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Root water uptake and long-distance transport under drought: Novel insights into intact plants using X-ray computed microtomography

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Maintenance of plant water balance depends on adequate root water uptake from the soil to meet the needs of a transpiring canopy. Abiotic stress such as water stress by drought can push the whole-plant hydraulic system to its functional limits, which is linked to changes of hydraulic resistances along the soil-plant atmosphere continuum. Drought-induced xylem embolism in the main stem can block long-distance water movement from root to canopy, but drought can have direct impacts on organ hydraulic performance from cell to tissue level. Reductions in root water uptake under drought has been attributed to changes in cell membrane permeability via aquaporins, development of suberized apoplastic barriers, mechanical damage of cortex tissue, and root shrinkage. For intact grapevine plants, we recently found that drought-induced damage of root cortical cells was linked with a precipitous drop in root hydraulic conductivity and preceded hydraulic failure associated with xylem embolism (Cuneo et al., 2016 Plant Physiology). Furthermore, we detected difference in root hydraulic properties under drought among grapevine genotypes.

However, we still lack an integrated understanding about the exact location and sequence of events leading to root hydraulic dysfunction in grapevine and other woody species under drought, and how this ultimately impacts long-distance water movement and whole-plant performance. To complicate things even more, current data indicate that discrepancies between hydraulic measurements made on excised samples and intact plants exist which can lead to misinterpretation of plant physiological responses.

To resolve some of these issues concerning our fundamental understanding of plant responses to abiotic stress, the main goal of our work has been to obtain direct insight into both tissue structure and corresponding hydraulic function of woody plants under in-vivo conditions by using novel experimental techniques such as X-ray computed microtomography (microCT). In addition to our work on root water uptake properties, our past research allowed us to characterize in great detail the spatial and temporal dynamics of xylem embolism formation and repair in grapevine and other woody species and elucidate the process of fiber water storage at unprecedented spatial resolution (e.g. Brodersen et al., 2010; Knipfer et al., 2016, 2017 Plant Physiology). At the EGU General Assembly 2018, I intend to present a synthesis of our recent research with focus on the interaction of root water transport, tissue-specific hydraulic function and long-distance water movement.

Water scarcity threatens ecosystem function and crop production in dry climates globally, and a better understanding of the true limits to root and whole-plant hydraulic function will significantly improve our ability to predict plant mortality under drought. Future research efforts are required to identify the appropriate hydraulic techniques for elucidating water transport function and to establish advanced imaging techniques to track water transport processes both in-vivo and at the root-soil interface.