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EFFECTIVENESS OF BIODECOMPOSERS IN SUNFLOWER CULTIVATION UNDER THE CONDITIONS OF THE SOUTHERN STEPPE OF UKRAINE

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The relevance of the study is the need to increase sunflower productivity and preserve soil fertility under conditions of climate change, increasing aridity, and declining soil organic matter content. The aim of the study was to determine the effectiveness of stubble biodestructors as an element of sunflower cultivation technology after grain maize and to assess their impact on yield and key fertility indicators of southern chernozem. The research was conducted in 2023–2025 in a field two-factor experiment using stubble biodestructors and mineral fertilizer $N_{30}P_{15}K_{15}$. It was established that applying stubble biodestructors increased sunflower seed yield even without mineral fertilization, whereas their combination with fertilizers yielded the greatest effect. On average over the years of research, the yield in the control was 1.94 t/ha; with the application of $N_{30}P_{15}K_{15}$ alone, 2.18 t/ha; with the use of biodestructors without fertilizers, 2.06–2.21 t/ha. The highest yields were obtained in treatments combining biodestructors with mineral fertilization – 2.30–2.48 t/ha, with the maximum value recorded for the treatment with the bacterial product "Ecostern" – 2.48 t/ha. The yield increase compared to the control averaged 0.19 t/ha with the use of biodestructors without fertilizers, 0.24 t/ha with mineral fertilizer alone, and 0.48 t/ha with their combined application. Even under the arid conditions of 2025, the integrated use of the studied factors resulted in higher productivity than the control. A positive effect of biodestructors on soil fertility indicators was substantiated. Their application led to increased content of mineral nitrogen, available phosphorus and potassium, hydrolyzable nitrogen, and organic matter. The maximum organic matter content in the 0–30 cm soil layer reached 5.27% under the combined application of biodestructors and mineral fertilizers. The practical significance of the obtained results lies in substantiating the feasibility of integrating stubble biodestructors with moderate mineral fertilization to increase sunflower productivity and improve fertility indicators of southern chernozem.

Keywords: sunflower, stubble biodestructors, plant nutrition, seed yield, biological approaches to restoring soil fertility indicators, humus content, and available nutrients.

Introduction. With changing climatic conditions, rising temperatures, and uneven as well as insufficient precipitation, plant productivity is highly dependent on and varies according to moisture availability (Yeremenko, et al. 2017). Indeed, moisture is typically the primary limiting factor in the Southern Steppe of Ukraine. This unfavorable situation is further aggravated by the loss of the main indicators of soil fertility, particularly the decline in humus and organic matter content, as well as increasing soil compaction. The deterioration of physical soil properties, in turn, reduces its ability to absorb and retain sufficient moisture. Even after substantial rainfall, water may not be fully absorbed by the soil but instead evaporates rapidly and is lost without benefiting the plants (Ozhovan, 2021; Polyakov & Nikitenko 2020; Gamajunova, 2017). This relationship has been identified for a great many soil types (Zhang, et al. 2018; Lopushniak et al., 2022; Nasibov et al., 2024).

For this reason, different soil types require enrichment with organic matter, which can improve key fertility indicators by increasing porosity and promoting root system development, thereby significantly enhancing water infiltration and water-holding capacity. The importance of enriching soil with organic matter has been emphasized by numerous researchers (Struijk, et al. 2020; Luo, et al. 2018; Horodyska & Kravchuk 2023).

Thus, Tsytsyura Ya. H. et al. established the positive effect of growing green manure crops and incorporating them into the soil (Tsytsyura et al., 2022). The most cost-effective way to enrich soil with fresh organic matter is to use crop residues from cereals, legumes, and other crops. The role of legumes is especially important, as they contribute not only valuable organic matter to the soil but also free biologically fixed nitrogen (Kalenska et al., 2022). However, legume crops currently occupy only a limited area. Under these conditions, greater attention should be paid to the incorporation of straw from cereal crops, maize, sunflower, and other crops into the soil (Gamayunova et al., 2024; Sydiakina, 2021; Tsyliuryk et al., 2019). Crop residues improve soil structure and enhance its physical properties. The presence of fresh organic matter increases soil water infiltration and water-holding capacity. Thus, enriching the soil with organic matter can regulate plant moisture requirements to some extent. This is also facilitated by improved mineral nutrition, which should be optimized (Zhuykov et al., 2024; Sydiakina & Ivaniv, 2023; Gamayunova et al., 2019). The formation of an optimal amount of aboveground biomass and leaf area improves shading of the soil surface, helps reduce weed infestation, and consequently ensures more efficient water use by plants, resulting in a significant increase in crop productivity (Domaratsky, 2021; Domaratsky et al., 2021; Domaratsky et al., 2024).

Sunflower responds significantly to nutrient management regimes, particularly to pre-sowing seed treatment and the application of biological products and growth-regulating substances during the growing season (Kurach et al., 2023; Chuiko et al., 2021; Sakharchuk & Garbar, 2018). The use of such products promotes physiological and biochemical processes in plants, improves root system development, and increases the efficiency of utilization of mineral nutrients and soil moisture (Kovalenko et al., 2021; Panfilova et al., 2023; Shebanin et al., 2024). This, in turn, ensures higher field germination and seed vigor, enhances plant growth and development during early organogenesis, and increases resistance to unfavorable abiotic and biotic environmental factors (Kachanova et al., 2023; Kovalenko et al., 2024; Pokopceva et al., 2024). As a result, yield formation processes are optimized, and crop productivity increases.

Materials and Methods. The study involving the early-maturing sunflower hybrid SY Chester was conducted during 2023–2025 in the experimental field of the Educational, Scientific and Practical Center of Mykolaiv National Agrarian University in Mykolaiv region. The soil was southern chernozem. The preceding crop in the experiment was grain maize. The yield of the preceding crop was 11 t/ha; at a grain-to-residue ratio of 1:1.3, the amount of aboveground biomass incorporated into the soil was about 15 t/ha.

The experiment was two-factorial.

Factor A – stubble biodestructor:

1. Control – without biodestructor + N_5 (ammonium nitrate) + 200 L/ha of water;
2. Ecostern Classic, 2 L/ha + N_5 (ammonium nitrate) + 200 L/ha of water;
3. Ecostern Light, 2 L/ha + N5 (ammonium nitrate) + 200 L/ha of water;
4. Ecostern Bacterial, 2 L/ha + N_5 (ammonium nitrate) + 200 L/ha of water;
5. Ecostern Detox, 2 L/ha + N_5 (ammonium nitrate) + 200 L/ha of water.

Factor B – mineral fertilizer:

1. Without fertilizers;
2. $N_{30}P_{15}K_{15}$.

The aboveground maize biomass was treated with biodestructors in mid-October together with N_5 (5 kg a.i. of ammonium nitrate). This was followed by disking to ensure uniform incorporation of the residues into the upper soil layer. Two weeks later, plowing was performed to a depth of 23–25 cm in order to improve soil aeration and water-holding capacity and to create favorable conditions for effective sunflower root development. At the four-leaf stage, sunflower crops were sprayed with Euro-Lighting herbicide according to the recommended application protocol to ensure effective weed control and reduce competition for moisture, light, and nutrients.

The sunflower experiment was conducted in accordance with zonal methodological recommendations and accepted standards (Ushkarenko et al., 2014; Rozhkov et al., 2016 a; Rozhkov et al., 2016 в).

Results and Discussion. The results indicate that both biological products and mineral fertilizers significantly affected sunflower seed yield, with a clear interaction between the factors (Table 1).

Table 1

Sunflower seed yield as affected by the studied factors, t/ha

Treatment variant		Years of cultivation			
Factor A – stubble biodestructor	Factor B – mineral fertilizer	2023	2024	2025	Average for 2023–2025
1.Control – without biodestructor + N_5 (ammonium nitrate) + 200 L/ha of water	Without fertilizers	2.54	2.43	0.84	1.94
	$N_{30}P_{15}K_{15}$	2.82	2.70	1.01	2.18
2.Ecostern Classic, 2 L/ha + N_5 (ammonium nitrate) + 200 L/ha of water	Without fertilizers	2.70	2.64	0.92	2.09
	$N_{30}P_{15}K_{15}$	3.01	2,95	1.07	2.34
3.Ecostern Light, 2 L/ha + N_5 (ammonium nitrate) + 200 L/ha of water	Without fertilizers	2.65	2,58	0.94	2.06
	$N_{30}P_{15}K_{15}$	2.94	2.89	1.08	2.30
4.Ecostern Bacterial, 2 L/ha + N_5 (ammonium nitrate) + 200 L/ha of water	Without fertilizers	2.90	2.78	0.94	2.21
	$N_{30}P_{15}K_{15}$	3.24	3.10	1.11	2.48
5.Ecostern Detox, 2 L/ha + N_5 (ammonium nitrate) + 200 L/ha of water	Without fertilizers	2.82	2.76	0.94	2.17
	$N_{30}P_{15}K_{15}$	3.17	3.09	1.12	2.46
LSD_{05}	for factor A	0.09	0.08	0.06	
	for factor B	0.08	0.10	0.08	
	for the interaction of factors A and B	0.12	0.11	0.08	

Source: developed by the author

In the control treatment without the application of a biodestructor or mineral fertilizers, the average sunflower seed yield in 2023–2025 was 1.94 t/ha, whereas the application of mineral fertilizer at a rate of $N_{30}P_{15}K_{15}$ increased it to 2.18 t/ha. The use of stubble biodestructors further increased yield, even without fertilizers. Thus, when Ecostern Classic (2 L/ha) was applied, the average yield without fertilizers was 2.09 t/ha; with Ecostern Light, 2.06 t/ha; with Ecostern Bacterial, 2.21 t/ha; and with Ecostern Detox, 2.17 t/ha. The highest sunflower seed yields were obtained when biodestructors were combined with mineral fertilization. On average over the three years, the maximum yield was recorded in the treatment with Ecostern Bacterial (2 L/ha) combined with $N_{30}P_{15}K_{15}$ at 2.48 t/ha, followed by Ecostern Detox (2 L/ha) at 2.46 t/ha. Slightly lower, but still high, yields were obtained with Ecostern Classic (2.34 t/ha) and Ecostern Light (2.30 t/ha) in combination with mineral fertilizers.

The analysis of yield dynamics over the years indicates that yields in 2023 and 2024 were considerably higher than in 2025 due to the unfavorable weather conditions in the final year of the study. However, even under the stressful conditions of 2025, the application of biodestructors in combination with mineral nutrition resulted in higher seed yields than the control. It should be noted that in the extremely dry year of 2025, sunflowers were not harvested at all in many farms of the Mykolaiv region. At the Educational, Scientific and Practical Center of Mykolaiv National Agrarian University, total precipitation in April, May, and early June amounted to about 70 mm, enabling the formation of a yield that, although low, was still sufficient for harvesting.

The LSD_{05} values indicate a statistically significant effect of both factor A (stubble biodestructors) and factor B (mineral nutrition), as well as their interaction, on sunflower seed yield in all years of cultivation. This confirms the feasibility of integrating biological products and mineral fertilizers into sunflower cultivation technology to increase crop productivity without reducing the main indicators of soil fertility.

An analysis of yield increases relative to the control treatment (without biodestructor and mineral fertilizers) showed that the application of stubble biodestructors without mineral fertilizers provided an average increase in sunflower seed yield of 0.19 t/ha over 2023–2025, whereas the use of mineral fertilizers alone at a rate of $N_{30}P_{15}K_{15}$ without biodestructors increased yield by 0.24 t/ha. The greatest effect was observed when biodestructors were combined with mineral nutrition, with the average yield increase over the control reaching 0.48 t/ha, indicating the effectiveness of the combined action of biological products and mineral fertilizers in sunflower cultivation technology.

The data presented in Figure 1 clearly show that both the application of biodestructors and the use of mineral fertilizers at $N_{30}P_{15}K_{15}$ had a positive effect on crop productivity, with their combination providing the greatest effect. In the control treatment, without fertilizers and without a biodestructor, yield amounted to 2.54 t/ha in 2023, 2.43 t/ha in 2024, and decreased sharply to 0.84 t/ha in 2025 (1.94 t/ha on average). The use of a biodestructor without fertilizers increased yield to 2.77 t/ha in 2023, 2.69 t/ha in 2024, and 0.93 t/ha in 2025, with an average of 2.13 t/ha, which was higher than in the control treatment.

The application of mineral fertilizer alone at $N_{30}P_{15}K_{15}$ (without a biodestructor) resulted in seed yields of 2.82, 2.70, and 1.01 t/ha in 2023, 2024, and 2025, respectively, with a three-year average of 2.18 t/ha. The highest yield levels were obtained when $N_{30}P_{15}K_{15}$ was combined with a biodestructor, reaching 3.12 t/ha in

2023, 3.01 t/ha in 2024, and 1.13 t/ha in 2025, with an average of 2.42 t/ha over 2023–2025.

Thus, averaged over the three years of cultivation, which differed substantially in weather conditions, the use of biodestructors without fertilizers increased yield relative to the control, whereas the combination of a biodestructor with mineral fertilization provided the greatest yield increase and partly mitigated the negative effects of the unfavorable conditions of 2025, confirming the feasibility of the integrated use of these technological components in sunflower cultivation. In addition, their combined application positively affected soil fertility indicators.

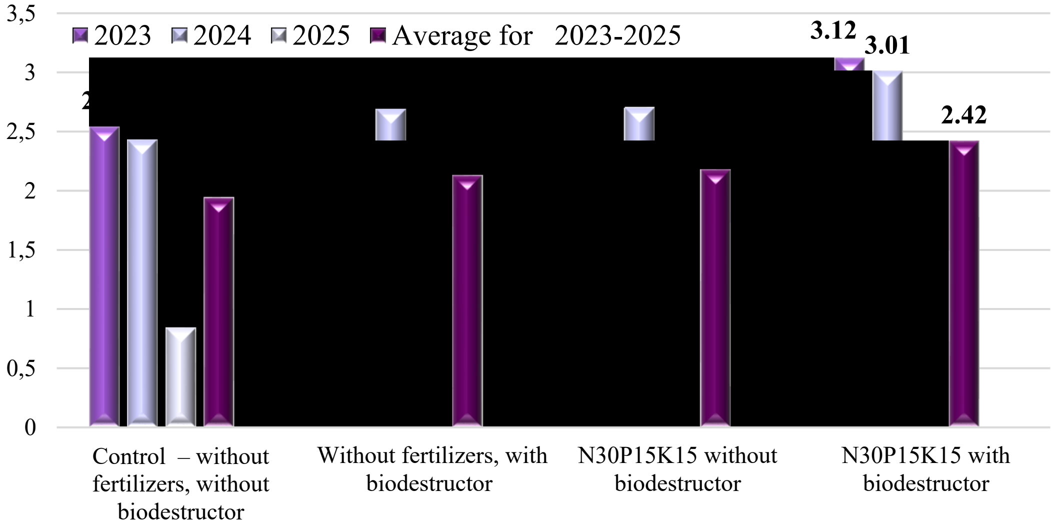

Fig. 1. **Effect of biodestructors and fertilization on sunflower seed yield by year of cultivation, t/ha**

Source: developed by the author

In the control treatment without a biodestructor, the mineral nitrogen content without fertilizers was 13.56 mg/kg (NO_3^- – 9.14; NH_4^+ – 4.42), whereas the application of $N_{30}P_{15}K_{15}$ increased it to 19.93 mg/kg (Table 2). The use of biodestructors significantly intensified mineralization: without fertilizers, the total mineral nitrogen content increased to 19.68–21.35 mg/kg, whereas in combination with $N_{30}P_{15}K_{15}$ it rose to 26.93–28.59 mg/kg. The highest mineral nitrogen content was determined in the soil of the treatment with Ecostern Bacterial, 2 L/ha + $N_{30}P_{15}K_{15}$, reaching 28.59 mg/kg (NO_3^- – 18.06; NH_4^+ – 10.53); similar values were also obtained with Ecostern Light + $N_{30}P_{15}K_{15}$ – 28.50 mg/kg.

The content of available phosphorus and potassium also showed an increasing trend. In the control treatment without fertilizers and biodestructors, the content of P_2O_5 was 185.7 mg/kg, and K_2O was 375.8 mg/kg, whereas under the use of biodestructors without mineral fertilizers, these values increased to 197.4–201.3 mg/kg for P_2O_5 and 382.6–390.2 mg/kg for K_2O. The highest values of P_2O_5 and K_2O were obtained when biodestructors were combined with $N_{30}P_{15}K_{15}$, particularly in the treatment Ecostern Bacterial + $N_{30}P_{15}K_{15}$: 206.4 mg/kg P_2O_5 and 394.7 mg/kg K_2O, respectively.

The data in the table confirm that stubble biodestructors increase the soil supply of available mineral nitrogen, phosphorus, and potassium, and that their combination with $N_{30}P_{15}K_{15}$ provides the most pronounced effect, indicating the expediency of integrating biological products with moderate mineral nutrition into sunflower cultivation technology.

Table 2

Content of available nutrients in the 0–30 cm layer of southern chernozem at sunflower harvest under the use of biodestructors and mineral fertilizers (average for 2023–2025), mg/kg of soil

Factor A – stubble biodestructor	Factor B – mineral fertilizer	Mineral nitrogen			P_2O_5	K_2O
		NO_3^-	NH_4^+	Total		
1.Control – without biodestructor + N_5 (ammonium nitrate) + 200 L/ha of water	Without fertilizers	9.14	4.42	13.56	185.7	375.8
	$N_{30}P_{15}K_{15}$	13.72	6.21	19.93	192.3	387.6
2.Ecostern Classic, 2 L/ha + 200 L/ha of water;	Without fertilizers	13.27	7.12	20.39	197.4	382.6
	$N_{30}P_{15}K_{15}$	17.81	10.03	27.84	204.9	391.7
3.Ecostern Light, 2 L/ha + N5 (ammonium nitrate) + 200 L/ha of water	Without fertilizers	13.80	7.41	21.21	198.7	389.4
	$N_{30}P_{15}K_{15}$	18.08	10.42	28.50	205.8	393.1
4.Ecostern Bacterial, 2 L/ha + N_5 (ammonium nitrate) + 200 L/ha of water;	Without fertilizers	13.82	7.53	21.35	201.3	390.2
	$N_{30}P_{15}K_{15}$	18.06	10.53	28.59	206.4	394.7
5.Ecostern Detox, 2 L/ha + N_5 (ammonium nitrate) + 200 L/ha of water	Without fertilizers	12.88	6.80	19.68	200.8	387.5
	$N_{30}P_{15}K_{15}$	17.67	9.26	26.93	203.9	392.4

Source: developed by the author

The data in Fig. 2 indicate a clear trend toward increased organic matter when biologization components of the technology are used in combination with mineral nutrition.

In the control treatment, the organic matter content was 4.43%. The application of mineral fertilizer $N_{30}P_{15}K_{15}$ alone increased this value to 4.89%. The highest values were recorded in treatments combining mineral fertilization with biodestructors: $N_{30}P_{15}K_{15}$ + Ecostern Classic – 5.09%; $N_{30}P_{15}K_{15}$ + Ecostern Light – 5.08%; $N_{30}P_{15}K_{15}$ + Ecostern Bacterial – 5.14%; and $N_{30}P_{15}K_{15}$ + Ecostern Detox – 5.27%.

Thus, the use of biodestructors in combination with mineral fertilization increased organic matter content compared with both the control and mineral fertilization alone. The greatest effect was observed in the Ecostern Detox treatment (5.27%), indicating the potential of combining crop residue biodegradation with optimized mineral nutrition to maintain and improve soil fertility.

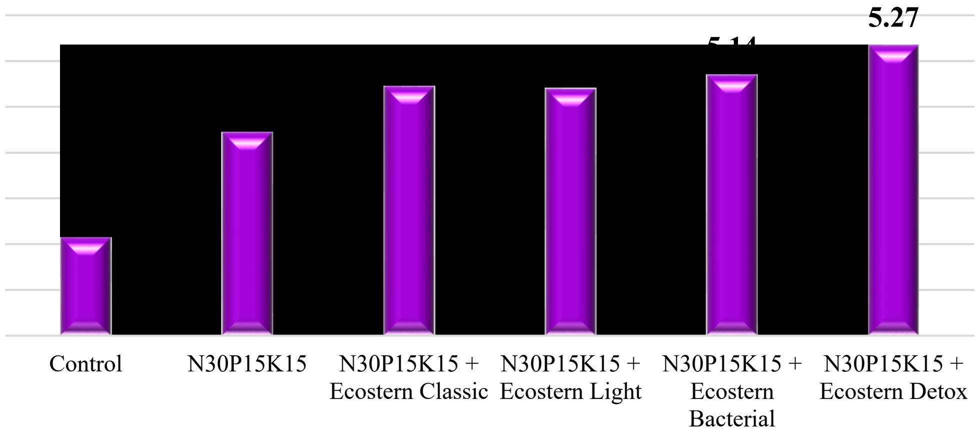

Fig. 2. **Organic matter content in the 0–30 cm soil layer after sunflower harvest under the influence of stubble biodestructors and mineral fertilizer (average for 2023–2025), %**

Source: developed by the author

In general, a clear trend toward increased soil supply with hydrolyzable nitrogen was observed under the use of mineral fertilizers and biological products (Fig. 3).

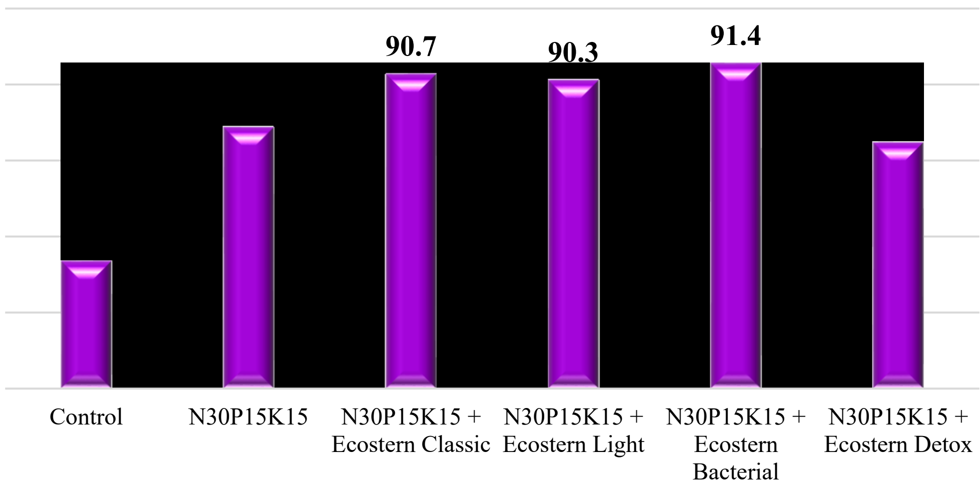

Fig. 3. **Hydrolyzable nitrogen content in the 0–30 cm soil layer after sunflower harvest under the influence of stubble biodestructors and mineral fertilizer (average for 2023–2025), mg/kg**

Source: developed by the author

In the control treatment, this indicator was 78.4 mg/kg. The application of $N_{30}P_{15}K_{15}$ alone increased the hydrolyzable nitrogen content to 87.2 mg/kg, indicating a positive effect of optimized nutrition on the soil nitrogen regime. The highest content was observed in the treatments combining mineral fertilization with biodestructors:

$N_{30}P_{15}K_{15}$ + Ecostern Classic – 90.7 mg/kg; $N_{30}P_{15}K_{15}$ + Ecostern Light – 90.3 mg/kg; and $N_{30}P_{15}K_{15}$ + Ecostern Bacterial – 91.4 mg/kg. This indicates enhanced organic residue transformation and nitrogen mobilization in the soil under the combined application of biodestructors and mineral nutrition.

Conclusions. During the cultivation of the early-maturing sunflower hybrid SY Chester in 2023–2025 on southern chernozem at the Educational, Scientific and Practical Center of Mykolaiv National Agrarian University, a two-factor experiment showed significant effects of stubble biodestructors and mineral fertilization on seed yield and the main indicators of soil fertility. In the control treatment (without biodestructors or fertilizers), the average yield was 1.94 t/ha; applying $N_{30}P_{15}K_{15}$ increased it to 2.18 t/ha, while using biodestructors without fertilizers raised it to 2.06–2.21 t/ha.

The highest seed yield levels were obtained when biodestructors were combined with $N_{30}P_{15}K_{15}$: the maximum was 2.48 t/ha (Ecostern Bacterial) and 2.46 t/ha (Ecostern Detox). On average, the increases over the control were as follows: +0.19 t/ha from biodestructors without fertilizers, +0.24 t/ha from fertilizers without biodestructors, and +0.48 t/ha from the combination of biodestructors with $N_{30}P_{15}K_{15}$, which indicates the effectiveness of the combined action of these factors and greater productivity stability even in the dry year 2025.

Biodestructors, especially against a fertilized background, increased the soil supply of mineral and hydrolyzable nitrogen, as well as available phosphorus and potassium; at the same time, the share of organic matter also increased (from 4.43% in the control to 5.08–5.27% when biodestructors were combined with $N_{30}P_{15}K_{15}$).

The conducted studies substantiate the expediency of integrating biological destructors and mineral fertilization into sunflower cultivation technology after grain maize to increase productivity and preserve (improve) the main fertility indicators of southern chernozem.

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ЕФЕКТИВНІСТЬ БІОДЕСТРУКТОРІВ ЗА ВИРОЩУВАННЯ СОНЯШНИКУ В УМОВАХ ПІВДЕННОГО СТЕПУ УКРАЇНИ

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Актуальність дослідження зумовлена необхідністю підвищення продуктивності соняшнику та збереження родючості ґрунтів в умовах кліматичних змін, посилення посушливості та зниження вмісту органічної речовини у ґрунті. Метою роботи було встановити ефективність біодеструкторів стерні як елемента технології вирощування соняшнику після кукурудзи на зерно та оцінити їх вплив на врожайність і основні показники родючості чорнозему південного. Дослідження проводили у 2023–2025 рр. у польовому двофакторному досліді з використанням біодеструкторів стерні та мінерального добрива N30P15K15. Встановлено, що застосування біодеструкторів стерні забезпечувало підвищення врожайності насіння соняшнику навіть без мінерального живлення, а їх поєднання з добривами формувало максимальний ефект. У середньому за роки досліджень урожайність у контролі становила 1,94 т/га, за внесення лише N30P15K15 – 2,18 т/га, за використання біодеструкторів без добрив – 2,06–2,21 т/га. Найвищу врожайність одержано у варіантах поєднання біодеструкторів із мінеральним удобренням – 2,30–2,48 т/га, при цьому максимальний показник забезпечив варіант із застосуванням Екостерн бактеріальний – 2,48 т/га. Приріст урожайності порівняно з контролем становив у середньому 0,19 т/га за використання біодеструкторів без добрив, 0,24 т/га – за внесення лише мінерального добрива та 0,48 т/га – за їх сумісного застосування. Навіть у посушливому 2025 році комплексне використання досліджуваних факторів сприяло формуванню вищого рівня продуктивності порівняно з контролем. Обґрунтовано позитивний вплив біодеструкторів на показники родючості ґрунту. За їх використання підвищувався вміст мінерального азоту, рухомих форм фосфору й калію, гідролізованого азоту та органічної речовини. Максимальний вміст органічної речовини у шарі ґрунту 0–30 см становив 5,27% за поєднання біодеструктора з мінеральними добривами. Практичне значення одержаних результатів полягає в обґрунтуванні доцільності комплексного використання біодеструкторів стерні та помірного мінерального удобрення для підвищення продуктивності соняшнику й поліпшення показників родючості чорнозему південного.

Ключові слова: соняшник, біодеструктори стерні, живлення рослин, урожайність насіння, біологічні підходи відтворення ознак родючості ґрунту, вміст гумусу та рухомих елементів живлення

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