Application Note RACCT9024

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Tomato Plant Root System Analysis by X-ray CT

About the sample: Plant roots

Plant root systems are the primary mechanism, by which plants obtain water and nutrients. By characterizing root systems, one can understand plant phenotypes to help breed plants with more efficient water and nutrient capture. The problem, however, is that traditional root characterization can be tedious and include 'shovelomics' techniques that require extraction of the plant from the soil and washing the root system prior to root phenotyping. More recently, non-destructive X-ray CT (computed tomography) techniques have been developed to characterize root system architecture. These methods offer the advantage that root system architecture can be characterized in situ.

Analysis procedure

1. In this example, a small tomato plant was scanned using a micro-CT scanner, CT Lab HX.
2. The CT image was segmented to isolate the root system using both thresholding and deep learning segmentation.
3. A root thickness analysis was performed to characterize the root system.

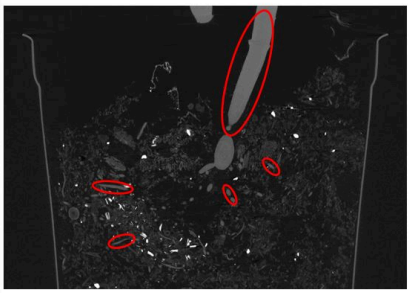
1. CT scan

A small tomato plant was scanned to produce a 3D grayscale CT image.

The cross-section shows the plastic container, soil, roots, and some region of the plant above the soil. The cross-section image indicates the location of roots throughout, in red, and illustrates a similar density for root and soil.

3D image

2D cross-section



2. Image segmentation

Segmentation for this sample was difficult because the soil and roots have similar X-ray absorption rates and thus little contrast difference. Additionally, deep learning techniques are not always successful given that the continuity of the root system isn't maintained. As a result, these data were segmented into roots and other material using a combination of both thresholding and deep learning segmentation. This approach aids to retain root continuity while eliminating as many non-root moieties as possible.

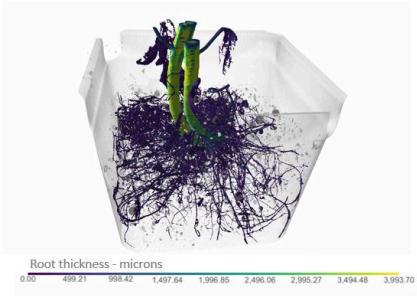
3D image

3D image with soil removed

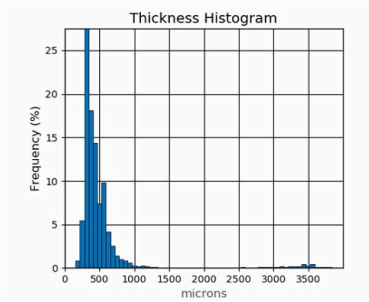
3. Root thickness analysis

The segmented roots were analyzed with respect to the root thickness. The root thickness varies from a few microns (purple) to 4 millimeters (yellow). Specifically, the stem and primary roots are larger (up to 4 mm) while the lateral roots are smaller (less than 1 mm). The root thickness histogram shows that there is greater frequency of smaller roots.

Root thickness distribution



Root thickness histogram



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