MRI of hydraulic failure in plants by means of a mobile, low field imager: can low spatial resolution be compensated by means of MRI relaxometry?

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Embolism formation in plants refers to the blockage of microscopic xylem vessels by air bubbles, as may be induced by severe drought. Emboli disrupt water transport from roots to leaves, causing hydraulic failure and ultimately plant mortality. Understanding the dynamics and spatial progression of embolism formation in the plant is crucial for assessing plant resilience in the face of climate change and extreme weather events.

Air emboli occur in xylem conduits that in most cases are much smaller than can be spatially resolved by MR imaging. A major strength of MR is that it can nonetheless visualize the process. MRI relaxometry allows to detect, rather than resolve, changes in tissue physicochemical properties and either quantify the corresponding NMR parameters, or to calculate high-contrast parameter maps.

The ability to detect embolism formation by means of spatially resolved relaxometry (i.e., with parameter maps of amplitude, T2, and combinations thereof) rather than to visualize it by brute resolving force, is especially helpful when dealing with low field MRI devices. These typically are based on permanent magnets that do not only have a lower field strength, but also lower homogeneity and higher peak width than laboratory-based supercon systems, and typically cannot muster the gradient strengths that such systems can. These factors together limit the spatial resolution that can be achieved.

In this contribution we explore how low spatial resolution can be chosen without losing the ability to detect embolism formation. By comparing MRI data of dehydrating poplar trees with highly resolved micro-CT images of the same specimens, we assess how micro-porous structures such as rays and wood fibers affect the results of spatially resolved MR relaxometry. Rays and fibers are structural wood elements that in broadleaf trees often occupy a larger fraction of the wood than do water conducting conduits (vessels and tracheids), but usually are overlooked both in terms of their contribution to MR contrast, as well as in terms of their function as a water storage compartment and contribution to stem hydraulic capacitance. To compare MRI and micro CT images automated routines were implemented, allowing for overlay, position correction and subsequent analysis of parameter images of dynamic changes in the xylem region.

We demonstrate that embolism formation can be quantified and visualized using a custom-built, mobile low-field MRI device, highlighting the potential for field-deployable MR imaging in plant hydraulic research.