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

Frédéric Rees, Romain Barillot, Marion Gauthier, Loïc Pagès, Christophe Pradal, Bruno Andrieu

To cite this version:

Frédéric Rees, Romain Barillot, Marion Gauthier, Loïc Pagès, Christophe Pradal, et al.. Simulating rhizodeposition as a function of shoot and root interactions within a new 3D Functional-Structural Plant Model. FSPM 2020 - 9th International Conference on Functional-Structural Plant Models, Oct 2020, Hanovre / Virtua, Germany. pp.22-23. hal-02964060

HAL Id: hal-02964060
https://hal.inrae.fr/hal-02964060
Submitted on 12 Dec 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Simulating rhizodeposition as a function of shoot and root interactions within a new 3D Functional-Structural Plant Model

Frédéric Rees¹, Romain Barillot², Marion Gauthier¹, Loïc Pagès⁴, Christophe Pradal⁵,⁶, Bruno Andrieu¹

¹ Université Paris-Saclay, INRAE, AgroParisTech, UMR ECOSYS, F-78850 Thiverval-Grignon, France
² INRAE, UR P3F, F-86600, Lusignan, France
³ ITK, avenue de l'Europe, F-34830 Clapiers, France
⁴ UR 1115 PSH, INRAE, Site Agroparc, Avignon, France
⁵ AGAP, CIRAD, INRAE, Montpellier Sup Agro, Univ Montpellier, France,
⁶ CIRAD, AGAP and Inria, Zenith, Univ Montpellier, France

For correspondence: frederic.rees@inrae.fr

Keywords: FSPM, wheat, exudation, carbon allocation, ArchiSimple, CN-Wheat

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\textsubscript{2} concentration or soil N availability.

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

References
Pagès et al., 2014, Ecological Modelling 290: 76-84, doi: 10.1016/j.ecolmodel.2013.11.014
Pradal et al., 2008, Functional Plant Biology, 35(10), 751-760. doi: 10.1071/FP08084
Book of Abstracts

Editors
Katrin Kahlen
Tsu-Wei Chen
Andreas Fricke
Hartmut Stützel

FSPM2020:
Towards Computable Plants

9th International Conference on
FUNCTIONAL-STRUCTURAL PLANT MODELS
5-9 October 2020