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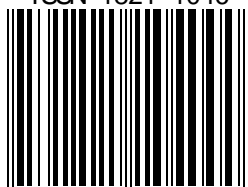
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THE POSSIBILITY OF USING SOME CONIFEROUS SPECIES FOR THE IMPROVEMENT OF THE CHARACTERISTICS OF MINE SOILS

Zoran MILETIĆ¹

Abstract: *On the reclaimed mine soils of the lignite mine “Kolubara” the influence of forest plantations of Japanese larch, Douglas fir and Austrian pine on the revitalization of the soils formed by waste-rock deposition was researched. The total yield of litterfall which is annually transported to the soil surface and the percent of nitrogen, phosphorous and potassium in the litterfall was determined. The following soil characteristics were determined: reaction of soil solution, the total amount of humus and nitrogen, as well as the forms of phosphorous and potassium which are available to the plants. It was concluded that the Douglas fir plantations had the most favourable effect on the revitalization of soils, whereas the Austrian pine and Japanese larch plantations had the significantly less favourable effect on it.*

Key words: mine soils, forest plantations, litterfall, humus, nitrogen, phosphorous, potassium

1. INTRODUCTION

The soils formed by waste-rock deposition from the open pits of lignite mines in Kolubarski basin are poor in the content of forms of nutrients which are available to the plants. Phosphorous and potassium are present in the overburden above the coal layer, out of which the tailing dumps are formed, but they are not found in the water-soluble forms that are available to the plants. The recently deposited waste-rock is devoid of the nutrients and humus, and, thereby, of the organic nitrogen, which is the source of the forms that are available to the plants

¹ Institute for Forestry, Belgrade, Serbia

(Stojanović et al 1977; Antonović et al 1978; Antonović et al 1984; Veselinović et al 1984; Šmit, Veselinović 1997; Šmit, Miletić 1997, Dražić, 1997; Miletić 2004, Miletić, Radulović 2005.).

By establishing the forest plantations on the deposited tailing dumps and forming the canopy of the vegetation cover the protective forest functions are established. Along with the main-protective function of the forests on mine soils, anthropogenic forest ecosystems should serve the meliorative function, i.e. improve the soil characteristics, its fertility and productive potential by the dead organic residues.

Humus is the stable and long-lasting source of the nutrients for the forest trees. The formation of higher quantities of humus under the plantations would enable the harmonized release of the nutrients over the whole growing season. Humus has the positive effect on other soil characteristics as well, mainly on the structure, since it fixes soil particles in the structural aggregates. In this way it indirectly accelerates the water infiltration, aeration of soil solum, and the ratio of some categories of pores in the differential soil porosity. The presence of humus increases the soil resistance to the eroding agents.

This paper is aimed at the study of the influences of some forest plantations on the creation of humus in the soil and biological accumulation of nitrogen, phosphorous and potassium.

2. METHODS

On three sample plots on the mine soils of lignite mines under the forest plantations of Douglas fir (*Pseudotsuga menziesii* /Mirb./ Franco), Japanese larch (*Larix leptolepis* Siebold et Zucc.) and Austrian pine (*Pinus nigra* Arn.) the annual yield of the litterfall on the soil surface was measured, the soil profiles were opened, and the samples of the soils were taken for the laboratory studies. The researches were done on the mine soils of lignite mine "Kolubara". The sites characterized by the mine soils of the heavier texture were selected, i.e. all observed mine soils belong to the textural class of clays and clay loams.

The following aspects were studied in the laboratory conditions:

- Determination of the quantity of macroelements in the litterfall by the ash analysis after the dry combustion in the following ways: potassium was determined flame-photometrically, phosphorous was determined colour-metrically, and calcium and magnesium complex-metrically. The quantity of nitrogen in the leaf litter was determined by using Kjeldahl's method.
- The soil analyses referred to: determination of the active and substitutional acidity electrometrically, the forms of phosphorous and potassium which are available to the plants by AL method according to Egner-Rihm, of nitrogen by using Kjeldahl's method, and the total quantity of humus by using Turin's method.

3. RESULTS

The litterfall of the observed species greatly differs, in both total amount which is transported to the soil during one year, and in chemical characteristics, i.e. content of the macroelements of nutrition (Table 1). The highest quantities of the litterfall during the year are transported to the soil surface under the Austrian pine plantations. In spite of the fact that Japanese larch is a broadleaf species, which in autumn reject all assimilation organs, it transports the significantly lower quantities of litterfall to the soil surface than the Austrian pine. Douglas fir produces almost half quantity of the litterfall in comparison with Japanese larch. Litterfall is the most significant source of the nutrients for the soil organic layer in the forest ecosystem, and, thereby, the main source of the organic carbon around which the humus is formed (Родин, Базилевич, 1965; Nordén, U. 1994). It implies that the highest quantities of the organic carbon are produced by the Austrian pine plantations, followed by the larch plantations, and the lowest quantities are produced by the Douglas fir plantations. Along with the litterfall of the species which were used for the reforestation, the part of the dead organic residues are produced by the native species which spontaneously inhabit the plantations. Japanese larch is the heliophilic species with the open crown, which enables the penetration of light to the soil surface and the occurrence of the native species in all layers of the larch plantations. As a result, the production of nutrient out of which the humus is formed by the native species is the highest under the Japanese larch plantation. Under the Austrian pine plantation the production of the dead organic residue by the native species is significantly lower than under the larch plantation, where, along with the less favourable light conditions, the spontaneous occurrence of the native species is prevented by a very powerful horizon of the soil organic layer. Under the Douglas fir plantation, due to the dense canopy and strong shade which is formed by this sciophilic species, there is almost no production of the organic residues by the native species.

Out of all observed plantations, the litterfall of the Japanese larch is the richest in the ash. Significantly high quantities of ashes were also reported in Douglas fir litterfall, and the lowest quantities in the Austrian pine litterfall. The highest percent of nitrogen was reported in the Japanese larch litterfall, which was followed by the Douglas fir litterfall, and the lowest percent in the Austrian pine litterfall.

By contrast to the nitrogen, the percent of phosphorous, as well as potassium, is the highest in the Douglas fir litterfall, considerably lower in black locust litterfall, and the lowest in the Austrian pine litterfall.

Table 1. *Characteristics of litterfall*

Plantation	Litterfall	Nutrient	Ash	N	P	K
	t/ha	%	%	%	%	%
Japanese larch	1044.00	90.54	9.46	0.83	0.005	0.757
Douglas fir	548.80	93.38	6.62	0.78	0.048	2.431
Austrian pine	1447.50	97.69	2.31	0.40	0.003	1.154

The forest plantations established on the tailings of the mining basin “Kolubara” by the production of litterfall on the soil surface provided the energy

material for saprophytic microorganisms and initiated microbial processes of decomposition of the dead organic residues (Miletić 2004, Miletić, Radulović 2005). The microbial processes affect the pedogenetic processes, mainly humification, the creation of humus-accumulative horizon and biological accumulation of nutrients in the surface soil layers.

In the mine soils under the observed plantations, the highest quantities of humus were reported under the Douglas fir plantation (Table 2). The yield of the organic residues out of which the humus is formed under the Douglas fir plantations is the lowest in all observed species, because along with the lowest production of litterfall there are no native species. The conditions for microbial activity under the observed plantation are unfavourable because Douglas fir is the sciophilic species which forms the dense canopy and casts the strong shade on the soil surface. It implies the unfavourable light conditions to the activity of saprophytic microorganisms which decompose the nutrients. By contrast to the soil under the larch plantation, where the native flora had the significant influence on the total production of the dead organic residues out of which the humus is formed, under the Douglas fir plantation there is almost no yield of the organic residues of other species to the soil. The Douglas fir litterfall is almost the only source of nutrients for the soil organic layer and for the soil.

The decelerated decomposition of the nutrient under the Douglas fir plantation enables the mutual connection of the intermediate products of the decomposition and the synthesis of the humus substances which are resistant to the further decomposition.

As the result of the multi-annual yield of the high quantities of the litterfall rich in potassium, under the Douglas fir plantations the surface layer of the mine soils was well-supplied with the forms of this element which are available to the plants. The content of the available forms of potassium is the highest in the surface layers of the soil, whereas it decreases with the increasing depth of the solum. In the deeper layers the content of the available potassium is within the limit of the mean availability, based on the threshold values for AL method.

By the contrast to potassium, the quantity of the forms of phosphorous which are available to the plants is lower under the Douglas fir plantations than under the Japanese larch and Austrian pine plantations. The fallen Douglas fir needles have the higher percent of phosphorous than other observed species. However, the total quantity of litterfall is very low, so the yield of phosphorous per a unit of area of the soil under the Douglas fir is even lower than under other plantations. The highest quantities of the forms of phosphorous which are able to the plants were reported under the Japanese larch plantation, the litterfall of which is richer in phosphorous and where the native plants significantly affect the cycle of this element in the artificially established ecosystem.

Under the Japanese larch plantation the twofold higher amount of the litterfall is transported to the soil surface, and the content of the total humus is half as much as under the Douglas fir plantation. It implies that the larch needles are to a lesser extent transformed into the humus, owing to which there is no higher biological accumulation of nitrogen. The quantities of the forms of phosphorous which are available to the plants are higher than under the Douglas fir plantations, but in this instance they are also within the limits of poor availability, whereas the

quantities of the forms of potassium which are available to the plants are somewhat lower than under the Douglas fir.

Table 2. *The characteristics of the mine soils under the different plantations*

Plantation	Dubina	pH H ₂ O	pH KCl	pH CaCl ₂	N	Humus	P ₂ O ₅	K ₂ O
Japanese larch	0 – 2	6.4	5.2	5.6	0.099	1.24	7.10	20.32
	2 – 7	5.8	4.6	5.1	0.071	0.58	4.00	19.10
	7 – 17	5.4	3.6	4.2	0.068	0.29	18.50	18.52
	17 – 100	6.7	5.4	6.3	0.089	0.27	4.50	13.71
Douglas fir	0 – 2	5.2	3.9	4.7	0.216	2.26	0.40	23.80
	2 – 7	5.3	3.9	4.9	0.097	1.24	0.20	17.80
	7 – 17	5.7	3.8	5.2	0.062	0.43	0.30	16.20
	17 – 100	6.8	4.6	5.8	0.041	0.27	0.30	13.30
Austrian pine	0 – 2	6.4	5.1	6.0	0.123	1.96	0.70	29.30
	2 – 7	6.7	5.1	6.3	0.070	1.01	3.80	20.30
	7 – 17	7.8	6.5	7.5	0.020	0.71	6.00	14.40
	17 – 100	8.0	6.8	7.6	0.016	0.28	5.20	17.67

Under the Austrian pine plantation the considerably higher quantity of the nutrient is transported to the mine soils than under the Douglas fir plantations. In spite of this fact, under the Austrian pine plantation the lower quantity of humus was reported than under the Douglas fir plantation. The Austrian pine litterfall is characterized by the unfavourable chemical properties. The content of all observed macroelements of nutrition is lower than in Douglas fir and larch. The low content of nitrogen in the litterfall implies the wide ratio of carbon and nitrogen. It results in the decelerated decomposition of the nutrient and in its accumulation in the horizon of the soil organic layer. Due to the lack of nitrogen in the litterfall, the processes of fermentation of the soil organic layer produce the organic acids and aggressive fulvic acids which do not contain nitrogen.

The Austrian pine plantations on all sites in Serbia acidify the soil (Knežević 1994). The production of the acidified products of the decomposition of the soil organic layer under the observed plantation on the mine soil also led to the visible acidification of the soil.

In the surface layers of soil under the Austrian pine plantation the higher content of the forms of phosphorous and potassium which are available to the plants than in the deeper layers of the soil was reported, which implies that under this plantation potassium is biologically accumulated.

4. CONCLUSION

The established forest plantations of Douglas fir, Japanese larch and Austrian pine, along with the protective and productive functions on the observed mine soils, have the meliorative role. The litterfall and products of its decomposition to a lesser or greater extent meliorate the soil characteristics in comparison with the recently deposited waste-rock. Out of the observed tree species, the Douglas fir plantation has the most favourable effect on the soil characteristics. Under the influence of the Douglas fir plantation, the significant increase of the content of humus and nutrient in the soil and biological

accumulation of nitrogen, and biological accumulation of nitrogen occur, as well as the transformation of phosphorous and potassium from the unavailable forms to the water-soluble forms which are available to the plants.

Austrian pine transports the highest quantity of the organic residues, out of which the humus is formed, to the soil surface. However, this plantation had the less favourable effect on the revitalization of the soil than Douglas fir. Owing to the wide ratio of carbon and nitrogen, the Austrian pine needles are decomposed very slowly and accumulated in the soil organic layer. The low quantities of humus are formed, which implies the low biological accumulation of nitrogen. The products of decomposition have acid reaction. Under the influence of the aggressive products of the decomposition of the nutrient, the soil is acidified. The higher quantities of the available forms of phosphorous and potassium in comparison with the mine soils under the Douglas fir are not the result of the accumulation via the litterfall, but of their mobility from the crystal structure of the mineral and transformation from the unavailable forms to the water-soluble forms under the influence of the aggressive organic acids (fulvic acids 1a).

The larch plantation had the least favourable effects on the revitalization of the mine soils. Under this plantation the lowest quantities of the humus and nitrogen were reported, and, at the same time, the lowest quantities of the forms of potassium which were available to the plants.

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THE POSSIBILITY OF USING SOME CONIFEROUS SPECIES FOR THE IMPROVEMENT OF THE CHARACTERISTICS OF MINE SOILS

Zoran MILETIĆ

Summary

On the reclaimed mine soils of lignite mine “Kolubara” under the influence of the litterfall of forest plantations and products of their decomposition the revitalization of soil occurs, i.e. the soil regains its natural characteristics, fertility and productive ability. It was concluded that the Douglas fir plantations, which produced the lowest quantity of the litterfall to the soil surface, had the most favourable effect on the revitalization of soil. Under the Douglas fir plantations the significant increase of the content of the total humus and nitrogen in the soil occurs, as well as the transformation of potassium from the water-insoluble forms to the forms which are available to the plants. The Japanese larch and Austrian pine plantations have significantly less favourable influence on the revitalization of the soil.

Reviewer: **Ph. D. Dragana Dražić**

