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DECOMPOSITION RATE OF PEATFORMING PLANTS AT THE INITIAL STAGES OF DESTRUCTION IN PEAT DEPOSITS OF THE OLIGOTROPHIC BOGS "BAKCHARSKOE" AND "TIMIRYASEVSKOE"

L.G. Nikonova[1], E.A. Golovatskaya[1], N.N. Tereshchenko[2]

[1] Institute of Monitoring of Climatic and Ecological Systems of the Siberian Branch of the Russian Academy of Sciences
[2] Siberian Research Institute of Agriculture and Peat (Siberian Research Institute of Agriculture and Peat – branch of the Siberian Federal Scientific Center of Agro-Bio Technologies of the Russian Academy of Sciences)
lili112358@mail.ru

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The research presents quantitative estimates of the decomposition rate of plant residues at the initial stages of the decay of four plant species (Eriophorum vaginatum, Carex rostrata, Sphagnum fuscum, Sphagnum angustifolium) in peat deposits of the oligotrophic bogs in the southern taiga subzone of Western Siberia. We also studied the change in the content of total carbon, nitrogen and ash elements in plant residues and the activity of microflora at the initial stages of decomposition. The studies were conducted in the bogs characterized by various hydrothermal conditions.

At the initial stage of the decay of peat-forming plants the maximum losses of mass occur in the first month of the experiment and reach 36-52% of the total loss of organic matter during the growing season. Sphagnum fuscum is the most resistant to decomposition. The most intense decomposition of Sphagnum fuscum at the initial stages of decomposition is characteristic for warmer and less humid conditions of the Timiryazevskoe bog.

It was revealed that mass losses of organic matter correlate well with total carbon losses. The most intensive decreasing of the total carbon content as well as mass loss of organic matter are observed after the first month of the experiment. The maximal decline of carbon in plant residues was received for Eriophorum vaginatum. During the decomposition of plant residues, the nitrogen content was decreasing, and the most intense nitrogen losses were characteristic for Sphagnum mosses. Nitrogen loss in peat-forming plants during the first month of decomposition varies depending on the locality conditions, but it becomes equal during the later decomposition stages. At the first stages of decomposition of plant residues, both the accumulation and the loss of ash elements were observed in the samples. Both the Bakcharskoe and Timiryazevskoe bogs were characterized by the accumulation of ash elements in plant samples of Eriophorum vaginatum. Dynamics of mass loss and removal of elements are directly related to the activity of microorganisms. The maximum number of microorganisms was found in July and September. Peat and plant samples located in the peat deposit of the Timiryazevskoe bog are more saturated with microorganisms of the nitrogen cycle, and samples from the Bakcharskoe bog are richer in carbon cycle microorganisms. Microorganisms of the lignocellulosic complex were less active as compared with other groups of microorganisms. The number of microorganisms assimilating the mineral forms of nitrogen are on average 1.5 times less than the number of microorganisms assimilating the organic forms. The positive correlation between the nitrogen content and the number of fungi was found. In addition, correlation between the numbers of denitrifiers and oligotrophs was found. It is explained by trophic relationshipsbetween these groups of microorganisms.

Key words: decomposition rate; microbial decomposers; Sphagnum fuscum; Eriophorum vaginatum; Sphagnum angustifolium; Carex rostrata.

INTRODUCTION

Russia ranks first in the world in terms of the area occupied by bog ecosystems. The most wetland region is Western Siberia, where oligotrophic bogs predominate [Babeshina and Dmitruk, 2009; Evseeva, 2012]. The peculiarity of bog biogeocenoses is the slow rate of decomposition of plant residues, because of which carbon is excluded from the cycle of substances for a long time [Tyuremnov, 1976; Inisheva et al., 2016]. The rate of decomposition depends on many factors, the main of which are the environmental conditions, the chemical composition of the peat-forming plants themselves, and the activity of microorganisms [Denisenkov, 2000]. The most intensive decomposition of organic matter occurs in thesummer, when the water table level decreases and atmospheric oxygen freely penetrates into the upper horizons of the peat layer. There is a weakening of decomposition processes in the winter associated with a decrease in the activity of microorganisms [Kozlovskaya et al., 1978; Mironycheva-Tokareva et al., 2013; Golovatskaya et al., 2017]. In the process of decomposition of organic matter of plant residues in peat deposits, the most active mass loss occurs at the initial stages [Koronatova, 2010; Peltoniemi, 2012; Vishnyakova, 2012; Filippova, 2018], because microorganisms primarily destroy readily available components, the content of which decreases over time and the rate of decomposition decreases [Boch and Mazing, 1979]. The residues of peat-forming plants can be divided into 2 groups by resistance to decomposition. (1) Not fixed in the botanical composition of the organic layer of peatlands (fast–decomposing fraction) – leaves of Chamaedaphne calyculata, Menyanthes trifoliata, and various grasses. (2) Permanently fixed in the botanical composition of peat (stable fraction) – all fractions of most shrubs, tillering nodes, roots and rhizomes of Carex grasses (sedges), Scheuchzeria, Eriophorum, all sphagnum mosses [Vishnyakova, 2012; Berg, 2018; Nikonova et al., 2019]. Modern climate changes can lead to increased decomposition of organic matter and, as a result, to a decrease in the world's peat reserves [Hogg et al., 1992]. Due to climate change and the increasing anthropogenic impact on natural ecosystems, the study of the processes of transformation of organic matter, especially at the initial stages of decomposition, becomes important.

Objective of the research is to study the influence of hydrothermal conditions and chemical composition of peat-forming plants on the dynamics of destructive processes at the initial stages of decomposition of peat-forming plants in the bog ecosystems of the South taiga subzone of Western Siberia.

OBJECTS AND METHODS OF RESEARCH

Studies of the dynamics of decomposition processes of plant residues of peat-forming plants were carried out on two oligotrophic peatlands. (1) – The oligotrophic bog “Bakcharskoe” in the Bakcharsky district of the Tomsk region on the territory of the “Vasyuganye” field station (IMCES SB RAS). (2) -The oligotrophic bog "Timiryazevskoe" in the Tomsk district of the Tomsk region on the territory of the Ob-Tomsk interfluve [Dyukarev, 2002]. According to data from the Bakchar and Tomsk weather stations, weather conditions in the Bakchar district are cooler than in Tomsk, and precipitation is higher on average in the Tomsk region, except in the summer months [Golovatskaya and Nikonova, 2013]. The Bakcharskoe bog is not subject to significant anthropogenic influence, and it can be considered a naturally developing one, in contrast to the Timiryazevskoe bog, which is located in the zone of influence of the Tomsk water intake, which is manifested in a decrease in the water table level (WTL). The WTL of the pine-shrub-sphagnum phytocenosis of the Timiryazevskoe bog are on average 15 cm lower than the WTL of the Bakcharskoe bog. In sedge-sphagnum fens, the difference between the average and the minimum water table level between the two bogs is insignificant [Nikonova et al., 2019].

Decomposition of plant material was studied in peat deposits of pine-shrub-sphagnum phytocenoses (ryams) and sedge-sphagnum fens.

An experiment to determine the rate of decomposition of peat-forming plants at the initial stages of destruction was carried out by laying vegetation in peat [Kozlovskaya, 1978]. Since May 20 2016, the research was conducted in ryam of the bog "Timiryazevskoe" (56°26'22" N 84°50'03" E); since May 20, 2017, the samples of plants were placed into peat deposit sedge-sphagnum fens of the bog Timiryazevskoe (56°26'25" N 84°50'15" E). In the Bakcharskoe bog, plant residues were placed in the peat deposit of ryam (56°58'34" N 82°36'27" E) and sedge-sphagnum fens (56°58'16" N. L. 82°37 ' 06 " E.L.) June 1, 2017. The rate of decomposition of the main peat-forming plants was studied in ryam for Sphagnum fuscum and Eriophorum vaginatum, and in sedge-sphagnum fens – Sphagnum angustifolium and Carex rostrata. The collected plants (mosses, dead grass) were dried to air-dry weight at room temperature under laboratory conditions until they reached a constant weight, crushed to a size of 1-2 cm and placed in nylon bags of 10 g. The samples plant material was placed in a peat deposit, to a depth of 10 cm from the surface in five-fold replication. Samples with plant residues were extracted monthly, until September in each of the 4 points (Timiryazevskoe ryam, Timiryazevskoe fen, Bakcharskoe ryam, Bakcharskoe fen). In the samples, the decrease in the mass of plant matter was determined by the weight method, after which the analyses were carried out (in three replication): 1) microbiological studies, 2) determination of the content of carbon, nitrogen and ash elements.

The determination of the amount of ash elements was carried out by dry ashing method, the content of total nitrogen and total carbon – by the Anstet method modified by V. V. Ponomareva and T. A. Plotnikova [Egorov and Durynina, 1998; Vorobyova, 2006]. When studying the activity of microflora, direct microscopy by Vinogradsky was used, as well as seeding on elective medium to determine the number of microorganisms involved in the cycle of transformations of nitrogen and carbon compounds [Mishustin, 1975, Ryabicheva, 2015]. Starch-ammonia agar (SAA) was used as a medium for detecting microorganisms that prefer mineral forms of nitrogen; for ammonifiers, a nutrient medium based on hydrolysate of fish meal (HFM – agar) was used. Aerobic cellulolytic microflora grown in an of Hutchinson-Clayton n's medium. Anaerobic cellulose destructors were analyzed on a liquid of Omelyansky's medium. Determination of oligotrophic microorganisms was carried out on agar water extract from peat and plant residues. Saccharolytic fungi were taken into account on the Chapek's medium, denitrifiers – on the Giltay's medium [Reshetnikova et al., 2007; Kazeev et al., 2016]. The number of microorganisms was determined by counting isolated colonies formed on elective medium and expressed as N × 104 CFU / 1 g of a.d.m. (absolutely dry matter) peat / plant residues). Statistical processing of experimental data was performed using the Microsoft Office Excel 2007 and STATISTICA 6 software package. In the figures and tables, the data is presented as an arithmetic mean with a standard error. In order to identify the mutual influence of factors on each other and on the rate of decomposition of organic matter, a correlation analysis was performed. All statistical analyses were performed at a significance level of $\alpha < 0,05$.

RESULTS

Mass loss at the initial stages of destruction. The studied plants are divided into two groups by species composition and chemical composition. Sphagnum mosses have the lowest carbon content (average carbon content reaches 38,3%) and nitrogen (0,65%) and the highest C/N ratio (61). They also have the lowest ash content (1,58%). The second group of plants is formed by grasses that have a more favorable chemical composition for microorganisms-destructors in terms of carbon content (43,75%), nitrogen content (0,75%), C/N ratio (57) and ash content (2,93). As a result of the research it was found that the destruction of organic matter in all samples is most active in the first month of decomposition (36 and 52% of the total losses during the growing period in the Timiryazevskoe and Bakcharskoe bogs, respectively). Except of E. vaginatum in the conditions of the Bakcharskoe ryam, for which the maximum decomposition rate is reached in the second month of the experiment. The highest mass loss of organic matter in the first month relative to the total mass loss (72%) was obtained for C. rostrata in the conditions of sedge-sphagnum fen of the Bakcharskoe bog. Among the studied plants, S. fuscum is the most resistant to decomposition (mass loss 9-18% of the initial value), and E. vaginatum is the least resistant (Fig. 1). The average mass loss over the all period of the experiment is 26% in the Timiryazevskoe bog and 22% in the peat deposit of the Bakcharskoe bog.

Changes in the total carbon content and activity of carbon cycle microorganisms during decomposition of plant residues. Carbon losses

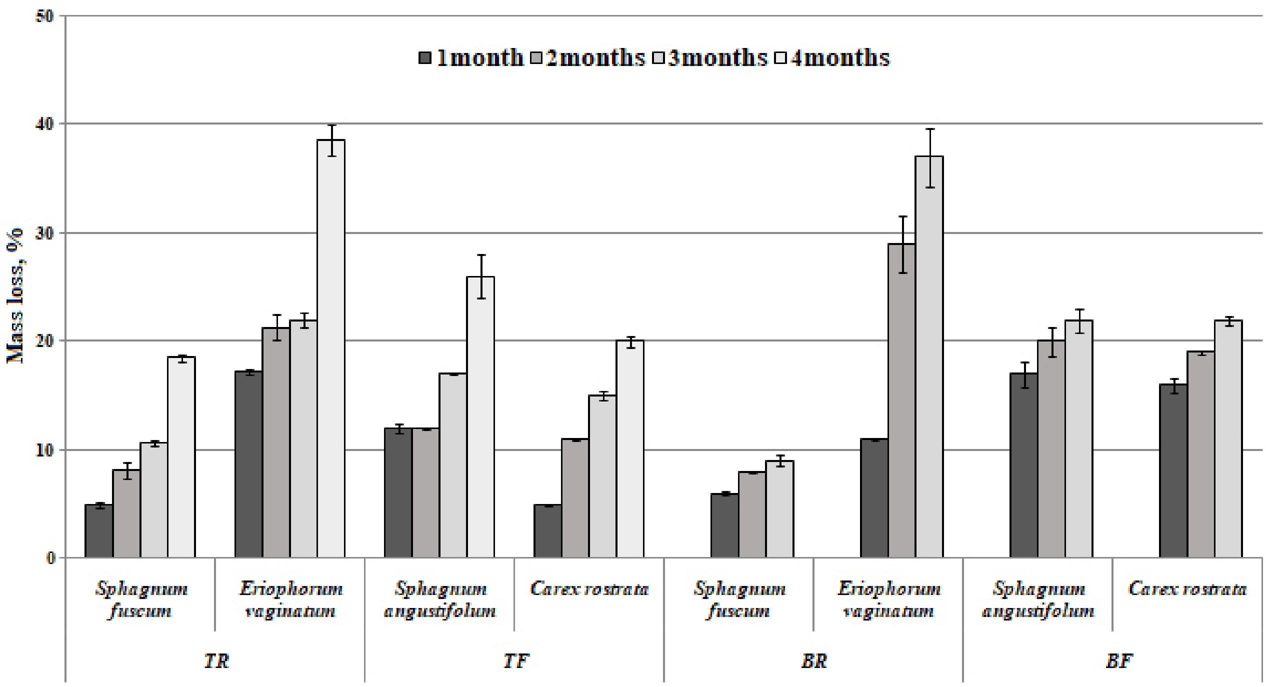
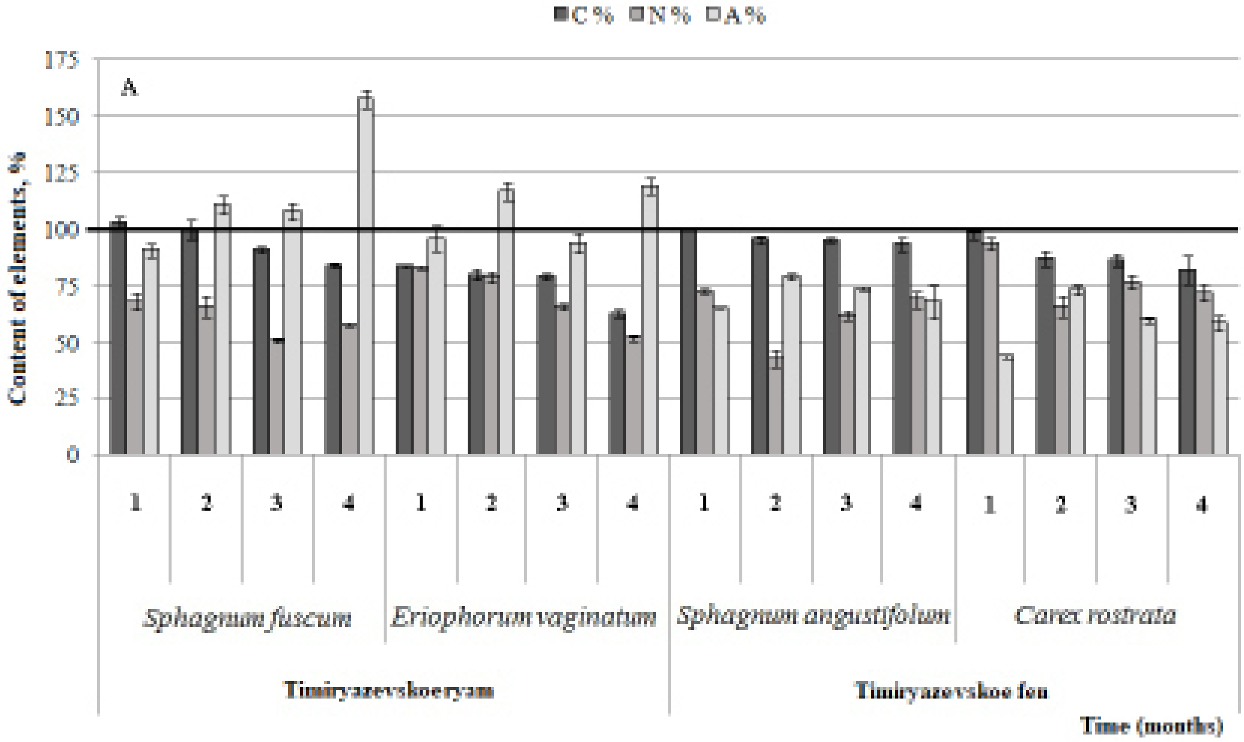


Fig. 1 Mass loss of peat-forming plant residuesin the peat deposits of the oligotrophic bog "Timiryazevskoe" and "Bakcharskoe" at the first stages of destruction, % of the primary mass. TR – Timiryazevskoe ryam, TF – Timiryazevskoe fen, BR – Bakcharskoe ryam, BF – Bakcharskoe fen

during decomposition of plant residues correlate well with mass losses (the correlation coefficient (r) is 0,63). The maximum carbon removal was recorded for C. rostrata in the second month of the experiment in the Timiryazevskoe bog. For sphagnum mosses, a low rate of carbon removal from plant samples was observed (S. angustifolium by 3,55% and S. fuscum by 6%) in the conditions of the Bakcharskoe bog. Moreover increase in the carbon content during the first month of the experiment in the conditions of the Timiryazevskoe bog (S. angustifolium by 0,43% and S. fuscum by 3%) was observed. For herbaceous plants, carbon losses during the experiment are higher and range from 15,4 to 37%, while sedge actively loses carbon in the conditions of the Bakcharskoe



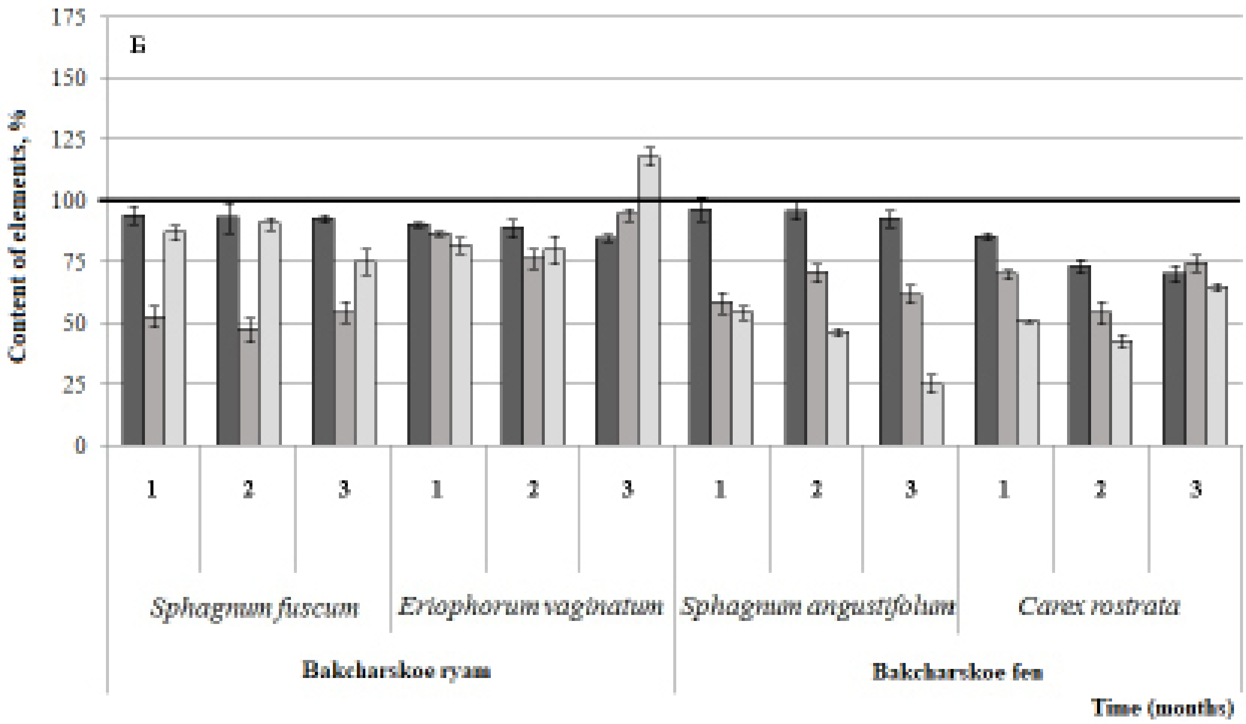


Fig. 2 Changes in the content of carbon (C), nitrogen (N) and ash elements (A) in plant residues during decomposition in the peat deposits of Timiryazevskoe (A) and Bakcharskoe (B) bogs (relative to the primary amount,%)

bog, and cotton grass – in the Timiryazevskoe bog (Fig. 2).

The predominant group of microorganisms among oligotrophs in both the Bakcharskoe and Timiryazevskoe bogs is bacteria. In the peat from the Timiryazevskoe bog, the largest number of oligotrophic microorganisms was observed in ryam, and in the Bakcharskoe bog – in the fen. During decomposition plant samples, the maximum number of oligotrophic microorganisms was observed in August in the fen, and in July in the ryam., With the exception of S. fuscum in the ryam of the Timiryazevskoe bog, where the maximum amount of oligotrophic microflora was observed in September (tables 1, 2).

The number of microorganisms that destroy cellulose in the studied plant samples and peat in both bogs was very low compared to other groups of microorganisms and was no more than 1,2×104 CFU/ 1 g a.d.m.. The depletion of peat soils by cellulolytic microflora was noted in the works of N. N. Naplekova, who showed that the number of aerobic cellulose destructors in eutrophic and oligotrophic peatlands of the Novosibirsk region, as a rule, does not exceed 5-10 and 0,1-0,8 thousand cells per 1 g of peat, respectively [Naplekova, 1974]. In the composition of the cellulolytic microbial community of plant residues fungi predominated in the conditions of ryams. And in the conditions of the fen – myxobacteria predominated, as well as fungi capable of synthesizing enzymes that destroy cellulose (tables 1, 2).

The maximum number of microorganisms was reached in July for all phytocenoses and has similar values. For most samples, the activity of the microflora of the carbon cycle is reflected an increase in the loss of organic matter during 1-2 months of decomposition (tables 1, 2). However, for S. fuscum in the conditions of ryam of the Bakcharskoe bog, the maximum number of these microorganisms was recorded only in August and September. A surge in the activity of carbon cycle microorganisms in September occurs in the peat of ryam the Timiryazevskoe bog, which is also reflected in the increase the loss of mass of plant residues.

The number of saccharolytic fungi on average was higher in the conditions of the Bakcharskoe bog. At the same time, in the conditions of ryams of both bogs, the number of saccharolytic fungi was approximately 5 times higher than in the fens. The maximum content of microorganisms of the saccharolytic complex among plant samples was recorded in the remains of S. fuscum and E. vaginatum in September.

Changes in the total nitrogen content and activity of nitrogen cycle microorganisms during decomposition of plant residues. During decomposition of grasses in the first month, nitrogen losses for E. vaginatum were 14% (Bakcharskoe ryam) and 17% (Timiryazevskoe ryam). For C. rostrata, nitrogen losses in the first month differed significantly depending on the location of the samples, so in the Timiryazevskoe bog, losses reached 7%, and in the conditions of the Bakcharskoe bog – 31%. However in September the total nitrogen losses were 26% (Timiryazevskoe bog) and 28% (Bakcharskoe bog). For sphagnum mosses, nitrogen losses during decomposition was more significant. At the first month, the maximum losses was also typical for samples laid in the Bakcharskoe bog, and reached 48% for S. fuscum and 42% for S. angustifolium (Fig. 2). In general, nitrogen losses from sphagnum moss residues occured evenly, but in August in S. angustifolium and in September in S. fuscum , was observed nitrogen accumulation relative to the previous month of decomposition.

During the all vegetation period, the average number of microorganisms participating in the nitrogen cycle in the Timiryazevskoe bog exceeded 4 times the total number of microorganisms in the nitrogen cycle of the Bakcharskoe bog in all studied samples. In relation to other groups of microorganisms, the number of denitrifiers was minimal, but in the conditions of the wetter Bakcharskoe bog, the number of this group of microorganisms was slightly higher. In all samples, the number of denitrifiers decreased in September, reaching its peak in the first months of decomposition (table 1-4).

Changes in the content of ash elements during decomposition of plant residues. For sphagnum mosses, changes in the content of ash elements were observed in the conditions of the Bakcharskoe bog, with the maximum losses characteristic of S. angustifolium (74%). In the conditions of the Timiryazevskoe bog, the accumulation of ash elements was recorded, with the maximum values in the samples of S. fuscum (an increase in the value to 58%). For grasses in the conditions of the Bakcharskoe bog, there was a decrease in the loss of ash elements by the fourth month. In the conditions of the Timiryazevskoe bog, there was an alternating increase and decrease in the content of ash elements in the remains of herbaceous plants. For E. vaginatum, in the ryams contain of ash elements increased on 18 and 19% in the Bakcharskoe and Timiryazevskoe bogs respectively.

DISCUSSION

Mass loss at the initial stages of decomposition. According to N.G. Koronatova [2010], who held short-term experiment of peat decomposition in conditions of peat deposits in fen and ryam

Table 1. Changes in the number of microorganisms of peat and plant samples at the initial stages of decomposition in the conditions of the Timiryazevskoe bog, N x 10^4 CFU / 1G of a.d m.

Phytocenosis	Sample	Time	Oligotrophic microflora	Cellulolytic microflora	Saccharolytic fungi	Denitrifiers
Pine-shrub-sphagnum phytocenosis	Peat	Initial	78,2	0,06	0,09	—
		June	216,8	0,08	0,40	—
		July	23174,0	1,21	2,70	—
		August	3522,7	0,05	8,58	—
		September	5280,1	<0,01	51,20	5,58
	Eriophorum vaginatum	June	117,9	0,06	0,25	—
		July	77571,0	0,63	5,44	—
		August	3173,4	0,16	2,02	—
		September	1086,8	0,04	17,48	0,05
	Sphagnum fuscum	June	1098,8	0,07	0,10	—
		July	12873,0	0,02	<0,01	—
		August	2679,5	0,01	6,30	—
		September	37361,4	0,05	30,71	<0,01
Sedge-sphagnum fen	Peat	Initial	59,7	0,16	0,22	<0,01
		June	334,0	0,18	0,02	0,01
		July	418,2	0,94	0,94	0,16
		August	533,4	0,10	2,07	0,16
		September	123,4	0,08	2,17	0,08
	Carex rostrata	June	402,2	0,05	0,02	<0,01
		July	1618,2	0,33	0,47	<0,01
		August	11570,4	0,04	18,18	0,12
		September	1744,2	0,01	1,35	0,03
	Sphagnum angustifolum	June	282,2	0,03	0,13	0,01
		July	400,0	0,37	0,58	0,01
		August	2120,0	0,21	0,42	0,01
		September	509,1	0,04	1,87	0,01

Note: «—» – no data

of Bakcharskoe bog, the active decomposition of organic matter happens in first month of destruction (40 and 50% of total mass loss during 3 month in ryam and fen respectively), that generally corresponds to the received data. The most intensive process of decomposition in the first month is typical for the Bakcharskoe bog (Fig. 1). Probably, less intensive decomposition of plant residues in the Timiryazevskoe bog was caused by weather conditions during the first month of the experiment – dry June 2016 (Hydrothermal coefficient (HTC) =0,7), excessively wet June 2017 in the Timiryazevskoe bog (HTC=1,7). Correlation analysis showed a moderate feedback between mass loss and HTC in the conditions of the Timiryazevskoe bog (r=-0,35), and a stronger relationship – in the conditions of the Bakcharskoe bog (r=–0,71). Intensive decomposition was also facilitated by an increase in aeration zone caused by a decrease in WTL, but both excessively dry and excessively wet conditions can inhibit the decomposition process [Dobrovolskaya et al., 2014]. In the conditions of the peat deposit of the Bakcharskoe bog, both in the fen and in the ryam, the rate of decomposition decreased gradually. Whereas in the conditions of the Timiryazevskoe bog, after a gradual decrease in the rate of decomposition, a surge in the activity of microorganisms was occurred in all samples, leading to a noticeable increase in the mass loss by September (Fig.1, table 1). Among the studied plants, the most resistant to decomposition is S. fuscum (mass loss of 9-19% of the initial value). The sustainability of sphagnum mosses due to the presence in their composition inhibiting the activity of micro-organisms and persistent chemical compounds, such as Sphagnols and hemicellulose. A very low lignin content, which either is not found in plant residues [Dobrovol'skaya et al., 2013], or is a negligible amount of 0.3-0.5% dry weight [Reznikov et al., 1968], can also contribute to slow decomposition. The least resistant species – E. vaginatum, while in a long-term experiment the cotton grass in conditions a sedge-sphagnum fen was the most resistant to decomposition among grasses, in contrast to C. rostrata [Golovatskaya and Nikonova 2013]. According to the research [Nikonova et al., 2019], the decomposition of plant residues is greatly influenced by the humidity of the substrate. So in drier conditions of ryams, the decomposition of E. vaginatum proceeds more intensively.

Changes in the total carbon content and activity of carbon cycle microorganisms during decomposition of plant residues. The carbon cycle is one of the main biogeochemical cycles in the biosphere. And And is determined by the ratio of the processes of production and destruction of organic matter. Organic matter of plant residues contains of 40-45% carbon [Vishnyakova and Mironycheva-Tokareva, 2010; Golovatskaya and Nikonova, 2013]. Accordingly, a change in mass leads to a change in the carbon content, so in a three-year experiment on the decomposition of plant residues [Nikonova and Golovatskaya, 2019], carbon losses are well correlated with mass losses (r=0,68). An increase in the carbon content of sphagnum moss samples (0,43-3%) at the earliest stages of destruction may be associated with the ability of sphagnum mosses to regenerate and actively vegetate even after the death of most part of the plant [Babeshina and Dmitruk, 2009]. In contrast to the processes of formation of organic matter plant that are made in result of photosynthesis, the destruction of organic matter largely depends on microorganisms.

As is known, oligotrophic microflora has a great affinity with the substrate, as these organisms need low concentrations of biogenic elements. The predominance of this group of microorganisms indicates a low rate of transformation of organic matter, since most often they mineralize the residues of the plant litter after the so-called "zymogenic" group of microorganisms, which is developing only if there is an easily accessible organic substance in the substrate [Mishustin, 1975]. In peat, where the decomposition process takes place, both in the fen and ryam, there was a surge in the activity of microorganisms in July and September, whereas in fresh plant remains in was observed in July and August, depending on the phytocenosis (ryam and fen, respectively). Significantly different from the other samples S. fuscum, where the maximum activity of oligotrophs in conditions of Bakcharskoe bog was observed in the first month, and in conditions of Timiryazevskoe bog only to the 4th month of the experiment. Fungi prevailed among the microflora, which, in general, is additional evidence of the low availability of organic matter for bacteria in S. fuscum.Cellulose destructors are an integral component of the carbon cycle, due to their ability under the action of cellulase enzymes, and hemicellulases transform complex high-molecular compounds forming the basis of the "skeleton" of plant residues [Naplekova, 1974; Rechkin and Ladygina, 2010]. Fungi – the first group of microorganisms that due to their micellar structure and ability to produce hydrolytic enzymes are most easily embedded in the micelles of lignocellulose fibers and loosen them from the inside. The different dynamics of the decomposition rate and the removal of carbon from different plant residues is explained by the composition and number of microorganisms involved in the decomposition process. For example, equal carbon removal in grasses may be due to approximately the same level of activity of the cellulolytic microflora in the first 3 months of the experiment. Not less important factor is the environment in which the decomposition processes take place. The study of microbiological properties of the peat in which placed the studied plant residues, showed that the peat of Timiryazevskoe bog enriched with microorganisms lignocellulosic complex compared with the peat of Bakcharskoe bog which is more favorable conditions for development of own microflora samples placed in peat.

The composition of the cellulolytic microbial community was dominated myxobacteria and fungi, which is probably caused by their greater resistance to dry periods, which were observed during experiment. The increased number of myxobacteria may also indirectly indicate the presence of readily available hydrocarbons in plant residues [Mishustin, 1975].

Cellulose destructors are accompanied by microorganisms of the saccharolytic complex – yeast and Mucor fungi, which are one of the main consumers of products of enzymatic hydrolysis of cellulose [Rechkin and Ladygina, 2010]. In the peat of Timiryazevskoe bog recorded the highest activity of fungi in September; in the peat of Bakcharskoe bog the greatest number of saccharolytic fungi was observed at the beginning of the experiment. As a rule, a high number of saccharolytic fungi as an indicator of increased activity of cellulolytic processes occurring in more favorable aerobic conditions [Naplekova, 1974]. The content of saccharolytic fungi in the peat has a close related with their content in the plant samples, and in better aerated conditions of ryams, this dependence is stronger compared to the fens. The correlation coefficients are equal to 0,97 and 0,84 for the ryams and 0,71 and 0,52 for the fens of the Timiryazevskoe and Bakcharskoe bogs respectively.

Changes in the total nitrogen content and activity of nitrogen cycle microorganisms during decomposition of plant residues. The organic carbon cycle is closely related to the nitrogen cycle [Rechkin and Ladygina, 2010, Golovchenko et al., 2013]. However, unlike the carbon cycle, which depends partly on the photosynthetic activity of plants, the nitrogen cycle with its stages – nitrogen fixation, ammonification, nitrification, denitrification – is entirely determined by the activity of bacteria [Rechkin and Ladygina, 2010]. The revealed significant difference in the change of the total nitrogen content in plant samples during the first month of the experiment is explained by the maximum number of microorganisms participating in the nitrogen cycle during this period in the samples of plants and peat of the Bakcharskoe bog.

The mineralization coefficient is one of the most informative indicators of the intensity of the process of microbial decomposition of organic matter. Its defined as the quantitative ratio of microorganisms that primarily absorb mineral forms of nitrogen, and microorganisms-ammonifiers. An increase in the mineralization coefficient usually indicates an increase in the rate of biodegradation of organic compounds in the soil. The results showed that the numbers of microorganisms digesting mineral forms of nitrogen, in conditions of the ryam was 1,7 times, and in conditions of the fen 1,2 times less than the microorganisms digesting organic forms of nitrogen. The higher mineralization coefficient (1,7) characteristic of the ryam is most probably due to the better aeration of the ryam peat deposit compared with the fen (table 3,4).

Although fungi grow faster and their biomass often exceeds the biomass of actinomycetes and bacteria at the first stages of destruction [Krasilnikov, 1958; Aristovskaya, 1980], the number of the latter in our studies for most samples exceeds the number of fungi. The correlation analysis revealed a moderate feedback between the nitrogen content and the number of fungi (r=-0,29), which perhaps explain a slight inhibition of the fungal microflora.

The final stage of the nitrogen cycle is denitrification – the reduction of nitrates to a gaseous state under anaerobic conditions [Rechkin and Ladygina, 2010]. The results of correlation analysis revealed a moderate relationship between the number of denitrifiers and oligotrophic microflora in plant residues (r=0.32), which probably indicate trophic conjugation of denitrifiers and the processes of heterotrophic nitrification carried out by oligotrophic fungi.

Changes in the content of ash elements during decomposition of plant residues. The metabolic activity of microorganisms is also greatly influenced by ash elements. They can indirectly regulate the decomposition rate of organic matter of peat-forming plants [Evdokimova and Mozgova, 1984; Sakovich and Bezmaternykh, 2005]. At the same time, a low content of ash elements in plants can lead to a decrease in the decomposition rateof organic matter [Morozova, 1991; Fedorets, 1997]. Similarly, in our studies, initially low-ash sphagnum mosses lost mass more slowly than other samples. And grasses with a higher content of ash elements was decomposed faster. During the experiment, both a decrease and an increase in ash content were observed. In the conditions of the Timiryazevskoe bog, there is an accumulation of ash elements and the maximum accumulation is characteristic of the main peat-forming species – S. fuscum. Dates about the accumulation of ash elements in plant residues during decomposition in the conditions of raised bogs is also found in the works of other authors. High ability to bioaccumulation ash elements characteristic sphagnum mosses [Nikonov, 1955; Kosykh, 2010; Lyapina 2015; Govorukha, 2017].

CONCLUSIONS

1. Greatest loss of mass of plant residues during destruction occurs in the first month of decomposition – from 36 to 52% of the total mass loss during the growing season. There is a relationship between hydrothermal coefficient and mass loss of plant residues: moderate feedback in conditions of Timiryazevskoe bog (r=–0,35), and a stronger correlation in conditions of the Bakcharskoe bog (r=–0,71). Sphagnum mosses have a slow rate of decomposition, the minimum decomposition at the initial stages is characterized by Sphagnum fuscum (mass loss during the growing season reaches 9-18%). The least sustainable in the initial stages of decomposition is Eriophorum vaginatum.

2. Carbon loss correlates well with mass loss. Herbs' carbon loss have grass plants compared mosses. Nitrogen losses for the most of peat-forming plants in the first month of decomposition are more active for the wetter conditions of the Bakcharskoe bog, in the further period the total losses have similar values. The greatest nitrogen losses are typical for sphagnum mosses. At the first stages of decomposition, there is an ambiguous change in the content of ash elements, and their accumulation is detected in some plant residues. The maximum accumulation is typical for Sphagnum fuscum in conditions of the ryam of Timiryazevskoe bog.

3. The maximum number of microorganisms in plant residues is observed in July and September. Plant residues placed in the Timiryazevskoe bog and peat itself are more saturated with microorganisms involved in the nitrogen cycle, and samples from the Bakcharskoe bog are rich in carbon cycle microorganisms.

4. In the composition of the cellulolytic microbial community, fungi predominate in the ryams, and in the conditions of the fens – myxobacteria. The largest number of oligotrophic microflora in peat is observed in ryam of Timiryazevskoe bog, and

Table 2. Changes in the number of microorganisms of peat and plant samples at the primary stages of decomposition in the conditions of the Bakcharskoe bog, N Ч 10^4 CFU / 1G of a.d.m. peat / plant residues

Phytocenosis	Sample	Time	Oligotrophic microflora	Cellulolytic microflora	Saccharolytic fungi	Denitrifiers
Pine-shrub-sphagnum phytocenosis	Peat	Initial	1656,8	0,02	3,13	<0,001
		July	2016,5	0,09	8,38	0,01
		August	1624,0	0,04	9,84	0,01
		September	63029,2	0,04	1,63	15,21
	Eriophorum vaginatum	July	1780,8	0,05	21,02	0,02
		August	17753,8	<0,001	10,58	0,38
		September	8410,8	<0,001	21,80	0,02
	Sphagnum fuscum	July	3996,2	<0,001	15,54	0,13
		August	2640,0	0,01	12,57	0,05
		September	2901,0	0,01	22,00	<0,001
Sedge-sphagnum fen	Peat	Initial	32071,2	0,07	4,45	0,20
		July	72548,0	0,92	0,81	0,28
		August	15662,4	0,01	0,06	0,01
		September	46416,0	<0,001	0,02	0,36
	Carex rostrata	July	672,1	0,09	6,61	0,07
		August	768,0	0,02	4,73	<0,001
		September	355,5	0,04	0,45	<0,001
	Sphagnum angustifolum	July	10700,0	0,40	0,26	0,61
		August	40460,0	0,01	0,31	<0,001
		September	228,6	0,01	0,13	0,01

Table 3. Changes in the number of microorganisms assimilating mineral and organic nitrogen forms of the Timiryazevskoe bog, N Ч 10^4 CFU / 1G of a.d. m. peat / plant residues

Phytocenosis	Sample	Time	Microorganisms that	Microorganisms that absorb mineral nitrogen	Mineralization coefficient
Pine-shrub-sphagnum phytocenosis	Peat	Initial	13,3	0,6	0,04
		June	1665,2	1263,7	0,76
		uly	27090,0	—	—
		August	9951,0	21926	2,20
		September	7715,0	103,2	0,01
	Eriophorum vaginatum	June	2195,0	37,3	0,02
		July	28140,0	—	—
		August	16593,0	23311,0	1,40
		September	<0,001	—	—
	Sphagnum fuscum	June	1271,0	195,4	0,15
		July	7980,0	—	—
		August	23341,0	23811,0	1,02
		September	10236,0	256	0,03
Sedge-sphagnum fen	Peat	Initial	78,9	67,6	0,86
		June	76,5	177,1	2,32
		July	222,1	159,0	0,72
		August	406,6	93,1	0,23
		September	40,8	31,4	0,77
	Carex rostrata	June	149,2	36,4	0,24
		July	547,3	30,6	0,06
		August	7647,7	375,7	0,05
		September	231,8	12,1	0,05
	Sphagnum angustifolum	June	95,8	241,9	2,53
		July	236	10,7	0,05
		August	786	44,5	0,06
		September	246,3	123,9	0,50

Note: «—» – no data

Table 4. Changes in the number of microorganisms assimilating mineral and organic nitrogen forms of the Bakcharskoe bog, N Ч 10[4] CFU / 1G of a.d.m. peat / plant residues

Phytocenosis	Sample	Time	Microorganisms that digest organic nitrogen	Microorganisms that absorb mineral nitrogen	Mineralization coefficient
Pine-shrub-sphagnum phytocenosis	Peat	Initial	821,9	688,9	0,84
		July	1319,4	417,6	0,32
		August	934,4	222,4	0,24
		September	2166,4	913,5	0,43
	Eriophorum vaginatum	July	1015,2	979,2	0,96
		August	4616,8	7516,8	1,63
		September	1048	3267,7	3,10
	Sphagnum fuscum	July	1601,2	33,4	0,02
		August	1101	110,5	0,10
		September	163,3	347,3	2,13
Sedge-sphagnum fen	Peat	Initial	166,8	111,2	0,67
		July	4961,6	3494,4	0,70
		August	1884,5	1189,7	0,63
		September	1924,8	1305,6	0,68
	Carex rostrata	July	515,7	124,7	0,24
		August	280,8	38,4	0,14
		September	382,8	30,6	0,08
	Sphagnum angustifolum	July	1634,2	1499,5	0,92
		August	5017,6	4090,8	0,82
		September	69,5	21,9	0,32

in the Bakcharskoe bog – in the fen. In addition, the number of saccharolytic fungi is higher in the conditions of ryams. In general, lignocellulose complex microorganisms are less active compared to other groups of microorganisms.

5. The number of microorganisms that digest mineral forms of nitrogen in ryams is on average 1,5 times less than the number of microorganisms that digest organic forms of it; while the number of bacteria exceeds the total number of fungi. A positive dependence between the nitrogen content and the number of fungi was found. A dependence between the number of denitrifiers and oligotrophic microflora was also found, which indicates trophic relationships between these groups of microorganisms.

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