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Simulating rhizodeposition as a function of shoot and root interactions within a new 3D Functional-Structural Plant Model

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Introduction

Rhizodeposition, *i.e.* the release of organic materials by roots, represents a significant portion of plant's carbon (C) budget, ranging from 5% to 15% of net photosynthesized C (Pausch and Kuzyakov, 2018). Various rhizodeposits can be released by roots, *e.g.* soluble exudates, secreted mucilage, sloughed cells, or volatile organic compounds. Despite their short lifetime, some of these products have been shown to favor plant growth, *e.g.* by increasing water and nutrient uptake. Among rhizodeposition processes, exudation has been suggested to depend on the concentration of carbohydrates inside the roots (Personeni et al., 2007). However, rhizodeposition not only depends on the availability of C in the roots, but also on the architecture of the root system, and many have shown that rhizodeposits are more concentrated in specific areas, such as root tips. Consequently, a Functional-Structural Plant Model (FSPM) would theoretically represent the best framework for simulating the spatial and temporal dynamics of rhizodeposition, as it can describe the evolution of both the metabolism and the architecture of the plant. The objective of this work is to create such a framework by coupling a whole-plant FSPM, a 3D root architectural model, and a new model simulating rhizodeposition.

Modelling approach

Our strategy has been to combine the FSPM *CN-Wheat* (Barillot et al., 2016), which describes the main processes of C and nitrogen (N) acquisition and transformation by an individual wheat plant and the 3D growth and development of its aerial organs, with the model *ArchiSimple* (Pagès et al., 2014) that simulates the development of the 3D root architecture for a range of plant species, and the new model *RhizoDep*, which calculates a full C balance in each part of a root system in order to simulate local rhizodeposition fluxes. The complementarity of the three models is illustrated in Figure 1: i) *CN-Wheat* is used to calculate the amount of C allocated from the shoots to the roots, ii) *ArchiSimple* provides the 3D structure of the root system, and iii) *RhizoDep* distributes the C provided by the shoots within the 3D root system and simulates the actual growth, respiration and rhizodeposition of each root element based on C availability. The major link between the three models lies in the exchange of C between aboveground and belowground tissues, which is driven by gradients of sucrose concentration in the different compartments of the plant.

Preliminary results & short-term perspectives

The coupling of the three models has been started using the *OpenAlea* platform and its *Multiscale Tree Graph* formalism (Pradal et al., 2008). First simulations were done using the allocation of C to the roots simulated by *CN-Wheat* as an input to the root model based on the effective coupling of *ArchiSimple* and *RhizoDep*. These simulations show how rhizodeposition is intrinsically dependent on the architecture of the root system and on the total amount of available C. For completing the coupling, several issues still need to be tackled, *e.g.* how N uptake and metabolism should be spatialized in a 3D root system, how it may be regulated by local C and N availability, and how rhizodeposition can modify soil N availability. However, this modelling approach has already led to a first prototype able to simulate rhizodeposition processes on a dynamic, 3D root system that is fully integrated within the functioning of the whole plant. Its refinement will offer unique opportunities to study the possible link between rhizodeposition and the environmental factors affecting plant growth, *e.g.* atmospheric CO_2 concentration or soil N availability.

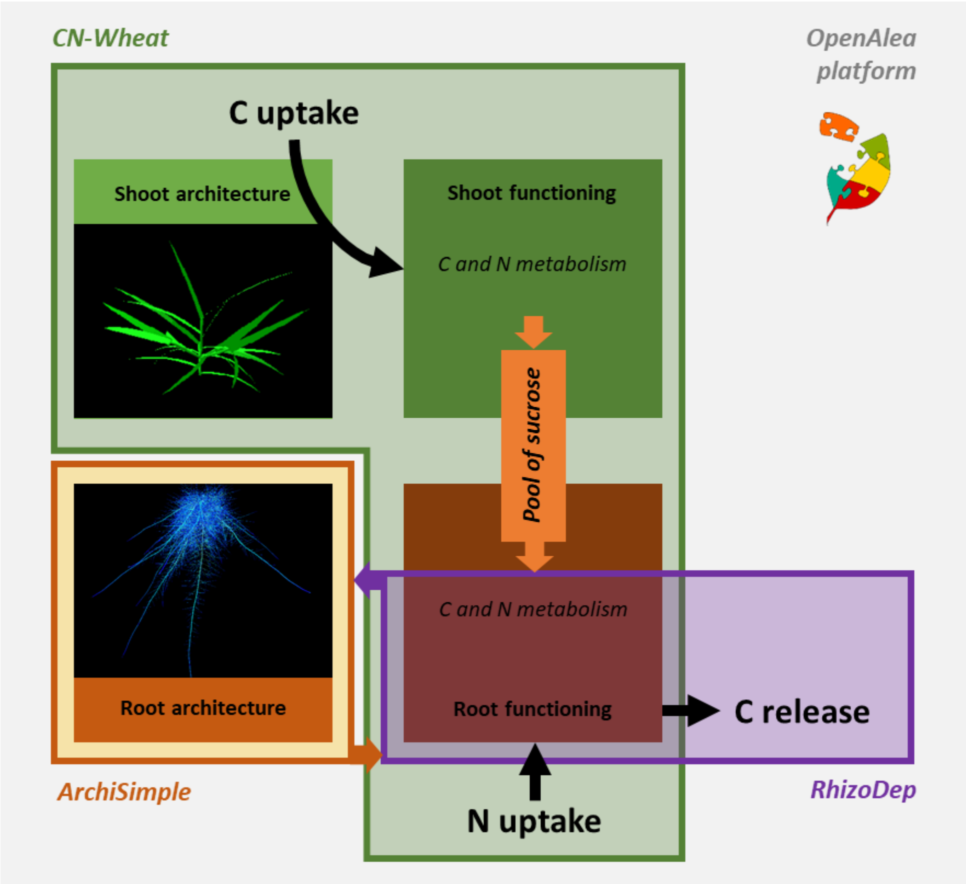

Figure 1: Modelling approach for simulating carbon rhizodeposition within a 3D plant model

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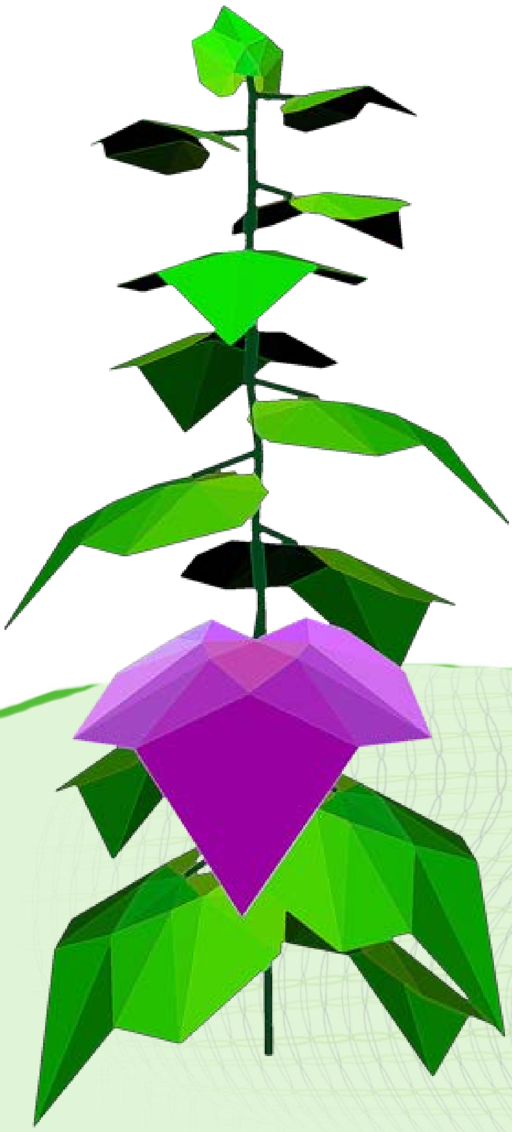

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