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Spectral induced polarization of the plant root: Experiments and numerical modeling.

Kuzma Tsukanov and Nimrod Schwartz
Department of Soil and Water Sciences, Robert H. Smith Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, PO Box 12, Rehovot 7610001 Israel (kuzma.tsukanov@mail.huji.ac.il)

Exploration of plant roots and monitoring their conditions during growth is of great importance. A promising method for the non-invasive investigation of plant roots is spectral induced polarization (SIP). To enhance understanding of the mechanism controlling the plant root's induced polarization response, we have conducted a series of experiments and constructed a physical-based numerical model. We measured the SIP signal of wheat root grown in the nutrient solution. The experiments have demonstrated a relationship between the SIP parameters (chargeability and relaxation time) and the root biomass and surface area. Monitoring the SIP response of roots poisoned by cyanide has revealed that the root polarization source is the cell membrane potential. In addition, we modeled plant root as a collection of 2-dimensional individual cells surrounded by an electrolyte. The SIP signal was calculated based on the numerical solution of the Poisson-Nernst-Planck equation. The model has supported the experimental results with the correlation between the magnitude of polarization and the root surface area. According to the model, the root polarization magnitude is related to the root's external surface area. The polarization length scale is the root's diameter, not the cell diameter. Based on these results and data from the literature, we suggest that at the low-frequency range associated with the SIP method, passing the current through the plant results in polarization of the individual cells, a relatively high polarization and relaxation time that is related to the cell length. On the other hand, injecting current to the growing medium results in the polarization of the external surface area of the root and polarization length scale related to the root diameter.