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Microbial biomass carbon and enzymes-degraders of carbohydrates in polar soils from the area of Livingston Island, Antarctica

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Abstract

Polar soils under different vegetation cover from Livingston Island (Antarctica) were studied analyzing indicators of carbohydrates decomposition in soils: organic carbon, biomass carbon, total nitrogen, C:N ratio, cellulase, amylase, and invertase activity. The highest values of microbial biomass in soils were indicated for sites with vegetation cover while the lowest values in soils without vegetation, which correlate with the content of total organic carbon and the C:N ratio. The highest percentage of biomass carbon compared to the total organic biomass carbon is obtained for two sites with mosses, and the lowest in sites without vegetation, followed by the sites with lichens. Cellulase activity is highest in polar soils with moss cover. Amylase activity depends more strongly on the type of vegetation. The highest amylase activity is detected in soils under algae cover and the lowest in soils without vegetation. Invertase activity is limited by the extreme soil and climatic conditions of Antarctica. A very strong, positive correlation is found between total carbon and total nitrogen. The relationship between total carbon and the C:N ratio, as well as between biomass carbon and amylase activity, is moderate, and positive. The higher dependence of amylase activity from organic carbon with microbial origin correlates with higher values of the enzyme amylase compared to the enzyme cellulase. There is a strong (cellulase) and very strong (amylase) positive relationship between the activity of enzymes and the combination of factors: total carbon, total nitrogen, C: N ratio and biomass carbon.

1. Introduction

Extreme weather conditions in Antarctica create one of the harshest habitats in the world. Low values of temperature and humidity, frequent freeze-thaw cycles, strong winds, strong sublimation and evaporation, high frequency of solar and especially ultraviolet radiation are significant limiting factors for the life of the ice continent (Cowan and Tow, 2004). In addition, geographical isolation and ecological stress provoke interest to study the endemic organisms there (Ruise et al., 2007). Microorganisms play a key role in nutrients cycle in the soils of the isolated Antarctic ecosystems, where organic matter is derived primarily from soil algae and slow-growing cryptogamous plants (Tibbles and Harris, 1996).

Antarctic sea vertebrates — seals, penguins, flying birds — periodically use the Antarctic coast for resting, moulting, breeding, resulting in the visited land is manured, creating new conditions for development of terrestrial biota (Tatur, 2002). The ornithogenic excrement, total organic carbon and phosphorus accumulation are the main factors controlling the microbial properties in Antarctic soils – microbial biomass, respiration, N-mineralization, enzymes activities follow the content of total organic carbon (Tscherco et al., 2003). A higher content of total organic carbon was found in polar soils with denser vegetation (Nustorova et al. 2002; Malcheva et al., 2020). Abakumov and Mukhametova (2014) concluded that sub-antarctic soils differ from Antarctic soils mainly by the increased thickness of organic layer, the content of total organic carbon, higher carbon microbial biomass, basal respiration, and metabolic activity levels. They obtained the highest values of total organic carbon in peat soils and soils under guano. The total organic carbon content varies from zero levels in soils of ahumic regolit (Ugolini and Bockheim, 2008; Campbell and Claridge, 1987; Bockheim, 2013) to 3-4% in soils under mosses, lichens and cereals (Abakumov, 2010; Simas et al., 2008), while in soils formed under guano the organic matter increased up to 30-40% (Simas et al., 2007).

Research on the enzyme activity of microbial communities in ecosystems from Antarctica is still relatively limited, the results reported are contradictory and this provoked interest in studying the activity of microbial enzymes under extreme con-

ditions in this area. The biological activity of soils before 2002 is summarised by Beyer and Bolter (2002). The research on soil enzymatic activity in Antarctica of ornithogenic, pristine and human-impacted soils under different vegetation cover is reported by Krishnan et al. (2011) and Bragazza et al. (2019). Krishnan et al. (2011) found that a total of 25% of the tested fungal isolates showed significant activity for amylase, 25% for cellulase and 43% for protease. Moss cover is strongly related to the amount of organic carbon in the soiland the higher content is determining a higher microbial biomass (higher abundance of fungi compared to bacteria) and a higher overall activity of hydrolytic enzymes involved in C, N and P degradation processes (Bragazza et al., 2019). Machuca et al. (2015) found the highest β-glucosidase and acid phosphatase activities in the rhizosphere of soils sampled from a continental site with richerdiversity of vegetation cover. High urease activity was found in soils from two sites and the lowest enzyme activity was recorded only in soil under *Deschampsia. antarctica*. Enzyme activity decreased with a decrease of the incubation temperature, which depends on the enzyme – for example the β-glucosidase is most sensitive to temperature change, while urease is least affected.

Antony et al. (2016) found various groups of microorganisms in the snow cover (Proteobacteria, Actinobacteria, Firmicutes, Bacteroidetes, Deinococcus-Thermus, Planctomycetes, Verrucomicrobia, Euryarchaeota, Basidiomycota, Ascomycota, Cryptomycota and Rhizaria). All test isolates produced one or more of the enzymes lipase, protease, amylase, β-galactosidase, cellulase and/or lignin-modifying enzyme. In the region Peninsula, the microbial presence and biochemical activity of isolated strains were studied, taking into account the reduced biogenicity of soils without vegetation and at higher altitude (Yergeau et al. 2007, 2009, 2012).

Activity of at least one extracellular enzyme was found in 60% of the total yeast isolates at 4 or 20°C when studying the activity of the enzymes: lipase, amylase, esterase, protease, pectinase, cellulase by Vaz et al. (2011). Cellulolytic and esterase activities are the most common and present in 76% of the isolates andthe activity of these enzymes was established to be highest in the rhizosphere of *Deschampsia antarctica*. Fenice et al. (1997) studied 33 fungal strains from the Antarctic region for their ability to produce extracellular enzymes. According to their results, lipases are usually present in large quantities in almost all strains, while polygalacturonase, amylase and phosphatase are common, and glucose oxidase, protease and DNAase activities are generally low or absent.

Proteolytic, caseinolytic and keratinase activity of thermophilic actinomycetes was established by Gushterova et al. (2004). Enzyme activity (protease, amylase, β-glucosidase) was found in 30 strains of yeast isolated from soils, mosses and lichens (Pavlova et al., 2004). Pavlova et al. (2004) investigated the lipid composition and production of β-glucosidase by *Cryptococcus visbniacii AL*. Five strains of yeast from soils, mosses and lichens were identified and the biosynthesis of exopolysaccharides was proven for all of them (Pavlova et al., 2004). The biochemical characteristics of other 5 strains of yeast isolated from soils and mosses were studied (Pavlova et al., 2004). The ability of newly isolated actinomycete strains from Antarctic soils to produce keratinolytic enzymes during their growth on sheep wool waste was also studied (Gushterova et al., 2005). The obtained results showed that both newly discovered strains – *Streptomyces flavis 2BG* (mesophilic) and *Microbispora aerata IMBAS-11A* (thermophilic) are very promising for efficient treatment of meat keratin waste.

The aim of the present study is to determine the microbial biomass carbon accumulation and the degree of enzymatic degradation of carbohydrates in polar soils from the coastal area of Livingston Island characterized by presence or lack of vegetation cover.

2. Materials and methods

2.1. Description of study area

Eight areas along the transect of coastal zone near to the Bulgaria Antarctic Base “St. Kliment Ohridski” in Livingston Island are chosen and sampled: Hesperides point Pluton (HPP), Caleta Argentina (CA), Jonson’s Dock (JD), HAN (Hannah point), SV (Sanctuary), PB (Playa Bulgara), BP (Bird Bazaar), PUN (Punta Hesperides). The locations of studied areas are illustrated in Fig. 1.

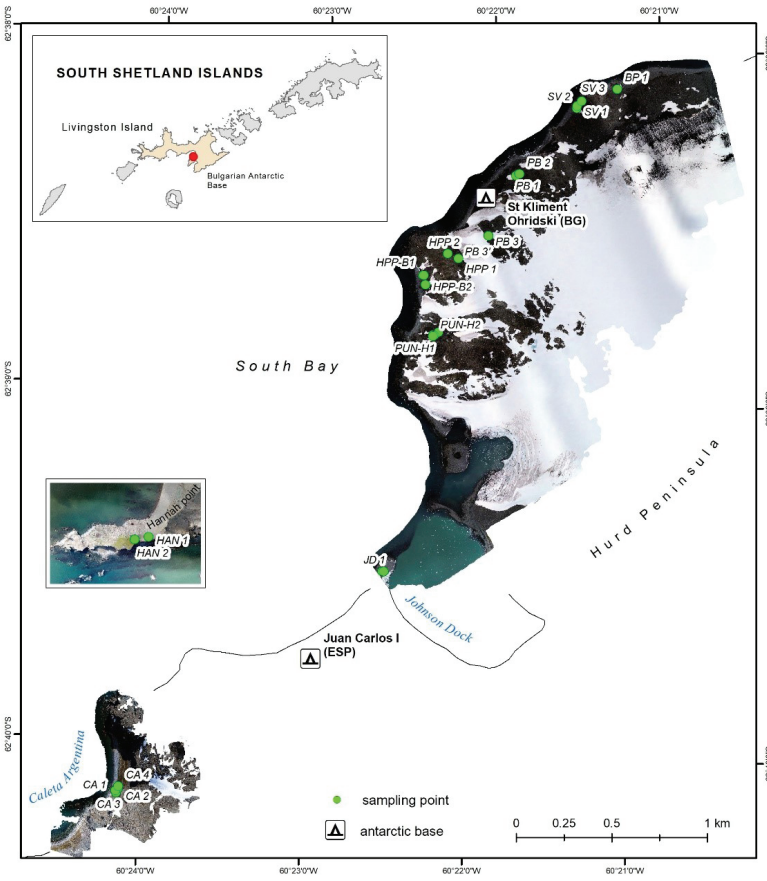


Fig. 1. Locations of the sampling sites in Livingston Island, Antarctica

2.2. Soil sampling and analysis of samples

The subject of the present study is polar soil collected from 29 sites differentiated by the type of vegetation cover from eight case-study areas: without vegetation cover (bare soil), mosses, lichens, grass vegetation. Soils in 25 sites are characterized by a low thickness and sampling is performed in the upper 0–7 cm soil layer. In 4 sites with a deeper soil profile the sampling included the deeper layer over 7 cm depth and the mean value was calculated, but differences in depth are discussed.

The sampling was realized in December 2019 at different depths, depending on the total thickness of the soil: 0–7 cm and over 7 cm. The soil is collected in three repetitions per site with sterile plastic auger with a total amount of 500 g, preserved in sterile plastic bags and put in refrigerator for storage and further transportation to the laboratory. The time of transportation from Livington island to Bulgaria was realized in refrigerator bag and cargo shipping by airplane for a period of 5 days after sampling and the deviation from the real activity (on site) of the microbiome due to the transportation period is the same for all samples collected. A mean sample per site and per soil layer is formed for chemical analyses immediately after arrival of the samples in the laboratory. Soil samples were analyzed by the following methods: soil typology – on field (Campbell and Claridge, 1987), total organic carbon – by the method of wet combustion of Tyurin; total nitrogen, C:N ratio; microbial biomass carbon – fumigation method (Cai et al., 2011). Enzyme activity of microorganisms (cellulase, amylase, invertase) is determined according the spectrophotometric method (λ 400 nm) indicated by Gradova et al., 2004. The analyses were carried out in laboratories of Forest Research Institute and University of Forestry.

2.3. Data Analysis

Statistical processing of the data from the analysed indicators included calculating the average value of three repetitions and determination of coefficient of variation (CV). Correlation and regression analysis was applied to determine the dependencies between the studied indicators. Microsoft Excel 2010 software product was used for the statistical analysis.

3. Results and discussion

The decomposition and accumulation of organic matter in soils depends on the content of total organic carbon, total nitrogen and the ratio C:N (Table 1). The results obtained for soil typology for different sites differentiated according to the aboveground vegetation cover are also included.

As it was indicated above the content of total organic carbon in polar soils varies in wide range from zero levels (Ugolini

Table 1
Site characteristics

No.	Site	Soil type
BARE SOIL, 0–7 cm		
1	HPP B1 bay	Haploturbel Typic
2	HPP B2 bay	Haploturbel Typic
3	CA 3	Intrazonal – Histel/Typic Hemistel
4	CA 2 (under nest)	Intrazonal – Histel/Typic Hemistel
5	SV 1	Hemistel Typic
6	PB 1	Haploturbel
MOSS COVER		
7	HPP B2 bay	Haploturbel Typic
8	JD 1	Haploturbel Lithic
9	BP 1	Spodorthel Lithic
10	SV 1	Hemistel Typic
11	SV 3	Hemistel Typic
12	PB 2	Haploturbel
13	PB 3, 0–7 cm	Haploturbel
	PB 3, over 7 cm	Haploturbel
14	HPP 1 Skua	Haploturbel Typic
15	HAN 1	Hemistel Typic
16	PUN-H1	Haploturbel Typic
17	PUN-H2, 0–7 cm	Haploturbel Typic
	PUN-H2, over 7 cm	Haploturbel Typic
18	HPP 2 Skua	Haploturbel Typic
GRASS COVER		
19	CA 1	Intrazonal – Histel/Typic Hemistel
20	JD 1	Haploturbel Lithic
21	PB 2	Haploturbel
22	HAN 2	Hemistel Typic
23	SV 2	Hemistel Typic
24	PB 3´, 0–7 cm	Haploturbel Typic
	PB 3´, over 7 cm	Haploturbel Typic
LICHENS COVER		
25	PUN-H2	Haploturbel Typic
26	CA 4, *Prasiola crispa* (algae) 0-7 cm	Intrazonal – Histel/Typic Hemistel
	CA 4, *Prasiola crispa* (algae), over 7 cm	Intrazonal – Histel/Typic Hemistel
27	HAN 1, *Prasiola crispa* (algae) cover	Hemistel Typic
28	HPP 1 Skua	Haploturbel Typic
29	HPP 2 Skua	Haploturbel Typic

and Bockheim, 2008; Campbell and Claridge, 1987; Bockheim, 2013) to 3–4% (Abakumov, 2010; Simas et al., 2008), or even up to 30–40% in soils formed under guano (Simas et al., 2007). Moreover, ornithogenic excrement, total organic carbon and phosphorus accumulation control – microbial biomass, respiration, N-mineralization in Antarctic soils, therofre the enzymes activities follow the content of total organic carbon (Tscherco et al., 2003). The C:N ratio in studied polar soils varied from 5.680 to 19.533. The tendence of higher values of C:N ratio is observed in soils under vegetation cover (under moss in site 13 PB 3 and under grass in site 24 PB 3´). The content of C and N in PB 3 – moss, over 7 cm, is the lowest compared to other sites (C – 0.0879% and N – 0.0045%), but the ratio C:N, as well as the percentage of biomass carbon to total carbon showed the highest values, which, however, does not relate to better enzyme activity at this site. The decomposition of cellulose is more embarassed than the decomposition of starch. It could be assumed that insofar as low C:N values are established for all studied sites, the soils in the harsh polar conditions are characterized by a deficiency of carbon and nitrogen sources for optimal development of the microflora and vegetation. At the same time, the low content of nitrogen sources presupposes its active immobilization by microbes, which further impairs the development of plants.

The accumulation of total organic carbon, total nitrogen and microbial biomass carbon is presented in Table 2. In terms of organic carbon content, the polar soils in the studied coastal area of Livingston Island are conditionally divided into three groups: 1) with organic carbon content between 3% and 5%, established mainly in soils under vegetation cover and with additional ornitogenic impact (SV3, CA2, CA1, PB2, PUN-H2); 2) with organic carbon content between 1% and less than 3%, established in bare soils and under lichens and mosses, but also in deeper soil layers (over 7 cm, where soils were deeper) (CA3, SV1, HPP 1 Skua, HPP 2 Skua, CA 4, PUN-H2, PB2, JD1, PUN-H2, PB 3´); and 3) with content of organic carbon less than 1%, and this amount was lowest in floodplains, two of which without vegetation (HPP B1, HPP B2) and one with moss vegetation (HPP B2), as well as in site PB 3 (under moss) for both sampling depths. Similar tendencies are found for the content of total nitrogen in the investigated variants.

The accumulation of total organic carbon and total nitrogen were higher in soils with vegetation cover (moss and grass separately), as well as in the soil near bird nests. On the other hand, low values of total organic carbon and total nitrogen were found in variants with the same vegetation. While in the variants with lichens, the content of C and N was average compared to the other variants. In general, the presence of organic substrates increases the content of organic carbon and total nitrogen in superficial soil layer, but is not the only factor for their accumulation. Influence is exerted by a complex of factors – vegetation, soil type, soil temperature, location (in floodplains the content of organic carbon and total nitrogen is lower regardless of the presence or absence of vegetation).

Microbial biomass showedthe highest values at sites with vegetation, which could be probably a consequence of the presence of exudates and mechanical waste from organic substances. Biomass carbon in sites indicated as “bare soil” drops up to 3.3 times. Therefore, in soils without vegetation cover, the values of microbial biomass carbon could be referred as controls. The moss and grass cover variants had higher microbial biomass carbon values compared to the variants with lichen cover (close to control). There is a decrease in depth on this indicator 1.1 times in soils with grass and moss cover – PB 3 and PB 3´.

As a relationship between total organic carbon and that of microbial origin, it can be noted that the highest values of total organic carbon are also found in soils under vegetation (SV 3, PB 3, CA 1). This trend is not clearly expressed for all sites with vegetation cover for total organic carbon compared to microbial organic carbon. A higher amount of total organic carbon is also found in the soil under the bird nest (ornitogenic impact), while the value of the microbial biomass at this site is low. This is probably due to the difficult-to-decompose organic matter that makes up the structure of the nests, while the exudates and debris from the plants activate the activity of soil microorganisms. Bragaza et al. (2019) also found that moss cover of polar soils was closely related to the amount of organic carbon in the soil and with its higher content determines a higher microbial biomass. A higher content of total organic carbon was found in polar soils with denser vegetation (Nustorova et al. 2002, Malcheva et al., 2020). The percentage of microbial biomass to the total organic carbon is presented in Fig. 2.

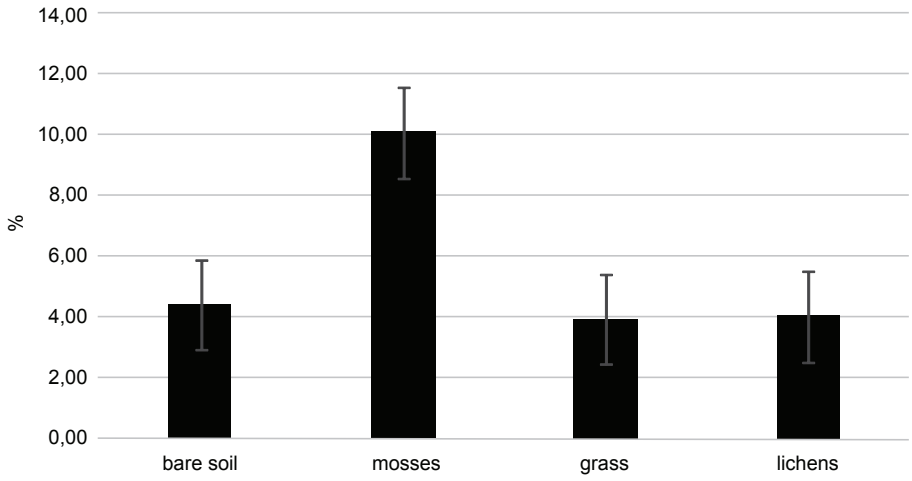


Fig. 2. Percentage participation of microbial biomass carbon in total organic carbon

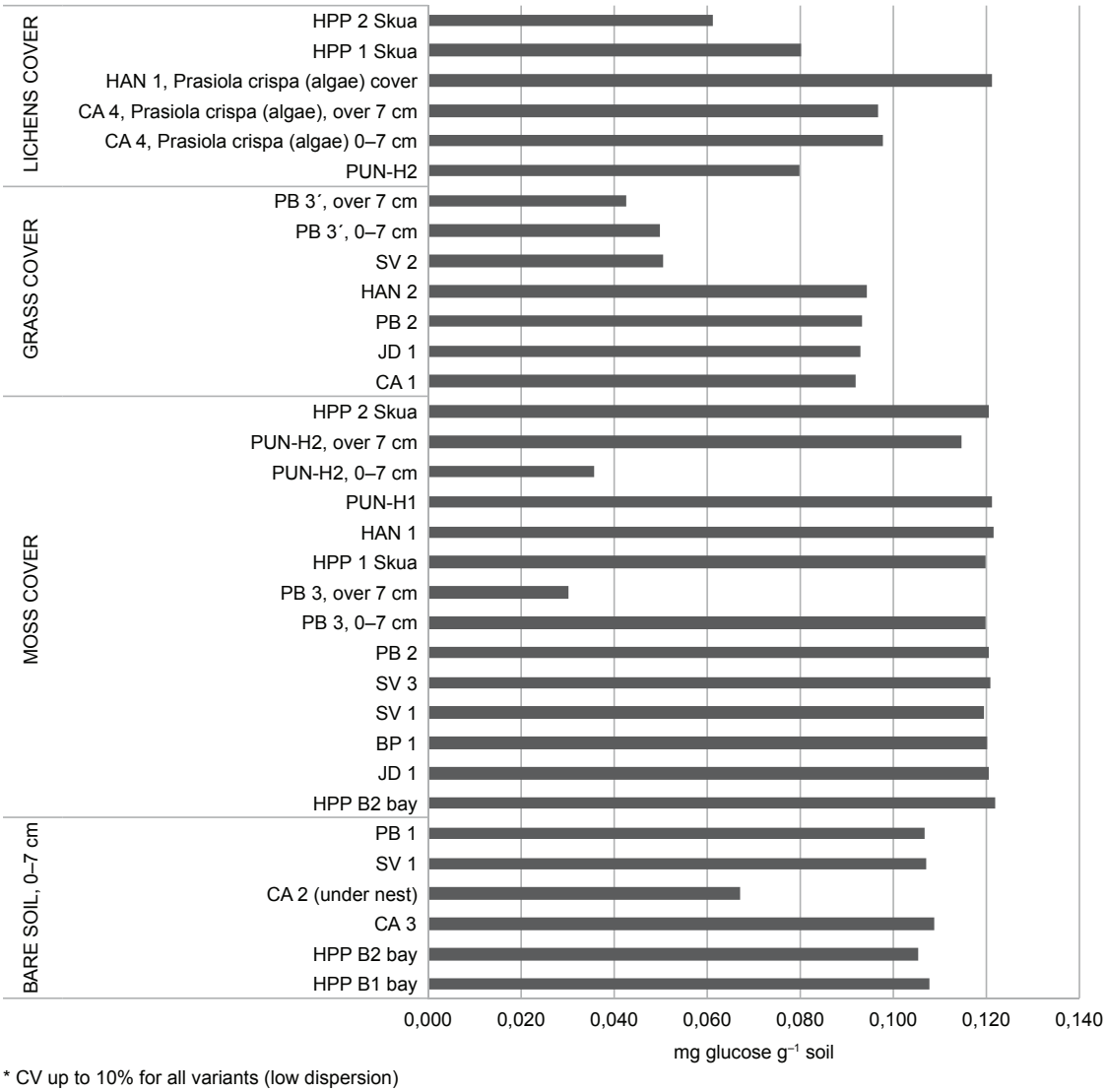
The highest percentage of biomass carbon in relation to the total organic carbon is determined in soil under moss, and the lowest (less than 1%) for: CA 2 under nest, CA 3, HPP 1 Skua, HPP 2 Skua.

With regard to the organic carbon of microbial origin, a clear trend is established between its content and the type of vegetation – biomass carbon has the highest values in soils with moss cover, followed in descending order by those with grass, lichen, nest and without vegetation (bare soil). Plant root exudates and residues activate the activity of soil microorganisms, which predetermines a clearer "vegetation-microbial biomass" trend compared to the distribution of total organic carbon and total nitrogen by organic cover type.

The enzyme activity of the studied soils is determined by the activity of enzymes involved in carbohydrate metabolism – degrading polysaccharides, which are the main structural and energy components in living cells – cellulase and amylase, as well as invertase.

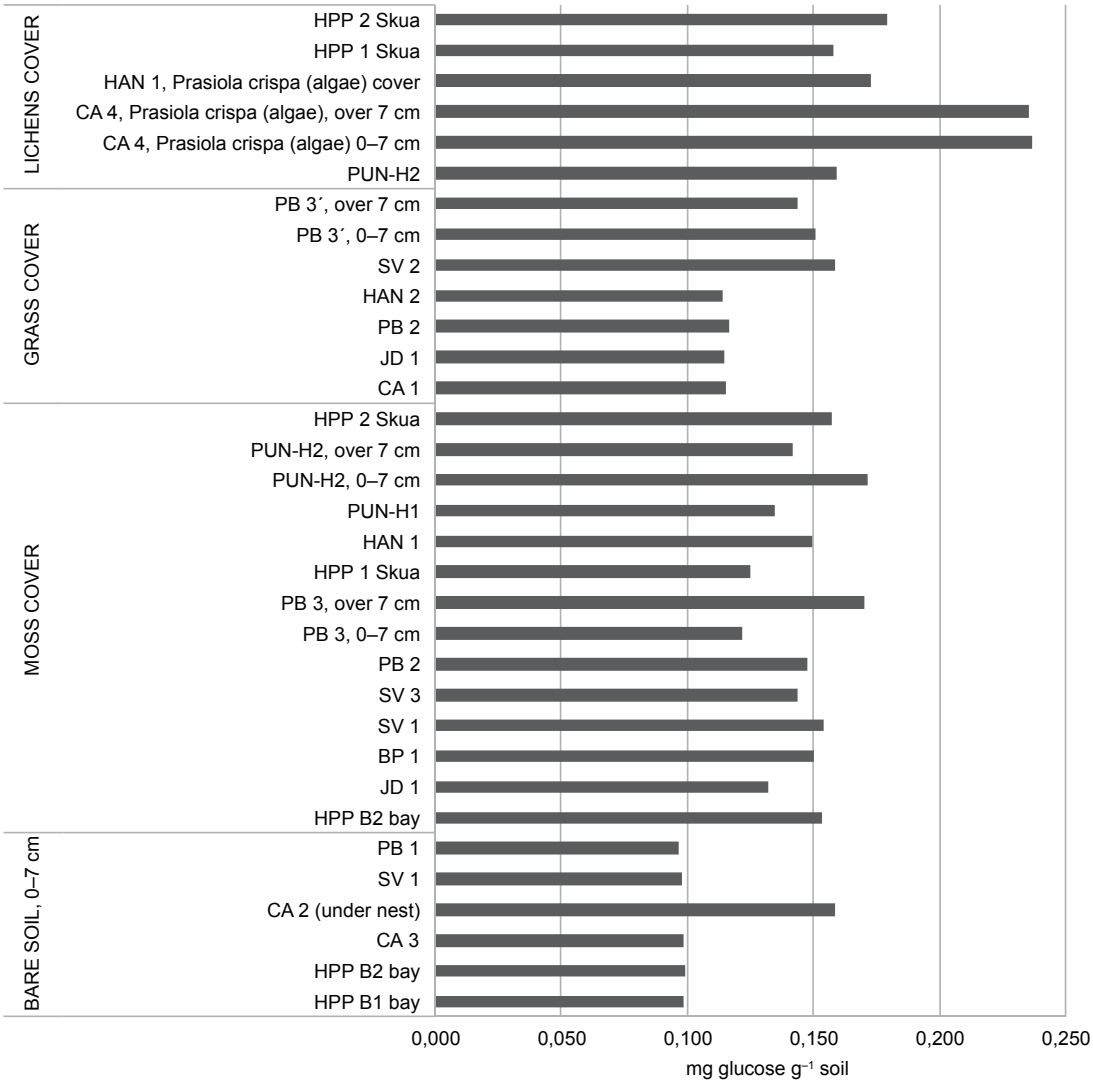
Cellulase activity is presented in Fig. 3. The highest values of cellulase activity are again determined in the soils with vegetation cover andAnexception was established for two sites with moss cover – PB 3 > 7 cm and PUN-H2. In the latter, the activity of the enzyme decreases to the highest degree. For the other samples, the cellulase activity decreases in the following order: "soil under moss" > "soil under grass" > "soil under lichens" > "soil under nest". There is a decrease in the depth of the enzyme activity – 4 times at the PB 3 site and 1.2 times at the PB 3´ site. There is a logical dependence for the presence of higher levels of cellulase in soils with vegetation and correspondingly higher values for cellulase activity. In the studied polar soils, however, with regard to the relationship between cellulase activity and vegetation, a clearer relationship was established only between the presence of moss and higher cellulase activity. In terms of higher enzyme activity, the site without an organic cover follow. The role of soil microorganisms surviving in extreme conditions is significant – in a previous study of the same variants, high biogenicity in soils without plant cover was found (Malcheva et al., 2020).

The amylase activity of the studied polar soils is presented in Fig. 4. Amylase activity is also highest in soils with vegetation cover.



* CV up to 10% for all variants (low dispersion)

Fig. 3. Cellulase activity



* CV up to 10% for all variants (low dispersion)

Fig. 4. Amylase activity

Amylase enzyme values decrease in the order: lichen, nest, moss, grass, no cover. The decrease is 2.5 times lower in bare soils. The presence of plant secretions and waste activate the production of the enzyme by microbes. In depth, the amylase activity increases up to 1.4 times in deeper soil under moss compared to the superficial layer in the same site. Similar tendence is observed in PB 3'.

Contrary to cellulase, for amylase activity a strong dependence is found between the presence of vegetation and enzyme values – to the highest extent for the soil under nest (with organogenic impact) and algal crust, where amylase activity is twice as high as cellulase.

Invertase activity showed negative values for all tested samples. Enzyme activity of polar soils, including for the studied enzymes cellulase and amylase, is also established by other authors for identified strains of bacteria, actinomycetes, yeasts, fungi (Antony et al., 2016; Vaz et al., 2011; Krishnan et al., 2011; Fenice et al., 1997; Gushterova et al., 2004, 2005; Pavlova et al., 2004). Biogenicity and enzymatic activities in these soils depend on soil temperature and biogenicity, altitude, organic carbon content, presence or absence of plant cover, sampling depth, and other factors (Bragazza et al., 2019; Machuca et al., 2015; Yergeau et al. 2007, 2009, 2012; Nustorova et al. 2002; Malcheva et al., 2020; Tscherco et al., 2003). According to Abakumov and Mukhametova (2014), sub-antarctic soils differ from Antarctic soils mainly by the increased thickness of organic layer, the content of total organic carbon, higher carbon microbial biomass, basal respiration, and metabolic activity levels.

The correlations between total carbon, total nitrogen, C:N ratio, biomass carbon, cellulase and amylase activities are presented by correlation analysis in the following Table 2.

A very strong, positive correlation is found between total carbon and total nitrogen ($r > 0.9$). The relationship between total carbon and the C:N ratio, as well as between biomass carbon and amylase activity, is moderate and positive. The other correlations are weakly positive or weakly negative. Moderately, negatively cellulase activity depends on the C:N ratio, as the higher values of one variable correspond to lower values of the other variable. The higher dependence of amylase activity from organic carbon with microbial origin correlates with higher values of the enzyme amylase compared to the enzyme cellulase.

Table 2
Contents of total org. and biomass C, total N and C:N ratio

No.	Site	Total C (%)	Total N (%)	C:N	Biomass C (%)
BARE SOIL, 0–7 cm					
1	HPP B1 bay	0.198	0.031	6.376	0.013
2	HPP B2 bay	0.088	0.012	7.205	0.014
3	CA 3	2.182	0.239	9.132	0.014
4	CA 2 (under nest)	4.174	0.585	7.132	0.016
5	SV 1	1.983	0.184	10.763	0.015
6	PB 1	0.793	0.087	9.078	0.015
MOSS COVER					
7	HPP B2 bay	0.099	0.012	8.131	0.042
8	JD 1	1.252	0.123	10.221	0.043
9	BP 1	0.694	0.089	7.818	0.044
10	SV 1	1.878	0.173	10.850	0.044
11	SV 3	4.661	0.403	11.566	0.043
12	PB 2	3.173	0.261	12.168	0.042
13	PB 3, 0–7 cm	0.198	0.031	6.480	0.045
	PB 3, over 7 cm	0.088	0.005	19.533	0.043
	Mean	0.143	0.018	8.131	0.044
14	HPP 1 Skua	0.694	0.061	11.325	0.043
15	HAN 1	0.522	0.078	6.680	0.039
16	PUN-H1	0.496	0.061	8.088	0.044
17	PUN-H2, 0–7 cm	2.777	0.245	11.329	0.044
	PUN-H2, over 7 cm	1.488	0.133	11.167	0.038
	Mean	2.132	0.189	11.269	0.041
18	HPP 2 Skua	0.496	0.080	6.229	0.044
GRASS COVER					
19	CA 1	3.471	0.376	9.229	0.034
20	JD 1	0.522	0.077	6.811	0.034
21	PB 2	1.289	0.104	12.384	0.035
22	HAN 2	0.730	0.129	5.680	0.035
23	SV 2	0.835	0.089	9.347	0.046
24	PB 3´, 0–7 cm	2.182	0.131	16.718	0.046
	PB 3´, over 7 cm	0.992	0.091	10.862	0.042
	Mean	1.587	0.111	14.308	0.044
LICHENS COVER					
25	PUN-H2	1.091	0.110	9.889	0.015
26	CA 4, *Prasiola crispa* (algae) 0–7 cm	1.587	0.190	8.369	0.033
	CA 4, *Prasiola crispa* (algae), over 7 cm	0.496	0.063	7.895	0.033
	Mean	1.041	0.126	8.2512	0.033
27	HAN 1, *Prasiola crispa* (algae) cover	0.522	0.078	6.680	0.038
28	HPP 1 Skua	1.884	0.157	11.986	0.016
29	HPP 2 Skua	1.785	0.187	9.541	0.015

* CV up to 10% for all indicators and variants (low dispersion)

Table 3
Correlation coefficients (r)

Indicators	Total org. C	Total N	C:N	Biomass C	Cellulase	Amylase
Total org. C	1					
Total N	0.942	1				
C:N	0.253	0.040	1			
Biomass C	–0.084	–0.183	0.210	1		
Cellulase	–0.143	–0.127	–0.504	0.053	1	
Amylase	0.049	0.061	0.109	0.263	–0.263	1

Through the created correlation matrix, a check for independence of the factors is made. The presence of correlation coefficients greater than 0.7 (even if only one in the matrix) indicates that there is a multicollinearity between the factor variables. Regression analysis is applied to determine the dependence of the enzymes cellulase and amylase on a complex of factors (total carbon, total nitrogen, C: N ratio and biomass carbon). A strong (cellulase) and very strong (amylase) positive relationship is established between the activity of enzymes and the combination of these factors (Table 3).

Table 4
Regression analysis

Cellulase activity Regression Statistics	
Multiple R	0.9284
R Square	0.8620
Adjusted R Square	0.8115
Standard Error	0.0395
Observations	32

ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.2726	0.0681	43,7082	2.03999E-11
Residual	28	0.0437	0.0016		
Total	32	0.3162			

Amylase activity Regression Statistics	
Multiple R	0,969238
R Square	0,939422
Adjusted R Square	0,897217
Standard Error	0,03919
Observations	32

ANOVA

	Df	*SS*	*MS*	*F*	Significance F
Regression	4	0.6669	0.1668	108.5526	3.1463E-16
Residual	28	0.0430	0.0016		
Total	32	0.7099			

4. Conclusions

Vegetation cover is one of the sources of organic substances in polar ecosystems in studied coastal area of Livingston Island and could be indicated as a factor for the formation of soil organic matter and its accumulation in polar soils.

Low values of C:N ratio were found for all studied sites, as the soils in the harsh polar conditions are characterized by a deficiency of carbon and nitrogen sources for optimal development of the microflora and vegetation. In general, in the soils under vegetation the C:N ratio reaches higher values than in the sites without vegetation – only soil and soil under the nest.

Biomass carbon of microbial origin has the highest values in soils with vegetation cover and the lowest in soils without vegetation, which correlates with the content of total organic carbon in most of the sites. The organic plant substances activate the activity of soil microorganisms, which predetermines a clearer "vegetation-microbial biomass" trend compared to the distribution of total organic carbon and total nitrogen by organic cover type. Biomass carbon compared to the total organic carbon has the highest percentage in two of the sites with moss vegetation, and the lowest in sites without vegetation, followed by the sites with lichens.

Cellulase and amylase activities depend on type of vegetation cover, which is stronger for amylase acitivity. Cellulase activity is highest in most moss-covered soils. In terms of higher cellulase activity, the sites without organic cover follow. While the highest amylase activity is found in soils under algae cover and the lowest in soils without vegetation cover. In general, the activity of both enzymes correlates with the values of the C:N ratio.

Invertase activity is limited in the soils developed under theclimatic conditions of Antarctica. No such activity was detected.

A very strong, positive correlation is found between total carbon and total nitrogen. The relationship between total carbon and the C:N ratio, as well as between biomass carbon and amylase activity, is moderate, positive. The higher dependence of amylase activity from organic carbon with microbial origin correlates with higher values of the enzyme amylase compared to the enzyme cellulase. There is a strong (cellulase) and very strong (amylase) positive relationship between the activity of enzymes and the combination of factors: total carbon, total nitrogen, C:N ratio and biomass carbon.

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