The phosphate state and biochemical mobilization of phosphorus compounds in arboreal plants' soils

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Keywords: degraded soils, phosphorus, biological recultivation, biochemical mineralization of organic phosphorus

SUMMARY

Some indices of the phosphoric fractions of primery degraded soils, which are formed separate areas of technogenic landscapes, on a spoil-bank of iron-ore mine in the near of Kryvyi Rig, under act of lignosa, which are used for biological recultivation of degraded soils are investigated. Maintenance of mineral phosphates and features of organic phosphorus accumulation are set in soil under arboreal planting. Nutrient supply of plants is enhanced by mobile phosphates and their dynamics during vegetation period. Activity of alkaline and acid phosphatase enzymes are concerned also. On the basis of the soil enzymes activity information it is stated, that under the 35-years-old plantage of Robinia pseudoacacia L. the biochemical mineralization of organic phosphorus compounds passes considerably more actively than under Pinus pallasiana D.Don.

INTRODUCTION

Phosphorus in soils has biogenic origin and its presence and amount are in close connection with the organic matter of soil. Gross maintenance of phosphorus in a humus type is the result of its biological transfer from a matter breed. In the process of pedogenesis and development of soil processes in a superficial layer the specific appears for each as soil phosphoric mode, which, in opinion of Nosko et al. (2006), is characterized by correlation of mineral and organic phosphates and their fractions, presence of the so-called mobile forms of phosphorus, which pass to different slightly acidic or alkaline extractants, and also the degree of mobile phosphorus and phosphatic potential. Forming of the different phosphoric fractions is, foremost, by the result of correlation of organic matter humification and mineralization processes, as its origin on the whole depends on phosphorus transfer intensity by the plants from a matter breed. As a result of biological recultivation of the spoil-bank of an iron-ore mine by the different types of arboreal breeds, which was conducted by the scientists of the Kryvyi Rig botanical garden, primitive degraded soils are formed, in which the biogenic accumulation and transformation processes of organic matters pass with different intensity, in particular also organic phosphorus compounds. Some researchers exactly these processes suggest to use for intensifying of pedogenesis in quality indexes (Makarov et al., 2002; Phedoretz, 1995). Lately the processes devoted to the biogeochemical role of plants at overgrowing of breeds different after composition activated also, including toxic, and influence of specific composition of groupments on forming of organic matter and feature of biochemical transformation of basic biogenic elements compounds (Gryhko, 1999; Kazeev et al., 2003; Phedoretz, 1995). Taking into consideration the facts resulted higher, the purpose of our work consisted in the implementation of the followings tasks: 1) to determine the features of organic phosphorus accumulation and their enzymatic mineralization in soil under the arboreal planting; 2) to explore supply of mineral phosphates in soil of investigational areas; 3) to estimate nutrition status of plants by mobile phosphates and his dynamics during a vegetation period.

MATERIALS AND METHODS

For the implementation of the set of objectives on a spoil-bank of an iron-ore mine monitoring areas were established under the artificial 35-year-old planting of *R. pseudoacacia* and *P. pallasiana*. Soil samples were taken from horizons of H (depth 0-10cm), hP (10-20cm), P (20-30cm) by the generally accepted methods, determination of acid and alkaline phosphatases activity in the soil samples was conducted by the methods of Khaziev (1990), determination of common organic phosphorus fraction after Ginzburg (1969) by successive extraction of phosphates of HCl and solution of NaOH. For determination of phosphorus mobile forms solution of $(NH_4)CO_3$ as a weak extractant was used.

RESULTS AND DISCUSSION

It is known for today, that on the initial stages of pedogenesis by living organisms the main inorganic forms of phosphorus of maternal breed, which gradually pass to the occluded forms non-available for the plants, are actively transformed and mastered. In course of time, as a result of receipt of organic matter as "mort mass", the proportion of organic phosphates increasing in the superficial layer of primitive soil, the accumulation of which

in a superficial layer depends on intensity of mineralization of dead plants biomass (Abakumow– Gagaryna, 2006; Makarov et al., 2002).

The research of phosphorus organic compounds maintenance under the arboreal planting resulted higher indexes under *R. pseudoacacia*, which was characteristic for all depths of selection of samples. For example, their amount in a superficial layer (0-10cm) under the groupments of *R. pseudoacacia* was greater in 3.2 times, than under *P. pallasiana* and made 208.8mg of P_2O_5/100g of soil (*Table 1*). Low proportion of organic phosphorus compounds under *P. pallasiana*, which was 17.05-23.72% from soil total phosphorus, testifies to the insignificant rates of mineralization organic matters of biomass which pine-needle consists. The resulted facts specify on more active transformation plant mort mass and accumulation of organic phosphorus compounds in planting of leafy breeds, than coniferous. By the general tendency distributing of organic forms downward on a type there is decreasing of their amount in layers 10-20 and 20-30cm 3.2 and 2.7 times respectively, in the primitive degraded soils under *R. pseudoacacia,* and 1.3 and 1.5 times under *P. pallasiana* as compared to the superficial layer. Next to the gradual decreasing of organic phosphates maintenance in soil downward on a type we set, different division of mineral phosphates were found. For example, under the 35-year-old artificial planting of *P. pallasiana* their proportion was highest in the superficial soil layer (0-10cm) and was 83% from total amount and gradually decreased in transition to the layers 10-20 and 20-30cm on 27.2 and 57.7% of the total amount respectively, which can be related to the increase of stone size. Unlike an area under *P. pallasiana*, in primitive soil under planting of *R. pseudoacacia* for superficial horizon there was the characteristic least maintenance of mineral phosphorus (38.7% from general) which was multiplied in transition to more deep layers 10-20 and 20-30cm accordingly on 7.2 and 51.3%. Such quantitative division of organic and mineral phosphorus forms under the artificial planting of *R. pseudoacacia* testifies to decreasing of mineral phosphates amount and active organic phosphates accumulation in the most bioactive superficial layers of soil and also their important role in the phosphoric nutrition of plants. Next to it substrates of a new spoil-bank mine dump presented by mixture of siltages did not contain any organic phosphates, and the amount of mineral one was within the limits of 185.2 and 193.8 mg of P_2O_5/100g of soil.

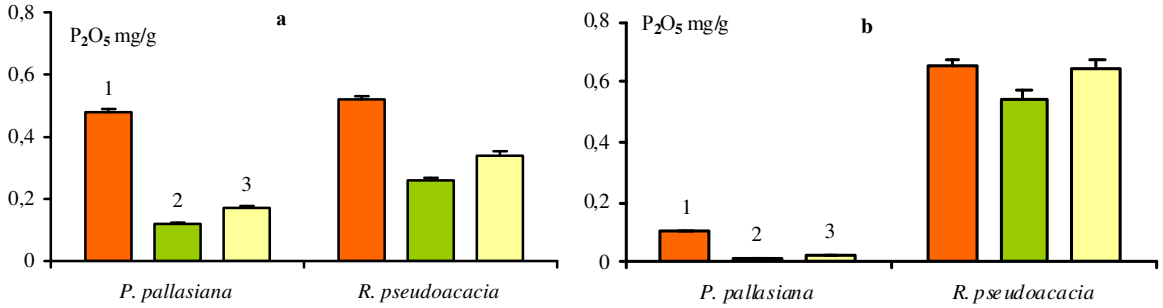
Table 1.

Contents of total, organic and mineral phosphates in soils of monitoring areas of spoil-bank damp of an iron-ore mine at their biological recultivation

Depth, cm	Total phosphorus content		Organic phosphorus content		Mineral phosphorus content	
	M ± m	V, %	M ± m	V, %	M ± m	V, %
The new dump without plants						
0 – 10	185.22±4.98	4.63	–	–	185.22±4.98	4.63
10 – 20	193.80±4.39	3.90	–	–	193.80±4.39	3.90
20 – 30	184.26±6.01	5.36	–	–	184.26±6.01	5.36
Plantation of *R. pseudoacacia* on the 35-year dump						
0 – 10	340.63±5.14	4.62	208.8±3.27	5.7	131.83±5.83	2.62
10 – 20	274.84±8.01	6.27	133.48±4.12	3.22	141.36±4.18	5.09
20 – 30	275.79±5.73	6.08	76.27±9.17	3.30	199.52±4.94	2.90
Plantation of *P. pallasiana* on the 35-year dump						
0 – 10	375.90±1.92	0.88	63.88±4.78	4.77	312.02±3.32	7.35
10 – 20	273.89±6.64	4.18	46.72±3.67	3.69	227.17±6.67	6.34
20 – 30	172.82±5.83	5.81	41.00±5.34	5.36	131.83±2.54	3.31

The conducted researches allowed to conclude that biological recultivation of dumps by arboreal breeds stipulates intensification of biochemical processes of simple organic phosphorus compounds mineralization. Under planting of *R. pseudoacacia* the greatest alkaline phosphatase activity was observed in superficial, most biologically active layer of soil, where the processes of plant's mort mass transformation were the most intensiv. The same high enzyme activity was found in the depth of 20-30cm (Fig. 1), where, for certain, the organic matters are accumulated due to migration from superficial layer of primitive soil. About the greater accumulation of organic matter in the superficial and lowest layers of soil shows also information in relation to the increase of alkaline phosphatase activity. So, enzyme activity was highest in superficial horizon H and lower on 50% in hP. In the deepest horizon of P alkaline phosphatase activity rose on 30% as compared to transitional hP, however, it did not achieve the characteristic values of superficial horizon H (*Figure. 1*). The conformity set to the tendency can be stipulated by that fact, the residual plants biomass which consists of overhead appears in plantage of *R. pseudoacacia*, heavier layer (0-3cm) from the semidecomposed leaves, and lower, where the processes of biological mineralization of organic matter pass more active.

Figure 1. **Activity of acidic (a) and alkaline (b) phosphatases in mg of P_2O_5 per g of soil after 24 hour under planting of *P. pallasiana* and *R. pseudoacacia***

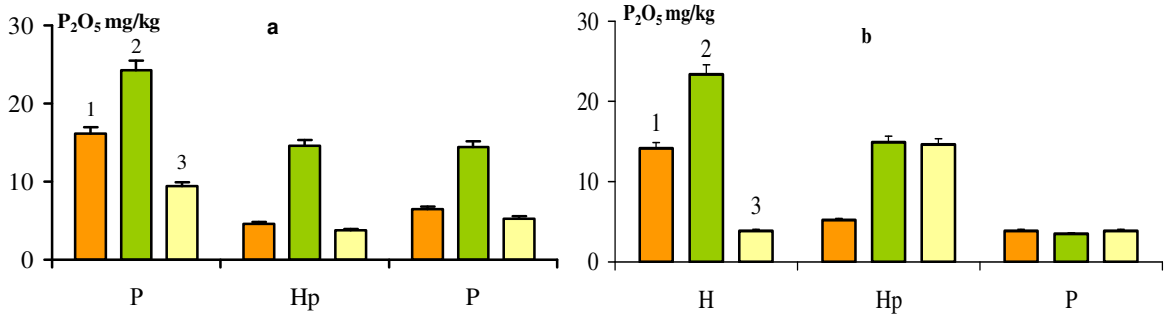


1 - horizon H, 2 - horizon hP, 3 - horizon P; *– statistically proved significant difference is in relation to control at p<0.05.

The study of phosphorus monoesters mineralization intensity, which is catalysed by alkaline phosphatase, resulted that in the soil of area under the *P. pallasiana*, in which the layer of plant residue mass is present from a pine-needle by a thickness 5cm, was the greatest in superficial humid horizon of H. The mineralization ratio was lower in horisons hP and P, decreased by 75 and 65% respectively. The comparative data analysis shows that alkaline phosphatase activity under the pine-trees was on 7% less, than under *R. pseudoacacia* in horizon of H and almost twice (on 46 and 50%) - in deeper horizons of hP and P. The results of alkaline phosphatase activity determined under planting of *P. pallasiana* resulted that the enzymes functioned only in the superficial layer, and, as compared to areas under a *R. pseudoacacia*, enzyme activity was less than that of 85%.

Comparing information of phosphatases activity in primitive soils of investigational areas, it is possible to draw the conclusion, that under planting of *R. pseudoacacia* the processes of enzymatic transformation of organic phosphorus pass most intensively, that can testify to the considerable supplies of organic phosphorus compounds which actively mineralized.

Figure 2. **Seasonal dynamics of mobile phosphates under planting of *P. pallasiana* (a) and *R. pseudoacacia* (b) P_2O_5 mg/kg**



1 - spring, 2 - summer, 3 - autumn; *– statistically proved significant difference is in relation to control at p<0.05.

The results of the research of mobile phosphorus amount in soil of both areas reveal the highest values in the most bioactive superficial layer of soil during the whole vegetation period. The determination of mobile phosphorus amount resulted that its maximal amount was contained in superficial horizon H in a summer period as under planting of *R. pseudoacacia* so under *P. pallasiana* and were 22.24 and 23.38mg of P_2O_5/kg respectively (Fig.1). In the deeper layers of soil in a summer period under both groupments made the amount of phosphorus mobile forms 14mg of P_2O_5/1000g of soil. At the time of spring the amount of mobile phosphorus in horizon of H under planting of *R. pseudoacacia* was on 33% less than that of by summer, while under the pine-trees - almost on 40%. In the deeper horizons of Hp and P at both times in autumn and summer the amount of mobile phosphates was the lowest and made from 3.46 to 6.51mg of P_2O_5/kg of soil *(Figure. 2)*.

In obedience to the scale of nutrient supply of plants by the phosphorus mobile forms such their distribution testifies middle scale material provision of plants by mobile phosphates in superficial, and low - in the deeper layers of primitive soils in a summer period. The results of determinations of mobile phosphates amount in primitive soils under artificial arboreal phytocenosys specify show the positive influencing of biological recultivation, which shows up in the increase of plants available phosphorus in the most bioactive superficial layer.

CONCLUSIONS

The results of the conducted researches allow us to draw the conclusion that the use of *R. pseudoacacia* for biologically recultivation of primitive soils promotes more intensive accumulation of organic phosphorus compounds under these planting, than that of under *P. pallasiana.* However, the investigated primitive soils are characterized by middle scale plant nutrition status of mobile phosphorus forms by summer and low by spring and autumn, that promotes the role of organic phosphorus compounds, which can come forward after biochemical mineralization in quality the source of supply to the plants and microorganisms of phosphate free ions. Comparing of phosphatase enzyme activities in primitive soils of investigational areas, it is to conclude, that under *R. pseudoacacia* plantage the enzymatic transformation processes of organic phosphorus are most intensive. That can result a sufficient supplies of organic phosphorus compounds which will be actively mineraled. With it together, it is necessary to continue research of phosphorus compounds transformation and mobilization intensity in soils of biologically remediated ore-mining dumps which are the necessary stage in development of the scientifically proved methods of biological diagnostics and monitoring of the technogenic-broken soils and ground processes.

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