Rooting for C: How soil mineralogy shapes root exudates, microbes and C dynamics under phosphorus fertilization

For discussion, look for this face

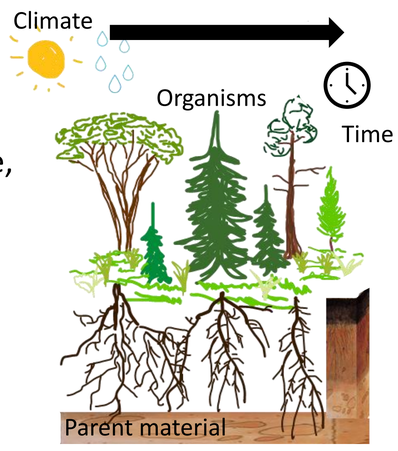
Sasha Pollet*[1], Jean-Thomas Cornelis[1], Chaoqun Wang[1], Thorsten Knipfer[1], Cindy Prescott[2], Amir Ahkami[3], Vimal Kumar Balasubramanian[3], Sophie Lehmann[3], Tanya Winkler[3], Tamas Varga[3], Kylee Tate[3], Young-Mo Kim[3], Guillaume Lobet[4]

[1] Faculty of Land and Food System, The University of British Columbia, Canada; [2] Faculty of Forestry, The University of British Columbia, Canada; [3] Pacific Northwest National Laboratory, USA; [4] Earth and Life Institute/Agronomy, UCLouvain, Belgium

Context

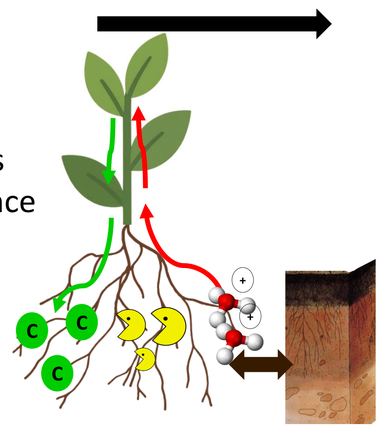
Ecosystem

Soil-forming processes vary over time and space, shaping key soil physicochemical properties (elemental stoichiometry, nutrient availability, pH, OM, and mineralogy, etc).



Soil-Plant-Microbes

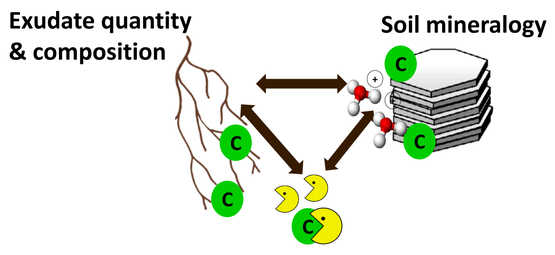
Soil properties influence nutrient availability, plants nutrient status, long-distance shoot–root signaling, root traits, exudation, and microbial communities.



Rhizosphere

Carbon dynamics depends on exudate profile, microbial communities and soil mineralogy.

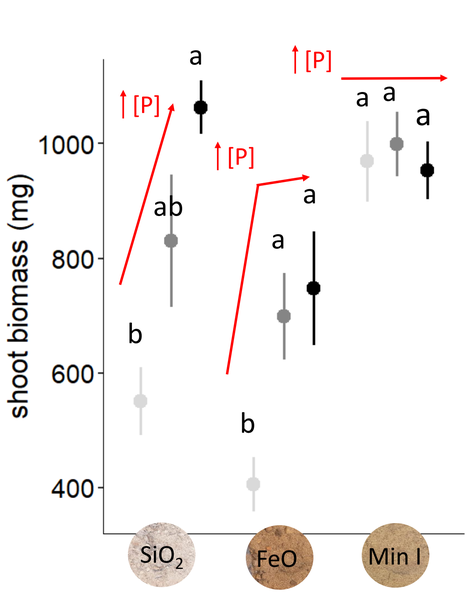
Formation of organo-mineral association

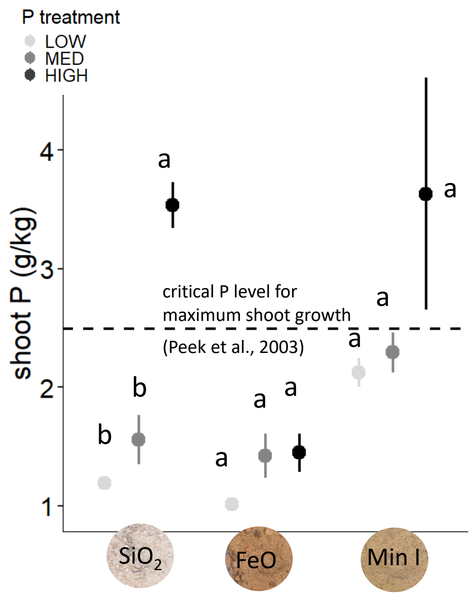


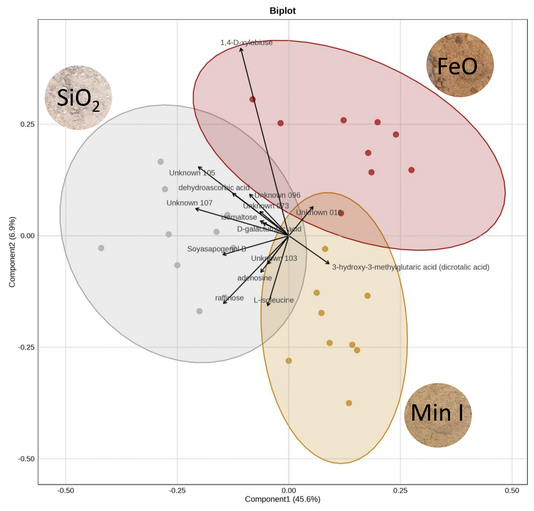
→ How does soil developmental stage regulate plant–microbe responses to P supply and shape soil C dynamics?

Results

Soil controls plant response to P supply



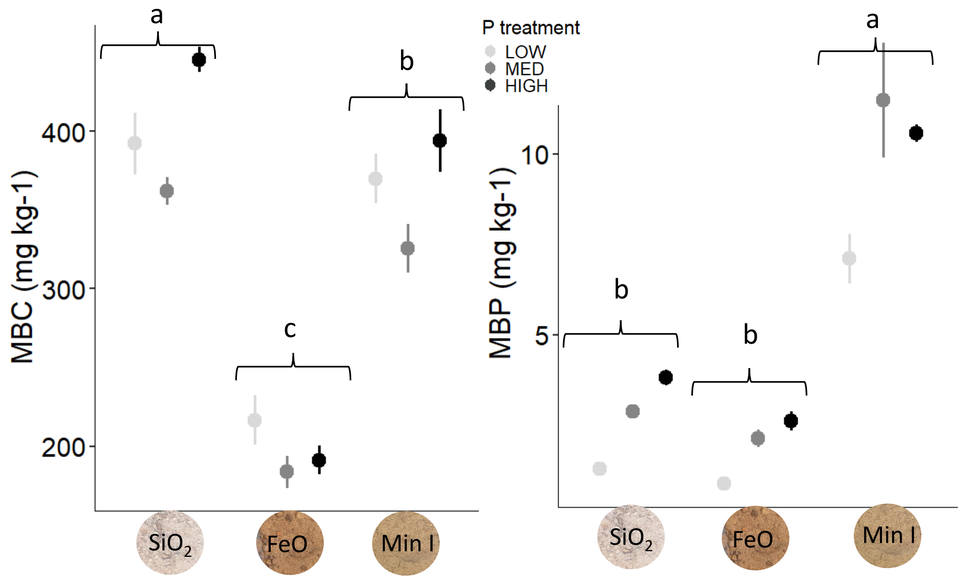




Soil-dependent variation in white lupin exudate profiles

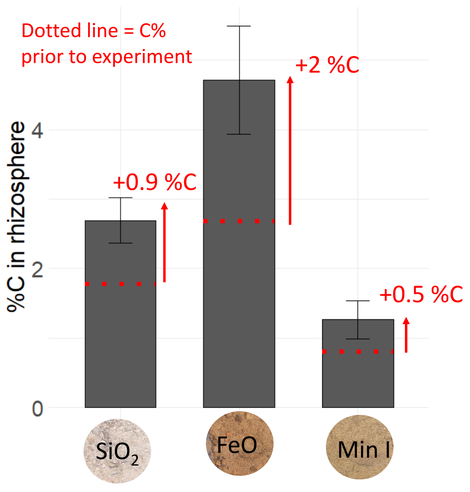
SiO₂: linear response to P addition
FeO: strong P adsorption on Fe oxides, limiting shoot biomass and [P]
Min I: primary minerals rich in P, no plant response to P supply

Microbial biomass is primarily impacted by soil

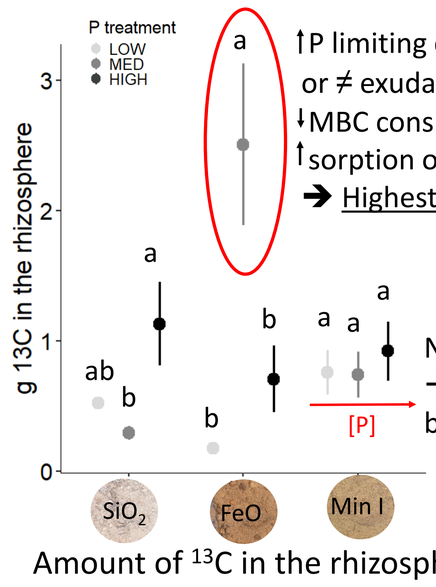


SiO₂: High SOM with high MBC, low MBP (P limitation). High extracellular enzyme activity for P and C acquisition.
FeO: Lowest MBC and MBP (strong Fe oxide stabilization). Enzyme activity // SiO_2.
Min I: high MBC and MBP (no P limitation) →Low enzyme activity.

Soil development stage drives rhizospheric C fate and plant–microbe responses to P supply



Higher rhizospheric C% increase in Feo (Al and Fe oxides).

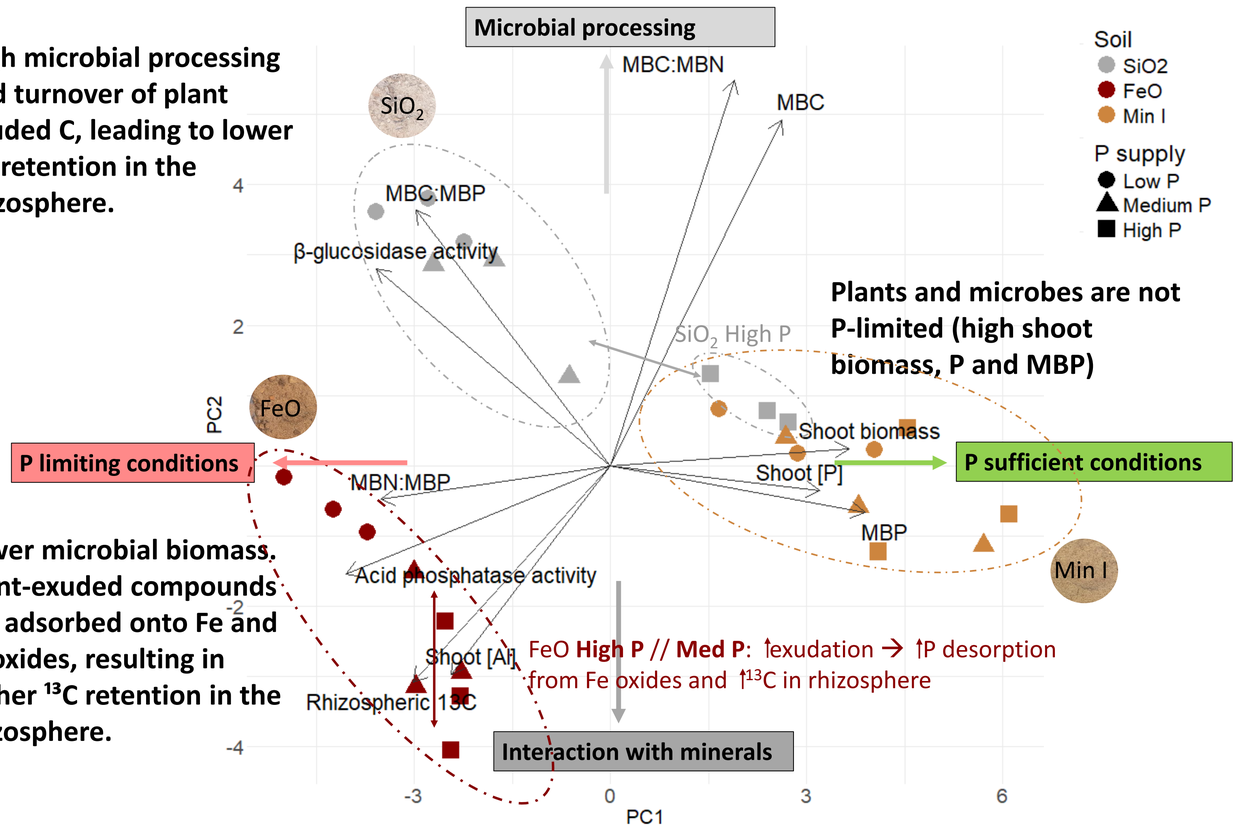


↑P limiting conditions →↑exudation? or ≠ exudate profile ?
↓MBC consumption
↑sorption on Fe oxides
➔ Highest ^{13}C in rhizosphere

No response to P supply
→ No effect on ^{13}C biogeochemical processing

Amount of ^{13}C in the rhizosphere after 7 days of ^{13}C-CO2 labeling depends on P supply and soil.

High microbial processing and turnover of plant exuded C, leading to lower ^{13}C retention in the rhizosphere.



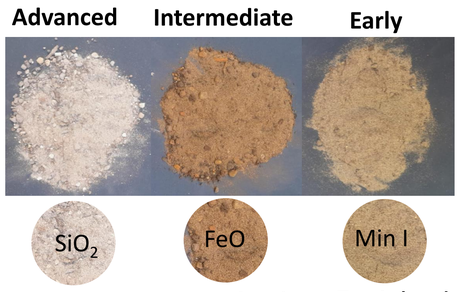
Plants and microbes are not P-limited (high shoot biomass, P and MBP)

Lower microbial biomass. Plant-exuded compounds are adsorbed onto Fe and Al oxides, resulting in higher ^{13}C retention in the rhizosphere.

FeO **High P // Med P**: ↑exudation → ↑P desorption from Fe oxides and ↑^{13}C in rhizosphere

Methods

Three soil developmental stages with different mineralogy:



Enriched in quartz

Enriched in Fe and Al oxides

Enriched in primary minerals

X

3 Phosphorus supply
Low (5 mg P/kg)
Med (15 mg P/kg)
High (40 mg P/kg)

- White lupin for 30 days in growth chamber
- ^{13}C-CO2 labeling for 7 days
- Exudate profile by GC-MS
- Microbial biomass C, N, P & Enzyme activity
- ^{13}C & C% in rhizospheric soil

Conclusion & Perspectives

Our results show a strong influence of soil developmental stage and its associated physicochemical properties on plant, microbes, and C dynamics in response to P fertilization.
To fully harness the potential of soil–plant interactions in agricultural systems, more integrated research approaches are needed that capture the interconnectedness of the shoot–root–microbe–mineral continuum.

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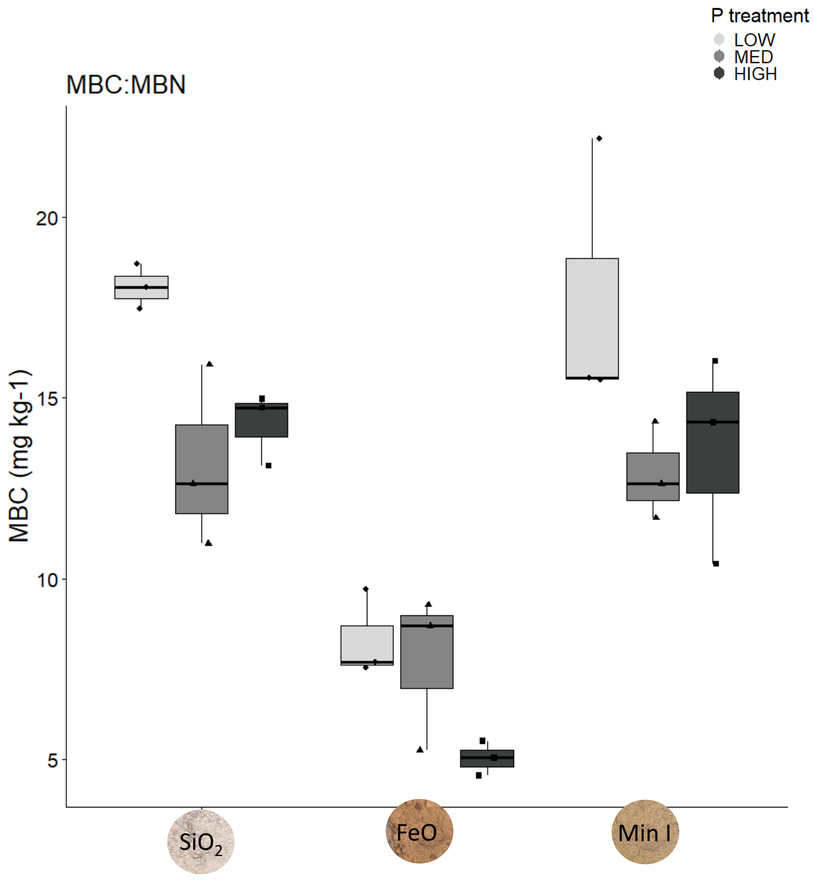
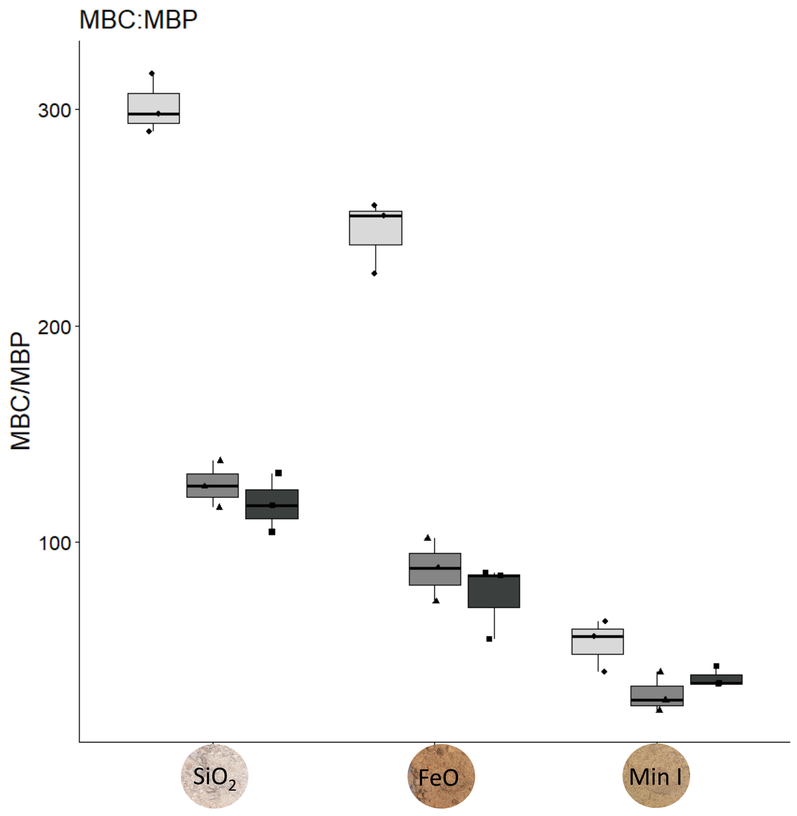
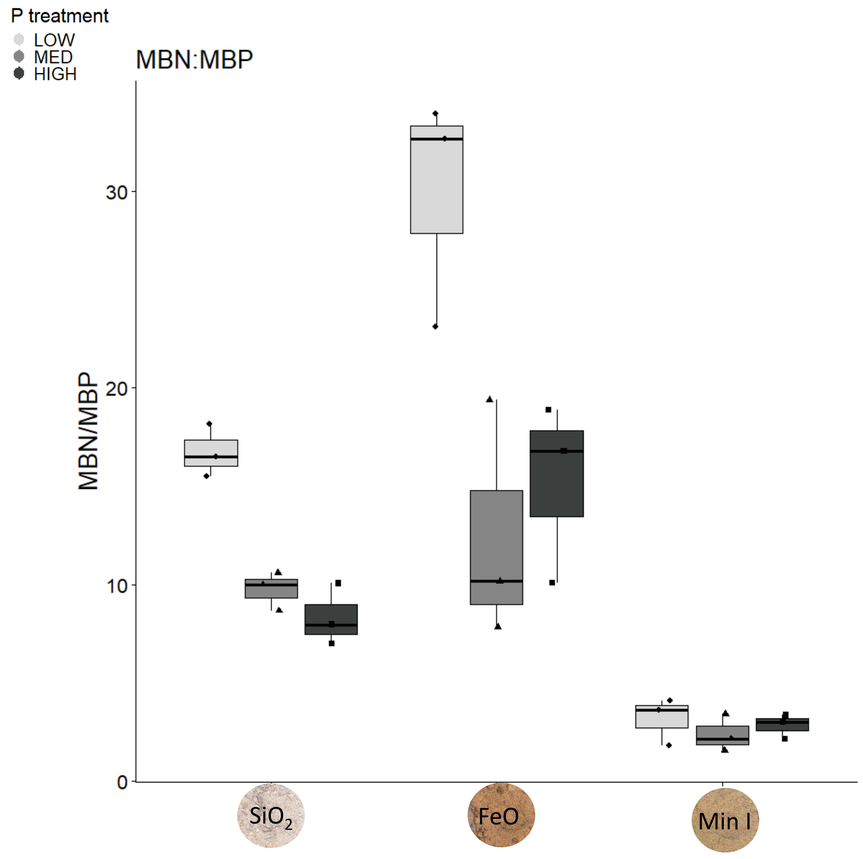
Microbial ratios







Enzymatic activity normalized by microbial biomass C