Microbial Biomass Carbon in Cryogenic Soil Profile

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Abstract: A strong direct correlation was discovered between humus carbon content and microbial biomass carbon in the studied soils. Comparing the carbon content of microbial biomass from frost cracks (humus pocket) in the soil from the same depths of the enclosing horizon, it should be noted that microbial biomass and humus indices in frost cracks are higher. Similar studies in agroecosystems are necessary to assess the influence of natural and anthropogenic factors on the soil microbial complex.

1 INTRODUCTION

Permafrost in soil-forming processes is a subfactor among the main factors of soil formation. It affects all factors of the soil-forming process, changing the properties and regimes of soils. Low temperature is one of the distinguishing features of the ecological conditions for the development of microbial cenosis in the studied soils (Kulikov, Dugarov, Korsunov, 1997; Kislov, Surkova, 2020). Long-term studies carried out in Transbaikalia by S.Sh. Nimaeva (Nimaeva, 1992), as well as a number of publications by other authors, make it possible to provide the problem factually, and to highlight issues for further research (Korsunova, Baldanov, Chimitdorzhieva, Valova, 2021; Korsunova, Valova, 2021; Chimitdorzhieva, Korsunova, Chimitdorzhieva, Tsybenov, Garankina, 2021).

The activity of the soil microbial complex, responsible for the process of transformation of organic substances, plays an important role in maintaining homeostasis in terrestrial ecosystems and the biosphere. The impact of unfavorable natural and anthropogenic factors leads to disruption of the synthesis processes and decomposition of substances related to the fertility of arable soils. Therefore, it is necessary to study the soil microbial complex, including observations of the carbon content of the microbial biomass. The activity of microbiological immobilization processes in soils can be judged by these indices (Zvyagintsev, 1991).

Permafrost soils, widespread in the central part of the Eravna forest-steppe basin in the south of the Vitim Plateau, are under the influence of cryogenic processes, where frost cracking of soils is often found and is clearly manifested. As a result of temperature fluctuations in the zone of annual heat cycles, frost cracks are formed in these soils. They are filled with humous material from the upper horizons and form typical humus pockets in the soil profile, which are reserves of conserved organic substance. Their area on the wall of the soil section can reach 30-50%, and the depth can reach 80-90 cm. Since soil microorganisms are the main agent of the destruction of organic substance and humus formation, the study of the carbon content of microbial biomass in frost cracks is of significant interest.

This work is aimed at determining the content of microbial carbon, which characterizes the active microbial biomass, in burozems and quasi-gley chernozems.

The objectives of our studies included the determination of the carbon content of microbial

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biomass in frost cracks (humus pocket) and in the enclosing soil layer.

2 OBJECTS AND METHODS OF REASEARCH

The study area is located in the boreal belt of the East Siberian permafrost-taiga region and belongs to the mountainous North Baikal soil province. The ridged part of the Eravna and Kondinsky depressions and their side parts and individual low places adjacent to them are occupied by light coniferous and deciduous forests and shrubs. In terms of vegetation and landscape, the forested part of this territory is a fragmentary permafrost southern taiga, directly contacting with the insular (basin) permafrost forest-steppe.

The climate of the Eravna basin, like the entire territory of Transbaikalia, is sharply continental. Cold, with little snow and long winter is followed by late windy and dry spring. Summer is hot and short. According to the Sosnovo-Ozerskaya meteorological station located in the study area, the average annual air temperature is -4.1ºC, with the average temperature of the warmest month (July) +17.1ºC and the coldest (January) -25.4ºC. The absolute minimum temperature reaches -50 to -54°C. The sum of biologically active temperatures is 1330°C. This leads to deep freezing of the soil and widespread frost cracking of the soil.

The objects of our research are permafrost soils, burozems and quasi-gley chernozems. The experimental sites were located at the Eravninsky soil-agrochemical station in Sosnovoozersk and on the Darkhituy ridge in the south of the Vitim Plateau. They are under the influence of cryogenic processes, where frost cracking of soils often occurs and is clearly manifested, which is in relation with the soil-frozen complexes formation.

The carbon content in the 0-20 cm layer of quasi-gley chernozem is high, 6.8-6.9%; it sharply decreases with depth: in the 20-30 cm layer - 1.0%, in 30-40 cm - 0.44%. In humus pockets at the same depths, carbon accumulates up to 5.37 and 4.65%. In the 40-50 cm depth pocket, carbon is 4.58%, and only at a depth of 60-70 cm it decreases to 0.33%. The sum of absorbed bases in the upper horizon is 35.4 - 36.8 mg-eqivalent/100 g of soil; the reaction of the environment is close to neutral (6.8-7.3), in the lower horizon it is slightly alkaline (8.3). The content of total nitrogen is 0.6% (Tsybenov, Chimitdorzhieva, Chimitdorzhieva, Rogova, Milkheev, Davydova, Korsunova, 2016; Tsybenov, Chimitdorzhieva, Rogova, Gongalskiy, 2016).

Burozems are characterized by a low content of humus. Down the profile, its content drops sharply in the enclosing horizon to 0.43-0.52%. In pockets, the content of humus can reach up to 8%, nitrogen enrichment is average - 11-15, its content in the upper horizon is 0.21-0.63%, and in the pocket -0.35-0.645. The soil has a slightly acidic reaction (water pH 6.2) due to the high content of exchangeable bases (35.9-36, mg-equivalent / 100 g of soil), in the lower layer the acidity slightly increases (water pH 5.9). In contrast to the pockets, the enclosing horizons are slightly more compacted.

To study the content of microbial carbon, 15-meter trenches and soil sections were made.

Microbial biomass carbon was determined by the rehydration method (Blagodatskiy, 1987). Statistical processing of experimental data was performed in the Microsoft Excel 2010 spreadsheet of Microsoft Office package.

3 RESULTS AND DISCUSSION

Due to sharply continental severe permafrost climatic conditions, the period of activity of the microbiota of the Transbaikalia soils is very short, and the deep coldness and proximity of the permafrost do little to stimulate the development of a significant thickness of the soil profile by the microbiota. Permafrost state of soil lasts for 7-8 months; it determines the formation of microflora adapted to cryogenic conditions. Extreme natural conditions of cryogenic ecosystems determine the peculiar composition and structure of the microbiocenosis, increase the vulnerability of the microbiota, at the same time improve their adaptability to changing conditions. Microbial biomass, its activity and the diversity of the microbial community are indices of changes in the soil environment (Ananyeva, Sushko, Ivaschenko, Vasenev, 2020; Ananyeva, Sushko, Ivaschenko, Kudeyarov, 2019).

The highest carbon content of microbial biomass was recorded in the quasi-gley chernozems of permafrost soils, where it is differentiated in depth with a maximum in the upper part and a subsequent decrease down the profile. Thus, in the upper horizon of 0-10 cm, this indice varied from 90.6 to 118 mg/100 g of soil; in a layer of 10-20 cm- from 69.4 to 89.6; in a layer of 20-30 cm -from 65.5 to 84.3; in a layer of 30-40 cm, on average, 20.8 and in a layer of

50-60 cm - 12 mg / 100 g, which is 6 - 10 times less than in the corresponding upper horizon. There is a significant decrease in this indice down the profile compared to pockets. A particularly noticeable increase in quasi-gley C-biomass in chernozems was recorded in humus pockets at a depth of 40 cm of chernozem soils 59.6 mg/100 g, and on average this indice was 2.9–3.2 times higher than in the soil stratum. In the lower part of the humus pocket (50-60 cm), its content is also quite high - 38.7 mg/100 g. According to early studies, the vast majority of microorganisms is concentrated in a thin humus horizon; when moving to horizon B, the number of microbiota in permafrost soils sharply decreases hundreds of times. However, frost cracks with humus filler are the exception. Probably, the input of significant amount of plant litter organic substances stimulates the soil microflora, and, a rather high content of C-biomass is observed even in the lower horizon. This is evidenced by the close direct correlation between the humus carbon content and microbial biomass carbon. The largest coefficient was marked for the meadow-chernozem soil in the frost crack (r=0.99) and in the soil profile (r=0.98). Similar correlations are described in the works of E.G. Gavrilenko (Gavrilenko, 2011). Also, the carbon content of the microbial biomass positively correlated with the moisture content (r=0.94-0.96).

A similar decrease in the carbon of microbial biomass down the profile is observed in the enclosing horizons of burozem, but with the lowest indices than in the meadow-chernozem soil from 51 in the 0-10 cm layer to 15.6 mg/100 g - 30-40 cm, which is 3.5 times smaller than the corresponding upper horizon, C-biomass trend to increase in the humus pocket of burozem, comparing the enclosing horizon, so in the 10-20 cm layer this indice averaged 43.7, in the 20-30 cm layer - 39.5 and in the 30-40 cm layer - 20.8 mg/100 g, which is 2.5 times less than in the chernozem quasi-gley soil.

Another feature of these soils is slow decomposition of incoming plant residues with a predominance of fungi in the microbial cenosis. Thus, a direct relationship between the content of C-biomass and the resource of organic matter in permafrost soils confirms the well-known dependence of the growth activity of microorganisms on the presence of a substrate, which is confirmed by studies of the decomposition kinetics of exogenous organic substances. It is interesting to note that in some cases the biological activity of soils increases after freezing and subsequent thawing. These phenomena may be due to an increase in the amount of soluble and easily hydrolysable organic compounds in the soil during its cryogenic destruction, followed by an outbreak of microflora.

The correlation between the content of C-biomass and soil moisture in the forest cenosis is also worth noticing, it was (r=0.91) in the humus pocket and less close (r=0.69) in the enclosing horizon. This proves that moisture plays a large role in the accumulation of carbon stock in microbial biomass, and the enclosing horizons are strongly compacted according to the results of the study. As evidenced by the results of the analysis, which show low density in the humus pockets of burozem 0.93-1.40 g/cm3, in the enclosing horizon it increased and reached 1.36-1.52 g/cm3. The chernozem quasi-gley permafrost soils trend to show the same results. Its indices are respectively 1.05-1.28 g/cm3, 1.56-1.58 g/cm3.

4 CONCLUSION

Thus, it was found that the maximum amount of C-biomass was observed in the upper horizons and primarily depended on the content of organic carbon and soil moisture, as well as its density. The significant amount of plant litter organic substances entry stimulates the soil microflora. The carbon content of microbial biomass in cryogenic cracks of burozem and quasi-gley chernozem has higher indices comparing to the enclosing horizons. The average indices of C-biomass in the upper layer of the frost crack in the studied soils is quite high and evenly distributed along the entire length of the humus pocket, while in soil stratum at the same depths of C-biomass it is significantly reduced.

New additional information on the quantitative content of microbial carbon in the studied soils was obtained. Its value is comparable to those available in the world scientific literature.

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