

Sprout density-induced tree species diversity enhances soil organic carbon accrual and microbial C-fixation during subtropical plantation regeneration

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Abstract: Forest structure can influence soil microbial communities and soil organic carbon (SOC) sequestration. However, soil microbes and, especially, microbial C-fixation pathways, respond to changes in stand structure during forest succession, and the mechanisms underlying their effects on SOC accumulation have not been fully explored. Here, we conducted an experiment using different retained sprout densities in 30-year natural regeneration stands of Chinese fir (*Cunninghamia lanceolata*) with different initial retained sprout densities. We investigated variations along decreased sprout density in plant diversity (tree species, structural, and functional diversities) and SOC fractions (particulate organic carbon and mineral-associated organic carbon), microbial diversity and CO₂ fixation pathways using metagenomic sequencing. Tree species, structural, and functional diversities, and the concentration of SOC fractions increased with decreasing sprout density. Fungal diversity increased with reduced sprout density, but bacterial diversity did not. The composition of bacterial and fungal communities differed among the different sprout density treatments because changes in plant diversity resulted in different litter inputs and root biomass, whereas variation patterns in microbial C-fixation pathways did not change. Most microbial C-fixation pathway abundances significantly increased with decreasing sprout density, and the reductive citrate cycle, Dicarboxylate-hydroxybutyrate cycle, and 3-hydroxy-propionate bicycle were the key C-fixation pathways in all sprout density treatments, indicating that low-energy-consumption anaerobic pathways exerted a great impact on soil CO₂ fixation during subtropical plantation succession. Majority of CO₂ fixation genes associated with microbial species were from the phyla Pseudomonadota and Actinomycetota (~98%). Although the microbial composition (~60%) dominated SOC fraction variations, especially those affected by fungi, microbial C fixation (~40%) also played a key role in SOC accumulation. These findings highlight that sprout density-induced plant diversity greatly alters microbial diversity and C-fixation capacity and enhances SOC accumulation. Our study provides new insights into above- and belowground biodiversity jointly regulating SOC sequestration during forest succession.

Key words: plant diversity; soil organic carbon fractions; CO₂ fixation pathways; microbial communities; forest carbon sequestration