Simulation of Auxin Accumulation and Transport in a Plant Root

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Abstract

Plant roots have an outstanding ability to grow in the direction of gravity or nutrients. Bending of the root tip in the preferred direction is achieved by asymmetric cell growth on the opposite sides of the root, dictated by asymmetrical distribution of the hormone auxin. Increase in auxin concentration inhibits elongation of cells, whereas decrease in auxin concentration stimulates elongation. However, the mechanism of the auxin-dependent growth inhibition remains unclear. To study this phenomenon, the knowledge of auxin concentration inside the cells is essential, but it is difficult to measure. By contrast, auxin transport mechanisms are well studied: membrane carrier proteins are pumping auxin in or out of the cells. Computational models can help to integrate data on auxin transporters to predict spacial and temporal dynamics of auxin.

We constructed a 2D-axisymmetrical finite-element model of the root in COMSOL Multiphysics® (Fig.1). The model geometry comprises individual cells of the root apex, separated by a thin layer of extracellular space. Membrane permeability for auxin is assigned for each cell boundary depending on carrier localization and diffusion permeability. Outer domain of the model simulates media, thus accounting for external auxin concentration. Transport equations are solved using Chemical-Reaction-Engineering module. COMSOL Multiphysics® provides a perfect platform for our model, as graphical user interface enables any interested user to easily interact with the model.

With the help of this model we analyze the experimentally obtained growth inhibition curves for a range of external auxin concentrations and find the time delay between auxin accumulation and growth inhibition. Auxin accumulation ratio is calculated showing highest concentration in the outer layer (epidermis) and a gradient along the length of the root (Fig.1). This study contributes to understanding of root growth inhibition by auxin.

Figures used in the abstract

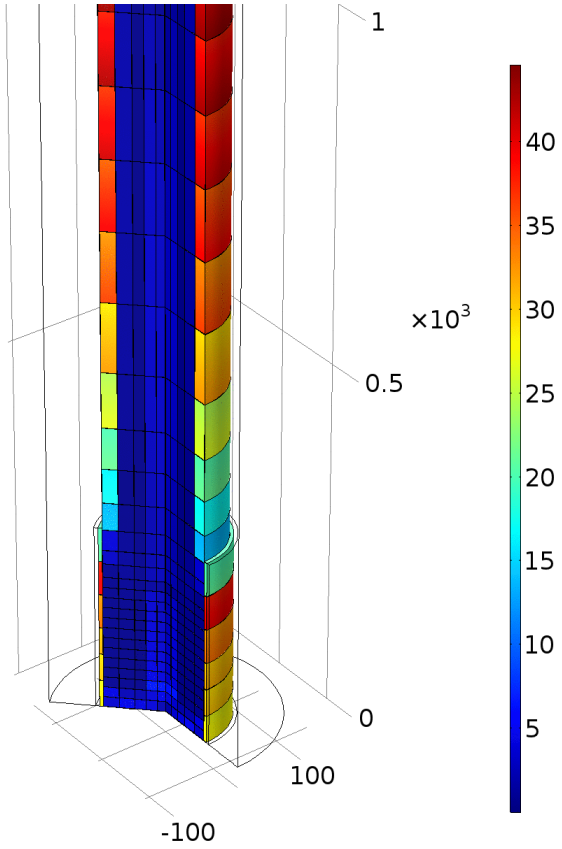

Figure 1: Accumulation ratio of auxin in the root at steady state (concentration inside the cells normalized by external concentration).