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Non-photosynthetic CO₂ fixation in an agricultural soil: Roles of plant-soil interactions, soil depth, pre-incubation, and fertilization

16. Biogeochemistry of Soil Carbon Stabilization

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Abstract text

Soil organic carbon (SOC) is central to soil fertility and climate regulation, yet the pathways contributing to its formation remain incompletely resolved. Non-photosynthetic CO₂ fixation represents a poorly constrained mechanism for incorporating carbon (C) into SOC, particularly in managed agricultural systems. Its relevance in croplands and the sensitivity of its quantification to experimental procedures remain largely unexplored.

We examined non-photosynthetic CO₂ fixation in Phaeozems at the long-term research station in Bad Lauchstädt, Germany, comparing soils from a bare-fallow plot maintained without vegetation for several decades with soils from an adjacent agricultural plot under crop rotation and organic fertilization. Soil samples were collected along a depth gradient, including topsoil, subsoil, and rhizosphere soil. In laboratory incubations, soils were exposed to ¹³C-labelled CO₂ either immediately after sampling or following a pre-incubation period. Subsoil measurements were corrected for abiotic carbonate formation, while carbonate contributions in topsoil were negligible. In addition, ammonium or nitrate was added to a subset of samples to assess whether nitrogen availability or form regulates non-photosynthetic CO₂ fixation.

Non-photosynthetic CO₂ fixation was consistently higher in SOC-poor subsoils than in SOC-rich topsoils and rhizosphere soils, indicating that fixation is promoted under microbial carbon limitation in the otherwise nutrient-rich soil. Fixation rates declined strongly after pre-incubation, particularly in subsoil, demonstrating that commonly applied laboratory procedures can substantially underestimate this process. In contrast, nitrogen additions did not systematically alter non-photosynthetic CO₂ fixation, suggesting that carbon rather than nitrogen availability constrained this pathway in the studied soil. Comparison with soil respiration indicated that non-photosynthetic CO₂ fixation can offset a measurable fraction of microbial CO₂ release and thus influence net soil carbon balances.

Our results highlight non-photosynthetic CO₂ fixation as a potentially important and underappreciated source of SOC in agricultural subsoils and underscore the need to account for methodological effects when assessing soil carbon stabilization processes.