SIMBAL: A structural-functional plant model to simulate C and N dynamics and shoot-root architecture of winter oilseed rape associated with legumes

Laurène Perthame, Frédéric Rees, Xavier Cornilleau, Céline Richard-Molard, Christophe Pradal, Alexandra Jullien

SIMBAL: A structural-functional plant model to simulate C and N dynamics and shoot-root architecture of winter oilseed rape associated with legumes.

Laurène Perthame[1], Frédéric Rees[1], Xavier Cornilleau[1], Céline Richard-Molard[1], Christophe Pradal[2,3], Alexandra Jullien[1]

[1] *Université Paris-Saclay, INRAE, AgroParisTech, UMR EcoSys, 91120 Palaiseau, France*
[2] *AGAP, Univ. Montpellier, CIRAD, INRAE, SupAgro, Montpellier, France*
[3] *INRIA, Univ. Montpellier, France*

For correspondence: laurene.perthame@agroparistech.fr

Keywords: plant model, fababean, plant-plant interactions, FSPM for agroecology

Introduction

Species mixtures are of great interest to promote low-input agricultural practices while maintaining agricultural production. For example, winter oilseed rape sown with a frost sensitive legume reduces the use of nitrogen fertilizer and herbicide while maintaining yield at levels equivalent to pure cropping (Lorin et al., 2016). A disadvantage of such mixtures is that the legume might compete with the cash crop for resources and reduce yield. To optimize management of these mixtures, it is necessary to better understand the ecophysiological processes that drive the sharing of resources between plants (e.g. carbon and nitrogen). Mechanistic functional-structural modeling (FSM) is particularly suitable for such studies as it allows the analysis of the processes underlying plant-plant interactions and integrates both the architectural growth processes of the plant and its functioning (e.g. acquisition/allocation of resources) (Louarn and Song, 2020). For example, the model Virtual Grassland (Louarn et al., 2014) simulates competition for C, N and water between several herbaceous and legume species. However, no FSM for mixtures of annual crops with frost sensitive legume that considers the feedback of the carbon/nitrogen functioning in both shoots and roots has been developed so far. Such a modeling approach is shown in this study, with the aim of filling knowledge gaps on the role of carbon-nitrogen interactions in plastic responses of plants in mixtures, by taking the case study of winter oilseed rape sown with frost sensitive fababean at vegetative stage.

Conceptual framework of C and N fluxes

The model SIMBAL (SIMulated *Brassica* Associated with Legumes) is based on the ARNICA FSM developed for *Arabidopsis thaliana* (Richard-Molard et al., 2009). The model simulates shoot and root architecture of winter oilseed rape in which C and N fluxes determine the growth of each organ (leaf, internode, root segment). C is preferentially given to shoot and N to roots. As showed in Fig.1, the total internal N amount results from root uptake and remobilization from storage (1) and determine the increment of leaf and internode area (4). N in leaves is distributed along the light gradient within the plant, while N in internodes is distributed homogeneously (3). The total internal C quantity results from photosynthesis (6) and remobilization of C storage (9). Root growth results from the N available to roots (2) and the C available after satisfaction of shoot demand (7). C storage is filled if total internal C quantity is superior to C organ demands (calculated as the C quantity necessary to produce a unit of leaf, internode or root surface) (9). N storage is filled from leaf senescence (driven by a leaf lifespan) (5) and when N quantity for shoot is superior to N used for actual total photosynthetic area (8). When the crop is grown in association with fababean rather than in monoculture, the light availability to the plant is reduced and parameters value such as phyllochron are modified based on experiments.

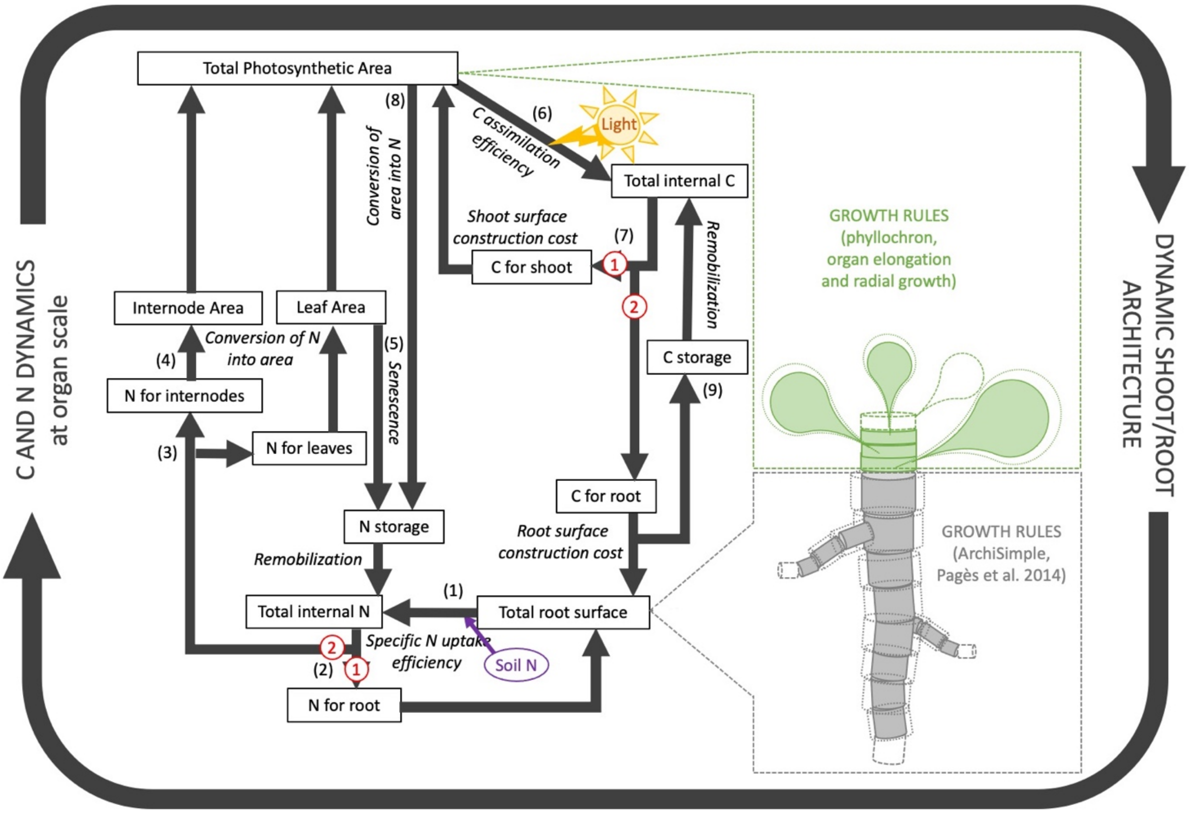

Fig.1: Conceptual framework of C and N dynamics and organ growth underlying the SIMBAL model

Towards a model of rapeseed and fababean mixture at the entire crop cycle

A first FSPM was built to study the N and C fluxes and organ growth within a whole plant of winter oilseed rape at the vegetative stage in OpenAlea (Pradal et al., 2008). This conceptual framework aims to be generic and adaptable to other species, in particular frost sensitive fababean. In the near future, we intend to develop the model upon the entire crop cycle of winter oilseed rape and to assess the effect of frost sensitive fababean on oilseed rape growth and CN functioning through direct (competition for light harvest and N uptake) and indirect (degradation of N-rich legume residues) effects.

References

Lorin et al., 2016, *Field Crops Res*. 193, 24-33, doi: 10.1016/j.fcr.2016.03.002
Louarn et al., 2014, *The future of European Grasslands*. 242
Louarn and Song, 2020, *Ann. Bot*. 126: 501-509, doi: 10.1093/aob/mcaa143
Pradal et al., 2008, *Funct. Plant Biol*. 35(10): 751-760, 10.1071/FP08084
Richard-Molard et al., 2009, *C.B.P*, 153(2), S229, doi: 10.1016/j.cbpa.2009.04.634