Hydraulic Viper, a virtual phenotyping pipeline for root hydraulic traits – multiscale approach.

Adrien Heymans[1], Valentin Couvreur[1], Félicien Meunier [2], Guillaume Lobet [1, 3]

[1] *Earth and Life Insitute, UCLouvain, Louvain-la-Neuve, Belgium*
[2] *CAVElab-Computational and Applied Vegetation Ecology, Ghent University, Ghent, Belgium*
[3] Agrosphere IBG3, Forschungszentrum Jülich, Jülich, Germany

For correspondence: Adrien.heymans@uclouvain.be

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Under water limitation, selecting the adequate root architectural features for a specific environment could increase plant performance (Comas et al., 2013). In this respect, optimizing the location of roots in space and time can help but it is the root hydraulic conductivity and the water potential being applied on all points of the root system that determine the amount of water transpirable by the plant. Moreover, root hydraulic conductivity can be a limiting factor along the water pathways between the soil and the leaf. Cell-scale hydraulic properties and anatomical features define the root hydraulic conductivities. Hydraulic properties are usually assumed to be controlled on the short- or medium-term by the plant while structural features are assumed to be long term (Vetterlein and Doussan, 2016). As such, root anatomy defines the baseline for the root radial and axial hydraulic properties. However, quantifying the influence of anatomical features on the hydraulic conductivity remains challenging due to complex and time-consuming experimental procedures. In addition, assessing their impact globally on a root system conductance is even more complicated.

We present here a virtual phenotyping pipeline for root hydraulic traits that will help better understand how cell-scale hydraulic properties and root anatomy could influence plant-scale hydraulic properties such as the whole root system conductance, the transpiration rate and the standard sink fraction. We used a model of water flow in root system hydraulic architecture to combine a generated root system architecture with specific hydraulic conductivities function: MARSHAL (Meunier et al., 2020). The hydraulic conductivities along the root axis were derived from the MECHA-GRANAR coupling (Heymans et al., 2020). This allows us to generate realistic root cross section anatomies and add the cell-scale hydraulic properties to the system to estimate radial and axial hydraulic conductivity. Finally, these evolving root system hydraulic architectures were placed in a set of environmental conditions to create the soil and atmospheric boundary conditions and estimate realistic root water uptake scenarios. Thus, the pipeline enables us to identify of the best combinations of traits for the tested scenarios.

In this case, we simulated 9 000 of root systems in total for three contrasted architecture types. We generated root cross sections for those root systems from a large sample of anatomical features and a broad range of cell-scale hydraulic properties and applied it accordingly to each root type. Per root system, we simulate five root cross sections, representing five root types (Tap-, Basal-, Shoot born-, Short lateral-, and Long lateral-root). This approach allowed us to highlight which combination of traits at the cell and organ level could potentially have the most impact on the global water uptake strategy for the selected environmental scenario and architectural types.

References

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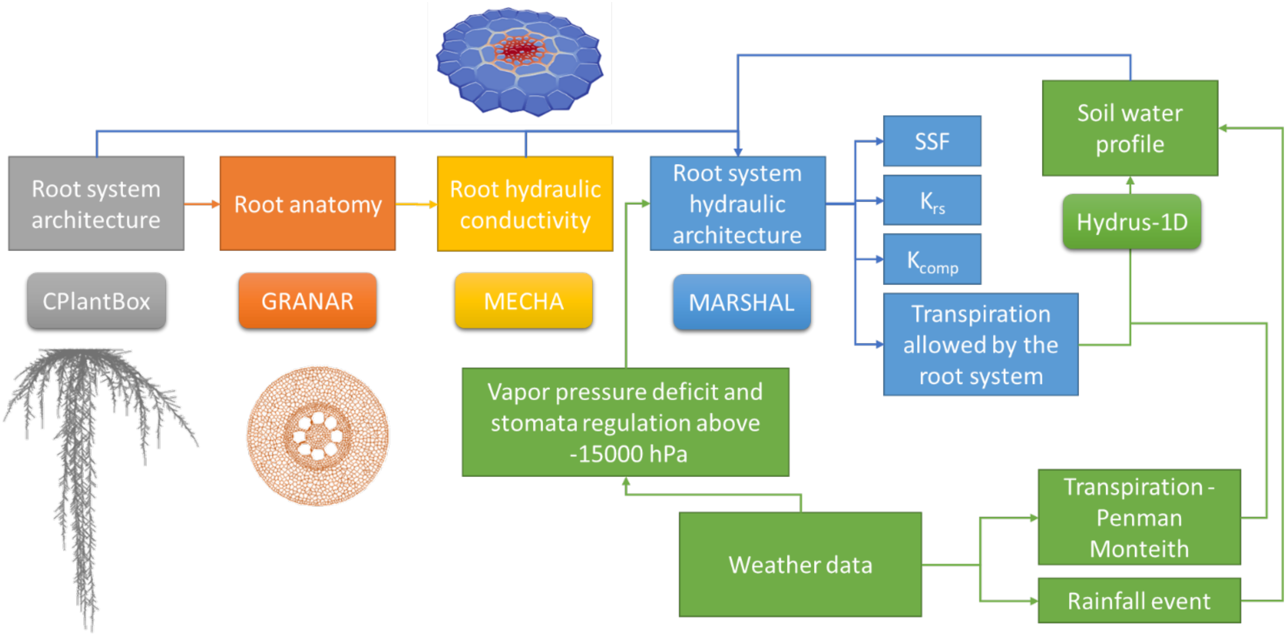

Overview of the pipeline work flow: 1. generation of a root system architecture; 2. creation of 10 root cross sections that represent the 5 different root types; 3. estimate the hydraulic conductivities: K_r and K_x; 4. resolve the hydraulic architecture and get the standard sink fraction, the root system conductance, the compensatory conductance, and the transpiration rate; 5. loop around the soil water flow and the root system hydraulic architecture