Research on Organic Carbon Mineralization Characteristics of Dominant Grass Species in Typical Grasslands

Bo Cheng[1,2], Hu Liu[1,2], Ge Nan[1,2], Xiumin Tian[1,2] and Jian Wang[1,2,*]

[1]Yinshanbeilu Grassland Eco-Hydrology National Observation and Research Station, China Institute of Water Resources and Hydropower Research, Beijing, Beijing, 100038, China
[2]Institute of Water Resources for Pastoral Area Ministry of Water Resources, Hohhot, Inner Mongolia, 010020, China

*Corresponding author's e-mail: wangjian@iwhr.com

Abstract. In order to investigate the soil organic carbon mineralization characteristics of different dominant herbaceous plant species in typical grasslands, *Leymus chinensis*(L) was selected as the experimental site, *Stipa Krylovii Roshev*(S), *Artemisia frigida*(A), and *Agrophorn crispam Gaertn*(C) communities were selected as dominant species in the soil, and organic carbon mineralization cultivation experiments were conducted using soil without aboveground plants as a control. The results showed that the larger the soil particle size, the more significant the promotion of soil organic carbon mineralization effect, The results indicate that (>2mm) (297.71mg·kg^{-1})>(1mm>soil particle size<2mm)<(242.67mg · kg^{-1})>(0.25mm>soil particle size<1mm) (208.36mg·kg^{-1})>(soil particle size<0.25mm) (186.51mg·kg^{-1}), Among all treatments, the excitation effect of S was 70.73%, L was 58.05%, A was 33.73%, and C was 7.68%. Among all the treatments, only the cD group had an excitation effect of -3.93%.

Keywords: rganic carbon mineralization, Typical grasslands, Promotion effect

1 Introduction

Grassland ecosystem carbon storage accounts for 15.2% of terrestrial ecosystem carbon storage, playing a crucial role as a source, sink, and reservoir in the global carbon cycle. Soil organic matter mineralization is a process through which microorganisms decompose active substances and organic components in soil, releasing carbon dioxide[1]. It is an important process in soil organic carbon turnover. The soil organic matter mineralization process is complex and influenced by numerous factors[2]. Some research results indicate that factors affecting soil aggregates also have an impact on soil organic carbon mineralization, especially the particle size of aggregates. The content of soil organic carbon increases with the size of soil aggregates[3]. Other studies have found that the rate of soil mineralization is related to the content of organic carbon in soil, with higher organic carbon content leading to a faster mineralization rate. Some scholars have also

W. He et al. (eds.), *Proceedings of the 2024 10th International Conference on Advances in Energy Resources and Environment Engineering (ICAESEE 2024)*, Atlantis Highlights in Engineering 36,
https://doi.org/10.2991/978-94-6463-708-3_3

shown that rainfall intensity, grassland type, grassland management methods, and soil physicochemical properties significantly affect soil organic carbon density, thereby influencing soil organic carbon mineralization[4-5]. Currently, research on soil organic matter mineralization mainly focuses on the impact of soil conditions, climatic conditions, and exogenous additives on soil organic matter mineralization, with a relatively large research scale[6]. There is less research on the impact of different aggregate sizes under different plant species on soil organic matter mineralization rates at a small scale. This experiment samples soil under different dominant species in typical grasslands, brings back soil particle size classification to the laboratory, conducts indoor constant temperature incubation experiments, and compares it with soil without plants, aiming to provide basic data for the carbon cycle in typical grassland soils. This is of great significance for regional ecological environment protection and the formulation of grassland management methods.

2 Materials and Methods

2.1 Experimental Design

2.1.1. Soil Sample Collection.

The experiment was carried out in the typical grassland area. A test plot (100m*100m) with flat terrain and uniform vegetation distribution was selected. The dominant species in the plot were mainly Leymus chinensis, Stipa krylovii, Artemisia frigida and Agropyron (Fig.1). Soil samples were collected in August 2021 (nearly a week without precipitation), and aboveground plants (CK) and Leymus chinensis were selected in the sample plot with a soil sampler with a diameter of 5cm, The soil 0-30 cm under L, C, S and A(As shown in Figure 1) was taken as the test sample. After taking out the soil, it passed a 2mm soil sieve to remove litter, animal residues and other impurities, and then put it into a fresh-keeping bag, put it into the incubator (4℃) and quickly bring it back to the laboratory. After extraction, some soil samples were placed in a ventilated environment without direct sunlight until their weight remained unchanged. Subsequently, the soil samples underwent physical and chemical property testing. The other part of the soil samples were stored in the refrigerator at -4 ℃ to prepare for the next stage of soil aggregate classification experiment and mineralization culture experiment.

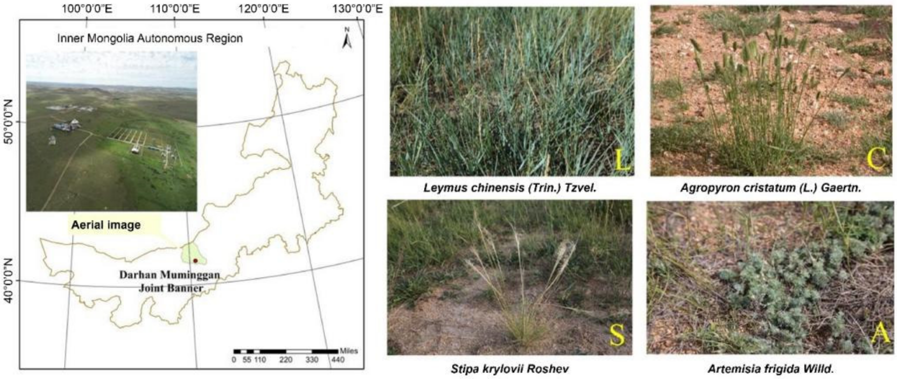

Fig. 1. Geographical location map of sampling area

2.1.2. Aggregate Classification.

The classification of soil aggregates adopts the optimum humidity dry screening method. First, the soil collected under the four vegetation types is put into a 25 ℃ constant temperature incubator for drying. After 2h, the soil is taken out, and the soil blocks in the soil are broken into about 2.5mm soil samples for standby. Then, the soil samples taken from the four vegetation types were successively passed through 2mm soil sieve, 1.5mm soil sieve, 1mm soil sieve, and 0.25mm soil sieve. The soil left in the soil sieve after passing the sieve constituted four soil particle size test samples (soil particle size>2mm (a), 1mm>soil particle size<2mm (b), 0.25mm>soil particle size<1mm, and soil particle size<0.25mm).

2.1.3. Mineralization Culture Experiments.

The organic carbon mineralization culture test was carried out in a constant temperature incubator. First, 20g of soil samples were weighed and evenly spread in a 200ml flask, and then 5g of quartz sand was added to each flask to increase the gap between the soils and enhance the reaction efficiency. Then, the soil moisture content of the test soil was adjusted to 55% of the maximum soil moisture capacity by spraying water in a watering can, and then placed in the dark for constant temperature culture at 25 ℃ for 7 days.

After 7 days of culture, Put it into the absorption cup, and put 10ml of 0.5 $mol \cdot L^{-1}$ NaOH solution , seal the mouth of the cuvette with a sealer, and then continue to culture in the incubator at 25 ℃ without light. Wait for days 2, 4, 6, 9, 12, 15, 20, 25, 30, 36, 42, 46, 56, 66 and 80. After taking out, titrate the solution in the absorbing cup with 0.5 $mol \cdot L^{-1}$ HCl standard solution, and count the consumed the amount of CO_2 released by each sample through the mineralization of organic carbon was calculated by HCl standard solution.

2.2 Data Analysis

Excel 2010 software was used to record and analyze the basic data, and origin 2019 software was used to calculate the histogram, bar graph and first-order dynamics fitting equation. The inter group differences of SOC mineralization were analyzed by one-way variance method, and then the test results were tested by the least significant difference (LSD) method.

3 Result Analysis

3.1 The Influence of Different Plant and Particle Size Conditions On SOC

During the entire mineralization cultivation process (80 days), the dynamic changes in SOC mineralization rate of soil aggregates of different particle sizes under different plant species showed a similar trend (Figure 2-a), with a rapid decrease in the early stage of cultivation (2-9 days), a slight fluctuation followed by a slow decrease in the middle stage of cultivation (10-36 days), and a stable trend in the late stage of cultivation (37-80 days). The mineralization rate of soil aggregates with different particle sizes generally shows a>b>c>d. The SOC mineralization rate of soil aggregates with plants on the ground is higher than that of soil samples without plants. Among all the samples, S. krylovii Roshev (S) had the highest SOC mineralization rate (14.49 $mg^{-1}kg^{-1}d$), while cristam (L.) Gaertn (C) had the lowest SOC mineralization rate, only 8.16 $mg^{-1}kg^{-1}d$, which is S The mineralization rate of Krylovii Roshev (S) SOC is 56.31%.

According to Figure 2-b, after 80 days of cultivation, The cumulative SOC mineralization rate of aL is the highest among all treatments. The SOC mineralization of soil samples with aboveground plants was higher than that of soil samples without aboveground plants. Among all treatments involving different dominant species and soil particle sizes, the results showed that (＞2mm)(297.71$mg\cdot kg^{-1}$)> (1mm>soil particle size<2mm) ＜ (242.67$mg\cdot kg^{-1}$)>(0.25mm>soil particle size<1mm) (208.36$mg\cdot kg^{-1}$)>(soil particle size<0.25mm) (186.51$mg\cdot kg^{-1}$). Among all the experimental groups, the SOC accumulation of the al treatment was the highest, reaching 389.76$mg\cdot kg^{-1}$, dC minimum (165.04$mg\cdot kg^{-1}$).

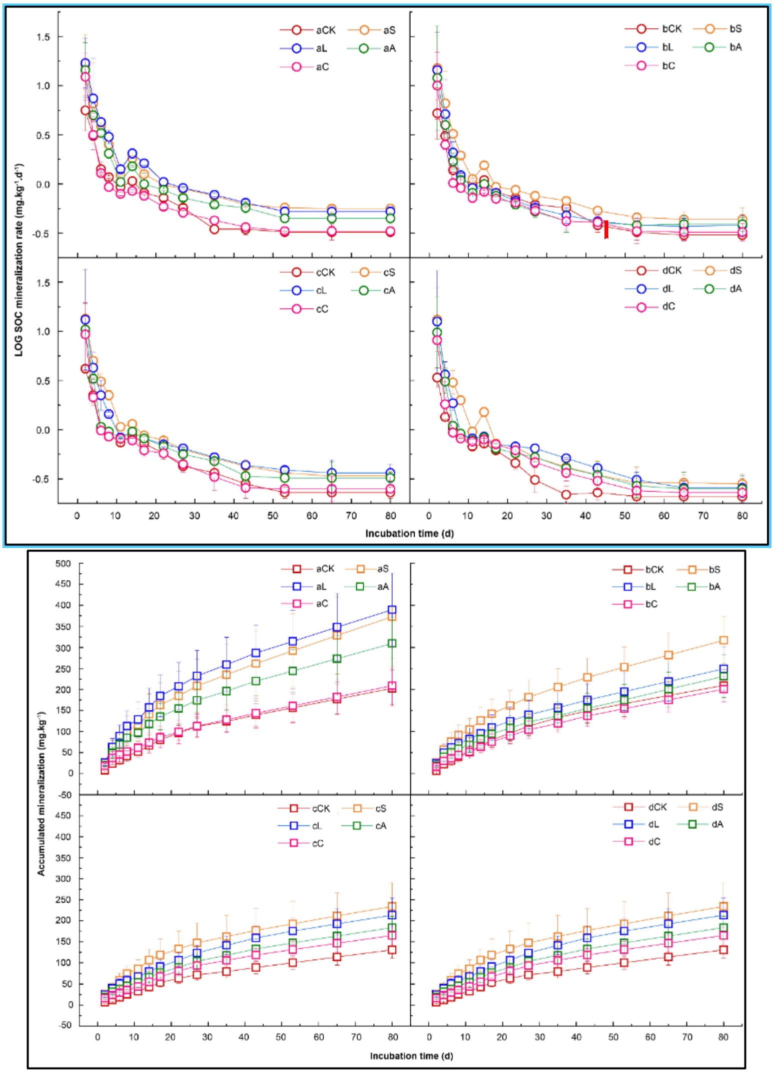

Fig. 2. SOC rates and cumulative mineralization in different experimental groups

3.2 Influence of Aboveground Plant Species on the PE On SOC Mineralization

In this study, the root exudates of different plants can be considered as exogenous organic matter. The stimulating effects of exogenous substances on soil organic carbon mineralization can be divided into positive and negative effects. Among all treatments, the excitation effect of *S. krylovii Roshev* was 70.73%, *L. chinensis* was 58.05%, *A. frigida* was 33.73%, and *A. cristam (L.) Gaertn* was 7.68%. Among all the treatments, only the cD group had an excitation effect of -3.93% (Fig.3).

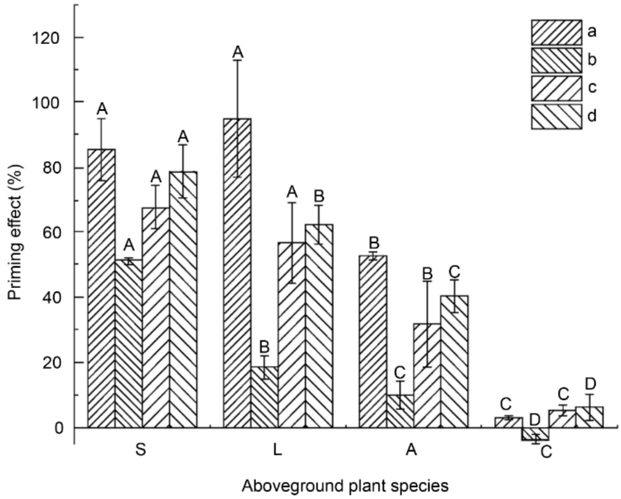

Fig. 3. SOC activation effects in different experimental groups

4 Conclusion

The increase in plant coverage on the ground slows down soil erosion, allowing the soil to better retain nutrients and moisture, thereby providing better conditions for the mineralization of soil organic carbon. Studies have shown that as the vegetation coverage on the ground increases, the soil moisture content continues to increase, resulting in an increasing proportion of clay particles in the soil and a continuous decrease in sand content[7]. This increases the water stability of soil aggregates and provides better conditions for soil organic matter mineralization. This is consistent with the experimental results and also indicates that aboveground plants can significantly increase the SOC mineralization rate and cumulative mineralization amount of soil aggregates at various particle sizes in typical grasslands.

During the growth process, different plant communities have varying effects on soil microbial communities due to their root structures, litter types, and secretions. This results in significant differences in soil moisture content, soil nutrients, and soil organic carbon content among different plant communities in the same region, leading to significant variations in soil aggregates[8]. Numerous studies both domestically and internationally have shown that soil aggregates play a crucial role in soil organic matter mineralization[9-10]. In the study of salt ponds in Ningxia, enclosure promoted the restoration of grassland vegetation, enhanced the stability of soil aggregates, and thus affected the rate of soil organic carbon mineralization. Some scholars have also found in their research on mineralization of soil aggregates that the mineralization rate of soil organic matter is directly proportional to the organic carbon content in soil aggregates. In addition, the particle size of soil aggregates is closely related to the rate and accumulation of SOC. Some scholars have found in their research that after long-term enclosure of grassland, the rate and accumulation of SOC in soil aggregates with a particle size of 2-2.25mm are the highest among all samples. This research result is similar to the pattern found in this study. This study found that at the same level of soil aggregates, the rate and accumulation of SOC in Sample L are the highest among all plants; when comparing the particle size longitudinally among all plant species with the same sample, the rate and mineralization of SOC increase with the increase of soil particle size (>2mm is the highest value).

References

1. Xu, L., Yu, G., He, N. (2019) Increased soil organic carbon storage in Chinese terrestrial ecosystems from the 1980s to the 2010s. Journal of Geographical Sciences. 29: 49-66.[CrossRef]
2. Feng, C. X., Godbold, D., et al. (2022). Temperature sensitivity of organic matter mineralization as affected by soil edaphic properties and substrate quality. CATENA.112: 127–139.[CrossRef]
3. Parkatti, V. P., Tahvonen, O., Viskari, T. , et al. (2023). Including soil alters the optimization of forestry with carbon sinks. Canadian Journal of Forest Research.[CrossRef]
4. Paulus, E. L., & Vitousek, P. M. (2024). Manganese and soil organic carbon stability on a hawaiian grassland rainfall gradient. Soil Biology and Biochemistry,109481.[CrossRef]
5. Hao, X., Yang, J., Dong, S., He, F. , et al. (2023). The influence of grazing intensity on soil organic carbon storage in grassland of china: a meta-analysis. The Science of the total environment, 924, 171439.[CrossRef]
6. Badewa, E. A., Yeung, C. C., Whalen, J. K. O. M. (2023). Compost and biosolids increase long-term soil organic carbon stocks. Canadian Journal of Soil Science, 103(3), 483-492.[CrossRef]
7. Hien, P. D., Hai, P. S., Thin, T. Q. , et al. (2023). Modeling organic carbon bound in clay and silt particles in highly weathered lateritic soils of the central highlands of vietnam. Modeling Earth Systems and Environment. 294: 63–69. [CrossRef]
8. Liang, G., Stark, J., & Waring, B. G. (2023). Mineral reactivity determines root effects on soil organic carbon. Nature Communications, 14(1).[CrossRef]
9. Wang, W., Zhang, H., Vinay, N., et al. (2023). Microbial functional genes within soil aggregates drive organic carbon mineralization under contrasting tillage practices. Land Degradation and Development.17: 34–38.[CrossRef]
10. Li, F., Zhou, J., & Peng, W. H. (2023). Effect of biochar and earthworms on mineralization of organic matter in top soil and deep soil. Environmental engineering science, 40(8), 340-346.[CrossRef]