Quantitative multi-scale analysis of water flow determinants in the soil-root system

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Finding plants that are well adapted hydraulically to specific pedo-climatic environments is aimed for present and future yield improvement and increasing the sustainability of our crop systems. Cultivated plants that have been selected through traditional farming systems in a region are most likely to express very different root anatomies and root hydraulic properties from place to place. These germplasms may have developed a root system hydraulic architecture particularly adapted in their location. A better understanding of the underlying properties could be put at use to target strategies, if needed, which could increase their water uptake in these specific environments.

Here, we associated different models into a structured network (figure 1) to virtually simulate water flow in the soil-root system over 30 days of crop development. This pipeline was built so we could pinpoint specific root anatomical traits, sub-cellular hydraulic properties and maturation rate which could improve the root water uptake in a chosen pedo-climatic environment. We tested this hypothesis on maize plants (*Zea mays* variety B73) and in three pedological conditions under a high evaporative demand and water limiting conditions. We generated 7168 maize plants from a single set of architecture traits but varying sets of anatomical traits, sub-cellular hydraulic properties and maturation rates and analysed their root water uptake dynamics in all three environments.

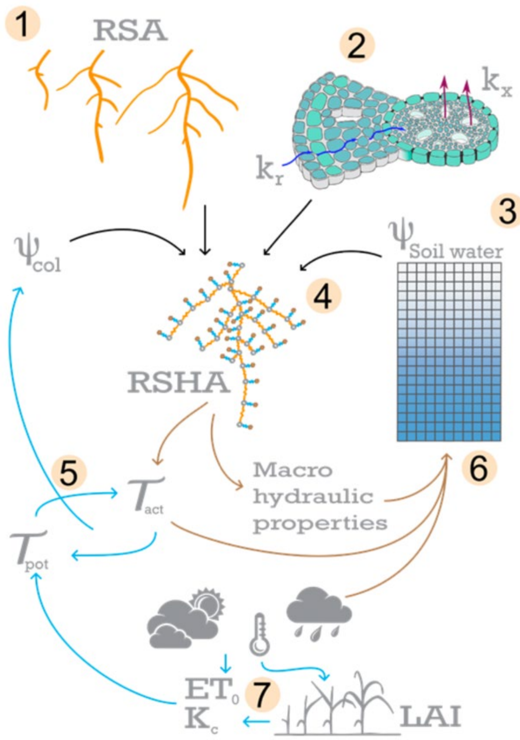

Figure 1 : Overview of the virtual phenotyping pipeline for root water uptake (Hydraulic Viper). (1) Generation of the root system architecture (RSA) (Schnepf et al. 2018); (2) association of the k_r, and K_x, on the root types axis (Heymans et al. 2021, 2020); (3) simulation of an initial soil water profile ($Psi_{soil,water}$); (4) Solving the root system hydraulic architecture (RSHA); (5) comparison between the root water uptake rate (T_{act}) with the potential water demand (T_{pot}). If needed, update of the collar water potential (Psi_{col}); (6) updated the soil water profile based on the implicit root water uptake model, and the atmospheric data. From this point, there is a loop on the soil water profile and the RSHA. (7) The atmospheric data were used to estimate the evapotranspiration rate of reference (ET_0) and the Leaf Area Index (LAI). From the LAI, the crop coefficient (K_c) was estimated which was used to estimate the T_{pot}.