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THE INFLUENCE OF FIRE CULTIVATION ON THE SOIL MICROORGANISMS

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ABSTRACT

An increase in the pesticide load in agro-cenoses leads to a decrease in the number of the main ecological and trophic groups of microorganisms, which causes a disruption of connections in agro-ecosystems and soil biological activity. For example, more than 95% of applied pesticides have a greater impact on soil microorganisms than on their target objects, as they are sprayed proportionally all over the field, regardless of the affected areas. In this case, fire treatment has the main benefit of a more targeted treatment, which is more focused on its main object of impact. But, as you know, fire can also cause significant damage to both soil and microorganisms living there. Soil microbiota is very sensitive to environmental changes, but it is completely killed only at soil temperatures above +120°C, so treatment with a fire cultivator that can work at both +100°C and +70°C has a high chance of becoming the safest way to control weeds. Despite the known negative effect of fires and flames on soils, to fully assess the impact of this method on soil and its fertility, it is necessary to investigate the impact of this treatment primarily on changes in the microbiological characteristics of the surface soil layer. The treatment was carried out using two modes of the fire cultivator (+70°C and +100°C). Microbiological analyzes of the soil were carried out according to generally accepted methods. The content of total biomass of microorganisms in the soil was determined by the rehydration method. Thus, to study the impact of fire cultivation on the direction of processes in the soil and the main ecological and trophic groups of microorganisms, we determined the content of total biomass of microorganisms, coefficients of mineralization-immobilization and oligotrophicity, cellulolytic activity, the number of bacteria, micromycetes, etc. Our analysis of the total microbial biomass of the selected soil samples allows us to assert the safety of the applied fire method of weed control. In the study of soil fouling lumps (Ashby's medium), 100% presence of bacteria of the genus *Azotobacter* was noted in all variants with temperature treatment. The analysis of soil samples on Ashby's medium showed that oligotrophs do not significantly change under fire treatment at 70°C, but some negative impact on the vital activity of these microorganisms is still observed under 100°C treatment. The obtained ecological coefficients of the direction of microbiological processes indicate the decreasing intensity of decomposition of soil organic matter, in particular humus compounds and reducing soil oligotrophicity indicates an increase in the content of nutrients in the soil. For the most environmental benefits, we recommend to use a milder fire treatment of 70°C, wich allows not only to control the weeds, but also stimulates and directs microbiological processes in a positive directio

Keywords: soil microorganisms, biodiversity, soil fertility, fire cultivation, weed control

INTRODUCTION

There are many weed control measures available, but recently, an alternative approach has emerged: burning weeds with a fire cultivator [0, 2]**.** It is presented as a more effective and environmentally friendly method than traditional agrochemical weed control methods. It is believed that this treatment is much safer than rather aggressive chemicals that can contaminate the soil, water bodies, and the surrounding environment.
By treating the soil with weeds with the flame for several seconds, the cultivator heats them up to +70°C, which is enough to destroy them or significantly slow down their development. Fire also allows you to control not only unwanted vegetation but also insect pests. It is a widely known fact that the biological properties of soils directly depend on the biodiversity of soil microorganisms and the functioning of their various ecological and trophic groups. The intensity and direction of microbial transformation of humus in agro-cenoses depend on a complex of natural and anthropogenic factors [3]. An increase in the pesticide load in agro-cenoses leads to a decrease in the number of the main ecological and trophic groups of microorganisms, which causes a disruption of connections in agro-ecosystems and soil biological activity. For example, more than 95% of applied pesticides have a greater impact on soil microorganisms than on their target objects, as they are sprayed proportionally all over the field, regardless of the affected areas. Thus, out of the total amount of pesticides applied, about 0.1% reaches the target organisms, and the residual amount contaminates the soil and the surrounding environment [3]. In this case, fire treatment has the main benefit of a more targeted treatment, which is more focused on its main object of impact. But, as you know, fire can also cause significant damage to both soil and microorganisms living there.

However, the degree of fire damage depends largely on the intensity of the fire, the duration and frequency of such action, and, of course, the characteristics of the soil and certain groups of microorganisms. Researchers from Ghana note that the temperature required to destroy most soil biological matter ranges from 50°C to 120°C and leads to the death of small roots, bacteria, fungi, and seeds in the soil [5]. And even temperatures that are not so critical that they cannot lead to the death of microorganisms can lead to significant changes in the composition of the microbial community, for example, from a dominant fungal to a bacterial one. Such changes in microbial communities are most often associated with the consequence of increased pH and the availability of nutrients (base cations) after exposure to high temperatures.

Soil microbiota is very sensitive to environmental changes, but it is completely killed only at soil temperatures above +120°C, so treatment with a fire cultivator that can work at both +100°C and +70°C has a high chance of becoming the safest way to control weeds. Also, it should be noted that there is evidence of a high survival rate of microorganisms under conditions of even very intense, but rapid and short-term exposure to high temperatures, and vice versa, low survival rate under relatively weak and prolonged fire treatments. Moreover, the direct effect of fire on soil microbes depends on many very individual characteristics, such as the water content of the soil [6].

Therefore, it is important to conduct detailed studies of these types of weed control to better understand the dynamics of the impact of such fire treatments on possible changes in soil microbial communities. Despite the known negative effect of fires and flames on soils, to fully assess the impact of this method on soil and its fertility, it is necessary to investigate the impact of this treatment primarily on changes in the microbiological characteristics of the surface soil layer.

MATERIALS AND METHODS

To investigate the impact of fire cultivation on the direction of processes in the soil and the main ecological and trophic groups of microorganisms, with the permission of A. Boris, P. Rykchlivskyi, I. Savchenko and M. Gritsyshyn, employees of the Institute of Mechanics and Automation of Agricultural Production of the National Academy of Sciences of Ukraine, took soil samples immediately after treatment with an industrial model of a fire cultivator developed and manufactured by National Scientific Center «Institute of Agricultural Engineering and Electrifacation» (Fig. 1) [0].

Figure 1. Fire cultivator

The treatment was carried out using two modes of the fire cultivator +70°C and +100°C. Microbiological analyzes of the soil were carried out according to generally accepted methods. The content of total biomass of microorganisms in the soil was determined by the rehydration method [7]. The direction of microbiological processes in the soil was determined according to K. Andreyuk et al. and methods described by V. Volkogon et al. [8, 9]. The mineralization-immobilization coefficient was calculated by the formula: $C_{m\text{-}i} = C_{SAA}/C_{MPA}$, where C_{SAA}, C_{MPA} – the number of microorganisms that grew on starch-ammonia and meat-peptone agar, respectively. The coefficient of oligotrophicity was calculated by the formula: $C_{oln}=C_{HA}/(C_{SAA} + C_{MPA})$, where C_{HA} – the number of microorganisms that grew on starvation agar. The coefficient of pedotrophicity was calculated by the ratio of the number of microorganisms on soil agar (C_{SA}) to the number of microorganisms grown on meat-peptone agar (C_{MPA}): $C_{ped}= C_{SA}/C_{MPA}$ [9, 11]**. S**tatistical processing of the experimental results carried out using computer programs [11].

RESULTS AND DISCUSSIONS

Soil microorganisms are the key components of the edaphic ecosystem, as they control 80-90% of soil processes and are the main responsible agents of soil fertility and quality. It is known, that they are crucial for the functioning of the entire soil system. Fire can affect soil microbes both through heating and by changing the properties of the soil itself. For example, changes in the composition or amount of organic matter can reduce the activity of soil microorganisms. In the short term, mainly due to the increase in soluble carbon and nutrients in soils exposed to fire, there is usually an increase in the respiration of the heterotrophic bacterial community. After exhaustion of organic compounds, that are easily mineralized, this initial increase in microbial respiration is usually followed by a decrease in residual forms of carbon and nitrogen are more prevalent [12, 13].

Therefore, it is important to pay attention, both to the study of the impact of treatment on the composition of soil microorganisms and to certain processes that may have an impact on the microbiota. Thus, to study the impact of fire cultivation on the direction of processes in the soil and the main ecological and trophic groups of microorganisms, we determined the content of total biomass of microorganisms, coefficients of mineralization-immobilization and oligotrophicity, cellulolytic activity, the number of bacteria, micromycetes, etc.

It is widely known that multidirectional biological processes take place in the soil. One of the main ones is the process of ammonification of soil organic matter. Nitrifying bacteria play an important role in this process, whose activity leads to the accumulation of nitrates. This process is one of the indicators of soil cultivation. It performs best when air is available and soil moisture is optimal. Assessment of soil respiration is a quantitative measure of total microbial heterotrophic activity and organic carbon decomposition. In our research, the evaluation of these indicators – CO_2 emissions and soil moisture, showed no negative impact of fire treatment. That is, the «soil breathing» of both variants of fire treatment using temperature regimes of 70ºC and 100ºC was at the level of the untreated control (Table 1).

Table 1. Influence of fire treatment on total microbial number and CO_2 emission.

Variant	Microbial biomass, µg C/g of soil	CO_2 emission, mg CO_2/kg
1. Control (without treatment)	61.1±5.1	51.1±1.8
2. Fire treatment (70ºC)	64.3±4.5	50.5±0.9
3. Fire treatment (100ºC)	63.7±2.3	51.3±1.1

The ratio of the above processes and their dynamics in the soil affects the content of ammonia, nitrates, nitrites, and other compounds in the soil. Their amount depends on the number and quality of soil microflora and their physiological state. They are also determined by a number of factors, the most important of which is the organic matter content. It is known that high organic matter content increases the number of different physiological groups of microorganisms. Our analysis of the total microbial biomass of the selected soil samples allows us to assert the safety of the applied fire method of weed control. It is known that maintaining the number of microorganisms, especially representatives of agronomically useful groups, is important for the normal functioning of the soil and maintaining its fertility. A detailed analysis of the composition and number of microorganisms of the main ecological and trophic groups confirms the data we obtained on total biomass (Fig. 2). Further, our data are in line with the literature, which shows that in most cases, short-term exposure to fire does not significantly affect the total number of archaea, bacteria, fungi, or nitrifiers [14]**.**

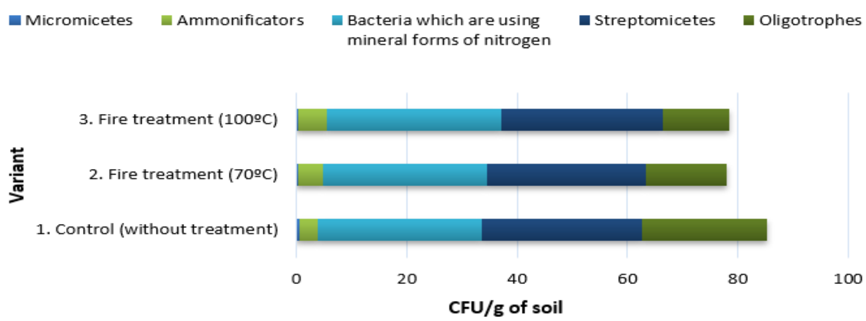

Figure 2. Microbial diversity

Considering the individual groups of microorganisms studied, paying attention to one of the most important groups of bacteria, oligotrophs (nitrogen-fixing or diazotrophs) is necessary. They play an essential role in establishing the nitrogen balance of the soil. They are capable of assimilating molecular nitrogen from the atmosphere and transforming it into an ammonia form available to plants. All representatives of this ecological and trophic group are capable of fixing atmospheric nitrogen and enriching the soil with biological nitrogen. According to the literature, representatives of this group, in particular the genus *Azotobacter*, are characterized by high sensitivity to stress factors, and therefore serve as a kind of indicator of the environmental condition. In general, nitrifying and nitrogen-fixing bacteria are the most sensitive to high temperatures, especially under conditions of prolonged exposure to them [15, 16]. In the study of soil fouling lumps (Ashby's medium), 100% presence of bacteria of the genus *Azotobacter* was noted in all variants with temperature treatment, but under the most intensive treatment (100ºC) they did not form such a large amount of biomass as in other studied variants (Fig. 3).

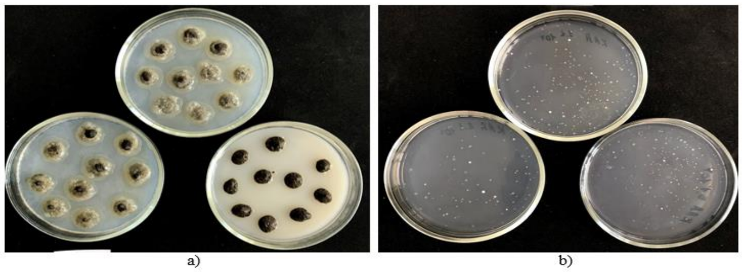

Figure. 3. The microorganisms studied: a) fouling lumps of bacteria of the genus *Azotobacter* (Ashby's medium); b) microorganisms that consume mineral nitrogen (Starch-ammonia agar medium)

The analysis of soil samples on Ashby's medium showed that oligotrophs do not significantly change under fire treatment at 70°C, but some negative impact on the vital activity of these microorganisms is still observed under 100°C treatment. This indicates a possible increase in the available nutrients necessary for the life of the soil microbiocenosis, since oligotrophic and pedotrophic microflora grow intensively on depleted soils due to their trophic specificity and lack of competition. That is, it can contribute to minor changes in the functional structure of soil microbial community, but this will only have a positive impact on this type of soil.

It is a well-known fact that cellulose decomposition by microbes is one of the indicators of soil ecology because it reflects the integrity of all components of the biocenosis (natural ecosystem). It was shown that the cellulose-degrading activity of the studied soils remains at the level of the control and allows us to once again confirm the harmlessness of the fire method of weed control.

To assess the direction of microbiological processes in the soil and a deeper analysis of possible changes in the structure of the soil-biotic complex, we have determined the following indexes: - mineralization and immobilization, which makes it possible to characterize the intensity of mineralization processes; - paedotrophy, which characterizes the degree of assimilation of soil organic matter by microflora; - oligotrophy, which reflects the degree of oligotrophy of soil microbial cenoses (Table 2) [17, 18].

Table 2 Direction of microbiological processes in the soil

Variant	Coefficient of mineralization/immobilization	Coefficient of oligotrophicity	Coefficient of pedotrophicity
1. Control (without treatment)	9.67	0.69	7.35
2. Fire treatment (70ºC)	6.62	0.43	3.27
3. Fire treatment (100ºC)	6.11	0.32	2.30

The obtained ecological coefficients of the direction of microbiological processes indicate the decreasing intensity of decomposition of soil organic matter, in particular humus compounds (decreased pedotrophicity), and reducing soil oligotrophicity indicates an increase in the content of nutrients in the soil.

Therefore, this type of treatment allows not only to control the weeds, but also stimulates and directs microbiological processes in a positive direction. However, for the most environmental benefits of this process, we recommend to use a milder fire treatment of 70°C.

CONCLUSIONS

Our analysis of the impact of fire cultivation on the direction of processes in the soil and the main ecological and trophic groups of microorganisms showed the usefulness of recommending this method for weed treatment. Moreover, its softer treatment with fire at 70°C allows not only to control the weeds, but also can stimulate and coordinate microbiological processes in a positive direction, i.e., to accumulate nutrients. This allows to recommend this method not only for weed control under traditional agricultural conditions, but also for organic farming.

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