Dynamics of microorganism population in the soil of pine plantations under technogenic load

Natalia A. Makeeva*

Federal Research Center of Coal and Coal Chemistry SB RAS (Institute of Human Ecology), 10 Leningradsky Ave, Kemerovo, 650065, Russia

Abstract. The degree of crown closure is an important parameter of tree plantations that determines the environmental conditions for all organisms in the ecosystem. Studies assess the effect of the degree of crown closure on the microorganism dynamics in the rock dump soil with and without a potentially fertile layer. It was found that the amount of soil microorganisms varies significantly during the period, which is associated with variations in the hydrothermal conditions of the soil. The activity of microorganisms decomposing mineral nitrogen and microscopic fungi varies depending on the degree of crown closure.

1 Introduction

One of the largest coal deposits in the world is located in the Kemerovo region. The activities of the coal mining industry inevitably lead to the formation of technogenic landscapes with the disruption of all components of the natural-geological environment. However, since the middle of the 20th century, reforestation efforts have been underway in the region [1]. The most widespread tree species used for the forest reclamation of coal mine dumps in the territory of Kuzbass is the common pine (*Pinus sylvestris* L.) [2]. Under the given conditions, pine is a dominant species that participates in the formation of the structure and functioning of the ecosystem. Both the physical properties of the environment and biological diversity are affected by pine trees.

The degree of crown closure is a crucial parameter for tree plantations, since such indicators as illumination and moisture depend on it to a large extent [3]. In addition, the degree of crown closure determines the intensity of the abscission and, consequently, the thickness of the litter that determines the amount of organic matter in the soil [4, 5].

The activity of microorganisms has a significant impact on the functioning of the soil. Soil microorganisms are responsible for the circulation of elements. They regulate individual stages of humification and contribute to the maintenance of soil fertility, thereby participating in the restoration of vegetation cover [6, 7].

The aim of this work is to examine the microorganism dynamics in the soil of pine plantations under technogenic burden.

* Corresponding author: natykor@bk.ru

2 Materials and Methods

The studies were carried out on the sites of the rock dump of the Kedrovsky coal mine with and without the application of a fertile soil layer (FSR) (Figure 1). Control sites were located in the Kuzbass Botanical Garden [8]. Observation sites (OS) were located in plantations of *Pinus sylvestris* L. II age class, determined by crown closure and the zoning of phytogenic fields (Table 1).

Table 1. Layout of the observation sites

Phytogenic zone	The degree of closeness of the crowns		
	20–30% (sparsely closed)	50–60 % (medium-closed)	80–90% (highly closed)
Undercrown	30 Ca	60 Ca	90 Ca
Cover	30 Cra	60 Cra	90 Cra
External	30 Ap	–	–

A B C

Fig. 1. Pine plantations: A – Dump without FSR, B – Dump from the FSR, C – Control

Soil samples were collected three times during the growing season (in the third decade of May, July, and September 2020–2022) at 5 points at each OS. The quantification of microorganisms was carried out using standard methods described in previous studies [8, 10]. The mathematical and statistical processing of experimental data was carried out using the standard MS Excel package [11].

3 Results and discussion

It is evident that the soil microorganism dynamics is largely determined by the hydrothermal conditions of the soil, and therefore can vary greatly during the growing season [10]. The number of microorganisms on starch-ammonia agar (SAA) varied from 360 to 16078 thousand CFU/g of dry soil, for microorganisms per MEA (meat-extract agar) – from 46 to 17255 thousand CFU/g dry soil, and for microscopic fungi – from 84 to 3821 thousand CFU/g of dry soil (Table 2). The maximum values for all groups of microorganisms were observed at the onset of the growing season, which is associated with sufficient soil moisture at high temperatures.

Table 2. Soil microorganism dynamics

OS	Control			Dump from the FSR			Dump without FSR		
	May	July	Sept.	May	July	Sept.	May	July	Sept.
Microorganisms grown on SAA									
30 Ca	1391	636	2276	2133	814	1402	1852	765	1202
30 Cra	2980	1714	601	1631	560	768	1775	624	1123
30 Ap	1606	1333	952	1695	892	1211	1531	732	928
60 Ca	14137	3457	1622	1458	917	475	1334	884	714
60 Cra	4981	843	4035	1491	360	526	1548	538	618
90 Ca	16078	2682	417	1917	1375	833	2112	1446	726
90 Cra	14902	4828	5148	684	1111	598	1321	1008	631
Microorganisms grown on MEA									
30 Ca	347	1721	3821	1439	351	98	1125	288	143
30 Cra	510	817	2222	620	1240	78	589	1005	105
30 Ap	715	314	736	1818	356	356	1645	255	304
60 Ca	2410	1564	2342	689	220	81	742	192	79
60 Cra	4138	345	2281	1111	881	46	929	764	56
90 Ca	12784	1111	2000	2682	268	176	2147	234	146
90 Cra	17255	4368	4051	917	333	133	888	269	95
Microscopic fungi									
30 Ca	815	3821	244	504	650	3659	489	713	1550
30 Cra	455	2222	576	676	495	2162	526	631	2123
30 Ap	209	736	589	360	946	1937	414	789	1738
60 Ca	675	2342	360	84	651	176	153	548	526
60 Cra	705	2281	482	402	643	602	397	531	746
90 Ca	196	2000	1067	179	641	470	201	614	894
90 Pcs	361	4051	1030	263	746	1096	177	575	966

The studies showed that microorganisms utilizing mineral forms of nitrogen (microorganisms grown on SAA) prevailed at all observation sites, indicating the intensive mineralization processes of organic matter. It serves as a parameter for the intensification of

mobilization processes in the soil. The low content of saprophytic microflora (microorganisms grown on MEA) in the soil of rock dumps may be attributed to the low biological activity of the rock, even despite the presence of a potentially fertile layer.

The maximum activity of microorganisms grown on SAA in the dump soil was observed in May and July in highly closed pine plantations both in the control and on dumps sites, while for microscopic fungi – in those sparsely closed. The function of microscopic fungi in the soil is to decompose organic compounds, including lignin. Although fungi are less sensitive to variations in the water and temperature regime of the soil due to a mycelial structure, the obtained results may indicate more favorable conditions of sparsely closed plantations in the dump. An increase in the number of fungi by the end of the growing season may be related to the accumulation of organic matter in the soil.

4 Conclusion

The results demonstrate that the number of soil microorganisms varies significantly during the growing season. Maximum values were observed at the onset of the growing season, which is associated with sufficient soil moisture at high temperatures. The predominance of microorganisms that utilize mineral forms of nitrogen indicates intensive mineralization processes of organic matter. The activity of microorganisms that decompose mineral nitrogen and microscopic fungi varies depending on the degree of crown closure. The number of microorganisms decomposing organic nitrogen is independent of the degree of crown closure. In addition, no relationship between the number of microorganisms and the phytogenic zone was established.

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