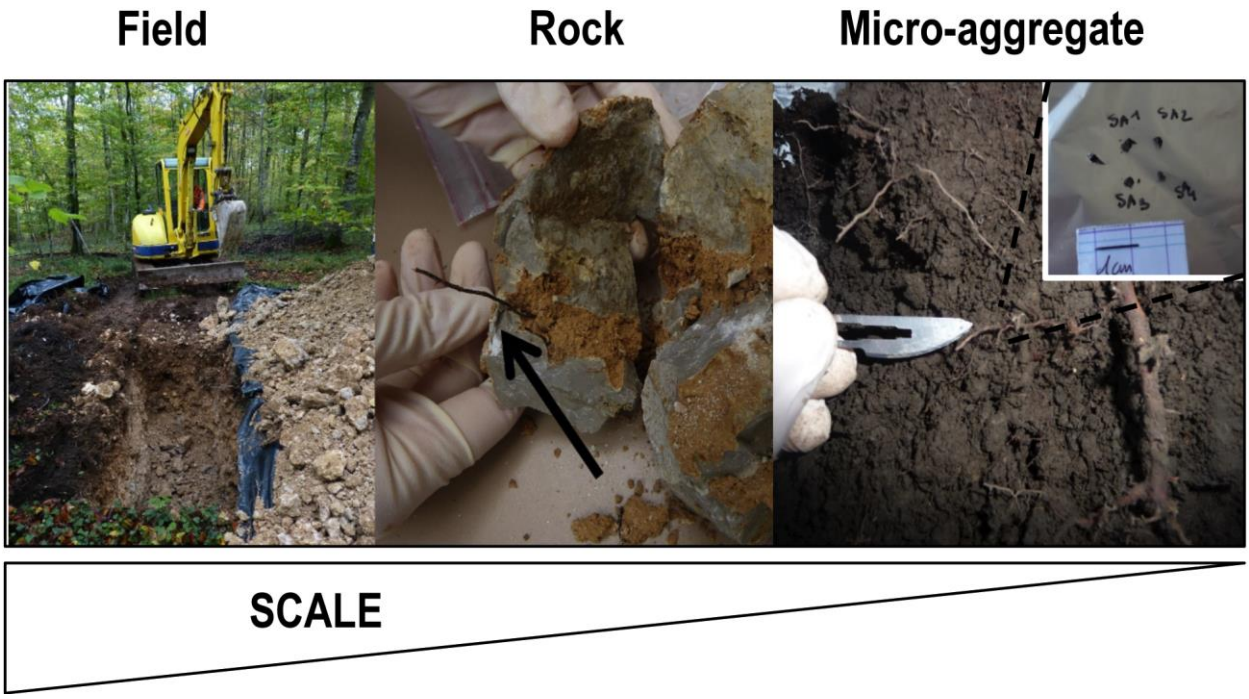
INABACT



Impact of Nutrient Availability on the diversity, function and functioning of the forest soil BACTerial communities: insights from the soil succession of the forest experimental site of Montiers-sur-Saulx

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Context — Understand the functioning of nutrient cycling, how these cycles are maintained in forest soils, how the trees access to the essential nutritive elements required for their growth, where come from these nutrients and how microbial communities are involved in these different processes are all fundamental questions. In the frame of the INABACT project, we were interested in the relationships between nutrient availability and the bacterial communities in different habitats and at different scales, with a central interest on the mineral weathering ability of bacteria. Whether the implication of soil microorganisms in the release of the nutrients entrapped into the soil minerals is established, the diversity and composition of the communities involved in this process and the factors driving their structure are poor or not known.

Objectives — The goals of the INABACT project were to determine at different scales and under different conditions how the availability of nutritive cations drive the taxonomic and functional structure of the microbial communities in forest soils.

Approach — The project was performed considering samples coming mainly from the experimental of Montiers, which is characterised by a toposequence and a land cover dominated by beech trees. Culture-dependent and -independent analyses were applied on rhizosphere and bulk soil samples. In parallel a microcosm approach was developed to test the relative impact of the manipulation of nutritive cation availability on the microbial communities. The impact of the soil properties on the microbial communities was also investigated on the soil chronosequence of Mendocino (CA, USA). At last, the tree species and mineral type effects were analysed on the Breuil site, where mesh bags containing minerals have been incubated below different tree species.

Key results —

- The INABACT project was rich in new advances in the understanding of the functioning of the soil forest microbial communities in relation to the availability in nutritive cations.
- At the scale of soil aggregates, our analyses done on the Streptomyces population coming from the richest soil (pH 7) of the Montiers site revealed a high functional diversity. This work demonstrated that the production of these metabolites could differ between Streptomyces strains highly-related or clonal as evidenced by MLST analysis, suggesting that evolution was quick enough to generate new variants with different inhibitory capacities among a Streptomyces population inhabiting the same microhabitat. Based on the bipartite interaction assays performed (sociomicrobiology), our results suggest that these variable metabolites could act as common goods and be beneficial to the whole population that shared the same micro-habitat. All these results are the subject of a publication currently under writing and enabled to initiate a new Labex project (SexSo) aiming to decipher the bases and the mechanisms underlying this variability of metabolite production.
- At the scale of the minerals, the analyses performed on the bacterial communities colonizing mineral surfaces (minerals conditioned in mesh bags) or from the surrounding bulk soil collected on the Breuil site revealed a strong effect of the physico-chemical properties of those minerals. Notably, a weatherable mineral such as calcite is colonized by bacterial communities significantly different from the surface of less weatherable minerals. The functional analyses done using bioassays evidenced an enrichment of effective mineral weathering bacteria on the less weatherable minerals. All these original results highlight that mineral surfaces represent real microbial habitats and reactive interfaces. They also suggest that the mineral weathering ability is an ecological advantage for microorganisms living in nutrient-poor conditions (Colin et al., AEM 2017). An additional analysis was done on the same sample to determine how the fungal communities are impacted (Colin et al. In prep).
- At the scale of the rhizosphere, our analyses revealed a strong differentiation of the bacterial communities from the surface horizon (10-20 cm) across the Montiers toposequence at both taxonomic and functional levels. Notably, beech trees having the same age appeared characterized by specific bacterial communities in their root vicinity varying according to the soil type, suggesting that beech trees adapt their rhizosphere microbiome according to the edaphic conditions. In term of function, the analyses done using the DNA-based Geochip microarray revealed that similar functions were present although the genomic background was different along the toposequence, suggesting a functional redundancy in the rhizosphere microbiomes (Colin et al., 2017). A more focus analyses performed on the mineral weathering ability has revealed a high effectiveness and frequency of mineral weathering bacteria in the most nutrientpoor soil of the toposequence. Those results suggest that effective mineral weathering bacteria are less frequent in the surface horizon of nutrient rich soils (Nicolitch et al., 2016). However, a similar analysis done on the bacterial communities living in the beech rhizosphere at the soil/bedrock interface (deeper soil horizon, 1m) in the same nutrient rich soil revealed that effective mineral weathering bacteria were enriched at the interface root/bedrock. All these results show that the soil bacterial communities associated to the beech rhizosphere are not structured in the same way in surface or deeper soil horizons, suggesting again a strong effect of the availability of nutritive cations on the bacterial communities (Nicolitch et al., 2016, 2017). These works are original and complementary to the previous ones and suggest that trees may use effective mineral weathering bacteria associated to their root system to access the nutritive elements required for their growth, even for deep root system.
- All the works performed in the project allowed us to test experimentally in microcosms the potential effect of the availability of nutritive cations on the taxonomic and functional structuration of the soil bacterial communities. To do it, microcosms containing soil collected in the nutrient-poor part of the Montiers toposequence have been amended or not with K and Mg (limiting nutrients in the soil considered). The analyses performed during a 2-month period revealed: i) a modification of the K and Mg concentration in the amended soil, ii) weak variations of the global taxonomic structure of the bacterial communities, but iii) important variation of the functional structure of the mineral weathering bacterial communities. The strong decrease of effective mineral weathering bacteria observed by culture-dependent approach or quantitative PCR evidence that the nutritive cations (K and Mg) have a rapid and important effect on the functioning of the soil microbiome (Nicolitch et al., in prep).
- A last important event of the INABACT project was the PhD viva of Océane NICOLITCH, which was defended in 2017 december thanks to a Labex Arbre grant.

Conclusions and future perspectives — The results obtained in the frame of the INABACT project improve our understanding of the complex interactions occurring between trees, microorganisms and the edaphic conditions. The approaches performed at different scales provide a new view of the different drivers determining the structure of the bacterial communities, the biotic ones (i.e., root exudates, secondary metabolites) and the abiotic ones (nutrient availability, pH, mineral type). Parts of the results are still under analysis and should be valorised as publications. To conclude, the INABACT project has clearly highlighted the key role of nutritive cations such as K or Mg on the biological functioning of the soil. Several research proposals directly related to the results generated have been submitted (EC2CO programm, INRA, Labex ARBRE) to develop more mechanistic approaches using model bacterial strains and/or synthetic model minerals. To date, a single project was granted through a Labex Arbre support (the GeMM project).

Valorisation —

Publications

Jeanbille, M., Buée, M., Bach, C., Cébron, A., Frey-Klett, P, Turpault, M-P., Uroz, S. 2016. Soil parameters drive the structure, diversity and functions of the bacterial communities across a temperate beech forest soil sequence. Microbial Ecology. 71, 482–493.

Nicolitch, O., Colin, Y., Turpault, M-P., Uroz, S. 2016 Soil type determines the distribution of nutrient mobilizing bacterial communities in the rhizosphere of beech trees. Soil Biology and Biochemistry. 103, 429-445.

Uroz, S., Buée, M., Deveau, A., Mieszkyn, S., Martin, F. 2016. Ecology of the forest microbiome: Highlights of temperate and boreal ecosystems. Soil Biology and Biochemistry. 103, 471-488.

Nicolitch, O., Y Colin, MP Turpault, L Fauchery, S Uroz. 2017. Tree roots select specific bacterial communities in the subsurface critical zone. Soil Biology and Biochemistry 115, 109-123.

Uroz, S. Oger, P. 2017. *Caballeronia mineralivorans* sp. nov., isolated from oak-Scleroderma citrinum mycorrhizosphere. Systematic and Applied Microbiology 40: 345-351

Colin, Y, O Nicolitch, MP Turpault, S Uroz 2017. Mineral types and tree species determine the functional and taxonomic structures of forest soil bacterial communities Applied and environmental microbiology 83 (5).

Colin, Y, O Nicolitch, JD Van Nostrand, JZ Zhou, MP Turpault, S Uroz. 2017. Taxonomic and functional shifts in the beech rhizosphere microbiome across a natural soil toposequence. Scientific Reports 7.

Conference

Colloque de l'Association française d'écologie microbienne (AFEM), (Anglet, France) 3-6 novembre 2015. Impact of nutrient availability on the structure of the forest bacterial communities : Insights from the Montiers soil succession O. Nicolitch, Y. Colin, M-P. Turpault, S. Uroz (Oral).

Summer school 'Function of microbial communities in soils: biotic interactions' (Neuherberg, Germany) 31th august-11th september 2015. Mineral weathering in forest soils: focus on the bacterial communities. Uroz et al. (Oral); Impact of nutrient availability on the structure of the forest bacterial communities : Insights from the Montiers soil succession O. Nicolitch, Y. Colin, M-P. Turpault, S. Uroz (Poster)Colloque 'Expérimentation sur le site de Montiers' (Champenoux, France) 20 mars 2015. Relation entre le type de sol et la structure taxonomique et fonctionnelle des communautés bactériennes, S. Uroz et al. (Oral)

First Global Soil Biodiversity Conference (Dijon, France) 2-5 décembre 2014. Impact of soil type on the structure of the microbial communities: Insights from the Montiers-sur-Saulx soil succession. Nicolitch, O., Jeanbille, M., Buée M., Colin Y., Turpault M-P., Frey-Klett P. and Uroz S. (Poster)

3rd Thünen Symposium on Soil Metagenomics. "From gene predictions to systems ecology" (14-16th of december, 2016; Braunschweig, Germany) Stephane Uroz, Yannick Colin, Océane Nicolitch, Marie-Pierre Turpault, Joy van Nostrand, Jizhong Zhou. Taxonomic and functional shifts of beech rhizosphere microbiome along a natural soil toposequence (Poster). Yannick Colin, Océane Nicolitch, Marie-Pierre Turpault, Stéphane Uroz. Short-term effects of minerals on the structure and weathering potential of soil bacterial communities under different tree stands (Poster).

Launch of the Global Soil Biodiversity Atlas in France (Académie d'agriculture (AAF); Paris, 28 November

2016). Uroz S. Exploration of the biodiversity and functions of the forest microbiome: a focus on temperate ecosystems. (Invited talk).

Journée du Labex ARBRE (Champenoux, France, 18 october 2016) Uroz, S., Turpault, M-P., Nicolitch, O., Colin, Y., Buée, M., Churin, J-L., Deveau, A., Bontemps, C., Leblond, P., Aigle, B., Angeli, N., Derrien, D., Besserer, A., .Impact of nutrient availability on the diversity, function and functioning of the forest soil bacterial communities: insights from the soil succession of the forest experimental site of montiers (Talk)

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14th Symposium on Bacterial Genetics and Ecology (BAGECO) 4–8 June 2017 • Aberdeen/Scotland : Uroz, S., Colin, Y., Nicolitch,O., Van Nostrand, J.D., Zhou, J.Z., Turpault, M-P. Taxonomic and functional shifts in the beech rhizosphere microbiome across a natural soil toposequence (Poster). Nicolitch, O., Colin, Y., Turpault, M-P., Fauchery, L. and Uroz, S. Exploration of the functional and taxonomic diversity of the bacterial communities occurring in the bedrock/root interface of beech trees (Poster).

FEMS 7th Congress of European Microbiologists (Valencia, Spain) 9-13 juillet 2017.A novel quorum-quenching enzyme identified in a hypersaline soil. Torres, M., Uroz, S., Salto, R., Fauchery, L., Llamas, I. (Poster).