Can the size of a root system be estimated by its electrical capacitance?

R. C. DIETRICH[1,2], A. G. BENGOUGH[1, 3], H. G. JONES[2], P. J. WHITE[1]
Email: Ralf Dietrich[1], ralf.dietrich@hutton.ac.uk; Glyn Bengough[1], glyn.bengough@hutton.ac.uk

[1] The James Hutton Institute, Invergowrie, Dundee DD2 5DA, UK
[2] Plant Science Division, College of Life Science, University of Dundee at The James Hutton Institute, Dundee DD2 5DA, UK
[3] Division of Civil Engineering, School of Engineering, Physics and Mathematics, University of Dundee, Dundee DD1 4HN, UK

Introduction

There is much interest in the use of capacitance measurement to estimate the size of intact root systems. The equipment required is cheap and easy to apply.

Many studies have reported good correlations between capacitance (C) and root system mass, and a linear relationship between these variables is predicted by a model proposed by Dalton (1995)

Two studies were conducted to test the Dalton model on hydroponically grown barley (*Hordeum vulgare* L. cv. Optic) and on barley grown in soil.

In the first study a range of treatments was used that included submerging roots gradually and cutting roots below the solution surface.

In the second study the plants were left to dry before the soil was incrementally watered from below.

References
Dalton F.N. (1995) In-situ root extent measurements by electrical capacitance methods. *Plant and Soil* **173**, 157-165.

Acknowledgements
Ralf C. Dietrich acknowledges a Ph.D- studentship of the James Hutton Institute and the University of Dundee.

Methods

Experimental design

Capacitance was measured with a C-meter by inserting one of two electrodes in the rooting medium and attaching the other to the plant (plant electrode).

In hydroponics sixteen whole root systems of different ages and 154 single roots were submerged and capacitance was determined (Fig. 1 a). Four of the root systems and ten individual roots were then partially submerged and capacitance was measured before and after the submerged root parts were chopped 2 mm below the surface (Fig 1 b). Finally the masses of the removed root parts and the sums of root cross-sectional areas at the immersion points were determined.

In the soil study 34 barley plants grew in pots with potting compost and were left to dry for 20 to 30 days. The soil of half of the pots was then incrementally watered from below by placing the pots in a basin and adjusting the height of the water table.

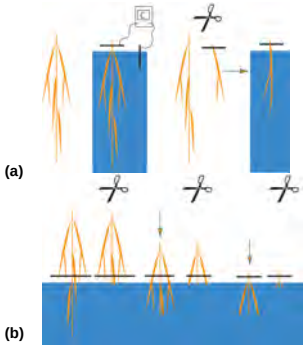

Figure 1 (a) Plant electrodes were attached to the top of the root system, roots were submerged to 5 mm from the plant electrode, and capacitance measured. (b) Roots were removed from the solution and partially resubmerged. Then the plant electrodes were attached to roots 5 mm above the solution and capacitance measured. Roots were trimmed 1 – 2 mm below the solution surface and the capacitance remeasured. This procedure was repeated incrementally by further submergence and trimming until no root remained.

Results

In hydroponics : Good correlations were found between capacitance and mass for whole submerged root systems in solution (Fig. 2 a; $R^2 = 0.865^{***}$). However, excision of submerged root parts had negligible effects on the observed capacitance implying that capacitance was not directly determined by root mass. In other tests (Fig. 2 b, $R^2 = 0.978^{***}$)[1] when roots were partially submerged capacitance correlated better with the sum of root cross-sectional areas at the solution surface than with root mass (no relationship found).

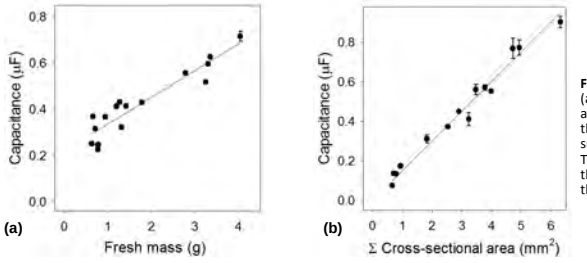

Figure 2 Relationship between capacitance and (a) fresh mass of 16 submerged root systems and (b) the sum of root cross-sectional areas at the solution surface for different depths of submergence of a representative root system. The regression line in (b) was forced through the origin. Dots represent the mean ± SD of three technical replicates.

In soil : The bulk of the root system in soil did not influence the capacitance (Fig 3). Good correlations were achieved between capacitance and the sum of shoot cross-sectional area at the soil surface but only after moistening ($R^2 = 0.932^{***}$)[1].

Capacitance was lower and the correlations poorer when the top soil was dry.

[1] for a regression line forced through the origin.

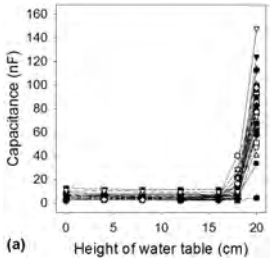

Figure 3. Capacitance of 34 plants measured at various positions of an incrementally raised water table in the soil of pots.

Conclusions

The model of Dalton is consistent with the initial observations reported here (Fig 1 a), but can not explain our other observations (Fig 1 b – 3). We found no further indication that capacitance would be related to root mass. Instead the capacitance is dominated by tissue near the solution surface and soil surface, when moist.