EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

*Ecological Engineering & Environmental Technology* 2021, 22(6), 114–121
https://doi.org/10.12912/27197050/141466
ISSN 2719-7050, License CC-BY 4.0

Received: 2021.07.31
Accepted: 2021.08.25
Published: 2021.09.17

# Soybean Productivity in Rice Crop Rotation Depending on the Impact of Biodestructor on Post-Harvest Rice Residues

Volodymyr Dudchenko[1], Olena Markovska[2*], Olena Sydiakina[2]

[1] Institute of Rice of NAAS, Studentska Street 11, Antonivka, Skadovsk district Kherson region, 75705, Ukraine
[2] Kherson State Agrarian and Economic University, Stritenska St. 23, 73006, Kherson, Ukraine
* Corresponding author's e-mail: mark.elena@ukr.net

**ABSTRACT**
The use of biodestructors in agricultural technologies for efficient decomposition of crop residues affects the number and species composition of soil fungi, especially pathogenic species, and as a consequence, plant productivity. However, to date, this issue has not been extensively studied. The purpose of this experiment was to develop an effective method of destruction of post-harvest residues using biological products to realize the productive potential of soybeans in rice crop rotation. The work was conducted on the experimental plots of the Institute of Rice NAAS (Skadovsk district, Kherson region, Ukraine) during 2016–2018. In the experiment, the treatment of post-harvest rice residues with a biodestructor Biocomplex-BTU "Ecostern" (1 l/ha) in combination with concentrated amide water-soluble fertilizer, carbamide (30 kg/ha) was carried out in autumn. Application of carbamide alone (30 kg/ha) was used as a control. "Ecostern" is a concentrated agent, which comprises antagonists of pathogenic microorganisms as well as fungi and bacteria that accelerate decomposition of plant residues. The application of biodestructor Biocomplex-BTU "Ecostern" (1 l/ha) in combination with carbamide increased the total number of pathogenic and saprotrophic fungi in the soil from 65.5 to 80.5 thousand /g of soil or by 22.9%. However, the content of pathogenic microflora under this condition was 21.8% lower compared to the control (30 kg/ha carbamide), and the number of saprotrophs increased 3.3-fold. Following the combined use of biodestructor "Ecostern" and carbamide, the number of antagonist fungi has doubled, while the number of toxin-forming fungi decreased by 9.4%. The yield of soybeans also increased by 0.6 t/ha or by 17.9% compared to the control. The increase in yield was observed due to the higher standing density of plants and the number of beans per plant. Before the harvest, the standing density of soybean plants was 45 pcs/m$^2$, which is 9.7% higher than the control (41 pcs/m$^2$), due to the high level of field germination of seeds. The number of beans was 24 and 28 pieces per plant, exceeding the control by 16.7%, and the weight of 1000 grains was 156.2 g and 157.5 g, which is 0.8% than the control.

**Keywords:** post-harvest residues, microorganisms, fertilizers, soil, rice, soybeans, grain yield, weight of 1000 grains.

## INTRODUCTION

Stubble, straw, stalks and other plant residues, which are crushed and buried in the soil, are a source of organic matter and act as an environmentally safe factor that can increase soil fertility. Post-harvest residues help reduce soil density, improve water permeability and microbiological activity of soils. Their decomposition is accompanied by an increase in the number and activity of soil microflora. Microorganisms accumulate nitrogen in large quantities. Its essential role in plant growth highlights the need to use plant residues as organic fertilizers and their contribution to the biological cycle of elements (Hamaiunova et al., 2018; Markovskaya, 2018; Kovalenko et al. , 2020; Markovska et al., 2020).

Modern agricultural technologies rely on widespread use of chemicals, which can negatively affect the activity of beneficial microflora and slow down decomposition of plant residues (Hillocks, 2012). At the same time, lignin and phenols accumulate in the soil, growth and development of cultivated plants are inhibited, processes of organic matter mineralization are impeded, and soil fertility deteriorates overall (Velička et al., 2009). Phytopathogenic fungi and bacteria retained on plant residues are capable of penetrating plant cells and tissues, which can lead to infections and significantly reduce crop yields (Ampt et al., 2019). These negative phenomena can be prevented by using biodestructors, which accelerate the decomposition of plant residues, transform them into organic matter, improve soil fertility and provide a steady increase in crop yields (Marinoha, 2010; Bolokhovsky, 2013; Korsun et al., 2017). Under natural conditions, the conversion of plant residues into bioavailable elements takes several years. For example, it was shown that only about 20–25% of wheat straw decomposes in six months, and about 50% in 18 months (Kushnaryov et al., 2012).

The positive effect of biodestructor "Filazonit MC" on the microbiological activity of dark gray podzolic soil was determined during the cultivation of early varieties of table potatoes. In the experimental plots where biodestructor was used, the degree of cellulose decomposition exceeded 50%. The highest yield was observed when 10 l / ha biodestructor was used, alongside with mineral fertilizers $N_{120}P_{100}K_{160}$ (Humeniuk, 2012). In the same experiment, maximum content of mineral nitrogen, mobile phosphorus and metabolic potassium in the soil were determined (Humeniuk, 2013), whereas in potatoes, potassium compounds were quantified (Bikin and Humeniuk, 2013).

The effectiveness of biodestructors "Vermistym-D", "P-3" and their mixtures was studied on chernozem typical AF "Kolos" in Skvyra district of Kyiv region. After harvesting winter wheat, straw was crushed, sprayed with biodestructors and buried in the soil at a depth of 8–12 cm. It was found that the use of a mixture of biodestructors Vermistim-D and P-3 in a ratio of 5: 1 provided the highest levels of biological activity (129.5 ± 3.5 mol $CO_2$) and potential nitrification activity (9.6 ± 1.1 μg of nitrogen/100 g of soil). Under the same condition, the highest numbers of ammonifiers and nitrogen-fixing bacteria in the root system of plants (16.67; 128 and 187.3 million/g of soil) were observed. Comparison of the effects between individual biodestructors indicated that the use of P-3 was advantageous. In general, biodestructors had a positive effect on the agrochemical properties of typical chernozem, in particular, on the content of compounds of easily hydrolyzed nitrogen, mobile forms of phosphorus and potassium (Tsentilo and Sendetsky, 2014).

Improvements in microbiological and agrochemical paraments of soil, when "Biodestructor of stubble" was used after harvesting of spring barley, were also observed on chernozem soils of the southern experimental plots of Nikolaev NAU. Treatment of stubble with biodestructor contributed to an increase in the total number of bacteria, including nitrogen fixers, and fungi capable of hydrolyzing cellulose. In addition, neutralization of the soil solution reaction was observed (Hamaiunova et al., 2011). The use of "Biodestructor of stubble" increased the content of nitrates, mobile phosphorus and metabolic potassium in the soil, which helped optimize the nutrient availability for winter wheat variety Kolchuga and, over the course of 5 years of research, increased grain yield by 0.45 t/ha when wheat was cultivated after spring barley and by 0.67 t/ha – after peas (Panfilova et al., 2019; Panfilova and Hamaiunova, 2019).

Activation of decomposition of plant residues of winter wheat stimulated by "Biodestructor of stubble" (2.5 l/ha) in combination with ammonium nitrate (20 kg/ha) was demonstrated in studies conducted on sod-carbonate soil (Male Polissya) used for growing flaxseed variety Nadiynyi. In the experiment with a biodestructor, a higher seedling density and better preservation of stems during the growing season were observed. When a biodestructor was used, flaxseed plants had a better developed root system, greater height and dark green color. Optimal plant development also ensured higher productivity. Thus, the yield of flaxseeds under experimental condition was higher by 0.13 t/ha and 0.21 t/ha compared to ammonium nitrate application and control, respectively. Experimental plot in which a biodestructor was used also had the highest weight of 1000 seeds (Kulish, 2014).

At the present stage of development of the agricultural sector, study of the biological activity of soils is crucial. Deeper understanding of microbiological processes will reveal patterns of transformation of organic matter, consequences of anthropogenic impacts on soils and ways to eliminate them. One of such measures is the use of biodestructors in modern agricultural technologies for efficient decomposition of plant residues. Microorganisms, enzymes and biologically active substances found in biological products accelerate the conversion of undecomposed organic matter into forms of nutrients that are available to plants, prevent development and spread of diseases, improve microbiological and agrochemical properties of soils. Optimization of acid-base balance and nutrient levels for plants, in turn, allow increasing the productive potential of crops and have a substantial economic impact. Determination of the effectiveness of biodestructors, their environmental safety and impact on soil formation is an urgent matter of the modern agronomic industry and is of scientific interest to many researchers.

## MATERIALS AND METHODS

The purpose of this study was to develop an effective method of destruction of post-harvest residues with the help of biological products to realize the productive potential of soybeans in rice crop rotation. The experimental part of the work was performed on the experimental plots of the Institute of Rice NAAS (Skadovsk district, Kherson region, Ukraine) during 2016–2018.

The climate of Kherson region is temperate-continental with relatively mild winters (average temperatures of winter months: -1 °C – -3 °C), hot and long summers (average temperatures: + 22 °C – + 23 °C, maximum – higher than 40 °C). The average annual air temperature ranges from +9.3 °C to +9.8 °C. The average annual precipitation in the region is about 400 mm, but the amount of precipitation has increased over the last decade. The north-western areas have the highest precipitation (450–470 mm), whereas southern – the lowest (300 mm). Summers account for most of the precipitation, mainly in the form of showers, while in winter the snow cover is unstable and in recent years – almost absent.

The soil cover of the experimental plot was represented by meadow-chestnut residual-saline medium-loam soils. The sum of absorbed bases ($Ca^{2+}$+ $Mg^{2+}$) was 15.38 mg-eq/100 g, absorbed Na – 0.75 mg-eq/100 g. pH of the aqueous extract was 7.2 and the type of salinity was chloride-sulfate. Humus content in the arable layer was 2.1% (according to Tyurin), nitrogen – 7.14–12.5 mg/100 g of soil, metabolic phosphorus and potassium according to Machigin 3.28–4.32 and 27.3–37.4 mg/100 g of soil, respectively. The soil density of soil in the arable layer was 1.40 g/cm$^3$.

In the experiment, treatment of post-harvest rice residues with biodestructor Biocomplex-BTU "Ecostern" (1 l/ha) in combination with concentrated amide water-soluble fertilizer carbamide (30 kg/ha) was carried out in autumn. Application of carbamide alone (30 kg/ha) was used as a control. "Ecostern" is a concentrated agent, which comprises fungi and bacteria that accelerate decomposition of plant residues as well as antagonists of pathogenic microorganisms and living cells of Bacillus subtilis, Azotobacter, Enterobacter, Enterococcus and fungi Trichoderma lignorum, Trichoderma viride. The CFU is 2.5 x $10^9$ per cm$^3$. This biodestructor is used after harvesting crops not only to accelerate the decomposition of post-harvest residues, but also to inhibit the development of phytopathogens, neutralize phytotoxins, improve biological activity of the soil, its physical and agrochemical properties.

The location of the experimental plots was systematic, and the experiment was repeated four times. The size of the sowing area was 30 m$^2$ and the record area was 24 m$^2$. Soybean variety of Ukrainian selection Oksana was sown at a density of 600 thousand/ha of seeds. The variety belongs to the middle-early maturity group and is used for grain direction. The weight of 1000 grains is 138.9 g, the protein content is 37.6%, the oil content is 21.4%, and the potential yield is 2.5–3.0 t/ha. It is characterized by high resistance to major diseases of the soybean crops. Sowing was perfomed in a wide-row method, with 38 cm between rows, in the second ten-day period of April with an Amazone Premiera 4500 seeder. $N_{30}$ in the form of sulfamoamophos was applied for pre-sowing cultivation. Soybean crops were irrigated by flooding during the flowering phase at the level of 1000 m$^3$/ha.

The experiment was conducted using field, laboratory, mathematical and statistical methods according to generally accepted in Ukraine methods and guidelines (Ushkarenko et al., 2008; Ushkarenko et al., 2014). Isolation of fungi from soil samples into pure cultures and determination of species composition was carried out in the department of plant protection against pests and diseases of the NSC "Institute of Agriculture NAAS". The experiment was accompanied by observations and record keeping (determination of seed germination, plant standing density, phenological phases, biometric and structural indicators). Soybean yield was determined using the method of direct combining of record plots (direct processing with a small-sized combine harvester "Yanmar"). Yield data were reduced to standard values – purity 100%, humidity 12%.

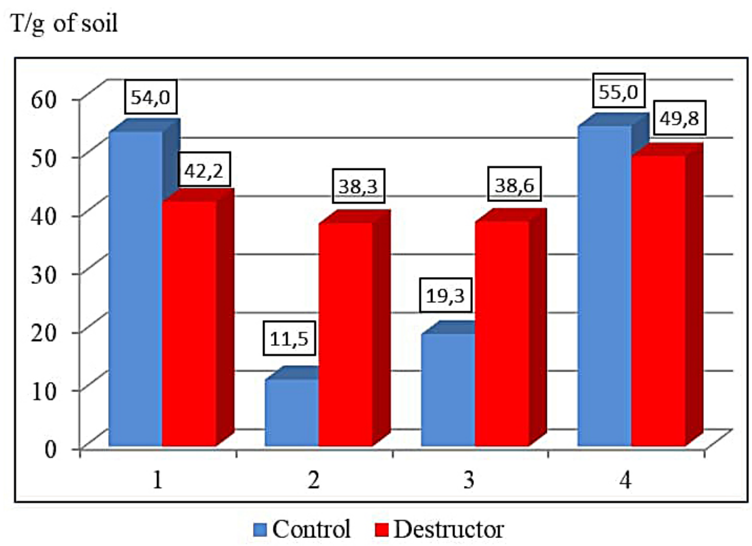
## RESULTS AND DISCUSSION

Fungi are an important constituent of soil fauna and their biomass is usually greater than the biomass of bacteria (Gaddeyya et al., 2012; Nosratabadi et al., 2017). Activity of fungi facilitates conversion of sparingly soluble organic substances into bioavailable forms. Depending on the energy source, fungi are classified into three groups: saprotrophic (reducers), mycorrhizal (bind root cells to soil particles) and pathogenic (parasites). Many fungi are saprotrophic. While they are considered non-pathogenic, some of them can cause infection (Underhill and Iliev, 2014). Biomass of potentially pathogenic fungi such as Histoplasma capsulatum, Sporothrix schenckii, Coccidioides immitis, Blastomyces dermatitidis and others in the soil gradually increases, which can lead to a higher frequency and severity of infectious diseases (Aghamirian and Ghiasian, 2012). The change in the number of pathogenic fungi in the soil when biodestructors are used to accelerate decomposition of post-harvest residues has not been well studied (Termorshuizen, 2016), which determined the relevance of this experiment.

The study of the effectiveness of concentrated amide water-soluble fertilizer carbamide (30 kg/ha) in combination with the biodestructor Biocomplex-BTU "Ecostern" (1 l/ha) on the decomposition of postharvest rice residues found that the total number of pathogenic and saprotrophic fungi in the soil was within 65.5 to 80.5 thousand/g of soil. The maximum number of pathogenic species was recorded in the control (30 kg/ha carbamide) – 54.0 thousand/g of soil. The use of biodestructor Biocomplex-BTU "Ecostern" (1 l/ha) in combination with water-soluble fertilizer carbamide (30 kg/ha) reduced this figure to 42.2 thousand/g of soil or by 21.8%. The content of saprotrophic microflora was 3.3 times higher than the control (Fig. 1).

Antagonistic fungi play an important role in inhibiting disease development and stimulating the growth of the plant root system (Chandra et al., 2020). Fungi from the genus Trichoderma produce helicase, which destroys the cell walls of pathogens, and other enzymes, in particular, gluconase, chitinase (Abdel-lateif, 2017) and cellulase, which promotes the competitive population of the rhizosphere of plants by this fungus (Cao et al., 2019; Li et al., 2020). Fungi from the genus Trichoderma also limit development of phytopathogens such as Rhizoctonia, Alternaria, Armillaria, Botrytis, Fusarium, Pythium, Phoma, Phytophthora, Ascochyta, Helmintosporium, Colletotrichum and prevent the damage of cereals and vegetable crops caused by root rot (Domsh et al.). Toxin-forming species of fungi produce metabolites of various chemical nature, in most cases, non-protein, that characterized by pathogenic action (Kondakova et al., 2019).

In our experiment, the minimum proportion of antagonist fungi, 19.3 thousand/g of soil, and the maximum proportion of toxin-forming species, 38.6 thousand/g of soil, was found in control (30 kg/ha carbamide). Treatment of post-harvest




Note: 1 - pathogenic species; 2 - saprotofic species;
3- antagonist fungi; 4 - toxin-producing species.

**Figure 1.** Number of fungi in soil samples with post-harvest rice residues (averages for 2016 – 2018)

residues with biological product "Ecostern" (1 l/ha) in combination with carbamide (30 kg/ha) contributed to an increase in the number of antagonist fungi in the soil (from 19.3 to 38.6 thousand/g of soil) and a reduction in toxin-forming fungi (from 55.0 to 49.8 thousand/g of soil).

According to the results of mycological analysis of soil samples with post-harvest rice residues, 38 isolates were found. Among them, 6 species of fungi belonging to 4 genera were identified: *Penicillium* (*Penicillium viridicatum* Westling, *P. Raciborskii* Zaleski, *P. Funiculosum* Thom), *Rhizopus* (*Rhizopus stolonifer* (Ehrenberg: Fries) Vuill.), *Fusarium (Fusarium oxysporum* (Snyd). EtHans), *Gliocladium (Gliocladium rozeum* Bainier).

Among saprotrophic fungi, species from the genus *Penicillium (Penicillium raciborskii* Zaleski, *P. Funiculosum* Thom) were found. Pathogens were represented by four species of fungi: *Penicillium viridicatum* Westling, *Rhizopus stolonifer* (Ehrenberg: Fries) Vuill., *Fusarium oxysporum* (Schlecht.) Snyd. etHans, *Gliocladium roseum* Bainier. Identified toxin-forming species were *Penicillium viridicatum* Westling, *Penicillium funiculosum* Thom, *Fusarium oxysporum* (Schlecht.) Snyd. Et Hans), *Gliocladium rozeum* Bainier.

The species composition of the pathogenic microflora differed depending on the experimental conditions. In the control (30 kg/ha carbamide), the presence of pathogenic fungi from three genera was determined: Fusarium – 47.1%, Penicillium – 11.8% and Gliocladium – 23.5%. Application of biodestructor "Ecostern" (1 l/ha) in combination with carbamide (30 kg/ha) helped reduce the number of fungi from genus Fusarium from 47.1% to 4.8% as well as increased the number of fungi from genus Penicillium from 11.8% to 42.9% and the proportion of pathogenic fungi from genus Rhizopus to 4.7%. Pathogenic fungi from the genus Gliocladium were present only in the control (23.5%) (Table 1).

Thus, the use of "Ecostern" (1 l/ha) in combination with carbamide (30 kg/ha) led to a reduction in the number of pathogenic fungi from 54.0 to 42.2 thousand/g of soil or by 21.8% and in the number of toxin-forming fungi from 55.0 to 49.8 thousand / g of soil or by 9.4%. It also caused an increase in the number of antagonist fungi from 19.3 to 38.6 thousand/g of soil or two fold.

As for the impact of studied experimental conditions on soybean yield, it was found to be 0.6 t/ha or 17.9% higher when biodestructor "Ecostern" (1 l/ha) was used in combination with carbamide (30 kg/ha). In addition, the content of post-harvest rice residues in the soil at the time of soybean sowing was lower by 1.25 g/kg of soil or by 20.3%, compared to the control, creating favorable conditions for seed germination

The significant increase in soybean yield when biodestructor "Ecostern" was used in combination with carbamide can be explained by better conditions for seed germination due to fewer post-harvest residues; positive effect of phytohormones present in the agent on germination and germination energy of seeds; reduction in pathogenic and increase in the amount of beneficial microflora for plants, which in turn, lowered the risk of diseases of the root system. Potassium-, phosphorus-mobilizing and nitrogen-fixing microorganisms and biologically active substances that constitute biodestructor Biocomplex-BTU "Ecostern" increased the overall biological activity, improved physical and chemical properties of the soil and created optimal conditions for growth and development of soybean plants.

Having analyzed structural elements of soybeans, it was found that the maximum productivity of the crop was achieved during combined use of biodestructor "Ecostern" and carbamide due to higher plant standing density and number of beans per plant (Table 2).

**Table 1.** Number of pathogenic fungi in soil samples with post-harvest rice residues (averages for 2016–2018)

| Experimental condition | Total pathogenic fungi | | Including genera. % | | | |
|---|---|---|---|---|---|---|
| | T/g of soil | % | *Fusarium* | *Penicillium* | *Rhizopus* | *Gliocladium* |
| Control (carbamide–30 kg/ha) | 54.0 | 82.4 | 47.1 | 11.8 | 0 | 23.5 |
| "Ecostern" (1 l/ha)+carbamide (30 kg/ha) | 42.2 | 52.4 | 4.8 | 42.9 | 4.7 | 0 |

Note: T – thousand

**Table 2.** Soybean yield and residual amount of post-harvest rice residues in the soil and structural elements of soybean crop yield (averages for 2016–2018)

| Studied indicators | Experimental condition | |
|---|---|---|
| | Control (carbamide–30 kg/ha) | "Ecostern" (1 l/ha) + carbamide (30 kg/ha) |
| Content of post-harvest rice residues, g/kg of soil | 6.16 | 4.91 |
| Plant standing density before harvest, pcs/m2 | 41 | 45 |
| Beans / plants | 24 | 28 |
| Weight of 1000 seeds, g | 156.2 | 157.5 |
| Seeds per bean | 2.4 | 2.4 |
| Yield, t/ha | 3.29 | 3.88 |
| Increase compared to control, t/ha | | 0.59 |
| $LSD_{05,}$ t/ha | | 0.34 |

Thus, before the harvest, the standing density of soybean plants was 45 pcs/m$^2$, which is 9.8% higher than the control (41 pcs/m$^2$) due to the high field germination of seeds. In turn, the number of beans was 24 and 28 pieces/plant, exceeding the control by 16.7%, and the weight of 1000 grains was 156.2 and 157.5, which was 0.8% higher than the control.

Using the calculation of the economic efficiency of soybean growing technology, the application of biodestructor Biocomplex-BTU "Ecostern" (1 l/ha) alongside with concentrated amide water-soluble fertilizer carbamide (30 kg/ha) was found to be highly profitable (254.6%).

## CONCLUSIONS

Treatment of post-harvest rice residues with biodestructor Biocomplex-BTU "Ecostern" (1 l/ha) in combination with concentrated amide water-soluble fertilizer carbamide (30 kg/ha) in autumn increased the total number of pathogenic and saprotrophic fungi in the soil from 65.5 to 80.5 thousand/g of soil or by 22.9%. The content of pathogenic microflora under the aforementioned condition was lower compared to the control (30 kg/ha carbamide) by 21.8%, and the number of saprotrophs increased 3.3-fold. Furthermore, the number of antagonist fungi doubled, while the number of toxin-forming fungi decreased by 9.4% compared to the control.

Mycological analysis of soil samples with post-harvest rice residues identified 6 species of fungi that belonged to 4 genera. Among the saprotrophic fungi, species from the genus *Penicillium* (*Penicillium raciborskii* Zaleski, *P. Funiculosum* Thom) were found. Pathogens were represented by four species of fungi: *Penicillium viridicatum* Westling, *Rhizopus stolonifer* (Ehrenberg: Fries) Vuill., *Fusarium oxysporum* (Schlecht.) Snyd. etHans, *Gliocladium roseum* Bainier. Identified toxin-forming species were *Penicillium viridicatum* Westling, *Penicillium funiculosum* Thom, *Fusarium oxysporum* (Schlecht.) Snyd. Et Hans), *Gliocladium rozeum* Bainier. Application of biodestructor "Ecostern" (1 l/ha) in combination with carbamide (30 kg/ha) helped reduce the number of fungi from genus *Fusarium* from 47.1% to 4.8% as well as increased the number of fungi from genus *Penicillium* from 11.8 % to 42.9% and the proportion of pathogenic fungi from genus *Rhizopus* to 4.7%.

The use of biodestructor "Ecostern" (1 l/ha) in combination with carbamide (30 kg/ha) increased soybean yield by 0.6 t/ha or by 17.9% due to higher plant standing density and the number of beans per plant. Before the harvest, the standing density of soybean plants was 45 pcs/m$^2$, which is 9.7% higher than the control (41 pcs/m$^2$) due to the high field germination of seeds. In turn, the number of beans was 24 and 28 pieces/plant, exceeding the control by 16.7%, and the weight of 1000 grains was 156.2 and 157.5, which was 0.8% than the control.

## REFERENCES


1. Abdel-lateif K.S. 2017. Trichoderma as biological control weapon against soil borne plant pathogens. African Journal of Biotechnology, 16(50), 2299–2306.
2. Aghamirian M.R., Ghiasian S.A. 2012. The prevalence of fungi in thesoil of Qazvin, Iran. Jundishapur J Microbiol, 6(1), 76–79.
3. Ampt E.A., van Ruijven J., Raaijmakers J.M., Termorshuizen A.J., Mommer L. 2019. Linking ecology and plant pathology to unravel the importance

of soil-borne fungal pathogens in species-rich grasslands. European Journal of Plant Pathology, 154(1), 141–156.

4. Bikin A.V., Humeniuk O.V. 2013. Influence of mineral fertilizers and biodestructor on potassium nutrition of table potato plants. Scientific works of the Institute of Bioenergy Crops and Sugar Beets, 18, 115–117 (in Ukrainian).
5. Bolokhovsky V. 2013. Reviving soil fertility. Agronomist, 3, 464–465 (in Ukrainian).
6. Cao Y., Zheng F., Zhang W., Meng X., Liu W. 2019. Trichoderma reesei XYR 1 recruits SWI/SNF to facilitate cellulase gene expression. Mol. Microbiol., 112, 1145–1162.
7. Chandra H., Kumari P., Bisht R., Prasad R., Yadav S. 2020. Plant growth promoting Pseudomonas aeruginosa from Valeriana wallichii displays antagonistic potential against three phytopathogenic fungi. Molecular Biology Reports, 47, 6015–6026.
8. Domsh K.H., Gams W., Anderson T.H. 2007. Compendium of soil fungi. Eching: IHW-Verlag, 672.
9. Gaddeyya G., Niharika P.S., Bharathi P., Kumar P.R. 2012. Isolation,and identification of soil mycoflora in different crop fields at Salur Mandal. Adv Appl Sci Res., 3(4), 2020-2026.
10. Hamaiunova V., Hlushko T., Honenko L. 2018. Preservation of soil fertility as basis for improving the efficiency of management in the Southern Steppe of Ukraine. Scientific development and achievements. London, 4, 13–27.
11. Hamaiunova V.V., Kovalenko O.A., Panfilova A.V., Bolokhovsky V.V. 2011. Microbiological activity of soil after spring barley when using stubble biodestructor. Scientific works of the Black Sea State University. Petro Mohyla of the Kyiv-Mohyla Academy complex. Series: Ecology, 150, 138, 61–63 (in Ukrainian).
12. Hillocks R.J. 2012. Farming with fewer pesticides: EU pesticide review and resulting challenges for UK agriculture. Crop Protection, 31(1), 85–93.
13. Humeniuk O.V. 2012. Influence of biodestructor on soil microbiological activity and yield of table potatoes. Bulletin of Agricultural Science, 11, 73–75 (in Ukrainian).
14. Humeniuk O.V. 2013. Nutrient regime of dark gray podzolic soil using stubble biodestructor. Bulletin of Kharkiv National Agrarian University named after V.V. Dokuchaev. Series: Soil science, agrochemistry, agriculture, forestry, soil ecology, 1, 129–134 (in Ukrainian).
15. Kondakova I.A., Levin V.I., Lgova I.P., Lomova Y.V., Vologzhanina E.A., Antoshina O.A. 2019. Mycotoxins of the grain mass are an important problem of agricultural enterprises. International Journal of Advanced Biotechnology and Research, 10(2), 223–230.
16. Korsun S.G., Klimenko I.I., Davydyuk G.V., Dovbash N.I., Shkarivska L.I. 2017. Ecological expediency of application of biodestructor "Ecostern" in intensive agriculture. Farming, 1, 69–73 (in Ukrainian).
17. Kovalenko A.M., Novohyzhnii M.V., Tymoshenko G.Z., Sergheyeva Yu.O. 2020. Features of application of destructors of stubble in the steppe zone. Bulletin of Agricultural Science, 2(803), 44–51 (in Ukrainian).
18. Kulish O. 2014. Influence of stubble biodestructor on oilseed flax seed yield in the area of small Polissya of Ukraine. Technical and technological aspects of development and testing of new equipment and technologies for agriculture of Ukraine, 18(2), 169–174 (in Ukrainian).
19. Kushnaryov A., Kravchuk V., Bobrovny E. 2012. Influence of degree of crushing and depth of laying of straw in soil on intensity of its decomposition with use of the biodestructor "Sternifag". Machinery and technologies of agro-industrial complex, 12, 24–27 (in Ukrainian).
20. Li J.X., Zhang F., Jiang D.D., Li J., Wang F.L., Zhang Z., Wang W., Zhao X.Q. 2020. Diversity of Cellulase-Producing Filamentous Fungi From Tibet and Transcriptomic Analysis of a Superior Cellulase Producer Trichoderma harzianum LZ117. Frontiers in microbiology, 11, 1617.
21. Marinoha P. 2010. Microbiological improvement of soils. Agronomist, 3, 28–29 (in Ukrainian).
22. Markovskaya O.E. 2018. Dynamics of microorganism in dark kastanozems in different systems of basic tillage and fertilizer in crop rotation on irrigation. Agrology, 1(3), 294–299 (in Ukrainian).
23. Markovska O., Maliarchuk M., Maliarchuk V., Ivaniv M., Dudchenko V. 2020. Modelling of humus balance under different systems of basic tillage and soil fertilization in crop rotations Ukrainian Journal of Ecology, 10(5), 291–295 (in Ukrainian).
24. Nosratabadi M., Kordbacheh P., Kachuei R., Safara M., Rezaie S., Afshari M.A., Jafari H. 2017. Isolation and identification of non-pathogenic and pathogenic fungi from the soil of Greater Tunb, Abu-Musa and Sirri Islands, Persian Gulf, Iran. Journal of Applied Biotechnology Reports, 4(4), 713–718.
25. Panfilova A.V., Hamaiunova V.V., Drobitko A.V. 2019. Yield of winter wheat depending on the predecessor and biodestructor of stubble. Bulletin of the Poltava State Agrarian Academy, 3, 18–25 (in Ukrainian).
26. Panfilova A.V., Hamaiunova V.V. 2019. Influence of stubble biodestructor on soil nutrient regime. Bulletin of Lviv National Agrarian University. Agronomy, 23, 229–233 (in Ukrainian).

27. Termorshuizen A.J. 2016. Ecology of fungal plant pathogens. Microbiology Spectrum, 4(6), 387–397.
28. Tsentilo L., Sendetsky V. 2014. Biological efficiency of biodestructors use. Bulletin of Zhytomyr National Agroecological University, 2(1), 93–99 (in Ukrainian).
29. Underhill D.M., Iliev I.D. 2014. The mycobiota: interactions between commensal fungi and the host immune system. Nat Rev Immunol, 14(6), 405–416.
30. Ushkarenko V.O., Nikishenko V.L., Goloborodko S.P., Kokovihin S.V. 2008. Disperse and correlation analysis in agriculture and plant science: textbook. Kherson: Aylant (in Ukrainian).
31. Ushkarenko V.O., Kokovikhin S.V., Holoborodko S.P., Vozhehova R.A. 2014. Metodologiya poliovoho doslidu (Zroshuvane zemlerobstvo). Kherson: Hrin DS (in Ukrainian).
32. Velička R., Rimkevičienė M., Kriauciuniene Z., Pupalienė R., Salina O. 2009. The effect of cellulose-degrading micro-organisms on the biodestruction of crop residues in the soil. Zemdirbyste-Agriculture, 96(1), 113–126.