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The role of root hairs in root water uptake - Insights from an image-based 3D model

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Plants acquisition of soil resources such as nutrients and water will be severely impeded in the near future as a consequence of climate change. Root hairs, tubular extensions of epidermal root cells, substantially increase the contact area between roots and soil and are hence considered a key rhizosphere trait increasing the capacity of plants to capture soil resources. While their pivotal role in the uptake of immobile nutrients such as phosphorus is well accepted, their effect on root water uptake remains controversial as it varies across plant species.
By means of image-based modelling, our objective was to identify environmental conditions (e.g. soil water content) and hair traits (e.g. root hair length and density) that determine the effectiveness of root hairs in root water uptake. Furthermore, we investigated the effect of drought stress-induced root hair shrinkage on root water uptake.
Using synchrotron radiation X-ray CT, we scanned root compartments of 8 days old maize seedlings (*Zea Mays* L.) grown in loamy soil, a complex porous medium. The acquired image-data served as a basis for our image-based 3D root water uptake model. By solving Richards equation numerically, we computed the propagation of water potential gradients across the root-soil continuum. The high spatial resolution of the acquired images allowed to explicitly take rhizosphere features, such as root hairs, root-soil matrix contact and aggregate structure into account. To determine the key parameters governing the effectiveness of root hairs in water uptake, we compared a set of six maize root compartments of approx. 1.4mm length before and after digitally removing their hairs. The quantification of root hair turgor-loss in response to progressive soil drying allowed us to implement hair shrinkage within our model.
We found that the effectiveness of root hairs in root water uptake mainly depends on 1) the root hair induced increase in root soil contact and 2) root hair length. Furthermore, our results suggest that root hairs potentially facilitate root water uptake under dry soil conditions (< -0.1MPa). However, in the dry range, root hair shrinkage severely impairs the effect of hairs. Depending on the turgor-loss curve, root hairs may still provide a positive effect on root water uptake in a narrow range of soil matric potential.

In summary, the effect of root hairs on root water uptake is determined by soil water content, root-soil contact, root hair length and the turgor-loss point of hairs.

Participation

In-Person

References

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