The Potential Bioavailability of Mineral-Associated Organic Nitrogen in the Rhizosphere

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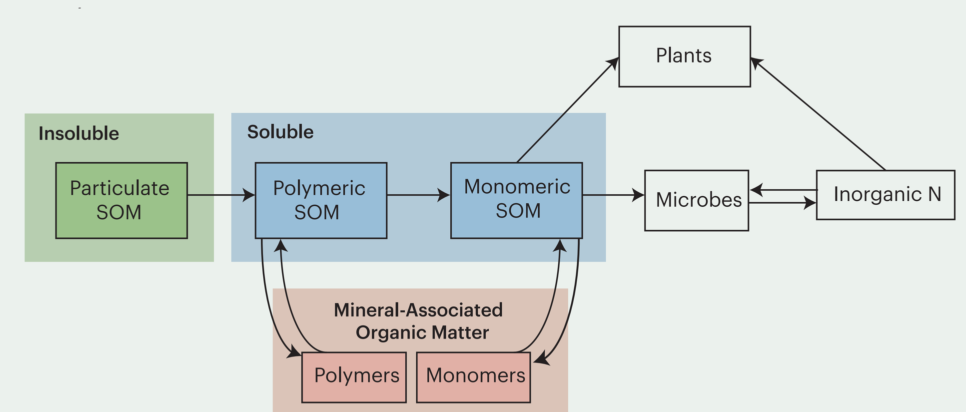
Introduction

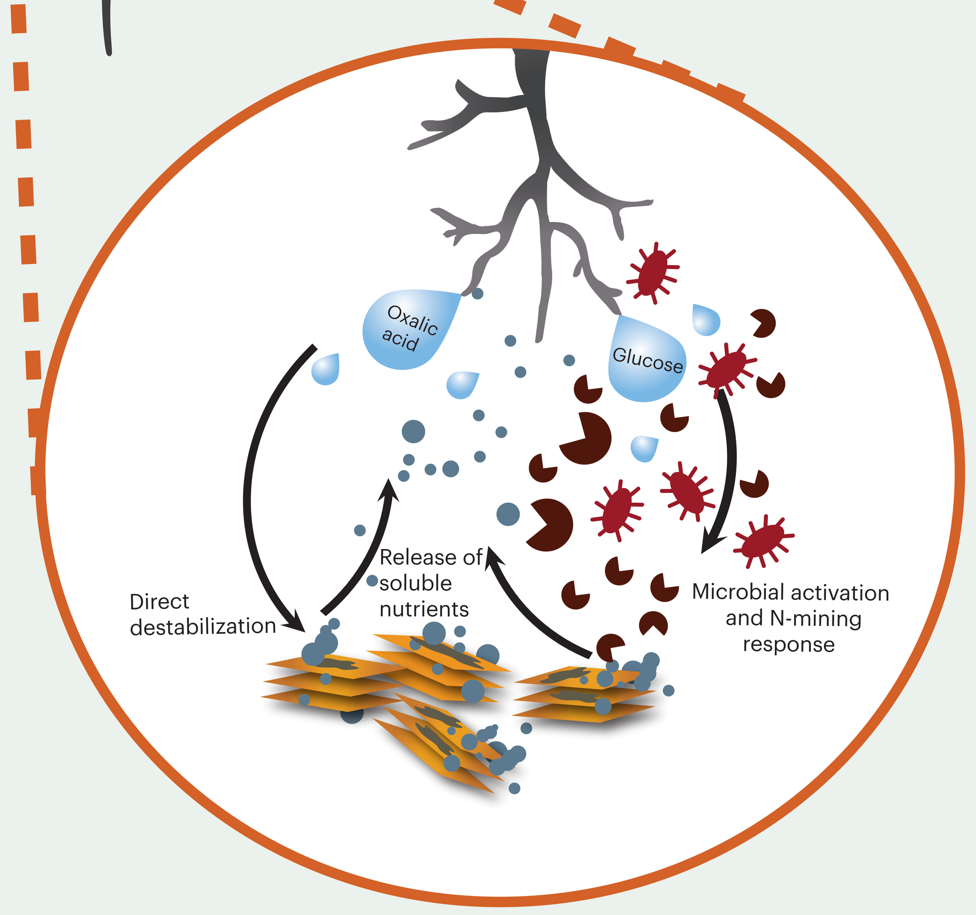
Despite decades of research progress, ecologists are still debating which pools and fluxes provide nitrogen (N) to plants and soil microbes across different ecosystems. Depolymerization of soil organic matter is recognized as the rate-limiting step in the production of bioavailable N; however, in many mineral soils, detrital polymers constitute a minor fraction of total soil organic N. The majority of organic N is associated with clay-sized particles where physicochemical interactions may limit the accessibility of N-containing compounds found therein. Although mineral-associated organic matter (MAOM) is considered a critical reservoir of soil N, a growing body of research now points to the dynamic nature of mineral-organic associations and their potential for destabilization.

In a new conceptual framework, we propose that mineral-associated organic matter (MAOM) is an overlooked and important mediator of bioavailable N, especially in the rhizosphere.

While physicochemical interactions with clays protect MAOM from decomposition, we argue that several biochemical strategies enable plants and microbes to disrupt mineral-organic interactions and effectively access MAOM. We hypothesize that root-deposited exudates enhance the direct and indirect (via microbial communities) destabilization, solubilization, and subsequent bioavailability of N from MAOM.



Conceptual model illustrating the role of mineral-associated organic matter (MAOM) and its continuous and dynamic exchange with the soil organic matter and monomer pools (an extension of the Schimel & Bennett (2004) model of soil N cycling).



Hypothesized mechanisms of MAOM-N destabilization:

Direct pathway (via organic acids):

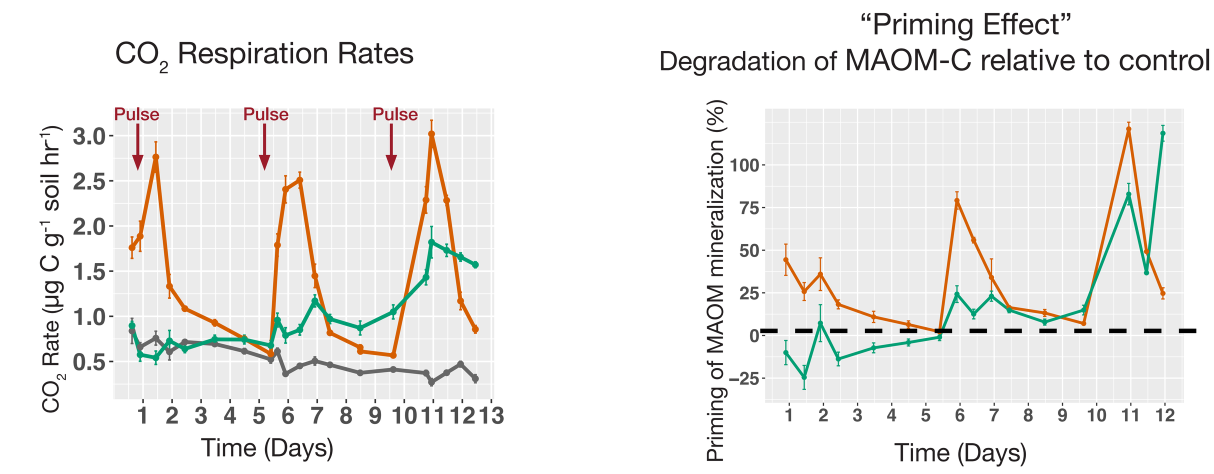
Organic acids interfere with metal-organic bonds and release formerly mineral-protected compounds into the soil solution.

Indirect pathway (via microbial community):

Microbes use root exudate C to grow and reproduce, which stimulates an N-mining response. Activated microbes will target the N-rich and low-molecular weight compounds that dominate MAOM.

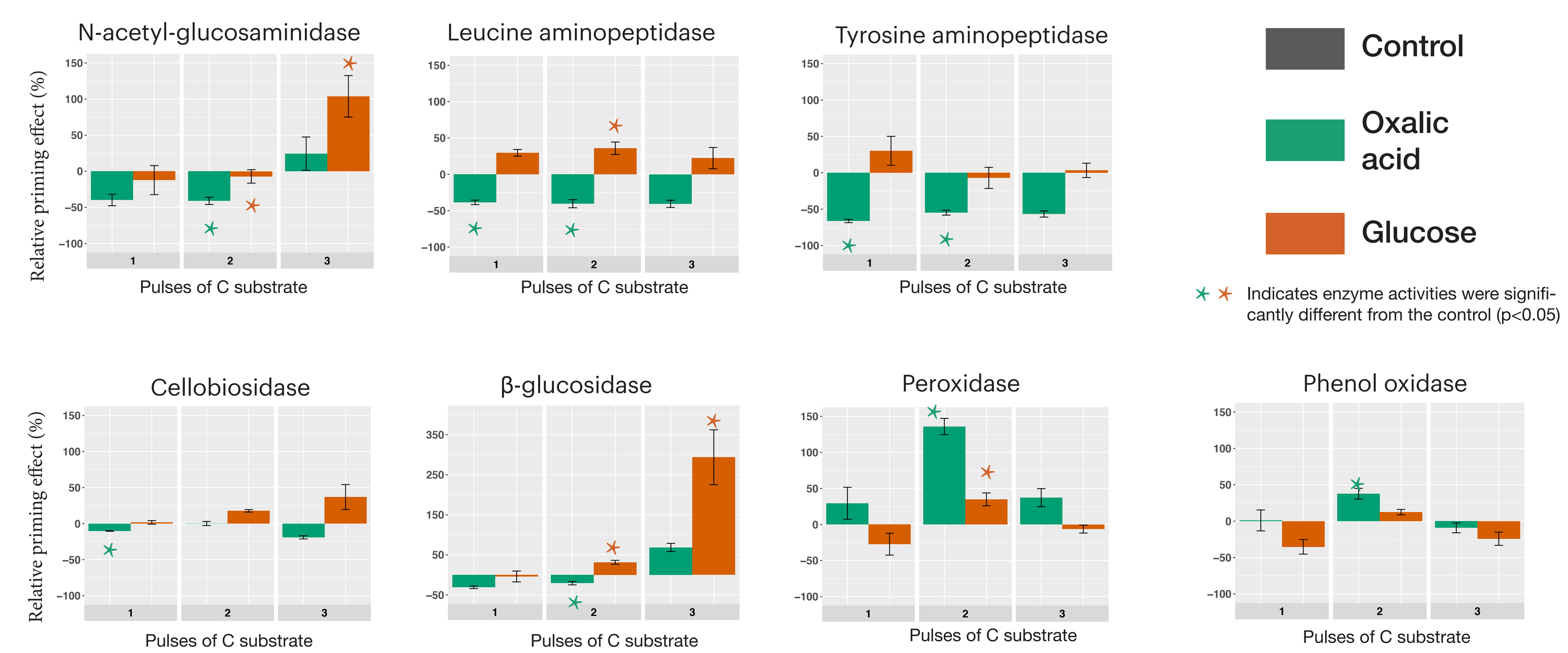
Results

Carbon substrates stimulate the degradation of MAOM-C

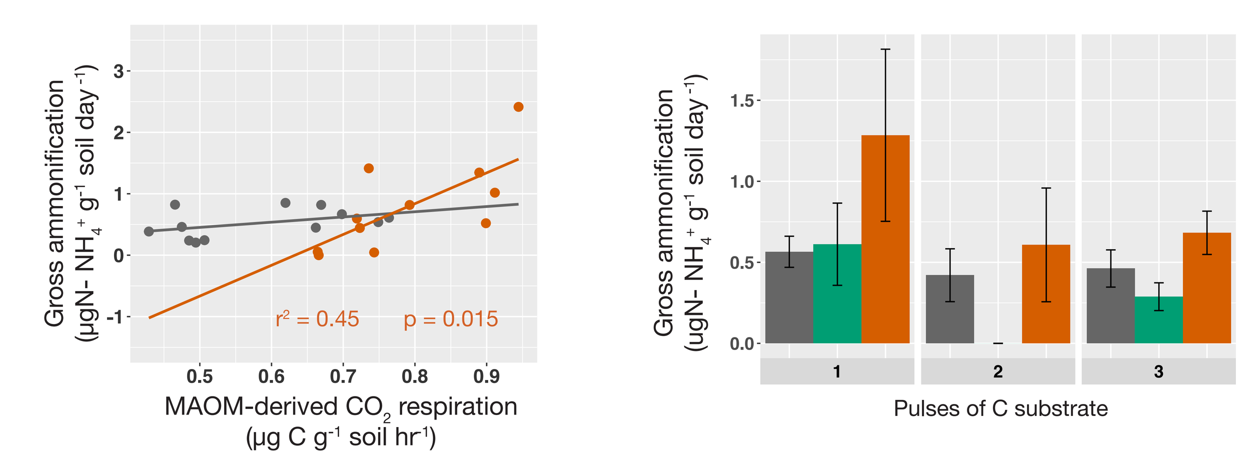


Both glucose and oxalic acid enhanced CO_2 respiration and the degradation of MAOM relative to the control ($p<.05$).

Carbon substrates stimulate C-acquiring, N-acquiring and oxidative enzyme activites



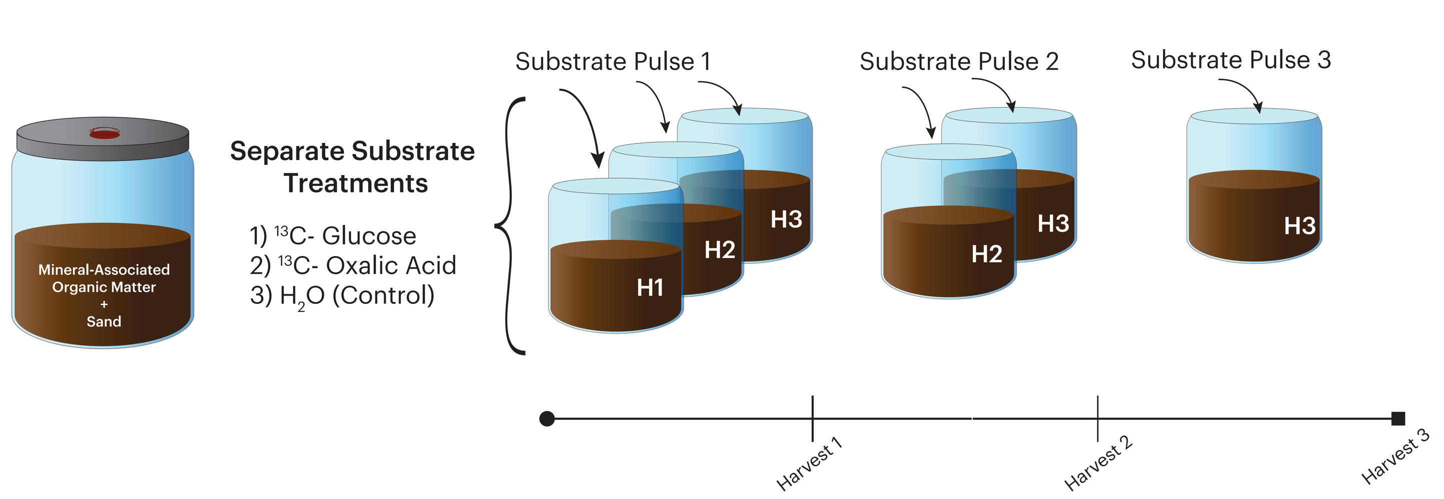
Gross N ammonification positively associated with priming of MAOM-C



Gross ammonium production was positively associated with MAOM-derived CO_2 respiration.

No significant differences between the control and C substrate treatments.

Laboratory incubation of mineral-associated organic matter



- Mineral-associated organic matter (<20µm) isolated from agricultural soils
- MAOM diluted with sterile sand, brought to ideal moisture conditions, and treated with 3 separate C substrates
- 15-day incubation with 3 separate harvests corresponding to number of C pulses

Measurements:
CO^2 respiration, ^{13}C-CO_2, C-acquiring, N-acquiring and oxidative enzyme activities, gross

Next steps

Abitioc control with sterile MAOM + sand to assess the direct effect of C additions on MAOM destabilization; measure metals released into solution.

Evaluate the MAOM priming response across a range of soils that vary in mineralogical composition (e.g., kaolinitic vs. smectitic soils).

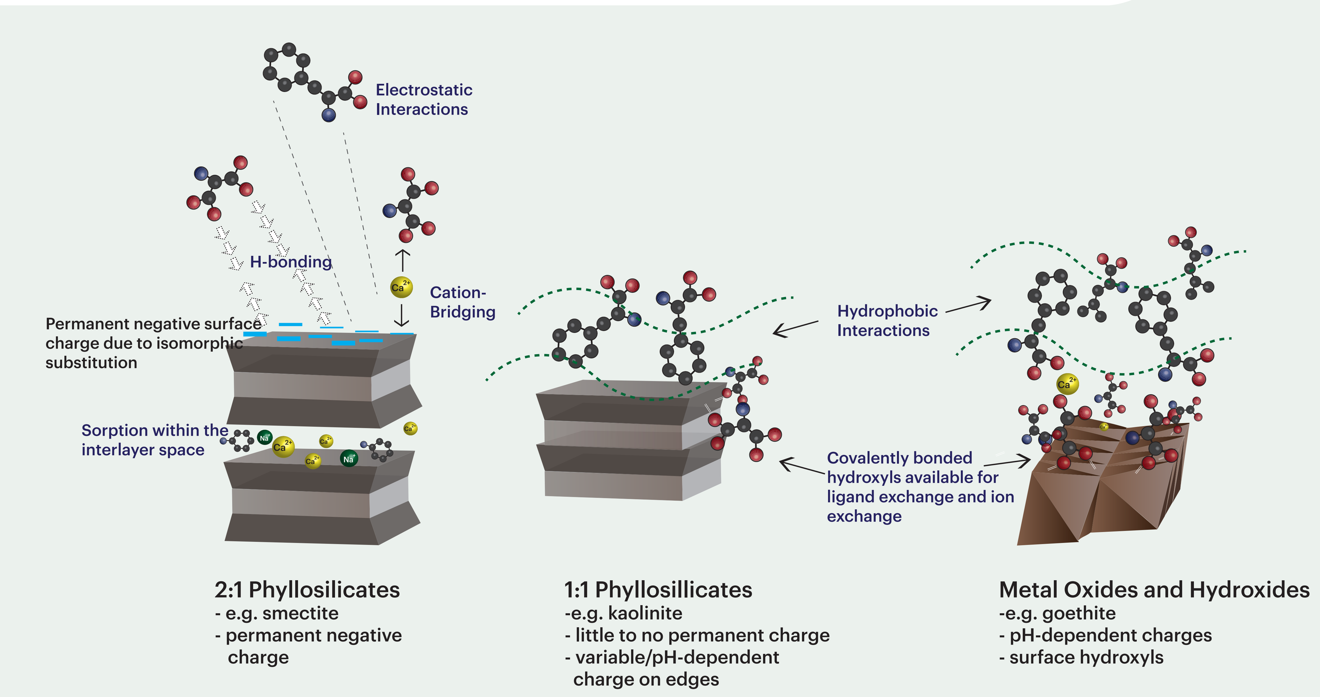


Illustration of variation in mineral-organic assoications across clay types.

Acknowledgments

This study was funded by a NSF Graduate Research Fellowship and the USDA National Institute of Food and Agriculture (grant number 2014-67019-21716).

References

Schimel JP, Bennett J (2004) Nitrogen mineralization: Challenges of a changing paradigm. Ecology 85:591–602. doi: 10.1890/03-8002