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INTRODUCTION OF MUSHROOM WASTE IMPACT ON SOIL FERTILITY AND YIELD OF SPRING WHEAT

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Abstract

The paper discusses the possibilities of the practical use of organic substrates after cultivation of fungi - basidiomycetes on them. The waste resulting from the cultivation of mushrooms is rich in nutrients and can be recycled as soil fertilizer and can also contribute to the remediation of polluted soils. The composition of the mycelial-substrate complex of the oyster fungus (Pleurotus ostreatus), in addition to the enzymatically active mycelium that absorbs pollutants, includes the mass of straw, which also contains nutrients and is able to improve the structure of the soil and increase its fertility. Straw material contains about 95% of organic matter. The dynamics of the humus content in soil samples was studied as a result of the introduction of P. ostreatus fungus production waste as a fertilizer. The use of fungus waste allows maintaining and slightly increasing (by 0.08–0.14%) the humus content in the soil. It also increases the yield of spring wheat to 29.5%.

***Key words**: mushroom waste, soil fertility, soil bioremediant.*

INTRODUCTION

Soil is the most important natural resource that ensures the existence of the biosphere and human beings as a part of it. As a result of anthropogenic activities, the soil is destroyed, its fertility is reduced and pollution is becoming global. The sources of pollution of agricultural land are mineral fertilizers, pesticides, some of which contain phenolic, organochlorine compounds, mercury and other heavy metals that accumulate in the soil, affecting its quality. Therefore, special attention is paid to restoring the productivity of disturbed soils and improving environmental conditions (Kachmazov, 2017).

Xylotrophic basidiomycetes, possessing a rich complex of nonspecific enzymes - polyphenolokidases that are able of destroying phenolic pollutants, including their chlorinated derivatives, were a topical object of research for a significant period of time (Muller et al, 1988; Álvarez-Martín, 2016; Sun et al, 2018). During the cultivation of fungi in the frame of biotechnological researches, the waste results from the cultivation of mushrooms, made up of the growing substrate and mycelium, have been actively discussed (Grimm et al, 2018).

The sorption properties of spent mushroom substrates also make them promising for the purification of media (Marín-Benito, et al, 2016; Menk, et al, 2019).

The aim of this work was to assess the possibility of using the waste of mushroom production - the spent mycelium of xylotrophic oyster mushrooms (*Pleurotus ostreatus*) as a bioremediant and a factor that increases soil fertility and plant productivity.

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MATERIALS AND METHODS

The research was carried out on the basis of the Penza State Agrarian University. A marker compound (2,4 dichlorophenoxyacetic acid) was used to study the destruction of halogenated polyphenols by the enzymes of *Pleurotus ostreatus* mycelium. This substance is used as a herbicide. The experiment studied the dynamics of the content of this substance in model substrates under the influence of enzymes of the *Pleurotus ostreatus* mycelium. For this, 2.4 D were added to sterile nutrient substrates of fungi in an amount of 10 mg/kg of dry substrate, calculated on the active ingredient. Then, monthly, as the mycelium developed, the dynamics of the content of the model toxicant in the substrate was noted. The control was a sterile substrate to which no fungal culture was added, but a similar concentration of the model compound was added.

To assess the change in the integral toxicity of extracts from the samples of the studied model substrates, biotesting techniques used in environmental studies were used. Biotesting is a technique of conducting analyzes to determine toxicity using living organisms. Toxicity is the degree of manifestation of the harmful effects of various chemical compounds and their mixtures. This is one of the important factors that determine the quality of the environment, quite informative, giving an idea of the degree of danger or safety of objects. Toxicity criterion is a reliable quantitative value of the test parameter, on the basis of which a conclusion is made about the toxicity of the object under study. Among the test parameters, the most often used are survival, fertility, suppression of the enzymatic and metabolic activity of organisms. Toxic effects recorded by biotesting methods include complex, synergistic, antagonistic and additional effects of all chemical, physical and biological components present in the test object, adversely affecting the physiological, biochemical and genetic functions of test organisms. In our studies, we used techniques based on the reactions of *Escherichia coli* and *Daphnia magna* test objects (Terekhova et al., 2014; Olkova et al., 2015).

Using the waste of the mushroom production of LLC "Botanik", located in the village of Lunino in the Penza region (Russia), which are straw cutting, partially fermented by the mycelium of the *Pleurotus ostreatus* fungus (Photo 1). A field experiment was carried out according to the following scheme:

1. No fertilizers (control);
2. Waste of mushroom production 4 t/ha (equivalent to 12 t/ha of manure in terms of carbon);
3. Waste of mushroom production 5 t/ha (equivalent to 15 t/ha of manure in terms of carbon);
4. Waste of mushroom production 6 t/ha (equivalent to 18 t/ha of manure in terms of carbon). The plot area was 5 m^2, the experiment was organized in four replicates, and the variants in the experiment were placed by the method of randomized repetitions. Spring wheat "Tulaykovskaya 10" was grown on the plots.

The soil in the area of the experiment is gray forest loamy, the humus content does not exceed 2.6%, which corresponds to the characteristics of soils of this type.

Statistical data processing was performed using the Excel functions of the Microsoft Office package.

RESULTS AND DISCUSSIONS

Through long-term cultivation of mycelium *Pleurotus ostreatus* on substrates using a marker compound (2,4 dichlorophenoxyacetic acid), it was found that the development of mycelium significantly decreases the content of the marker compound in the substrate (Figure 1).

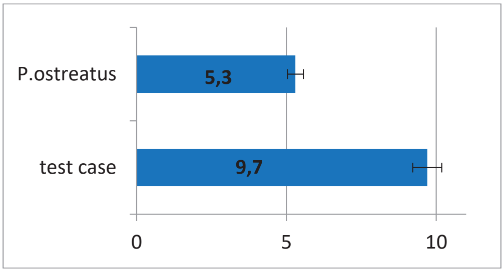

Figure 1. Content of 2,4 dichlorophenoxyacetic acid in the model substrate (mg / kg) under the influence of *Pleurotus ostreatus* mycelium after 12 months of cultivation ($p < 0.05$, error bars - mean error)

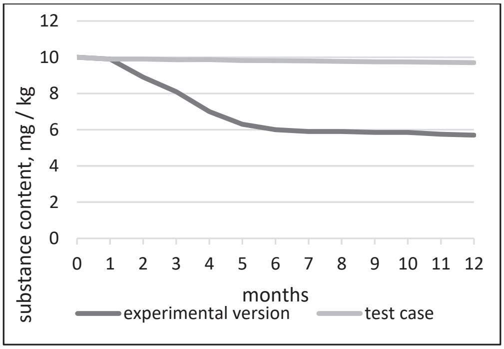

Figure 2. Dynamics of the loss of 2,4 dichlorophenoxyacetic acid in the model substrate (mg / kg) under the influence of *Pleurotus ostreatus* mycelium during the cultivation period ($p < 0.05$)

The results of studying the dynamics of the decrease in the content of the model pollutant are also indicative. It was found that the destruction of the substance by mycelium enzymes occurs unevenly, and the maximum

rate of loss falls on 3-5 months of development (Figure 2).
Such results could be explained by the most significant volumes of the formed mycelium biomass during this period. This, in turn, potentially provides the volumes of synthesized enzymes, as well as the area of the material that absorbs the pollutant molecules.
Considering the large volumes of waste oyster mushroom substrate resulting in mushroom growing, it should be noted that the mycelium of the studied fungus (*P. ostreatus*) can be considered as a bioremediant of soils contaminated with phenolic compounds.
The composition of the mycelial-substrate complex of *Pleurotus ostreatus* mycelium that is enzymatically active and absorbing pollutants, includes the mass of straw, which also contains nutrients that could improve the structure of the soil and increase its fertility. Since the straw contains about 95% of organic matter valuable for increasing fertility, and with five tons of straw, 20 ... 25 kg of nitrogen, 5 ... 7 kg of phosphorus, 60 ... 90 kg are returned (Shvetsova, 1988).
Studying the dynamics of the humus content, a mycelial-substrate complex was introduced into the experimental soil samples as a bioremediate - a waste after growing oyster mushroom. The reproduction of such a remediation technique can only be ensured by the volumes of waste of the fungus, which is widely cultivated in industrial conditions.
The results of a three-year field experiment shown that the humus content in soils without fertilization gradually decreases, while the use of mushroom waste as fertilizers allows maintaining and slightly increasing the humus content in the soil by 0.08 ... 0.14% (Table 1).

Table 1. The influence of wastes from mushroom production on the humus content in the soil (%, $p > 0.05$)

Experience Option	Humus content			
	original value	First year	second year	third year
The control	2.60	2.60	2.59	2.58
Waste from *P. ostreatus* production (4 t / ha)	2.62	2.64	2.73	2.70
Waste from *P. ostreatus* production (5 t / ha)	2.59	2.70	2.72	2.69
Waste from *P. ostreatus* production (6 t / ha)	2.61	2.72	2.75	2.73

Table 2. The influence of wastes from mushroom production on the spring wheat yield "Tulaykovskaya 10" ($p > 0.05$)

Experience Option	Productivity t / ha	Deviation from control	
		t / ha	%
No fertilizer (control)	2.34 ± 0.21	-	-
Waste from *P. ostreatus* production (4 t / ha)	2.59 ± 0.18 *	0.25 ± 0.02 *	10.7
Waste from *P. ostreatus* production (5 t / ha)	2.87 ± 0.23	0.53 ± 0.03	22.6
Waste from *P. ostreatus* production (6 t / ha)	3.03 ± 0.19	0.69 ± 0.07	29.5

** differences are unreliable*

The influence of wastes from *P. ostreatus* production on the spring wheat yield is shown in Table 2. The maximum yield was observed in the variant with the rate of 6 t/ha, where it was 3.03 t/ha before, which is higher than in the control, by 0.69 t/ha or 29.5%.
On average, over three years, field germination of spring wheat compared to control, according to the options relative to the control, increased by 1.3-10.8%. The most significant indicators, exceeding the control values, were obtained in the variant with the introduction of 6.0 t/ha of mushroom waste. The application of mushroom waste as soil fertilizer contributed to a significant increase in the spring wheat yield (Table 3).
Fertilization with waste from mushroom production has contributed to a significant increase in spring wheat yield (Table 2). The maximum yield was observed in the variant with the rate of 6 t/ha, where it was 3.03 t/ha compared to control, which is higher than in the control by 0.69 t/ha or 29.5%.
Mixing the waste substrates was carried out using mechanization means (Photo 2).

Table 3. The influence of wastes from mushroom production on the spring wheat yield "Tulaykovskaya 10" (p> 0.05)

Evperience option	Productivity t/ha	Deviation from control	
		t/ha	%
No fertilizer (control)	2,34±0,21	-	-
Waste from P. ostreatus production (4 t / ha)	*2,59±0,18**	*0,25± 0,02**	*10,7*
Waste from *P. ostreatus* production (5 t / ha)	2,87±0,23	0,53± 0,03	22,6
Waste from *P. ostreatus* production (6 t / ha)	3,03±0,19	0,69± 0,07	29,5

* *differences are unreliable*

Photo 1. Mycelial-substrate complex, which is a waste of mushroom production - straw cutting, partially fermented by the mycelium of the fungus

Photo 2. Mixing of volumes of introduced mushroom production wastes using mechanization mean

CONCLUSIONS

Spent mycelium on an organic carrier - waste from the production of oyster mushroom, possessing active enzyme complexes, are promising for bioremediation of soils contaminated with phenols.

In addition, the use of organic waste of mushroom production allows to improve the structure of the soil, having a positive effect on the humus content in the topsoil.

A significant increase in the yield of spring wheat "Tulaykovskaya 10" was established with the introduction of mushroom waste as fertilizers.

The greatest effect was obtained on the variant with the rate of waste application of 6 t / ha. Thus, the use of mushroom production wastes provides both an environmental effect in terms of bioremediation of contaminated agricultural soils and an agronomic effect in terms of maintaining soil fertility and increasing crop yields.

Waste from the production of oyster mushroom possessing an active enzyme complexe are important for bioremediation of soils contaminated with phenols.

In addition, the use of organic waste from mushroom production allows improving the structure of the soil, having a positive effect on the humus content in the arable soil layer.

A significant increase in the yield of spring wheat "Tulaykovskaya 10" was recorded with the introduction of mushroom waste as fertilizers.

The greatest effect was obtained on the variant with the rate of 6 t/ha waste application. Thus, the use of mushroom waste provides both an environmental effect in terms of bioremediation of contaminated agricultural soils and an agronomic effect in terms of maintaining soil fertility and increasing crop yields.

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