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COMPREHENSIVE ECOLOGICAL EVALUATION OF AGROTECHNOLOGIES OF AGRICULTURAL CROP GROWING

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ABSTRACT

In today's conditions, generally accepted technologies for growing agricultural crops don't take into account the natural adaptability of certain types of plants and agrophytocenoses to complex and often intensive growing conditions. Food shortages and a growing population, climate changes, the emergence of new varieties and hybrids of agricultural crops, the emergence of resistant pests, diseases, weeds, the increase and diversity of plant protection products and agrochemicals directly affect both the quality and yield indicators of cultivated crops, the agroecosystem, and the environment natural environment. A comprehensive evaluation of wheat winter, corn, sunflower, and soybean cultivation technologies was carried out based on comprehensive indicators: soil fertility of the agrocenosis, phytosanitary state of crops, crop productivity, impact on the microbiocenosis. As a result, it was established that all the studied technologies belong to the II class, that is, the agroecosystems were in a satisfactory ecological state. In this way, it is allowed to use the researched technologies for growing the main agricultural crops. But agricultural producers are recommended to monitor the state of soil fertility, to vary the amount of fertilizer application in accordance with the set goals of the cultivated crop, in order to provide quality plants and soil, to carefully monitor the phytosanitary state of crops. The obtained data show that a comprehensive ecological assessment of the technologies of growing agricultural crops allows to objectively assess and identify imperfect technological operations and develop recommendations for their improvement.

Keywords: agrocenosis, agro-landscape, monitoring, climate, phytocenosis, flora.

INTRODUCTION

Agricultural land by 2022 was 42 million ha (78.9 % – arable land and perennial crops, 13 % – pastures, 8.4 % – hayfields) or 70% of the country's total fund (Martynyuk, 2024; Nikoliuk et al., 2024). The yield of crops and the productivity of crop rotations in agroecosystems is determined by the interaction of a number of different factors: the volume of removal of nutrients by precursors, the ratio of main and non-commercial products, the amount and quality of plant residues of the low-value part of the crop, stocks of mobile biogenic elements, the ratio of nitrogen to carbon, biological activity of the soil, agrophysical properties, phytosanitary condition of crops, etc. (Kudrya, 2021).

The increase in the number of people on Earth, food shortages, climate change, the emergence of new intensive varieties of agricultural crops, the emergence of resistant pests, diseases, weeds, constant improvement and production of new modern and innovative plant protection products and agrochemicalsOn the one hand, all of the above has a negative, and sometimes devastating, impact on agroecosystems. On the other hand, it promotes the pursuit of agricultural products for higher profits due to the yield and quality of products. The ecological potential of species adaptability is manifested in a complex way and serves as the basis for the survival of the species in the conditions of climate change. Adaptation of higher plants to the abiotic factors of the environment is provided by the mechanism of avoidance and tolerance. Currently, the generally accepted technologies for growing agricultural crops don't yet take into account the natural adaptability of certain types of plants, agrophytocenoses to complex and often intensive growing conditions. Scientists both in Ukraine and all the time emphasize issues related to the state of the environment (Tucker, 2017, Fahrig et al., 2011, Kanash, 2005), in particular, it is clearly stated in one of the fundamental documents on agricultural policy, as well as general agricultural politicians policy - Common Agrarian Policy (SAR, 2025). The EU Commission on Agriculture approved the resolution "Indicators for the Integration of Environmental Concerns into the Common Agricultural Policy", which defines a package of agro-ecological indicators (AEI). In 2002, the IRENA (Indicator Reporting on integration of Environmental concerns into Agricultural policy) system (IRENA, 2025) was proposed to improve, develop and formulate AEI at the appropriate geographical level. The criterion for evaluating the productivity of agrocenoses corresponds to the indicator of the IRENA system No. 7 and includes indicators of soil fertility, phytosanitary state of crops, product quality and productivity, and the state of microbiocenosis. It is recommended to carry out an ecological assessment of crop cultivation technologies taking into account the above indicators (Ecological examination., 2008) followed by a comprehensive assessment of the ecological state of agrocenoses by class to establish the perfection of crop cultivation technologies. The environmental examination of crop cultivation technologies carried out in this way allows you to objectively evaluate them and identify imperfect technological operations and develop recommendations for their improvement. Which, in turn, will allow obtaining high-quality and safe plant products and avoid negative impact on the surrounding natural environment and ensure the safe functioning of the agricultural landscape as a whole.

In view of all the above, we conducted a comprehensive ecological assessment of the technologies of the main agricultural crops of cereals (winter wheat, corn), oilseeds (sunflower), and legumes (soybean).

Materials and methods. The ecological assessment of crop cultivation technologies was carried out in the fields of the Skvyra research station of organic production of the Institute of Agroecology and and Environmental Management National Agrarian Academy of Sciences (Skyvira, Kyiv region). The study was conducted on winter wheat of the Kolonia variety, Pioner P8834 hybrid corn, NSH-555 sunflower variety, and Mentor soybean variety.

The scheme of the experiment included the following options: 1. Control; 2. Fertilizer; 3. Herbicide; 4. Insecticide; 5. Fungicide; 6. Fertilizer+herbicide+insecticide+fungicide (FHIF). All fertilizers and plant protection products (PPP) were selected in accordance with the agricultural techniques of crop cultivation and are listed in Table 1 (listed by active substances and trade names). The registered area of the experimental plot is 25 m^2, repeatability is 4 times.

The ecological evaluation of agricultural crop cultivation technologies was carried out according to three main indicators (soil fertility; phytosanitary condition; quality and safety of products). A series of all reference information values of each indicator was determined by generally accepted methods (Ecological examination., 2008). The ecological evaluation of the danger of PPP on soil microorganisms was determined in the laboratory by the method of paper discs and classification of the degree of danger for biological objects of the soil ecosystem (Ecological assessment., 2024). The experimental data obtained were processed by the method of variance analysis (Moiseichenko & Yeschenko, 1994).

All obtained results for each of the indicators were converted into ball according to the scoring system. Further, on the basis of the balls for each of the main categories, the total combined ecological evaluation (ball) of the technology and the class of the agrocenosis state were calculated. The impact of technologies on the ecological state of agrocenoses was assessed by class (Ecological examination., 2008):

- *I class* – unsatisfactory state (deviation from the optimum in the direction of deterioration exceeds 25 %);
- *II class* – satisfactory state (deviation from the optimum in the direction of deterioration is more than 10 %, but not higher than 25 %);
- *III class* – normal state (deviation from the optimum towards deterioration does not exceed 10 %);
- *IV class* – optimal state (deviation from the optimum and the side of the decrease isn't a loss).

The following gradation of technologies was used to determine the perfection of crop cultivation technologies according to ecological indicators (Ecological examination., 2008):

- I class < 1.5 balls – the technology is imperfect and cann't be recommended for production;
- II class = 1.5-2.4 balls – the technology needs significant refinement before implementation in production;
- III class = 2.5-2.9 balls – certain technological processes in technology need to be refined;
- IV class = 3.0 balls – the technology is perfect and can be recommended for production.

RESULTS AND DISCUSSION

A comprehensive ecological evaluation of agricultural crop cultivation technologies was carried out taking into account 3 key indicators: soil fertility, phytosanitary state of crops, product quality and yield. Each key indicator includes a number of representative indicators that allow you to objectively show the state of the key indicator of the agroecosystem. For each complex indicator, an ecological evaluation was determined separately, then the complex ecological evaluation of the growing technology and its score were calculated. The results of the complex ecological technology of growing winter wheat, corn, sunflower and soybeans are presented in table 2 and fig. 1–4.

The soil fertility of the agroecosystem plays a crucial role in obtaining a high-quality harvest.
The evaluation of this indicator was carried out by comparing the actual values of the main agrochemical parameters of the soil with the optimal ones. However, the ecological evaluation of soil fertility shows that the researched winter wheat growing technologies using fertilizers and researched plant protection products (Table 2) are generally normal. But according to the humus indicator, they are unsatisfactory, and need to be refined from the point of view of the aspect of humus accumulation during crop cultivation. When growing corn, according to the soil fertility indicator, it is determined that the condition of the soil under the crops is satisfactory and normal, corresponding to the II-nd class. Soil fertility indicators of the agroecosystem where sunflowers were grown were assessed as satisfactory and normal. It is appropriate to note that in the options where herbicide and insecticide were applied, the humus content parameter in these options was recorded as unsatisfactory and, accordingly, 1 ball. However, the generall ecological evaluation for these options according to the soil fertility indicator was 1.8 and 2.6, respectively. In turn, this indicates that the herbicide and insecticide only affect the indicator of humus content in the soil and do not affect other agrochemical indicators. Studies of soil fertility according to the ecological evaluation of soybean agroecosystems indicate a normal state (control - 1.6; variant with introduction of FHIF - 2.6).

Determining the phytosanitary status of agrocenoses of agricultural crops included determining the harmfulness of weeds, insects, and diseases in agroecosystems (Table 2).
The harmfulness of weeds in crops depends largely on the phase of crop development. The phase in which the clogging of crops causes maximum damage to them is the herbocritical period. For example, in wheat winter, the herbocritical period lasts 30-40 days after emergence; corn – within 1-8 weeks after emergence or from 3 to 14 leaves in crops. Pests and diseases of agricultural crops affect the development of plants throughout the growing season, from seedlings to harvest and storage. In general, the analysis of crop cultivation technologies according to the system of phytosanitary status indicators turned out to be normal (III class), satisfactory (II class) and unsatisfactory (I class).
During the ecological evaluation of technologies, winter wheat crops were classified as unsatisfactory (1 ball) and satisfactory (2 balls) according to phytosanitary indicators, namely, indicators of weeding and the spread of diseases. In the studied agrocenoses of winter wheat, the economic threshold of harmfulness (ETH) of weeds, pests and diseases significantly exceeded the norm. The generall ecological evaluation based on the phytosanitary state of the agrocenosis ranged from 1 to 2.3, depending on the research variant, and was satisfactory (Table 2). Corn, sunflower, and soybean crops had unsatisfactory (1 ball), satisfactory (2 balls) and fair (3 balls) conditions.
The general ecological evaluation based on the phytosanitary state of the agrocenosis ranged from 1 to 2.3, depending on the research variant, and was satisfactory (Table 2). Corn, sunflower, and soybean crops had unsatisfactory (1 ball), satisfactory (2 balls), and fair (3 balls) status. The agrocenosis of corn was unsatisfactory (1 ball), satisfactory (2 balls) according to indicators of weeding, spread of pests and diseases depending on the variant, and normal (3 balls) according to indicators of weeding and spread of diseases.

In the variant with complex application of fertilizers and pesticides, the overall ecological evaluation according to the phytosanitary indicator was 2.6 for the agrocenosis of corn, 2.3 for soybeans and sunflowers. The agrocenosis of corn had an unsatisfactory state (1 ball) according to the indicators of weeding, a satisfactory state (2 balls) according to the indicators of the spread of diseases, and a normal state (3 balls) according to the indicators of the spread of pests; the general ecological evaluation in the options where insecticide and fungicide were used was 1.6.
Sunflower crops were in unsatisfactory condition (1.3 points for the option with the use of insecticide and fungicide), satisfactory (2 points for the option with the use of herbicide). Soybean crops in all phytosanitary indicators had the first class and were characterized by an unsatisfactory state in terms of the spread of pests and pathogens. In recent years, soybean crops have been particularly affected by the weevil pest. This pest used to be widespread only on segetal vegetation, and later started to damage cultivated plants. Today, soybean and sunflower crops suffer from it. The spread of this particular pest was observed in experimental fields. Satisfactory state (2 balls) was observed by weeding indicators. This is probably due to the fact that thifensulfuron-methyl herbicide was used in soybean crops, which has a significant effect on weed plants, the number of weeds was reduced by 50-70%. Such a result of the normal, satisfactory and unsatisfactory condition of crops according to phytosanitary indicators, in addition to non-compliance with cultivation technologies and insufficient provision of the use of plant protection products, is also influenced by weather and climate conditions. Moderately warm snowless and low-frost winters contribute to the preservation of the number of pests, pathogens and weed seeds in the soil. While hot summers contribute to the active reproduction of pests, which give an average of 3 to 5 generations during the growing season, when under normal weather conditions – 1-2 generations. Cold and wet springs contribute to the spread of pathogens, mainly on grain crops, which significantly affected the formation of the harvest and its quality.

In the general evaluation of the phytosanitary status by crops and variants, it should be noted that winter wheat crops have a phytosanitary status that belongs to the I (unsatisfactory) and II (satisfactory) class. The best II (satisfactory) class was characterized by variants with the use of an insecticide and the variant where a complex of fertilizers + plant protection agents was used. Accordingly, the ecological evaluation for the above-mentioned agrocenoses of winter wheat was fixed at the level of 2 and 2.3. In corn crops, the options with a complex where the overall score was at the level of 2.6, which corresponds to III class, and with the use of fertilizer with a score of – 2 (II class) proved to be the best. In sunflower and soybean crops, the best options in terms of phytosanitary status were the option with the use of a complex of fertilizers and protection agents 2.3 (II class) and the option with the use of herbicide 2.0 (II class).

Ecological evaluation of agricultural crop technology based on productivity indicators.
The structure of indicators of the quality of agricultural products includes physical, biochemical and yield indicators (Table 2).

Table 2. Evaluation of crop cultivation technologies.

№	Research option	Ecological evaluation (EE)			EE (complex)	Evaluation, Ball
		Soil fertility	*Crop productivity*	*Phytosanitary state*		
Wheat winter (Colony)						
1	*Control*	1.8	1.25	1.0	1.4	I
2	*Fertilizer*	2.2	2.25	1.6	2.0	II
3	*Herbicide*	2.0	2.0	1.6	1.9	II
4	*Insecticide*	1.8	2.0	2.0	1.9	II
5	*Fungicide*	2.0	2.0	1.6	1.9	II
6	*FHIF*	2.2	3.0	2.3	2.5	III
Corn (Pioneer P8834)						
1	*Control*	2.0	1.0	1.0	1.3	I
2	*Fertilizer*	2.2	2.0	2.0	2.1	II
3	*Herbicide*	2.0	2.25	1.3	1.9	II
4	*Insecticide*	2.0	2.0	1.6	1.9	II

5	*Fungicide*	2.0	2.0	1.6	1.9	II
6	*FHIF*	2.0	3.0	2.6	2.5	III
Sunflower (NSH-555)						
1	*Control*	2.0	1.0	1.0	1.3	I
2	*Fertilizer*	2.2	3.0	1.6	2.3	II
	Herbicide	1.8	2.0	2.0	2.0	II
4	*Insecticide*	1.8	2.25	1.3	1.8	II
5	*Fungicide*	2.0	2.5	1.3	1.9	II
6	*FHIF*	2.6	3.0	2.3	2.6	III
Soybean (Mentor)						
1	*Control*	1.6	1.25	1.0	1.3	I
2	*Fertilizer*	2.6	2.5	2.0	2.4	II
3	*Herbicide*	1.6	2.0	1.3	1.6	II
4	*Insecticide*	2.0	1.75	1.6	1.8	II
5	*Fungicide*	1.8	2.0	1.3	1.7	II
6	*FHIF*	2.6	2.75	2.3	2.9	III

As a result of the research, it was determined that the performance and quality indicators of winter wheat have the II-nd class - satisfactory and the III-rd class - normal, only on the control variant the I-st class is unsatisfactory. In the variant where all protective means and fertilizers were used, the indicator of ecological evaluation according to the productivity indicator was 3.0. Such a high level of ecological *evaluation* was influenced by wheat productivity - 4.5 t/ha, weight index of 1000 seeds - 44.9 g, protein content at the level of 14.9 %, gluten - 23.8 %. It was established that the researched corn growing technologies (fertilizers, herbicides, insecticides, fungicides) are satisfactory (2 balls) in terms of seed quality and yield.

Yield indicators and seed quality were at the optimum level and had a deviation of no more than 10%. In the variant where plant protection products were used in a complex manner (variant FHIF), the indicator of ecological *evaluation* was 3. When evaluating the quality of sunflower according to the researched cultivation technologies, it was found to be unsatisfactory (1 ball – control), satisfactory (2 balls – variants with herbicide, fungicide, insecticide) and normal (3 balls – variant with fertilizer; variant with a complex of all PPP).

So, for all experimental options, the quality indicators of sunflower seeds were at the optimal level. The yield of sunflower on average was 3.22 t/ha in the control and 3.31-3.33 t/ha in the variant with fertilizer application and complex application of plant protection products and fertilizers. Analyzing the technology of growing soybeans, it was found that the researched technologies are in an unsatisfactory state according to quality indicators, namely protein, oil in the control version, weight of 1000 seeds in the version where insecticide was used (1 ball). The content of protein in terms of dry matter at the optimal rate of 40.0 % with the technology used was from 37.7-39.3 %, oil at the optimal rate of 13-26 % in variants with the introduction of fertilizers and complex introduction of drugs of oil was 20.9 %, while the yield index was at the level of 1.26-1.27 t/ha, with the optimal index 2 t/ha. Therefore, the overall assessment of soybean cultivation technologies based on productivity indicators was the lowest score on the control 1.25, the highest on the variant where fertilizer was applied - 2.5 and the variant with FHIF - 2.75 balls.

A comprehensive evaluation of winter wheat cultivation technology indicates a satisfactory and normal ecological condition. That is, the deviation from the optimal value in the direction of deterioration exceeded 25 %, and the deviation from the optimal value in the direction of deterioration did not exceed 10 %. It was established that the technologies for growing winter wheat belonged to the II class (satisfactory ecological condition) fig. 1.

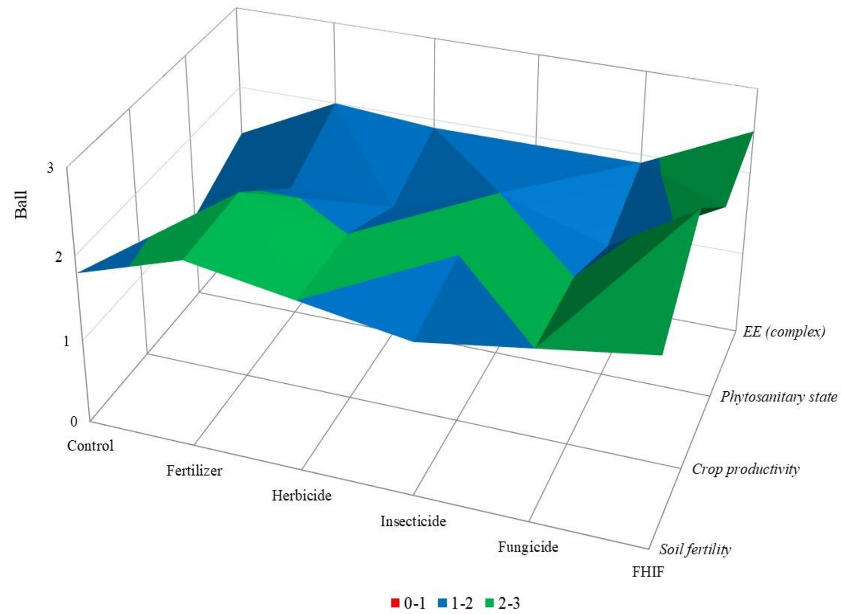

Figure 1. Comprehensive ecological evaluation of wheat winter growing technologies.

It was established that the main technological inconsistencies in the cultivation of winter wheat were the use of dew protection agents and the level of soil fertility that would correspond to optimal conditions, especially humus content. In general, the complex FHIF technology for growing winter wheat needs to be refined in terms of the use of plant protection products, precursors and fertilizers before being put into production.

The comprehensive evaluation of the corn cultivation technology belonged to the II class (satisfactory ecological condition) fig. 2.

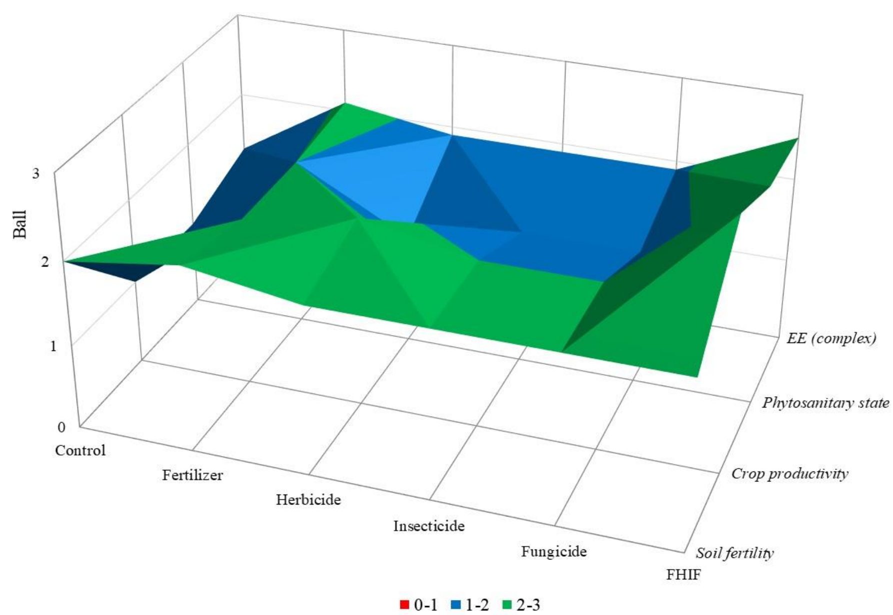

Figure 2. Comprehensive ecological evaluation of corn growing technologies.

During the comprehensive evaluation of sunflower growing technologies, we noted that the proposed technologies are satisfactory (II class) fig. 3.

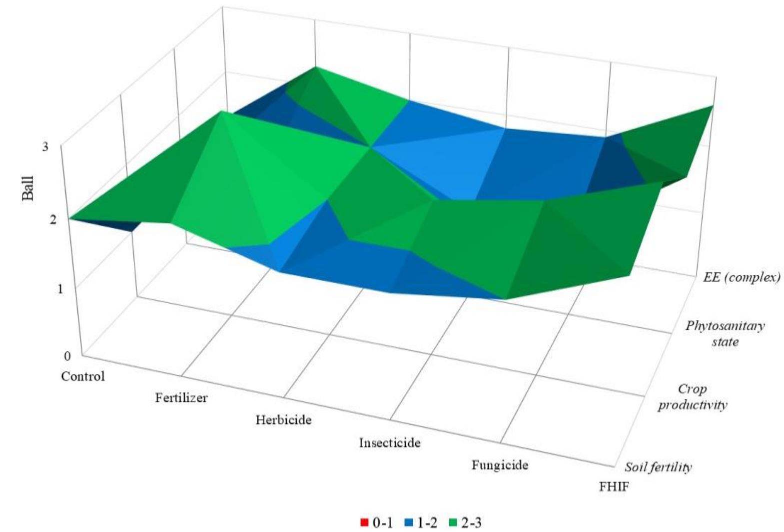

Figure 3. Comprehensive ecological evaluation of sunflower growing technologies.

That is, such technologies can be introduced into production and used, but the phytosanitary condition and soil fertility should be carefully monitored.

Evaluating the condition of soybean crops, it should be noted that the ecological condition is satisfactory (II class) fig. 4.

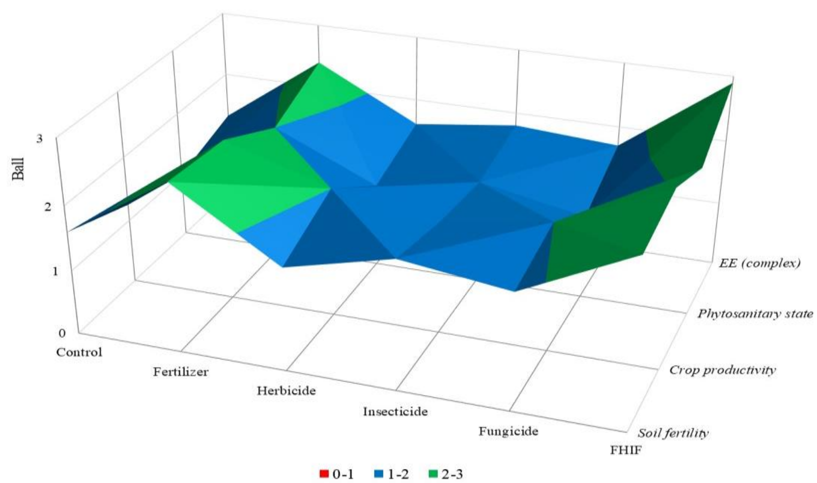

Figure 4. Comprehensive ecological evaluation of soybean growing technologies.

Among the shortcomings of these technologies is the state of soil fertility and phytosanitary state, which further provoked and significantly affected the level of productivity and quality of seeds.

Ecological evaluation of technologies for growing agricultural crops according to the impact on the microbiocenosis of the soil.

When pesticides are used in agriculture, the drugs directly fall into the soil. Since the soil is a complex three-phase (solid, liquid and gaseous) system, the kinship of pesticides is manifested simultaneously to three phases of the environment. Pesticides and their metabolites in soil are in a labile state with all three of its phases. However, due to their polyfunctionality and speed of ontogenesis, soil microorganisms are the most sensitive indicators of the impact of applied substances on ecosystems. On the basis of the previously proposed scale of the danger of pesticides and agrochemicals for soil biota (Ecological assessment., 2024), an assessment of the main pesticides used in the experiments (Table 1) during the cultivation of agricultural crops was carried out.

Table 1. Use of agrochemicals and pesticides in crop cultivation technologies.

Agricultural crops	**Name and standards of plant protection products (PPP) (g, kg, l/ha, m^2, t)**			
	Fertilizers	***Herbicides***	***Insecticides***	***Fungicides***
Wheat winter (Colony)	*Ammonium nitrate* (the mass percentage of N = 34.4 %), (60)	*Caliber 75* (tribenuron-methyl, thifensulfuronmethyl, 500 g/kg +250 g/kg), (0,06)	*Atrix, KE* (α-cypermethrin, 100 g/l), (0,3)	*Stark* (azoxystrobin, 250 g/l), (0,8)
Corn (Pioneer P8834)	*Carbamide* (the mass percentage of N = 46.2 %), (25)	*Sulfonyl* (nicosulfuron, 750 g/kg), (0,08)	*Credo, SK* (carbendazim, 500 g/l), (0,35)	*Amistar Extra 280 SC* (Cyproconazole+Azoxy strobin, 80g/l+200g/l),(0,8)
Soybean (Mentor)	***ANP fertilizer*** (N 15 %, P_2O_5 15 %, K_2O 15 %, S 9 %), (65)	Harmony (thifensulfuron methyl, 750 g/kg) (0,008)	*Ampligo 150 SC* (chlorantraniliprole + λ-cyhalothrin 100 g/l+50 g/l), (0,4)	*Stark* (azoxystrobin, 250 g/l), (0,5)
Sunflower (NSH-555)	*Nitrogen-phosphorus-potassium fertilizer* (N 6 %, P_2O_5 7 %, K_2O 20 %, CaO 30 % SO_3 2 %), (80)	*Agritox Turbo* (2-methyl-4-chlorophenoxyacetic acid+dicamba hd, 660 g/l +90 g/l), (1,0)	*Pharaoh* (chlorpyrifos+λ-cyhalothrin, 480 g/l +7.5 g/l), (0,2)	Stark (azoxystrobin, 250 g/l), (0,8)

As a result of experimental studies (Table 3), it was established that most of the pesticides used in the technology of growing the main agricultural crops are moderately dangerous for soil biota.

Table 3. Evaluation of PPP used in studies according to the scale of pesticide danger for soil biota.

PPP by active substance	**Danger scale**
Herbicide	
S-metolachlor	moderately dangerous
Dicamba	dangerous
Thifensulfuronmethy	moderately dangerous
Tribenuron-methyl+thifensulfuronmethyl	moderately dangerous
Nicosulfuron	moderately dangerous
Fungicide	
Azoxystrobin	moderately dangerous
Azoxystrobin+cyproconazole	moderately dangerous
Insecticide	
λ-cyhalothrin	moderately dangerous
α-cypermethrin	moderately dangerous
Carbendazim	moderately dangerous
Chlorantraniliprole + λ-cyhalothrin	dangerous
Chlorpyrifos+λ-cyhalothrin	dangerous

It was found that the ZZR with the active substances – dicamba, chlorantraniliprole + λ-cyhalothrin and chlorpyrifos + λ-cyhalothrin is dangerous for soil microorganisms. Thus, it is recommended to adjust or replace the use of these PPE data with a safer one when growing agricultural crops.
Therefore, the researched technologies need significant refinement, namely: the fertilization system must take into account the level of soil fertility and provide for an increase in the rates of fertilizer application to achieve optimal parameters of its fertility; soil cultivation should complement the plant protection system and be aimed at improving the phytosanitary condition of crops. Such changes in technologies will contribute to increasing the productivity of the researched crops and ensure the necessary level of profitability of their cultivation, as well as significantly reduce the technological impact on the state of phytocenoses.

CONCLUSIONS

- In order to substantiate the optimization of human activity in agrolandscapes to increase the productivity and quality of crop production and reduce the debilitating impact on the phytocenoses of agrolandscapes, it is first of all necessary to identify and determine the main factors of influence. It is expedient to assess the level of influence of one or another factor using indicators, criteria and indicators.
- As a result of the preliminary evaluation of technologies for growing winter wheat, corn, sunflower and soybeans, it was established that they belong to the II class (satisfactory ecological state). Therefore, the researched technologies can be implemented in production and used. However, it is necessary to monitor the state of fertility indicators, especially the content of humus in agroecosystems, to vary the amount of fertilizer application in order to provide plants with quality nutrients; inspect the phytosanitary condition of crops. It has been experimentally proven that the researched technologies need correction. We believe that it is expedient to revise the fertilization system taking into account the level of soil fertility and to foresee an increase in the rates of fertilizer application in order to achieve optimal parameters of its fertility; soil cultivation should complement the plant protection system and be aimed at improving the phytosanitary condition of crops. Such changes in technologies will help increase the productivity of the studied crops and ensure the necessary level of profitability of their cultivation. In addition, this will reduce the negative impact on the environment, reduce the spread of segetal vegetation in semi-natural phytocenoses.
- Thus, the carried out ecological examination of the technologies for growing the main agricultural crops will allow: to make reasonable management decisions regarding the suitability of agricultural land and obtaining safe and high-quality agricultural products, to determine the priority of the targeted use of territories, will allow to use the available resources as efficiently as possible and to organize the cultivation of agricultural crops.

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