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Plant carbon inputs through shoot, root, and mycorrhizal pathways affect soil organic carbon turnover differently

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ABSTRACT

Plant carbon (C) inputs via shoot, roots, and the associated mycorrhizal fungi are vital drivers of soil organic C (SOC) stock and turnover. Both the amounts and proportions of plant C inputs to the soil through these pathways can be affected by soil fertility. Yet, we know little about how divergent pathways of plant C inputs contribute to SOC cycling under different soil fertility. By growing the C4 grass *Cleistogenes squarrosa* in C3 soils, we quantified the contributions of shoot, roots, and arbuscular mycorrhizal fungi (AMF) to SOC turnover with different fertility in a temperate grassland. Our four-year field experiment showed that soils with higher fertility sequestered more shoot-, root- and AMF-derived C, which were mainly driven by greater soil microbial biomass. Irrespective of soil fertility, roots contributed the most (44%) to new SOC formation, while shoot (28%) and AMF (28%) exerted similar but lower contributions. We found that the positive priming effects induced by roots and AMF were greater in more fertile soils, which were primarily associated with more root- and AMF-derived C, respectively. Across all the soil fertility levels, root pathway had an equal impact on new SOC accumulation and native SOC losses via priming effects, and thus caused no net SOC changes. However, the priming effect induced by AMF pathway was 60% higher than the root pathway across treatments. The disproportionately large priming effects relative to new SOC accumulation induced by AMF led to net SOC losses, especially in soils with higher fertility. Overall, we demonstrated that plant C inputs through shoot, root, and mycorrhizal pathways have differential impacts on SOC turnover. Our quantitative estimation should be valuable for more accurately modeling how much plant-derived C can be sequestered in the soils and advancing our understanding of future SOC dynamics under global changes.

1. Introduction

Soil organic carbon (SOC) is mainly derived from plant C inputs through shoot, roots, or the associated mycorrhizal fungi (Jackson et al., 2017). Compared to shoot C inputs, a certain fraction of which are lost during their travel from litter layer to mineral soil, C inputs via root or mycorrhizal pathway have more chances to physicochemically interact with soil matrix and are more likely retained in soil (Rasse et al., 2005; Sokol et al., 2019a). Therefore, plant C inputs through different pathways may induce diverse effects on SOC accumulation and turnover (Schmidt et al., 2011; Jackson et al., 2017; Frey, 2019).

Soil fertility sustains the primary productivity of plants and is a crucial variable regulating photosynthate allocation among plant organs and the associated mycorrhizal fungi (McConnaughay and Coleman, 1999; Chapin et al., 2011). Global changes, especially land-use changes, have triggered grassland degradation and reduced soil fertility (Sneath, 1998; Gibson, 2009). Restoration of degraded grasslands by gaining SOC has become a part of the global C agenda for mitigating climate change, and is also considered as a contributor to improving soil health and ecosystem functioning (Smith, 2014; Mbow et al., 2017). To better understand SOC sequestration in degraded grasslands, it is essential to quantify the contributions of different plant C input pathways to SOC turnover (Jackson et al., 2017; Frey, 2019), and to explore how they are affected by soil fertility.

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