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The flow of water: Critical factors of root axial water transport determined

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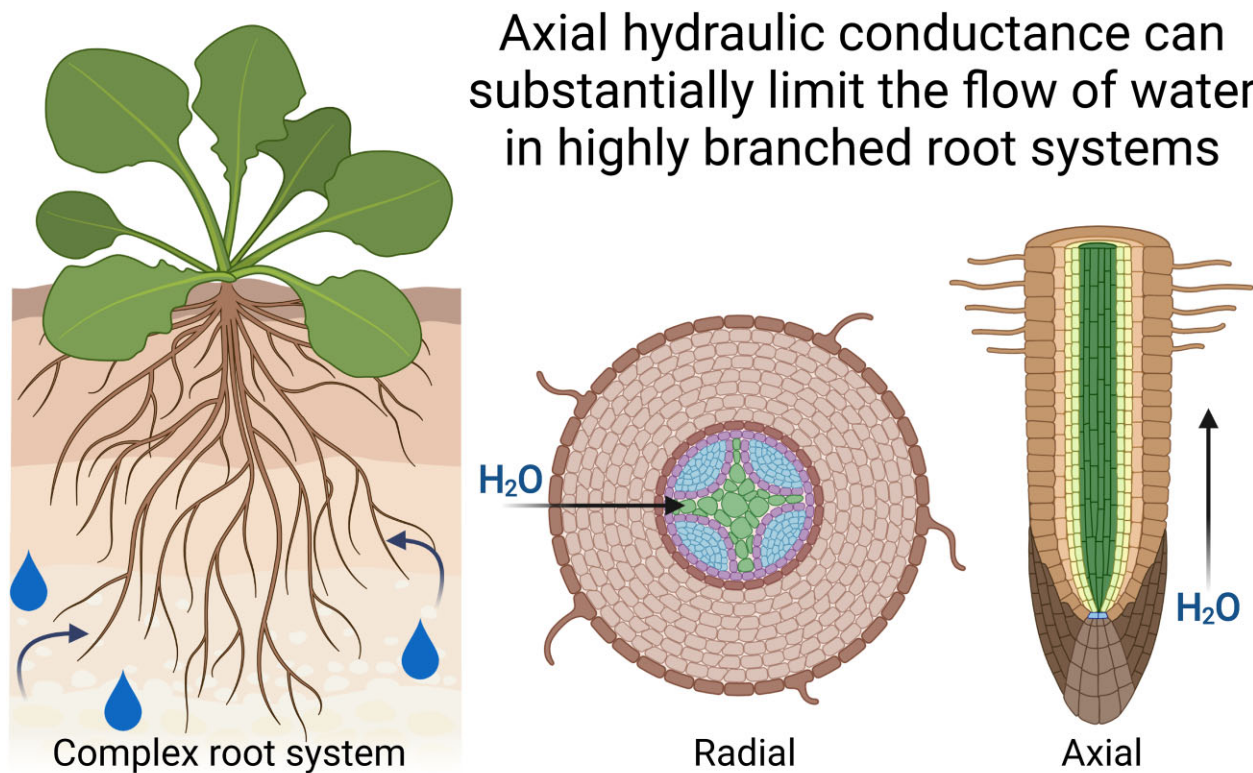*Author for correspondence: swege@uni-bonn.de

Our finite natural resources require that we produce new innovative strategies to grow our crops, maintaining high yields while simultaneously reducing the strain on the environment. One of the most critical natural resources in agriculture is water, and irrigated agriculture accounts for >70% of global water withdrawals (Faurès et al., 2002). This not only constitutes a critical strain on our water resources, but field irrigation can also have severe negative side effects, in particular soil salinization. Soil salinization is one of the major factors leading to pronounced yield losses over time (Munns et al., 2020). A comprehensive understanding of how water flows through plants is, therefore, key for a sustainable agriculture.

Land plants take up almost all water via their root systems. Water movement can be classified into two types: radial water flow from the surface of the root to the central cylinder and axial water flow toward the shoot within the central cylinder (Figure 1). The latter occurs primarily in xylem vessels, and water flow capacity or hydraulic conductance in the large hollow vessels is classically estimated to be less restrictive as compared to radial hydraulic conductance. Although several lines of evidence show that axial hydraulic conductance is lower than theoretical estimates, detailed experiments on the relative contributions of axial and radial conductivity are sparse, in particular in complex root systems. Yet, this information is crucial to understand which modifications of plant root systems might be beneficial to optimize water uptake and water use efficiency, and to prepare our crops for a future in which less water will be available (Maurel and Nacry, 2020).

In this issue of *Plant Physiology*, Boursiac et al. (2022a) developed the hydraulic mathematical model "HydroRoot" and used it in combination with a cut-and-flow experimental procedure to investigate root hydraulic conductance of complex and highly branched root systems. In cut-and-flow experiments, entire root systems were placed into a pressure chamber, and the shoots were removed to measure pressure-induced sap flow. Then, the roots were sequentially mechanically ablated with the cuts progressing from the tips to the base, leaving open xylem vessels in direct contact with the solution. This resulted in root systems with cuts in roots of different orders and at different distances to the respective root tips. Before and after each sequential cut, pressure-induced sap flow was measured to determine hydraulic conductance of the modified root system. Using this method, and in combination with HydroRoot, both axial and radial conductances were obtained in a single experiment and for the same plant. With this approach, Boursiac et al. (2022a) showed that axial conductance in particular increases less with distance to the root tip than expected from classical models. They found that, in highly branched root systems, axial hydraulic conductance can be as strongly limiting as radial hydraulic conductance for water transport to shoots (Figure 1). While Boursiac et al. (2022a) used the model plant Arabidopsis (*Arabidopsis thaliana*, *Brassicaceae*), similar highly branched roots systems are present in many of our noncereal crops, ranging from potatoes (*Solanum tuberosum*, *Solanaceae*) and common beans (*Phaseolus vulgaris*, *Fabaceae*) to lettuce (*Lactuca sativa*, *Asteraceae*) and cotton (*Gossypium hirsutum*, *Malvaceae*).

These findings, adding to previous results and models, are therefore important for plant breeding strategies aiming to produce new plant varieties with optimized root system architectures. In particular, HydroRoot can help to identify root sections that are key for water uptake, which can support irrigation management and help prevent soil salinization (Doussan et al., 1998; Meunier et al., 2017; Couvreur et al., 2018). Depending on the environment, a more or less

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Axial hydraulic conductance can substantially limit the flow of water in highly branched root systems

Figure 1 Both axial and radial root hydraulic conductance are limiting factors for water movement to shoots. The flow of water from the soil to the shoot is determined by the hydraulic conductance or water flow capacity of the root, which can be divided into radial and axial hydraulic conductance. Radial hydraulic conductance is linked to water movement through the apoplast and across plasma membranes toward the central cylinder, whereas axial hydraulic conductance is linked to water movement in xylem vessels toward the root–shoot–junction. Created with BioRender.com.

branched root system might be more beneficial for optimizing water use efficiency. The plant root system is developmentally dynamic, and its complexity depends not only on the plant species or variety but also on environmental cues. A combination of experimental and modeling approaches will therefore help uncover this complex relationship and help prepare our plants for the future (Meunier et al., 2017; Couvreur et al., 2018; Boursiac et al., 2022b).

Conflict of interest statement. None declared.

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