Decomposition rate of peat-forming plants in the oligotrophic peatland at the first stages of destruction

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Abstract. The research presents quantitative estimates of the decomposition rate of plant residues at the initial stages of the decay of two plant species (Eriophorum vaginatum and Sphagnum fuscum) in a peat deposit of the oligotrophic bog in the southern taiga subzone of Western Siberia. We also studied a change in the content of total carbon and nitrogen in plant residues and the activity of microflora in the initial stages of decomposition. At the initial stage of the transformation process of peat-forming plants the losses of mass of Sph. fuscum is 2.5 times lower than E. vaginatum. The most active mass losses, as well as a decrease in the total carbon content, is observed after four months of the experiment. The most active carbon removal is characteristic for E. vaginatum. During the decomposition of plant residues, the nitrogen content decreases, and the most intense nitrogen losses were characteristic for Sph. fuscum. The microorganisms assimilating organic and mineral nitrogen are more active in August, the oligotrophic and cellulolytic microorganisms – in July.

1. Introduction

The role of peatlands in the global carbon cycle are discussed by a number of researches. The peatlands are the unique terrestrial ecosystems, which act as a long-term sink of atmospheric carbon. Now the process of carbon accumulation dominates in native peatlands. The peatlands covering only 3% of the Earth’s land area hold the equivalent of half of the carbon that is contained in the atmosphere as CO₂ [1, 2]. The low rate of decomposition of plant residues in peat bogs is the main mechanism allowing efficient accumulation of carbon in the peat deposits. The knowledge of quantitative indices characterizing the cycle of chemical elements in bog systems is necessary for studying the mechanisms of wetlands stability and productivity and for the substantiation of the evolution forecast for wetlands caused by the changes in the environment. The processes of transformation of plant residues in mineral soils of different natural zones have been thoroughly studied [3–8]. However, the studies devoted to the dynamics of decomposition of peat-forming plants are relatively small [4, 9–19]. The rate of decomposition of peat-forming plants depends on many factors, the main ones being the environmental conditions, the chemical composition of peat-forming plants and the activity of microorganisms [4, 19]. An important role in the study of the decomposition rate of plant residues in a peat deposit is played by the analysis of the first decomposition stages as during this period the destruction occurs most intensively.
The purpose of this work is to study the dynamics of decomposition processes at the first stages of decay of peat-forming plants in the bog ecosystems of the Southern taiga subzone of Western Siberia.

2. Material and methods

The researches were carried out in the territory of the Ob’-Tom’ interfluve in the oligotrophic bog “Timiryazevskoe” (Tomsk district, Tomsk region) in the pine-dwarf shrub-Sphagnum phytocenosis. A specific point of research was pine-shrub-Sphagnum phytocenosis. The chosen bogs are typical for the southern taiga subzone of Western Siberia. We studied plant litter decomposition and nutrient release for two peat-forming plants: vascular plant species (Eriophorum vaginatum) and moss species (Sphagnum fuscum) using litterbag technique [4].

The litter of E. vaginatum and Sphagnum residues (10 cm from the heads of sphagnum mosses) was dried in laboratory up to air-dry state, and its portions of 5-6 g were placed into nylon bags (15×15 cm). In May 2016, the prepared samples were put into the peat soil to the depth of 10 cm from the moss surface. The samples were taken out of the peat soil each month from June to September 2016. The samples were dried in laboratory to the air-dry condition, weighed to determine their dry mass and calculate the losses.

The losses of the plant mass were calculated as a percentage of the initial sample weight according to the following formula:

$$\text{Loss} \, (\%) = \frac{(M_0 - M_t)}{M_0} \times 100, \quad (1)$$

where $M_0$ is the mass of the initial sample, $M_t$ is the mass of the sample after the time $t$ (1, 2, 3 and 4 months).

In each sample the contents of carbon, nitrogen were determined before and after decomposition in accordance with [4, 20–22], and the losses of their initial content were calculated by the formula:

$$\text{Loss of an element} \, (\%) = \frac{(X_0M_0 - X_tM_t)}{X_0M_0} \times 100, \quad (2)$$

where $X_0$ is the initial content of the element, mg/g, $X_t$ is the content of the element after time $t$ (1, 2, 3 and 4 months).

The total number of microorganisms in decomposing plant residues was studied using direct microscopy method. The activity of microorganisms was studied using Koch method. The number of microorganisms involved to the nitrogen cycle was determined on the GRM medium (for using organic nitrogen sources) and starch ammonia agar (for using organic mineral nitrogen sources). The number of microorganisms involved to transformations of carbon compounds was determined on the Hutchinson-Clayton medium.

3. Results

The results of the experiment showed that the rate of plant residues decomposition was rather low in the first three months perhaps because of the weather conditions in the 2016 vegetation period (very arid). The rate of decomposition increased only by the fourth month and reached 18.5% in the Sph. fuscum samples and 38.5% in E. vaginatum samples (figure 1). The E. vaginatum samples decomposed 2.0-3.5 times faster than the mosses samples at all stages of transformation. The maximum difference was observed in the first month of the experiment.
The investigated plant residual species differ in the content of carbon and nitrogen: *E. vaginatum* is characterized by a higher content of carbon (44%) and nitrogen (0.81) compared to *Sph. fuscum* – 41% and 0.51%, respectively. During decomposition of plant samples there was a carbon and nitrogen carrying out. The maximum losses of carbon for 4 months were received to *E. vaginatum* (37%) (figure 2).

Fast removal of carbon in *E. vaginatum* samples occurred in the first and fourth months (16%), during the second and the third months the removal of carbon was very slow (1-5%). In the first two months of the experiment the carbon loss in *Sph. fuscum* samples was not observed, but in the end of the experiment the removal of carbon reached 16% of the original content (figure 2). The maximum number of cellulolytic microflora in *Sph. fuscum* residues was observed only in the beginning of the growing season – in June, but in September the activity of cellulolytic microflora increased again (table 1).

The dynamics of the nitrogen content in the studied species under their decomposition were different. During the decomposition of plant residues, both the mineralization of nitrogen and its immobilization (accumulation) may occur. According to [23], the process of N accumulation may take place at the first stages of decomposition due to the destruction of nitrogen-free compounds, nitrogen fixation and nitrogen consumption by fungal hyphae from the soil. Nitrogen removal starts only after reaching a critical concentration of nitrogen in the plant residues.

In the first month nitrogen losses of about 17% of the original content were observed in the process of *E. vaginatum* samples decomposition. For *Sph. fuscum*, a direct relationship was found between the amount of ammonifiers and the decrease in the nitrogen content. The maximum number of these microorganisms in the samples of *Sph. fuscum* was observed in August. In September, the number of microorganisms absorbing both mineral and organic forms of nitrogen decreases in comparison with August and that explains the relative increase in N content in *Sph. fuscum* samples (table 1).
For plant residues *Sph. fuscum* the total number of microorganisms significantly increased by August – September. For *E. vaginatum* samples and peat samples taken from the plant locations (10 cm), the maximum activity of microorganisms was observed in July. An improvement in the aeration conditions of the peat deposit in August is also indicated by an increase in the number of microorganisms that assimilate both organic and mineral nitrogen. The increase in the number of microorganisms occurred mainly due to fungi, which was very demanding for the presence of sufficient oxygen in the substrate (table 1).

As it is well known, oligotrophic microorganisms may use nitrogen or carbon nutrition from substrate containing very low concentrations of these elements [24]. Among the studied plant samples the largest number of oligotrophic microorganisms was found in *E. vaginatum* samples. The maximum number of these microorganisms was fixed in July. For the *Sph. fuscum* samples the maximum number of oligotrophic microorganisms was observed in September (table 1). It is noteworthy that the dominant group among the oligotrophic microorganisms was bacteria, the fungi share was much less.

### Table 1. Total number of microorganisms in peat and plant residues.

| Sample     | Month | Microorganisms assimilating organic nitrogen (GRM agar) \((N \times 10^4 \text{ CFU*/ g of d.s.**})\) | Microorganisms assimilating mineral nitrogen (SAA) \((N \times 10^4 \text{ CFU*/ g of d.s.**})\) | Oligotrophic microorganisms (hungry agar) \((N \times 10^4 \text{ CFU*/ g of d.s.**})\) | Cellulosolytic microflora, (Hutchinson-Clayton medium) \(N \times 10^4 \text{ CFU*/ g of d.s.**}) |
|------------|-------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Peat       | 1     | 1665 1643 22 1264 1234 301 | 216.8 0.261 <10 | 23174.0 1.206 <10 | 77571.0 0.63 0.51 |
|            | 2     | 27090 24147 \(<10^3\) | | | |
|            | 3     | 9951 2552 7399 21926 21378 548 | 3522.7 0.052 <10 | 5280.1 <10 | |
|            | 4     | 7715 7714 1 10322 10250 72 | | | |
| *Sph. fuscum* | 1   | 1272 1262 10 195 195 \(<10^3\) | 1998.78 0.229 0.115 | 12873.0 0.007 <10 | 9873.4 0.009 <10 |
|            | 2     | 7980 7980 \(<10^3\) | | | |
|            | 3     | 23341 11646 11695 23811 22526 1285 | 2679.5 0.009 <10 | 37361.4 0.043 <10 | |
|            | 4     | 10236 10065 171 256 256 \(<10^3\) | 37361.4 0.043 <10 | 77571.0 0.63 0.51 | |
| *E. vaginatum* | 1   | 2195 2146 49 3733 3726 \(<10^3\) | 1178.8 0.42 <10 | 2679.5 0.009 <10 | |
|            | 2     | 28140 71 28070 | | | |
|            | 3     | 16593 658 15933 23311 23016 296 | 3173.4 0.157 <10 | 77571.0 0.63 0.51 | |
|            | 4     | | | | |

Footnote: CFU* – colonies forming units; d.s.** – dry soil; *** – Sphagnum residues (10 cm from the moss surface); “––” – no data.

### 4. Conclusion

The decomposition of *Sph. fuscum* is a major contributor to the peat formation process at the initial stages. Decreasing of the total carbon content, as well as mass loss, was most active in the third and fourth months of the experiment. *E. vaginatum* residues were characterized by the most intensive carbon removal. During the decomposition of plant residues the most intensive nitrogen losses were characteristic for *E. vaginatum*. The nitrogen content in *Sph. fuscum* residues was increasing during two months but then its content decreased. The microorganisms assimilating organic nitrogen were most active in the peat samples and in the *Sph. fuscum* remains. The *E. vaginatum* samples are characterized by the prevalence of microorganisms assimilating inorganic nitrogen. The
microorganisms assimilating organic and mineral nitrogen were most active in August and the oligotrophic and cellulosolytic microorganisms were more active in July.

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