Diagnosing Physiology and Pathology of Roots in Soil using Neutron Imaging

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An in vivo neutron imaging of 3D and 2D method was developed to quantitatively measure water content for diagnosing physiology and pathology of plant roots growing in pot soil Photosynthesis requires that plants draw carbon dioxide from the atmosphere while exposing them to water loss. For organic matter made by the plant, approximately a fraction of water is absorbed by the roots, up-taken through xylem. Even not fairly water balance in the roots can cause dehydration and physiological malfunction. New advances in neutron imaging techniques are spreading out new approaches for noninvasively studying pathology of roots in soils. The quantification of water content is very admissible using a developed calibration procedure that involves taking a water phantom of varying volume embedded in soil with several moisture conditions while in Monte Carlo simulation. Neutron imaging procedure for diagnosing root pathology and water quantification measurement of root embedded in soil was set up. The aim of this methodology is to enable the non-destructive quantification of water content within a root embedded in cylindrically shaped soil with Al pot of 60 mm diameter using neutron imaging. The objective is to non-destructively quantify water amount contained in Al phantom embedded in cylindrically shaped soil of Al pot 60 mm diameter using a predominantly thermal neutron beam. This can be made possible without many complex corrections of spectral effects, forward scattering and so on if a good calibration method can be established. The calibration in this case involves Al water phantom of varying diameters of 30 mm (water content, 7.065 mL), 20 mm (water content, 3.140mL), 10 mm (water content, 0.78 mL), 5 mm (water content, 0.196 mL) and 3 mm (water content 0.071 mL) embedded in soil. The shape of the Al phantom models the root. This Al phantom embedded in soil is scanned under the same conditions as the roots embedded in soil. The conditions include the experimental setup, the scanning and reconstruction protocol, the data extraction protocol, and soil conditions. Many parameters affecting soil condition include fraction of coarse-to-fine aggregation, moisture content and soil density. When the amount of soil is kept constant, as in this case, all of these parameters relate to attenuation. Different soil conditions were modelled as a function of attenuation. Nine soil conditions were modelled using varied moisture content in the soil. The water filled into Al Phantom embedded in each soil moisture condition of is 0%, 2.6%, 3.8%, 4.8%, 6.3%, 7.7%, 9.1%, 9.9%, and 12%, respectively and scanned using neutron imaging. This is to establish a water content level calibration as a function of the soil condition. Before the water quantification in the root can be conducted, the penetration of the soil will be determined and a suitable water calibration will be chosen. In cases where the soil property condition of the investigated root does not match any of the nine conditions calibrated for, then a calibration curve is predicted mathematically from the existing eleven conditions. This prediction is done by plotting the water attenuation value obtained from the experiment against soil condition attenuation value for each diameter of the Al phantom, fitting a mathematical solution, and predicting the water attenuation value for the root soil condition one is looking for. The method for water content determination within the root consists of several steps: Simulation with McStas showed the same tendency. Using the neutron images, the simulated results of measuring the amount of 0.071 mL ~ 7.065 mL water in various soil with less than 12% humidity showed nearly the same trend as an actual experiment. An estimation of water content of roots planted in soil is qualitatively estimated by the beam penetration value from calibration curve of neutron imaging data of water phantom in soil. The roots were 3D-imaged and their weights were physically measured outside the soil in both their saturated and dry states. This comparison was found to be off from the weight measurements by 5% due to neutron scattering effect . A neutron tomography procedure was set up to determine root water content and diagnose plant diseases in the soil. NI facilitated the noninvasive visualization of the root architecture in situ and allowed quantification of its water content during periodical checks during the winter. The images of axial slices from a neutron tomogram, which show the water and organic matter volume in roots embedded in the soil are shown .Eight 3-year-old roots in soil from the field were 3D-imaged with NT to measure the water content qualitatively. The roots in Al pot 20, 23 and 28 had a higher water content than those in Al pots 15, 16, 17and 18 with root volumes of 5.94~11.21 cm3 . In 2010, 3-year-old roots from the

Jinan field were imaged with NT. Aluminum phantoms of varying diameters filled with water were embedded in moist soil conditions of 1.3%~7.7% to generate a calibration curve for quantifying the water level (Fig.3a). The quantification of water content of the 3-year-old roots in plant 1 and plant 2 soil moisture 7.7%, were 70.0% (5%), /55.0% (5%), and 70.0% (5%), respectively (Fig. 3b~c). 3 slices at different positions of the root length were segmented and compute the penetration value of each position of the root was computed. The water amount level at each position of the root by substituting the computed penetration value into the mathematical solution of the applicable calibration curve was estimated. The water percentage in the root is determined from the average amount) of water phantom and the average root in equation. NI measurements of roots in field showed a water content of >60%, which indicated healthy conditions Neutron imaging can be used to visualize in vivo photomorphogenesis in the plant roots based on the sensitivity to different light wavelengths for photosynthesis stint.