Directions for Reducing Pesticide Pressure on Agro-Landscapes

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Abstract. Measures have been developed to reduce chemical pesticide pressure on the environment. The impact of biopreparations on the productivity elements and seed quality of sunflower hybrids was determined. The application of the biopreparation Agat-25K was characterized by a direct positive influence on the increase in sunflower head diameter. For example, the hybrid Yason demonstrated an increase in this indicator by 15.2% due to the use of the Agat-25K biological protection method. Furthermore, Agat-25K contributed to a 4.6% increase in the weight of 1,000 seeds, with the hybrid Yason showing an average weight of 63.5 g, compared to the control (60.7 g). However, a decreasing trend in husk content was observed across all hybrids, averaging from 5.3% to 6.8%. The maximum average seed yield of 3.17 t/ha was produced by the hybrid Rimi, while yields decreased by 8.7% and 34.5% for the PR64E71 and Yason hybrids, respectively. Among the biopreparations, Agat-25K had an undeniable advantage, enhancing seed productivity by 16.4%–33.4%. In terms of oil yield per unit area, Rimi led with 1.66 t/ha, while PR64E71 and Yason recorded decreases of 10.9%–26.6%. Agat-25K also exhibited superiority in oil productivity.

1 Introduction

Considering the European Union's Green Deal strategy in agriculture, which involves significantly reducing the use of chemical pesticides and mineral fertilizers in food production and mitigating the environmental impact of crop cultivation technologies, the application of biological methods for protecting plants from harmful organisms is timely and relevant. In Ukraine, research is being conducted on the use of biological plant protection agents derived from natural sources that do not negatively impact the environment [1]. These biopreparations offer the potential to reduce plant damage from harmful organisms and stimulate the growth and development of crops [2].

Pests and plant diseases significantly reduce crop yields and agricultural production volumes, drawing attention to plant protection issues in the agricultural industry. Researchers emphasize that fungal and bacterial infections lead to considerable losses in crops. Chemical

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methods for controlling pathogens involve multiple health and environmental risks. Biological control offers a promising solution to reduce crop losses due to diseases and pests without posing threats to environmental sustainability [3].

Scientists also point out that intensive crop cultivation systems, which rely heavily on synthetic chemicals, raise public concern over pesticide residues contaminating soils and water bodies. Excessive reliance on chemical methods of plant protection has led to increasing threats in biocenoses, particularly in agrocenoses, including contamination of plants, soils, water, and food products with chemical pesticide residues, decreased pest resistance to protective agents, and disrupted ecosystem stability due to the loss of biodiversity caused by chemical substances. These effects pose health risks and harm the natural environment [4, 5].

There is growing interest in biological functional preparations and the development of biotechnologies, including biostimulants and biopesticides, derived from proteins, oligosaccharides, and bioactive compounds. Organic biomass fractions as sources of biologically active substances have recently attracted the attention of academic and industrial stakeholders in the search for and development of new biostimulants and biopesticides. Driven by high economic returns and the need to improve biosecurity, researchers are focused on developing new biopreparations. The discovery of new compounds with biostimulant and biopesticide properties is partly stimulated by the rapidly growing biopreparations market, projected to reach a total value of $19.5 billion by 2030 (with biostimulants comprising 38% and biopesticides 62%), growing at an annual rate of more than 10%. These factors align with the new trends of the bioeconomy and zero-waste initiatives, supporting the goal of sustainable agriculture to reduce fertilizer use by 20% and chemical pesticide use by 50% by 2030 [6–11].

The European Biostimulants Industry Council (EBIC) defines biostimulants as biologically active substances, including industrial by-products classified as fertilizing products, aimed at enhancing plant growth or the plant rhizosphere by improving nutrient use efficiency, resistance to abiotic stress, qualitative traits, or nutrient availability in the soil or rhizosphere. According to plant protection regulations, biopesticides must include at least one agent active against pests or diseases, which may consist of any compound or combination of compounds, including natural products derived from plant by-products [12–14].

It is recognized by scientists that a significant challenge for agricultural production lies in the parallel evolution of pests and the selective breeding achievements aimed at creating pest-resistant genotypes. In the state of Iowa, pests are observed to be adapting to pesticides as a result of their systematic use on corn crops, particularly when corn is grown continuously without rotation. Moreover, the consistent increase in synthetic pesticide use contributes to the growing resistance of harmful organisms and negatively impacts the environment [15].

In modern global agricultural production, there is a rapidly growing trend towards sustainable farming practices. Biological control, in its narrow classical sense, is a method of combating pests, weeds, and plant diseases using natural enemies. It is based on natural mechanisms ("predator-prey," "parasite-host") with active human intervention in the process of regulating and suppressing pests and pathogens [16].

Recently, there has been considerable scientific and practical interest in the application of biopreparations on various crops, including sunflower. These biopreparations enhance the ability of cultivated plants to make better use of available vegetative factors, leading to increased productivity.

In production, the potential of sunflower hybrids has not been fully realized. One of the ways to improve the quality and productivity of sunflower seeds is through the optimization of cultivation technology elements, particularly the use of biopreparations. In this regard, research in this area, especially under conditions of climate change, is highly relevant and necessary for agricultural production.

1.1 Objective

The aim of the study is to determine the impact of biopreparations on the productivity elements and seed quality of sunflower hybrids.

2 Materials and Methods

The research was conducted during the period from 2016 to 2018 at the experimental field of the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, located in the southwestern part of Kherson region, 12 km from the city of Kherson. A two-factor experiment (Factor A – hybrids, Factor B – biopreparations) was established using the randomized split-block method with four replications.

Sunflower Hybrid Jason – Original breeder: V.Ya. Yuriev Institute of Plant Production. Jason is an early-maturing, linoleic-type, versatile sunflower hybrid. Sunflower Hybrid PR64E71 – Original breeder: Pioneer (USA). A medium-maturing linoleic-type hybrid with high oil content. Sunflower Hybrid Rimi – Original breeder: NS SEME, Institute of Field and Vegetable Crops, Novi Sad, Serbia. A medium-early, oil-type hybrid.

Biopreparations *Agat-25K* – Inactivated bacteria *Pseudomonas aureofaciens* strain N16, titer 3-6X10^10 cells/ml, with biologically active substances containing a total amino acid content of 38%. *Gaupsin* – Aqueous suspension of *Pseudomonas aureofaciens* strains B-111 (IBM B-7096) and B-306 (IBM B-7097), their metabolic products, and starting doses of macroelements (N, P, K). *Trichodermin* – A microbiological preparation based on the antagonist fungus *Trichoderma viride (lignorum)*.

The experiments followed generally accepted methodological recommendations for conducting field research [17, 18].

3 Research Results

Key indicators for yield structure, which significantly change under the influence of natural factors and agronomic conditions, are crucial in determining productivity. These indicators include head diameter, seed hull content, and the weight of 1,000 seeds.

Measurements revealed that the head diameter was greatly influenced by weather conditions, with the largest average size across hybrids and biopreparations recorded in the favorable year of 2016 (31.7 cm). The smallest diameter (22.2 cm) was observed in the dry year of 2017 (Table 1).

It is important to note that, on average, for the first factor, the Rimi hybrid showed a clear advantage, with an average head diameter of 27.8 cm. For the PR64E71 and Jason hybrids, this indicator decreased by 4.9% and 15.6%, respectively, to 24.0 cm and 26.4 cm.

The use of the biopreparation Agat-25K demonstrated a direct positive effect on increasing sunflower head diameter. For example, in the variant with the Jason hybrid, this biological solution contributed to a 15.2% increase in the studied indicator.%.

Table 1. Head diameter of sunflower hybrids under the influence of biopreparations (cm).

Hybrid (Factor A)	Biopreparation (Factor B)	Years			Average for 2016-2018 by Factors	
		2016	2017	2018	B	A
Yason	Control	24.0	20.9	21.5	22.1	24.0
	Agat-25K	30.8	22.1	23.7	25.5	
	Gauspin	28.5	21.7	22.9	24.4	
	Trichodermin	27.1	21.2	23.5	23.9	
PR64E71	Control	28.3	21.9	22.9	24.4	26.4
	Agat-25K	35.7	23.6	24.6	28.0	
	Gauspin	34.7	22.8	23.8	27.1	
	Trichodermin	32.7	22.1	24.1	26.3	
Rimi	Control	30.9	21.4	24.9	25.7	27.8
	Agat-25K	36.9	23.3	27.1	29.1	
	Gauspin	34.8	23.1	26.2	28.0	
	Trichodermin	36.1	22.7	25.6	28.1	
Average		31,7	22.2	24.2		
HIP_{05}, cm	A	1.21	0.88	0.95		
	B	1.16	0.72	0.77		

The use of the biopreparations Trichodermin and Haupsin also proved effective, contributing to an increase in head diameter by 8.1 - 10.2%. When the PR64E71 hybrid was treated with Agat-25K, the head diameter increased by 14.7%. For the Rimi hybrid, the head diameter increased by 13.1% with the application of this preparation. Other preparations showed lower efficiency - Haupsin increased the head diameter by 8.9 - 11.3% over the research years, while Trichodermin improved it by 7.9 - 9.4%.

The seed hull content is an important indicator of the economic value of the yield. Reducing its proportion in seed yield is a target for breeding and technological measures. In the study, the impact of weather conditions in 2016, 2017, and 2018 on hull content was found to be minimal, as was the influence of the studied factors and their variants (Table 2).

Table 2. Seed hull content of sunflower hybrids depending on the influence of biopreparations (%).

Hybrid (Factor A)	Biopreparation (Factor B)	Years			Average for 2016-2018 by Factors	
		2016	2017	2018	B	A
Yason	Control	21.0	22.8	22.1	22.0	21.4
	Agat-25K	19.6	21.5	20.8	20.6	
	Gauspin	20.2	22.0	21.3	21.2	
	Trichodermin	20.8	22.6	21.9	21.8	
PR64E71	Control	21.2	22.8	22.1	22.0	21.3
	Agat-25K	19.4	21.5	20.8	20.6	
	Gauspin	20.0	22.0	21.3	21.1	
	Trichodermin	20.5	22.4	21.7	21.5	
Rimi	Control	20.3	22.1	21.6	21.3	20.8
	Agat-25K	19.0	21.3	20.3	20.2	
	Gauspin	19.8	22.2	20.8	20.9	
	Trichodermin	19.5	21.7	21.2	20.8	
Average		20,1	22.1	21.3		
HIP_{05}, cm	A	0.56	0.68	0.63		
	B	0.50	0.57	0.52		

On average, for factor A (hybrids), there was a slight trend towards a decrease in this indicator when growing the Rimi hybrid. The hull content was highest for the Jason hybrid—21.4%, and nearly the same for the PR64E71 hybrid—21.3%. Only the Rimi hybrid showed a trend of a 0.6% and 0.5% reduction in hull content compared to the first and second sunflower hybrids. Unlike factor A, under factor B (biopreparations), there was a negative trend toward reduced hull content across all hybrids when using the biopreparation Agat-25K, with an average reduction of 5.3% to 6.8%. The application of Haupsin and Trichodermin had a less pronounced effect (less than 5%), especially the latter, with only a 0.9–2.3% reduction. Overall, the difference in hull content for factor B was also minimal, ranging from 0.6% to 4.2%. The lowest values were observed in the variants where seeds of all hybrids were treated with Agat-25K and Haupsin.

The weight of 1,000 seeds was significantly affected by the favorable weather conditions during the research years (Table 3).

Table 3. Weight of 1,000 sunflower seeds of the studied hybrids depending on the influence of biopreparations, g.

Hybrid (Factor A)	Biopreparation (Factor B)	Years			Average for 2016-2018 by Factors	
		2016	2017	2018	B	A
Yason	Control	61.2	58.3	62.6	60.7	61.7
	Agat-25K	65.3	61.1	64.1	63.5	
	Gauspin	62.9	60.3	61.8	61.7	
	Trichodermin	62.4	58.9	61.3	60.9	
PR64E71	Control	62.9	59.2	61.8	61.3	63.5
	Agat-25K	67.3	63.8	65.7	65.6	
	Gauspin	65.5	60.4	64.2	63.4	
	Trichodermin	66.4	59.8	64.9	63.7	
Rimi	Control	67.3	62.6	65.9	65.3	67.5
	Agat-25K	71.3	64.3	69.5	68.4	
	Gauspin	69.7	65.7	68.4	67.9	
	Trichodermin	69.8	66.4	68.5	68.2	
Average		66,0	61.7	64.9		
HIP_{05}, cm	A	1.17	0.83	0.98		
	B	0.98	0.65	0.74		

The highest average seed weight - 66.0 g - was recorded in 2016, which had favorable weather conditions. In contrast, in the dry year of 2017, this indicator dropped to 61.7 g, or by 6.9%. On average, the Rimi hybrid provided the maximum weight of 1,000 seeds, reaching 67.5 g. For PR64E71 and Jason hybrids, this seed quality parameter decreased by 6.3–9.3%.

The application of the biopreparation Agat-25K increased the weight of 1,000 seeds in the Jason hybrid variant by an average of 4.6% (up to 63.5 g), compared to the control variant (60.7 g). The effect of other biopreparations (Haupsin, Trichodermin) was minimal—only 0.3–1.6%.

For the PR64E71 and Rimi hybrids, a certain increase in seed weight was also observed, rising by 4.7–6.9% with the application of Agat-25K. The effectiveness of Haupsin and Trichodermin was lower, increasing the weight of 1,000 seeds by only 3.4–4.6%, respectively.

It was found that the sunflower seed yield varied significantly during the research years due to differences in precipitation levels (Table 4).

Table 4. Yield of sunflower hybrids depending on the use of biopreparations for plant protection, t/ha.

Hybrid (Factor A)	Biopreparation (Factor B)	Years			Average by Factors	
		2016	2017	2018	B	A
Yason	Control	2.45	1.74	2.03	2.08	2.36
	Agat-25K	3.16	2.16	2.70	2.68	
	Gauspin	2.92	1.98	2.27	2.39	
	Trichodermin	2.79	1.89	2.16	2.28	
PR64E71	Control	2.90	1.92	2.48	2.43	2.91
	Agat-25K	3.74	2.67	3.32	3.25	
	Gauspin	3.63	2.21	3.22	3.02	
	Trichodermin	3.38	2.54	2.96	2.96	
Rimi	Control	3.17	2.45	2.75	2.79	3.17
	Agat-25K	3.88	3.01	3.46	3.45	
	Gauspin	3.63	2.69	3.22	3.18	
	Trichodermin	3.76	2.64	3.34	3.25	
Average		3,28	2.33	2.83		
HIP_{05}, t/ha	A	0.14	0.09	0.11		
	B	0.12	0.07	0.09		

It was determined that under favorable conditions in 2016, the yield increased to 3.88 t/ha for the Rimi hybrid when the seeds were treated with the biopreparation Agat-25K before sowing. Due to the deficit of precipitation and elevated temperatures in 2017, this indicator decreased by 2.2 times (to 1.74 t/ha) in the control variant with the Jason hybrid.

On average, over the period 2016–2018, and according to factor A (hybrid), the highest seed yield, reaching 3.17 t/ha, was formed by the Rimi hybrid. For the PR64E71 hybrid, a decrease of 8.7% was noted, resulting in a yield of 2.91 t/ha. The lowest seed yield, averaging 2.36 t/ha, was recorded for the Jason hybrid, which was 23.7–34.5% lower than the other hybrids.

Regarding the second factor (B – biopreparation), all sunflower hybrids showed an advantage with the use of Agat-25K. For example, in the variant with the Jason hybrid, seed yield increased to an average of 2.68 t/ha when seeds were treated with this biopreparation before sowing, which was 28.9% higher than the control. The Haupsin biopreparation also resulted in a high yield of 2.39 t/ha, which was 15.3% higher than the variant without biopreparations. The least effective was Trichodermin, which increased yield by only 9.8% over the control. In the PR64E71 hybrid, Agat-25K's effectiveness led to a 33.4% yield increase, with other biopreparations increasing yield by 24.1% and 21.7%. For the Rimi hybrid, the highest efficiency was demonstrated by Agat-25K and Trichodermin, with yield increases of 23.7% and 16.4%, respectively, compared to the control.

Laboratory analysis revealed a slight difference in the fat content of the sunflower seeds (Table 5). The highest fat content, 53.4%, was recorded in the relatively wet 2016 for the Rimi hybrid, with seed treatment by Agat-25K. Due to the negative effects of the drought in 2017, the lowest fat content was 50.0%, observed in the PR64E71 hybrid without the use of biopreparations (control with clean water treatment).

On average, for the hybrid composition (factor A), an increase in oil content was observed, reaching 52.4% in the Rimi hybrid, which is higher than the Yason and PR64E71 hybrids by 0.9-1.1% (with oil content of 51.9-52.0%). The application of biopreparations contributed to a slight increase (by 0.8-1.2%) in the oil content of the seeds of the studied crop.

Table 5. Fat content in the seeds of the studied sunflower hybrids depending on the influence of biopreparations, %.

Hybrid (Factor A)	Biopreparation (Factor B)		Years			Average by Factors	
			2016	2017	2018	B	A
Yason	Control		51.7	50.7	51.0	51.1	51.9
	Agat-25K		52.4	51.4	51.7	51.8	
	Gauspin		52.4	51.5	51.9	51.9	
	Trichodermin		52.7	52.4	52.9	52.7	
PR64E71	Control		52.3	50.0	50.4	50.9	52.0
	Agat-25K		52.8	52.5	52.8	52.7	
	Gauspin		52.7	51.2	51.6	51.8	
	Trichodermin		53.2	51.8	52.5	52.5	
Rimi	Control		52.4	50.8	51.8	51.7	52.4
	Agat-25K		53.4	52.6	52.9	53.0	
	Gauspin		53.0	52.5	52.7	52.7	
	Trichodermin		53.2	51.5	52.3	52.4	
Average			52.7	51.6	52.0		
HIP_{05}. %		A	0.95	0.73	0.84		
		B	0.82	0.52	0.78		

An important indicator of sunflower cultivation efficiency is the oil yield per unit of sowing area (see Table 6). In the years of the study, an increase in this indicator was noted in the favorable year of 2016, averaging 7.73 t/ha, which is 44.3% higher compared to the drought year of 2017 and 17.6% higher than in the challenging weather conditions of 2018.

Table 6. Conditional oil yield when cultivating sunflower hybrids depending on biopreparations, t/ha.

Hybrid (Factor A)	Biopreparation (Factor B)	Years			Average by Factors	
		2016	2017	2018	B	A
Yason	Control	1.27	0.88	1.04	1.06	1.22
	Agat-25K	1.66	1.11	1.40	1.39	
	Gauspin	1.53	1.02	1.18	1.24	
	Trichodermin	1.47	0.99	1.14	1.20	
PR64E71	Control	1.52	0.96	1.25	1.24	1.52
	Agat-25K	1.98	1.40	1.76	1.71	
	Gauspin	1.91	1.13	1.66	1.57	
	Trichodermin	1.80	1.32	1.55	1.56	
Rimi	Control	1.66	1.24	1.43	1.44	1.66
	Agat-25K	2.07	1.58	1.83	1.83	
	Gauspin	1.93	1.41	1.69	1.68	
	Trichodermin	2.00	1.37	1.75	1.71	
Average		1.73	1.20	1.47		

The cultivation of the Rimi hybrid using the biopreparation Agat-25K resulted in a maximum conditional oil yield of 2.07 t/ha during the favorable year of 2016. The Agat-25K biopreparation also demonstrated high efficiency with other hybrids. In the dry year of 2017, the conditional oil yield in the Yason hybrid decreased to 0.88 t/ha in the control variant of factor B, marking an absolute minimum. On average across the hybrid composition, the highest oil yield per unit of sowing area was 1.66 t/ha for the Rimi hybrid, while the yield for the PR64E71 and Yason hybrids decreased by 10.9-26.6%.

The Agat-25K biopreparation showed a significant advantage among the studied preparations. For the Yason hybrid, the treatment with Agat-25K ensured the highest conditional oil yield, averaging 1.39 t/ha, which was 31.1% higher than the control and exceeded other biopreparations by 12.1-15.8%. When cultivating the PR64E71 hybrid, the use of the Agat-25K biopreparation contributed to a 37.9% increase in this indicator compared to the control, and by 8.9-9.6% relative to other biopreparations. A similar increase was observed for the Rimi hybrid, with increases of 27.1% and 7.0-8.9%, respectively.

4 Conclusions

A significant influence of weather conditions, biopreparations, and genotype on the elements of productivity and seed quality of sunflower hybrids in the Southern Steppe of Ukraine was established. The application of the Agat-25K biopreparation in the cultivation of the PR64E71 sunflower hybrid increased the head diameter by 14.7%, while for the Rimi hybrid, the increase was 13.1%. The Yason hybrid exhibited the highest husk percentage at 21.4%, while the PR64E71 hybrid had a similar level at 21.3%. The difference in the studied indicator when using biopreparations was also insignificant (0.6-4.2%). The lowest husk percentage was observed in all hybrid variants treated with Agat-25K and Gauspin preparations.

The maximum weight of 1000 seeds was recorded at 66.0 g (on average across the experimental variants) in the favorable weather conditions of 2016, while in the drought year of 2017, this indicator decreased to 61.7 g, or by 6.9%. On average across the hybrid composition, the highest value of this indicator was provided by the Rimi hybrid (67.5 g). In plots with the PR64E71 and Yason hybrids, this seed quality indicator decreased by 6.3-9.3%. The Agat-25K biopreparation contributed to an increase in the weight of 1000 seeds in the Yason hybrid by 4.6% to 63.5 g. The effects of other biopreparations (Gauspin, Trichodermin) were negligible, showing increases of only 0.3-1.6%.

Laboratory analysis determined that the maximum oil content was recorded in the Rimi hybrid (52.4%), which is only 0.9-1.1% higher than that of the Yason and PR64E71 hybrids (51.9-52.0%). The application of biopreparations contributed to a slight increase (by 0.8-1.2%) in this seed quality indicator. The cultivation of the Rimi hybrid using the Agat-25K biopreparation resulted in the highest conditional oil yield of 2.07 t/ha in the favorable weather year of 2016. Among the hybrids (averaging across the variants of biopreparation application and years), this indicator was highest (1.66 t/ha) in the Rimi hybrid. The Agat-25K biopreparation had a positive effect in terms of increasing the conditional oil yield per hectare of sunflower sowing area, resulting in a 31.1% increase compared to the control and exceeding other biopreparations by 12.1-15.8%.

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