

The effect of biological preparations on CO₂ emission and microflora in the root zone of corn

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Abstract. The process of improving farming systems reflects the main periods of development of the agricultural sphere as a whole. The development of farming systems is an integral part of industrial production, as well as scientific and technological progress. It is important to spread and implement so-called alternative farming systems that eliminate or minimize the use of agrochemicals. Crop residues are an important source of arable soil fertility reproduction, while the microbial transformation of fresh organic matter in arable soils informs processes such as food production, the greenhouse effect, and the global carbon cycle. In turn, the integral indicator that most clearly and fully reflects the nature of the intensity of mineralization of organic matter in the soil is the emission of carbon dioxide. Thus, the purpose of the article is to conduct research during the growing season on the processes of "soil respiration" and the amount of microflora in the soil of the basal zone of plants, which will make it possible to reveal the influence of the elements of biologization of agriculture on the indicators of the biological activity of podzolized chernozem. CO₂ emission processes and the abundance of the main groups of microflora were monitored during the 2020 growing season in the stationary field experiment "Influence of different levels of biologization of agriculture on soil fertility". The article presents the results of observations of carbon dioxide emissions and other indicators of biological activity of the soil in order to determine the effectiveness of the implementation of elements of biologization of agriculture. It was established that the application of a complex of agricultural measures (soil treatment with a stubble destructor, pre-sowing treatment of seeds with a biopreparation and two-time foliar treatment with a humic preparation) increased CO₂ emissions and increased the number of microflora in the root zone of corn compared to the control. A significant increase in the yield of corn grain from the use of a complex of biological preparations was noted (up to 16% depending on the variant)

Keywords: emission of carbon dioxide, biologization of agriculture, agricultural activities, soil microflora, corn

INTRODUCTION

The development of agricultural systems in any country primarily reflects the main stages of the development of agriculture in general. The renewal and evolution of farming systems are inextricably linked with industrial production and scientific and technological

progress. One of the new challenges of modern times is the deterioration of the environment and agro-ecosystems, in particular, the increase in soil degradation, which necessitates a change in the modern strategy of agriculture. It is likely that the path of further intensive

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general chemicalization of agriculture is economically impractical and ecologically dangerous. In this regard, in many countries, the so-called alternative farming systems, which exclude or minimize the use of agrochemicals, have become widespread. In Ukraine, studies of the effectiveness of various measures of biologicalization of agriculture have also been conducted for a long time [1;2], and with the adoption of the Law of Ukraine "On the Production and Circulation of Organic Products", these issues have become particularly relevant.

Plant residues are the most important resource for reproducing the fertility of arable soils. One of the most expedient means of their use is to work them into the soil, without removing them from the field, in order to reproduce organic matter and preserve the functional properties of soils in agrocenoses. However, post-harvest plant residues of grain crops decompose rather slowly due to the high content of lignin and cellulose and low nitrogen content, which can lead to a decrease in the yield of fertilized crops that follow them in the crop rotation. One of the ways to accelerate the decomposition and increase the humification coefficient of stubble and straw, which has become widespread in recent years in the practice of the agro-industrial complex, can be their treatment with microbial preparations - stubble destructors. At the same time, the introduction of highly effective strains and consortia of destructive microorganisms is ensured directly on the straw and, in the future, into the soil [3].

Microbial transformation of fresh organic matter in arable soils determines such processes as the global carbon cycle, food production, and the greenhouse effect. The integral indicator that most fully reflects the intensity of mineralization of organic matter in the soil is the emission of carbon dioxide.

In recent years, considerable attention has been paid to the impact of CO₂ concentration on the kinetics of soil microbial respiration.

It has been established that the increase in the amount of CO₂ in the atmosphere can affect the biomass and activity of soil microorganisms only indirectly - due to the increase in the amount of root exudates and other organic substrates of plant origin accessible to microbial decomposition [4-6]. Depending on the type of plant under which the microbial population is formed, both an increase and a decrease in the emission flow can be observed.

In some scientific studies, it has been established that the use of biological destructors accelerates the processes of mineralization and humification of straw in the soil, reduces the manifestation of phytotoxicity, and increases the yield of subsequent crops [7-10]. In field experiments on chernozem soils, during autumn processing and plowing of winter wheat straw with microbiological fertilizer Baikal EM-1 (2-3 l/ha), the number of plant residues that did not decompose before spring decreased from 8.5 to 1.9 and 3, 2 t/ha. In production

tests on sod-podzolic soil, after processing chopped straw with this biopreparation (with the introduction of urea - 10-12 kg per 1 ton of straw) by spring, plant residues were almost completely decomposed [11].

According to O. De Kok-Mercado, microbial biopreparations can show limited decomposing effectiveness in agricultural soils due to a certain dependence of the growth of microorganisms on environmental factors. This author's research examined the effectiveness of a microbial preparation, which includes the microorganisms *Bacillus subtilis*, *Rhodotorula lactose*, *Debaromyces hansenuii*, *Hansenula anomala*, *Cladosporium cladosporioides*, designed specifically to activate the decomposition of plant residues in No-Till agricultural systems, namely to intensify the decomposition of corn residues in the loamy soil of Iowa. It is assumed that this preparation is characterized by the potential ability to accelerate the decomposition of plant residues and can be effective in soils with a low content of organic matter and low activity of the indigenous soil microbial community [12].

At the same time, along with certain positive results that testify to the effectiveness of biological preparations designed to accelerate the decomposition of straw, there are experimental data of some researchers that showed the absence of a stable and sustainable effect from the use of destructors both in terms of increasing the decomposition of straw and in relation to changes in the emission flow of carbon dioxide gas from the soil [13-15]. The effect of "effective microorganisms" (EM) was investigated in a field experiment (2003-2006) in Switzerland. The experiment was developed in order to clearly distinguish the influence of microorganisms directly and the substrate that served as their nutrient medium (introduction of the drug after sterilization). In this study, no effect of introduced microorganisms (EM) was found on yield and soil microbiological parameters such as soil respiration and microbial biomass. Based on the obtained results, it was concluded that "effective microorganisms" are not able to improve the yield and quality of the soil in the medium term (4 years) in agriculture in the conditions of the temperate climate of Central Europe [16].

In view of the above, the purpose of the article is to conduct observations during the growing season on the processes of "soil respiration" and the number of microflora in the soil of the root zone of plants, which will allow to reveal the influence of elements of biologization of agriculture (application of a complex of biological preparations, which includes a stubble destructor) on indicators of biological activity podzolized chernozem.

MATERIALS AND METHODS

CO₂ emission processes and the abundance of the main groups of microflora were studied during the 2020 growing season in the stationary field experiment

“The influence of different levels of biologization of agriculture on soil fertility” (registered under No. 07 in the Register of “Stationary Field Experiments of Ukraine”), which was established in 1989 in SE “DG “Grakivske” NNC “IGA named after O.N. Sokolovsky” near the village. Novy Korotych of the Kharkiv district of the Kharkiv region. The soil of the experimental field is chernozem, gilded with low humus, heavy loam on forest-like loam. The arable layer of the soil contains: humus according to the Tyurin method 4.1% [17]; of total nitrogen – 0.21% [18], mobile phosphorus according to the Chirykov method – 111 mg/kg of soil, mobile potassium according to the Chirykov method – 90 mg/kg of soil [19]. They studied the effect on “breathing” and the number of soil microorganisms of the complex application of biological preparations of various purposes. For the study, four variants of the experiment were laid:

1. Soil treatment with the Humistern stubble destructor, pre-sowing seed treatment with the biopreparation Humikor, two-time foliar treatment of plants with the liquid humic preparation Humisol-Plus 03 Corn (in the phase of 3-5 and 9-11 leaves) (all preparations produced by AF “Hermes”);
2. Control, without treatments;
3. Urea + soil treatment with the Humistern stubble destructor, pre-sowing seed treatment with the biopreparation Humikor, two-time foliar treatment of plants with the liquid humic preparation Humisol-Plus 03 Corn (in the phase of 3-5 and 9-11 leaves);
4. Urea, without processing.

The cultivated plant is corn for grain.

Observations of the intensity of CO₂ emissions from the soil were carried out in the field three times during the growing season of 2020. Instrumental control of the intensity of carbon dioxide emission from the soil surface was carried out using a testo 535 portable gas analyzer with isolation from atmospheric air. Measurements were performed 3-5 times a day with further averaging and statistical processing of the results. Simultaneously with the measurements of the intensity of carbon dioxide release, the temperature and humidity of the soil in the 0-20 cm layer were determined using a portable thermometer and hygrometer.

Portable gas analyzers are a convenient means of preliminary operational control of the gas composition of the soil. The testo 535 portable gas analyzer is designed to determine the concentration of carbon dioxide in soil air and in the surface part of the atmosphere. The device has a display part and an infrared probe-absorber. Probe type – 2-channel infrared sensor. The measurement range is from 0 to 104 ppm CO₂. The portable CO₂ gas analyzer is especially useful in cases that require mobility and frequent changes of the place of observation, because the light weight and compactness make this device very convenient to use. To increase the accuracy and objectivity of the mea-

surement results, you should choose an exposure of up to 15 minutes, a working chamber with an average absorption volume of 2-3 dm³ with a vertical fixation of the infrared probe at a distance of 1.5-2 cm from the soil surface [20].

The number of the main groups of microflora in the soil samples of the basal zone of plants was determined by the method of microbiological sowing of the soil suspension with the appropriate dilution on solid nutrient media [21-24]: organotrophic bacteria - on meat-peptone agar (MPA), microorganisms that assimilate nitrogen from mineral compounds, and actinomycetes – on starch-ammonium agar (KAA), oligotrophic microorganisms – on starvation agar (HA), fungi – on Richter's medium, Azotobacter – on Ashby's medium with the addition of trace elements, phosphate-mobilizing bacteria on Muromtsev's medium (for bacteria that dissolve mineral phosphates soil), and Mönkinoi (for bacteria that dissolve soil organic phosphates); (repetition 3 times: each soil sample was sown on each nutrient medium in 3 parallel Petri dishes). Soil samples for microbiological research were taken twice during the growing season - the first time 3 weeks after the last treatment of plants with liquid humic fertilizer, the second time – 2 months after the first, before harvesting.

RESULTS AND DISCUSSION

According to the results of field measurements obtained during the growing season of 2020, the difference in the release of carbon dioxide from the soil surface for the tested options is quite significant. The obtained results show an increase in the emission flow of carbon dioxide with the use of a complex of agricultural measures (treatment with a stubble destructor, treatment of seeds with a biopreparation and two-time foliar treatment with a humic preparation) (Fig. 1; 2).

An increase in the intensity of “breathing” was also observed with the introduction of urea. The data of many authors confirm that the use of biological preparations accelerates the decomposition of high-carbon plant residues and increases the biogenicity of the soil. The effectiveness of biological preparations also increases in combination with compensatory doses of nitrogen [25; 26].

The positive effect of the use of a complex of biological preparations on the microflora remained at the end of the growing season, although it was weaker than what was observed in July. The number of bacteria assimilating organic nitrogen compounds in the soil samples of variants treated with preparations without mineral fertilizers was 37-59% higher than that of the soil of the control plots, microorganisms assimilating mineral nitrogen – by an average of 31%, actinomycetes – by 11 %, oligotrophic microorganisms – by 5-8%. The number of micromycetes, as in the previous sampling period, decreased by 8-32%. On average, the number of microorganisms of the studied groups in the

soil of the root zone of corn in the variants with the use of agricultural measures without the introduction of mineral fertilizers was 15% higher than the control indicators. In the soil samples of the root zone of the plants, selected on the plots of options with additional treatment with urea, a larger number of microorganisms was also observed with the use of agromeasures, also to a lesser extent, than during the previous period of sampling. The number of organotrophic bacteria in the soil samples of the variants treated here was greater than in the control soil (surface treatment of the soil

with urea) by 11-49%, microorganisms that assimilate nitrogen mineral compounds by 54%, oligotrophs by 10%, eutrophs by 46%. The number of microscopic fungi decreased by 12-45%. Generalization of the data obtained during the second sampling showed that at the end of the growing season in the soil of the basal zone of plants with the use of a complex of preparations, the number of microorganisms of the main groups was on average higher than in the control, by 15% in the case without mineral fertilizers and by 18% in the background of urea.

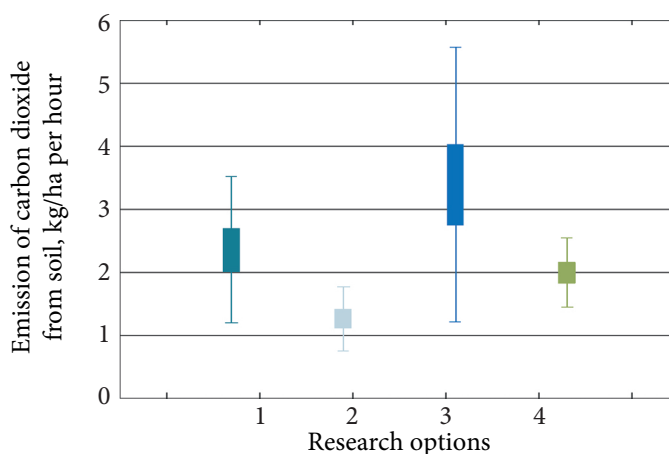


Figure 1. Emission of carbon dioxide from the soil in different versions of the experiment, kg/ha per hour

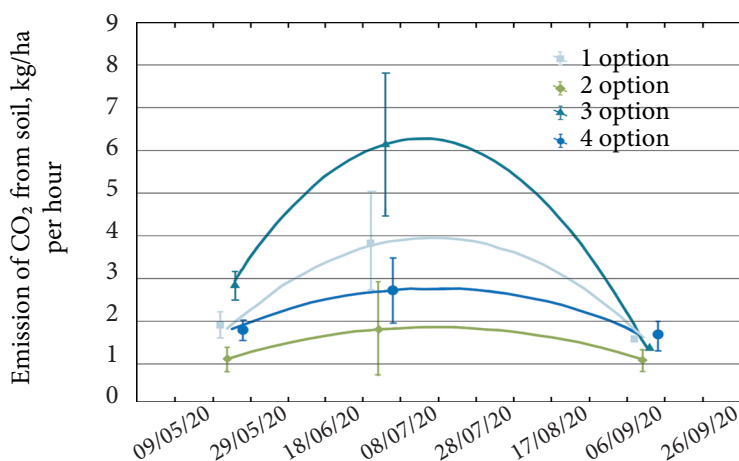


Figure 2. Seasonal dynamics of carbon dioxide emissions from the soil in different variants of the experiment, kg/ha per hour

The amount of CO₂ produced by the soil is determined both by biological factors (the rate of growth and development of plants and microorganisms, root respiration) and by the physical conditions of the environment (temperature and humidity of the air and soil, etc.). In this regard, the emission of CO₂ from the soil surface has quite clear daily and sea-

sonal dynamics. The authors observed an increase in emission in the summer period with a gradual fading until autumn (Fig. 2).

As you know, biological preparations “work” most actively during the initial period of decomposition, in optimal conditions of humidity and temperature for microbiota. The accompanying observations

of soil temperature and humidity showed the highest values in June-July, and in September, soil humidity was critically low, close to the humidity of plant wilt-

ing. According to the authors, this became one of the limiting factors that suppress “soil respiration” in the autumn period (Fig. 3, 4).

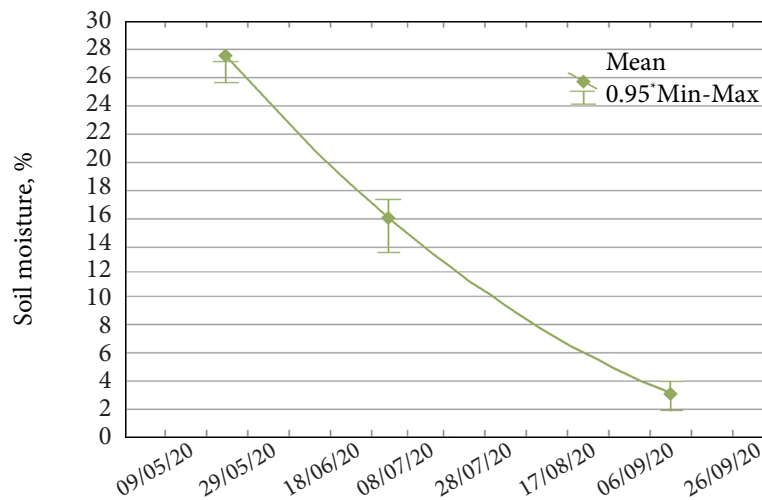


Figure 3. Seasonal dynamics of moisture in the arable soil layer

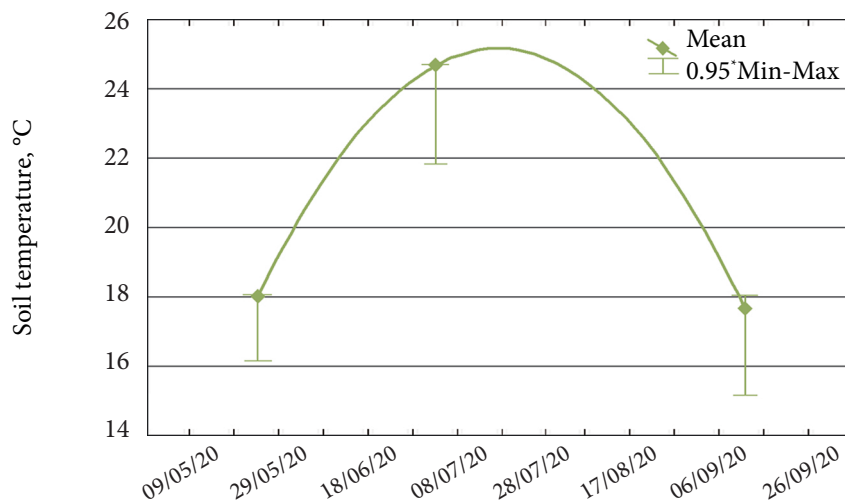


Figure 4. Seasonal temperature dynamics of the arable soil layer

As it known, root respiration makes up approximately 40% of the total soil respiration. Therefore, the growth of vegetation and root mass of plants significantly affects the overall emission flow. In particular, the influence of changes in humidity and soil temperature, as the main natural factors regulating the course of biological processes, during the growing season is covered by the action of a set of anthropogenic factors, primarily due to the contribution of root respiration. The largest contribution of root respiration to the emission flow is made by grain stubble crops – winter rye, winter wheat, barley, CO₂ intake from the soil

under which is 35% higher than from the soil under steam. Row crops (corn, sunflower) are inferior to them in this, probably due to less coverage by the root system of the upper soil layer [27; 28].

The obtained yield data of corn grain demonstrate a significant increase in the yield with the use of a complex of agricultural measures (treatment with a stubble destructor, seed treatment with a biopreparation and two-time foliar treatment with a humic preparation) both without the introduction of mineral fertilizers – by 14.5%, and against the background of urea – by 16% (Fig. 5).

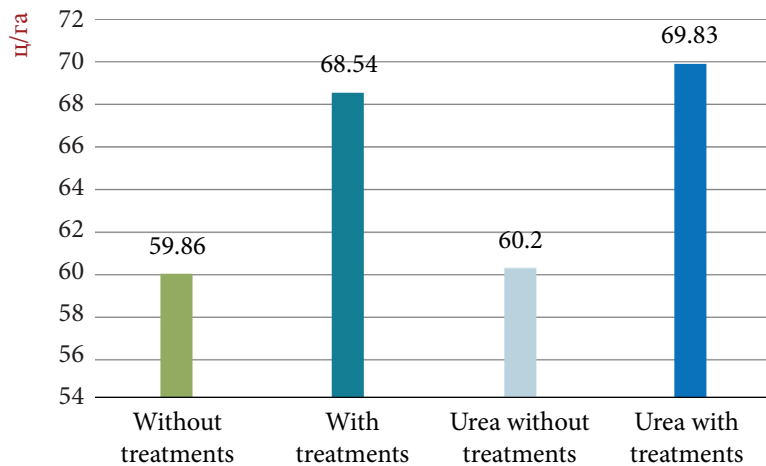


Figure 5. Grain yield of "DN Vita" corn

CONCLUSIONS

According to the obtained data, the use of a complex of agricultural measures, which includes the use of a stubble destructor, has a significant impact on the formation of the emission flow of carbon dioxide from podzolized chernozem and the microbial community in the root zone of plants. It has been confirmed that CO₂ emission from the soil surface has quite clear daily and seasonal dynamics. We recorded an increase in emission in the summer period with a gradual fading until autumn, which illustrates the direct connection of "soil respiration" with the seasonality of the microbial coenosis.

The influence of hydrothermal factors and the growth of the root mass of the plant are undoubtedly significant factors in changes in the emission flow. But the systematic complex application of biological preparations can, by accelerating the decomposition of high-carbon plant residues and increasing the biogenicity of the soil, significantly affect the dynamics of carbon dioxide production and the balance of soil carbon as a whole.

An increase in the number of microflora in the root zone of corn plants was noted, in particular, agronomically useful bacteria – nitrogen-fixing, phosphate-mobilizing, which contribute to the optimization of plant root nutrition.

In the conditions of the growing season of 2020, reliable increases in the yield of corn grain of the "DN Vita" variety from the use of a complex of biopreparations amounted to 14.5% without the introduction of mineral fertilizers, against the background of urea – 16%.

The use of modern microbial preparations in corn cultivation technologies can also limit non-productive losses of compounds of biogenic elements in the soil profile. Prospective studies are aimed at scientific justification for the further introduction into agricultural production of microbial preparations based on beneficial microorganisms, which can significantly reduce the chemical load on the environment and contribute to carbon sequestration in the soil.

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Вплив біопрепаратів на емісію CO₂ та мікрофлору у прикореневій зоні кукурудзи

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Анотація. Процес удосконалення систем землеробства відбиває основні періоди розвитку сільськогосподарської сфери в цілому. Розвиток систем землеробства є невід'ємною частиною промислового виробництва, а також науково-технічного прогресу. Важливим є розповсюдження та впровадження так званих альтернативних систем землеробства, що нівелюють або мінімізують використання агрохімікатів. Рослинні рештки є вагомим джерелом відтворення родючості орних ґрунтів, водночас перетворення мікроорганізмами свіжої органічної речовини в орних ґрунтах ознаменує такі процеси, як виробництво продовольства, парниковий ефект, а також глобальний кругообіг вуглецю. У свою чергу, інтегральним показником, що найбільш чітко та повно відображає характер інтенсивності мінералізації органічної речовини в ґрунті, є емісія вуглекислого газу. Таким чином, метою статті є проведення досліджень протягом вегетаційного періоду за процесами «дихання ґрунту» та кількістю мікрофлори у ґрунті прикореневої зони рослин, що дасть змогу виявити вплив елементів біологізації землеробства на показники біологічної активності чорнозему опідзоленого. За процесами емісії CO₂ та чисельністю головних груп мікрофлори спостерігали впродовж вегетаційного періоду 2020 р. у стаціонарному польовому досліді «Вплив різних рівнів біологізації землеробства на родючість ґрунту». У статті викладено результати проведення спостережень за емісією вуглекислого газу та іншими показниками біологічної активності ґрунту з метою визначення ефективності впровадження елементів біологізації землеробства. Встановлено, що застосування комплексу агрозаходів (обробка ґрунту деструктором стерні, передпосівна обробка насіння біопрепаратом та двократна позакоренева обробка гуміновим препаратом) посилили емісію CO₂ та підвищили чисельність мікрофлори у прикореневій зоні кукурудзи порівняно з контролем. Відмічено достовірний приріст урожаю зерна кукурудзи від застосування комплексу біопрепаратів (до 16 % залежності від варіанту)

Ключові слова: слова: емісія вуглекислого газу, біологізація землеробства, агрозаходи, мікрофлора ґрунту, кукурудза