Biological activity and humus state of soils in the near-adjacent part of the Selenga River

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Abstract. Peculiarities of humus formation and manifestation of biological activity of soils are revealed. The objects of research are grey forest nonpodzolized, alluvial meadow soils as arable land, meadow-marsh soils as hayfield. Humus condition of the studied soils is in satisfactory condition within each soil type. The current state of the humus fund of old-arable grey forest soils is characterized by low humus content and unsatisfactory composition, which is caused by the absence of fertility change. The productivity of meadow-marsh soils is high and considerably exceeds grey forest and alluvial meadow soils. The information obtained on biological activity, can be used in agricultural practice to assess soil productivity, as well as in environmental monitoring.

1. Introduction

Organic material and optimal humus regime are one of the fundamental and applied problems of soil science and farming. Humus supplies plants with necessary macro- and microelements, regulates physical and biological properties of soil, fulfils soil protecting, energetic and ecological functions and it is the main factor of soil fertility formation. Each soil type is characterized by certain parameters of humus level and composition, which depend on area characteristics of pedogenesis. In arable soils it is observed a significant change of humus content and its qualitative composition having significant impact on soil processes and, primarily, on humification and biological activity [1,2].

The status of enzymes in the soil and their role in pedogenesis is determined by ecological conditions. Therefore, there is a direct connection between enzymatic activity and pedogenesis factors. It indicates intensity and orientation of pedogenic processes and changes in soils as a result of natural and anthropogenic factors. However, the current knowledge of the humus condition and enzymatic activity of arable and hayfield soils of different genesis in the delta part of the Selenga River is very limited. In comparative aspect, the enzymatic activity of soils in the near-bench floodplains and levee on several islands in the Selenga delta has been studied [3]. The available data on the humus composition, characteristics of microbiota and their activity refer to virgin soils [4-7].

Our study area belongs to the deltaic meadow-swamp and forest-steppe region according to the natural zoning. Specific processes and effects resulting in unique landscape conditions and intrazonal ecosystems
are peculiar to it. Most of this area is a riverside plain of the Selenga River, indented by numerous channels and oxbow lakes. The topsoil and ecosystems of the study area evolve under the continental climate of Eastern Siberia, slightly transformed by the influence of Lake Baikal, especially in the spring-summer period. Furthermore, the vegetation cover of biotopes is exposed to influence of out-of-control grazing use, affecting the humus status of soils. Hence, the relevance of the research topic under consideration is predetermined by the significance of these natural sites.

The soil cover and ecosystems of the study area develop under the conditions of the continental climate of Eastern Siberia, somewhat transformed by the influence of Lake Baikal, especially in the spring and summer period [8]. In addition, the vegetation cover of biotopes is affected by uncontrolled pasture use, which reflected on the humus state of soils [9]. Hence, the relevance of the research topic under consideration is predetermined by the significance of these natural sites.

Under conditions of anthropogenic pressure and environmental pollution arise the need to predict and create conditions required to maintain sustainable soil fertility as part of the protection of the natural environment of Lake Baikal. In this regard, it is relevant to search for sensitive methods to detect the initial stages of soil degradation. The aim of this research is to identify biological activity of soils and to determine the humus condition in the riverside plain adjacent to the water area of Lake Baikal.

2. Research objectives and methods

The soils studied were of the following types located along the transect: grey forest nonpodzolized, alluvial meadow soils under arable land and meadow-marsh soils under hayfields from Kamensk village to Timlyui station and Zakaltus village.

Grey forest soils in the Selenga River basin are formed on the lower parts of the ridges under grassy birch and pine-larch forests. They are characterized by the absence of podzolization, weak leaching, intensive accumulation of humus and considerable thickness of the humus horizons. The granulometric composition has a large number of dusty and silty fractions, typical for loess-like loams. Alluvial meadow soils are formed in the depressed areas of the low, high and central floodplain under the influence of floods and as a result are characterized by a humus horizon with a significant amount of alluvium-impregnated humus and pronounced signs of gleyization. Soils develop under meadow and less often shrub (willow) vegetation associations in steppe zones with a wide distribution of carbonate rocks. Meadow-swamp soils are formed in the conditions of long-term surface and ground moistening with almost constant capillary rim on their surface and periodic flooding. The aeration zone is unstable. They are distributed in depressions on flat plains and along river terraces in areas with close groundwater occurrence. They develop predominantly under mesophilic cereal vegetation and are characterized by a well-developed humus horizon.

The physical and chemical properties of soils were measured in compliance with the methods accepted in soil science [10]. The fractional-group composition of humus was determined by the Tyurin method modified by Ponomareva-Plotnikova [11]. The intensity of cellulose decomposition in natural conditions was determined by the application method [12], catalase – gasometrically, urease – colorimetrically by the A Sh Galstyan method [13]. The obtained data have been processed by methods of mathematical statistics [14].

3. Results and discussion

The morphological profile of grey forest soils is characterised by negligible humus accumulation and the absence of a podzol-forming process. The sum of absorbed bases in the upper horizons is 25 mg-equiv./100 g of soil and almost does not change with depth. The main role in soil absorbing complex of soils belongs to calcium.
In soils under natural vegetation, forest litter, herbaceous residues form a 1-3 cm thick litter on the surface. In the upper part of the humus horizon there is a very large amount of semi-decomposed roots, which are concentrated in a layer of 3-4 cm.

In the arable soils studied, the total phytomass input is 46 cwt/ha, with underground phytomass exceeding above-ground more than twice.

The rate of decomposition of plant residues can be indirectly estimated from the decomposition of cellulose. The rate of decomposition by linseed microflora is known to reflect the intensity of mineralization of organic material entering the soil. In grey forest soils the decomposition of cellulose during the vegetation period was 38.2%.

According to the level of catalase and urease activity according to the scale of D G Zvyagintsev, these soils are poor [15]. G Zvyagintsev, these soils are characterized as poor. The average values of catalase activity during the vegetation period in this soil were only 2.9 ml O₂/min, urease activity was 0.85 NH₃ (1g/24h).

The humus level is low, at 2.2% in the arable horizon and 2.4% in the subsoil horizon, with reserves of 86 t/ha in the 0-30 cm layer, being low.

Humic acids slightly outnumber fulvic acids in the group composition of arable humus. The ratio Cgc : Cfc is 1.13. The type of humus is fulvate-humate. The degree of humification of organic matter is 35 %. In subsoil horizon the amount of humic acids slightly decreases – Sgk : Sfk = 0.98.

A distinctive feature of the fractional composition of humus is a similar distribution of humic and fulvic acids in fractions. Fractions of humus substances associated with calcium prevail, that is probably due to the formation of soils on loess-like carbonate loams, a significant number of exchangeable bases in the soil-absorbing complex and slightly alkaline medium. The content of HA-2 is 20.7 % and FA-2 – 15.1 % of the sum. The share of firmly bound HA and FA is average. Reactive humic acids are detected in small amounts. The non-hydrolysable residue is 34-39 %.

Thus, the transformation of herbaceous forest plant fallout on grey forest soils containing sufficient amounts of exchangeable bases and intermittent biological activity produces fulvate-humus of the humus type. According to the system of indicators of humus condition, grey forest soils are characterized by low content and stock of humus, high degree of humification of organic matter, very low content of free humic acids, medium content of calcium-bound HAs and high content of strongly bound humic acids. The amount of insoluble residue is medium.

The distribution of organic residues entering the soil under conditions of deep freezing and slow thawing causes low thickness of the humus horizon and small humus reserves in grey forest soils. However, agronomically valuable fractions that provide significant stability of humus substances prevail in the humus composition.

The next object of our research was alluvial meadow soil, which was characterized by the following indicators: slightly alkaline medium, pH – 7.4-7.5, capacity of absorption in humus-accumulative horizon is high and makes 44-48 mg-equiv./100g soil, in the lower horizons decreases to 20-25 (Table 1). The total amount of phytomass entering arable alluvial meadow soil is 66.4 c/ha with almost equal amounts of above-ground mass and roots. The microbiological transformation of organic matter of plant residues occurs quite intensively. Mineralisation of cellulose was 53.8 %.

In alluvial meadow soil the average activity of catalase and urease were 4.9 ml O₂/min, and 1.8 NH₃ (1g/24h) respectively, which refers to the average enrichment of these enzymes.

The thickness of humus horizon is 30 cm, humus content is 6.95-7.1 %, and humus reserves are high – 96 t/ha.

The group composition of humus in alluvial meadow soil is characterized by predominant accumulation of humic acids. The ratio Cgc : Cfc is 2 and 2.1 in the arable and sub arable horizons, respectively. Consequently, the type of humus is humate. The degree of humification of organic matter is more than 50 %. In the composition of humic acids fractions related to calcium prevail. Taking into
account the fact that humus is mainly represented by humic acids, the content of HA-2 is 42 % of the total carbon, and the amount of FA-2 is 15 %. The mobile fractions are at the lowest level, about 3 %. The content of the third fraction as a part of humus substances, firmly connected with haloxides, is at an average level. Non-hydrolysable residue is 24.3 % of total carbon.

Thus, despite the short period of biological activity, the process of humification in the alluvial meadow soils under study is intensive and leads to significant humus accumulation and the prevalence of humic acids in the humus composition. The soils are characterized by high potential fertility, although the variable moisture regime may limit their bioproductivity. High absorption capacity, directly related to the content, composition of humus and the amount of silty fractions, means a high level of soil sorption properties. It is this indicator that ensures the ecological role of humus and protects the ecosystem from pollution.

The medium of meadow-marsh soils is slightly alkaline, the absorption capacity is 25 mg-eq/100g in the humus horizon and smoothly decreases with depth (Table 1).

The productivity of meadow-marsh soils is high and considerably exceeds grey forest and alluvial meadow soils. The total phytomass stock of meadow-swamp soils is 166 cwt/ha, with the underground part accounting for 90%. Root residues are the main source of humus in the studied soils. The highest concentration of roots is observed in the 0-10 cm soil layer. With depth their content decreases sharply.

Cellulose decomposition was 34.6% of initial weight, which is a low value. In the upper soil layers, where the main mass of meadow-swamp vegetation roots is concentrated, the moisture content was up to 19.5 % in some cases.

Activity of catalase and urease during vegetation period was 5.2 ml O₂/min, and 1.5 NH₃ (1g/24h) respectively, indicating that these soils are moderately enriched with these enzymes.

The humus content is 4.19 % in the humus-accumulative horizon and decreases sharply with depth. This is due to overmoistening of the lower horizons, which leads to inhibition of soil microbiological processes. And its reserves in 0-20 cm layer are 67 t/ha.

Fractional composition of humus shows that in the upper horizon humus of fulvate-humate type, as the ratio Cgc : Cfc = 1.3 and degree of humification of organic matter is 40 %. But already at a depth of 20 cm the amount of humic acids is halved and the humus becomes humate-fulvate. Under unfavourable humidification conditions, mainly fulvic acids are formed during the transformation of organic matter.

The stable second and third fractions (15 and 17 %, respectively) predominate in the humic acid composition, with HA-3 in the first place, and the mobile fractions are inferior in quantity. In the composition of fulvic acids prevails FA-2 – 14-20 %, the content of the third fraction is low. The average content of mobile fulvic acids in the upper horizon changes to a very low one with depth. The proportion of insoluble residue is 30-51 %.

4. Conclusion
The humus condition of the studied soils is satisfactory within each type of level of soils, however, when assessing their biological condition, it can be noted that the activity of enzymes increases with growth of organic matter, as evidenced by the correlation analysis of the relationship between catalase activity and soil humus content (r = 0.75). In the soils studied by us the content of humus increases from floodplain-meadow, meadow-swamp to grey forest soils. In the same direction the urease activity also increases, which is characterized by the highest correlation coefficient: r = 0.93.

The soils near the Selenga River have a similar level of catalase activity in comparison with the soils of Western Siberia, and according to D G Zvyagintsev’s enrichment scale [15], the meadow-swamp and alluvial meadow soils are estimated as moderately enriched, while grey forest soils are poor.

The same pattern is observed when determining urease activity in meadow-swamp soil – 1.5 mg NH₃ (1g/24h); alluvial meadow soil – 1.8 NH₃ (1g/24h); grey forest soil – 0.85 NH₃ (1g/24h). These figures indicate similarly low activity of this enzyme in all studied soils of the Selenga River delta.
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