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AGROCHEMICAL CHARACTERISTIC OF SOILS UNDER THE CONDITION OF INTENSIVE CHEMIZATION AND RESOURCE-SAVING TECHNOLOGIES

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Today, in Ukraine, the territories for commercial use occupy 92 % of the entire area of the country. The plowed area of agricultural land is more than 54 %, despite the fact that in the developed countries of Europe this indicator does not exceed 35 %. The current afforestation of the country's territory is 16 %, which is insufficient to ensure ecological balance (for example, a similar indicator in European countries is 25-30 %).

The highest plowed lands are located in the Southern and Central parts of Ukraine – about 90 %. The problem of plowing is aggravated by the irrational use of agricultural lands, and, as a result, by the insufficient recovery of soil fertility, which in its turn leads to a yearly decrease in humus content. For example, in virgin black soils in the fertile layer there is on average 10 % of humus, and in plowed black soils of Ukraine this indicator is 3.7-4 % on average. In addition, such unjustified intensive use of soils actually leads to significant emissions of CO_2 *into the air, which in some cases is greater than emissions from industry. According to some scientists, the consequences of such land use lead to the displacement of soil zones, which means the rapid expansion of the Steppe.*

One of today's catastrophic problems is the use of an unlimited amount of pesticides, using which agricultural producers treat the soil to obtain high yields. And due to its unique feature – high buffering capacity, Ukrainian soils absorb significant amounts of these chemicals, which lead to their presence in the soil for hundreds of years. The problem of high levels of heavy metals in soils also remains a priority at the moment. It is most relevant in the territories adjacent to industrial cities, on the fields located along the roads, as well as in zones of ecological disasters. At the moment, there are no properly formed statistics and records of poisonings caused by chemical means of plant protection in Ukraine. The majority of pesticides enter the human body through food, and the situation is worsened by the fact that in Ukraine it is sometimes allowed to use such pesticides that have been long prohibited for use in Europe.

Key words: *pesticide pollution, agroecological condition of soils, agricultural crops, intensive chemization, resource-saving technologies.*

Бреус Д.С. Агрохімічна характеристика ґрунтів за умов інтенсивної хімізації та ресурсозберігаючих технологій

На сьогодні в Україні території, що зайняті під господарське використання складають 92% всієї площі країни. Розораність земель сільськогосподарського призначення складає понад 54%, при тому, що розвинених країнах Європи цей показник не перевищує 35%. Сучасне заліснення території країни складає 16 %, що для забезпечення екологічної рівноваги є недостатнім (для прикладу аналогічний показник в європейських країнах становить 25-30 %).

Найбільша розораність землі відмічається на Півдні країни та у центральній Україні її частині – близько 90 %. Проблема розораності погіршується нераціональним використанням сільськогосподарських земель, і, як результат, недостатньою відновлюваністю родючості ґрунту, що в свою чергу призводить до зниження в ньому вмісту гумусу. До прикладу, в цілинних чорноземах в родючому шарі ґрунту знаходиться в середньому 10 % гумусу, а в чорноземних ґрунтах України, цей показник складає в середньому 3,7-4%. Крім того, таке необґрунтовано інтенсивне використання ґрунтів фактично призводить до значних викидів CO_2 *в повітря, що в деяких випадках є більшими за викиди від промисловості. За твердженнями багатьох науковців, наслідки такого використання призводять до зміщення ґрунтових зон, що означає стрімке розширення Степу.*

Однією з катастрофічних проблем сьогодення є використання необмеженої кількості пестицидів, якими виробники сільськогосподарської продукції обробляють ґрунт для отримання високих врожаїв. А через свою унікальну особливість – високу буферність, українські ґрунти вбирають в себе значні кількості цих хімікатів, що призводить до присутності їх у ґрунтах протягом сотень років. Пріоритетною на даний час лишається також проблема важких металів в ґрунті. Вона є найбільш актуальною на територіях прилеглих до промислових міст, на полях, що розташовані уздовж узбіч доріг, а також у зонах екологічних катастроф. На даний момент в Україні не існує належно сформованої статистики та обліку отруєнь, що були викликані хімічними засобами захисту рослин. У своїй більшості в організм людини пестициди потрапляють через продукти харчування, а ситуацію погіршує те, що в Україні іноді дозволено використовувати такі пестициди, що вже давно заборонені для використання в Європі.

Ключові слова: *забруднення пестицидами, агроекологічний стан ґрунтів, сільськогосподарські культури, інтенсивна хімізація, ресурсозберігаючі технології.*

Statement of the problem. The problems associated with the deterioration of the agroecological condition of the soils of Ukraine and, as a result, the decrease in the quality of agricultural products grown on them, are becoming significantly more acute. These problems originate from the end of the 20th century, when the use of chemical plant protection agents reached a significant scale, and the commercial activity of those times could be compared in terms of intensity with natural geological processes, which actually put the future of human civilization on the verge of ecological disaster. According to expert assessments of the World Health Organization (WHO), the intensity of human diseases in industrially developed countries on 60 % depends on the polluted environment, namely atmospheric air, water, and products of livestock and crop production. Therefore, the purpose of the research is to determine the impact of intensive chemical treatment on the agroecological condition of soils and on the final agricultural products [9].

Analysis of recent studies and publications. Depending on the intended use of plant products, a number of standard rules are applied to it, primarily related to the assessment of the chemical composition of the crop, the content of toxicants, and the determination of the chemical properties of various substances that arise and accumulate in plants in the process of development and growth. Anthropogenic factors lead to certain disturbances in the metabolism of organisms, which in turn can lead to an increased accumulation of toxic substances in plant products, a decrease in the biochemical quality of grain, which in its turn leads to a loss of crop yields [7].

The main sources of soil pollution, and later the transfer from it to grain products, are the metallurgical, mining, petrochemical and chemical industries, which lead to the accumulation of mainly heavy metals in grain products; energy, especially nuclear (NPP) and thermal (TPP) power plants, which affect the accumulation of radionuclides (accidents at nuclear power plants) and heavy metals (from TPPs) in grain products; motor vehicles also affecting the accumulation of heavy metals in grain products; military actions that lead to the accumulation of radionuclides, heavy metals and petroleum products in soil and as a result in grain products. A separate part in this list takes agriculture, due to the use of pesticides, fertilizers, irrigation and drainage measures in crop production and agriculture, as well as wastewater in animal husbandry, occurs the accumulation of almost all toxicants in grain products: heavy metals, nitrates, and pesticides [2].

If to consider the effect of nitrates, their increased content in plants is dangerous for human health. Most people are relatively easily able to tolerate a dose of 150-200 mg of nitrates per day, the maximum permissible dose is 500 mg, and a dose of 600 mg per day is considered toxic for an adult. Even a dose of 10 mg per day is toxic for infants [6].

Regarding the environmental impact of heavy metals, pesticides and mineral fertilizers used in agriculture are a significant source of their accumulation. Analyzing the results of researches of famous Ukrainian scientist Balyuk S.A., it can be concluded that the response to soil contamination by heavy metals of different grain crops is not the same. Winter wheat, winter rye, spring barley and oats have low reaction on them. Among them, rye has the greatest adaptive potential, and spring barley – the lowest [1]. The ecologically safe harvest of ear crops is formed with the presence of heavy metals in the soil at the level of 1-2 Clarks, which is half the maximum permissible level in the soil. When 5-6 Clarks are reached, it is possible to observe suppression of plant growth, a decrease in their productivity and, as a result, the quality of products. Corn and sunflower can withstand soil contamination with heavy metals up to 4 Clarks or 1.0-1.5 maximum permissible levels [5].

Also, some scientists note that the ingress of heavy metals into grain products due to the use of mineral fertilizers is significantly less compared to the general pollution of ecosystems, but it cannot be ignored due to the cumulative nature of the impact of all factors on the environment. In pesticides and fertilizers, heavy metals appear from raw materials and as a result of imperfect manufacturing techniques. When using nitrogen fertilizers, 1.3 mg/kg of cadmium and 174.4 mg/kg of lead enter the soil, 2.7 mg/kg of cadmium and 138.1 mg/kg of lead when using phosphorus fertilizers [4].

A significant part of heavy metals contained in mineral fertilizers is in a potentially acid-soluble (mobile) form. Under certain conditions, heavy metal ions that are present in mineral fertilizers and are sufficiently mobile in the soil enter plants, accumulate in significant quantities and, following trophic food chains, enter the body of animals or humans [8].

Most researchers consider that the main types of mineral fertilizers used in agriculture and which may contain heavy metals are primarily phosphorus-potassium fertilizers. As for the unjustified use of organic fertilizers, it also causes soil contamination with heavy metals. Namely, together with one ton of manure, about 4 grams of copper, 25 grams of zinc and 0.3 grams of cobalt enter the soil. One kilogram of dry weight of organic fertilizers have 15-250 mg of Zinc, 6.6-16 mg of Lead, 0.3-0.8 mg of Cadmium, 2-60 mg of Copper, 7.8-30 mg of Nickel, and 30-550 mg of Manganese [3].

Materials of the research. The research was conducted on dark-gray podzolized soils. Signs of podzolization on the studied areas are weakly manifested in comparison with gray soils, and the humus accumulation processes are highly manifested. Thus, they have a humus-rich enough upper part of the profile, but a humus-free lower one. Dark-gray podzolized soils have the following characteristic properties: the humus-alluvial horizon has weak density, and the following horizons have very compacted structure. Their granular structure is medium- and light loamy.

The agro-physical assessment of dark-gray podzolized soils is within the limits of satisfactory and good, characterized by a normal stable water regime. In these soils, the number of water-resistant aggregates noticeably increases, they have slight floatation processes, and rare form the crusts. The moisture capacity increases significantly, but the amount of unavailable moisture also increases. Soils have high fertility by nature [10].

The research established that under the conditions of the right-bank forest-steppe within the Vinnytsia region, with the use of intensive chemization technologies on dark-gray podzolized soils, the highest humus content was determined in the field under winter rape and was 4.4 % on average. On the research plot under sunflower, the humus content was 4.2 %, under corn – 3.7%, under spring barley – 3.5%, and under winter wheat was 2.3 % on average during the research period (Table 1).

The highest content of nitrogen was recorded in the soils under sunflower – 98.0 mg/kg. In the area occupied by spring barley and corn, the content of nitrogen was 21.4 % less, on the field under winter wheat – by 28.6 % less, and on the area occupied by winter rape – by 35.7 % less, and amounted to 63.0 mg/kg.

Table 1

Agrochemical characteristics of soils under condition of intensive chemical treatment (average indicators during 2019-2021)

Crop	Humus content, %	The content of the main nutrients, mg/kg			Calcium content, mg.eq/kg	Acidity	
		N	P	K		Hydrolytic, mg.eq/100 g	pH_{salt}
Winter wheat	2.3	70.0	307.0	239.0	116.0	0.97	6.1
Spring barley	3.5	77.0	281.0	197.0	148.0	0.28	7.0
Corn	3.7	77.0	319.0	112.0	148.0	0.35	6.7
Sunflower	4.2	98.0	280.0	170.0	160.0	0.36	6.7
Winter rape	4.4	63.0	159.0	100.0	164.0	1.60	5.8

The content of mobile phosphorus at the highest level was recorded in the soils occupied under corn and amounted to 319.0 mg/kg. The content of mobile phosphorus was 3.8 % less on the plot occupied by winter wheat, on the field with spring barley the phosphorus content was 281.0 mg/kg, which is 11.9 % less than the highest indicator, on the plot occupied by sunflower the content of mobile phosphorus was lower by 12.2 % and on the plot under winter rape its content was 159.0 mg/kg, which is 50.1 % less than the highest indicator.

The highest content of mobile potassium was recorded in the soils under winter wheat at the level of 239.0 mg/kg. The potassium content on the area used for growing of spring barley was 17.6 % less, on the area used for sunflower cultivation – 28.9 % less, in the area used for corn – 53.1% less, and under winter rape – by 58,2 % less, which is equal to 100.0 mg/kg.

The calcium content at the highest level was recorded in the soils under winter rape, which was 164.0 mg.eq/kg. The calcium content was 2.4 % less on the plot used for growing sunflower, 9.7 % less in the soil used for growing spring barley and corn in both cases, and 29.2 % less on the plot used for winter wheat which amounts 116.0 mg.eq/kg.

Hydrolytic acidity at the highest level was recorded in the soils used for the cultivation of winter rape and amounted to 1.60 mg.eq/100 g. In the area occupied by winter wheat, hydrolytic acidity was 39.4 % less, in the areas with sunflower and corn, hydrolytic acidity was 77.5 % and 78.1 % less, respectively, and the lowest level was recorded in the plot under spring barley, which was 0.28 mg.eq/100 g or 82.5 % less than the highest indicator.

The most alkaline soils were recorded in the areas used for the cultivation of spring barley, where the pH_{salt} level was 7.0. In the soils cultivated under corn and sunflower, the saline level of acidity was at the level of 6.7, and under winter wheat and winter rape, pH_{salt} was recorded at the level of 6.1 and 5.8, respectively.

During the use of resource-saving technologies, the highest level of humus content was recorded in the soils used for the cultivation of winter wheat and amounted to 3.4 %, which, compared to the conditions of intensive chemical treatment, increased by 47.8 %.

In the area occupied by sunflowers, the humus content was 3.2%, which, compared to the conditions of intensive chemical treatment, decreased by 23.8 %. On the plots with peas and spring barley, the availability of humus was 3.0 and 2.9 %, respectively. The lowest supply of humus was observed on soils used for growing soybeans and amounted to 2.3 %, this level of supply of humus was at the same level as during the application of intensive chemical treatment in fields with winter wheat (table 2).

The highest content of nitrogen was observed in soils under winter wheat, spring barley, and sunflower, it was recorded in soils at the level of 77.0 mg/kg. In the plots with peas and soybeans, the content of nitrifying nitrogen was recorded at the lowest level and amounted to 70.0 mg/kg and 63.0 mg/kg, respectively.

Mobile phosphorus was recorded at the highest level in the soils used for growing peas and soybeans and amounted to 249.0 mg/kg and 236 mg/kg, respectively. For all other agricultural crops, there was a significant decrease in the level of mobile phosphorus in the soil in comparison with the use of intensive chemical methods, namely, in the fields under winter wheat, the level of content decreased by 253.0 mg/kg, under spring barley by 198.0 mg/kg, and under sunflower by 114.0 mg/kg.

Table 2

Agrochemical characteristics of soils under condition of resource-saving technologies (average indicators during 2019-2021)

Crop	Humus content, %	The content of the main nutrients, mg/kg			Calcium content, mg.eq/kg	Acidity	
		N	P	K		Hydrolytic, mg.eq/100 g	pH_{salt}
Winter wheat	3.4	77.0	54.0	49.0	96.0	0.78	6.2
Spring barley	2.9	77.0	83.0	48.0	70,0	3.48	5.0
Peas	3.0	70.0	249.0	90.0	95.0	0.31	7.2
Sunflower	3.2	77.0	166.0	94.0	90,0	0.76	6.2
Soybeans	2.3	63.0	236.0	65.0	86.0	0.48	6.4

The highest content of mobile potassium during the application of resource-saving technologies was recorded in the soils used for sunflower cultivation and amounted to 94.0 mg/kg, which is 76.0 mg/kg less than during the application of intensive chemical treatment. In the lands occupied by peas, the content of mobile potassium was 90 mg/kg, under soybeans – 65.0 mg/kg, and on the lands occupied by the cultivation of winter wheat and spring barley the content of mobile potassium was at the lowest level of 49.0 mg/kg and 48.0 mg/kg, respectively.

When studying the calcium content in the soils under the researched crops using the resource-saving technologies, the decrease was observed in all fields. The highest amount of calcium was recorded in the plots with winter wheat which amounted to 96.0 mg.eq/kg. The lowest amount was observed in fields with spring barley at the level of 70.0 mg.eq/kg.

Studying the hydrolytic acidity, it was determined that the soil on the field with spring barley had acidity at the level of 3.48 mg.eq/100 g. On the all other fields, the acidity ranged from 0.31 to 0.78 mg.eq/100 g, with the lowest on the field with peas.

The most alkaline soils were recorded on the plots used for growing peas, where the pH_{salt} level was 7.2. On the soils under sunflower and winter wheat, the saline level of acidity was at the level of 6.2, and under soybeans and spring barley pH_{salt} was recorded at the level of 6.4 and 5.0, respectively.

Conclusions. From the presented data, it can be seen that the distribution of nutrients in the soil under the conditions of cultivation of various agricultural crops sharply differs during the application of intensive chemical treatment.

Thus, when growing sunflowers, it can be observed a sufficient supply of humus, a high concentration of almost every nutrient element. The acidity of the soils under this crop is also within the range of optimal nutrient absorption (from 6.0 to 6.7).

On the contrary, during the study of soils under winter rape, it can be observed a decrease in the amount of nutrients by all indicators except calcium, as well as the level of humus availability, which is higher than in the area under sunflower and amounts to 4.4 %. The acidity of the soil under this culture is recorded at 5.8, which significantly reduces the availability of basic nutrients.

Analyzing the agrochemical study of the soils under the investigated agricultural crops, during the application of resource-saving technologies, it can be concluded that there was a decrease in the content of nutrients in all the main indicators of the agrochemical state of the soils. Thus, the content of humus on fields with spring barley and sunflower decreased by 17.0 % and 23.8 %, respectively. On fields under winter wheat, the humus content increased by 32.4 % with the use of resource-saving technologies. The highest amount of nutrients in the studied soils was recorded in the fields occupied under peas, the lowest under spring barley.

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