MycorrWeath

Experimental characterization and quantification of the contribution of biological weathering from mycorrhizal fungi to tree nutrition by isotopic dilution

Principle investigator: Gregory VAN DER HEIJDEN

Partners: UMR 1136 Interactions Arbres/Microorganismes

Collaboration: Roger FINLAY, Swedish University of Agricultural Sciences

---

Context — Quantifying the weathering inputs of Ca, Mg and K is essential in order to determine the sustainability of Mg, Ca and K plant-available pools over time, help forest managers and policy makers manage forest soil fertility in a sustainable manner and prevent cases of forest decline. The weathering flux is most commonly estimated through geochemical modelling approaches. However, it has been shown that trees directly access nutrient sources in soil minerals through root-microorganisms associations in the rhizosphere (biological weathering). Mycorrhizal fungi play a very important role in tree nutrition by i) greatly increasing the volume of prospected soil and ii) actively contributing to the biological weathering of soil minerals. The deconvolution of the mineral weathering input flux into its biological and geochemical components is challenging with conventional experimental methods.

Objectives — The overall goal of this project was to develop stable isotopic labelling techniques (^{26}Mg, ^{44}Ca and ^{41}K) to trace and quantify the contribution of mycorrhizal fungi and biological weathering to plant nutrition. For this, we carried carry out the first experimental trials using isotopic dilution techniques in plant-mycorrhiza-soil microcosm systems using natural soil.

Approach — Isotopic dilution techniques enable to isotopically label the soil labile pools (*i.e.* in chemical equilibrium with soil solution) of Mg, Ca and K. For plants that are grown in a mineral soil substrate (low carbon content) which has been isotopically labelled, the Mg, Ca and K isotopic signature of plant pools is the result of a mixture of cations originating from i) the soil labile pool and ii) the weathering of soil minerals. The mineral weathering flux can be calculated by measuring the isotopic composition of the soil labile pool and the plant pool and applying an isotopic mixing equation of the two end-members.

Compartmentalized rhizotron system were setup to control the access of roots and/or fungi to different soil volumes. The root system of the plant grows in Compartment A (isotopically labelled natural mineral soil substrate). A nylon mesh (30 µm) prevents roots but allows the mycelia of mycorrhizal fungi to colonize compartment B (ground granite). The centre compartment (A) can be rotated to mechanically rupture mycelia that colonizes compartment B. The effects of mycorrhizal fungi on nutrient acquisition and tree nutrition are then studied by comparing rhizotron systems in which mycelia colonizes both compartments (A+B) and systems in which mycelia colonizes only compartment A. For this first assay, we focused on one soil substrate (soil sampled from the mineral soil horizons (40-70cm) of the Breuil-Chenue experimental site) and one tree species (Scots pine *Pinus sylvestris*).

Key results —

- We showed that the isotopically exchangeable pools of Mg, Ca, and K (measured with isotopic dilution approach) are greater than traditionally measured exchangeable pools. The isotopically exchangeable pools are mainly composed of traditionally measured exchangeable pools (88.8−98.5% for Mg, 74.7−97.7% for Ca, and 68.7−77.1% for K) but are also composed of pools extracted with the Tamm reagent (oxalic acid, pH 3) and nitric acid (1 mol·L−1): 1.5−11.2% for Mg, 2.3−25.3% for Ca, and 22.9−31.3% for K.

- The results of the compartmentalized rhizotron experiment are not yet available. Experimental design and setup required a lot of development (rhizotron conception and construction, automated individual rhizotron watering system, isotopic labelling trials) and the experiment was only setup in the Spring of 2018. This project has enabled to acquire the necessary skills and knowledge for such experimental approaches which may be applied at greater scales in future research projects.

- This project has initiated a partnership between the INRA BEF unit and the Swedish University of Agricultural Sciences and opened possibilities of collaborations on future research projects.

Main conclusions including key points of discussion — The isotopically exchangeable pools are a very relevant indicator of the availability of Mg, Ca, and K in the soil on short time scales (source and sink pools) and the isotopic dilution method is a very promising approach to characterize and quantify the processes responsible for the depletion and/or replenishment of these pools over longer time scales.

Future perspectives — The role of the isotopically exchangeable pools and the role of biological weathering in plant nutrition are still to be determined. The rhizotrons will be sampled in 2019 to assess the distribution of isotopic tracers in the system and the isotopic dilution over two growth seasons. These results should enable us to i) validate the experimental approach and ii) experimentally measure for the first time the contribution of biological weathering to soil processes and Ca, Mg and K tree nutrition. We expect this project to be the cornerstone for future research projects to answer research questions related to the mechanisms of mycorrhizal and tree root nutrient uptake.

Valorisation —

van der Heijden, G., Bel, J., Craig, C.-A., Midwood, A., Mareschal, L., Ranger, J., Dambrine, E. and Legout, A.;2018;Measuring Plant-Available Mg, Ca, and K Pools in the Soil—An Isotopic Dilution Assay;ACS Earth and Space Chemistry;2 (4) 292-313.