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TECHNOLOGICAL INDICATORS FORMATION OF THE WINTER WHEAT GRAIN QUALITY UNDER THE CONDITIONS OF AGRICULTURE ENVIRONMENTALIZATION OF THE STEPPE OF UKRAINE

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Abstract. Wheat is the leading food grain in the global food balance. Ukraine is among the top 10 world grain producers and therefore the issue of increasing the production of high-quality, environmentally friendly grain is extremely relevant. The aim of the work was to study the influence of the system of agrotechnical measures for the greening of agriculture on the formation of technological indicators of the quality of winter wheat grain, which will make it possible to obtain high-quality environmentally friendly wheat grain in the conditions of the Southern Steppe of Ukraine, as well as reduce the negative pressure on the environment of modern factors of intensification of agriculture. The assessment of the quality of winter wheat grain was carried out according to such technological indicators as the protein content, the quantity and quality of gluten, the falling number, the weight of 1000 grains and bulk density. The experiments were carried out in a grain-rowed short-rotation 5-field crop rotation with alternating crops: peas – winter wheat – corn – sunflower – winter barley. The soil of the experimental plot is southern chernozem, low-humus, medium-thick, difficult loamy in the forest. The conducted studies have shown that the quality of grain changes both from the system of the main soil cultivation in the crop rotation, and from the use of spreaders of by-products of the predecessor, and the influence of these factors manifested itself depending on the weather conditions over the years of research in different ways. The best result with the element of biologization of agriculture was obtained with the use of the biodestructor Cellulad 2 l/ha, which significantly improves the technological indicators of the quality of winter wheat grain. So, on average, over the years of research, the best grain was obtained in the variant with a system of no-till multi-depth tillage against the background of the introduction of the biodegradable Cellulad 2 l/ha with the protein content of 12.6%, the crude gluten content of 23.4%, the gluten quality indicator according to its deformation index is 82.2 conventional units of the VDC device and the falling number of 334.3 s. With the introduction of additional nitrogen N_{10} per 1 ton of by-products, as an energy material for the efficient decomposition of organic matter by soil microorganisms, an increase in the quality of winter wheat grain is also observed, but the results are inferior to the best option. Carrying out a moisture-saving system of a non-linear mid-depth basic tillage increases the action of a biodestructor in the conditions of the arid Southern Steppe of Ukraine.

Keywords: winter wheat, technological indicators of grain quality, greening of agriculture, crop rotation, tillage systems, destructor of straw.

Introduction. Formulation of the problem

Wheat, including winter wheat, has always been and still remains the leading food grain crop in the world food balance. This season 2022/23, despite Russia's military aggression against Ukraine, our state will remain among the top 10 world grain producers, and therefore the issue of increasing the production of high-quality, environmentally friendly grain is becoming a priority for domestic agricultural producers.

However, the world experience in the development of agricultural production in highly developed countries has shown that, in addition to benefits, the intensification of agriculture and grain production leads to significant negative consequences – a drop in soil fertility, a decrease in the quality of grain, in particular wheat, as a leading grain crop, saturation of the food market with products harmful for human health, deterioration of the ecological state of the environment, degradation of natural ecosystems, landscapes, etc.

Therefore, the use of environmentally friendly farming schemes is an urgent task. It will not only increase the production of winter wheat and improve its quality, but also reduce the negative impact on the ecosystem of our country.

Analysis of recent research and publications

Ukraine is one of the major players in the international grain markets and its exports help to improve global grain availability and hence food security. Developed agricultural traditions, favorable agro-climatic factors and high quality of land resources make it possible to grow a variety of grains, legumes and oilseeds in Ukraine. The most popular agricultural crop is wheat, which, in terms of production volumes, which the entire Ukrainian agribusiness is engaged in, accounts for 40–50% of all grain crops [1].

Leading grain market experts state with concern that the growth of world wheat production in the last years of the 21st century, despite the introduction of modern scientific technologies, has slowed down significantly. Today, additional investments aimed at increasing the grain productivity of wheat are much less effective than it was observed in the 60–90 s of the last century [2].

Ukrainian grain has a high competitiveness, significant comparative and trade advantages. Grain export is one of the main ones in the structure of Ukraine's foreign trade. However, feed grains dominate in the structure of grain exports. Therefore, Ukraine needs to increase the production and export supply of high-quality grain and products of its processing [3].

Against the background of the growing export potential of Ukraine, which ranks high among the world's leading producers and exporters of wheat, such as the USA, Canada, Australia, EU countries, Ukraine's lagging behind the world level in the field of grain quality looks especially inappropriate [2].

The issues of assessing the quality of wheat grain for food purposes and changing its individual technological quantitative and qualitative indicators in different years have been and are being dealt with by leading domestic scientists – M.V. Romensky, I.T. Merko, V.A. Morgun, A.I. Yakovenko, D.A. Zhigunov, O.I. Rybalko and others.

According to the regulatory document (DSTU 3768:2019 Wheat. Specifications), soft wheat grain intended for use for food and non-food purposes, as well as for trade, is divided into 4 classes according to a number of quality indicators. For grain for food purposes, these are, first of all, such indicators as bulk density, protein content, gluten content, gluten quality, falling number, etc. In addition to the indicated class-forming quality indicators, such an indicator as the weight of 1000 grains is used to characterize the size of grain and seeds.

Studies of the dynamics and trends in the production and quality of wheat grain in Ukraine, conducted by ONTU scientists for the period 2004–2019 [4], showed annual changes in individual wheat quality indicators. Thus, in the studied period, the average wheat bulk density in the country ranged from 770 to 808 g/l, which meets the requirements of most export contracts, which ranged from 750–770 g/l per batch. According to the data of grain procurement enterprises in the south of Ukraine, in 2019, there was an arrival of individual batches of wheat with a bulk density of 670 g/l. The protein content with certain fluctuations did not change significantly and amounted to 11.3–13.0%. According to the data of the enterprises, batches of wheat of the 4th class with a protein content of 9.2–10.0% were increasingly encountered, they most often had an increased content of grains damaged by the wheat bug – up to 5–6%. The class-forming indicator "the gluten content" varied within 21.6–26.9%. The wheat of the studied period was distinguished by a high falling number, which was in the range of 292–380 s (with the exception of 2004 and 2015 with the lowest values of 226 and 286 s, respectively). The increase in the falling number is associated primarily with climatic conditions and drying of freshly harvested crops.

Well-known Ukrainian scientist-geneticist Dr. Biol. Sciences O.I. Rybalka [2], whose scientific interests are now focused on the creation of varieties of cereals with improved nutritional value of grain for use in the field of healthy (functional) nutrition, emphasizes that recently in the world attention has noticeably increased to the quality of wheat grain – a multifaceted problem that has become today for wheat, this important world food crop, without exaggeration, the number one issue. He notes that, despite the significant successes of modern world genetics, biotechnology, genetic engineering, breeding and wheat grain cultivation technology, attention should be focused on the fact that our Ukrainian national component in the world technical progress related to the quality of wheat grain, unfortunately, is still very insignificant and leaves much to be desired.

According to agricultural scientists, the main factors that have a significant impact on the yield and quality of grain, including winter wheat, are the sufficiency of fertilization of sown areas, seed quality, pest control and crop rotation. Of course, at the same time, there must be favorable weather and climatic conditions that will provide a sufficient amount of moisture in the soil. Otherwise, sufficient fertilizer with mineral fertilizers in the absence of moisture, is leading to even worse consequences.

However, excessive intensification of grain production through increased use of chemical fertilizers and weed and pest control can backfire.

The United States of America, Canada, Great Britain and the countries of Western Europe were the first to face the negative consequences of the intensification of agriculture, where, as a result of extremely excessive chemicalization of agricultural production, which ensured high gross yields, it had an extremely negative impact on the environment and human health. That is why, feeling a growing environmental threat, along with highly intensive farming, there was the development and implementation of alternative farming systems for the production of safe food products that not only support livelihoods, but also improve people's health while improving the ecological situation of the environment and preserving and restoring fertility of soils [5].

This is how the most common alternative farming systems appeared: organic, biological, organico-biological, ecological, biodynamic, etc. Their main concept was the rejection of the use of mineral fertilizers and chemicals of plant protection, and on the contrary, the full-scale use of all types of organic fertilizers, primarily by-products of agricultural crops, siderates, the introduction into the structure of sown areas of crop rotation of legumes and perennial leguminous grasses, the introduction of a system of shallow tillage soil, taking into account the biological requirements of cultivated plants. The main goal of alternative agriculture is to provide people with ecologically clean food products [6]. Thus, according to data [7], the use of biologization elements in wheat cultivation technology ensured an increase in grain productivity by 13% compared to a full dose of nitrogen, while the grain quality did not change significantly.

Other researchers [8] also speak in favor of biologization of agriculture, who, on the basis of conducted studies, established the positive effect of the use of a combination of growth stimulants and microfertilizers, which gave the largest grain yield and was the most economically efficient. At the same time, according to the data of [9], a positive effect was established due to the inoculation of A. Brasilense on the N content in the leaves and grains of winter wheat on soils with low nitrogen content.

And the reduction of carbon emissions due to its biological fixation under the influence of consistent biologization of agriculture deserves special attention [8-10].

Unlike the countries of Western Europe, the United States of America and Great Britain, in Ukraine the consequences of the powerful intensification of agriculture, which coincided with the country's independence, were such phenomena as the use of unreasonably high rates of mineral fertilizers and chemical plant protection products, which led to soil and water pollution by toxic and ballast substances; rejection of multi-field crop rotations, transition to monoculture and permanent crops, unsystematic intensive tillage, decline in animal husbandry and, as a result, lack of organic fertilizers, destruction of the scientifically based structure of sown areas with the rejection of crops of perennial and annual legumes and their mixtures, etc. Of course, all this has led to a significant deterioration in the ecological state of the environment, degradation, and in some cases even the destruction of natural landscapes and a decrease in soil fertility.

Land degradation and desertification is one of the most serious challenges for the sustainable development of the country, which entail significant environmental and socio-economic problems.

However, in order not to repeat the mistakes of the widespread model of economic development and intensification of the agricultural sector in industrialized countries, which in terms of the level of consumption of natural resources and the amount of pollution per capita exceeds similar indicators in developing countries by 20–30 times, Ukraine followed a different path [11].

Thus, under the pressure of internal and external requirements of the market of agricultural products and socio-economic challenges, at first a forced, spontaneous transition to biological agriculture took place in Ukraine, but with non-compliance with its basic principles, which only over time acquired a certain status and was formalized at the legislative level [9-11].

Innovative developments of the prerequisites for the development of organic farming and ways of ecologization of intensive farming, their implementation in Ukraine were carried out by well-known domestic scientists, such as P.I. Boyko [7,12], I.V. Goncharuk [5], V.M. Cool [6], S.P. Lysenko [10], S.P. Tanchik [13], G.M. Gospodarenko [14], M.K. Shikula [11], A.I. Shuvar [8] and others.

However, the world experience in the development of organic farming and the domestic analysis of analogues of domestic organic farming showed that it is impossible to effectively solve the food problem and improve the economic efficiency of management through organic farming, and that is why at the present stage of development of the agricultural business, it is impossible to give preference to just such a system of management in its various modifications is not advisable.

Currently, one of the promising areas for improving the farming system is its biologization. Therefore, in the conditions of modern production of agricultural products, it is necessary to ensure the ecological orientation of the farming industry, introduce elements of biologization into existing intensive farming systems, which are focused mainly on the use of biological rather than chemical and technical means of production in order to increase the economic and environmental efficiency of management using environmental and economic management at the state level [11-13].

The main direction of the greening of modern agricultural production occurs with the introduction of innovative technologies for the biologization of existing farming systems in order to ensure the sustainable development of agricultural production, the preservation and restoration of a favorable environment, the production of environmentally friendly products, the prevention of soil degradation and the preservation of their fertility [15].

The biologized farming system of the future should consist of a scientifically based consistent set of interrelated agrotechnical, reclamation and organizational and economic activities that ensure the efficient use of land for growing crops along with the preservation and reproduction of soil fertility. Such a system involves the introduction of an adapted structure of sown areas and a crop rotation system, the use of various organic fertilizers, such as manure, by-products of predecessors, green manure, as well as microbial and other biological products. A special component of modern biologization is the use of processing systems to save energy resources and minimize the impact on the soil [16]. A certain positive effect on the yield and grain quality of systems for minimizing tillage for winter wheat is given in [17,18], however, according to [19-21], grain quality was largely influenced by the conditions of the year than tillage systems, which are more degrees provided changes in grain evenness and their ash content.

In addition to increasing the productivity of agricultural crops and preserving and restoring soil fertility, the main task of biologization is to ensure the high quality of the products obtained. It is well known that the level of provision of plants with available forms of nitrogen in the soil at the time of grain formation is decisive in improving the quality of winter wheat grain [22-27].

It is believed that a balanced mineral nutrition of winter wheat plants throughout the growing season is the main guarantee of obtaining high and stable yields of high-quality grain of this crop.

Studies [10,14,26,27] found that the response of crops to the application of nitrogen fertilizers is limited when the content of residual nitrogen in the soil is high enough, while in conditions of low availability of this element, more nitrogen is required to increase the yield and quality of grain and protein in the grain, but the efficiency of nitrogen fertilizer application increases significantly.

In the zone of risky farming of the Southern Steppe of Ukraine, the use of farming biologization factors is rather limited, their effectiveness has not been sufficiently studied and requires additional research to identify and develop the most effective innovative technologies for biologization of known adapted high-intensity technologies for growing crops. About the features of the introduction of factors of biologization of agriculture were given in the works of E.A. Yurkevych [12].

Unfortunately, as noted by O.I. Rubalko, our wheat grain is still far from meeting the level of quality of the world-wide glory of Ukrainian black soil, on which it is grown. The issue of the quality of wheat grain in Ukraine, which should have acquired signs of an important state strategic program for a long time, remains today a systemic problem with many components, the non-solving of which has become chronic [2].

Thus, solving the problems of production and improving the quality of winter wheat grain based on the methods of biologization of agriculture is an important task of the present, to the solution of which our research is directed.

The aim and objectives of the study. The aim of the work is to study the influence of the system of agrotechnical measures for the greening of agriculture on the formation of technological indicators of the quality of winter wheat grain, which will make it possible to obtain high-quality environmentally friendly wheat grain in the Southern Steppe of Ukraine. Also to reduce the negative pressure on the environment of modern factors of intensification of agriculture in the conditions of a negative balance of organic matter in the soil and global climate change.

The **tasks of the work** are the study of the influence of the factor of the main tillage system and the factor of the use of straw decomposers on the technological indicators of the quality of winter wheat grain:

1) protein content;
2) gluten content and quality of gluten;
3) falling number;
4) weight of 1000 grains;
5) bulk density.

Research materials and methods

The research was carried out on a farm in the Bilgorod-Dnistrovsky district of the Odesa region of Ukraine. The soil of the experimental plot is southern chernozem, low-humus, medium-thick, difficult loamy in the forest. In the experiments, a grain-rowed short-rotation 5-field crop rotation with alternating crops was used: peas – winter wheat – corn – sunflower – winter barley.

The experiments were carried out according to a two-factor scheme.

Factor A of the main tillage system:
A1 – differentiated (control);
A2 – no-till multi-depth;
A3 – no-till shallow.
Factor B in the application of straw decomposers:
B1 – water treatment (control);
B2 – introduction of nitrogen N_{10} per 1 ton of straw;
B3 – introduction of the biodestroyer Cellulad 2 l/ha.

Variants of experiment are placed in three repetitions by the method of split plots. The total area under the experiment was 15 ha, the total area in the experiment: tillage – 2500m^2, straw spreaders – 830m^2, accounting area – 50m^2. In the experiment, zoned varieties and hybrids of agricultural crops were sown, including the zoned variety of winter soft wheat Wisdom Odesa.

Agrotechnics for growing crops in the experiment, in addition to the studied options, was recommended for the study area.

After growing winter wheat grain according to generally accepted methods, the following technological indicators of its quality were determined:

– the protein content in terms of dry matter was determined according to DSTU ISO 20483:2016 (ISO 20483:2013, IDT) Cereals and legumes. Determination of nitrogen content and crude protein by the Kjeldahl method;

– the gluten content was determined according to DSTU ISO 21415-1:2009 Wheat and wheat flour. Gluten content. Part 1. Manual determination of crude gluten;

– the quality of gluten was determined by the index of its deformation in conventional units of the VDC device;

– the weight of 1000 grains was determined according to DSTU ISO 520:2015 Cereals and legumes. Determination of the weight of 1000 grains;

– the bulk density of the grain was determined by the volume-weight method on a liter snowstorm with a falling weight according to DSTU GOST 10840:2019 Grain. Method of determining bulk density;

– the falling number was determined on the PChP-7 device in accordance with DSTU ISO 3093:2009 Wheat, rye and flour from them, wheat, durum and semolina from durum wheat. Determination of the falling number by the Hagberg-Perten method (ISO 3093:2004, IDT). The method is based on rapid gelatinization of an aqueous suspension of flour in a boiling water bath, followed by measurement of the degree of liquefaction of the starch gel under the action of alpha-amylase.

The statistical significance of the experimental data obtained was assessed by the least significant difference (LSD_{05}) for a probability level of 95%.

Results of the research and their discussion

Factors of biologization of agriculture, chosen to determine the impact on the quality of winter wheat grain, differently influenced the technological quality indicators, which also changed over the years of research. There was no significant direct effect of the processing system on grain quality indicators, but due to changes in soil conditions under the influence of various processing systems aimed at optimizing the moisture supply and mineral nutrition of plants, a certain positive trend is observed.

So, on average, over the years of research, an increase in the protein content in the grain of winter wheat (Table 1) was established from 10.6% in the variant with the system of shallow tillage to 11.8% in the variant with the system of no-till deep tillage without the use of measures to improve the decomposition of by-products in the experience. At the same time, there were certain changes in the protein content over the years of research. So, in 2020, these indicators were at the level of 11.3–11.8%, respectively (Table 2); in 2021 10.4–11.6% (Table 3) and in 2022 10.1–11.8% (Table 4).

Similarly, there were changes in the content of winter wheat gluten. On average, over the years of research, its content fluctuated in variants without the use of means of improving the breakdown of by-products from 19.1% in the variant with a system of no-till shallow tillage to 21.3% in the variant with a system of no-till multi-depth soil tillage (Table 1). Moreover, over the years of the study, fluctuations in the gluten content in the experiment were at the level of 19.4–21.3% in 2020 (Table 2); in 2021, 18.7–21.1% (Table 3) and in 2022, 19.3–21.5% (Table 4), respectively, depending on the system of the main tillage in crop rotation.

An important indicator is not only the amount of gluten in the grain of winter wheat, but also its quality in terms of conventional units of VDC. According to the results of the research, it was found that the quality of gluten was satisfactory, and the VDC index varied on average from 106.5 in the variant with the system of non-linear fine processing to 89.5 conventional units in a system of non-linear mid-depth tillage without the use of means to improve the decomposition of by-products of the predecessor (Table 1). Under the influence of weather conditions during the growing season of winter wheat, certain changes also occurred in terms of the quality of gluten, which amounted to 93.7–83.5 for these main tillage systems in the crop rotation in 2020 (Table 2); in 2021 111.8–87.3 (Table 3) and in 2022 114.0–96.5 conv. units VDC (Table 4).

Table 1 – Grain quality of winter wheat in a crop short-rotation under the influence of the main soil cultivation systems and the introduction of straw spreaders, average for 2020-2022

Options		Crude protein dry matter, %	Wet gluten		Falling number, c
Factor A (soil cultivation system in crop rotation)	Factor B (application of straw decomposers)		content, %	quality, conv. un. VDC*	
Differentiated (control)	without decomposer (control)	11.4	19.8	97.3	278.7
	application of N_{10} per 1 ton of straw	11.6	20.8	94.2	287.4
	with decomposer	11,8	21.4	88.9	295.5
No-till multi-depth	without decomposer	11,8	21.3	89.3	300.8
	application of N_{10} per 1 ton of straw	12.0	21. 9	85.1	310.6
	with decomposer	12.6	23.4	82.2	334.3
No-till shallow	without decomposer	10.6	19.1	106.5	247.1
	application of N_{10} per 1 ton of straw	11.3	20.3	97.2	259.7
	with decomposer	11.4	20.7	93.8	280.6
LSD_{05}	Factor A	0.18-0.35	0.33-0.68	5.4-7.1	1.8-38
	Factor B	0.18-0.35	0.33-0.68	5.4-7.1	1.8-3.8
	Interaction AB	0.37-0.70	0.68-1.31	10.4-14.3	3.8-6.3

Notes: VDC* – gluten deformation meter.

Table 2 – Winter wheat grain quality in short-rotation crop rotation under the influence of the main tillage systems and the introduction of straw decomposers, 2020

Options		Crude protein dry matter, %	Wet gluten		Falling number, c
Factor A (soil cultivation system in crop rotation)	Factor B (application of straw decomposers)		content, %	quality, conv. un. VDC	
Differentiated (control)	without decomposer (control)	11.4	19.5	92.9	266.5
	application of N_{10} per 1 ton of straw	11.6	20.8	88.6	284.2
	with decomposer	11.7	21.7	83.2	292.0
No-till multi-depth	without decomposer	11.8	21,3	83.8	289.6
	application of N_{10} per 1 ton of straw	12.2	22,8	81.2	300.9
	with decomposer	12.7	23.4	80.1	323.8
No-till shallow	without decomposer	11.3	19.4	93.7	263.0
	application of N_{10} per 1 ton of straw	11.5	20.7	88.6	274.3
	with decomposer	11.6	20.9	86.8	288.0
LSD_{05}	Factor A	0.21	0.33	2.1	6.7
	Factor B	0.21	0.33	2.1	6.7
	Interaction AB	0.40	0.68	4.7	12.2

Table 3 – The quality of winter wheat grain in short-rotation crop rotation under the influence of the main tillage systems and the introduction of straw decomposers, 2021

Options		Crude protein dry matter, %	Wet gluten		Falling number, c
Factor A (soil cultivation system in crop rotation)	Factor B (application of straw decomposers)		content, %	quality, conv. un. VDC	
Differentiated (control)	without decomposer (control)	11.4	19,4	90.8	258.5
	application of N_{10} per 1 ton of straw	11.5	21.0	87.7	261.6
	with decomposer	11.7	21.1	85.3	273.3
No-till multi-depth	without decomposer	11.6	21.1	87.3	263.2
	application of N_{10} per 1 ton of straw	11.8	21.3	83.6	269.3
	with decomposer	12.1	22.4	81.1	294.9
No-till shallow	without decomposer	10.4	18.7	111.8	244.4
	application of N_{10} per 1 ton of straw	11.3	19.4	93.1	255.5
	with decomposer	11.4	20.0	87.7	261.6
LSD_{05}	Factor A	0.35	0.68	1.8	7.1
	Factor B	0.35	0.68	1.8	7.1
	Interaction AB	0.70	1.31	3.8	14.3

Table 4 – Winter wheat grain quality in short-rotation crop rotation under the influence of the main tillage systems and the introduction of straw decomposers, 2022

Options		Crude protein dry matter, %	Wet gluten		Falling number, c
Factor A (soil cultivation system in crop rotation)	Factor B (application of straw decomposers)		content, %	quality, conv. un. VDC	
Differentiated (control)	without decomposer (control)	11.5	20.4	108.1	311.0
	application of N_{10} per 1 ton of straw	11.7	20.5	106.4	316.3
	with decomposer	11.9	21.4	98.1	321.1
No-till multi-depth	without decomposer	11.8	21.5	96.9	349.7
	application of N_{10} per 1 ton of straw	11.9	21.7	90.5	361.6
	with decomposer	13.0	24.5	85.3	384.3
No-till shallow	without decomposer	10.1	19.3	114.0	234.0
	application of N_{10} per 1 ton of straw	11.1	20,8	109.8	249.4
	with decomposer	11.3	21.1	107.0	292.3
LSD_{05}	Factor A	0.18	0.33	3.8	5.1
	Factor B	0.18	0.33	3.8	5.1
	Interaction AB	0.37	0.70	6.3	10.4

In addition to indicators of the protein content, gluten and its quality, the amylolytic activity of grain, which is characterized by a falling number, is of particular importance for baking bread. This indicator in the experiment over the years of research, depending on the system of the main cultivation of the soil against the background without the use of means to improve the decomposition of by-products of the predecessor in the crop rotation, on average over the years of research, ranged from 247.1 s in the variant with a system of non-linear mid-depth tillage in crop rotation with fluctuations over the years, depending on weather conditions (Table 1).

The use of means to improve the decomposition of by-products of predecessors in the crop rotation, namely the application of nitrogen fertilizers (ammonium nitrate NH_4NO_3) N_{10} per 1 ton of by-products and the use of biodegrader Cellulade 2 l/ha, had a significant impact on the quality of winter wheat grain. Thus, on average, over the years of research, the use of these measures ensured an improvement in the quality of winter wheat grain in all variants of the main tillage systems (Table 1), but the best grain was obtained in the variant with a system of no-till mid-depth tillage against the background of the application of the biospreader Cellulad 2 l/ha with a protein content of 12.6%, gluten content of 23.4%, a falling number of 334.3 s and a VDC of 82.2 conventional units. The variant with the introduction of N_{10} per 1 ton of by-products also had high quality indicators of winter wheat grain, but was inferior to the best variant in accordance with the protein content by 0.6%, gluten by 1.5%, the falling number by 23.7 s, and the VDC indicator by 2.9 conventional units. In the variant with a system of shallow tillage in a crop rotation, winter wheat grain was obtained from the lowest quality, which was inferior in terms of quality to both the control variant and especially the variant with a system of deep tillage in a crop rotation. It was found that in this variant of the main soil cultivation system, against the background of N_{10} application per 1 ton of by-products, grain quality indicators were inferior in terms of protein content by 0.3%, gluten by 0.5%, the falling number by 27.7 s and the VDC indicator at 3.0 conv. unit. When applying the biodegrader Cellulad 2 l/ha, these indicators of grain quality were also inferior to the control variant in accordance with the protein content by 0.4%, gluten by 0.7%, the falling number by 14.9 s and the VDC by 4.5 conventional units . An even greater drop in the quality of grain occurred in this variant compared to the system of non-linear mid-depth tillage in the crop rotation and amounted to the background of the introduction of N_{10} per 1 ton of by-products in terms of protein content by 0.7%, gluten by 1.6%, the fall number by 53.6 s and the VDC indicator by 12.1 conventional units, and against the background of the introduction of the biodestructor Cellulad 2 l/ha, these indicators were 1.2%, respectively; 2.7%; 53.7 s and 11.6 conventional units.

Thus, under the conditions of 2020 (Table 2), which was noted as unfavorable for the growth and development of winter wheat plants according to hydrothermal indicators, the higher crude protein content was 11.8% and gluten content was 21.3%, with a falling number of 289.6 s and VDC 83.8 conv. units in the background without the use of measures to improve the decomposition of by-products, provided an option with a system of multi-depth no-till tillage. This information can be explained by the fact that it is this system of basic tillage that creates prerequisites for improving nitrogen nutrition of winter wheat plants, as it is one of the important factors that increase the quality of winter wheat grain.

In the variants of the experiment with systems of differentiated (control) and especially no-till shallow tillage, these indicators deteriorated by 0.4–0.5%, respectively; 1.8–1.9%; 23.1–26.6 s and 9.1–9.8 conditional units.

The use of resources to improve the decomposition of by-products of the predecessor, including the biodegrader Cellulad 2 l/ha, significantly improves the quality of winter wheat grains for all options for basic tillage systems. In the variant with the system of differentiated basic tillage in the crop rotation (control), the introduction of N_{10} 1 t of by-products of the predecessor ensured an increase in the content of protein and gluten by 0.2–1.3%, respectively, and with the introduction of the biodegradant Cellulad 2 l/ha, these indicators increased by 0.3–2.2%. The quality of winter wheat grain in the experiment against the background of the system of shallow basic soil cultivation was not significantly inferior to the control variant, but the positive trend of grain quality growth due to the introduction of N_{10} per 1 ton of by-products and Cellulade biodegrader 2 l/ha remained. So, in this variant of the main soil cultivation system in the crop rotation, the protein and gluten content increased by 0.2–1.3 and 0.3–1.5%, respectively. The best grain was obtained in the variant of the experiment with a system of no-till mid-depth tillage in the crop rotation and the very use of the biodegrader Cellulade 2 l/ha, which provided the highest protein and gluten content in the grain in the experiment. So, in comparison with the variant with a system of differentiated and shallow no-till tillage, the protein and gluten content in winter wheat grain increased by 1.0–1.1% and 1.7–2.5%, respectively (the least significant difference LSD_{05}=0.40–0.68).

In the conditions of 2021, which was characterized as favorable in terms of moisture for the growth and development of winter wheat, a fairly high grain yield of this crop was obtained, which determined the regular insignificant deterioration in grain quality indicators, but the trend in the influence of the systems of the main cultivation of the soil and the use of a biospreader, also kept this year. The highest protein and gluten content was obtained in the variant where the system of non-soil deep tillage was carried out against the background of the introduction of the biodestructor Cellulad 2 l/ha and amounted to 12.1 and 22.4%, respectively (Table 3). As in the previous year, the variants with a system of differentiated and no-till tillage for the introduction of the biodestructor Cellulade 2 l/ha were inferior in these indicators by 0.4–0.7% and 1.3–2.4%, respectively (LSD_{05}= 0,70–1,31). The efficiency in the experiment of the variant of the system of no-till main soil cultivation in crop rotation against the background of the use of the no-till Cellulad 2 l/ha is also evidenced by the fact that, compared with the control variant, the indicators of grain protein content and gluten content increase by 0.7–3.0%, respectively.

In the options with a system of differentiated (control) and shallow no-till tillage, a significant decrease in winter wheat grain quality indicators was noted, due to the deterioration of agrophysical and agrochemical indicators of soil fertility under the conditions of the arid Steppe of Ukraine in these systems.

In 2022, there were extremely unfavorable conditions for the growth and development of winter wheat plants, and therefore a sufficiently low grain yield was obtained, but the quality of the grain was not only not inferior to the previous favorable year, but even somewhat exceeded last year's indicators. The best prerequisites for obtaining high-protein grain and a high content of gluten were created in the variant with a system of no-till multi-depth tillage in crop rotation against the background of the introduction of the biodestructor Cellulad 2 l/ha with protein content of 13.0% and gluten content – 24.5% (Table 4). This option was characterized by the highest indicators of the falling number (354.3 s) and the value of VDC (85.3 cond. units). The variant of the experiment, which provided for the introduction of N_{10} per 1 t of by-products of the predecessor against the background of a system of no-till multi-depth tillage, was inferior to the variant with the introduction of Celulad 2 l/ha, respectively, in terms of protein content by 1.1%, gluten content by 2.8%, the falling number of 22.7 s and the VDC value is 5.2 conditional units.

The lowest grain quality indicators of winter wheat in the experiment, regardless of the application of measures to increase the efficiency of the decomposition of by-products of the predecessor, were obtained in the variant with the system of shallow tillage, however, even under this system of the main tillage, the use of the biodestructor Cellulad 2 l/ha ensured a certain improvement in the quality of grain of winter wheat in comparison with the variant with the introduction of N_{10} per 1 ton of by-products of the predecessor.

Thus, in the conditions of 2020, there was a positive trend towards an increase in the content of protein and gluten in winter wheat grain against the background of the use of straw biodegrader Cellulad 2 l/ha. So, with the system of a differentiated system of basic tillage (control), the use of a biodegrader provided an increase in the protein content by 0.42% and gluten by 2.13%. In the variants with a system of shallow tillage in the crop rotation, winter wheat grain with the lowest quality indicators was obtained, although the tendency to improve these indicators against the background of the use of a biodegrader remained. This version of the processing system against the background of the use of a biodegrader was inferior to the control for protein content by 0.12%, and gluten, respectively, by 0.8% (Table 2). Under the conditions of 2020, the best grain was obtained in general in the variants of the experiment with a system of no-low deep tillage in the crop rotation, and the very use of the biodegradant Cellulad 2 l/ha provided the highest protein content and gluten content in the grain in the experiment. So, in comparison with the variant with a system of differentiated and shallow non-tillage treatment, the protein content and gluten content in the winter wheat grain increased by 0.93–1.05% and 1.78–2.58%, respectively (LSD_{05} = 0.21–0,33). For the remaining quality indicators, which largely depend and are determined by the mass fraction of protein and gluten– the number of falling and the quality of gluten, the same previous trend of their change according to the experimental options was established.

In the conditions of 2021, which was characterized as favorable in terms of moisture for the growth and development of winter wheat, a fairly high grain yield of this crop was obtained, which determined the regular insignificant deterioration in grain quality indicators, but the trend in the influence of the systems of the main cultivation of the soil and the use of a biospreader, also kept this year. The highest protein content and gluten content was obtained in the variant where the system of non-soil deep tillage was carried out against the background of the introduction of the biodestructor Cellulad 2 l/ha and amounted to 12.1 and 22.4%, respectively (Table 3). As in the previous year, the variants with a system of differentiated and shallow tillage were inferior in these indicators by 0.48–0.69% and 1.28–2.42%, respectively (LSD_{05}= 0,35–0,68).

In the options with the system of differentiated (control) and shallow tillage, a significant decrease in winter wheat grain quality indicators was noted, which can be explained by the deterioration of agrophysical and agrochemical indicators of soil fertility under the conditions of the arid Steppe of Ukraine in these systems of the main tillage

In 2022, there were extremely unfavorable conditions for the growth and development of winter wheat plants, and therefore a rather low grain harvest was obtained, but the grain quality not only was not inferior to the previous favorable year, but even somewhat exceeded last year's figures to a certain extent. The best prerequisites for obtaining high-protein grains and a high gluten content were created in the variant with a system of non-low deep tillage in crop rotation against the background of the introduction of the biodestructor Cellulad 2 l/ha with the protein content 12.96% and gluten content 24.47% (Table 4).

The lowest indicators of winter wheat grain quality in the experiment with the use of the biodestructor Cellulad 2 l/ha were obtained in the variant with a system of fine no-till tillage.

Similar changes have taken place and are such indicators of grain quality (Table 5) as the weight of 1000 grains and grain size. On average, over the years of research, the best grain in terms of these indicators was obtained in the variant with a system of non-low deep tillage against the background of the introduction of the biodestructor Cellulad 2 l/ha, when the weight of 1000 grains was 38.6 g, and the weight was 731.0 g. by the system of differentiated tillage according to these indicators by 1.1–9.1 g, and the variant with the system of shallow no-till tillage in the crop rotation by 2.1–31.7 g, respectively.

Studies of the change in the weight of 1000 grains and the bulk density of grain showed that in the experiment there is a positive trend in improving these indicators from the use of means of biologization of agriculture against the background of various systems of basic soil cultivation.

So, in 2020 (Table 6), with a system of differentiated basic tillage in a crop rotation, the weight of 1000 grains and the grain size without the use of means to improve the decomposition of the by-products of the predecessor were 35.8 g and 681 g/l, respectively, with a system of non-linear mid-depth tillage – 36.0 g and 685 g/l, or 0.2 g and 4.0 g/l more compared to the control, while with the no-till shallow tillage system, these figures were at the level of 35.4 g and 670 g/l or 0.4 g and 11 g/l less compared to the control.

Favorable conditions for the formation and maturation of winter wheat grain, which developed in 2021, significantly affected the indicators of the weight of 1000 grains and grain size (Table 7), where they were the largest over the years of research, but the trend of the influence of various systems of the main soil cultivation in the crop rotation on these indicators of grain quality remained. So, they were respectively at the level of 39.2 and 761 g/l in the variant with a system of differentiated tillage (control), without the use of means to improve the by-products of the predecessor; 39.8 g and 774 g/l in the variant with the no-till mid-depth tillage system, or 0.6 g and 13 g/l more compared to the control variant, and the lowest physical indicators of winter wheat grain quality were obtained in the variant with the system shallow treatment and amounted to 38.0 g and 750 g/l, respectively, or 1.2 g and 11 g/l less than the control.

The next year (2022) was very difficult in terms of weather conditions for the growth and development of winter wheat plants, the period was especially dry and hot during grain formation, which is why grain with low quality indicators was obtained from a weight of 1000 grains and grain size (Table 8). These indicators of the quality of winter wheat grain in the variant with a system of differentiated tillage without the use of means to improve the decomposition of the by-products of the predecessor were at the level of 33.6 g and 644 g/l, respectively, in the variant with a system of no-low deep tillage, respectively, 34.6 g and 656 g/l, or 1.0g and 12.0 g/l more than the control, and the lowest values of 33.0 g and 638 g/l, respectively, were obtained in the variant with a no-till shallow tillage system. The use of means for improving the decomposition of by-products of the predecessor provided in the experiment the improvement of the weight of 1000 grains and the bulk density of winter wheat grain.

The largest weight of 1000 grains and bulk density, which amounted to 35.2 g and 672 g/l, which exceeded the control by 0.3 g and 9.0 g/l, respectively, were achieved in the variant with a system of mediumdepth tillage without soil when applying biodestructor Cellulade 2 l/ha. The use of the biodestructor Cellulad 2 l/ha in the system of shallow tillage led, on the contrary, to a decrease in these indicators of the quality of wheat grain, which were inferior to the control variant and the variant with a system of shallow tillage in terms of weight of 1000 grains and bulk density 0.6–0.9 g and 12.0–21 g/l.

Variants of the experiment, where it was used to improve the decomposition of by-products of the precursor of applying N_{10} per 1 ton of straw, in terms of the effect on winter wheat grain quality indicators, to a certain extent, were inferior to the options with the use of the biodestructor Cellulad 2 l/ha in terms of weight of 1000 grains and bulk density with background of the system of differentiated, no-till multi-depth and no-till shallow tillage, respectively, by 0.4–0.8; 0.6–1.2 and 0.5–0.9 g.

On average, over the years of research, the experience retains the established patterns on the influence of various systems of the main soil cultivation and measures to improve the decomposition of by-products of the winter wheat precursor on the quality of the resulting grain, especially in favor of the use of the biodegrader Cellulad 2 l/ha, as one of the factors of biologization of agriculture (tables 1, 5).

Approbation of research results. The studies were carried out in the conditions of a farm located in the Bilgorod-Dnistrovsky district of the Odesa region, Ukraine.

Table 5 –The weight of 1000 grains and the bulk density winter wheat grains in a short-rotation crop rotation under the influence of the main soil cultivation systems and the introduction of straw decomposer, average for 2020–2022

Options		Weight of 1000 grains, g	Bulk density, g/l
Factor A (soil cultivation system in crop rotation)	Factor B (application of straw decomposers)		
Differentiated (control)	without decomposer (control)	36.2	695.3
	application of N_{10} per 1 ton of straw	37.1	703.3
	with decomposer	37.5	712.3
No-till multi-depth	without decomposer	36.6	705.0
	application of N_{10} per 1 ton of straw	37.7	720.0
	with decomposer	38.6	731.0
No-till shallow	without decomposer	35.5	686.0
	application of N_{10} per 1 ton of straw	36.1	692.3
	with decomposer	36.5	699.3
LSD_{05}	Factor A	0.31-0.42	3.2-6.8
	Factor B	0.31-0.42	3.2-6.8
	Interaction AB	0.63-0.83	6.3-6.8

Table 6 – Weight of 1000 grains and grain size of winter wheat in a short-rotation crop rotation under the influence of systems of basic soil cultivation and the introduction of straw decomposer, 2020

Options		**Weight of 1000 grains, g**	**Bulk density, g/l**
Factor A (soil cultivation system in crop rotation)	**Factor B (application of straw decomposers)**		
Differentiated (control)	without decomposer (control)	35.8	681
	application of N_{10} per 1 ton of straw	36.6	690
	with decomposer	37.2	707
No-till multi-depth	without decomposer	36.0	685
	application of N_{10} per 1 ton of straw	38.0	722
	with decomposer	38.7	736
No-till shallow	without decomposer	35.4	670
	application of N_{10} per 1 ton of straw	35.8	680
	with decomposer	36.2	687
LSD_{05}	Factor A	0.40	6.8
	Factor B	0.40	6.8
	Interaction AB	0.82	12.5

Table 7 – Weight of 1000 grains and grain size of winter wheat in a short-rotation crop rotation under the influence of systems of basic soil cultivation and the introduction of straw spreaders, 2021

Options		Weight of 1000 grains, g	Bulk density, g/l
Factor A (soil cultivation system in crop rotation)	Factor B (application of straw decomposers)		
Differentiated (control)	without decomposer (control)	39.2	761
	application of N_{10} per 1 ton of straw	40.1	765
	with decomposer	40.4	767
No-till multi-depth	without decomposer	39.8	774
	application of N_{10} per 1 ton of straw	40.4	778
	with decomposer	41.8	785
No-till shallow	without decomposer	38.0	750
	application of N_{10} per 1 ton of straw	38.8	755
	with decomposer	39.1	760
LSD_{05}	Factor A	0.31	3.2
	Factor B	0.31	3.2
	Interaction AB	0.63	6.3

Table 8 – Weight of 1000 grains and grain size of winter wheat in a short-rotation crop rotation under the influence of systems of basic soil cultivation and the introduction of straw decomposer, 2022

Options		Weight of 1000 grains, g	Bulk density, g/l
Factor A (soil cultivation system in crop rotation)	Factor B (application of straw decomposers)		
Differentiated (control)	without decomposer (control)	33.6	644
	application of N_{10} per 1 ton of straw	34.5	655
	with decomposer	34.9	663
No-till multi-depth	without decomposer	34.0	656
	application of N_{10} per 1 ton of straw	34.6	660
	with decomposer	35.2	672
No-till shallow	without decomposer	33.0	638
	application of N_{10} per 1 ton of straw	33.8	642
	with decomposer	34.3	651
LSD_{05}	Factor A	0.42	4.0
	Factor B	0.42	4.0
	Interaction AB	0.83	8.2

Conclusion

The conducted studies on the quality of winter wheat grain showed that it changes both from the system of the main tillage in the crop rotation, and from the use of spreaders of by-products of the predecessor, and the influence of these factors occurred depending on weather conditions over the years of research in different ways.

Particularly noteworthy is the option with the element of biologization of agriculture, the use of the biodestructor Cellulad 2 l/ha, which not only is not inferior to the option with the introduction of N_{10} per 1 ton of by-products, but also significantly improves the technological indicators of the quality of winter wheat grain.

So, on average, over the years of research, the best grain was obtained in the variant with a system of no-till multi-depth tillage against the background of the introduction of the biodegradable Cellulad 2 l/ha with a mass fraction of protein of 12.6%, a mass fraction of crude gluten of 23.4%, the gluten quality indicator according to its deformation index is 82.2 conditional units of the VDC device and the falling number is 334.3 s.

The option with the introduction of additional nitrogen as an energy material for the effective decomposition of organic matter by soil microorganisms is designed exclusively for microorganisms existing in the soil, while with the introduction of a biodestructor their number in the soil increases and, most importantly, they are in an active form, which saves free soil nitrogen compounds. In this variant, with the introduction of N_{10} per 1 ton of by-products, an increase in the quality of winter wheat grain is also observed, but the results are inferior to the best variant in accordance with the protein content by 0.6%, the crude gluten content by 1.5%, its deformation index gluten 2.9 conv. unit VDC device and the falling number of 23.7 s .

Carrying out a moisture-saving system of non-linear mid-depth basic tillage increases the action of the biodestructor in the conditions of the arid Southern Steppe of Ukraine.

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ФОРМУВАННЯ ТЕХНОЛОГІЧНИХ ПОКАЗНИКІВ ЯКОСТІ ЗЕРНА ПШЕНИЦІ ОЗИМОЇ ЗА УМОВ ЕКОЛОГІЗАЦІЇ ЗЕМЛЕРОБСТВА СТЕПУ УКРАЇНИ

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Анотація. Пшениця є провідною продовольчою зерновою культурою у світовому балансі продовольства. Україна входить у топ-10 світових виробників зерна і тому питання збільшення обсягів виробництва високоякісного, екологічно чистого зерна є надзвичайно актуальним. Метою роботи було дослідження впливу системи агротехнічних заходів екологізації землеробства на формування технологічних показників якості зерна пшениці озимої, що дозволить отримати високоякісне екологічно чисте зерно пшениці в умовах Південному Степу України, а також зменшити негативний тиск на навколишнє середовище сучасних факторів інтенсифікації землеробства. Оцінку якості зерна пшениці озимої проводили за такими технологічними показники як масова частка білка, кількість та якість клейковини, число падіння, маса 1000 зерен та натура. Досліди проводили у зернопросапній короткоротаційній 5-типільній сівозміні з таким чергуванням сільськогосподарських культур: горох – пшениця озима – кукурудза – соняшник – ячмінь озимий. Ґрунт дослідної ділянки чорнозем південний, малогумусний, середньопотужний, важкосуглинковий на лесі. Проведені дослідження показали, що якість зерна змінюється як від системи основного обробітку ґрунту у сівозміні, так і від застосування розкладників побічної продукції попередника, при чому вплив цих факторів проявлявся залежно від погодних умов за роки досліджень по різному. Найкращий результат з елементом біологізації землеробства отримано при застосуванні біодеструктора Целюлад 2 л/га, який суттєво поліпшує технологічні показники якості зерна пшениці озимої. Так, в середньому за роки досліджень найкраще зерно було отримане у варіанті з системою безполицевого різноглибинного обробітку ґрунту на фоні внесення біорозкладнику Целюлад 2 л/га з масовою часткою білка 12,6%, масовою часткою сирої клейковини 23,4%, показником якості клейковини за індексом її деформації 82,2 ум. од. приладу ВДК та числа падіння 334,3 с. Із внесенням додаткового азоту N_{10} на 1т побічної продукції, як енергетичного матеріалу для ефективного розкладання органічної речовини ґрунтовими мікроорганізмами, також спостерігається підвищення показників якості зерна пшениці озимої, але результати поступаються кращому варіанту. Проведення вологозберігаючої системи безполицевого різноглибинного основного обробітку ґрунту підвищує дію біодеструктора в умовах посушливого Південного Степу України.

Ключові слова: пшениця озима, технологічні показники якості зерна, екологізація землеробства, зернопросапна сівозміна, системи обробітку ґрунту, біодеструктор соломи.