Change of root water uptake profiles in drying soils

D. van Dusschoten, Y. Müllers, J. Kochs and J.A. Postma, IBG-2, Plant Sciences, Forschungszentrum Jülich, Germany

Introduction

Plant water uptake is dependent on several root and shoot characteristics, their interaction which each other, and on water availability relative to root placement. This becomes especially important when soil is drying. Since very few technologies exist that can accurately monitor soil water content (θ) over time little is known about what happens exactly in the soil. Here we present a new technology, the Soil Water Profiler (SWaP) with which θ profiles can be very precisely monitored over time. By combination with modulated light intensity the active plant driven root water uptake (U_p) can be distinguished from passive redistribution of water through the roots (U_s) and the soil (rSWF, together S_r). We will show here how these components of Root Water Uptake (RWU) respond to progressively drying soils.

Experimental setup

Maize plants were grown in 500 mm long tubes (i.d. 81 mm), in a climate chamber (14h light, varying between 300 & 700 μE/(m²s)). Water content was monitored continuously using the Soil Water Profiler. The SWaP consists of a resonant circuit whose resonance frequency is strongly dependent on θ. This dependency was calibrated to an accuracy of 0.002 cm³/cm³. Precision : 0.000005 cm³/cm³. Four plants could be measured simultaneously along the complete length of a soil column with plant. Plants were removed on a weekly basis to monitor root growth using MRI and NMRooting for data analysis [1]. Vertical profiles of θ were obtained after deconvolution of a series of readings along the vertical axis (z) of the tube and with reference to the calibration curves. δθ/dt can also be obtained directly after numerical differentiation.

Theoretical model based on Couvreur [2]

Root water uptake has an active, plant driven, light dependent component (U_p(z) cm³/(cm³.h)) and a passive, soil water potential driven redistributive component that is lumped together with redistributive soil water flow in S_r. Rapid light modulations allows us to separate these components as transpiration (main part of U_tot) and with reference to the calibration curves, δθ/dt can also be obtained directly after numerical differentiation.

Conclusions

We developed a soil water content sensor with unprecedented precision. In it’s simplest form it can be used to investigate θ along a long pot. This is far superior to gravimetric measurements or local TDR measurements. In combination with modulating light intensities any corresponding fluctuating of δθ/dt indicates the presence of active roots and so can be used to detect rooting depth. This would take several hours but is an easily automated task. The determination of plant driven root water uptake profiles requires very few additional steps, non of which are difficult or require any special knowledge, so the SWaP should be a very easy tool to study the effect of drying soils on RWU performance and total plant water use, especially when combined with other technologies that can measure xylem or plant potential. In this way different genotypes can be compared as this low cost sensor can be used in parallel. When the sensors and pots are insulated the SWaP can be used outside using artificial shading to induce fluctuating transpiration rates.