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The Influence of Biological Preparations on the Microbiological Activity of Sod-Podzolic Soil for the Cultivation of Food Potatoes

Abstract. In the present-day world, the demand for organic products is growing, but there is an insufficient number of studies on the impact of biological preparations on soil fertility parameters. Indicators of microbiological activity are not the same for different soil types, which is why it is necessary to investigate them in detail in specific soil and climatic conditions, especially on zonal soils, which are sod-podzolic soils in Polissia. Research on the impact of various biological preparations on soil fertility indicators for the cultivation of one of the most popular crops in Ukraine – food potatoes – is relevant. The purpose of this study was to establish the effect of treatment of potato tuber seeds with biological preparations and introduction of a biodestructor for better decomposition of siderate on the focus of microbiological processes in the soil. The study was carried out in an experiment at the Volyn State Agricultural Research Station of the Institute of Potato Growing of the National Academy of Agrarian Sciences of Ukraine. The soil of the experimental site was sod-medium-podzolic sandy soil on water-glacial deposits. The stationary experiment included variants with the addition of siderate to the soil without a destructor (Background 1) and with the addition of the Ecostern destructor to the siderate (Background 2). The effectiveness of the following biological preparations was also investigated: Mycohelp, Agat, Regoplant, Fitohelp, Stimpo. Soil analysis for microbiological indicators was carried out in samples taken from the 0-20 cm layer. The focus of microbiological processes in the soil was found by the corresponding coefficients. It was found that the oligotrophicity coefficient was less than one on the variants using the Ecostern biodestructor during the growing season of potatoes, which indicates a good supply of easily digestible organic substances to the soil microbiota, while on the variants without Ecostern during the ripening phase, the oligotrophicity coefficients exceeded one. The coefficient of pedotrophicity changed more during the growing season than according to the variants of the experiment. In the seedling and flowering phase of potatoes, mineralisation-immobilisation coefficients were low in all variants of the experiment, which indicates the predominance of synthesis of organic matter. The materials of this paper are of practical value for farmers and producers of organic crop production in the issue of plant residue management for the use of biodestructors in the technology of growing food potatoes

Keywords: biodestructor, siderate, oligotrophic factor, pedotrophic factor, humification

INTRODUCTION

Ukraine is one of the five countries with the largest planting areas of this crop, but in terms of yield it is considerably inferior to other countries [1]. This is because 90% of the potato harvest comes from private households. The low yield of potatoes is caused by low-quality seed material, its damage by many pathogens [1] and insufficient nutrients [2-4]. O.Sh. Iskakova [3] notes that potato cultivation technologies should ensure both high yield and the achievement of a prominent level of profitability.

That is why it is important to form a favourable culture nutrition regime, as well as protection from stressful phenomena.

In Ukraine, the market of biological preparations is intensively developing. This is due to the growing demand for environmentally friendly products [5].

However, literary sources hold conflicting information regarding the positive or absent effect of biological preparations on indicators of biological activity

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of soils, which is why this issue is relevant and requires detailed investigation.

Research conducted in the Ternopil region proved the feasibility of treating potato tubers with Albit (100 ml per 1 tonne of seeds) followed by spraying twice during the growing season at 50 ml per 1 ha [6]. The yield of potatoes and their need for nutrients were more influenced by weather conditions, variety, and the content of nutrients in the soil [7; 8].

In poor sod-podzolic soils, nitrogen is in the first minimum among nutrients. Nitrogen affects the growth of plants, photosynthesis, metabolism, and as a result, the productivity and indicators of the crop quality [9]. When developing technologies for growing potatoes, it is important to find new alternatives to chemical fertilisers [10].

In Polissia, one of the most critical tasks in the area where sod-podzolic crops are spread is to ensure an increase in the content of organic matter in the soil, including humus. In the conditions of a shortage of conventional fertilisers, an effective alternative to humus is the use of crop residues [11].

Biologisation, the use of biological preparations, is a new trend in modern agar production [12]. According to studies [13], the effectiveness of biostimulants was manifested in the improvement of soil properties: the structural composition of the soil, the nutrient regime, the increase in biological activity in the deeper layers of the soil, the better development of the rhizosphere and the yield of winter wheat compared to the control.

According to researchers, biostimulants can be used as bioactive products in agriculture to increase plant productivity and resistance to stressful conditions [14].

The special role of microorganisms in the functioning of soils as elements of ecobiosystems: they take part in the small biological cycle of substances and energy in the soil, as well as in their influence on soil fertility indicators, namely on the transformation of nutrients in the soil, primarily nitrogen and carbon [15-17].

In the studies of R.A. Vozhehova *et al.* [18], the yield of summer-planted potatoes did not depend on the variants for treatment of tubers with chemical and biological preparations, and the average yield for three years was 20.86 t/ha, excluding the variant with additional treatment of plants with a biological preparation of fungicidal action Haupsin, where the yield increase was 0.33 t/ha.

The purpose of this study was to investigate the focus of microbiological processes in sod-medium-podzolic soil using a biodestructor for better decomposition of siderate and treatment of potato tuber seeds with biological preparations. The task of this study was to prove changes in the coefficients of oligotrophy, pedotrophy and mineralisation-immobilisation with the use of various biological preparations.

MATERIALS AND METHODS

The research was conducted under experimental conditions based on the Volyn State Agricultural Research

Station of the Institute of Potato Breeding of the National Academy of Sciences of Ukraine in 2019-2021 on sod-medium-podzolic sandy soil typical for the Polissia zone of Ukraine.

Potatoes of the Partner variety were grown in the experiment: a medium-early Ukrainian food potato variety. The vegetation period was approximately 107 days.

A two-factor stationary experiment included the following variants:

Factor A.

1. Control (without siderate biodestructor).
2. Biodestructor Ecostern in a dose of 1.2 l/ha.

The siderate was white mustard (200 c/ha), which was introduced into the soil.

Factor B. Treatment of potato tubers and 3-time spraying during the growing season of potato plants with biological preparations.

1. Control (without biological preparation).
2. Background – (introduction of Mycohelp 2.0 l/ha into the soil) + triple treatment during the growing season, Agat 25 – 100 ml/ha
3. Background + triple treatment during the growing season, Regoplant – 50 ml/ha.
4. Background + triple treatment during the growing season, Phytohelp – 1.0 l/ha.
5. Background + triple treatment during the growing season, Stimpo – 15 ml/ha.
6. Treatment of tubers with Mycohelp – 2.0 l/t + triple treatment with Mycohelp – 1.0 l/ha during the growing season.
7. Treatment of tubers with Regoplant 50 ml/t + triple treatment with Regoplant 50 ml/ha during the growing season.
8. Treatment of tubers with Fitohelp - 1.0 l/t + triple treatment with Fitohelp – 1.0 l/ha during the growing season.
9. Treatment of Stimpo tubers – 15 ml/t + triple treatment of Stimpo 15 ml/ha during the growing season.

Soil analysis for microbiological indicators was performed in samples taken from the 0-20 cm layer. In the studies, the number of microorganisms of the main ecological-trophic and taxonomic groups was found according to the method of microbiological sowing of soil suspension on different solid agarised nutrient media. Organotrophic bacteria were determined by sowing on meat-peptone agar, the number of microorganisms that assimilate nitrogen from mineral compounds and actinomycetes – on starch-ammonium agar, oligotrophic microorganisms – were grown on starvation agar, fungi – on Richter's nutrient medium. The number of microorganisms is given in colony-forming units (CFU) per one gram of dry soil, having previously determined the relative humidity of the soil sample using the thermostat-weight method. Subsequently, the obtained number of colonies was counted, considering the humidity coefficient, as well as the dilution of the soil suspension. Experimental studies were carried out in triplicate.

Microbiological soil monitoring was evaluated according to the methodical recommendations of V.M. Patyka and O.V. Sherstoboeva [19]. The focus of microbiological processes in the soil was determined according to the following coefficients.

The coefficient of oligotrophy (C_{ol}) was calculated as the ratio of the number of microorganisms capable of assimilating nutrients from very dilute solutions to the total number of eutrophic microorganisms according to the formula (1):

$$C_{ol} = N_{StA} / (N_{SAA} + N_{MPA}) \quad (1)$$

Next, the coefficient of pedotrophicity (C_{ped}) was determined according to the ratio of the number of microorganisms on soil agar (N_{SA}) to the number of those microorganisms that grew on meat-peptone agar (N_{MPA}) (2):

$$C_{ped} = N_{SA} / N_{MPA} \quad (2)$$

The coefficient of mineralisation-immobilisation (C_{m-i}) was determined as the ratio of the number of microorganisms that immobilise mineral forms of nitrogen to the number of organotrophs according to the formula (3):

$$C_{m-i} = N_{SAA} / N_{MPA} \quad (3)$$

where N_{SAA} , N_{MPA} is the number of microorganisms grown on starch-ammonium and meat peptone agar. Where N_{SA} is the number of microorganisms grown on starvation agar.

RESULTS AND DISCUSSION

Based on the ratio of ecological and trophic groups of microorganisms, namely nitrogen-fixing, oligotrophic, and microorganisms involved in the mineralisation of humic substances, it is possible to judge on the focus of the mobilisation processes in the soil. In this regard, the coefficients of oligotrophicity (StA/Zv), mineralisation (SAA/Zv) and pedotrophicity (SA/Zv) were calculated. These microbiological coefficients allow generalising the processes occurring in the soil, as well as to establish their focus. At elevated values of nitrogen mineralisation-immobilisation coefficients, changes in transformation of organic compounds occur, namely the dominance of organic matter decomposition over synthesis. On the other hand, a decrease in the pedotrophic factor can be interpreted as a decrease in the intensity of decomposition of soil organic matter. The results of the study of changes in the coefficients of the intensity of soil-biological processes in agrophytogeocenoses of potatoes under different systems of biological preparations are presented below.

The coefficient of oligotrophy (C_{ol}) for its growth indicates the spread of microorganisms in the soil that can exist in the absence or low concentrations of nutrients compared to other eutrophs. C_{ol} in the seedling and flowering phase of potatoes in all soil samples under study was low (≤ 1) (Fig. 1), which indicates a good supply of soil microorganisms with labile organic substances, as well as the presence of sufficient sources of carbon and nitrogen for the functioning of the soil microbial complex.

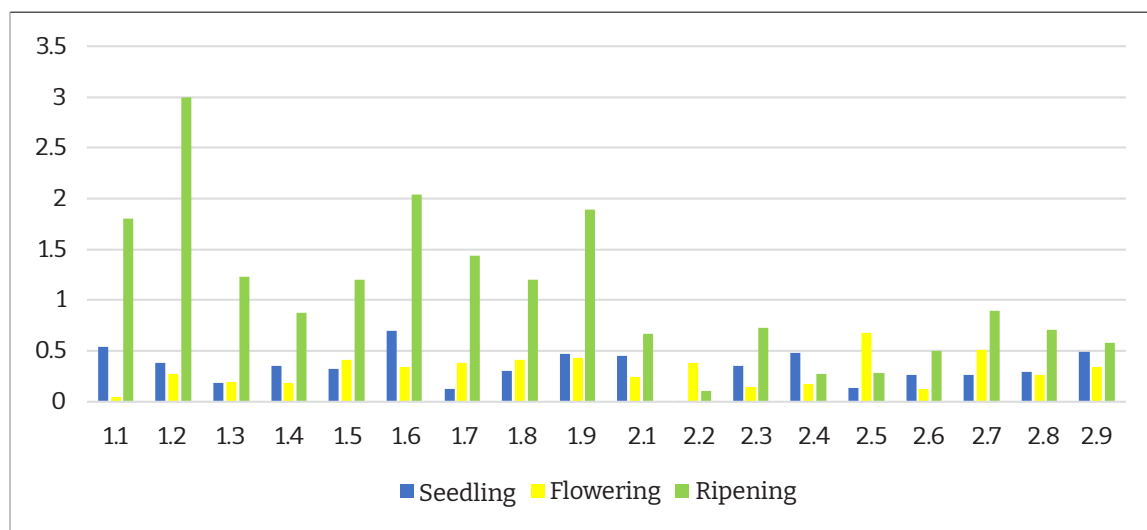


Figure 1. Microbiological coefficient of oligotrophy in sod-podzolic soil for growing potatoes

In the potato ripening phase, the situation changed slightly, C_{ol} increased (≥ 1) on background 1, where Ecoster biodestructor was not applied, which indicates a 10% decrease in the content of nutrients in the soil. The highest values of this indicator ranged from 1.2 on variants 3 and 8 (Treatment of tubers with Fitohelp – 1.0 l/t + triple treatment with Fitohelp – 1.0 l/ha during the growing season and Treatment of tubers with Fitohelp – 1.0 l/t + triple

treatment with Fitohelp – 1.0 l/ha during the growing season) to 2.9 in variant 2 (introduction of Mycohelp 2.0 l/ha to the soil + triple treatment during the growing season with Agat 25 – 100 ml/ha). On the variants of the background using Ecoster biodestructor at 1.2 l/ha, the C_{ol} on all variants of feeding potato plants was lower than 1 (C_{ol} ranged from 0.11 to 0.895), which indicates an elevated supply of soil nutrients, especially nitrogen.

The positive effect of biological preparations on improving the nutrient status of the soil, which is evidenced by the higher C_{oi} values compared to the control: on background 1 without the introduction of a biodestructor in the seedling phase, this indicator was 0.545, and in the phase of maturation of potato tubers – 1.8. Comparing different biopreparations in terms of their influence on the C_{oi} , it was established that the best feeding conditions for food potatoes were with Regoplant preparation in variant 7 ($C_{oi}=0.13$), slightly higher values were established in variant 3 with the introduction of Mycoplant and treatment with Regoplant during vegetation ($C_{oi}=0.185$). On variants 4, 5, and 8, the C_{oi} values in the seedling phase did not substantially differ from each other.

On the background 2 with the application of Ecosterne, the best conditions of the nutritional regime were on the variant 2 with the application of Mycohelp and the treatment with Agat vegetation, where the C_{oi} values were the lowest – 0.01. The highest values were set on variant 9 using Stimpo: on the background without the destructor, they were 0.43-1.89, and with the destructor – 0.345-0.58. The opposite dynamics were noted by O.Yu.Kolodiazhnyi and M.V. Patyka [20]: during the growing season of winter wheat, the coefficient of oligotrophy on the research variants decreased (0.03-0.67).

The intensity of decomposition of soil organic matter can be judged according to the coefficient of pedotrophicity. Table 1 shows changes in this coefficient due to the use of biological preparations on food potatoes.

Table 1. Microbiological coefficient of pedotrophicity (C_{ped}) in sod-podzolic soil during the main phases of potato plant development

| Factor A | Factor B | Development phase | | |
|---|--|-------------------|-----------|----------|
| | | Seedling | Flowering | Ripening |
| Background 1. Without biodestructor | 1. Control (without biological preparation) | 1.795 | 0.055 | 0.305 |
| | 2. Application of Mycohelp 2.0 l/ha + triple treatment with Agat 25 – 100 ml/ha | 0.835 | 0.035 | 0.12 |
| | 3. Application of Mycohelp 2.0 l/ha + triple treatment with Regoplant – 50 ml/ha | 1.09 | 0.03 | 0.36 |
| | 4. Application of Mycohelp 2.0 l/ha + triple treatment with Fitohelp – 1.0 l/ha | 0.695 | 0.3 | 0.36 |
| | 5. Application of Mycohelp 2.0 l/ha + triple treatment with Stimpo – 15 ml/ha | 1.14 | 0.005 | 0.365 |
| | 6. Treatment of tubers with Mycohelp – 2.0 l/t + triple treatment with Mycohelp – 1.0 l/ha during the growing season | 2.17 | 0.415 | 0.465 |
| | 7. Treatment of tubers with Regoplant – 50 ml/t + triple treatment with Regoplant – 50 ml/ha during the growing season | 0.595 | 0.005 | 0.41 |
| | 8. Treatment of tubers with Fitohelp – 1.0 l/t + triple treatment with Fitohelp – 1.0 l/ha during the growing season | 1.155 | 0.395 | 0.425 |
| | 9. Treatment of tubers with Stimpo – 15 ml/t + triple treatment with Stimpo – 15 ml/ha during the growing season | 1.665 | 0.18 | 0.73 |
| Background 2. Ecosterne 1.2 l/ha | 1. Control (without biological preparation) | 1.72 | 0.42 | 0.155 |
| | 2. Application of Mycohelp 2.0 l/ha (background) + triple treatment with Agat 25 – 100 ml/ha | 0.355 | 0.095 | 0.025 |
| | 3. Application of Mycohelp 2.0 l/ha + triple treatment with Regoplant – 50 ml/ha | 0.91 | 0.525 | 0.15 |
| | 4. Application of Mycohelp 2.0 l/ha + triple treatment with Fitohelp – 1.0 l/ha | 1.63 | 0.405 | 0.065 |
| Background 2. Ecosterne 1.2 l/ha | 5. Application of Mycohelp 2.0 l/ha + triple treatment with Stimpo – 15 ml/ha | 0.95 | 0.935 | 0.125 |
| | 6. Treatment of tubers with Mycohelp – 2.0 l/t + triple treatment with Mycohelp – 1.0 l/ha during the growing season | 1.34 | 0.29 | 0.25 |
| | 7. Treatment of tubers with Regoplant – 50 ml/t + triple treatment with Regoplant – 50 ml/ha during the growing season | 1.34 | 0.35 | 0.35 |
| | 8. Treatment of tubers with Fitohelp – 1.0 l/t + triple treatment with Fitohelp – 1.0 l/ha during the growing season | 3.45 | 0.21 | 0.195 |
| | 9. Treatment of tubers with Stimpo – 15 ml/t + triple treatment with Stimpo – 15 ml/ha during the growing season | 1.18 | 0.07 | 0.4 |

High values of C_{ped} (≥ 1) in the seedling phase of potatoes on background 1 without a biodestructor were observed on variants 1, 3, 5, 6, 8, 9, which indicates an increase in the intensity of decomposition of soil organic matter on these variants.

C_{ped} indicators proved the active decomposition by microorganisms of the remains of sideral culture. This indicator depended more on the period of soil sampling than on variants with biological preparations. In the seedling phase, variants 2, 4, 7 without a destructor were characterised by low C_{ped} values – 0.835; 0.695; and 0.595, respectively, which indicates a decrease in the amount of organic matter in the soil. In the phase of flowering and ripening of potatoes, C_{ped} decreased in all variants of the experiment and was within 0.03-0.75, which indicates a decrease in the amount of organic matter (residues of siderate) in the soil.

On background 2, with Ecostern 1.2 l/ha in the seedling phase of the culture, an elevated intensity of organic matter decomposition was observed in variants 1, 4, 6, 7, 8, 9. In variants 2, 3, 5, the intensity of organic matter

decomposition was insubstantial. During the flowering and maturing phase of potatoes, the C_{ped} did not exceed 1, which indicates insufficient supply of “fresh” organic matter to the soil and low intensity of its decomposition. The lowest C_{ped} values were found on variant 9 with the use of Stimpo – 0.07 and on variant 2 with Mycohelp and Agat treatment – 0.095. On variants 8, 6, 7, 4 and 1, the C_{ped} value was 0.21; 0.29; 0.35; 0.405; and 0.42, respectively. Upon applying Mycohelp to the soil and Stimpo vegetation treatment, the value was 0.935.

The C_{ped} value was also influenced by various agrotechnical measures. The studies of O.B. Panchenko, I.D. Prymak and I.A. Panchenko [21] established the influence of different tillage systems and found the lowest C_{ped} values for tillage, and the highest values for ploughing with different depths. The C_{m-i} shows the predominance of the decomposition processes of organic substances over their synthesis. During the seedling phase of potatoes, the C_{m-i} were low in all variants of the experiment, which indicates the predominance of organic matter synthesis processes (Fig. 2).

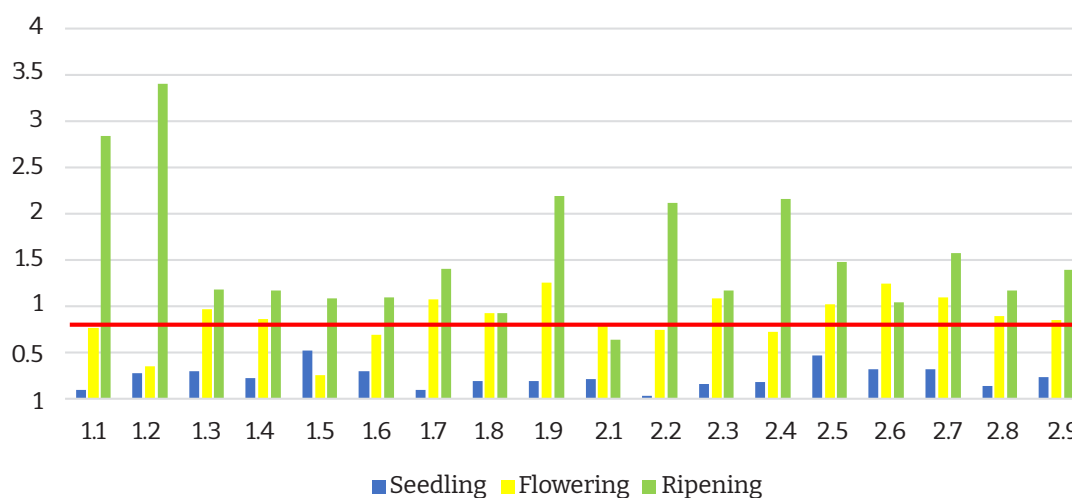


Figure 2. Microbiological coefficient of mineralisation-immobilisation (C_{m-i}) of nitrogen in sod-podzolic soil for growing food potatoes

A similar trend was observed in the flowering phase. The C_{m-i} coefficients were within 0.25-1.25 on background 1 without a destructor, and the highest values (1.25) were found on the Stimpo tuber treatment and vegetation treatment variants, and the smallest (0.25), which ensure flow in the soil of synthesis of organic matter, – on the variants with Mycohelp applied to the soil and vegetation treatment with Stimpo, as well as on the variant with the Mycohelp applied to the soil and vegetation treatment with the Agat PE preparation. In the seedling phase, the application of Ecostern stubble biodestructor did not cause any substantial differences in the values of this coefficient: C_{m-i} was 0.1-0.515 on background 1 without biodestructor, 0.025-0.205 on background 2 with biodestructor. Ecostern showed a more pronounced effect in the flowering phase, where the values were 0.25-1.25 and 0.715-1.24, respectively, on background 1 and 2. Thus, the

positive effect of the biodestructor on decomposition of white mustard and the supply of potato plants with nutrients during the flowering period of potatoes was established, which is also confirmed by the C_{ol} values.

During the ripening phase of potatoes, microbiological processes shifted even more towards the mineralisation of organic matter in all variants of the experiment. The C_{m-i} in the flowering and ripening phase approached the optimal indicators ($C_{m-i} = \text{approx. } 1.0$) when using Ecostern biodestructor 1.2 l/ha for all biological preparations, which indicated a balanced carbon-nitrogen cycle. On background 1 without a biodestructor, C_{m-i} was the highest on the variant with Mycohelp and Agat treatment (3.4), as well as on the variant with Stimpo (1.25); on background 2 – on variant 4 with Mycohelp + Phytohelp (2.16) and Mycohelp + Agat (2.12).

S.O. Hudz [22] established that the lowest C_{m-i}

values were for the biological fertilisation system. He also found an increase in C_{ped} values under the industrial fertilisation system, which indicates an increase in the intensity of decomposition of soil organic matter. As for C_{oi} , the optimal values were for ecological and biological fertilisation systems – 0.69-0.96 and 0.81-0.93, respectively.

CONCLUSIONS

1. The use of Ecosterne biodestructor at 1.2 l/ha on white mustard as a siderate on sod-medium-podzolic soil contributed to increasing the availability of nutrients during the growing season of food potatoes, as evidenced by the C_{oi} values of less than 1 (0.01-0.895). On the background without a stubble destructor, the lowest C_{oi} values were established when using Mycohelp and Regoplant biological preparations, and the highest values were set with the variant with Stimplo.

2. The C_{ped} depended more on the period of soil sampling than on variants with biological preparations and was 0.355-1.795 in the seedling phase, 0.005-0.935 in the flowering period, and 0.12-0.465 in the ripening period.

3. According to the C_{m-i} , the advantage was proved in the variant with Mycohelp soil treatment 2.0 l/ha + triple vegetation treatment with Agat 25 – 100 ml/ha. The positive effect of the biodestructor on the decomposition of organic matter of siderate was found. During the ripening period, the C_{m-i} in the flowering and ripening phase approached the optimal values (C_{m-i} = approx. 1.0) when using Ecosterne biodestructor 1.2 l/ha.

Studies on the impact of the destructor and biological preparations on improving the humus condition of sod-podzolic soil are promising.

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Вплив біопрепаратів на мікробіологічну активність дерново-підзолистого ґрунту за вирощування картоплі столової

Анотація. В умовах сьогодення у світі зростає попит на органічну продукцію, проте недостатня кількість досліджень із вивчення впливу біопрепаратів на параметри родючості ґрунтів. Показники мікробіологічної активності неоднакові для різних ґрунтових відмін, саме тому необхідно детально вивчати їх в конкретних ґрунтово-кліматичних умовах, особливо на зональних ґрунтах, якими в Поліссі є дерново-підзолисті. Актуальними є дослідження щодо впливу різних біопрепаратів на показники родючості ґрунту за вирощування однієї із найбільш популярних в Україні культур – картоплі столової. Мета роботи – встановити вплив обробки насіння бульб картоплі біопрепаратами та внесення біодеструктора для кращого розкладу сидерату на спрямованість мікробіологічних процесів у ґрунті. Дослідження проводили у досліді на Волинській державній сільськогосподарській дослідній станції Інституту картоплярства НААН України. Ґрунт дослідної ділянки – дерново-середньопідзолистий супіщаний ґрунт на водно-льодовикових відкладах. Стаціонарний дослід включав варіанти із заробкою у ґрунт сидерату без деструктора (Фон 1) та із внесенням десруктора Екостерн на сидерат (Фон 2). Також вивчали ефективність біопрепаратів: Мікохелп, Агат, Регоплант, Фітохелп, Стимпо. Аналіз ґрунту на мікробіологічні показники проводили у зразках, які відібрані з шару 0-20 см. Спрямованість мікробіологічних процесів у ґрунті визначали за відповідними коефіцієнтами. Встановлено, що на варіантах із застосуванням біодеструктора Екостерн протягом вегетаційного періоду картоплі коефіцієнт оліготрофності складав менше одиниці, що свідчить про добру забезпеченість ґрунтової мікробіоти легкозасвоюваними органічними речовинами, тоді як на варіантах без застосування Екостерна у фазу досягання коефіцієнти оліготрофності перевищували одиницю. Коефіцієнт педотрофності більше змінювався протягом вегетаційного періоду, ніж за варіантами досліді. У фази сходів і цвітіння картоплі коефіцієнти мінералізації-імобілізації були низькими на всіх варіантах досліді, що свідчить про переважання процесів синтезу органічної речовини. Матеріали статті становлять практичну цінність для фермерів та виробників органічної продукції рослинництва у питанні управління рослинними рештками за застосування біодеструктурів у технології вирощування картоплі столової

Ключові слова: біодеструктор, сидерат, коефіцієнт оліготрофності, коефіцієнт педотрофності, гуміфікація