Developing an electrode design for EIT field measurements on crop root systems

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The root system is an important component of the biosphere, linking the soil to the vegetation-atmosphere environment. To improve crop breeding, production and management, it is essential to better understand root-soil interactions and associated processes. Especially root architecture, growth and activity play a key role in nutrient uptake of crops. To date, studies of root systems are scarce compared to those of shoots due to challenges associated with investigating the hidden roots in the soil. Furthermore, the variable structure of the root system and the small diameter of fine roots pose an additional challenge for their observation. Hence, the development of non-invasive methods for studying plant roots in situ is important.

The spectral induced polarization (SIP) method is more and more used for environmental and near-surface applications in the vadose zone. Especially the method of electrical impedance tomography (EIT) that is used to image the subsurface distribution of electrical conduction and polarization properties is capable of characterizing and monitoring root extension and physiological processes. Within the context of the establishment of EIT as a tool for root system characterization and monitoring at the field scale, we here present a newly developed electrode design to monitor crop root systems on the field scale during an entire growing season. Electrodes used in a farmed field should influence the soil and crops as little as possible and they need to be non-polarizable to prevent polarization effects when using the required narrow electrode spacing. Hence, the use of available non-polarizable electrodes containing lead or other contaminating materials is undesirable. Here, we propose a novel electrode design consisting of a PVC tube with a metal stick and bentonite as the filling electrolyte. The clay-filled electrode is able to maintain a high moisture content for extended time periods and therefore allows good contact to the soil while minimizing polarization effects.

The new electrode design has been tested during three test series that were conducted between 2015 and 2017. In the first test we compared the new bentonite electrodes to two well known electrode types (stainless steel and Pb/Pb-Cl) in parallel measurements. The results show a comparability of the newly developed electrodes to the stainless steel electrodes, both provided stable phase signals and not too high magnitudes during the 35 days. In the second test, the electrodes were installed in a field experiment for five months for EIT monitoring during a growing season. In the summer season, the soil got very dry and so did the bentonite in the electrodes that led to high transfer resistances and low current injection, which resulted in inaccurate EIT measurements. In a next step, electrodes with a more stable bentonite mixture were evaluated.

{Results and conclusion on next page}

The results for this electrode design showed that even for a very dry environment (sand box) the electrodes provide a longer stability and accurate EIT measurements. After saturating the sand again, the electrodes apparently absorb the water indicating that drying of the electrodes is reversible. For this reason, electrodes tested in a field experiment in a lawn showed a consistently high quality of measurements because intermittent rainfall rewetted the bentonite.

It was concluded from the test measurements and the field experience that the newly developed electrode design is practicable for the use in EIT field measurements on crop root systems. During long drought periods, it is advisable to extend the current electrode design with a drip irrigation system to maintain a wet and thus intact bentonite filling. Without such a system, the electrodes will eventually dry and become too resistive for accurate measurements, especially in summer.