



Structural evidence for soil organic matter turnover following glucose addition and microbial controls over soil carbon change at different horizons of a Mollisol



Yue-Ling Zhang^{a,1}, Shui-Hong Yao^{a,1}, Xiao-Yan Cao^c, Klaus Schmidt-Rohr^c, Daniel C. Olk^d,
Jing-Dong Mao^{e,*}, Bin Zhang^{a,b,*}

^a National Engineering Laboratory for Improving Fertility of Arable Soils, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, PR China

^b Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Harbin 150081, PR China

^c Department of Chemistry, Brandeis University, 415 South Street, Waltham, MA 02453, USA

^d USDA-ARS National Laboratory for Agriculture and the Environment, 1015 N. University Blvd, Ames, IA 50011, USA

^e Department of Chemistry and Biochemistry, Old Dominion University, 4541 Hampton Blvd, Norfolk, VA 23529, USA

ARTICLE INFO

Keywords:

Soil carbon sequestration
Soil organic matter turnover
Microbial communities
Carbon isotopes
Nuclear magnetic resonance (NMR)
spectroscopy

ABSTRACT

Soil organic matter (SOM) in subsoils stores more than half of terrestrial organic carbon (C), and may sequester more C with increasing organic input due to its low C content (or high mineral reactivity) and high chemical stability. Organic inputs can stimulate microbial decomposition of native SOM (known as the priming effect), while being microbially decomposed and transformed into SOM. Yet, microbial controls over these processes and their influence on soil carbon change in soil profile remain elusive because of technical challenge to separate them. We overcame this challenge by employing a novel approach of combining ¹³C and ¹²C isotopes with quantitative solid-state ¹³C nuclear magnetic resonance (NMR). We used soil samples taken from three soil horizons in a Mollisol profile that dominated with fused-ring aromatics for a 43-day incubation. The signal intensities of the most dominant fused-ring aromatics and nonpolar alkyl groups were reduced due to the priming effect following the addition of ¹²C enriched glucose. Those signal intensities of O-alkyl and nonpolar alkyl groups increased in SOM spectra following the addition of ¹³C-labeled glucose, demonstrating accumulation of glucose and microbial residues. With the increasing glucose concentration, priming effect estimated using isotopic method and the magnitudes of signal loss estimated using ¹³C NMR both increased as exemplified for the Ap horizon soil. However, soil organic C content increased only when the added glucose concentration was beyond a previously non-quantified priming saturation threshold (between 36.0 and 100.0 g glucose-C kg⁻¹ SOM-C). The increase of soil organic C was larger in the subsoils than in the topsoil due to lower microbial biomass, higher microbial growth efficiency (MGE) and mineral reactivity, which were related to the reduced priming effect and enhanced accumulation of microbial and glucose residues in the subsoils. The higher MGE in the subsoils agreed with stronger shifts of microbial community composition, characterized by phosphorous lipid fatty acid profiling, with changing glucose concentration during the incubation. Our findings highlighted the importance of priming saturation threshold, microbial mediation and mineral reactivity, but not SOM recalcitrance, in controlling the dynamics of SOM. Our study provided a novel approach to quantify these parameters and understand the controlling factors in relation to different plant types and soil types.

1. Introduction

Soil organic matter (SOM) contains more carbon (C) than plant

biomass and atmospheric CO₂ combined, and more than half of soil C is stored in subsoils down to 2 m (Jobbágy and Jackson, 2000). Even minor changes of soil C may have significant implications for the

* Corresponding author. National Engineering Laboratory for Improving Fertility of Arable Soils, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, PR China.

** Corresponding author.

E-mail addresses: jmao@odu.edu (J.-D. Mao), zhangbin01@caas.cn (B. Zhang).

¹ These authors contributed equally to this work.