

CHANGING THE BIOLOGICAL ACTIVITY OF SOIL IN SUNFLOWER CROPS

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Abstract

The current problem of the research is the justification of the application of intensive technologies for sunflower cultivation using progressive methods of obtaining a highly productive crop based on the principles of resource conservation, biologization and ecologization. The objective is the study of toxicity and biological activity of soil after sowing sunflower. Our aim was to determine the biological activity and toxicity of soil and the comparative influence of agricultural practices in studying soil toxicity. When determining the toxicity of the soil, it was concluded that at the beginning of the study, favourable conditions for crop development were formed on soils processed by moldboard cultivation. An increase in soil toxicity was observed with zero tillage. This was expressed in a decrease in seed germination and the mass of sprouts. During a repeated study in 2024, the toxicity of the soil with zero tillage decreased, and seed germination increased by an average of 5–8%. As a result of the accumulation of plant residues on the soil surface, an upper humus layer is formed, leading to constant penetration of air into the soil.

Key words: soil biological activity, plant residues, toxicity, zero tillage, anaerobic respiration, microorganisms

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Introduction. Opinions are increasingly being expressed about the need to combine microbiological analysis with other methods that allow us to judge the biological state of the soil [1]. Opposing processes are constantly taking place in the soil: on the one hand, those that determine the effective fertility and biological activity of the soil (mineralization processes, the release of enzymes and other physiologically active substances); on the other hand, the undesirable activity of inhibitor microbes. They cause biological toxicity of the soil, reduce its fertility and the yield of agricultural crops. Research has also shown that excessive acidity suppresses the activity of beneficial microflora in the soil. At the same time, many bacteria and fungi develop, which secrete substances that are toxic to plants [2,3]. Soil microorganisms can have not only a positive effect on soil fertility and plant development, but also a negative effect on the biological properties of the soil due to the ability of some representatives of the soil microflora to synthesize phytotoxic substances. Testing the activity of various groups of soil microorganisms in soils can be determined using various application methods. A decrease in the dry mass of flax cloth is an indicator of the work of cellulose-destroying microorganisms, which affects the parameters of the biological activity of microorganisms in the soil. Surface soil treatment has a positive effect on the activity of soil cellulose-decomposing microorganisms [4,5]. The degree of decomposition of flax cloth during the vegetation of winter wheat in these variants was 45.8–48.7% against the control of 45.4%. The process of decomposition of linen in the experiment with spring wheat was less intensive.

***Trichoderma asperellum* in PS Perfect Pro – plant growth regulator.** The current problem of the study is the justification of the application of intensive technologies for sunflower cultivation using progressive methods for obtaining a highly productive crop based on the principles of resource conservation, biologization and ecologization. The *Trichoderma* fungus is promising for the production of industrial enzymes, phytohormones that accelerate plant growth, antibiotics for biocontrol of plant diseases, and has made a great contribution to the development of industry, agriculture, and drug production. *Trichoderma asperellum* is widely distributed in various soils, roots and foliar environments [6].

Methods. In a long-term stationary field experiment, established in the fall of 2021, sunflower cultivation was studied using moldboard (recommended by scientific institutions of the region) and zero tillage. The studied soil treatments were carried out in the experimental variants. The introduction of zero tillage is a complex, long process, the results of which are visible only after 5–8 years. The same treatment was carried out during the study period. Due to the fact that the area in which the research was conducted is arid, with a sharply expressed continentality, it was decided to lay out the experiments using drip irrigation. Due to the fact that the research was conducted with mineral fertilizers, which slag (pollute) the soil, it was decided to study the toxicity of the soil [7,8]. The predecessor of the sugar sunflower was winter wheat. The experiment is two-factor

in fourfold repetition. The research period is 2021–2024.

Factor A options: Option 1: control – moldboard tillage. Option 2: zero tillage.

Factor B – biostimulants and mineral fertilizers to increase field germination and growth were introduced at the initial stages of development.

PS Perfect Pro – plant growth regulator – helps to solve one of the most important problems in agronomy: the negative impact of stress factors on the plant. PS Perfect Pro contains *Trichoderma asperellum*, Silatran. The biological activity of the soil was determined by the “application” method in the 0.0–0.3 m layer. The linen cloth method is used to judge the energy of soil mobilization processes. The soil toxicity was determined by the biotest method in laboratory conditions. Twenty-five spring wheat seeds were used as a test plant.

Results. As a result of the impact of mineral fertilizers on the soil and various soil treatments, changes in the degree of decomposition of flax cloth were observed. A pattern of decreased microbial activity was observed with zero tillage. In the first year of the study (2021), the degree of decrease in linen decomposition averaged 3.1%. Data obtained on filter paper were used as a reference. Seed germination rates for samples collected from the experimental plot, cultivated under moldboard and zero-till conditions, were, on average, 12.2% lower than those on filter paper. In soils with mineral fertilizer, an increase in viable seeds was observed. Seedling length also showed a consistent decrease in all treatments relative to the filter paper. A soil toxicity study using the experimental methodology was planned to be conducted at the end of the trial, in 2021. To more clearly demonstrate changes in soil toxicity, it was decided to use the 2024 filter paper data as a control. A noticeable trend was toward increased seed germination in samples collected from zero tillage soils. Seed germination in the zero tillage variant ranged from 81% to 89% (Table 1).

Over three months with moldboard tillage, the degree of decomposition of the linen varied in the following values: 51.7–55.8% (Fig. 1a); with zero tillage 48.7–51.0% (Fig. 1b). The highest percentage of linen decomposition occurs in the 0.2–0.3 m layer, which was observed during the exposure of the linen after 3 months of the study. Before this, during the two preceding months, no noticeable difference in the degree of decomposition of the linen by layers was observed.

As a result of repeated observation in 2024, the activity of microorganisms in zero tillage was noticeable, which is confirmed by the degree of decomposition of the linen. The highest activity of microorganisms was recorded in the variant with the use of mineral fertilizer and biostimulant. Against the background of zero tillage, a higher activity of aerobic microorganisms was noticeable, which led to positive dynamics of decomposition of linen. In 2024, a pattern of microorganism activity was observed in zero tillage. The degree of decomposition of cellulose web in this soil treatment averaged 62.1% (Fig. 1d), in moldboard tillage – 51.5% (Fig. 1c). Microorganism activity in moldboard tillage was observed in the 0.2–0.3 m

T a b l e 1
Influence of agro-technology on soil biotoxicity after sunflower, %, 2021

Factor A	Factor B	Seed germination, %		Sprout length, mm		Growth, %		Absolutely dry weight, g		
		I	II	I	II	I	II	I	II	I
Moldboard tillage	Filter paper (control)	93	94	112.1	112.3	99.8	100	0.25	0.25	0.012
	Control	75	75	103.1	102.5	91.1	91.4	0.19	0.20	0.010
	PS Perfect Pro	76	76	104.5	103.8	93.2	92.6	0.21	0.20	0.010
	N ₁₈₀ P ₁₂₈ K ₆₈	79	78	106.1	104.1	94.6	92.9	0.22	0.21	0.010
	PS Perfect Pro+N ₁₈₀ P ₁₂₈ K ₆₈	81	80	108.5	106.6	96.7	95.2	0.22	0.23	0.011
Zero-tillage	Control	74	81	102.6	104.0	91.6	92.9	0.20	0.23	0.010
	PS Perfect Pro	75	82	103.2	105.6	92.0	94.2	0.21	0.23	0.011
	N ₁₈₀ P ₁₂₈ K ₆₈	76	86	103.9	111.5	92.7	99.4	0.22	0.24	0.012
	PS Perfect Pro+N ₁₈₀ P ₁₂₈ K ₆₈	77	89	105.6	116.1	94.0	104	0.21	0.26	0.013

Note: I – 2021; II – 2024

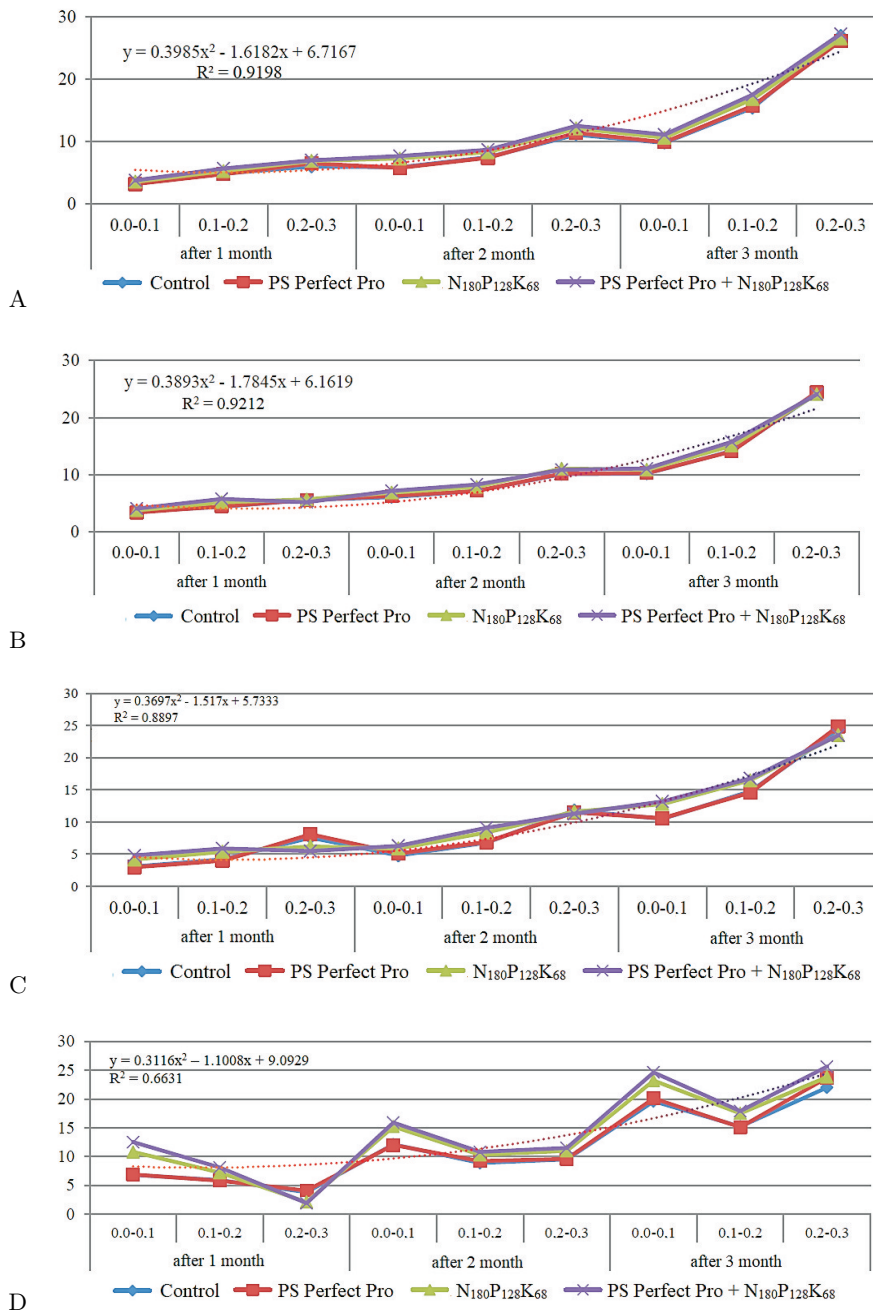


Fig. 1. Dependence of the influence of factors on the biological activity of the soil in crops (A) with moldboard tillage, %, 2021; (B) with no-tillage, %, 2021; (C) with moldboard tillage, %, 2024; (D) with no-tillage, %, 2024

layer, in zero tillage in the 0.0–0.1 m layer. Having examined the data on the biological activity of the soil, we concluded that the intensity of flax decomposition by zero tillage was higher than by moldboard tillage. This observation was facilitated by the annual accumulation of plant residues in the upper soil layer. As a result, low activity of the uncultivated soil layer was formed. After moldboard tillage, the activity of microorganisms was observed in the 0.2–0.3 m layer. When examining the layers, it is evident that the degree of flax decomposition in the 0.2–0.3 m layer is stronger than in the 0.0–0.1 m layer. After moldboard tillage, a looser arable layer was created, which had an insignificant effect on the decomposition of cellulose throughout the entire soil layer. To calculate the statistical dependence of the effect of fungi on the meat-peptone agar medium on the biological activity of microorganisms, the Pearson CC (correlation coefficient) was calculated. For moldboard tillage, the CC in 2021 had a value of $r = 0.9198$, for zero tillage $r = 0.9212$. In a repeated study in 2024, the following values of the correlation coefficient were observed: for moldboard tillage $r = 0.8897$, for zero tillage $r = 0.6631$. A close correlation dependence was noted for the experimental factors, the relationship between the features was high and direct. In a repeated study in 2024, the correlation dependence for moldboard tillage was partially reduced, but nevertheless it remained high.

Soil toxicity is caused by the accumulation of physiologically active substances. Among them are phenolic compounds, organic acids, aldehydes, alcohols, the composition and concentration of which depend on the temperature and humidity of the soil, on microorganisms and plants [9]. At low concentrations of toxic substances in the soil, a stimulating effect is detected, but with an increase in their content, strong inhibition of plant growth or seed germination occurs. In stationary experiments (Ganja region) it was found that the water extract from the soil of permanent crops of winter wheat and barley, taken at the beginning of the spring vegetation, reduced the germination of seeds of these crops by more than 20% and inhibited the growth of the root system, which was one of the reasons for the sparseness of permanent crops. Determination of soil toxicity was carried out in laboratory conditions. Toxicity was determined on a test crop – spring wheat. Soil sampling was carried out after harvesting sunflower. Initially, toxicity was determined in 2021, then at the end of the study in 2024. The data obtained on the filter paper were taken as a reference point. The germination of seeds in samples taken from the experimental plot, cultivated by moldboard and zero tillage relative to the filter paper was lower by an average of 12–20%. Factor B: Sunflower; Option 1: Control (without biostimulant and mineral fertilizers); Option 2: PS Perfect Pro* (Encrusting sunflower seeds with the biostimulant PS Perfect Pro before sowing – the consumption rate of the preparation is 20 g/t. Pre-sowing seed treatment. The consumption rate of the working solution is 10 l/t); Option 3: $N_{180}P_{128}K_{68}$; Option 4: PS Perfect Pro + $N_{180}P_{128}K_{68}$ (Fertilizers were applied in the form of $N_{32}P_{32}K_{32}$ simultaneously with sowing, the remaining part

during the vegetation period of plants with irrigation water. Fertilizer application was calculated for the planned yield). On soils with the use of mineral fertilizer, the growth of viable seeds was observed. The length of the sprout also had a pattern of decreasing in all variants relative to the filter paper. Seed germination in samples with different soil treatments was higher in the moldboard tillage variant. The average germination of test crop seeds was 78% for moldboard tillage and 75% for no-tillage. Insufficient moisture, anaerobic respiration, and a slowdown in active microbiological processes had a negative impact on the structural state of the soil. This led to the accumulation of toxins and an increase in soil toxicity in samples taken from soil cultivated by zero-tillage. The inhibitory effect of toxins affected not only seed germination, but also the length of the test crop sprout. The greatest sprout growth was observed in the moldboard tillage samples. The growth was 94.4%. A repeat study of soil toxicity was planned to be carried out at the end of the experiment according to the experimental methodology. For a visual change in soil toxicity, it was decided to take the 2021 data on filter paper as a control. A tendency towards an increase in seed germination is noticeable on samples taken from soils cultivated by zero tillage. Seed germination in the zero tillage variant varied from 81 to 89%. The increase in seed germination by zero tillage was 10% in 2024 relative to the 2021 data. An increase in the length of the seedlings was noticeable in the zero tillage. In the sample, it is higher than the filter paper by 5 and 8% in the variant with the use of mineral fertilizer and growth biostimulant. A decrease in the toxicity of the soil was observed in the zero tillage variants, as evidenced by an increase in seed germination, an increase in the length and dry mass of the seedlings. The dry mass of all seedlings increased from 4 to 12%, depending on the location of the study. Soil toxicity varied in the variants, which is explained by the accumulation of root secretions by plants, plant residues and metabolic products of microorganisms. The changes in the germination of test crop seeds are clearly shown in Fig. 2, which shows comparative data from the 2021 and 2024 studies on soil cultivation factors, mineral fertilizers and growth biostimulants. Figure 2 shows that with moldboard tillage in 2021, the germination of test crop seeds was slightly higher than in 2024. In a repeat study in 2024, the toxicity of the soil after zero tillage decreased in all variants, seed germination increased by an average of 5–8%. Plant residues were left on the soil, and at the end of the study, a large stock of plant residues had formed on the soil surface. Analyzing the dynamics of toxicity of soil samples, we can conclude that at the beginning of the study, favourable conditions for the development of the studied crop were formed on soils processed by moldboard cultivation. With zero cultivation, an increase in soil toxicity was observed, which was expressed in a decrease in seed germination and the mass of sprouts.

Due to insufficient air, the amount of toxins in the soil increases, the vital activity of beneficial soil microorganisms and animals is suppressed, which leads to the oppression of plants. On the surface of the soil, there are organic remains,

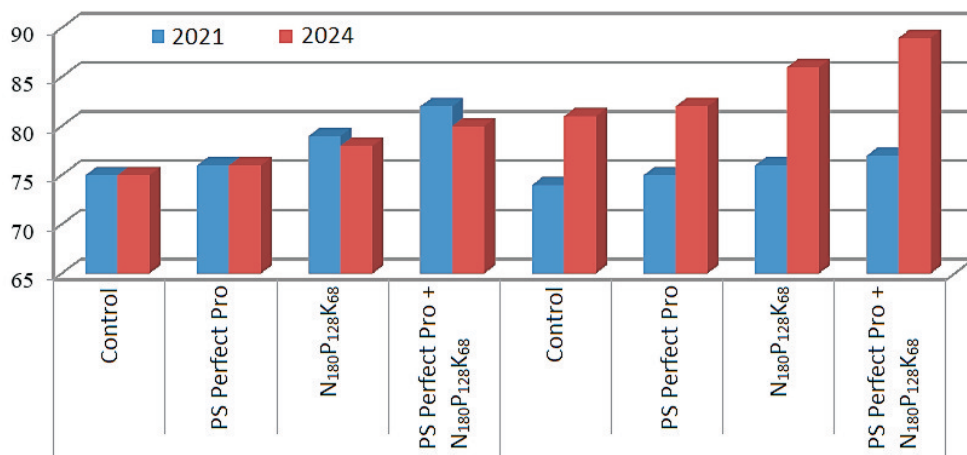


Fig. 2. Comparative influence (of agrotechnical methods) on the germination of spring wheat seeds in the study of soil toxicity after sowing sunflower, %

Note: The chart demonstrates an increase in the measured metric for all treatments from 2021 (blue bars) to 2024 (red bars). The highest values are consistently observed with the combined treatment “PS Perfect Pro + N₁₈₀P₁₂₈K₆₈” for both years shown

the content of which increases from the lower layers to the upper ones, and are not covered with a crust [10]. The roots of plants are thicker at the top, and the above-ground parts of plants remain on the surface, which forms the upper humus layer, which guarantees constant penetration of air into the soil, permeable to a considerable depth due to numerous decomposing roots and channels created by the activity of earthworms.

Conclusion. When analyzing the data on the biological activity of the soil, we observed the activation of microorganisms in the upper soil layer (0.0–0.1 m) for zero tillage. For moldboard tillage, microorganisms were active in the 0.2–0.3 m layer. A general pattern of increasing biological activity in the variant of using mineral fertilizer and growth biostimulant was revealed, which leads to a decrease in soil toxicity in all experimental variants. It was noted that with an increase in soil activity, toxicity decreased.

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