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INFLUENCE OF THE SYSTEMATIC APPLICATION OF FERTILIZERS ON THE INTENSITY OF ACCUMULATION OF NITRATES IN AGRICULTURAL CROPS

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Abstract

The article considers the influence of mineral and organic fertilizers on the productivity and quality of winter wheat. During the investigation it was found that the average yield of winter wheat by means of potential soil fertility in 3-year was 2,3±0,1 t/ha.

Systematic application of the fertilizers in crop rotation helped to increase the yield of winter wheat. After the treatment $N_{60}P_{60}K_{60}$ the additions in 1,1 t/ha (47,8%) to the control have been received. On the plots where winter wheat was tested the aftereffect of manure 30 t/ha in combination with $N_{60}P_{60}K_{60}$ increases the yield on 1,1 and 1,2 t/ha (47,8 and 52,2%) respectively. The highest yield of winter wheat obtained by application of mineral fertilizers in quantity $N_{120}P_{120}K_{120}$ was 3,8±0,3 t/ha (addition 64,0% to the control). In addition to the investigations of the different fertilizer type's influence and their dosage on the winter wheat productivity their impact on the quality of the following indicators: crude protein content and gluten has been evaluated.

On the control option the average protein content was 12,45±0,45. The record amount of protein observed after $N_{120}P_{120}K_{120}$ application was 13,25±0,45%. It should be noted that the quality of the gluten protein content and the winter wheat grain in all these tests is significantly higher compared with controls.

The average gluten content in the control test was 21,4±2,75%, while during the fertilizer using it varied in the range of 24,6–28,2%. The highest protein was observed after $N_{120}P_{120}K_{120}$ application 28,2±3,5%.

Besides that, the nitrate content in the grain and plants of winter wheat after different doses of mineral and organic fertilizers have been examined.

It should be noted that the nitrate content in winter wheat grain is independent from the fertilizer and varied from 43 to 51 mg/kg, in the straw this dependence has been slightly observed. So if the control has 129,5 mg/kg nitrate content, in the fertilized tests it varied from 129,5 to 153,0 mg/kg. Maximum nitrate content was on the plot after the minimum $N_{60}P_{60}K_{60}$ application and manure usage at 30 t/ha.

Comparative study of the influence of mineral and organic fertilizers, as well as their combinations showed that after the application of organic fertilizer fewer nitrates accumulates in plants than after mineral and organic-mineral.

Studies have established that the hazard coefficient of nitrates in sunflower seeds grown under conditions of intensive chemicalization of agriculture was 0,4, in winter rapeseed and spring barley – 25,0% less, winter wheat – 50% less. The lowest nitrate hazard ratio was found in corn grain – 0,03, which is 92,5% less than in sunflower seeds.

Keywords: nitrates, mineral fertilizers, organic fertilizers, winter wheat, productivity, fertilizer dosage.

World experience shows that an increase in crop production is possible mainly due to an increase in crop yields and only as a result of an intensification of agricultural production. The basis of measures aimed at the intensification of agriculture, first of all, is a scientifically grounded system of application of mineral and organic fertilizers, which contributes not only to the growth of crop yields, but also to the preservation and improvement of soil fertility, as well as ensuring the ecological balance of agricultural landscapes [1].

One of the features of modern agriculture is the strengthening of the negative anthropogenic impact on the soil and the increase on this basis of the processes of deterioration of soil fertility associated with the irrational use of arable land, a reduction in the use of organic and mineral fertilizers, and intensive mechanical soil cultivation. Under these conditions, there is an increase in the processes of erosion, dehumification with the manifestation of stably uncompensated humus mineralization, deterioration of the agrochemical and agrophysical properties of the soil, and the balance of nutrients is disturbed [2].

In recent years, agricultural technologies of a new generation have been widely used in agriculture, which have led to significant changes in the methods of cultivating crops and methods of reproducing soil fertility.

The scientific and practical experience accumulated in our country and abroad indicates that the transition to a new generation of farming systems with modern technologies for the cultivation of agricultural crops is not a private task, but has the character of a major national economic problem, the solution of which is associated with successful development. of all crop production in the near future. The mass development of a new generation of technologies has now become an urgent task, not only because they accumulate the latest achievements of foreign and domestic agricultural science and technology, but also with the possibility of overcoming with their help the difficulties that have developed in field cultivation (low profitability, depreciation of the fleet of cars and high rates of decline in soil fertility).

The situation is aggravated by the high cost of technologies traditionally developed in agriculture, based on constant plowing and a low return on the means of intensification invested in production.

The need for sustainable growth in crop production, on the one hand, and the high requirements of crops for nitrogen nutrition, on the other, require the introduction of increased doses of nitrogen fertilizers in agroecosystems. However, their use often leads to negative consequences: shortage or low-quality yield due to the discrepancy between the crop demand for nitrogen and the ability to regulate nitrogen nutrition at the expense of soil resources during the growing season of plants [1]. In addition, insufficiently substantiated application of nitrogen fertilizers often causes environmental disturbances: pollution of commercial products and the environment with various mineral nitrogen compounds [2, 3]. The most serious ecological consequences are associated with the eutrophication of water bodies, sometimes leading to irreversible consequences in natural ecosystems [4, 5]. All this requires further improvement of the plant nitrogen nutrition system and the search for new approaches to the development of theoretical foundations for regulating the balance and transformation of nitrogen-containing compounds in agroecosystems.

To increase yields and to feed cultivated plants, stimulate their growth and fertility in agriculture, chemical fertilizers are often used, which deliver potash salts to plants.

Nitric acid – nitrate combined with potassium, calcium or ammonium - is a cheap and effective means of delivery. However, when they are regularly introduced into the soil in large volumes, they have the specificity of accumulating in certain parts of plants.

By themselves, nitrates are not dangerous and non-toxic salts, but in the body or plants themselves, as a result of metabolic processes, nitrous compounds, undeoxidized nitric acid salts are obtained from them. They have the properties of free radicals, damage cells and DNA, have mutagenic (cause cell mutations) and carcinogenic (cause tumor growth) effects [12].

In addition, nitrates from vegetables, fruits or cereals under conditions of humidity and heat or during digestion in the human intestine under the influence of

the colon microflora are converted into nitrite compounds. Large quantities of these substances are hazardous to human health.

Nitrites are perfectly absorbed from the intestines into the blood and form a special compound with blood hemoglobin – methyl hemoglobin, it is a very strong chemical compound that is not able to carry oxygen [6].

If the concentration of methemoglobin rises to 10−15%, the first signs of poisoning may appear − weakness and drowsiness, lethargy. After a few hours, signs of toxicities and acute poisoning appear: nausea and vomiting, the liver enlarges and becomes painful.

With the progression of poisoning, the pressure drops sharply, the pulse becomes weak and uneven, the hands and feet become cold, and breathing quickens. At the same time, a headache may appear, ringing in the ears, severe weakness and convulsive twitching of the muscles on the face occur, coordination is disturbed and there may be loss of consciousness, a coma.

The most dangerous in this regard can be early vegetables and fruits out of season. The largest amounts of nitrates are accumulated by all varieties of cabbage − white cabbage, broccoli, cauliflower and Brussels sprouts [7, 13].

To prevent excessive accumulation of nitrates in plants, it is necessary, on the one hand, to regulate the amount of mineral nitrogen in the soil, on the other, to create conditions for the most productive use of nitrogen, which is used to form organic matter, that is, the crop.

The accumulation of nitrates in plants is influenced by both nitrogen norms and lighting, the ratio of nutrients in the environment, agricultural technology, weather conditions, and the like. So, shading of plants (nitrogen has an advantage over phosphorus and potassium) and rainy weather contribute to the accumulation of nitrates in plants [12].

To prevent excessive accumulation of nitrates from fertilizers, excessive one-sided application of nitrogen fertilizers should not be allowed, especially if there is a lack of phosphorus, potassium and other nutrients in the soil.

There are other ways to reduce nitrate levels in plants. To do this, it is necessary to carefully take into account the biological properties of crops and the nutrient regime of soils, grow vegetables against a high agronomic background.

Vegetable products with a low nitrate content can be obtained with a moderate nitrogen nutrition of plants at a young age, enhanced with nitrogen during the period of intensive growth of the leaf apparatus, the main nitrogen nutrition regime during the ripening of ears and root crops [14].

From literary sources, there are known ways to reduce the content of nitrates in plant products: chemical reclamation of acidic soils; a rational fertilization system that takes into account the optimal ratios of nutrients for each crop and provides for the introduction of mineral fertilizers in optimal doses simultaneously with organic and micronutrient fertilizers; introduction of trace elements – molybdenum, copper, boron, manganese, as well as iron and sulfur; the use of amide, ammonia forms of nitrogen fertilizers and nitrogen fertilizers of prolonged action; completion of nitrogen fertilization 30 days before harvesting; preventing the use of mineral fertilizers simultaneously with pesticides, as this increases their toxic effect; increasing doses of phosphorus-potassium fertilizers, which weaken the negative impact of nitrogen fertilizers; selection of varieties that are not capable of accumulating nitrates; ensuring maximum illumination and preventing excessive development of the leaf apparatus of plants; harvesting vegetables ripe, but not overripe, as this leads to the accumulation of nitrates; it is advisable to pick vegetables in the afternoon and in sunny weather; the use of nitrogen-fixing bacterial preparations; technological processing of vegetable raw materials and products of its processing (washing, soaking, cooking, frying, fermentation, pickling) [12].

In addition, fruits grown in greenhouse conditions are dangerous, while ground vegetables are usually low in nitrate. In greenhouses and industrial farms, all plants are necessarily treated with nitrates or pesticides; such volumes cannot be weeded or processed manually. Manufacturers, in order to reduce production costs and increase yields, also add growth factors.

Agriculture at the present stage cannot guarantee environmentally friendly products. Therefore, the search and development of measures to significantly reduce the intake of nitrates in the human body is one of the urgent problems.

In this regard, the purpose of our research was to study the accumulation of nitrates in plants and their effect on the quality of winter wheat with the systematic use of mineral fertilizers.

To achieve this goal, the following tasks were identified:

− to consider the impact of long-term use of mineral and organic fertilizers on the productivity and quality of winter wheat grain;

−- to determine the content of nitrates in winter wheat plants in different phases of ontogenesis.

The studies were carried out in 2018–2020. on the territory of PP «Zeto» Shargorodsky district of Vinnitsa region.

The object of research was the soils of the farm, represented by ordinary medium-thick medium-humus medium-loamy black soil, on which the winter wheat agrocenosis was placed.

To assess the effect of mineral and organic fertilizers on increasing soil fertility and productivity of winter wheat, we studied the options for applying various doses of these fertilizers [8, 14].

In order to assess the content of nitrates in winter wheat plants, plant samples were taken during tillering and harvesting from accounting plots with an area of 1 m^2. The selection of plant material was carried out in 3 replicates.

As a result of the conducted research, it was found that the yield of winter wheat, obtained due to the potential soil fertility, averaged 2.3 ± 0.1 t/ha for 3 years (Table 1).

The systematic application of fertilizers in the crop rotation helped to increase the yield of winter wheat.

With the introduction of $N_{60}P_{60}K_{60}$, an increase to the control of 1.1 t ha (47,8%) was obtained. On the variants where winter wheat experienced an aftereffect of manure of 30 t/ha in combination with $N6_0P_{60}K_{60}$, the yield increase was 1,1 and 1,2 t/ha, respectively (47,8 and 52,2%). The highest yield of winter wheat was obtained with the application of mineral fertilizer at the rate of $N_{120}P_{120}K_{120}$ and amounted to 3,8 ± 0,3 t/ha (an increase of 64,0% to the control).

In addition to assessing the yield of winter wheat grain per unit area, we also evaluated the yield of by-products (straw). According to the research results, the yield of winter wheat straw due to potential fertility averaged 3,35 ± 0,05 t / ha over 3 years. Systematic fertilization has increased the yield of wheat straw.

With the introduction of $N_{60}P_{60}K_{60}$, an increase to the control of 1,5 t/ha (44,8%) was obtained. When applying manure of 30 t/ha and in combination with $N_{60}P_{60}K_{60}$, the increase in control is 1,5 and 1,65 t/ha (44,8 and 49,3%). The highest productivity of winter wheat straw was obtained with the introduction of $N_{120}P_{120}K_{120}$ and amounted to 5,45 ± 0,45 t/ha, which is 2,1 t/ha (60,0%) more than in the control.

Table 1

Influence of long-term use of fertilizers on productivity and quality of winter wheat (average for 2018–2020)

Experience options	Productivity of winter wheat grain, t / ha	Addition to control		Straw yield, t / ha	Addition to control		Winter wheat quality	
		т/га	%		т/га	%		
The control	2,3±0,1	-	-	3,35±0,05	-	-	12,45±0,45	21,4±2,75
$N_{60}P_{60}K_{60}$	3,4±0,3	1,1	47,8	4,85±0,45	1,5	44,8	13,05±0,45	25,7±3,25
$N_{120}P_{120}K_{120}$	3,8±0,3	1,5	65,2	5,45±0,45	2,1	60,0	13,25±0,45	28,2±3,5
Manure 30 t/ha	3,4±0,3	1,1	47,8	4,85±0,35	1,5	44,8	12,95±0,45	24,6±3,1
Manure 30 t/ha + $N_{60}P_{60}K_{60}$	3,5±0,6	1,2	52,2	5,00±0,80	1,65	49,3	12,9±0,40	27,3±3,45

The most important indicator of the quality of wheat grain is the protein and gluten content. The more protein in a grain, the higher its nutritional value. For good bread, it is desirable to have at least 14% protein in the grain. The quality of gluten should correspond to the first group with its content in grain at least 28,0% [9].

As shown by the results of our studies, in the control variant, the average protein content was 12,45±0,45%. The largest amount of protein was observed with the introduction of $N_{120}P_{120}K_{120}$ – 13,25 ± 0,45%. It should be noted that the quality of gluten and protein content in the grain of winter wheat for all considered options are significantly higher than in the control.

The gluten content in the control variant averaged 21,4± 2,75%, with fertilization it varied within 24,6–28,2%. The largest amount of protein was observed with the introduction of $N_{120}P_{120}K_{120}$ – 28,2 ± 3,5%.

Due to the natural fertility of ordinary black soil, a low average annual productivity (2,3 t/ha) was ensured.

The use of fertilizers has increased the productivity of winter wheat. The leading role was played by nitrogen fertilizers. The maximum productivity of winter wheat grain (high and high level) is achieved with the introduction of full mineral fertilizer ($N_{60}P_{60}K_{60}$ and $N_{120}P_{120}K_{120}$) and the combined application of manure and $N_{60}P_{60}K_{60}$.

In addition to the quality indicators of the products obtained, the content of nitrates in it is of no small importance, since in large quantities they have carcinogenic properties.

As you know, there are no agricultural products without nitrates, since they are the main source of nitrogen in plant nutrition.

To obtain not only high, but also high-quality yields, it is necessary to introduce mineral nitrogen fertilizers and organic matter into the soil. The need for plants in nitrogen depends on many factors: type, variety, weather conditions, soil properties and the amount of previously used fertilizers. The results of numerous studies indicate that in connection with the intensive use of nitrogen fertilizers, there are many cases of excessive accumulation of nitrates in plants [10, 11].

Analysis of domestic and foreign literature shows that at present the level of pollution of plant materials with nitrates is quite high. Mainly, nitrates enter the human body with vegetables, fruits and berries. In the case of a balanced diet, they account for about 70,0% of the daily dose, the rest come with water, meat and other products [5]. In Ukraine, the permissible daily dose of nitrates for an adult has been established, which is 325 mg [6].

The reasons for the excessive accumulation of nitrates in crop products can be the use of ultra-high doses of nitrogen fertilizers, imbalance in the nutrition of plants with macro- and microelements throughout the growing season, imperfection of the technique of applying nitrogen fertilizers to the soil [9].

The increased content of nitrates in plants can be caused not only by the use of high doses of nitrogen fertilizers, but also by a number of other factors affecting the metabolism of nitrogen-containing compounds. The rate of nitrate recovery in plants depends not only on the amount of nitrogen introduced, but also to a large extent on the ratio of various nutrients, illumination, temperature, humidity, and some other external factors.

Excessive accumulation of nitrates in plant biomass is associated, as a rule, with a violation of the correspondence between their intake and the ability of

plants to include nitrogen in their own protein compounds.

Thus, the concentration of nitrates in plants is determined, on the one hand, by the intensity of absorption of mineral nitrogen by plants, and, on the other hand, by factors influencing the intensity of its assimilation [9].

Table 2 presents data characterizing the effect of fertilizers on the content of nitrates in winter wheat plants.

Table 2

Nitrate content in winter wheat plants (average for 2018–2020), mg/kg

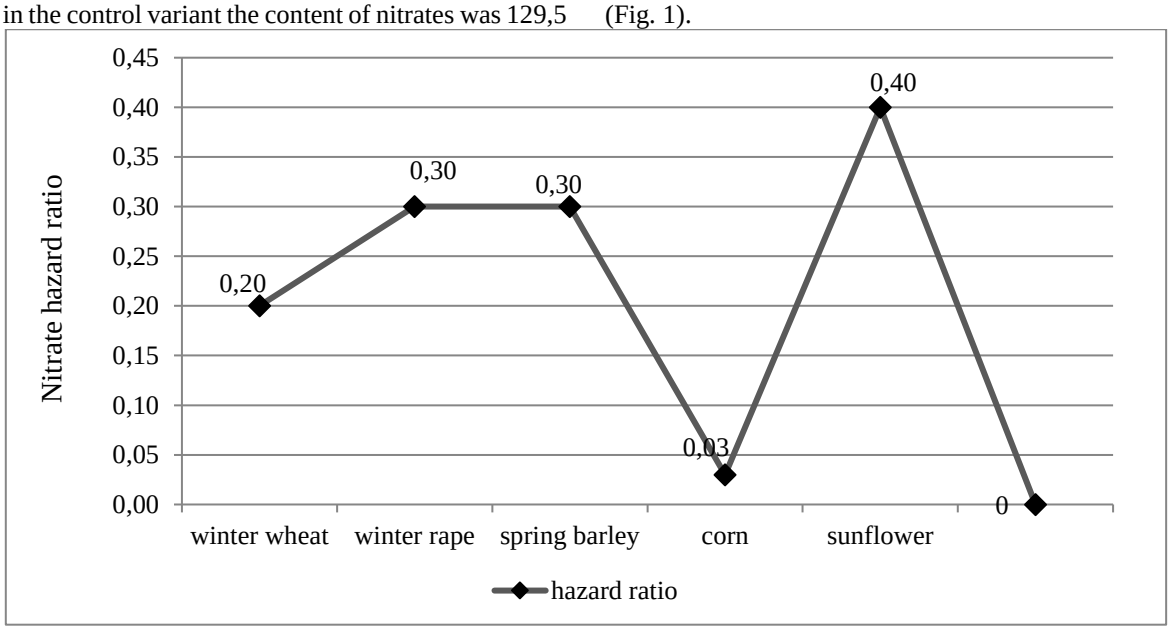
Варианты опыта	Timing of sampling		
	Tillering	Cleaning	
		corn	straw
The control	179,5±25,5	43±6	129,5±22,5
$N_{60}P_{60}K_{60}$	248,5±35,5	51±7	153±27,0
$N_{120}P_{120}K_{I20}$	307,0±44,0	47,5±6,5	142±25,0
Manure 30 t/ha	188,0±27,0	43±6	129,5±22,5
Manure 30 t/ha + $N_{60}P_{60}K_{60}$	213,5±30,5	45,5±6,5	137,0±24,0

As shown by the research results, in all variants with fertilization, the content of nitrates in the green mass of winter wheat was higher than in the control. In the control variant, the nitrate content was 179,5 mg/kg, in the fertilized variants it varied from 188,0 to 307,0 mg/kg. The accumulation of nitrates above the MPC (500 mg/kg) in the green mass of winter wheat on average for 3 years of research was not observed.

The content of nitrates in winter wheat grain did not depend on fertilization and varied from 43 to 51 mg/kg; in straw, this dependence was insignificant. So, if in the control variant the content of nitrates was 129,5 mg/kg, then in the fertilized variants it varied from 129,5 to 153 mg/kg. The maximum nitrate content was in the variant where $N_{60}P_{60}K_{60}$ was applied, the minimum – when the manure was applied at 30 t/ha.

The hazard ratio of nitrates is obtained by dividing the amount of nitrates in grain by the maximum allowable amount of nitrates in grain and seeds [6].

The hazard coefficient of nitrates in sunflower seeds grown under conditions of intensive chemicalization of agriculture was 0,4, in winter rapeseed and spring barley – 25,0% less, winter wheat – 50% less (Fig. 1).

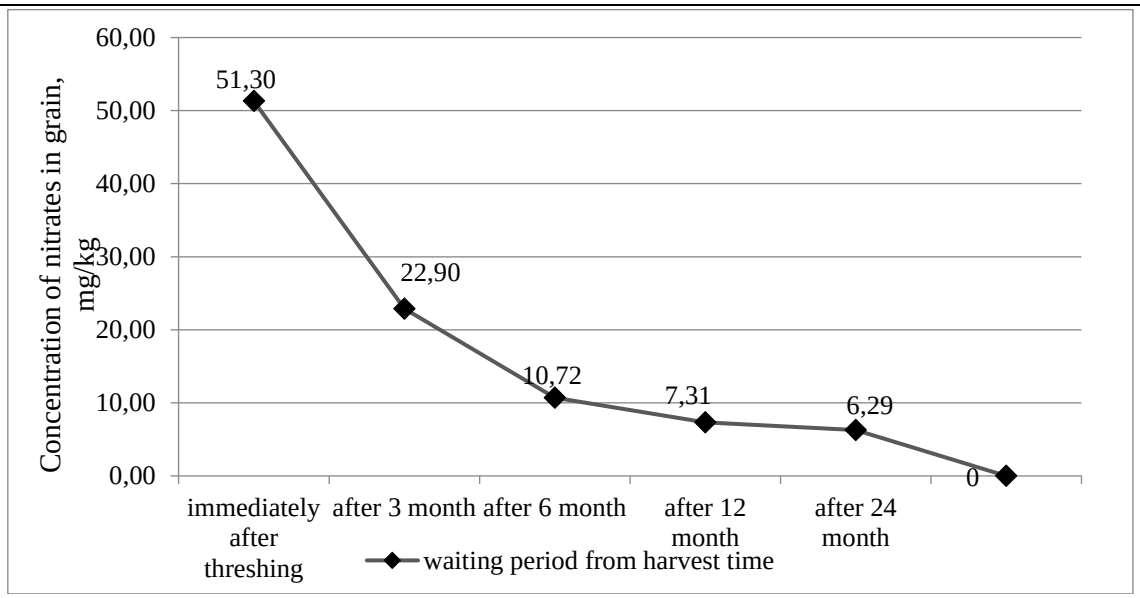


Drawing 1. The hazard ratio of nitrates in grain and seeds of field crops (2018–2020 pp.)

The lowest nitrate hazard ratio was found in corn grain – 0,03, which is 92,5% less than in sunflower seeds.

So, the lowest hazard ratio of nitrates was in corn grain grown under conditions of intensive chemicalization of agriculture.

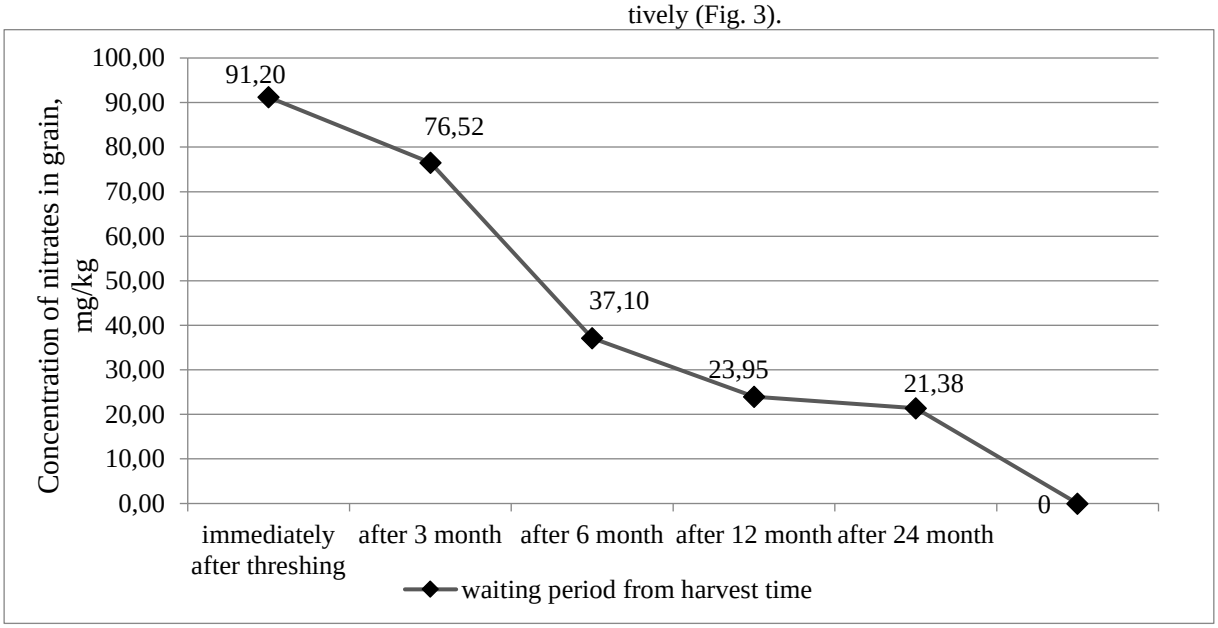
Figure 2 shows the dynamics of changes in the content of nitrates in the grain of field crops under conditions of intensive chemicalization of agriculture, depending on the waiting period, mg/kg.



Drawing. 2.
Dynamics of changes in the concentration of nitrates in winter wheat grain depending on the shelf life, mg/kg

The dynamics of changes in the content of nitrates in the grain of winter wheat grown under conditions of intensive chemicalization of agriculture, depending on the waiting period, showed that 3 months after harvesting grain of winter wheat grown under conditions of intensive chemicalization of agriculture, the content of nitrates decreased by 55,4%, after 6 months – by 79,1%, after 12 months – by 85,8% compared to the period of grain harvest and after 24 months – by 87,7% and amounted to 6,29 mg/kg.

In the grain of spring barley collected, the content of nitrates was 91,2 mg/kg. After 3 months, the concentration of nitrates decreased and amounted to 76,52 mg/kg. 6 and 12 months after the harvest of spring barley, the concentration of nitrates decreased still and amounted to 37,10, 23,95 and 21,38 mg/kg, respectively (Fig. 3).



Drawing. 3. Dynamics of changes in the concentration of nitrates in the grain of spring barley depending on the shelf life, mg/kg

According to the results of our research, it was found that the content of nitrates in the grain of winter wheat did not depend on the application of fertilizers and varied from 43 to 51 mg/kg; in straw, this dependence was insignificant. So, if in the control variant the nitrate content was 129,5 mg/kg, then in the fertilized variants it varied from 129,5 to 153,0 mg/kg. The maximum nitrate content was in the variant where N60P60K60 was applied, the minimum when manure was applied 30 t/ha.

A comparative study of the effect of mineral and organic fertilizers, as well as their combinations, showed that when using organic fertilizers, there is less accumulation of nitrates in plants than mineral and organomineral ones.

It was also found that the duration of storage of the main products of agrocenosis ensures the regulation of

the content of nitrates in terms of toxic and environmental indicators. On the example of winter wheat grain, it is shown that the content of nitrates after 6 and 12 months of storage decreases by 79,1 and 85,8% in comparison with their content after harvest.

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