Researchers image roots in the ground

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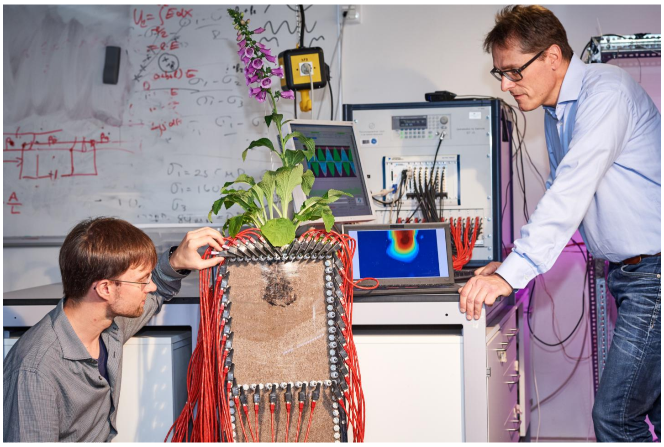

Maximilian Weigand (left) and Prof. Dr. Andreas Kemna of the Department of Geophysics of the Steinmann-Institute of the University of Bonn use electrical impedance tomography to visualize the root activity of plants. Credit: Volker Lannert/Uni Bonn

It's a familiar hazard of vacation time: While you're conspicuously absent, your colleagues in the office forget to water and fertilize the plants - often leaving behind nothing but a brownish skeleton. Whether a plant thrives or wastes away depends above all on whether its roots get enough water and nutrients. Geophysicists at the University of Bonn have now visualized such processes for the first time using electrical impedance tomography. The researchers have now published their results in the scientific journal *Biogeosciences*.

Plants imbibe the vital cocktail of water and mineral nutrients through their roots. This twisting organ not only provides purchase in the soil - the fine root hairs actually grow actively into soil zones where the fount of nutrients bubbles particularly richly. Plants take up minerals either directly from the soil solution or get them from clay minerals or humic substances. In the end, these microscopically small processes at the root hairs of plants also determine whether the world population goes hungry or has enough to eat. This connection explains the great scientific interest in these processes in the soil.

The mineral substances in the soil are usually present in the form of electrically charged ions. "The ions influence the electrical properties of the roots, which enables us to visualize the uptake of nutrients by roots in a new way", says Prof. Dr. Andreas Kemna, geophysicist at the University of Bonn. His team has now developed a new method: The scientists "x-ray" the root systems of the plants using electrical impedance tomography, which is also used as an imaging technique in medicine.

"Unlike doctors, however, we not only measure electrical conductivity, but also electrical polarizability, which is influenced by the uptake of nutrients at the plant root", explains Prof. Kemna. While conductivity describes the ability of a medium to transport electrical charges, polarizability is the ability to align local positive and negative charges using an electrical field - similar to a compass needle in a magnetic field.

Conclusions regarding nutrient uptake by the root system

The researchers are experimenting with the roots of living crops, which are embedded in a transparent Plexiglas box filled with a nutrient solution. The researchers apply an alternating electric field to this so-called rhizotron. The electrical polarization processes this produces vary with the uptake of ions by the roots. Numerous measurement sensors on the rhizotron record the polarization signals, which are transformed into tomographic images with the aid of special numerical algorithms.

By performing the electrical impedance tomography at different measurement frequencies, the researchers get frequency-dependent tomograms, which can be visualized in color as cloud-like forms on the computer screen. The individual fine roots can not be recognized. "However, the resolution is good enough to permit conclusions regarding the nutrient dynamics of the root system of a plant", says doctoral candidate Maximilian Weigand of Professor Kemna's team.

When the plant is particularly active, for instance due to a rich offering of nutrients, water, and light, then there are correspondingly great changes in the polarization signals at the roots - for instance in the daytime compared to nighttime. However, if there is a stress situation, such as drought or a dearth of nutrients, then the lack of nutrients also leads to a visible drop in polarizability. This can then be visualized and observed through the tomography.

"With this study, we have demonstrated the fundamental feasibility of the method", says Prof. Kemna. The next step is to use theoretical models to reproduce the electrical polarization processes in such measurements. In addition, the scientists also want to test their system out in the field, where there are still no suitable, non-destructive measurement methods to record the activity of root systems. Together with the Jülich Research Center, a test with winter wheat is underway in Selhausen in the context of the Transregional Collaborative Research Centre "Patterns in Soil-Vegetation-Atmosphere Systems - Monitoring, Modelling and Data Assimilation".

Prof. Kemna gives an example: "If we can optimize nutrient uptake, we will be able to anticipate and react better to the risks of drought due to climate change and possibly increase crop yields". The new method could be of valuable service in gaining a better fundamental understanding of the interactions between roots and soil.

More information: Maximilian Weigand et al, Multi-frequency electrical impedance tomography as a non-invasive tool to characterize and monitor crop root systems, *Biogeosciences Discussions* (2016). DOI: 10.5194/bg-2016-154

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