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PNNL-34898

Worth More Dead than Alive? Quantifying Necromass Persistence for Terrestrial Carbon Storage

September 2023

Kaizad F. Patel

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Abstract

The continuous cycle of plant-associated microbial biomass growth, death, and decay provides a consistent supply of necromass-C throughout the rooting zone of the soil profile. These inputs are obviously important for resource allocation and soil quality, but microbial necromass-C may play a critical, but currently unknown, role in mitigating the impacts of climate change through atmospheric decarbonization. Microbial necromass is the largest terrestrial sink of persistent carbon in soils, thus its fate and preservation will have a major impact on global C budgets. Our current understanding of the ecosystem controls on necromass generation, biogeochemical transformation, and stabilization is lacking. The objective of this project is to explore the specific influence of rhizosphere and necromass inputs on soil carbon pools.

Summary

There has been much interest and discussion in increasing belowground C stocks to combat soil degradation, carbon loss, and rising atmospheric carbon dioxide levels. Researchers are increasingly looking to microbial necromass and MAOM as SOM pools to focus on, because of their persistence in soil. In order to increase belowground C accumulation, we need to ensure that inputs exceed consumption. Necromass stocks in soil reflect the balance between production and consumption, and stabilization plays an important role. Important factors to consider include: (a) microbial traits as they are related to different soil and plant types; (b) physicochemical controls on necromass stabilization, including organo-mineral interactions and occlusion within aggregates. As part of this work, we are developing a global database of soil necromass indices based on values published in the literature. We have over 2000 data points, and we will be publishing this in the near future, along with a “data descriptor” paper providing details on the database. We are also working on a perspectives article (to be published in the near future) highlighting the current state of soil microbial necromass research and knowledge gaps that need to be addressed.

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Acronyms and Abbreviations

SOM: soil organic matter

MAOM: mineral-associated organic matter

1.0 Introduction

Microbial necromass is an important component of soil organic matter (SOM), accounting for 30-80 % of SOM across different soil types and ecosystems (Liang et al. 2019; Angst et al. 2021; Miltner et al. 2012). There has been considerable interest in soil microbial necromass in the recently published literature, including numerous reviews (Kästner et al. 2021; Camenzind et al. 2023; Wu et al. 2023; Cao et al. 2023), meta-analyses (Zhou et al. 2023; Ni et al. 2020; Wang et al. 2021; J. Hu et al. 2023; Zhang et al. 2023), and primary research articles (Buckeridge et al. 2020; Warren 2022; Cai et al. 2023). Given the strong contribution of microbial necromass to SOM, it is important to understand the pathways of formation, consumption, and stabilization of microbial necromass, including turnover and implications for soil carbon storage. This wealth of recent interest provokes new thinking about microbial necromass and soil carbon and highlights key knowledge gaps that must be addressed in order to understand formation and stabilization of soil necromass – i.e., understanding turnover processes and mechanisms, and not just stocks.

1.1 Stability and turnover of microbial necromass

Microbial residues are primarily recalcitrant in soil as proteins and lipids (Angst et al. 2021). Amino sugars such as glucosamine, galactosamine, and muramic acid are decomposition products of cell wall components peptidoglycan and chitin, and are more resistant to decomposition and therefore accumulate in soils during microbial decomposition (Kögel-Knabner 2002). These amino sugars therefore can serve as microbial (bacterial and fungal) biomarkers, formed as decomposition products of microbial cell walls. Many studies have tried to quantify necromass based on amino sugar concentrations in soil (glucosamine as proxy for fungal necromass and muramic acid as a proxy for bacterial necromass) (Liang et al. 2019). More recently, techniques like stable isotope labelling (Throckmorton et al. 2015; Warren 2022), pool dilution (Y. Hu et al. 2018), and stable isotope probing (Dong et al. 2021) have been used to study the fate of microbial necromass.

There has been much interest and discussion in increasing belowground C stocks to combat soil degradation, carbon loss, and rising atmospheric carbon dioxide levels. Researchers are increasingly looking to microbial necromass and MAOM as SOM pools to focus on, because of their persistence in soil (Georgiou et al. 2022). In order to increase belowground C accumulation, we need to ensure that inputs exceed consumption. Necromass stocks in soil reflect the balance between production and consumption, and stabilization plays an important role. Important factors to consider include: (a) microbial traits as they are related to different soil and plant types; (b) physicochemical controls on necromass stabilization, including organo-mineral interactions and occlusion within aggregates. As part of this work, we are developing a global database of soil necromass indices based on values published in the literature. We have over 2000 data points, and we will be publishing this in the near future, along with a “data descriptor” paper providing details on the database. We are also working on a perspectives article (to be published in the near future) highlighting the current state of soil microbial necromass research and knowledge gaps that need to be addressed.

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