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Novel analytical tools to identify key plant root traits to minimize water stress over the whole crop cycle

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Determining the optimal plant characteristics to efficiently take up water in a heterogeneous and dynamic environment would be of great benefit in the quest for more resilient food production systems. Combinations of optimal root structural (e.g. root length, elongation rates) and functional (e.g. radial or axial hydraulic conductivity) traits – called ideotypes- have already been identified, which should improve plant performance in terms of transpiration. However, the identification of optimal root traits for ideotypes suffers from several issues. First, root system phenotyping is still a complex and time-consuming procedure. Second, the quantification of the impact of these trait changes on the potential transpiration (and yield) is usually missing (i.e. trait sensitivity). Third, the temporal evolution of optimal traits is usually not considered. Fourth, it has been emphasized that optimal root traits are only valid for specific pedo-climatic conditions while it has been demonstrated that no root system can perform ideally in any situation (local optimum). Finally, there is probably not only one unique optimal ensemble of traits: other combinations could lead to similar water uptake behavior (non-unicity).

To understand the impacts of plant trait selection in an ocean of complexity, we developed an analytic pipeline based on mathematical models.

First, we developed "plant-scale effective parameters", which characterize the ability of plants to take up water in heterogeneous conditions. These macroscopic parameters are easy to determine, can be related unambiguously to a set of traits and can be estimated from models or measurements. Second, we developed analytical relations to calculate the value of these macroscopic parameters from functional or structural trait quantification. This allowed us to estimate, for instance, how a change of 20% of root cell radial conductivity affects the total plant root conductance. Finally, we identified optimal strategies, i.e. evolution of plant macroscopic parameters in time as a function of the environment. These tools allowed us to define the concept of "eco-ideotypes", i.e. ideal combination of local traits that minimize water stress over their crop cycle in a particular environment and to quantify them without the need of an explicit root system architecture map. These new tools were compared to a FSPM model simulation over whole crop cycle to validate their performances.