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Influence of the pyrogenic impact upon the state of soil microbiocenosis of eight- and twenty-years old fallows (lea lands)

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Abstract. The restoration dynamics of the biological activity of soils after fires of various intensity is an urgent problem. Pyrogenic effects (fires) affect the state of microscopic soil inhabitants: bacteria, micromycetes, etc., causing their death and reducing their physiological and biochemical activity. From a theoretical and practical points of view it is important to study changes in the community of the soil microorganisms during the restoration of phytocenoses in the post-pyrogenic areas. Investigations of Albebeluvisoil were carried out as an example in geographically close areas: 1 and 2 – soil, withdrawn from agricultural use in 1987 (twenty-years-old fallow); 3 and 4 – soil, withdrawn from agricultural use in 2000 (eight-years old fallow. Studies of the state of the post-pyrogenic and background sections of the eight-year-old and twenty-year-old fallows showed that the mechanism of the effect of fire upon the soil microbiocenosis differs 3 and 14 months after it took place. After the fire during a three-month period there are general processes that lead to a decrease in the number of unicellular living organisms, which also lose their physiological and biochemical activity, there is an increase in mineralization, based on compounds of elements such as carbon and nitrogen. The exception is humus. There is also an increase in soil phytotoxicity of soil. The conducted researches have established that after 14 months the processes of active decomposition of humus begin to decrease and in general the phytotoxicity of soil decreases. There are also observed processes of increase in the number of single-celled living organisms on the basis of nitrogen and phosphorus. After 26 months the consequences of the fire are minimized: the difference in the number of microorganisms and their physiological and biochemical activity becomes statistically unreliable,

with the exception of micromycetes, mobilizers of mineral and organophosphates, nitrifying and denitrifying microorganisms; the difference in total biological activity is reduced from 12.6 to 8.67%, in phytotoxicity - from 16.0 to 2.89%.

Key words: pyrogenic impact, microbiocenosis, fallow (lea land), mineralization, humus, phytotoxicity.

INTRODUCTION

Due to climate changes (warming and drought), forest fires take place in many countries, which also affect agricultural lands and fallows (lea lands). Despite the prohibition of burning straw, grain and other plant residues, as well as the dry grass in spring, these operations are still widespread on agricultural lands. The effect of fires (the pyrogenic impact) on soils is of interest to many researchers and practitioners around the world (Fonseca et al., 2017; Hobley et al., 2017; Girona-Garcia et al., 2018). However, the effect of the pyrogenic impact on the number and correlation of microorganisms in various types of ecological systems has not yet been studied enough, and it is a wide field of activities for the microbiologists.

The soil temperature and moisture are two key factors that control the biological processes in ecosystems and soils (Song et al., 2018; Moya et al., 2019; Strydom et al., 2019). Changes in the hydrothermal properties of the soil can lead to changes in the number of the soil microorganisms. The direct effect - heating of the soil - affects the number of microorganisms, killing or changing their reproductive capabilities; heating indirectly changes the content of the soil organic matter (the source of nutrition of microorganisms). Prolonged thermal impact upon the soil leads to degradation of the microbial community (Barreiro & Díaz-Raviña, 2021). The change in microbiocenosis depends on the intensity of fire and on the amount of the combustible material and root residues in the soil layer. The pyrogenic effect is of complex nature, and a decrease in the values of biological parameters depends on several factors: temperature, duration, intensity of exposure to smoke and ash from the combustion products, soil moisture. The complex effect of the straw combustion leads to a decrease in the microbial biomass by 39% and a decrease in the number of nitrogen-fixing bacteria relative to the control values by 29. Suppression of the dehydrogenases and catalase activity from the class of oxidoreductases is 44–53%, and the activity of hydrolases (phosphatase and invertase) is 16–18% (Kazeev et al., 2020). The maximum impact was noted for the top layer of the soil (0–1 cm) compared to the 4–5 cm layer.

At the same time fires lead to the release of significant amounts of carbon and nitrogen oxides into the atmosphere and the loss of the organic matter reserves of the ecosystems, contained in the phytomass, litter, and the upper layers of soil (Caldwell et al., 2002). It has been established that between the pyrogenic and the background plots there are differences in the intensity of respiration and the ratio of the dissolved organic carbon to the total carbon of the soil.

The aim of this investigation was to estimate the influence of the pyrogenic factor upon the quantity and correlation of microorganisms of the main ecological and trophic groups, the intensity and direction of mineralization processes in soils with different periods of withdrawal from the agricultural use.

MATERIALS AND METHODS

Studies were conducted on soils characterized by such indicators: soil type - gray forest, coarse loamy light loamy soil; in the horizon of layer 0–20 cm was the following content: humus 2.5%, easily hydrolysable nitrogen 7.6 mg per 100 g of soil with complete absence of moisture, as well as mobile phosphorus 14.5 mg and exchangeable potassium 12.3 mg per 100 g of dry soil. At the same time, the soil index: pH (KCl) was 6.7.

The experiments were carried out on geographically close areas: 1 and 2 – the soil, withdrawn from agricultural use in 1987 (twenty-years-old fallow); 3 and 4 – the soil, withdrawn from agricultural use in 2000 (eight-years-old fallow). The area of the twenty-years-old fallow is 1.0 ha, and an eight-year fallow is 0.8 ha. In order to facilitate a spontaneous restoration of the grassy cenoses, the effect of the spontaneous overgrowth of the arable lands which have been withdrawn from intensive crop rotation was used. This approach ensures that the restoration process makes optimal use of natural resources and mechanisms, while also reducing the reliance on fossil energy and manual and mechanised human labour. One of the main reasons for this is the persistence of viable seeds in the soil. In most cases, these seeds belong to the 25–40 highest plant species and can be found in a 0–10 cm layer, with up to 30–40 thousand viable seeds per m².

Another factor is the external dispersal of seeds from neighbouring phytocenoses thanks to the activity of various animals, birds of prey, the wind that carries the seeds, the water that moves over the soil surface during rainfall, other seeds of cultivated plants, among other things.

Observations in the experiments were made according to methods, generally accepted in meadow cultivation.

A medium-intensity fire (according to a conditional assessment) occurred in early April 2007, as a result of which the moss, lichens, litter and undergrowth of trees burned out over most of the area. A low-intensity fire (the second one) occurred in early April 2008, while only the litter, accumulated in 2007 burned out in the area of the twenty-years-old fallow, and accumulations for the entire period of the fallow state burned out in the area of the eight-years fallow. The background area is the area where the fire did not occur.

The available number of unicellular living organisms was determined by preparing appropriate soil suspensions, which were added inside the required nutrient medium. This technique was originally validated in (Alef & Nannipieri, 1995) and is now widely used in similar studies. Further, other critical indicators such as the intensity of soil mineralization processes, as well as the probability of formation of bacteria and their colonies (BFC), the resulting total biological activity of the soil and its phytotoxic properties were determined using more advanced techniques, which are outlined and successfully validated in (Hobley et al., 2017; Malynovska & Tkachenko, 2018). In addition, there was a need to establish the values of such an indicator as specific photodegradation activity, which is determined by the appropriate coefficient Muromtsev's agar medium according to the method, developed by us (Malynovska, 2021).

To determine the metabolic activity of microorganisms directly in the soil, the method of analysis of the dynamics of the appearance of colonies was used, which makes it possible to simultaneously determine the number and composition of the complex of chemoorganoheterotrophic bacteria in soils (Kim et al., 2022). The probability of the

colony formation (RPF) reflects the physiological and biochemical activity of the bacterial cells in the natural environment.

In order to evaluate the results obtained from the field experimental studies, their statistical processing was carried out. It mainly concerned the assessment of the reliability of the obtained results and their relative error. For this purpose, we used the methodology of statistical processing of measurement results, which has been successfully tested on similar topics and is described in (Welham et al., 2015; Bulgakov et al., 2022). To test the significance of difference between means 95% *LSD*-value LSD_{05} – Least Significant Difference, were calculated.

RESULTS AND DISCUSSION

Studies conducted in 2007 showed that 3 months after the high-temperature pyrogenic impact on the soil occurred, the available number of unicellular living organisms of the most studied groups related to ecology and their physiological activity sharply decreases in the soil deposits, the intensity of mineralization processes increases in comparison with background sites (Malynovska & Soroka, 2008).

The fire of 2008, due to its low power, had practically no effect upon the content of ammonifiers, cellulolytics, autochthonous microorganisms, streptomycetes and micromycetes, and organophosphate mobilizers in the soil of a twenty-years-old fallow (Tables 1, 2). At the same time the number of azotobacter, nitrifying bacteria, pedotrophs and mineral phosphate mobilizers significantly decreased. In the case of the latter ones the specific phosphate-dissolving activity also decreased. Thus, due to two fires in the soil of the long-term fallow, there decreased, first of all, the number of microorganisms, involved in the carbon cycle. A decrease in the number of microorganisms occurs, in our opinion, due to heating of the upper layers of the soil during the fire, and later, due to a decrease in the plant density and a decrease in the amount of the root secretions. On the other hand, as a result of the entry of mineral substances into the soil after the fire, the number of microorganisms of the nitrogen cycle increases: immobilizers of mineral nitrogen, oligonitrophils, and denitrifiers.

Table 1. The available number of single-celled living organisms based on the carbon cycle in the Albebeluvisoil of twenty-years-old and eight-years-old fallows, million CFU * / g in soil samples with complete absence

Variant	Pedotrophs	Cellulose–destructive	Polysaccharide-synthesizing	Autochthonous	Streptomycetes	Micromycetes	Total number
Twenty years old fallow in the fires of 2007 and 2008	59.6	24.7	4.17	5.46	14.0	50.4	442.8
Twenty years old fallow in the fire of 2007	33.3	25.0	1.14	5.90	12.5	48.4	417.1
Eight years old fallow in the fire of 2007	58.5	33.1	3.35	3.59	15.7	78.8	513.3
Eight years old fallow, the background plot	56.0	59.0	2.98	1.96	18.3	75.7	470.4
LSD_{05}	5.5	9.6	0.9	1.8	2.8	3.0	

Note: * – a colony forming unit.

It was shown in (Malynovska & Soroka, 2008) that the microorganisms of the soil that experienced the influence of the pyrogenic factor 3 months after fire, are in a less active physiological and biochemical state compared to the microorganisms of the background plot; their BFC is reduced; compared to the corresponding indicators of the background plot: ammonifiers - by 72.2%, mineral nitrogen immobilizers - by 25.0, oligonitrophils - by 22.7, pedotrophs - by 61.5, cellulose-decomposing bacteria - by 94.7%. The number of microorganisms, as a result of a fire, does not decrease as significantly as their physiological and biochemical activity.

Table 2. Nitrogen and phosphorus based single-celled living organisms available in the Albebeluvisoil of twenty and eight years of fallows, million CFU * / g of absolutely dry soil

Variant	Ammonifiers	Mineral nitrogen immobilizers	Oligonitrophils	Azotobacter, % fouling of soil lumps.	Nitrifying (autotrophs)	Denitrifiers	Mobilizers of mineral phosphates	Mobilizers of organophosphates
Twenty years old fallow, the fires of 2007 and 2008	60.6	88.5	62.8	14.7	0.64	51.2	0.76	3.79
Twenty years old fallow, the fire of 2007	59.0	79.5	36.7	97.0	0.87	8.51	5.62	3.03
Eight years old fallow, the fire of 2007	59.1	101.1	25.3	2.67	0.46	122.7	4.09	4.46
Eight years old fallow, the background plot	67.8	128.7	29.2	3.01	0.49	10.6	4.48	8.95
LSD_{05}	2.0	8.4	3.1	5.8	0.2	2.0	1.2	0.68

Note: * – a colony forming unit.

The results, obtained in 2008, confirm this pattern: the physiological activity of microorganisms in the area that experienced the impact of two fires is lower than the activity of microorganisms in the area that experienced the impact of one fire: ammonifiers - by 56.8%, mineral nitrogen immobilizers - by 32.8%, pedotrophs - by 50.0%, cellulolytics - by 26.3%, micromycetes - by 18.0%, mobilizers of organophosphates - by 250.0%, autochthonous microorganisms - by 59.0% (Table 3). The soil microorganisms of the eight-years-old fallow, 14 months after the fire, are also less active than the microorganisms of the background plot: ammonifiers, mineral nitrogen immobilizers, cellulose-decomposing, micromycetes and nitrifying bacteria.

In works (Carballas et al., 2009; Díaz-Raviña et al., 2010; Bárcenas-Moreno & Díaz-Raviña, 2013) it was shown that the micromycetes are more sensitive to the pyrogenic factor than the bacteria. According to the results obtained by us, the opposite trend is observed: the mycelial forms are more resistant to fire than the prokaryotes. For example, the number of micromycete CFU in the soil of an eight-years-old fallow of the postpyrogenic plot does not statistically significantly differ from the corresponding indicator of the background plot, and the number of CFU of streptomycetes is reduced by 16.6% (Table 1). The number of micromycetes and streptomycetes in the soil of a twenty-year-old fallow after one fire also does not statistically significantly differ from

the corresponding indicator of the soil of a twenty-year-old fallow after two fires. The same authors (Bárcenas-Moreno & Díaz-Raviña, 2013; Carballas et al., 2009; Díaz-Raviña et al., 2010) report that the carbon cycle microorganisms are more sensitive to the pyrogenic factor than the nitrogen cycle microorganisms. According to the obtained data 14 months after the fire, the number of pedotrophs and polysaccharide-synthesizing bacteria in the post-pyrogenic and the background plots did not statistically significantly differ, and the number of cellulolytic agents, as a result of the fire, decreased by 78.2%. However, the number of microorganisms of all studied groups of the nitrogen and phosphorus cycle, with the exception of nitrifiers and denitrifiers, significantly decreases as a result of fire in the soil of the eight-years-old fallow (Table 2). Especially sharply reduced is the number of ammonifiers (by 14.7%), mineral nitrogen immobilizers (by 27.3%), azotobacter (by 12.7%) and organophosphate mobilizers (by 102.7%). In our opinion, it is impossible to judge so unambiguously about the representatives of different cycles of transformation of macroelements; both the strength of the fire and the duration of the period after its passage will be essential in determining the sensitivity.

The soil that has experienced the impact of two fires is characterized by a higher intensity of microbiological processes, compared to the soil that has experienced the impact of the pyrogenic factor only in 2007. This confirms the general regularity, established on the basis of a study of the effect of the 2007 fire: in the post-pyrogenic areas the intensity of mineralization of the organic (the pedotrophy index) and the nitrogen-containing substances (the nitrogen mineralization coefficient) increases (Malynovska & Soroka, 2008).

Table 3. Probability of formation of colonies of microorganisms (λ, h^{-1} 10^{-2}) in the Albebeluvisoil of twenty- and eight-years old fallows

Variant	Ammonifiers	Mineral. Nitrogen immobilizers.	Oligonitrophils	Pedotrophs	Cellulose–decomposing	Micromycetes	Mineral. Phosphates mobilizers	Mobilizers of organophosphates	Autochthonous	Nitrifying	Denitrifying
Twenty years old fallow, the fires of 2007 and 2008	0.88	0.67	0.35	0.52	0.19	0.39	0.08	0.08	0.04	0.05	0.34
Twenty years old fallow, the fire of 2007	1.38	0.89	0.36	0.78	0.24	0.46	0.06	0.28	0.06	0.05	0.01
Eight years old fallow, the fire of 2007	0.58	0.43	0.38	0.63	0.28	0.37	0.14	0.35	0.11	0.06	0.04
Eight years old fallow, the background plot	0.63	0.78	0.35	0.68	0.42	0.47	0.12	0.32	0.07	0.12	0.03

Despite the fact that in the areas, affected by one and two fires, the number of autochthonous microorganisms is the same, the activity of the humus destruction is lower in the area, affected by two fires (Tables 1 and 4). Since in the case of the fire in 2007 it was shown that 3 months after the fire the intensity of humus mineralization remains the same, it can be assumed that in 2008 the influence of the fire of the previous year

manifests itself as: the supply of the mineral elements with ash reduces the activity of decomposition of the humic substances similarly to how it is observed when mineral fertilizers are applied (Malynovska & Tkachenko, 2018; Malynovska et al., 2021). The high level of the humus mineralization activity in the area that has experienced the impact of one fire coincides with the high physiological and biochemical activity of autochthonous microorganisms in the soil of this variant (Tables 3 and 4).

The activity of the humus destruction in the soil of an eight-year-old fallow increases as a result of a fire by 75.1%, which does not coincide with the data obtained in the example of a twenty-years-old fallow. Probably, this can be explained by the fact that these two deposits have different phytocenosis. A twenty-years-old fallow has a denser and more diverse phytocenosis containing large areas of alfalfa; and over 20 years a powerful litter has formed, from the combustion of which a large amount of ash was formed, which improved the plant growth in the next growing season, which, in turn, led to a decrease in the activity of the humus decomposition. Phytocenosis of the eight-years-old fallow consists of the grass plants, spaced at a distance from each other - the ground reed grass (*Calamagrostis epigeios*), which, when dying in autumn, is scattered by winds and no litter is formed; respectively, as a result of a fire, no noticeable amount of ash is formed, and there is no improvement in the mineral nutrition of the plants.

Table 4. Data showing the intensity of ongoing mineralization processes and phytotoxicity of the Albebeluvisoil twenty and the eight years old fallows

Variant	Pedotrophy index	Oligotrophy coefficient	Nitrogen immobilization coefficient	Humus mineralization activity, %	Total biological activity	Specific phosphate mobilizing activity	Mass of 100 plants of test crop – winter wheat, g
Twenty years old fallow, the fires of 2007 and 2008	0.98	1.04	1.46	9.20	997.5	0.536	20.3
Twenty years old fallow, the fire of 2007	0.56	0.62	1.35	17.7	988.4	0.601	18.1
Eight years old fallow, the fire of 2007	0.99	0.43	1.71	6.13	1,007.8	0.417	16.2
Eight years old fallow, the background plot	0.83	0.43	1.90	3.50	1,020.5	0.267	18.8
LSD_{05}							0.15

The toxicity of the soil of a long-term fallow in the area affected by two fires is by 12.2% lower than the toxicity of the soil of the area affected by one fire (Table 4), although in the example of the 2007 fire. It was shown that 3 months after the fire, soil toxicity of the post-fire site was 10.1% higher than the background site (Malynovska, 2021). The reason for the decrease of the soil toxicity in the area affected by two fires may be improvement of mineral nutrition of the plants 14 months after the first fire. In this case there takes place superposition of the negative effects of the second fire and the positive effects of the first fire. Improvement of mineral nutrition of phytocenosis due to

various reasons, in particular, application of mineral fertilizers, leads to a decrease in the soil toxicity (Malynovska & Tkachenko, 2018; Malynovska et al., 2021).

It was shown by previous investigations that fire leads to the disappearance of azotobacter from the soil of a long-term fallow for at least three months (Malynovska & Soroka, 2008). 14 months after the fire the amount of azotobacter in the soil of a long-term fallow is restored to its previous level (97%). The fire of 2008 slows down the recovery of the number of azotobacter, but not so significantly as after the previous fire, which led to the disappearance of this microorganism. The reason may be the great force of the fire in 2007 - the litter, accumulated during the previous 20 years, was burning, but in 2008 - the litter, accumulated only in one year. The soil of the eight-years-old fallow was previously characterized by an insignificant content of azotobacter; the fire of 2007, as for the long-term fallow, led to its disappearance; after 14 months, its number reached 87% of the initial level (Table 2).

In the soil of the eight-years-old fallow, 14 months after the fire, the number of mineral nitrogen immobilizers is still reduced by 27.4%, oligonitrophils by 16.0, azotobacter by 13.0, cellulose decomposers by 79.0, streptomycetes by 36.1, and organophosphate mobilizers by 101.0% (Table 2). The microorganisms of the post-pyrogenic plot of this fallow, as 3 months after the fire, are characterized by lower physiological activity than the microorganisms of the background plot. By maximum difference in the physiological and biochemical activity are characterized the immobilizers of mineral nitrogen, cellulose-decomposing bacteria and nitrifiers.

The total number of microorganisms in the soil of the eight-years-old fallow, 14 months after the fire in 2007, already exceeds the total number of microorganisms in the soil of the background plot by 9.12%; probably, most of the negative consequences of the fire have already been overcome by the ecosystem, and the biological processes have become more active due to the improvement in the mineral nutrition of phytocenosis. However, it should be emphasized that the number of microorganisms of most of the studied groups remains reduced in the post-pyrogenic soil; the main group of microorganisms, due to which the total number of microorganisms in the soil after the fire increases, are denitrifiers. In the background plot the soil has by 36.8% more moisture than in the post-pyrogenic plot, which is a consequence of burning the litter biomass, which prevents the soil from drying out. Consequently, the destruction of the litter and heating of the upper layers of the soil negatively affects the physical state of the soil and its microbiocenosis.

By intensity of consumption of the organic matter and humus, the soil of the post-pyrogenic plot of the eight-years-old fallow exceeds the indicators of the background plot; however, in contrast to the observations carried out 3 months after the fire on the twenty-years-old fallow, the intensity of the podsolization process levels off in these areas, and the process of nitrogen mineralization becomes less intense. The consequences of the fire in 2007 still affect the phytotoxicity of the soil of the eight-years-old fallow: it is by 16% higher than the toxicity of the soil of the background plot. The total biological activity of the soil on a twenty-years-old fallow 3 months after the fire remains 37.8% lower than in the background plot (Malynovska & Soroka, 2008). However, after 14 months, the total biological activity of the soil that survived two fires is almost the same as that of the soil that survived one fire (Table 4). However, it is only 12.6% less than the corresponding indicator of the background plot on the eight-year-

old fallow land. Consequently, this indicator after the fire is quickly restored due to high physiological activity of soil microorganisms.

Thus, fires lead to a decrease in the number, and the physiological and biochemical activity of microorganisms of the main ecological, trophic and functional groups of the fallow soils; this decrease occurs 3 and 14 months after the fire. The amplitude of fluctuations of these indicators depends on the group of microorganisms and the age of the fallow.

Table 5. The number of microorganisms in the carbon cycle of the Albebeluvisoil of a nine-year fallow, 26 months after the fire, million CFU*/ g of absolutely dry soil, data from 2009

Variant	Pedotrophs	Cellulose decomposing	Polysaccharide-synthesizing	Autochthonous	Streptomycetes	Micromycetes	Total number
Nine-year fallow, fire in 2007	52.6	32.8	2.52	7.32	6.49	0.232	347.9
Nine-year fallow, the background area	56.0	37.4	2.06	7.96	5.54	0.244	354.7
LSD_{05}	1.5	2.4	0.4	0.18	0.88	0.010	

Note: * – a colony-forming unit.

To identify the longer-term effects of the fires, studies were also carried out 26 months after the 2007 fire on a site of a nine-year-old fallow. As a result of the studies it was found that the difference between the soil that was affected by the fire and the soil in the background area became less significant. The number and physiological and biochemical activity of microbial cells of most groups are practically the same or differ insignificantly (Table 5–7). Thus, 14 months after the fire the number of ammonifiers in the soil of the background site exceeds the corresponding indicator of the post-pyrogenic site by 14.7%, and after 26 months the opposite trend is observed, and the number of ammonifiers in the soil of the post-pyrogenic site begins to exceed the number of microorganisms of this group in the soil of the background site (Table 6).

Table 6. The number of microorganisms in the nitrogen and phosphorus cycle of the Albebeluvisoil of a nine-year fallow, 26 months after the fire, million CFU*/ g in soil samples with complete absence of moisture, data from 2009

Variant	Ammonifiers	Mineral nitrogen immobilizers	Oligonitrophils	Azotobacter, % fouling of soil lumps.	Nitrifying (autotrophic)	Denitrifiers	Mineral phosphate mobilizers	Organophosphate mobilizers
Nine-year fallow, fire in 2007	121.0	57.7	41.8	0	1.24	20.2	2.52	1.44
Nine-year fallow, the background area	117.1	59.0	45.2	0	0.99	18.6	2.40	2.16
LSD_{05}	3.66	1.98	2.89	-	0.12	1.11	0.10	0.19

Note: * – a colony-forming unit.

The number of nitrifying bacteria 14 months after the fire is approximately the same in the soil of the background and post-pyrogenic areas, and after 26 months the number of nitrifiers in the soil of the post-pyrogenic area compared to the background area increases significantly (by 25.3%). In the investigated soils the number of denitrifiers is leveled out, which at the previous stage of monitoring in the post-pyrogenic soil exceeded the number of denitrifiers in the undamaged soil by 11.6 times (Table 2).

Since organophosphates were destroyed in the fire flame, after 14 months the amount of the organophosphate mobilizers in the post-pyrogenic soil was half that in the undamaged soil (Table 2). After 26 months the difference still remains, yet the difference is no longer so significant and amounts to 50% (Table 6).

The number of cellulose-decomposing microorganisms in the post-pyrogenic soil, due to the combustion of litter 14 months after the fire, was significantly less than in the undamaged soil; however, 26 months after the fire the numbers of microorganisms in this group became very similar in value (Tables 1 and 5). At the previous stage of monitoring there were significantly more autochthonous microorganisms involved in the destruction of humus in the post-pyrogenic soil than in the undamaged soil (by 83.2%), but a year later the trend changed to the opposite, and the number of autochthonous microorganisms in the undamaged soil exceeded their number in the post-pyrogenic soil, i.e., to. the effect of the entry of mineral elements into the soil due to a fire has ceased to be significant. Besides that the difference in their physiological and biochemical activity in the analyzed soils ceased to be statistically significant (Table 7).

Table 7. Probability of the formation of colonies of microorganisms (λ, hour^{-1}. 10^{-1}) in the soil of a nine-year-old fallow 26 months after the fire, data from 2009

Variant	Ammonifiers	mmobilizers mineral. nitrogen	Oligonitrophils	Pedotrophs	Pulp-degrading	Micromycetes	Mineral mobilizers. phosphates	Organophosphate mobilizers	Autochthonous	Nitrifying	Denitrifying
Nine-year fallow, fire in 2007	2.52	0.16	6.02	5.85	5.22	1.53	2.28	3.32	0.57	0.076	6.79
Nine-year fallow, the background area	2.88	0.18	5.78	5.90	5.11	2.01	2.06	3.56	0.55	0.099	6.11
LSD_{055}	0.38	0.02	0.25	0.10	0.15	0.20	0.11	0.14	0.12	0.012	0.44

It should be noted that, in contrast to the previous stage of observations, when the physiological and biochemical activity of microbial cells in the post-pyrogenic soil was significantly lower than that of the undamaged soil (Table 3), 26 months after the fire the difference between the cell activity becomes statistically insignificant, with the exception of micromycetes, mobilizers of mineral and organophosphates, nitrifying and denitrifying microorganisms (Table 7). In addition to this, for micromycetes, nitrifying and denitrifying microorganisms the trend, identified at the first stage of observations, remains.

Table 8. Data showing the intensity of the processes taking place mineralization processes and phytotoxicity of the soil of a nine-year-old fallow 26 months after the fire, data from 2009

Variant	Pedotrophic index	Oligotrophic coefficient	Nitrogen immobilization coefficient	Humus mineralization activity, %	Total biological activity	Specific phosphate mobilizing activity	Weight of 100 plants of test culture – winter wheat, g
Nine-year fallow, fire in 2007	0.435	0.398	0.477	13.9	1,117.2	0.395	17.3
Nine-year fallow, the background area	0.478	0.386	0.504	14.2	1,214.1	0.401	17.8
LSD_{05}	0.34	0.15	0.22	0.55	82.0	0.18	0.35

26 months after the fire the relationship between the intensity of the mineralization processes in the post-pyrogenic and undamaged soil also changes (Table 8). Thus, the development of total soil organic matter and humus mineralization become more intense in the undamaged soil while the process of mineralization-immobilization of nitrogen compounds remains less intense in the post-pyrogenic soil. The same patterns are observed regarding the oligotrophic coefficient, which indicates a deficiency of nitrogen mineral elements in the post-pyrogenic soil. The undamaged soil is still characterized by greater total biological activity than the post-pyrogenic soil; however, the difference is reduced from 12.6 to 8.67%. The difference in phytotoxicity of the post-pyrogenic and undamaged soil is also reduced from 16.0 to 2.89%.

CONCLUSIONS

The mechanism of the effect of a fire upon the soil microbiocenosis of an eight-years-old and twenty-years-old fallows differs 3 and 14 months after it has taken place. The consequence of the fire after 3 months is a decrease in the number of microorganisms of all the investigated ecological and trophic groups. After 14 months, due to the improvement of the mineral nutrition of phytocenosis post-pyrogenic soil, the number of several groups decreases, while others, mainly of the nitrogen and phosphorus cycles, increase.

The physiological activity of microorganisms in the plots that have experienced the impact of one and two fires, 14 months after the fire, remains lower, compared to the activity of microorganisms in the background plot after 26 months - levels off, with the exception of the physiological and biochemical activity of the micromycete cells, mobilizers of mineral and organophosphates, nitrifying and denitrifying microorganisms.

The total biological activity of the soil after the fire recovers quite quickly due to the high physiological activity of the soil microorganisms: the soil indicators of an eight-year-old fallow 14 months after the fire are only by 12.6% less than the corresponding indicator of the background plot after 26 months - by 8.67%.

The soil that has experienced the impact of two fires is characterized by a greater intensity of the microbiological processes, compared to the soil that has experienced the impact of one fire. It increases the intensity of mineralization of the organic (pedotrophy index) and nitrogen-containing substances (the nitrogen mineralization coefficient). At the same time, due to the improvement of mineral nutrition of phytocenosis, the activity of the humus decomposition decreases.

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