NMR Imaging of Drought-Induced Vessel Blockage and Restoration Of Hydraulic Conductivity in Citrus and Blueberry Plants

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Introduction

The mechanics of water movement in plants is unusual because water is transported under a state of hydrostatic tension through vessels known as xylem. Under drought conditions this tension can become severe and lead to cavitation, resulting in trapped gas bubbles that block flow. The resulting loss of hydraulic conductivity deprives leaves of water, leading to wilting and ultimately death. Recently, NMR imaging has become a powerful tool for studying plant hydraulics in vivo because of its non-destructive nature. The goal of this study was to determine whether the functional status of citrus xylem vessels could be determined (i.e. water-filled and functional vs. air-filled and non-functional) using nuclear magnetic resonance imaging at the UF AMRIS facility, and whether citrus fruit development could be non-destructively studied.

Experimental

Stem and fruit samples from Hamlin Orange trees were collected at the UF-IFAS Citrus Research & Education Center in Lake Alfred, FL and sent overnight to the Gainesville campus. Samples were loaded into the 4.7T and 11T NMR imaging systems to establish which instrument and imaging parameters (e.g. gradient echo, spin echo, 2D vs. 3D, etc.) would provide sufficient images for this study.

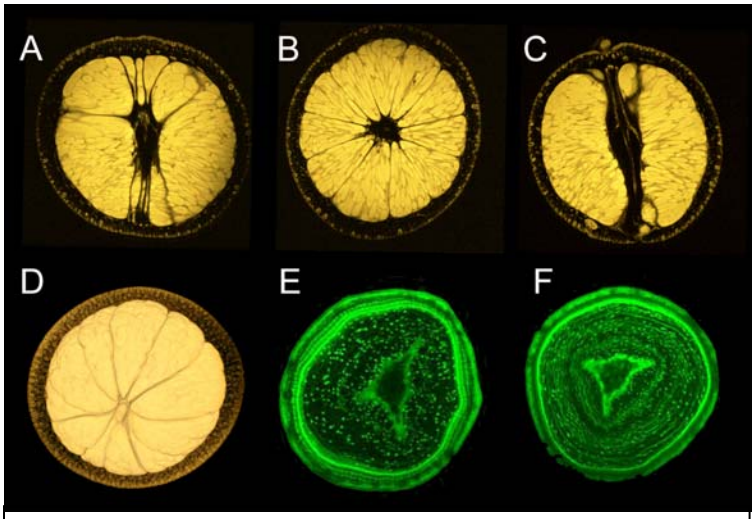

Figure 1: Two dimensional NMR imaging of Hamlin Orange fruit in the xy, xz, and yz planes (A-C, respectively). Fruit is approximately 4cm in diameter. Three dimensional NMR image of an orange rendered with Avizo software (D). Transverse cross sections through citrus stems

Results and Discussion

The preliminary data generated using the 11T instrument provided the best resolution when comparing the two instruments (11T vs. 4.7T). The spin-echo parameters provided excellent detail of the Hamlin Orange, including the individual segments, juice sacks, oil glands in the peel, and seeds. The 2D images (Figure 1A-C) proved to be of sufficient quality that we will begin a season-long developmental study of citrus with and without “Citrus Greening” disease that causes fruit to become misshapen. During this past year we were able to image fruit from different stages of development. We are currently growing citrus trees with long stems so that live plants can be mounted in the instrument such that the whole tree is threaded through the horizontal bore of the magnet. In this way we can visualize the functional status of citrus vessels in vivo using this non-destructive technique (Fig. 1E,F).

Conclusions

The imaging tools at the UF AMRIS facility have proven to be of sufficient resolution to produce preliminary data that will be a strong component of an upcoming USDA grant (2014). If funding is secured through this agency we will continue to use the UF AMRIS facility to explore the implications of drought on citrus development.

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