Imaging sorghum roots in natural soil

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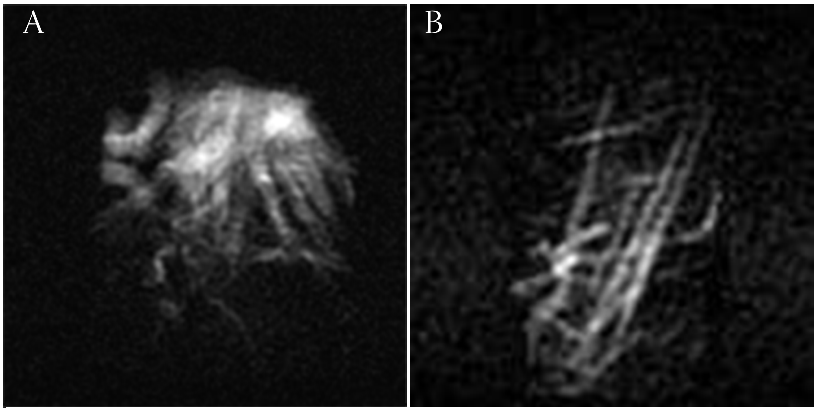
Introduction: It is relatively easy to measure the parts of crop plants that are above ground to improve agricultural procedures and plant genetics. Nonetheless, the roots are important parts and the world lacks a good way to measure their configuration *in situ*. One typically digs the roots up and washes off the soil. Then, they are not as they were in the ground. This project endeavors to image the roots of energy sorghum (*Sorghum bicolor*) in natural soils. Previous plant-root MRI pursuits were complicated by the fact that almost all natural soils have high magnetic susceptibility and researchers used their existing high-field laboratory MRI systems [1-5]. Either high-susceptibility soils distorted the images or the water in special synthetic or low-susceptibility soils had similar relaxation to the water in roots and the two were difficult to separate.

Methods: We constructed a prototype 47 mT (2 MHz proton resonance) electromagnet, magnetic-field-gradient coils, and a quadrature, double-saddle RF coil to image 250 ml samples. At this lower field, water in roots in natural soils has T_2*>3 ms, T_1 about 1 s, and T_2 about 300 ms. Water in natural soils has T_1 about 4 ms and T_2 about 1 ms. By using a 16-echo, spin-warp sequence with 7 ms echo spacing, we avoid signal from soil water and make images of roots alone.

Results and Discussion: The signal-to-noise ratio (SNR) is expectedly low compared to higher-field systems. It currently takes about 9 hours to make a 3D image. Alternatively, we take 8 or 10 2D spin-warp images (third dimension is unresolved) with equally-spaced view angles that rotate 180 degrees around the vertical axis. When the images are played as frames if a video, the roots appear to rotate about the vertical axis. The mind's eye constructs a 3D image of the roots. One can stop the video at appropriate views to measure branching angles and one can extract root diameters. Thus, we gain the necessary biological information without a full 3D image in about 20% of the scan time. We also take advantage of the fact that the roots are sparse and appear as light streaks in a dark background. We can detect roots smaller than the voxel size and ascertain the partial volume they fill by pixel brightness. Thus, we can use coarse-resolution images that deliver relatively high SNR in short scan times.



A shows a single frame of sorghum crown roots grown in Houston Black soil in a greenhouse; **B** shows field-grown roots in a clay loam.

We are currently assembling a full-size, field-deployable system. The roots will remain *in situ* but soil around them will be excavated to make room for the MRI system. A 244 mm ID, 267 OD PVC pipe will be pressed into the ground around the chosen plant roots to maintain them in their natural configuration. An approximately 0.7 m diameter annular hole will be excavated around the sample and the MRI system with 620 mm OD and 279 mm clear bore will be lowered in place for imaging.

References:

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