Automated Root Tracking with "Root System Analyzer"

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Crucial factors for plant development are water and nutrient availability in soils. Thus, root architecture is a main aspect of plant productivity and needs to be accurately considered when describing root processes.

Images of root architecture contain a huge amount of information, and image analysis helps to recover parameters describing certain root architectural and morphological traits. The majority of imaging systems for root systems are designed for two-dimensional images, such as RootReader2, GiA Roots, SmartRoot, EZ-Rhizo, and Growscreen, but most of them are semi-automated and involve mouse-clicks in each root by the user.

"Root System Analyzer" is a new, fully automated approach for recovering root architectural parameters from two-dimensional images of root systems. Individual roots can still be corrected manually in a user interface if required.

The algorithm starts with a sequence of segmented two-dimensional images showing the dynamic development of a root system. For each image, morphological operators are used for skeletonization. Based on this, a graph representation of the root system is created. A dynamic root architecture model helps to determine which edges of the graph belong to an individual root. The algorithm elongates each root at the root tip and simulates growth confined within the already existing graph representation. The increment of root elongation is calculated assuming constant growth. For each root, the algorithm finds all possible paths and elongates the root in the direction of the optimal path. In this way, each edge of the graph is assigned to one or more coherent roots. Image sequences of root systems are handled in such a way that the previous image is used as a starting point for the current image. The algorithm is implemented in a set of Matlab m-files.

Output of Root System Analyzer is a data structure that includes for each root an identification number, the branching order, the time of emergence, the parent identification number, the distance between branching point to the parent root base, the root length, the root radius and the nodes that belong to each individual root path. This information is relevant for the analysis of dynamic root system development as well as the parameterisation of root architecture models.

Here, we show results of Root System Analyzer applied to analyse the root systems of wheat plants grown in rhizotrons. Different treatments with respect to soil moisture and apatite concentrations were used to test the effects of those conditions on root system development. Photographs of the root systems were taken at high spatial and temporal resolution and root systems are automatically tracked.