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Effects of biotic and abiotic factors on soil organic matter mineralization: Experiments and structural modeling analysis

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ABSTRACT

Soil organic matter (SOM) mineralization is affected by various abiotic and biotic factors, as well as the input of exogenous organic substances. Our previous studies have shown that SOM mineralization in flooded rice paddies is lower than that in adjacent upland soils in subtropical agro-ecosystems. However, the main factors contributing to the differences in SOM mineralization remain unclear. To compare the effects of biotic and abiotic factors on SOM mineralization between upland and paddy soils, we incubated upland and paddy (flooded) soils with three low molecular weight organic substances (LMWOS, i.e., glucose, acetic acid, or oxalic acid) for 30 days under field conditions. Generally, the average CO_2 efflux from upland soil was higher than that in paddy soil with the same LMWOS addition. The total content of phospholipid fatty acids (PLFAs) in paddy soil was 2–5 times higher than that of upland soil, irrespective of the LMWOS added. Redundancy analyses indicated that microbial community composition was influenced mainly by the low redox potential (Eh) and dissolved organic carbon in paddy soil. Structural equation modeling revealed that, among abiotic factors, temperature exerted indirect effects on SOM mineralization by influencing biotic factors in both soils; Eh has a positive and direct effect on SOM mineralization in paddy soil. In terms of biotic factors, SOM mineralization in upland soil was mainly regulated by the quantity of bacteria. In paddy soil, SOM mineralization was largely influenced by the ratio of fungal to bacterial PLFAs and peroxidase activity.

1. Introduction

Soil organic matter (SOM) is particularly important for sustaining the productivity of agro-ecosystems [1], in which mineralization of SOM is regarded as an important process in regulating global C cycling [2]. Abiotic factors such as climate (e.g., temperature and precipitation) and soil physicochemical properties (e.g., soil moisture and aeration, etc.) are typically identified as key predictors of SOM mineralization. An exponential relationship has been observed between SOM mineralization and temperature [3–6]. Furthermore, changes in soil moisture can alter the temperature sensitivity of SOM mineralization [7]. High soil moisture levels limit oxygen availability, and thus contribute to a decrease in redox conditions [8], which leads to a decrease in SOM mineralization via effects on microbial activity and metabolism [9]. Biotic factors such as exoenzyme activity, microbial composition, and microbial activity also play important roles in regulating SOM mineralization [10,11]. Exoenzyme activity influences SOM mineralization by regulating soil biochemical processes, including the formation and decomposition of labile organic substances. Bacteria and fungi generally comprise 90% of the total soil microbial biomass, and are responsible for the majority of SOM mineralization [12]. The biomass and ratio of bacteria and fungi are correlated with the microbial metabolic quotient, which reflects the carbon-use efficiency [13,14]. Overall, the exoenzymes are responsible for the hydrolysis and humification of SOM [15], whereas microbial composition and microbial activity determine the rate of carbon loss from the soil. To date, however, few studies have simultaneously considered both abiotic and biotic factors as predictors of SOM mineralization. Therefore, there is an urgent need to determine the direct and indirect contributions of individual factors and the key drivers of SOM mineralization.

Soils contain many types of LMWOS with distinct properties that can be utilized by microorganisms, e.g., glucose, acetic acid, and oxalic

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