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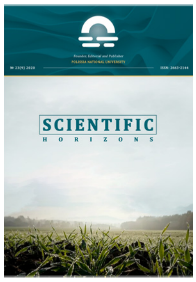

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Productivity of Short-Rotary Crop Cultivation under Different Systems of Basic Tillage in Organic Agriculture of the Steppe of Ukraine

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Abstract. Long-term reform of the agricultural sector in Ukraine is taking place under difficult economic and natural conditions. In modern agriculture, the most relevant ones are biologized measures and technologies for growing crops and resource- and energy-economic restoration of soil fertility. Studies of the impact of the system of basic tillage and the use of straw bio-decomposers and postharvest residues in organic farming were conducted in the most common and typical for the southern region of the steppe of Ukraine short-rotation crop cultivation with the following alternation of crops: peas – winter wheat – winter barley – ½ sunflower fields + ½ corn fields. During the years of the first cultivation, the experiment showed the advantages of a system of differentiated tillage, where even without the use of bio-decomposers, the highest yield of cereals was obtained – 3.64 tons/ha and sunflower – 2.20 tons/ha (check experiment). The application of the planar-free system combined with multi-depth and especially planar-free shallow soil processing, main tillage caused a decrease in grain yields by 0.11-0.39 tons/ha and sunflower by 0.28-0.42 tons/ha, respectively. With the use of bio-decomposers provided by brands Ecostern and Cellulad, yields' growth is in the range of 0.13-0.25 t/ha or 4.5-8.7% for cereals and 0.10-0.23 t/ha or 5.4-12.4% for sunflower. The application of the Ecostern bio-decomposer 1.5 l/ha provided an increase in the yield from 1 ha of crop rotation area of grain, fodder, fodder-protein units and digestible protein on average in all systems of basic tillage by 4.7, respectively; 4.5; 4.3 and 5.4%, and with the introduction of Cellulad 2.0 l/ha, these figures increased by 9.5, respectively; 8.9; 8.6 and 10.8% compared to options without the introduction of bio-decomposers

Keywords: farming, bio-decomposers, economic and natural conditions, restoration of soil fertility, yields' growth

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INTRODUCTION

At the current stage of development of Ukraine, as a country with a strong agro-industrial complex aimed at integration into the European Community, increasing the production of agricultural products is impossible without improving the agricultural sector. The main goal of reforming the agricultural sector of the country's economy is to obtain from each hectare of land the largest amount of high quality, environmentally friendly products with minimal production costs, while maintaining and increasing soil fertility and environmental protection. The past decade for Ukraine's agriculture has been characterized with a high rate of intensification of the industry, which is opposite in the background of excessive anthropogenic pressure on agricultural landscapes and their high level of depletion [1]. In today's world, more and more people are thinking about the excessive chemicalization of agricultural production, contributing to high level of total harvests. All of it has an extremely negative impact on the environment and human health. The first in the world to face the negative consequences of the intensification of agriculture were the advanced economies of Western Europe, such as the United States, Canada, Great Britain, and others. Progress in the modern world not only brings material welfare to mankind, but also causes an ever-increasing ecological load on the biosphere – soil, natural and artificial reservoirs, rivers, atmosphere, living organisms, etc. [2]. Opinions of scientists and producers of agricultural products have appealed to the alternative farming systems, including biological.

The ultimate goal of alternative agriculture is ecologically balanced agriculture and animal husbandry in order to provide people with ecologically clean food. Alternative agriculture does not mean a return to the old extensive technology, although it does not preclude the use of some of its elements. However, new systems must be competitive, i.e. highly productive [3]. However, at the present stage of agricultural development, the idea of organic farming requires a new approach, new technical solutions for the maximum possible returning to the soil of nutrients in the form of straw, manure, compost, municipal waste, green manure. The key to the effective development of agriculture around the world is the development and implementation of innovative, adapted farming systems. According to the National Standard of Ukraine [4] the term "biological system of agriculture" is a system of agriculture without the use of chemical fertilizers and pesticides. In Ukraine, as well as around the world, the demand for quality and safe food is growing, and the term "organic products" and "organic production" has recently become especially popular. In the nearest future, Ukraine should become a European leader in the production of organic food, as it has a large area of highly fertile land in Europe. Organic farming is a promising way of agricultural development in the world and in Ukraine. In agricultural science, sufficient experimental experience has been accumulated of the crucial importance of tillage in the system of agriculture. It is under the action of tillage that the agrophysical and agrobiological properties of the soil, its water, air, heat and nutrient regimes are regulated, the number of weeds, pests and the spread of pathogens in agrophytocenoses of field crops are regulated. Tillage ensures that the seeds and fertilizers are wrapped to the required depth, and other additional conditions are created for normal plant growth and development and crop formation [5-7].

In recent decades, Ukraine has carried out an extensive work to improve existing system and developing new one, more efficient tillage systems in accordance with specific soil and climatic conditions. Appropriate systems of basic, pre-sowing tillage and crop care have been developed, the need for differentiation of depth and number of tillage in crop rotation has been substantiated, and a system of soil protection tillage has been proposed for areas where wind and water erosion are observed [8-10]. Ukrainian modern agriculture uses differentiated tillage for individual crops in crop rotations using the latest equipment and technologies: a combination of plowing, tilting the soil without or before ploughing, chiseling, surface tillage (discs and cultivators) and the method of direct sowing without tillage. Studies conducted in recent years have shown that mechanical tillage, which aims to create optimal conditions for growth, development and crop formation of agricultural plants, occupies a leading place in the agricultural system. The main tillage, which uses 60-75% of the total fuel consumption and funds intended for tillage throughout the growing season is a major element in the overall process cycle. The variety and features of existing methods and systems of tillage solve its main task in creating optimal conditions in the arable layer, where a significant part of the absorbing surface of the root system of plants is concentrated and it is in this layer of soil should be sufficient for germination and further development of plants. and organic compounds. Only by scientifically-based cultivation adapted to a specific group of agroecological soil conditions are favorable for the life of field crops [11-13].

The leading link in any system of agriculture is the rational structure of areas under cultivation and the system of crop rotations. This link acquires special significance under the conditions of the biological system of agriculture. It is responsible for the process of self-regulation of soil fertility and expanded reproduction of soil fertility. In Ukraine, crop rotations have a classic ecological basis. One crop rotation includes a large composition of crops from different families, i.e. they can simultaneously grow crops with different biological properties. Agrotechnical and biological basis of crop rotations with a wide range of crops is provided by the annual change of different plants in the field. The sharper the difference between crops and the greater the period between the return to the same field of the corresponding group of plants, the higher the effect of the entire crop rotation. Due to the rotation of crops with different biological properties, better conditions are created for the growth and development of plants and increase in the collection of ecologically clean products of organic farming. However, the productivity of crop rotations in organic farming is inferior to crop rotations with organo-mineral fertilizer system by 16-22% [14]. The main performance by increasing their crop rotation is optimal saturation of high-yielding crops while maintaining, restoring and improving soil fertility. Different crop rotation, as well as the use of optimal fertilization and tillage system significantly affect crop productivity in general: grain and oilseed yields from 1 ha of crop rotation area, yield of grain, fodder, feed-protein units and digestible protein from 1 ha of arable land. After all, the productivity of crop rotations is determined in kind by the collection of basic products, and for the general assessment of crop rotation – in the conversion of all products (main and secondary) into grain, feed, feed protein units and digestible protein [15; 16].

The aim of the research. The research envisages: to establish the influence of different systems of basic tillage and application of bio-decomposers of straw Ecostern 1.5 l/ha and Cellulad 2 l/ha in short-rotation crop rotation on the yield of individual crops and overall crop rotation productivity in organic farming of the Southern Steppe of Ukraine.

MATERIALS AND METHODS

Evaluation of crop rotation efficiency should be carried out comprehensively, taking into account a number of indicators. To compare the productivity of short-rotation field crop rotation, depending on the factors studied in the experiment, the indicators of grain and seed production of oilseeds, yield of grain, feed, feed protein units and the availability of digestible protein were taken into account. Conducting organic farming in the arid Southern Steppe of Ukraine has certain features and weaknesses and therefore the focus should be on the implementation of elements of biologization of agriculture, based on specific soil and climatic conditions of farms management and specialization. Undoubtedly, the best conditions for the biologization of agriculture and the production of environmentally friendly products are created in farms of mixed type with the presence of certain livestock industries. In farms of grain or grain-oil specialization, which is the vast majority of farms in the Southern Steppe, there are problems with the implementation of biologization measures. Of particular importance, this problem is in terms of global warming and the conditions for the growth of harmful effects of drought in the southern region. It is the lack of precipitation, and sometimes the complete absence of them in the second half of the growing season, makes it impossible to obtain seedlings of green crops, low share of by-products of field crops in drought, low productivity of legumes and low share in the structure of sown areas, all worsens balance of nutrients in the soil. Thus, according to Ye. Yurkevych [17-20], for four years of research in the Southern Steppe, not even seedlings of post-harvest green manure crops were obtained, due to the lack of productive moisture in the soil. The research is carried out in a grain-rotating short-rotation 4-field crop cultivation with the following alternation of crops: peas – winter wheat – winter barley – ½ sunflower fields + ½ corn fields. The soil of the experimental plot is chernozem(blacksoil) ordinary, low-humus, medium-thick, heavy loam in the forest. Place of research: Ivaniv district of Odesa region of Ukraine. Scheme of the experiment: two-factor experiment:

Factor A – main tillage systems:

a_1 differentiated – check;
a_2 – planar-free multi-depth;
a_3 – planar-free shallow;

Factor B – bio-decomposers of by-products:

b_1 – without bio-decomposers
b_2 – Ecostern 1.5 l / ha;
b_3 – Cellulite 2.0 l / ha.

Variants of the experiment are placed in 3 repetitions by the method of split sections. The total area under experiment – 7.78 ha land area in the experiment: soil tillage – 2158 m^2, bio-decomposers – 2160 m^2. In the experiment, zoned varieties and hybrids of crops were sown (Table 1).

***Table 1**. Scheme of basic tillage systems in the experiment*

Variants of basic tillage systems	No. crops in crop rotation			
	1	2	3	4
	Peas for grain	Soft winter wheat	Winter barley	½ corn for the grain ½ sunflower
Differentiated (check)	Planar deep, 23-25 cm	Shallow, 10-12 cm	Planar-free shallow, 10-12 cm	Planar deep, 25-27 cm Planar deep, 25-27 cm
Planar-free different-depth	Planar-free shallow, 12-14 cm	Planar-free shallow, 10-12 cm	Planar-free shallow, 10-12 cm	Planar-free shallow, 12-14 cm Planar-free shallow, 12-14 cm
Planar-free shallow	Planar-free shallow, 10-12 cm	Planar-free shallow, 10-12 cm	Planar-free shallow, 10-12 cm	Planar-free shallow, 10-12 cm Planar-free shallow, 10-12 cm

Agricultural techniques for growing crops in the experiment, in addition to the options studied, were recommended for the study area, taking into account the requirements of organic farming. The total crop rotation productivity was determined in kind by the volume of main and by-products from 1 ha of crop rotation area, as well as in the conversion of these products into grain units by V. Grevtsov [21] coefficients, feed, feed protein units and digestible protein according to M. Tomme [22] tables. The obtained results were subjects to statistical analysis of variance according to B. Dospekhov [23].

RESULTS AND DISCUSSION

In addition to economic, energy and agro-technical assessment of the effectiveness of any crop rotation, farmers and scientists are largely interested in its productivity. This indicator makes it possible to assess the agro-technical impact of predecessors, the system of basic tillage, fertilizers, ameliorants, biostimulants, etc., on increasing soil fertility, which determines the yield of each crop and crop rotation in general. Table 2, Figures 1 and 2 shows the average data for assessing the productivity of short-rotation oilseed crop rotation for the first rotation, depending on the implementation of different systems of basic tillage in crop rotation and the use of bio-decomposers of crop by-products of crop rotation.

LSD (Least Significant Difference). The scheme of short-rotation crop rotation for research of the impact of the system of basic tillage and the use of bio-decomposers of straw and after harvest residues in organic farming was chosen on purpose. Crops grown in crop rotation are typical are the most common and the most typical for agriculture in the arid southern region of the Steppe of Ukraine. The development of measures aimed at increasing the productivity of this crop rotation will improve the market supply of agricultural products with grain and oil.

***Table 2**. Productivity of short-rotation crop cultivation depending on the studied factors, average 2015-2018 [t/ha]*

Tillage system	Crops rotation in rotation	Crop capacity, [t/ha]		Yield of arable land, [t/ha]			
		Cereals	Oilseeds	Grain units	Feed units	Feed and protein units	Digestible protein
Without bio-decomposers							
Differentiated (check)	Peas	2.41		3.90	3.85	4.83	0.58
	Winter wheat	3.61		4.12	5.35	5.04	0.48
	Winter barley	2.87		2.64	4.73	3.74	0.28
	Sunflower		2.20	2.51	0.65	1.36	0.21
	Corn	5.68		3.81	6.19	4.85	0.35
Total in crop rotation				**16.99**	**20.77**	**19.81**	**1.89**
Average in crop rotation		**3.64**	**2.20**	**4.25**	**5.19**	**4.95**	**0.48**
Planar-free Multi-depth	Peas	2.33		3.79	3.74	4.68	0.57
	Winter wheat	3.60		4.11	5.34	5.03	0.47
	Winter barley	2.95		2.71	4.85	3.83	0.28
	Sunflower		1.92	2.20	0.57	1.19	0.18
	Corn	5.21		3.49	5.67	4.44	0.32
Total in crop rotation				**16.30**	**20.16**	**19.17**	**1.82**
Average in crop rotation		**3.53**	**1.92**	**4.08**	**5.04**	**4.80**	**0.46**
Planar-free shallow	Peas	2.21		3.58	3.54	4.43	0.53
	Winter wheat	3.22		3.67	4.77	4.50	0.42
	Winter barley	2.58		2.37	4.24	3.35	0.25
	Sunflower		1.78	2.03	0.53	1.10	0.17
	Corn	4.97		3.34	5.43	4.25	0.31
Total in crop rotation				**14.99**	**18.59**	**17.68**	**1.68**
Average in crop rotation		**3.25**	**1.78**	**3.75**	**4.64**	**4.42**	**0.42**

Table 2, Continued

Tillage system	Crops rotation in rotation	Crop capacity, [t/ha]		Yield of arable land, [t/ha]			
		Cereals	**Oilseeds**	**Grain units**	**Feed units**	**Feed and protein units**	**Digestible protein**
Bio-decomposer Ecostern 1.5 l/ha;							
Differentiated (check)	Peas	2.63		4.26	4.20	5.27	0.63
	Winter wheat	3.86		4.41	5.72	5.39	0.51
	Winter barley	3.01		2.78	4.97	3.93	0.29
	Sunflower		2.32	2.64	0.69	1.43	0.22
	Corn	6.01		4.03	6.56	5.14	0.37
Total in crop rotation				**18.12**	**22.13**	**21.15**	**2.01**
Average in crop rotation		**3.88**	**2.32**	**4.53**	**5.54**	**5.29**	**0.50**
Planar-free Multi-depth	Peas	2.51		4.07	4.02	5.03	0.60
	Winter wheat	3.86		4.40	5.72	5.39	0.51
	Winter barley	3.08	2.16	2.83	5.06	4.00	0.30
	Sunflower		1.98	2.31	0.61	1.25	0.19
	Corn	5.49		3.69	6.00	4.69	0.34
Total in crop rotation				**17.30**	**21.39**	**20.36**	**1.93**
Average in crop rotation		**3.73**	**2.02**	**4.33**	**5.35**	**5.09**	**0.49**
Planar-free shallow	Peas	2.37		3.84	3.79	4.75	0.57
	Winter wheat	3.46		3.95	5.12	4.83	0.46
	Winter barley	2.72		2.50	4.47	3.53	0.26
	Sunflower		1.86	2.12	0.56	1.15	0.17
	Corn	5.23		3.51	5.71	4.47	0.32
Total in crop rotation				**15.97**	**19.74**	**18.80**	**1.79**
Average in crop rotation		**3.44**	**1.86**	**3.99**	**4.94**	**4.70**	**0.45**
Bio-decomposer Cellulad 2.0 l/ha;							
Differentiated (check)	Peas	2.67		4.32	4.26	5.34	0.64
	Winter wheat	4.03		4.59	5.96	5.62	0.53
	Winter barley	3.15		2.90	5.19	4.10	0.30
	Sunflower		2.38	2.72	0.71	1.47	0.22
	Corn	6.10		4.09	6.65	5.20	0.38
Total in crop rotation				**18.63**	**22.77**	**21.73**	**2.09**
Average in crop rotation		**3.99**	**2.38**	**4.66**	**5.70**	**5.43**	**0.52**
Planar-free Multi-depth	Peas	2.54		4.13	4.08	5.10	0.61
	Winter wheat	4.01		4.57	5.94	5.60	0.53
	Winter barley	3.18		2.92	5.22	4.12	0.30
	Sunflower		2.11	2.41	0.63	1.30	0.20
	Corn	5.55		3.72	6.05	4.74	0.34
Total in crop rotation				**17.75**	**21.91**	**20.86**	**1.98**
Average in crop rotation		**3.82**	**2.11**	**4.44**	**5.48**	**5.21**	**0.50**

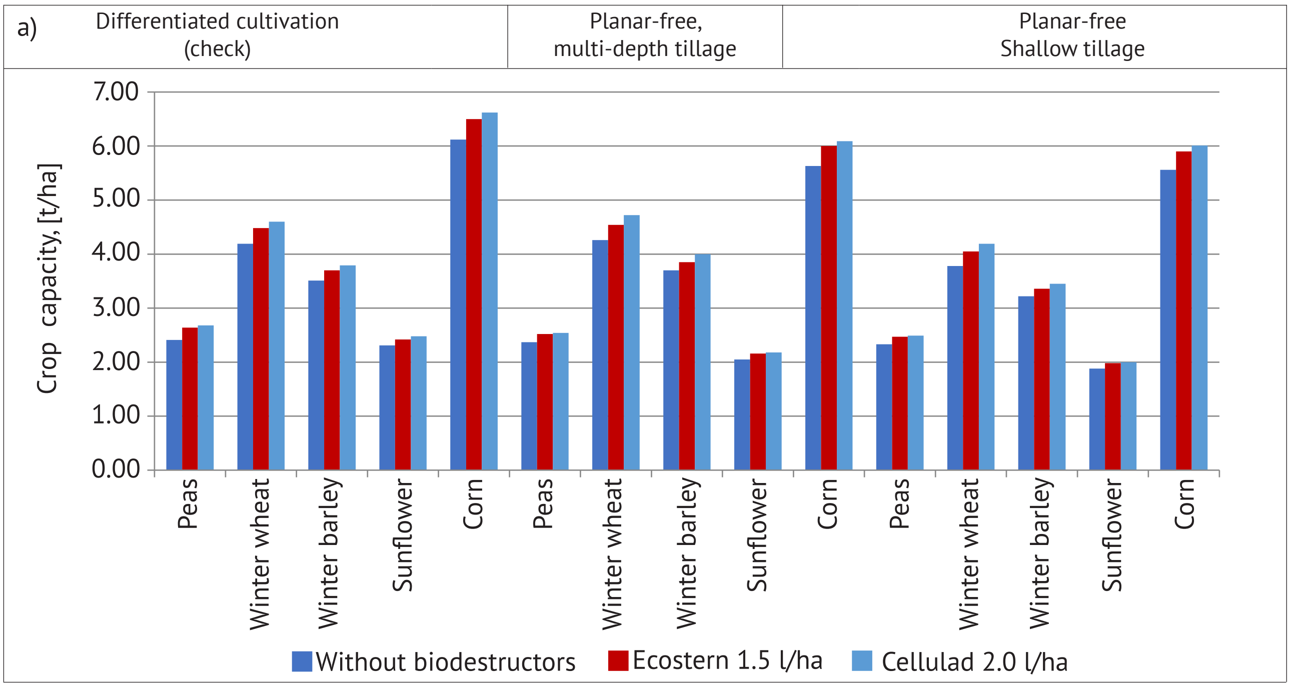
Table 2, Continued

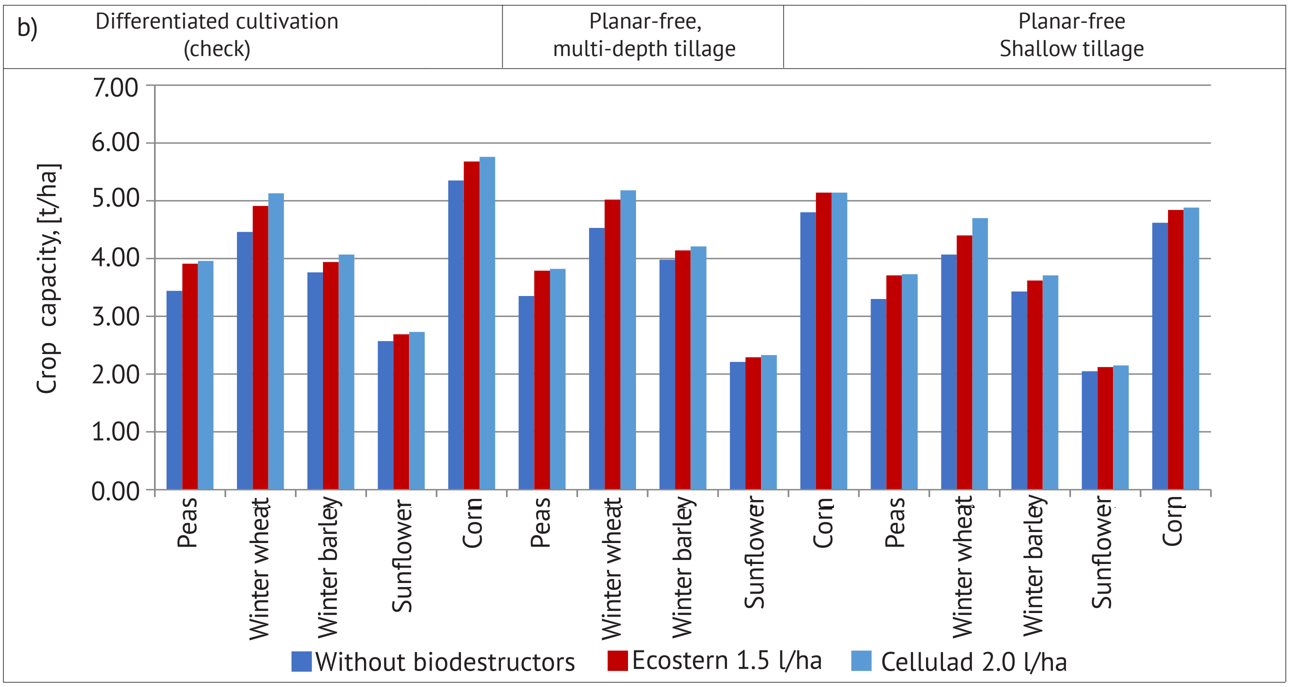
Tillage system	Crops rotation in rotation	Crop capacity, [t/ha]		Yield of arable land, [t/ha]			
		Cereals	Oilseeds	Grain units	Feed units	Feed and protein units	Digestible protein
Planar-free shallow	Peas	2.39		3.88	3.83	4.80	0.58
	Winter wheat	3.66		4.18	5.42	5.11	0.48
	Winter barley	2.81		2.59	4.62	3.65	0.27
	Sunflower		1.90	2.17	0.57	1.17	0.18
	Corn	5.30		3.55	5.77	4.52	0.33
Total in crop rotation				**16.36**	**20.20**	**19.25**	**1.83**
Average in crop rotation		**3.54**	**1.90**	**4.09**	**5.05**	**4.81**	**0.46**
LSD_{05}	Factor A	0.03-0.06	0.03-0.08	0.02	0.01-0.03	0.02-0.03	0.02-0.09
	Factor B	0.03-0.06	0.03-0.08	0.02	0.01-0.03	0.02-0.03	0.02-0.09
	Interaction of AB factors	0.05-0.11	0.04-0.14	0.04	0.02-0.05	0.03-0.06	0.03-0.15

During the years of the first rotation (Table 2, Fig. 1, 2), the experiment showed the advantages of a system of differentiated tillage, where even without the use of bio-decomposers, the highest crop capacity of cereals was obtained – 3.64 t/ha and sunflower – 2.20 t/ha (check). The application of the system of planar-free shallow tillage caused a slight decrease in the yield of grain crops by 0.11 t/ha and sunflower by 0.28 t/ha. An even greater decrease in the crop capacity occurred in the experiment in the version with a system of planar-free shallow main tillage, where the yield of cereals was – 3.25 t/ha, or 0.39 t/ha less than the check experiment, and sunflower respectively – 1.78 t/ha, or 0.42 t/ha less.

The productivity of the group of both grain and oilseeds as a whole, as well as individual crops of short-rotation field crop cultivation, changed under the influence of factors that were studied in the experiment and the weather conditions of the research years. It was found that without the use of straw bio-decomposers, the highest grain crop capacity was obtained in the experiment in the version with a system of differentiated basic tillage in crop rotation in 2016 – 4.25 t/ha (Fig. 1). This year is characterized as very favorable in terms of hydrothermal parameters (hydrothermal coefficient = 2.18). Some decrease in grain yield occurred in variants with a system of planar-free multi-depth and planar-free shallow main tillage in crop rotation, respectively, by 0.08-0.39 t/ha, or 1.9-9.2% (LSD_{05}=0.05 t/ha). Similarly, for oilseeds – sunflower, the yield in the version with a system of differentiated basic tillage in crop rotation was – 2.57 t/ha, which is 0.36-0.52 t/ha, or 14.0-20.2% more in comparison with the systems of planar-free multi-depth and planar-free shallow main tillage (LSD_{05}=0.09 t/ha). The yield of grain and oilseeds was slightly lower in 2015, although this year was generally favorable for the growth and development of field crops and hydrothermal indicators exceeded the average long-term data (hydrothermal coefficient = 1.06), but elevated temperatures during filling and grain formation winter crops led to its ignition and the formation of lean grain with a low mass of 1000 grains. The grain yield without the introduction of straw bio-decomposers this year was – 4.06 t/ha in the version with a system of differentiated main tillage in crop rotation and significantly exceeded the options with a system of planar-free shallow and pl nar-free shallow main tillage by 0.07-0.3, or 1.9-8.4% (LSD_{05}=0.03 t/ha). The cultivation of oilseeds – sunflower on the system of planar-free shallow main tillage led to a decrease in seed crop capacity, respectively, by 0.26-0.43 t/ha, or 11.3-18.6% (LSD_{05}=0.05 t/ha). in comparison with the control variant, with the system of differentiated tillage, where the seed yield was at the level of 2.31 t/ha.

In the conditions of 2017 (hydrothermal coefficient = 0.91) and 2018 (hydrothermal coefficient = 0.42) years, which according to weather conditions, namely the level of moisture and temperature were characterized as sufficiently unfavorable for the growth and development of cereals and oilseeds, the authors observed significant reduction of the total productivity of cultivated crops in short-rotation crop cultivation. But even in these years, the highest yields of cereals and oilseeds were obtained without the use of bio-decomposers of straw, in the version with a system of differentiated basic tillage: 2017 – 3.09 t/ha of grain and 2.08 t/ha – sunflower; 2018, respectively – 3.17 t/ha of grain and 1.83 t/ha of sunflower. It is the difficult weather conditions of these years, insufficient moisture and abnormal heat, did not allow plants to realize their potential productivity. Thus, compared to the best 2016, in the version without the use of straw bio-decomposers, with a system of differentiated basic tillage in crop rotation, the productivity of cereals decreased by 1.16-1.08 t/ha, respectively, or 27.3-25.4%, and for sunflower by 0.49-0.74 t/ha, or 19.1-28.8%. The response of cereals and sunflower to the minimization of basic cultivation in extreme years was also not the same. In 2017, the introduction of systems of planar-free multi-depth and planar-free shallow main tillage led to a decrease in grain yields without the introduction of straw bio-decomposers by 0.19-0.43 t/ha, or 6.1-13.9% (LSD_{05}=0.06 t/ha), and oil – sunflower by 0.27-0.41 t/ha, or 13.0-19.7% (LSD_{05}=0.08 t/ha). The same pattern was revealed in the studies of V. Tsikov [24] and S. Tanchyk et al. [25] under the conditions of the ecological system of agriculture. Similar changes took place in 2018, where the use of systems of planar-free shallow multi-depth and planar-free shallow main tillage without the use of straw bio-decomposers, led to a decrease in grain yields by 0.13-0.43 t/ha, or 4.1-13.6% (LSD_{05}=0.05 t/ha). A similar pattern of the influence of systems of minimization of basic tillage in crop rotation on the yield of oilseeds – sunflower, where its yield in the version with a system of differentiated basic tillage was – 1.83 t/ha, and in options with a system of non-planar tillage it significantly decreased by 0.21-0.33 t/ha, respectively, or by 11.5-18.0% (LSD_{05}=0.04 t/ha). The reaction of individual cereals crop rotation to the systems of basic tillage in crop cultivation was different depending on their biological characteristics and weather conditions of the year. Over the years of research, the best soil conditions were observed in the case with a system of differentiated basic tillage. However, in the case of winter wheat and winter barley crops, the experiment did not observe a clear advantage of the system of differentiated basic tillage for yield formation in comparison with the systems of planar-free deep and shallow main tillage. On the contrary, in winter barley, slightly higher grain yield was in the variant with the system of planar-free multi-depth basic tillage, while in winter wheat grain crop capacity decreased under such a system of basic tillage. But these crops significantly reduced the capacity in the option with a system of planar-free shallow main tillage in short-rotation crop cultivation.





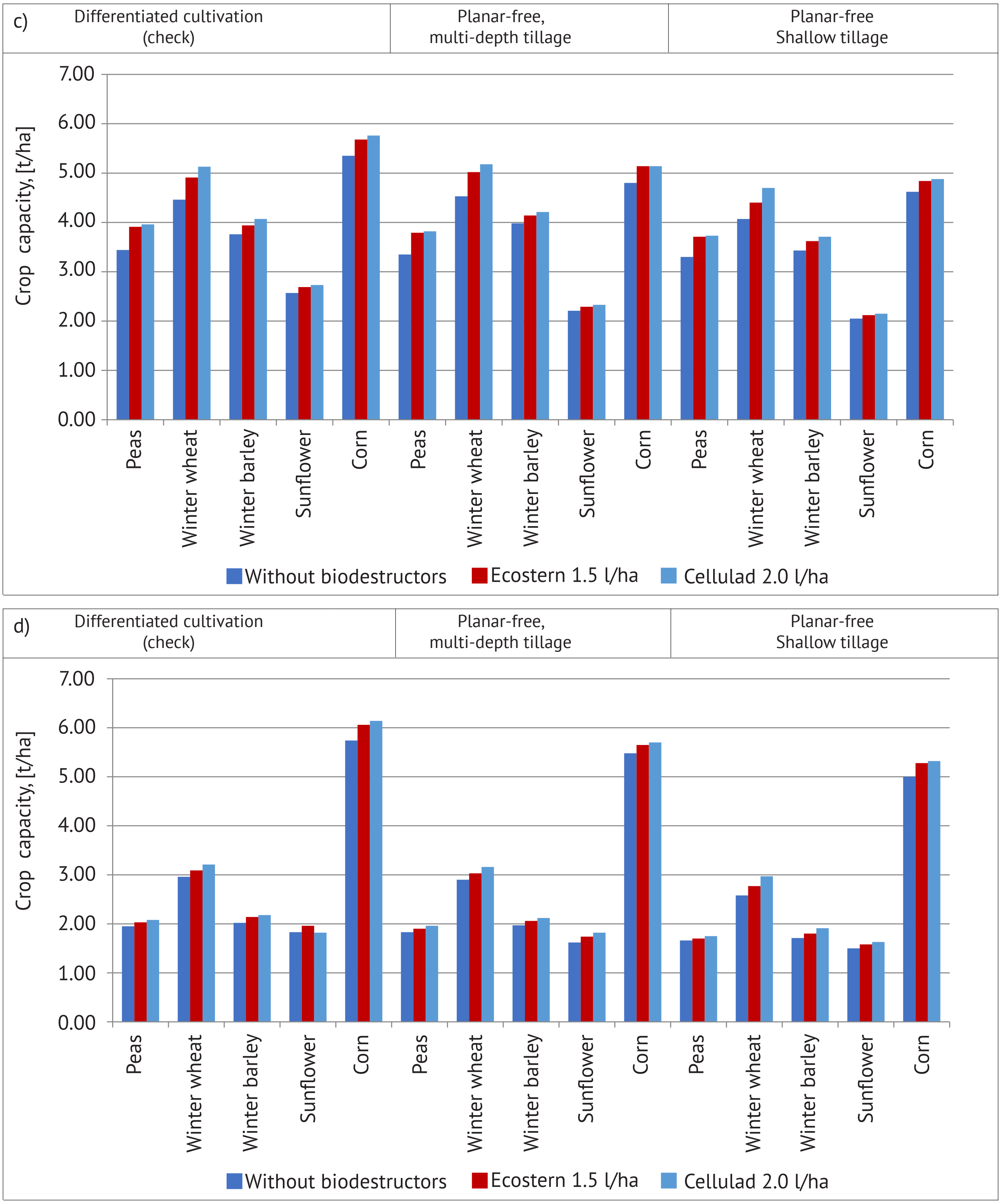


***Figure 1**. Crop capacity of cereals and oilseeds depending on tillage and used bio-decomposers for 2015-2018: a) 2015, b) 2016, c) 2017, d) 2018*

Thus, over the years of research, for winter wheat grain change for systems of planar-free multi-depth and planar-free shallow main tillage in short-rotation crop cultivation in comparison with the check variant – system of differentiated main tillage compared to the background without bio-decomposers within straw:

2015, +0.09 and -0.41 t/ha, (LSD_{05}=0.03 t/ha);
2016, +0.07 and -0.39 t/ha, (LSD_{05}=0.04 t/ha);
2017, -0.12 and -0.40 t/ha, (LSD_{05}=0.06 t/ha);
2018, -0.06 and -0.38 t/ha, (LSD_{05}=0.05 t/ha).

The same applies for winter barley, respectively:

2015, +0.19 and -0.29 t/ha, (LSD_{05}=0.03 t/ha);
2016, +0.22 and -0.33 t/ha, (LSD_{05}=0.04 t/ha);
2017, -0.04 and -0.23 t/ha, (LSD_{05}=0.06 t/ha);
2018, -0.05 and -0.31 t/ha, (LSD_{05}=0.05 t/ha).

The reaction of spring crops of peas and especially corn and sunflower to the use of systems of planar-free shallow multi-depth and planar-free shallow main tillage in short-rotation crop cultivation was extremely negative. Thus, the following decrease in yield was observed in the experiment, respectively:

2015, -0.04 and -0.08 t/ha, (LSD_{05}=0.03 t/ha);
2016, -0.09 and -0.14 t/ha, (LSD_{05}=0.04 t/ha);
2017, -0.05 and -0.33 t/ha, (LSD_{05}=0.06 t/ha);
2018, -0.12 and -0.29 t/ha, (LSD_{05}=0.05 t/ha).

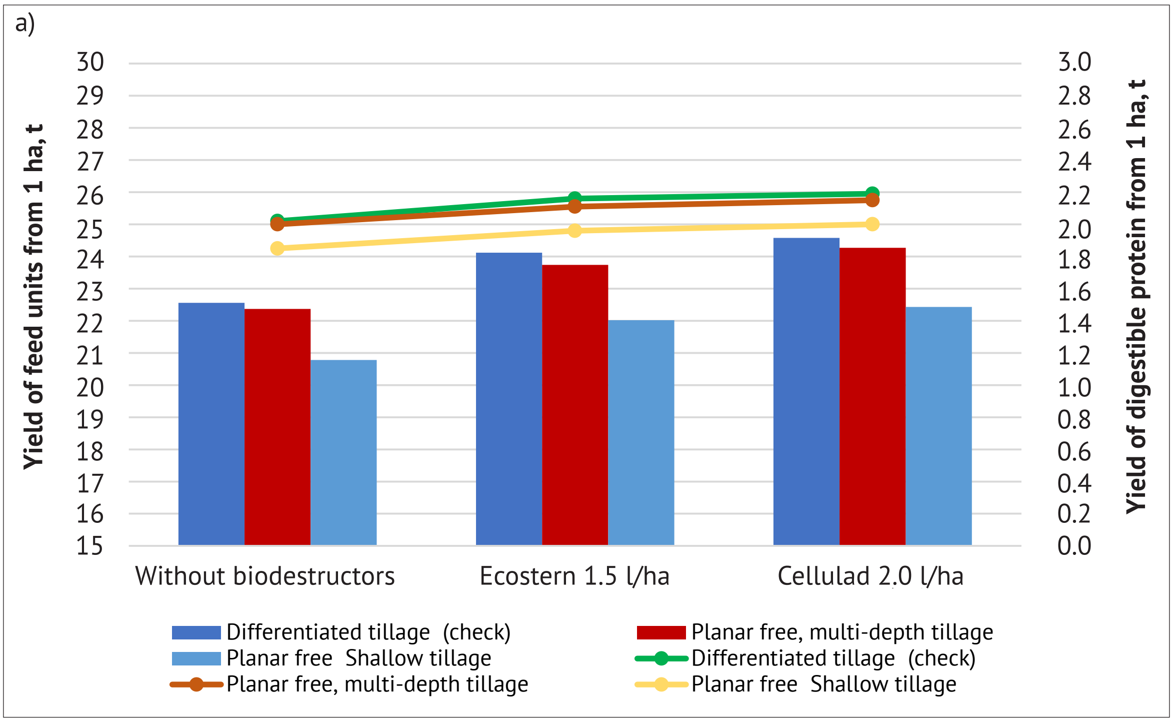
The reaction of sunflower culture was much greater to the use of planar-free systems of different depths and shallow basic tillage in crop rotation, namely:

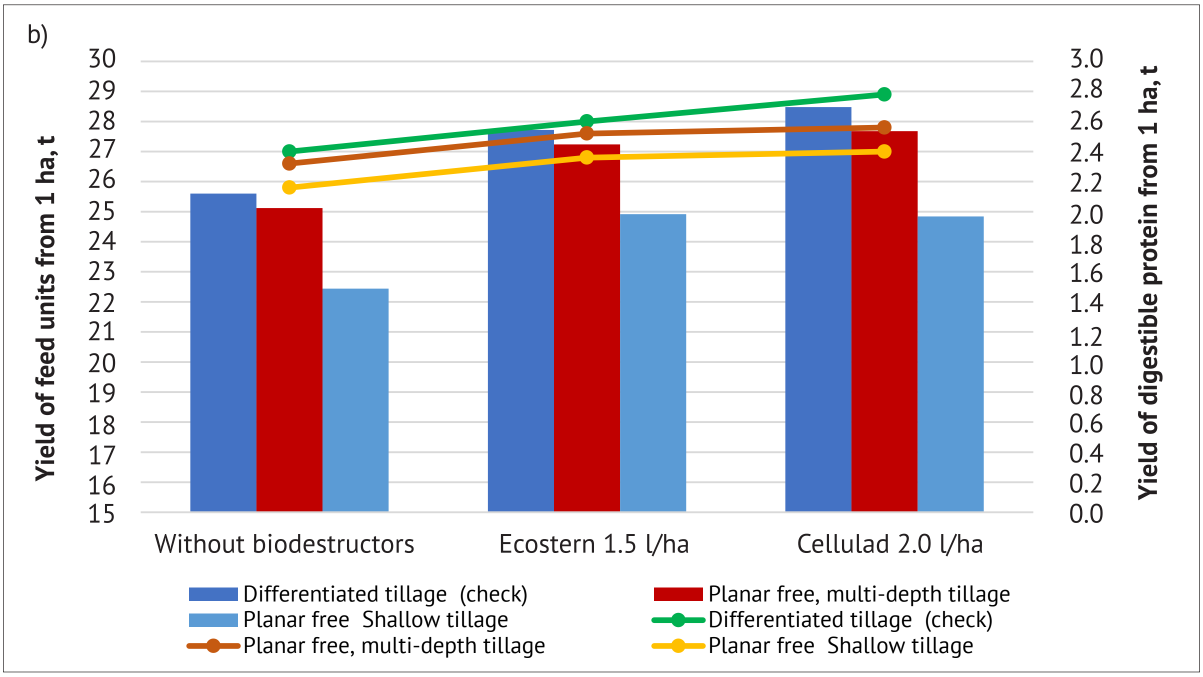
2015, -0.26 and -0.43 t/ha, (LSD_{05}=0.03 t/ha);
2016, -0.36 and -0.52 t/ha, (LSD_{05}=0.05 t/ha);
2017, -0.13 and -0.41 t/ha, (LSD_{05}=0.08 t/ha);
2018, -0.21 and -0.33 t/ha, (LSD_{05}=0.04 t/ha).

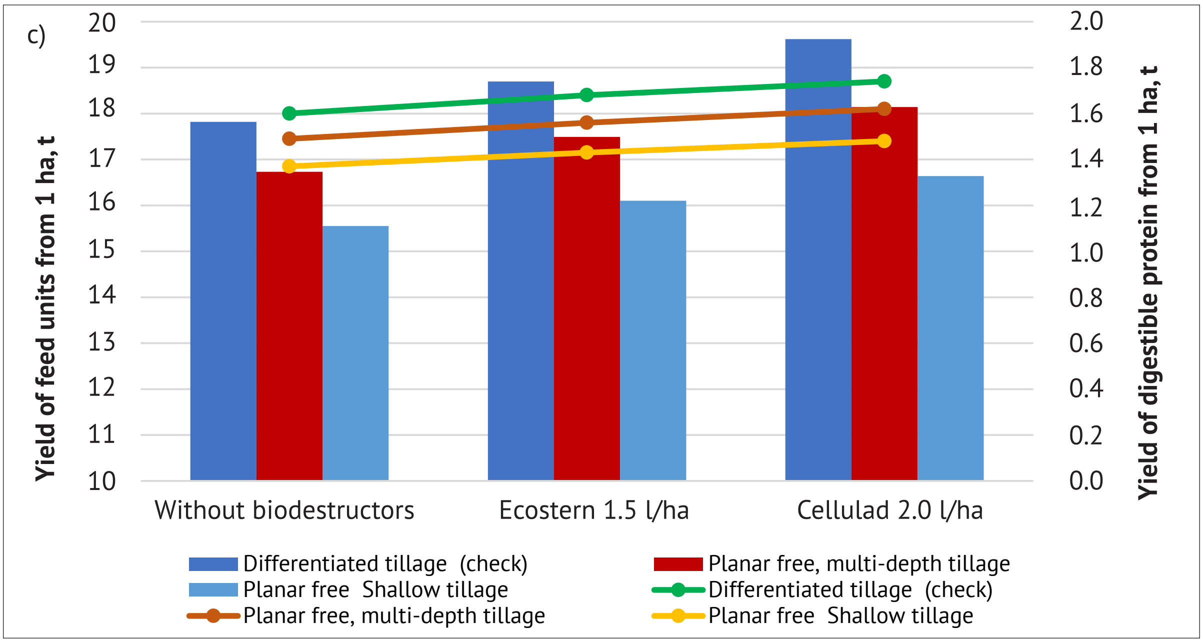
And the corn crop reacted the most to the minimization of the system of basic tillage in crop rotation:

2015, -0.49 and -0.56 t/ha, (LSD_{05}=0.03 t/ha);
2016, -0.55 and -0.73 t/ha, (LSD_{05}=0.04 t/ha);
2017, -0.61 and -0.81 t/ha, (LSD_{05}=0.06 t/ha);
2018, -0.26 and -0.74 t/ha, (LSD_{05}=0.05 t/ha).

According to the results of the research it is revealed that not only the systems of basic tillage in short-rotation crop cultivation, but also the use of various bio-decomposers of straw Ecostern and Cellulad significantly affected the yield of individual crops and overall crop rotation productivity as a whole. The efficiency of straw bio-decomposers was determined by the conditions of the year, as well as by different ways of post-harvest residues entering the soil depending on the system of basic tillage in short-rotation crop cultivation. However, it was found that the bio-decomposer Cellulad, in terms of efficiency, exceeds the bio-decomposer Ecostern. Thus, on average, for all variants of the main tillage systems in 2015, the application of the bio-decomposer Ecostern 1.5 l/ha increased the yield capacity of grain crops by 0.25 t/ha, or 6.4% (LSD_{05}=0.03 t/ha), and sunflower – by 0.11 t/ha, and 5.3% (LSD_{05}=0.03 t/ha). When using the bio-decomposer Cellulad 2.0 l/ha, the yield increased by 0.41 t/ha, or by 9.7% (LSD_{05}=0.03 t/ha), and 0.13 t/ha and 5.7 by sunflower, respectively (LSD_{05}=0.03 t/ha). Deterioration of plant moisture conditions due to lack of precipitation in 2017 significantly reduced the effectiveness of straw bio-decomposers. Against the background of the introduction of the bio-decomposer Ecostern 1.5 l/ha on average for all systems of basic tillage in crop rotation, the increase in grain yield was only 0.13 t/ha, or 4.5% (LSD_{05}=0.06 t/ha), and for sunflower 0.10 t/ha, or 4.5% (LSD_{05}=0.08 t/ha). Against the background of the application of the bio-decomposer Cellulad 2.0 l/ha, the increase in grain yield was 0.25 t/ha, or 8.7% (LSD_{05}=0.06 t/ha), and for sunflower, respectively, 0.23 t/ha and 12.4% (LSD_{05}=0.08 t/ha).




b)
Yield of feed units from 1 ha, t
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
Yield of digestible protein from 1 ha, t
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Without biodestructors
Ecostern 1.5 l/ha
Cellulad 2.0 l/ha
Differentiated tillage (check)
Planar free, multi-depth tillage
Planar free Shallow tillage
Differentiated tillage (check)
Planar free, multi-depth tillage
Planar free Shallow tillage


c)
Yield of feed units from 1 ha, t
20
19
18
17
16
15
14
13
12
11
10
Yield of digestible protein from 1 ha, t
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Without biodestructors
Ecostern 1.5 l/ha
Cellulad 2.0 l/ha
Differentiated tillage (check)
Planar free, multi-depth tillage
Planar free Shallow tillage
Differentiated tillage (check)
Planar free, multi-depth tillage
Planar free Shallow tillage

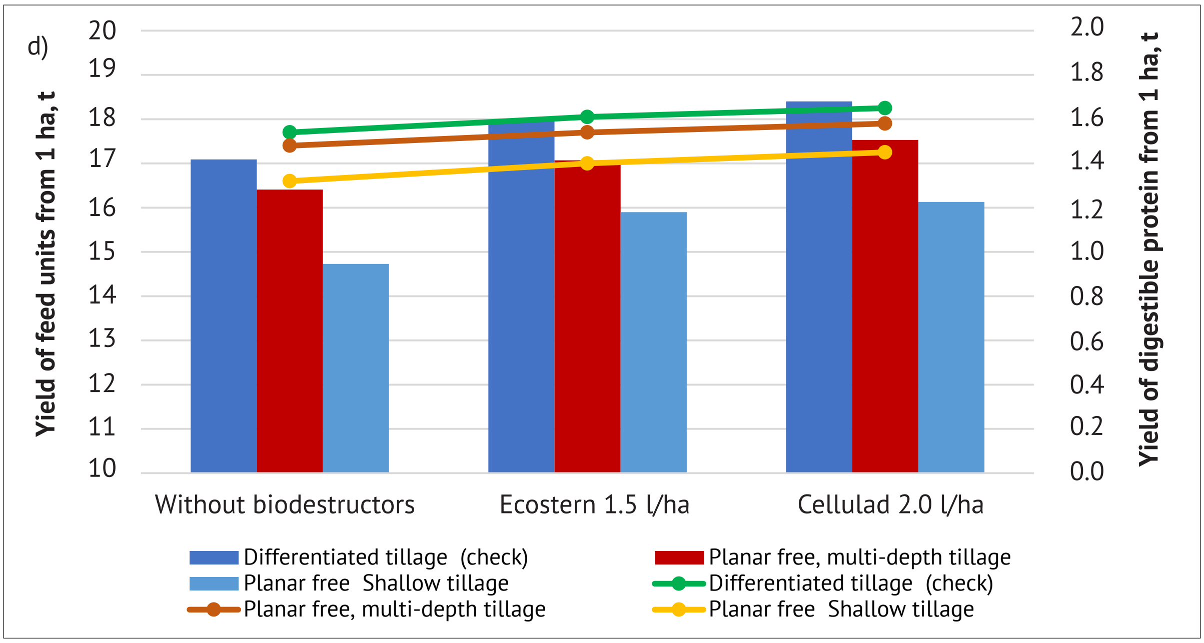


Figure 2. *Total productivity of short-rotation crop cultivation depending on tillage and used bio-decomposers for 2015-2018: a) 2015, b) 2016, c) 2017, d) 2018*

In 2018, the use of Ecostern straw bio-decomposer 1.5 l/ha provided an increase in grain yield for all systems of basic tillage in crop rotation at the level of 0.15 t/ha or 5.0% (LSD_{05}=0.05 t/ha) and sunflower by 0.11 t/ha, or 6.7% (LSD_{05}=0.04 t/ha). But the largest increase in yield this year was observed against the background of the application of the bio-decomposer Cellulad 2.0 l/ha and averaged on all systems of basic tillage, on cereals 0.23 t/ha, or 7.7% (LSD_{05}=0.05 t/ha), and for oilseed sunflower – 0.17 t/ha, or 10.3% (LSD_{05}=0.04 t/ha). Also, in the researches of V. Malyarchuk and M. Starodubtseva [26], A. Kushnaryov et al. [27] they proved the effectiveness of bio-decomposers with the background of a system of differentiated basic tillage in crop rotation. According to the results of research conducted during 2015-2018. The experiment showed a clear pattern of the advantage of the system of differentiated tillage in grain plowing short-rotation crop cultivation in comparison with planar-free multi-depth and planar-free shallow systems of basic tillage (Table 2). Thus, without the use of straw bio-decomposers in the differential system of basic tillage, the aver-age crop capacity of cereals was – 3.64 t/ha, which exceeded the options with planar-free multi-depth and planar-free shallow tillage, respectively, 0.11-0.39 t/ha (LSD_{05} A=0.03-0.06), or 3.0-10.7%. The same pattern was observed for the influence of basic tillage systems on the productivity of oilseeds – sunflower, where the yield of seeds according to the system of differentiated tillage without the use of bio-decomposers – 2.20 t/ha, which is 0.28-0.42t/ha (LSD_{05} A=0.03-0.08), or by 12.7-19.1% more in comparison with variants with the system of planar-free different depth and planar-free shallow tillage.

The scientific works of A. Kuznetsov [28], V. Loshakov [29], O. Tsyuk [30] proved that the productivity of crop rotation largely depends on its structure, selection of crops, fertilization system, system of basic tillage. A similar pattern can be traced in studies on other indicators of crop rotation productivity, namely grain units, feed, feed protein units and digestible protein, which are derived from the productivity of individual crops in crop rotation (Table 2). Thus, high yields of cereals and sunflower on the background of the system of differentiated main tillage during the first rotation of crop rotation provided the highest yield from 1 ha of arable land grain units – 4.25 t/ha, feed units – 5.19 t/ha, feed and protein units – 4.95 t/ha and 0.48 t/ha of digestible protein. In the case with the system of planar-free multi-depth basic tillage in crop rotation, the productivity was lower per 1 ha of arable land by 0.17 tons of grain units, 0.15 tons of feed units, 0.15 tons of feed-protein units, and digestible protein not significant only by 0.02t compared to the check experiment (LSD_{05}=0.06 t/ha). The lowest crop rotation productivity was in the experiment, which used a system of planar-free shallow main tillage. In this embodiment, the yield from 1 ha of arable land grain units decreased by 11.8%, feed units by 10.6%, feed protein units by 10.7% and digestible protein by 12.5%. The use of bio-decomposers Ecostern and Cellulad for all cases of the system of basic tillage in crop rotation has increased the crop capacity of cereals and sunflower and crop rotation productivity in general. However, the effectiveness of these bio-decomposers was different. Thus, the yield of cereals and sunflower from the use of bio-decomposer Ecostern at a dose of 1.5 l/ha on the background of planar-free shallow tillage increased by

0.19 t/ha (LSD_{05} B=0.03-0.06) and 0.08 t/ha LSD_{05} B=0.03-0.08).

In the variant with the system of planar-free multi-depth main tillage, the application of the bio-decomposer Ecostern 1.5 l/ha provided an increase in grain yield by 0.20 t/ha (LSD_{05} B=0.03-0.06), and sunflower by 0.10 t/ha (LSD_{05} B=0.03-0.08), but the greatest effect from the use of this bio-decomposer was obtained for the system of differentiated main tillage, where the yield of cereals increased by 0.24 t/ha, respectively (LSD_{05} B=0.03-0.06), and sunflower – by 0.12 t/ha (LSD_{05} B=0.03-0.08). A similar trend is observed in the change in crop rotation productivity under the influence of the application of the bio-decomposer Ecostern at a dose of 1.5 l/ha and other indicators, which is due to changes in crop yields in crop rotation. The largest yield from 1 ha of arable land of grain units was on the background of the system of differentiated main tillage – 4.53t, feed units – 5.54t, feed-protein units – 5.29t and digestible protein – 0.50t, which significantly exceeded the control option (without the use of the bio-decomposer Ecostern), respectively, by 0.28; 0.35; 0.34; and 0.02t. The smallest increase in crop rotation productivity in the experiment from the use of Ecostern bio-decomposer 1.5 l/ha was observed in the variant using shallow planar-free main tillage, where crop rotation productivity at the yield of 1 ha of arable land grain units increased by only 0.24t (LSD_{05} B=0.02), feed units at 0.30t (LSD_{05} B=0.01-0.03), feed protein units at 0.28t and digestible protein at 0.03t (LSD_{05} B=0.02-0.09). An option of the experiment with a system of different depth planar main tillage in crop rotation occupied an intermediate position in terms of crop rotation productivity, where the increase from the use of bio-decomposer Ecostern 1.5 l/ha was grain units – 0.25t (LSD_{05} B=0.02), feed units – 0.31t (LSD_{05} B=0.01-0.03), feed protein units – 0.29t (LSD_{05} B=0.02-0.03) and digestible protein – 0.03t (LSD_{05} B=0.02-0.09), which is confirmed statistically.

Comparing the effect of the use of different bio-decomposers in the experiment, the authors found that the bio-decomposer Cellulad at a dose of 2.0 l/ha was characterized with increased efficiency compared to the bio-decomposer Ecostern at a dose of 1.5 l/ha. Thus, with its application, the yield of cereals and sunflower significantly increased against the background of the system of differentiated main tillage, respectively, by 0.35 (LSD_{05} B=0.03-0.06) and 0.18 t/ha (LSD_{05} B=0.03-0, 08), thus provided the highest level of crop capacity increase in the experiment. In the options of the experiment with the system of planar-free multi-depth and planar-free shallow main tillage in crop rotation with the application of bio-decomposer Cellulad at a dose of 2.0 l/ha, there was also an increase in grain and sunflower yields compared with the application of bio-decomposer Ecostern, but it tillage. The increase in yield from the use of bio-decomposer Cellulad at a dose of 2.0 l/ha in these variants was approximately the same and was cereals and sunflower – 0.29 and 0.19 t/ha and 0.29 and 0.12 t/ha, respectively, and at a significant level. The same pattern is observed in the improve-ment of crop rotation productivity in general with the use of bio-decomposer Cellulad at a dose of 2.0 l/ha. The best option in the experiment on the yield from 1 ha of arable land of grain, feed, feed-protein units and digestible protein was the option using a system of differentiated basic tillage in crop rotation where the yield of grain units was – 4.66 t/ha, feed units – 5.70 t/ha, feed and protein units – 5.43 t/ha and digestible protein, respectively – 0.52 t/ha.

Thus, under the differential system of basic tillage, the average yield of cereals without the use of bio-decomposers was – 3.64 t/ha, which exceeded the options with planar-free shallow and planar-free shallow tillage, respectively, 0.11-0.39 t/ha (LSD_{05} A=0.03-0.06), or 3.0-10.7%. The same pattern was observed for the influence of basic tillage systems on the productivity of oilseeds – sun-flower, where the yield of seeds according to the system of differentiated tillage without the use of bio-decomposers – 2.20 t/ha, which is 0.28-0.42 t/ha (LSD_{05} A=0.03-0.08), or by 12.7-19.1% more in comparison with variants with the system of planar-free different depth and planar-free shallow tillage. This indicates that in the conditions of the Southern Steppe of Ukraine, heavy soils in the system of basic tillage in crop rotations require periodic application of shelf plowing, especially for crops such as peas, corn and sunflower. Considering the impact of the introduction of bio-decomposers of straw External 1.5 l/ha and Cellulad 2.0 l/ha on the level of yield of cereals and sun-flower in crop rotation, it was found that its growth is in the range of 0.13-0.25 t/ha or 4.5-8.7% for cereals and 0.10-0.23 t/ha or 5.4-12.4% for sunflower. The introduction of the bio-decomposer Ecostern 1.5 l/ha provided an increase in the yield from 1 ha of crop rotation area of grain, feed, feed protein units and digestible protein on average in all systems of basic tillage, respectively, by 4.7; 4.5; 4.3 and 5.4%, and with the introduction of Cellulad 2.0 l/ha, these figures increased by 9.5, respectively; 8.9; 8.6 and 10.8% compared to options without the introduction of bio-decomposers.

CONCLUSIONS

The conducted research claimed the possibility and certain efficiency of introduction of the system of organic agriculture in the zone of risky agriculture of the arid Steppe of Ukraine. On the basis of scientific research and the results obtained, the following preliminary conclusions can be made that in the years of research the system of basic tillage in grain-row short crop rotation in organic farming have different efficiencies, which largely depends on the conditions of the year. The experiments did not confirm the effectiveness of the system of systematic shallow non-planar basic tillage in crop rotation, as one of the main substantive aspects of organic farming. Considering the influence of different systems of main tillage in short-rotation grain crop cultivation, the advantage of the system of differentiated main tillage over the systems of planar-free multi-depth and planar-free shallow main tillage.

Thus, the highest average grain yield in the experiment, with a differentiated system of basic tillage on the background of the application of the bio-decomposer Cellulad 2.0 l/ha was – 3.99 t/ha, which exceeded the options with planar-free shallow and planar-free tillage, respectively, by 0.17-0.45 t/ha, or 4.3-11.3%. The same pattern was observed for the influence of basic tillage systems on the productivity of oilseeds – sunflower, where the yield of seeds according to the system of differentiated basic tillage and the use of bio-decomposer Cellulad 2.0 l/ha was – 2.38 t/ha, which is 0.27-0.41 t/ha, or 11.3-20.2% more in comparison with the options with the system of planar-free shallow and planar-free shallow tillage. That is necessary statistically. Applying the technology of accelerated destruction of straw and plant residues using bio-decomposers Ecostern and Cellulad, the experiment showed higher efficiency of bio-decomposer Cellulad at a dose of 2.0 l/ha.

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Продуктивність короткороторного вирощування сільськогосподарських культур за різних систем базового обробітку ґрунту в органічному землеробстві Степу України

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Анотація. Довгострокове реформування аграрного сектору в Україні відбувається у складних економічних та природних умовах. У сучасному сільському господарстві найбільш актуальними є біологізовані заходи й технології вирощування сільськогосподарських культур, ресурсо- та енергоекономічного відновлення родючості ґрунтів. Дослідження впливу системи базового обробітку ґрунту та використання біорозкладачів соломи й залишків після збору врожаю в органічному землеробстві були проведені в найпоширенішому та типовому для південного регіону степу України, короткооборотному вирощуванні сільськогосподарських культур із наступним чергуванням посівів: горох – озима пшениця – озимий ячмінь – ½ полів соняшника + ½ полів кукурудзи. За роки першого вирощування експеримент показав переваги системи диференційованого обробітку ґрунту, де навіть без використання біорозкладачів було отримано найвищий урожай зернових – 3,64 т/га та соняшнику – 2,20 т/га (перевірка експерименту). Застосування комбінованого різноглибинного обробітку у поєднанні з ґрунту, основний обробіток ґрунту спричинив зниження врожайності зернових на 0,11–0,39 т/га та соняшнику відповідно на 0,28–0,42 т/га. З використанням біорозкладачів, що надаються марками Ecostern та Cellulad, зростання врожайності знаходиться в діапазоні 0,13–0,25 т/га або 4,5–8,7 % для зернових культур та 0,10–0,23 т/га або 5,4–12,4 % для соняшнику. Застосування біорозкладача Ecostern 1,5 л/га забезпечило збільшення врожайності з 1 га площі сівозміни зерна, корму, кормово-білкових одиниць та засвоюваного білка в середньому у всіх системах базового обробітку ґрунту на 4,7 відповідно; 4,5; 4,3 та 5,4 %, а з внесенням Cellulad 2,0 л/га ці показники зросли відповідно на 9,5; 8,9; 8,6 і 10,8 % порівняно з варіантами без впровадження біорозкладачів

Ключові слова: землеробство, біорозкладачі, економічні та природні умови, відновлення родючості ґрунтів, зростання врожайності