Dynamics of nitrogen and phosphorus accumulation in the litter of silver birch growing in different environmental conditions

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Abstract. The paper presents the data from a study of nitrogen and phosphorus content in the litter of silver birch growing in different environmental conditions. The research object was 20- to 25-year-old silver birch trees. The observation plots were laid on the planned dump of the Kedrovsky open-pit coal mine with the application of a potentially fertile soil layer (PFL) and without applying PFL, as well as on the Kuzbass Botanical Garden territory (control). The research was conducted using common methods. The study aims to assess the accumulation of nitrogen and phosphorus in the litter of silver birch growing in different environmental conditions. The maximal accumulation of nitrogen was observed in the control zone, of phosphorus – on the planned mine waste dump with PFL application. The studies have shown that the application of PFL has a positive effect on nitrogen and phosphorus accumulation in birch litter.

1 Introduction

According to the Ministry of Coal Industry of Kuzbass, in 2023, 91.8 million tons of coal were extracted, including 61.5 million tons by open-pit mining. With this mining technique, the area of waste dumps increases. Moreover, the nearby territories undergo considerable anthropogenic changes in soil, animal, and vegetation cover. Thus, the total area of disturbed lands requiring rehabilitation approximately doubles. All this results in extremely difficult environmental conditions in the Kuznetsk Basin, where 70% of the population is concentrated [1].

Soil reclamation of disturbed lands is a necessary way to restore destroyed ecosystems, preserve biodiversity, and increase the carrying capacity of the territory. Prior to the biological stage of soil reclamation, a potentially fertile soil layer (PFL) is applied to some mine waste dumps. The PFL is the lower part of the soil profile possessing physical, chemical, and, to a limited extent, agrochemical properties favorable for plant growth.

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In Kemerovo Oblast (Kuzbass), the most common species used for soil reclamation of disturbed lands is Scots pine as it takes root well in different soil types [2, 3]. In case of vegetation overgrowth of waste dumps, the emerging plantations often contain silver birch besides Scots pine. Together, they create highly productive stable stands.

Leaf litter in the process of its formation loses a significant part of the components characteristic of mature leaves. For instance, photosynthetic pigments and proteins are destroyed, and nitrogen and other microelements are reutilized within the plant organism. In dying leaves before leaf shedding, some secondary compounds accumulate. It is relevant to study the indicators of plant litter chemical composition since different plant species synthesize and release unequal amounts of various substances into the environment [4].

Nitrogen is one of the most important macroelements. Plant development is impossible without it. Nitrogen is responsible for metabolism. Moreover, it is found in the composition of all proteins, cytoplasm, cell nuclei, amino acids, chlorophyll, hormones, vitamins, and other compounds.

Phosphorus plays an essential role in the biological processes of all organisms, in the functioning of ecosystems and the biosphere in its entirety. Phosphorus is indispensable for such processes as photosynthesis, metabolism, and reproduction. Photosynthesis and phytobiomass creation are the starting point of the biogeochemical cycle in the biosphere [5]. In terrestrial ecosystems, phosphorus is the main element regulating the accumulation of carbon, nitrogen, and organic sulfur in soils.

This work aims to assess nitrogen and phosphorus accumulation in the litter of silver birch growing in different environmental conditions.

2 Materials and Methods

The research was conducted in 2023. The observation plots (OP) are located in the stands of silver birch (*Betula pendula* Roth.) of age class II on the territory of the Kuzbass Botanical Garden (control) and the waste rock dump of the Kedrovsky open-pit coal mine (experiment) on the plots without applying PFL (OP 1) and with PFL application (OP 2).

The Kuzbass Botanical Garden is located in the left-bank part of Kemerovo, in the flood plain of the Tom River (in the area of Lake Sukhovskoye) to the east of the existing and designed architectural ensembles of the developing city center. The embankment of the Tom River, whose streambed makes a sharp turn in this area, limits the territory of the garden from the north and the east. The area in close proximity to the Tom River is low-lying, swampy, mainly occupied by bushes. The areas allocated for the arboretum (dendrological park) occupy a more elevated part of the botanical garden and are located on two terraces with a height difference of up to 6.0 m. The upper terrace is represented mainly by fallow lands (former arable lands) crossed by shallow dry valleys. The Kedrovsky open-pit coal mine is located 25 km north of Kemerovo on the western flank and the southern closure of the Kedrovsko-Krokhalevskaya brachysyncline (basin) in the Central part of the Kemerovo geological-industrial region of Kuzbass.

Leaf litter was sampled during the third ten-day interval of May, July, and September. Specimens were taken from quadrats measuring 30x60 cm, 60 cm from the trunk of each model tree, dried to an air-dry state and weighed (Figure 1). The samples were brought to an absolute dry state in a laboratory oven at 105°C in closed weighing bottles for 4 hours. In the subsamples, the total content of nitrogen and phosphorus was determined by wet ashing technique [6].

Fig. 1. Litter of silver birch on the territory the waste rock dump of the Kedrovsky open-pit coal mine

3 Results and discussion

The environmental conditions of the stands are formed under the influence of climatic, edaphic, and agrotechnological factors which determine moisture, light and temperature regime of the surface, and nutrient availability to plants. The most unfavorable conditions for plants exist on the planned waste dump without PFL application (OP 1). OP 2 is characterized by a higher nutrient content due to the application of PFL. The control is based on the undisturbed soils of the Botanical Garden.

The research has established that nitrogen content in birch litter accumulates uniformly from May to September on all OPs. The maximum accumulation was observed in the control zone, the minimum – on OP 1 (Table 1).

Table 1. Nitrogen and phosphorus content in the litter of silver birch growing in different environmental conditions, 2023

Observation plots	Nitrogen, %*	Phosphorus, %*
May		
OP 1	0.80	0.89
OP 2	0.85	1.26
control	1.35	0.54
July		
OP 1	0.86	0.93
OP 2	0.90	1.36
control	1.42	0.66
September		
OP 1	0.95	0.75
OP 2	1.12	0.98
control	1.51	0.50

* The standard error of the mean does not exceed 5%

Phosphorus accumulates unevenly in litter: in September, it accumulated less than in May and July on all OPs. The maximum phosphorus content in birch litter was observed in the waste dump area with PFL application (OP 2) during all observation periods (Table 1). The control had the least amount of phosphorus in the litter, i. e. 1.96–2.3 times less than in the dump area with the application of PFL. It is known from literature that phosphorus accumulation is affected by climatic conditions, the activity of various groups of microorganisms, and other factors [7, 8].

4 Conclusion

Thus, the conducted studies have shown that PFL application has a positive effect on nitrogen and phosphorus accumulation in birch litter.

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