GREENLAB as a tool to solve source-sink relationships in tomato – Application to the quantification of specific leaf area and fruit set dependences to the level of competition for assimilates

Gaëtan Louarn[1], Yang Lili[1], Dong Qiaoxue[1], Phillipe De Reffye[2].

[1] China Agricultural University (CAU), College of Information and Electrical Ingeneering, Box 63, 100083 Beijing, China.
[2] INRIA Roquencourt, Equipe Digiplante, F78153, Le Chesnay, France

Abstract –

The definition of relevant indicators to quantify the satisfaction of organ demands is of practical importance in crop models. In the case of greenhouse tomato for instance, environmental conditions change drastically around the year, leading in winter to significant reductions of specific leaf area (controlling leaf area expansion and ultimately light interception and crop productivity) and fruit set proportion (partly controlling yield through the number of fruits initiated) that can be related to fluctuations in the competition for assimilates. The supply-demand ratio (S/D) defined in process-based models to account for this phenomenon presents the main drawback of using a rather arbitrary and non-functional potential demand function. This function is valid only for a limited range of growing conditions and management practices. Its use is particularly questionable in studies implying a strong modification of the productivity potential through manipulation of plant and/or stand architecture (e.g. pruning, planting density…).

The mathematical model GREENLAB on the contrary seeks to estimate actual organ sink strengths by optimisation procedures against biomass measurements performed regularly in the course of plant development. It rests on a simple mathematical formalism applied to all plant organs of a given type and can be used in any growing condition. However, in spite of several numerical case studies, S/D estimated using this method have never been compared with measurements on real plants.

The present study aims at evaluating the possibility of using GREENLAB as a solver of source-sink relationships and as a potential supplier of ecophysiological variable characterising the competition for assimilates among organs. To do so, we tried to link overall plant S/D computed with the recently validated GREENLAB-tomato, with observed fluctuations of fruit set and specific leaf area (SLA). Plants grown at four planting densities (1, 2.8, 6.1, 11.2 plant.m^{-2}) and for two sowing dates (spring: 15/03/06; autumn: 15/08/06) were used to generate a gradient of assimilate availability.

Model fitting were accurate from organ to whole plant scales in all the studied situations. This result confirmed that both net production (S) and net demand (D) were dynamically estimated with a satisfying range of precision. S/D evolution displayed a characteristic shape for all the treatments (minimal a few days after seed reserve extinction; maximal around fruit set on the first truss; stabilisation after fruit set on the 5^{th} truss) that was consistent with our knowledge of sink-source relationships in indeterminate tomato cultivars. A sigmoidal relationship between average S/D during the week following flowering and fruit set was found. A clear relationship between average S/D during leaf expansion and SLA was also identified. However this last relationship differed between experiments in spring and autumn indicating that other environmental variables were involved in SLA determinism.

To conclude, this study showed how interesting mathematical structure-function models can be from an analytical point of view for plant physiologists. In our particular case, it helped to build a generalised variable synthesising all together resource availability, plant growth and plant development to explain a targeted process (e.g fruit set). Focusing on modelling outlook, it also demonstrated how this kind of model, proceeding from a bottom-up integration of physiological knowledge, can be used as a research framework for its own complication. Response curve have now been established and could be included in a more sophisticated version of the model linking functionally organogenesis and growth.