A novel method for monitoring root growth by electrical impedance spectroscopy (EIS)

Tapani Repo[1], Janne Laukkanen[2] and Raimo Silvennoinen[2]

METLA JOENSUUN YLIOPISTO

1) The Finnish Forest Research Institute, Joensuu Research Centre, P.O. Box 68, FIN-80101 Joensuu, Finland, tapani.repo@metla.fi
2) University of Joensuu, Department of Physics, P.O. Box 111, FIN-80101 Joensuu, Finland

Background

The electrical properties of the root-soil system change with root growth. According to an earlier study, the capacitance of the plant-substrate system changed with root growth [1]. We assumed that the resistance at the plant-substrate interface changes with an increase in the contact surface area.

Material and methods

- The root growth of willow (*Salix myrsinifolia*) cuttings was monitored by a displacement method [2] and was compared with the EIS parameters
- The cuttings were cultivated in hydroponics in a growth chamber
- The impedance spectra (IS) of the plant-solution system were measured using Agilent 4294A Precision Impedance Analyzer at 489 frequencies between 40Hz and 340kHz (Fig. 1)
- The IS was modelled by the equation

$$Z = R + \frac{R_1}{1+(j\tau_1\omega)^{\Psi_1}} + \frac{R_2}{1+(j\tau_2\omega)^{\Psi_2}} + \frac{1}{\tau_3(j\omega)^{\Psi_3}} \quad (1)$$

  where *Z* is the complex impedance, R is the series resistor, and R_i, τ_i and Ψ_i, (i = 1,2) are the resistors, relaxation times and distribution coefficients of the relaxation times respectively. τ_3 and Ψ_3 are the parameters, and *j* is the imaginary unit
- The parameters were estimated by means of a Complex Nonlinear Least Squares (CNLS) curve fitting program

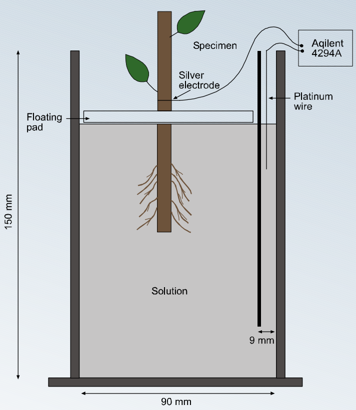

Fig. 1. The measuring cell for the IS measurements.

Results

- The IS consisted of two overlapping arcs and an 'elbow' at low frequencies (Fig. 2)
- The distributed model (Equ. 1) fit well with the IS
- The root mass increased during the study (Fig. 3)
- The sum of the resistances R_1+R_2 decreased during the study (Fig. 4)
- The mean Pearson's correlation coefficient between the root mass and (R_1+R_2) was -0.70 (Fig. 5)

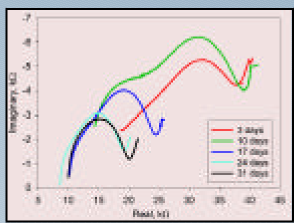

Fig. 2. A typical IS of willow at one-week intervals. The low frequency (40 Hz) is on the right and the high frequency (340 kHz) on the left.

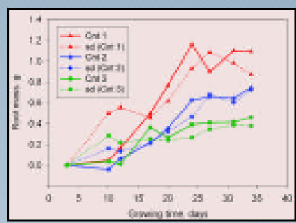

Fig. 3. The mean root mass of willow cuttings (by displacement method) in three hydroponic containers (Cnt) with standard deviations (sd) (n=20).

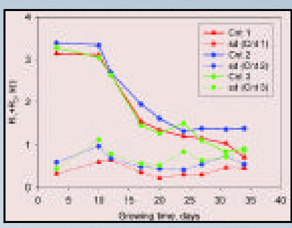

Fig. 4. The mean of the sum of resistances R_1 and R_2 of willows in three hydroponic containers (Cnt) with standard deviations (sd) (n=20).

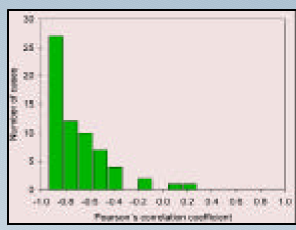

Fig. 5. The frequency distribution of the Pearson's correlation coefficient (r) for the relation between (R_1+R_2) and the root mass.

Conclusions

- The EIS method produced promising results for root growth
- Pearson's correlation coefficients correspond with the results achieved by using the capacitance method and minirhitzotron imaging
- The effects of the soil on the results suggest the need for further studies to be made

References

[1] Dalton, F.N. 1995. Plant and Soil 173: 157-165
[2] Burdett, A.N. 1979. Can. J. For. Res. 9: 63-67