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Root properties revealed from spectral induced polarization.

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Exploration of root systems is challenging, as there is no direct access to the root. Recently, the spectral induced polarization (SIP) method is proposed to monitor roots in a noninvasive fashion. The SIP method is sensitive to polarization processes at relatively low-frequency range (mHz to KHz). To monitor roots, the relationship between root properties and its electrical signature needs to be established, and this is the main objective of this work.

We conducted a series of experiment to reveal the dependency between SIP signal and root's physical properties such as root mass, total surface area, etc. SIP response was measured for the different part of the root (from the beginning of the stem to the tip of the root) such that the distribution of the SIP signal along the root length was obtained. A linear relationship between root surface area and the magnitude of polarization was observed. A positive relationship between root biomass and polarization was also observed. In addition, and in order to shed light on the mechanism governing the SIP response of root, we conduct an experiment in which we add cyanide (Carbonylcyanide 3-chlorophenylhydrazone) to the growing medium. Following the addition of 2 mg/l of cyanide, a steep decrease in polarization was observed. The decrease in polarization is associated with the changes in root membrane potential caused by the cyanide.

To better understand the experimental results, we simulate single root polarization using the Poisson-Nernst-Planck equations in the frequency domain. Using the model, we demonstrated relationships between cell properties and cell polarization. We showed that the relaxation time increases with increasing cell diameter and that the polarization increases with increases of the cell membrane potential.

In accordance with the model, the decrease in the polarization of the root under the impact of cyanide supports the hypothesis that the cell membrane electrical double layer is the source of the plant root polarization. The relationships between the physical properties of plant root grown in hydroponics and SIP signal demonstrates the potential to phenotype plant roots using the SIP method.