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Effect of fertilizer and cultivation systems and herbicide application on soil biological activity under spring barley cultivation and its yield

Wpływ sposobu uprawy, nawożenia i herbicydów na aktywność biologiczną gleby i plonowanie jęczmienia jarego

Summary: The results of the research devoted to the change of the biological composition of the soil under the conditions of activation of microbiological vital activity and increase in the number of earthworms in the technology of spring barley cultivation are presented. It was found that the organic system of growing crops against the background of manure, cereal straw and green manure in comparison with the organo-mineral system obtained a positive dynamics of decomposition of linen tissue and the development of earthworms in the soil.
The highest grain yield was formed by agrocenosis of spring barley with the introduction of Lancelot 450 WG – 0.033 kg·ha^{-1} + Axial 50 EC – 1 dm^3·ha^{-1} (tube exit phase) – 4900 kg·ha^{-1} and 4700 kg·ha^{-1} for organo-mineral and organic fertilizer systems in accordance.

Key words: agrophytocenosis, cultivation systems, fertilizer system, herbicide application**,** biological activity of soil, spring barley, crop yields

INTRODUCTION

In the system of ecological monitoring of the environment, one of the main criteria for biotesting is the intensity of biological processes in the soil. Extremely high informativeness of biological indicators makes it possible to comprehensively assess the condition of the soil [Tyburski and Makulec 2013, Natywa et al. 2014]. Indicators include both the activity of microorganisms and the soil mesofauna [Feledyn-Szewczyk et al. 2017].

Microbiological activity is one of the important indicators of soil fertility, which indicates the regularity of the processes of conversion of organic matter and characterizes the intensity of biochemical activity of soil microorganisms, which are indicators of qualitative changes in soil fertility and affect the phytosanitary and agricultural condition of crops, product quality and the environment [Meena and Singh 2013].

Earthworms play an important role in the formation of fertility and soil quality [Pfiffner 2014]. Earthworms are one of the most important organisms that are actively involved not only in soil formation, but also promote health, increase soil biological activity and better adapt the farming system to climate change, contributing to the positive development of the ecosystem [Zrazhevsky 1957, Titov 2012, Melnyk et al. 2015, Feledyn-Szewczyk et al. 2017]. The content of organic substances available to plants, the level of nutrient supply, and the structure of the soil depend on their activity. Their number and diversity are considered an important criterion of soil fertility [Dospekhov et al. 1977, Noskov 1999, Horodniy et al. 2003, Shastry et al. 2017].

The myco- and meso-soil fauna is strongly influenced by the applied agrotechnical measures, such as tillage, crop rotation, the use of mineral and organic fertilizers or pesticides [Hryńczuk and Weber 2004, Flohre et al. 2011, Kłyś and Malejky 2018].

The level of biological activity indicates the intensity of the decomposition of organic matter and allows to assess the impact of organic and mineral fertilizers, as well as the effectiveness of the introduction of new technologies for growing crops [Kraska et al. 2013, Mubeen et al. 2014, Sellam and Poovammal 2016]. Under modern conditions of agriculture there is an acute problem of lack of organic fertilizers of animal origin. The volume of their introduction in Ukraine per 1 hectare (ha) in 2019 decreased by 22 times compared to 1990 [Yatsuk 2015]. The decrease in the production of organic fertilizers of animal origin and their application to the fields is due to a significant reduction in the number of farm animals. If as of January 1, 1990, in particular, there were 25.2 million head of cattle, in 2019 – 3.33 million heads respectively [Tanchyk et al. 2010, Winnicki and Żuk-Gołaszewska 2017, Shuvar and Korpita 2020]. According to the State Statistics Service of Ukraine (1998–2019), the amount of mineral fertilizers applied per unit area of agricultural land decreased from 105.1 $kg \cdot ha^{-1}$ NPK in 1990 to 56.3 $kg \cdot ha^{-1}$ in 2019 [Yatsuk 2015]. Therefore, every year, due to soil depletion, Ukraine does not receive agricultural products by $ 5 billion [Yatsuk 2015].

An important reserve for the use of local resources of organic fertilizers are crop residues and combined with green manures. However, they are not yet fully involved in enriching soils with organic matter. The use of straw for fertilizer affects the improvement of physical and chemical properties of the soil, enhancing the activity of the microflora, increasing the humus content in the soil [Budonnyy and Shevchenko 2006, Singh et al. 2007, Farooq et al. 2011, Shuvar and Korpita 2016, Demydes et al. 2020]. Under the conditions of green manure use, the content of humus, structural particles of soil, capillary moisture content increases, acidity decreases, the mobility of aluminum slows down, the amount of absorbed bases in the soil absorption complex increases [Peralta et al. 2018, Singh et al. 2018]. Organic fertilizers show the greatest return in combination with mineral fertilizers, on the basis of which organo-mineral fertilizer systems are created for various crop rotations [Kocira et al. 2020]. Therefore, the study of biological activity of the soil under the organic fertilizer system is relevant at the present stage of agricultural development [Natywa et al. 2014].

Many years of research by a number of authors [Zrazhevsky 1957, Shuvar et al. 2011, Pannaci and Tei 2014, Melnyk et al. 2015, Shuvar et al. 2019] show that herbicides have high physiological activity and not only kill weeds, but also significantly affect the course of biochemical processes in cultivated plants and the microbiological activity of the soil.

Taking into account the above, a study was carried out aimed at determine the effect of fertilizer system and herbicide application on soil microbiological activity and the number of earthworms as an indicator of soil fertility. The essence of the hypothesis was the formation of more vermibiota and better activation of soil biochemical processes under the influence of herbicides under the organic fertilizer system

MATERIAL AND METHODS

The study of the influence of fertilizer and cultivation systems and herbicide application on the microbiological activity and mesofauna of agrocenosis of spring barley variety Sontsedar was performed during 2017–2020 in the experimental field of Lviv NAU on dark gray podzolic medium loam soil – typical for the western forest-steppe of Ukraine. The arable layer (0–30 cm) is characterized by the following agrochemical parameters: humus content – 20–25 $g \cdot kg^{-1}$, the reaction of the soil solution is slightly acid (pH 5.5–6.5), hydrolytic acidity – 2.0–4.2 mg $Eq \cdot 100\ g^{-1}$ (0.2–0.42 cmol (+) kg^{-1} of soil, the degree of saturation with bases – 75–90%, N (according to Cornfield [Pankiv 2017]) – 51.2, P_2O_5 (according to Chirikov [Pankiv 2017]) – 92 and K_2O (according to Maslova [Pankiv 2017]) – 107 $mg \cdot kg^{-1}$ of soil. Agrotechnological features of spring barley cultivation in the experiment are generally accepted for the specified conditions of the territory [Pankiv 2017]. The climate in the zone is moderately continental. Alternation of crops in crop rotation according to the scheme: peas (Gotivsky variety) – winter wheat (Myronivska variety) – potatoes (Volya variety) – spring barley (Sontsedar variety) – table 1.

Two research factors were adopted in the study: Factor A – fertilizer and cultivation system (organo-mineral and organic systems) and Factor B – the using of herbicides (the same on both systems) (tab. 2).

The total area of the plot in the experiment was 0.27 ha. The estimated area of the plot for determining the effect of herbicides was 73.5 m^2 (7 m × 10.5 m). Placement of plots in the experiment is randomized (3 repetitions).

The biological activity of the soil was determined by the method of Mishustin and Petrova [Myshustyn and Petrova 1963, Dospekhov et al. 1977] using applications of linen as a chemically homogeneous source of fiber. Linen was installed in the ground during the experiment. The duration of decomposition exposure is in the dynamics of 30, 60 and 90 days. The number of earthworms was determined by the method of stationary soil study. The number of earthworms was determined by excavating a 25 × 25 cm monolith and then dividing it into layers of 0–10, 10–20, and 20–30 cm. Accounting was performed at the beginning of the spring barley growing season and during its harvesting [Myshustyn and Petrova 1963, Dospekhov et al. 1977].

The results obtained were processed statistically in SAS v.91 software, using single- or multi-factor variance analysis. Tukey's confidence intervals ($p \leq 0.05$) were used to verify the significance of the differences between the means. In our study we applied correlation-regression analysis with using spreadsheet Microsoft Excel. Correlation-regression analysis is the construction and analysis of an economic-mathematical model in the form of a regression equation (correlation equation), which expresses the dependence of the resultant feature on one or more feature factors and evaluates the degree of connection density [Kulinich 2010].

Table 1. The scheme of alternation of crops in crop rotation in years

Alternation of crops in crop rotation in years				
Field number	2017	2018	2019	2020
organo-mineral system				
1	peas ($N_{45}P_{45}K_{45}$)	winter wheat ($N_{60}P_{60}K_{60}$)	potatoes (manure 30 Mg·ha^{-1} + $N_{90}P_{90}K_{90}$)	spring barley ($N_{60}P_{60}K_{60}$)
2	winter wheat ($N_{60}P_{60}K_{60}$)	potatoes (manure 30 Mg·ha^{-1} + $N_{90}P_{90}K_{90}$)	spring barley ($N_{60}P_{60}K_{60}$)	peas ($N_{45}P_{45}K_{45}$)
3	potatoes (manure 30 Mg·ha^{-1} + $N_{90}P_{90}K_{90}$)	spring barley ($N_{60}P_{60}K_{60}$)	peas ($N_{45}P_{45}K_{45}$)	winter wheat ($N_{60}P_{60}K_{60}$)
4	spring barley ($N_{60}P_{60}K_{60}$)	peas ($N_{45}P_{45}K_{45}$)	winter wheat ($N_{60}P_{60}K_{60}$)	potatoes (manure Mg·ha^{-1} + $N_{90}P_{90}K_{90}$)
organic system				
1	peas ($N_{20}P_{20}K_{20}$)	winter wheat ($N_{10}P_{10}K_{10}$ + cultivation of white mustard (variety Etalon) postharvest) (18 Mg·ha^{-1})	potatoes (manure 45 Mg·ha^{-1})	spring barley (winter rape (variety Atlant) + N_{15})
2	winter wheat ($N_{10}P_{10}K_{10}$ + cultivation of white mustard (variety Etalon) postharvest) (18 Mg·ha^{-1})	potatoes (manure Mg·ha^{-1})	spring barley (winter rape (variety Atlant) + N_{15})	peas ($N_{20}P_{20}K_{20}$)
3	potatoes (manure Mg·ha^{-1})	spring barley (winter rape (variety Atlant) + N_{15})	peas ($N_{20}P_{20}K_{20}$)	winter wheat ($N_{10}P_{10}K_{10}$ + cultivation of white mustard (variety Etalon) postharvest) (18 Mg·ha^{-1})
4	spring barley (winter rape (variety Atlant) + N_{15})	peas ($N_{20}P_{20}K_{20}$)	winter wheat ($N_{10}P_{10}K_{10}$ + cultivation of white mustard (variety Etalon) postharvest) (18 Mg·ha^{-1})	potatoes (manure Mg·ha^{-1})

$N_{45}P_{45}K_{45}$ (…) – content of the pure component in kg·ha^{-1}

Table 2. Diagram of the experiment of field of Lviv NAU (Ukraine) in 2017–2020

Factor A – fertilizer and cultivation system	Factor B – the using of herbicides
Organo-mineral system	1. without the use of herbicide (control)
	2. Calibre SX 50 SG – 0.050 kg·ha^{-1}
	3. Granstar 70 WG – 0.025 kg·ha^{-1} + Axial 50 EC – 1 dm^3·ha^{-1} (tube exit phase)
	4. Prima – 2/3 (0.5 dm^3·ha^{-1}) + Lontrel 300 SL – 1/3 (0.060 kg·ha^{-1}) + Axial 50 EC – 1 dm^3·ha^{-1} (tube exit phase)
	5. Lancelot 450 WG – 0.033 kg·ha^{-1} + Axial 50 EC – 1 dm^3·ha^{-1} (tube exit phase)
Organic system	1. without the use of herbicide (control)
	2. Calibre SX 50 WG – 0.050 kg·ha^{-1}
	3. Granstar 70 WG – 0,025 kg·ha^{-1} + Axial 50 EC – 1 dm^3·ha^{-1} (tube exit phase)
	4. Prima – 2/3 (0.5 dm^3· ha^{-1}) + Lontrel 300 SL – 1/3 (0.060 kg·ha^{-1}) + Axial 50 EC – dm^3·ha^{-1} (tube exit phase)
	5. Lancelot 450 WG – 0.033 kg·ha^{-1} + Axial 50 EC – 1 dm^3·ha^{-1} (tube exit phase)

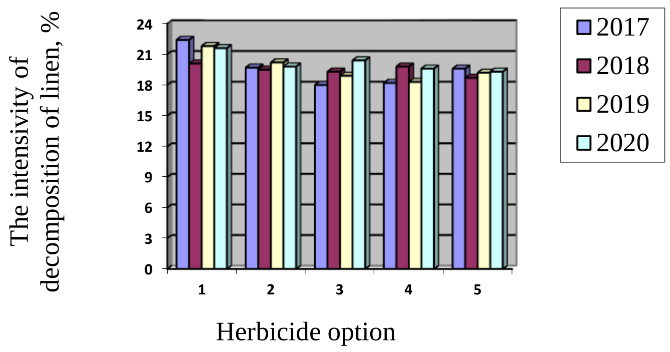
RESULTS AND DISCUSSION

Microbiological activity

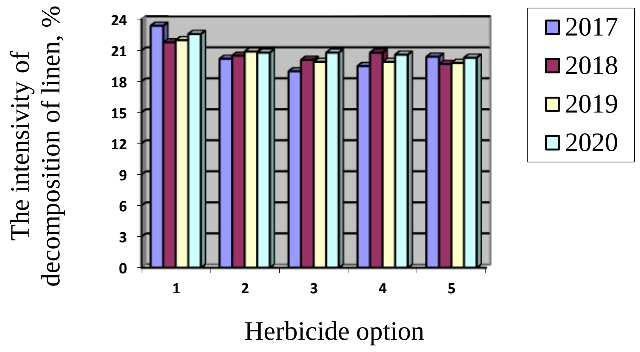
Therefore, the use of herbicides should have a scientific approach and be based on a comprehensive study of their impact on the basic physiological and biochemical processes of crops that underlie the formation of their productivity.

Modern agriculture requires in-depth comprehensive soil research. The technology of growing any crop without scientifically sound adjustment of these conditions does not provide the expected yield and product quality. Currently, it is important to study such an indicator of soil microbiological activity as the intensity of soil respiration, because the activation of biochemical processes in the soil is due to the growth of the number of microorganisms in it and the intensification of their vital processes. These processes are inextricably linked to the active activity of soil worms. Therefore, determining their number can serve as an important criterion for assessing the overall biological activity of the microbial component of the cenosis [Zrazhevsky 1957, Titov 2012, Melnyk et al. 2015, Feledyn-Szewczyk et al. 2017].

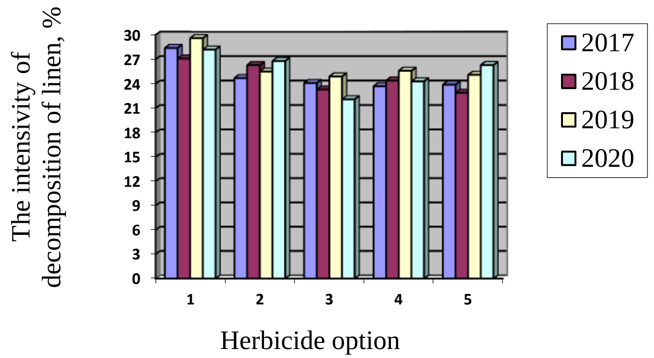
Studies (2017–2020) have shown that the intensity of microbiological processes in the soil (based on the degree of decomposition of linen in the arable soil layer) depended on the type and amount of fertilizers applied (Fig. 1). Other authors also show the influence of mineral and organic fertilization on the microbiological activity of the soil [Natywa et al. 2014]. In their opinion, fertilization, especially with nitrogen, affects soil microorganisms and enzymes through a higher yield of plants and, consequently, a greater amount of post-harvest residues, and by shaping the soil pH according to the dose and type of fertilizer according to Natywa et al. [2014], increasing the amount of organic matter mass causes to a large extent an increase in the total porosity of the soil, and consequently a decrease in its specific density. These factors help microorganisms penetrate the soil and use the food base more efficiently. This fact reduces the competition between microorganisms and



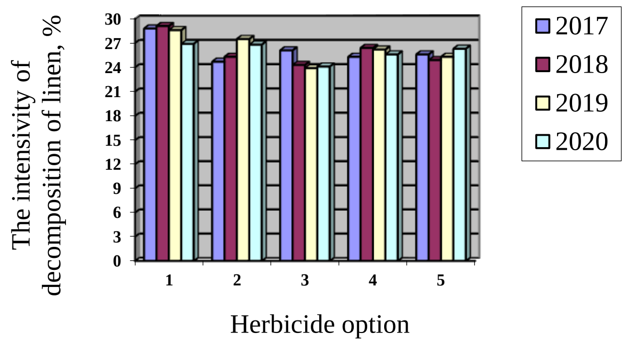
A. Organo-mineral fertilizer system 30 days



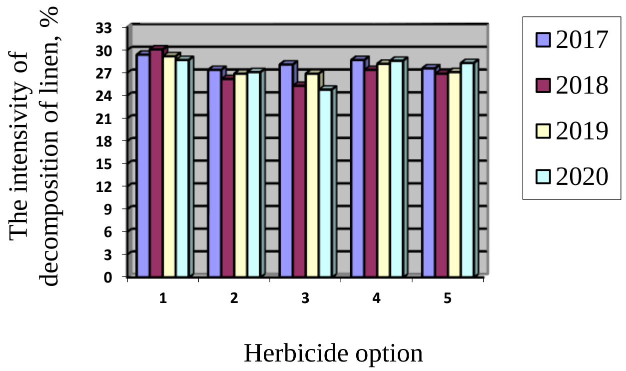
B. Organic fertilizer system 30 days



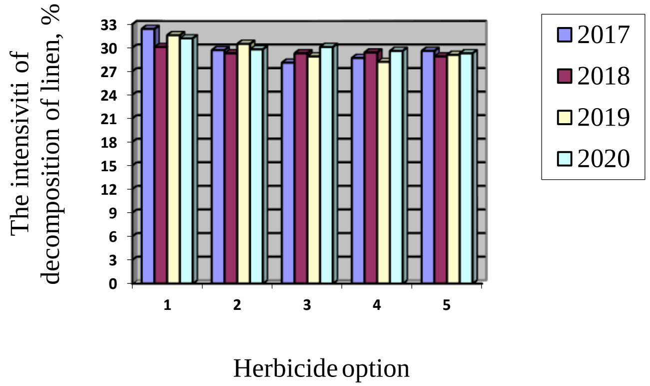
C. Organo-mineral fertilizer system 60 days



D. Organic fertilizer system 60 days



E. Organo-mineral fertilizer system 90 days



F. Organic fertilizer system 90 days

Herbicide options: 1. Without the use of herbicide (control); 2. Calibr: 0.050 kg·ha^{-1}; 3. Granstar: 0.025 kg·ha^{-1} + Axial: 1 dm^{3}·ha^{-1} (tube exit phase); 4. Prima: 2/3 (0.5 dm^{3}·ha^{-1}) + Lontrel: 1/3 (0.060 kg·ha^{-1}) + Axial: 1 dm^{-3}·ha^{-1} (tube exit phase); 5. Lancelot: 0.033 kg·ha^{-1} + Axial: 1 dm^{-3}·ha^{-1} (tube exit phase)

Fig. 1. The intensity of decomposition of linen in the soil layer 0–30 cm under different fertilizer and cultivar systems and the use of herbicides (average for 2017–2020)

plants. Also, in the opinion of Runowska-Hryńczuk [1992], organic-mineral fertilization and appropriate crop rotation have a positive effect on the biological activity of the soil, as opposed to using only mineral fertilization. Its unfavorable effect on the biological and chemical properties of the soil is manifested by a decrease in plant yields. According to Gallego et al. [1996] respiration capacity is a sensitive indicator of soil biological balance changes, and the value of this indicator was positively correlated with plant yields. These authors showed a 7-fold increase in carbon dioxide emission as a result of fertilization with manure, and the incorporation of biomass into the soil in the form of grass, clover, straw, remains of alfalfa, oats and sorghum stimulated soil respiratory activity up to 5 times.

Studies have shown that the most active cellulolytic activity was manifested in both fertilizer systems on a herbicide-free background compared to variants with the use of herbicides. Changes in the quantitative composition of soil microflora and enzymatic activity under the influence of long-term persistence of herbicides in the soil were also shown in research Baćmaga et al. [2007]. Wyszkowski and Wyszkowska [2004] also believe that plant protection products deposited in the soil may pose a threat to organisms living in this environment. Their toxicity is manifested, among others, by reduction in their number and changes in enzymatic activity. The disturbance of the biological balance of the soil is visible in the amount of elements available to plants in the soil solution, which is associated with a lower yield of plants.

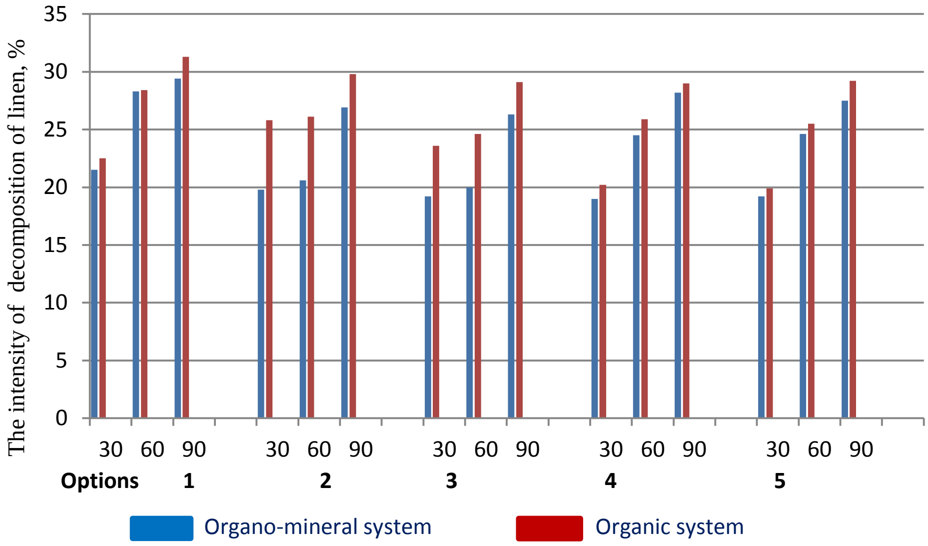
Under the organic system, the intensity of microbiological processes in the soil (cellulolytic activity) was on average 9.8–12.5% higher over the years of the study compared to the intensity of the organo-mineral system (fig. 1).

Under the both system, the intensity of decomposition of linen in the variants of herbicide application on average over the years of the study was 6–8% lower than in the control variants (Fig. 2).

The number of earthworms in the soil

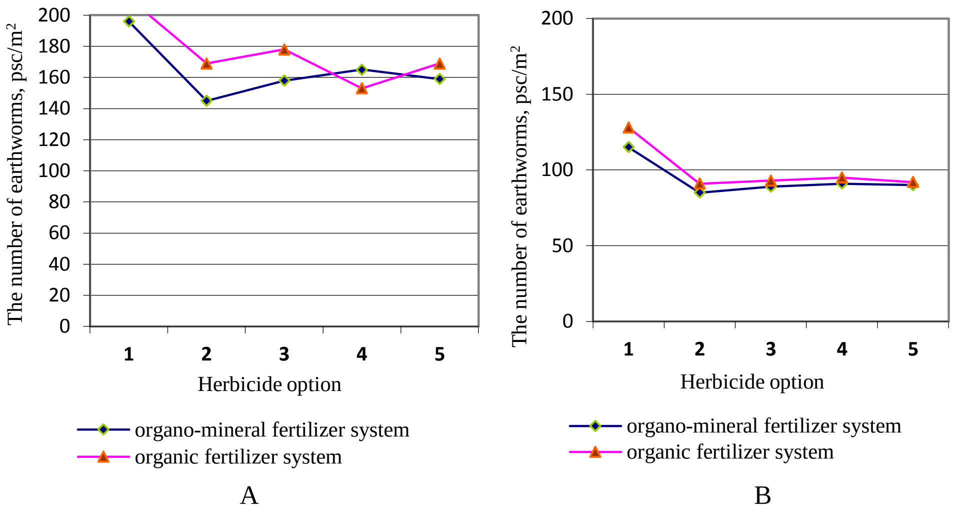
It was found that over the years of research, the largest number of worms was at the beginning of the spring barley vegetation in both fertilizer systems, in particular, in the herbicide-free version (control). During the growing season of the crop under the influence of herbicides, different dynamics of earthworms with a tendency to decrease their number was revealed. Also in the study by Pfiffner [2014], the number of earthworms significantly decreased under the conditions of pesticide application. He believes that most of them probably do not kill earthworms directly. When used in the recommended doses, they show little toxicity. However, by limiting the number of weeds, the availability of this mesofauna to organic matter on the soil surface decreases, and consequently the size of the population is limited.

During the growing season the most favorable conditions for the development of meso-fauna developed under the organic fertilizer system, due to the introduction of organic fertilizers in combination with mineral nutrition, which provided better conditions for the existence of vermibiota. This is confirmed by the previous studies by Irmler [2010], which showed a positive effect on the abundance of earthworms of the change of management from conventional to ecological, in which management is similar to the organic system used in the research. The population of earthworms in the organic fertilizer system was 1.2–1.7 times higher than in the organo-mineral system. At the time of harvesting spring barley, the maximum was detected in the control, where there were 128 pieces/m^2, which is 13 pieces/m^2 more than in the organo-mineral fertilizer system (Fig. 3).



Options: 1. Without the use of herbicide (control); 2. Calibr: 0.050 kg·ha^{-1}; 3. Granstar: 0.025 kg·ha^{-1} + Axial: 1 dm^3·ha^{-1} (tube exit phase); 4. Prima: 2/3 (0.5 dm^3·ha^{-1}) + Lontrel: 1/3 (0.060 kg·ha^{-1}) + Axial: 1 dm^3·ha^{-1} (tube exit phase); 5. Lancelot: 0.033 kg·ha^{-1} + Axial: 1 dm^3·ha^{-1} (tube exit phase)

Fig. 2. Comparison of the decomposition of linen for both fertilizer systems during 30, 60 and 90 days of the exposure period on average over the years of research



Herbicide options: 1. Without the use of herbicide (control); 2. Calibr: 0.050 kg·ha^{-1}; 3. Granstar – 0.025 kg·ha^{-1} + Axial – 1 dm^3·ha^{-1} (tube exit phase); 4. Prima: 2/3 (0.5 dm^3·ha^{-1}) + Lontrel: 1/3 (0.060 kg·ha^{-1}) + Axial: 1 dm^3·ha^{-1} (tube exit phase); 5. Lancelot: 0.033 kg·ha^{-1} + Axial: 1 dm^3·ha^{-1} (tube exit phase)

Fig. 3. The number of earthworms in the soil layer 0–30 cm depending on the fertilizer system: **A.** At the beginning of the spring barley vegetation, **B.** At the time of harvest, pcs/m^2 (average for 2017–2020)

Thus, the enrichment of the soil with various forms of organic fertilizers (manure 45 Mg·ha^{-1}, green manure fertilizer) against the background of moderate doses of mineral fertilizers in the agrocenosis of spring barley enhances the decomposition of linen and the development of soil mesofauna (based on the developed research scheme).

Grain yield of spring barley

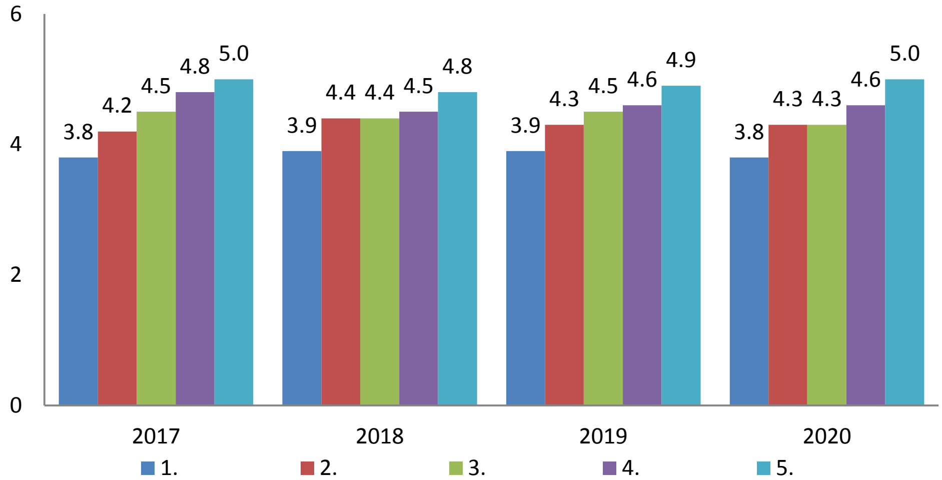
With the organic system of growing crops with the application of manure, cereal straw and green manure, compared with the organo-mineral fertilizer system, a positive dynamics of decomposition of linen and more intensive development of soil biota – earthworms in the soil. Also, the use of herbicides had a direct impact on the formation of spring barley yield, correlation-regression analysis revealed differences in the formation of polynomial trend values, which have significant and high values of the coefficient of determination, indicating a close relationship between the studied indicators (Figs 4 and 5).

The level of spring barley yield was influenced by fertilizer and cultivation systems and herbicide application (tab. 3). It is established that on the dark gray podzolic medium loamy soil of the western Forest-Steppe of Ukraine under the organo-mineral fertilization system the highest yield of spring barley on average for four years was provided by the use of Lancelot 450 WG – 0.033 kg·ha^{-1} + Axial 50 EC – 1 dm^3·ha^{-1} (tube exit phase) – 4.9 Mg·ha^{-1} (+ 25.6% to control). Against the organic fertilization system, the highest yield of spring barley on average over the years of research was provided by the application of Lancelot 450 WG – 0.033 kg·ha^{-1} + Axial 50 EC – 1 dm^3·ha^{-1} (tube exit phase) – 4.7 Mg·ha^{-1} (+ 27.0% to control).

Table 3. Grain yield of spring barley Sontsedar for organo-mineral and organic systems depending on the herbicide application (Mg·ha^{-1})

Variants of the experiment	Year of research				Average for 2017–2020	Gain to control (%)
	2017	2018	2019	2020		
1. Without the use of herbicide (control)	3.8 ±0.1 ^{a}	3.9 ±0.1 ^{a}	3.9 ±0.2 ^{a}	3.8 ±0.2 ^{a}	3.9 ±0.2 ^{a}	–
2. Calibr: 0.050 kg·ha^{-1}	4.2 ±0.2 ^{ab}	4.4 ±0.1 ^{b}	4.3 ±0.2 ^{b}	4.3 ±0.2 ^{b}	4.3 ±0.2 ^{b}	10.3 ±0.5
3. Granstar: 0.025 kg·ha^{-1} + Axial: 1 dm^3·ha^{-1} (tube exit phase)	4.5 ±0.1 ^{bc}	4.4 ±0.2 ^{b}	4.5 ±0.2 ^{b}	4.3 ±0.1 ^{b}	4.4 ±0.1 ^{b}	15.4 ±0.8
4. Prima: 2/3 (0.5 dm^3·ha^{-1}) + Lontrel: 1/3 (0,060 kg·ha^{-1}) + Axial: 1 dm^3·ha^{-1} (tube exit phase)	4.8 ±0.1 ^{cd}	4.5 ±0.1 ^{bc}	4.6 ±0.4 ^{bc}	4.6 ±0.3 ^{bc}	4.6 ±0.1 ^{bc}	18.0 ±3.6
5. Lancelot: 0.033 g·ha^{-1} + Axial: 1 dm^3·ha^{-1} (tube exit phase)	5.0 ±0.2 ^{d}	4.8 ±0.1 ^{c}	4.9 ±0.2 ^{c}	4.7 ±0.1 ^{c}	4.9 ±0.2 ^{c}	25.6 ±1.4

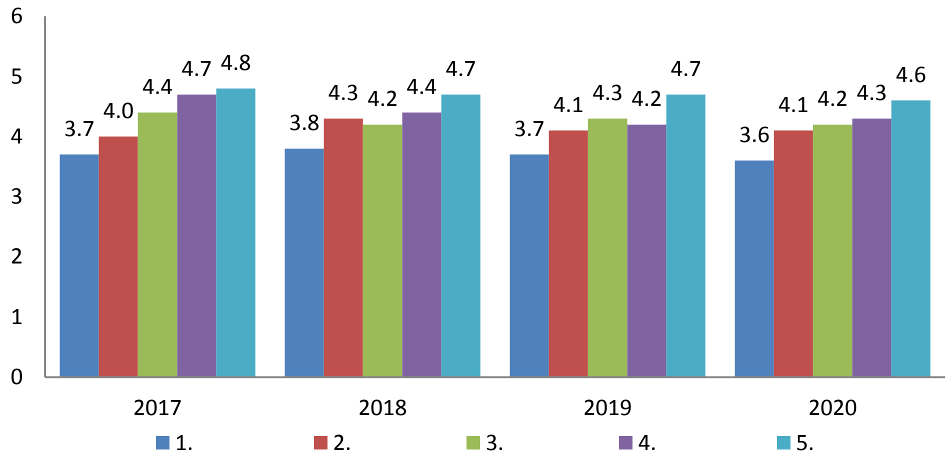
The same letters indicate the lack of significant differences between mean values in the particular category (within a single column)



Herbicide options: 1. Without the use of herbicide (control); 2. Calibr: 0.050 kg·ha^{-1}; 3. Granstar: 0.025 kg·ha^{-1} + Axial: 1 dm^3·ha^{-1} (tube exit phase); 4. Prima: 2/3 (0.5 dm^3·ha^{-1}) + Lontrel: 1/3 (0.060 kg·ha^{-1}) + Axial: 1 dm^3·ha^{-1} (tube exit phase); 5. Lancelot: 0.033 kg·ha^{-1} + Axial: 1 dm^3·ha^{-1} (tube exit phase)

1) Y = –0.05X2 + 0.25X + 3.6; R^2 = 1
2) Y = –0.05X2 + 0.27X + 4; R^2 = 0.6
3) Y = –0.025X2 – 0.075X + 4.425; R^2 = 0.546
4) Y = 0.075X2 – 0.425X + 5.125; R^2 = 0.737
5) Y = 0.075X2 – 0.365X + 5.275; R^2 = 0.836

Fig. 4. Grain yield of spring barley in the organo-mineral fertilizer system using correlation-regression analysis (Y – yield of spring barley, X – application of herbicides)



Herbicide options: 1. Without the use of herbicide (control); 2. Calibr: 0.050 kg·ha^{-1}; 3. Granstar: 0.025 kg·ha^{-1} + Axial: 1 dm^3·ha^{-1} (tube exit phase); 4. Prima: 2/3 (0.5 dm^3·ha^{-1}) + Lontrel: 1/3 (0.060 kg·ha^{-1}) + Axial: 1 dm^3·ha^{-1} (tube exit phase); 5. Lancelot: 0.033 kg·ha^{-1} + Axial: 1 dm^3·ha^{-1} (tube exit phase)

1) Y = –0.05X2 + 0.21X + 3.55; R^2 = 0.9
2) Y = –0.075X2 + 0.385X + 3.725; R^2 = 0.484
3) Y = 0.025X2 – 0.175X + 4.525; R^2 = 0.546
4) Y = 0.1X2 – 0.64X + 5.25; R^2 = 0.986
5) Y = –0.06X2 + 4.85; R^2 = 0.9

Fig. 5. Grain yield of spring barley in the organic fertilizer system using correlation-regression analysis (Y – yield of spring barley, X – application of herbicides)

Studies have shown that the system of organic fertilizers, which includes the application of manure, straw, cereals and greens, had a greater impact on soil microbiological processes (cellulose-destroying ability of microorganisms and the development of soil biota – earthworms) than the organo-mineral system.

CONCLUSIONS

As a result of our research, we were convinced that the organic fertilizer system provides better biochemical processes in the soil, which lead to more intensive decomposition of linen and an increase in the number of earthworms. It should also be noted that for both fertilizer systems in the control variants 25–30% more earthworms were found in comparison with the variants with the use of herbicides. That is, the use of herbicides reduces the number of earthworms.

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