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A novel rhizotron platform for studying root–soil hydraulic interactions in heterogeneous environments

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The objective of this study is to investigate experimentally how plants adjust their structural and functional properties when facing soil water heterogeneity from the plant down to the organ scales. We developed a novel rhizotron platform, each rhizotron equipped with 9 hydraulically isolated compartments, wherein constant spatial patterns of local soil water potential can be imposed while monitoring water consumption and root development. In the validation experiment, maize plants (cv. B104) were grown under constant and homogeneous water potential in this rhizotron platform for four weeks, before entering a fifth week in which different levels of water potential were imposed. The desired local soil water potentials were successfully applied and adjusted. The local water consumption and root morphological traits were monitored in real time, indicating that root water uptake and root elongation correlate with root age and local soil moisture. At the whole-plant scale, more negative soil water potentials resulted in a lower cumulative water uptake, while at the local scale, cumulative water uptake within individual compartments increased more rapidly as root length within the same compartment increased, indicating a direct coupling between local root development and local water extraction. These observations highlight a strong spatial-temporal linkage between root traits and soil water conditions. Together, the validated rhizotron platform enables root plasticity studies by establishing quantitative and dynamic measurements for soil–root hydraulic interactions at the plant and organ scale, providing a promising platform for future studies exploring how maize plants respond to spatial and temporal heterogeneity in soil water environments.