2.79 tons/hectare (difference 0.54 tons/hectare, or 24.0%). The range of divergence of sunflower seed yield indicators under the influence of pre-sowing seed treatment and foliar fertilization was much smaller - 0.30 tons/hectare (12.7%) and 0.21 (8.7%), respectively.

In general, according to the experiment, due to the optimization of pre-sowing treatment of seeds and foliar fertilization (sixth variant of factors A and B), the yield of sunflower seeds was increased by 0.45 tons/hectare or almost 20.0% in an average of two years, which indicates that the need to pay significant attention to pre-sowing seed treatment and foliar fertilization.

Since the main purpose of sunflower cultivation is to obtain edible oil, it is of interest to determine the theoretical collection of oil per unit area (from 1 hectare). Indeed, a higher seed yield does not always guarantee a larger oil harvest from 1 hectare, as the oil content in the seeds may decrease.

Somewhat inferior to other crops in terms of productivity, sunflower, due to the high content of oil in the seeds, is significantly ahead of them in terms of oil yield from 1 hectare. Thus, the main competitor of sunflower - soybean, is extremely rarely able to ensure the collection of oil from 1 hectare of more than 1 t, while for sunflower, in order to cross this mark, it is enough to form an average yield at the level of 2.5 tons/hectare. In the conducted experiment, all investigated options, even in less favorable weather conditions of 2022, were able to ensure oil collection of more than 1.0 tons/hectare.

The largest collection of oil in an average of two years - 1,417 tons/hectare, was obtained in the variant of pre-sowing treatment of seeds with a mixture of Micofrend, BlackJack and "PMK-U" and carrying out two foliar fertilization with a mixture of BlackJack growth stimulator with formulations of Jiva complex fertilizer recommended for a specific period of plant growth MIX (Table 2).

Table 2

Oil collection from 1 hectare of sunflower crops depending on the combined effect of pre-sowing seed treatment and foliar fertilization, t.

Option of feeding (factor B)	Option of pre-sowing seed treatment (factor A))						Average	Rank group
	1*	2	3	4	5	6		
2022 year								
I	1,043	1,136	1,142	1,083	1,136	1,173	*1,119*	●
II	1,080	1,172	1,198	1,130	1,189	1,262	*1,172*	●●
III	1,066	1,178	1,161	1,095	1,165	1,220	*1,148*	●
IV	1,105	1,205	1,228	1,157	1,224	1,286	*1,201*	●●
V	1,077	1,192	1,204	1,132	1,198	1,251	*1,176*	●●
VI	1,091	1,190	1,207	1,158	1,209	1,264	*1,187*	●●
VII	1,054	1,177	1,191	1,126	1,186	1,228	*1,160*	●
Average	*1,074*	*1,179*	*1,190*	*1,126*	*1,187*	*1,241*	1,166	
Rank group	●	●●●	●●●	●●	●●●	●●●●		
NIR_{05} of the main effect A – 0,047 tons/hectare; NIR_{05} of the main effect B – 0.051 tons/hectare; NIR_{05} of partial comparisons A – 0.054 tons/hectare; $NIR_{05}$of partial comparisons B – 0.56 tons/hectare								
2023 year								
I	1,249	1,356	1,328	1,292	1,379	1,429	*1,339*	●
II	1,289	1,413	1,389	1,326	1,433	1,497	*1,391*	●●
III	1,272	1,369	1,380	1,355	1,434	1,481	*1,382*	●
IV	1,303	1,439	1,449	1,370	1,472	1,547	*1,430*	●●
V	1,292	1,427	1,408	1,364	1,446	1,513	*1,408*	●●
VI	1,296	1,441	1,427	1,367	1,477	1,521	*1,422*	●●
VII	1,286	1,434	1,398	1,362	1,421	1,503	*1,401*	●●
Average	*1,284*	*1,411*	*1,397*	*1,348*	*1,437*	*1,499*	1,396	
Rank group	●	●●●	●●●	●●	●●●●	●●●●●		
$NIR_{05}$of the main effect A – 0.042 tons/hectare; NIR_{05} of the main effect B – 0.045 tons/hectare; NIR_{05} of partial comparisons A – 0.48 tons/hectare; NIR_{05} of partial comparisons B – 0.053 tons/hectare								
Average for 2022 and 2023 years								
I	1,146	1,246	1,235	1,188	1,258	1,301	*1,229*	
II	1,185	1,293	1,294	1,228	1,311	1,380	*1,282*	
III	1,169	1,274	1,271	1,225	1,300	1,351	*1,265*	
IV	1,204	1,322	1,339	1,264	1,348	1,417	*1,316*	
V	1,185	1,310	1,306	1,248	1,322	1,382	*1,292*	
VI	1,194	1,316	1,317	1,263	1,343	1,393	*1,304*	
VII	1,170	1,306	1,295	1,244	1,304	1,366	*1,281*	
Average	*1,179*	*1,295*	*1,294*	*1,237*	*1,312*	*1,370*	1,281	

*Note: * – the content of variants of factors A and B is given in the item – Materials and methods of research. ** – rank groups of indicators of the main effects of factors according to Duncan's statistical criterion*

Compared to the control, the increase in the indicator was 0.271 tons/hectare or almost 24.0%. Directly according to the years of research, the highest collection of oil from 1 hectare was also in this variant.

In contrast to the seed yield, the oil collection in the variants of three foliar top dressings was somewhat lower than after two top dressings. This trend is connected with the decrease of the oil content in the seeds, despite the fact that the yield did not increase significantly. Thus, on average, according to years and variants of pre-sowing seed treatment, after the third foliar treatment, the oil content in seeds decreased by 1.0–1.2% (Table 3). At the same time, the oil content in the control version and the versions of one and two foliar feedings in 2022 and 2023 was actually the same.

Table 3

Oil content in sunflower seeds depending on the combined effect of pre-sowing seed treatment and foliar fertilization, %

Option of feeding (factor B)	Option of pre-sowing seed treatment (factor A)						Average
	1*	2	3	4	5	6	
2022 year							
I	51,4	52,6	51,9	52,3	52,1	52,6	*52,2*
II	51,2	52,8	52,1	52,3	52,4	52,8	*52,3*
III	51,5	52,6	51,6	51,9	52,0	52,6	*52,0*
IV	51,4	52,4	51,8	52,1	52,3	52,7	*52,1*
V	51,3	52,5	51,9	52,2	52,1	52,8	*52,1*
VI	50,5	51,1	50,3	50,8	50,6	51,6	*50,8*
VII	50,2	51,4	50,7	51,4	50,9	51,4	*51,0*
Average	*51,1*	*52,2*	*51,5*	*51,9*	*51,8*	*52,4*	51,8
2023 year							
I	49,2	50,8	50,5	49,7	50,9	51,4	*50,4*
II	49,4	51,0	50,7	49,3	50,8	51,1	*50,4*
III	49,1	50,7	50,4	49,8	51,2	51,6	*50,5*
IV	48,8	50,5	51,2	49,3	50,6	51,4	*50,3*
V	49,3	50,8	50,3	49,6	50,9	51,1	*50,3*
VI	48,0	49,7	49,2	48,3	49,4	50,2	*49,1*
VII	48,7	50,3	49,6	49,0	49,7	50,6	*49,7*
Average	*48,9*	*50,5*	*50,3*	*49,3*	*50,5*	*51,1*	50,1
Average for 2022 and 2023 years							
I	50,3	51,7	51,2	51,0	51,5	52,0	*51,3*
II	50,3	51,9	51,4	50,8	51,6	52,0	*51,3*
III	50,3	51,7	51,0	50,9	51,6	52,1	*51,3*
IV	50,1	51,5	51,5	50,7	51,5	52,1	*51,2*
V	50,3	51,7	51,1	50,9	51,5	52,0	*51,3*
VI	49,3	50,4	49,8	49,6	50,0	50,9	*50,0*
VII	49,5	50,9	50,2	50,2	50,3	51,0	*50,4*
Average	*50,0*	*51,4*	*50,9*	*50,6*	*51,1*	*51,7*	51,0

*Note: * – the content of variants of factors A and B is given in the item – Materials and methods of research. ** – rank groups of indicators of the main effects of factors according to Duncan's statistical criterion*

Pre-sowing treatment of seeds with researched drugs lays a better foundation for the growth and development of plants, partially solving the problem of deficiency of nutrients, moisture, phytohormones, amino acids, etc. At the same time, the best conditions are provided during the entire growing season of the plants. As a result, in the variants of pre-sowing seed treatment with a mixture of all drugs, an increase in the oil content in the seeds was noted. In particular, on average over the years and foliar fertilization, oil collection from 1 hectare in this variant was 51.7%, while in the control it was 50.0%. Compared to other options for pre-sowing seed treatment, an increase in the oil content of seeds was also noted.

Pre-sowing treatment of seeds with a mixture of three preparations provided both the highest seed yield and the highest oil content in seeds, which is why this factor has a greater effect on oil collection from 1 hectare than on seed yield. In this variant, compared to the control, the seed yield increased by 12.7% on average over the years, while the oil yield from 1 hectare increased by 16.2%.

According to the statistical analysis using the rank criterion, in 2022 and 2023, the collection of oil from 1 hectare of crops in the sixth variant of factor A (1.286 and 1.547 tons/hectare, respectively) was significantly higher compared to both the control and other variants . The indicators of oil collection in this variant referred to separate rank groups (in 2022 to the fourth, in 2023 to the fifth).

The effect of the interaction of factors on the change in oil content in seeds has not been established. The regularities and strength of influence of foliar fertilizing options on changes in seed oiliness against the background of different options of pre-sowing seed treatment were practically the same. In the same way, the influence of the investigated options for pre-sowing seed treatment for different options of foliar fertilization did not change.

Like the seed yield, the oil yield from 1 hectare underwent greater changes under the influence of weather conditions, while their influence was somewhat smaller than that of the seed yield. Thus, the range of differences in seed yield indicators under the influence of weather conditions was 24.0% (2.25 tons/hectare in 2022 and 2.79 tons/hectare in 2023), and differences in oil collection from 1 hectare - 19.7% (1.166 tons/hectare in 2022 and 1.396 tons/hectare in 2023).

A slightly smaller influence of the weather conditions of the year on the collection of oil from 1 hectare is due to the lower content of oil in the seeds of the sunflower of 2023, which is more favorable for growth and development. In particular, the average of the studied factors, the content of oil in the seeds of sunflower in 2022 was 51.8 %, and in 2023 – 50.1% (Table 3).

Discussion. Both in terms of seed yield and oil collection from 1 hectare, the best was the option in which the seeds were treated with a mixture of the studied drugs. The obtained data are consistent with the results of studies by Shcatula Y. (2021), in which the higher efficiency of pre-sowing treatment with several bacterial preparations was noted.

The results of the effectiveness of pre-sowing treatment of seeds in different weather conditions correlate with the literature data of other authors (Kozlova O. P., 2018; Yeremenko O. A., 2017), who note a higher effectiveness of bacteriization and stimulation of seeds in less favorable weather conditions, primarily with a lack of precipitation.

The obtained results of seed yield and oil collection did not reveal a better option of foliar fertilization. In contrast to the results of research by other authors (Klymchuk M., et al., 2020; Kovalenko O. A., et al., 2022), which revealed a high effect of early foliar feeding during the phase of 3-6 leaves on the yield of sunflower seeds (yield in-

crease by 15–20%) in the conducted experiment, the effectiveness of feeding with a mixture of growth stimulants with complex microfertilizers during the 12th-13th microphase was significantly lower, besides, in 2023, it was not statistically proven.

Conclusions. The regularities of the complex effect of pre-sowing seed treatment in combination with foliar fertilization on seed yield, content and oil collection from 1 hectare of Aurora hybrid sunflower have been established, namely:

1. The highest seed yield (2.66 tons/hectare) and oil collection (1.370 tons/hectare) were obtained in the variant of pre-sowing seed treatment with a mixture of the mycorrhiza-forming drug Mycofriend, the growth stimulator based on humic substances - BlackJack and the bacterial drug "PMK-U". Variants in which seeds were treated with one of these drugs, as well as with a mixture of Mikofrend with "PMK-U" in terms of seed yield and protein collection significantly exceeded the control, but were inferior to the variant of the combined use of all drugs.

2. Both in terms of seed yield and oil collection from 1 hectare, the options where three foliar feedings were carried out did not differ significantly from the options with two foliar feedings. On average by year and options of pre-sowing seed treatment, the highest oil collection from 1 hectare - 1.316 tons/hectare, was in the option of carrying out two foliar top dressings during the 12-13th and 35-37th microphases according to the classification of VVSN with a mixture of Blackjack growth stimulator with complex water-soluble fertilizer Jiva MIX.

3. In general, according to the experiment, the best option was the combination of pre-sowing treatment of seeds with a mixture of Micofrend, Blackjack, "PMK-U" and two foliar feedings during the 12-13th and 35-37th microphases with a mixture of Blackjack growth stimulator with Jiva complex fertilizer MIX. Seed yield in 2022 and 2023 in this variant was 2.44 and 3.01 tons/hectare, and oil yield was 1.286 and 1.547 tons/hectare, respectively. On average, over the years, the increase in seed yield compared to the control was 19.2%, and oil collection from 1 hectare was 23.6%. A greater influence on the collection of oil from 1 hectare is caused by an increase in the oil content.

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