Non-destructive observation of xylem embolism development in deciduous hardwood species under water stress

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Ⅰ.Introduction

Global climate change is becoming a major issue, and extraordinary high or low temperatures and increasing drought would have negative impacts on forest ecosystems. Distribution of plant species is mainly limited by cold tolerance and drought tolerance. To know how plants respond to drought is important for predicting future changes of forest ecosystems.

Water-stress induces cavitation in xylem of plant stem. Cavitation and embolism occurs in a water-filled vessels under tension when air bubbles sucked into the conduit via a pit membrance pore from adjacent air-filled conduit. Embolisms result in loss of water conductivity in xylem. Hydraulic conductivity has been measured by destructive methods using cut branches, which show large variation among samples. Thus, details of changes in hydraulic conductivity under water stress could not be elucidated. In this study, we used Magnetic Resonance Imaging (MRI) which can visualize the water in xylem non-destructively. Our goal is to clarify the detailed process of xylem embolism development under water stress by using MRI.

Ⅱ.Materials and Methods

Images of water distribution in a stem at the position of 4~6mm was periodically acquired with MRI for potted seedings of *Cercidiphyllum japonicum, Betula platyphylla* and *Rhododendron reticulatum* after stopping irrigation. Leaf water potential was measured in midnight as an indicator of water stress. To evaluate embolism repair, three pots of *C. japonicum* and *B. platyphylla* were rewaterd after progress of embolism and images were acquired 1 and 12 hours after rewatering. Position of annual rings was identified by microscopic observation of *B. platyphylla* and *R. reticulatum* sampled after the experimental period.

Ⅲ.Results and Discussion

Figure1 shows MRI images acquired during dehydration and rehydration process. In *C. japonicum* and *B. platyphylla*, embolized (black) areas in 1-year or 2-year-old xylem enlarged as water potential decreased, while current-year xylem kept its function. Embolism repair was not observed 12 hours after re-watering, when water potential has recovered in both species. MRI images were cut into annual rings, then Percent Loss of Water-distribution area (PLW) was calculated for each image by equation (1). Relation between water potential and PLW were described by Weibull function.

$$\mathrm{PLW(\%)} = \left(1 - \frac{\text{Water-distribution area in each image}}{\text{Water-distribution area before dehydration}}\right) \times 100 \quad \cdots(1)$$

In *B. platyphylla,* PLW of 1- and 2-year-old xylem increased sharply when water potential decreased to -1~-2 MPa, while PLW of current-year xylem increased gradually. Degradation of pit membrance pore by aging (Sperry et al.1991) can be the mechanism of this difference in embolism development among annual rings. PLW plots of whole xylem fitted well to the vulnerability curve in Ogasa et al. (2010) drawn by a destructive method. Therefore, our new method by MRI is shown to be reliable.

This study revealed the difference in xylem vulnerability to cavitaion among annual rings under water stress. *C. japonicum* and *B. platyphylla* were thought to be adapted to drought by maintaining water transport in current-year xylem under water stress.

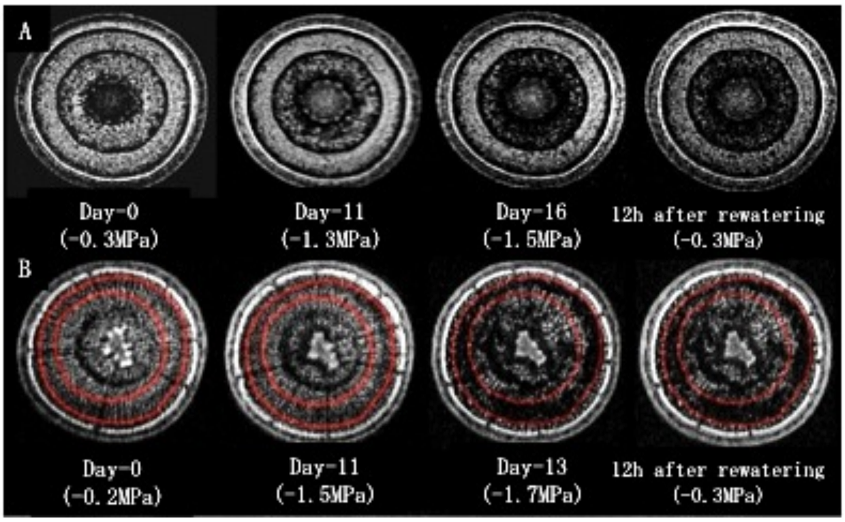

Figure 1 MRI pictures of *C. japonicum* (A) and *B. platyphylla* (B).
Days after stopping irrigation and water potential are shown below each picture.
Red line shows boundary of annual rings.

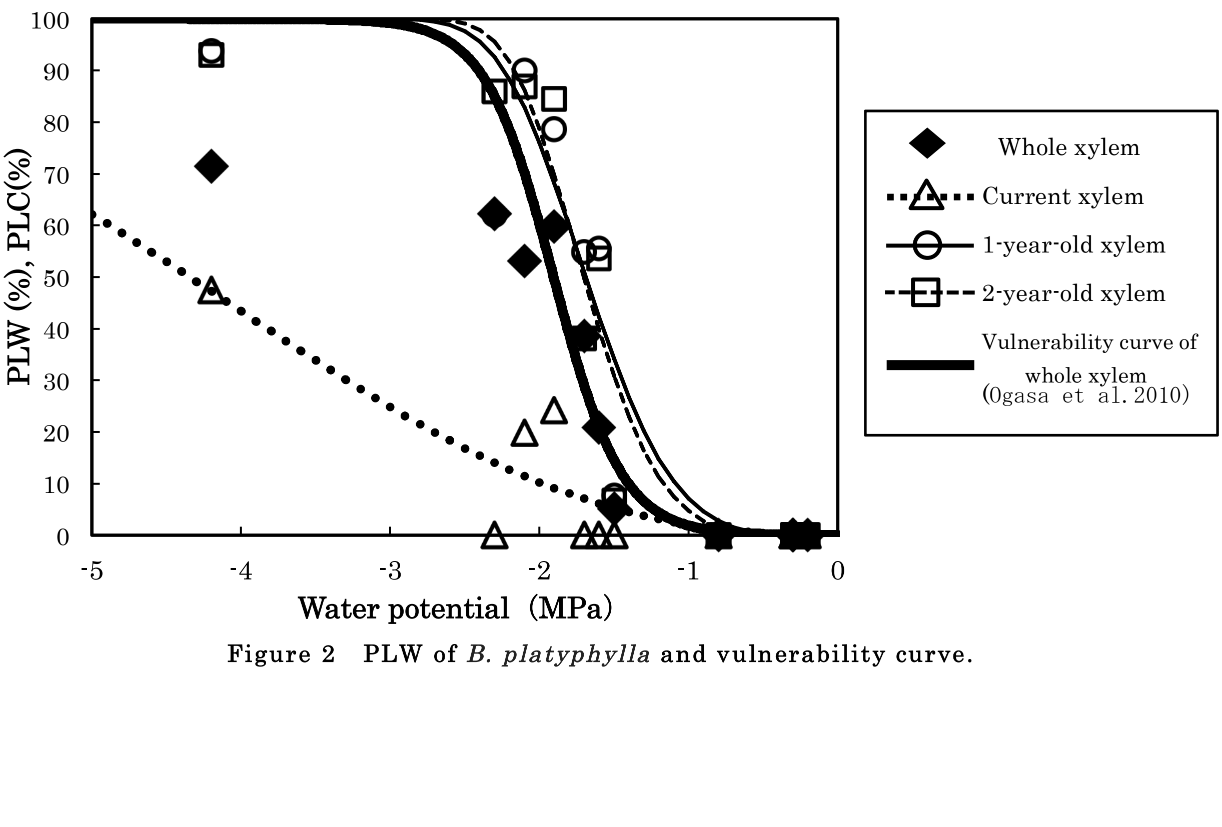

Figure 2 PLW of *B. platyphylla* and vulnerability curve.