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Dynamics of xylem cavitation during a simulated drought in *Eucalyptus camaldulensis* saplings, a species with solitary vessels

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Introduction

With the ongoing climate change, water stress is prone to become a commonplace event leading plant growth and productivity worldwide under threat because of the disruption of their water status. Forests are highly sensitive to climate change due to the lack of sufficient knowledge related to tree adaptive responses to environmental fluctuations. Structural and physiological adaptations to drought require complex interactions between anatomy, physiology and biochemistry. Thus, long term maintenance of hydraulic integrity is crucial for survival of tree, including important forestry species that are widely distributed worldwide such as *Eucalyptus camaldulensis*. Xylem, the main pathway for water transport over long distances of this species, is made of solitary vessels surrounded by different imperforate tracheary elements and parenchyma that may influence in a poorly known way their xylem safety and hydraulic efficiency.

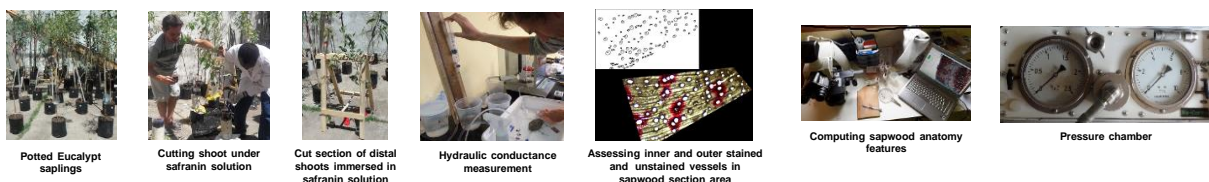
Aims

The aims of this study were to unravel the dynamics of embolism spread in the complex xylem vessel-structure for potted saplings of *E. camaldulensis* assigned to simulated protracted water stress.

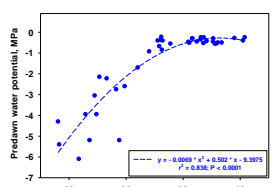
Material and methods

We carried out a pot experiment on 48 saplings of *E. camaldulensis* under a 12 m² shelter in the city of Tandil (37° 19'S; 59° 09'W, 188 m a.s.l.), Argentina.

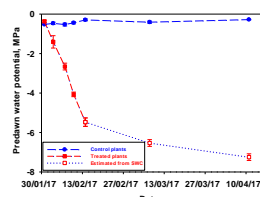
We relied on staining and hydraulic methods to test for links between xylem anatomical features and the propagation of embolism within the study plants. We used safranin solution to assess sapwood area traits of 8 control and 9 water-stressed saplings. We chose them as to cover roughly a range from 15% to 100% percent loss hydraulic conductance (PLC). We completed additional measurements such as predawn and leaf water potential (Ψ_w), stomatal conductance (g_s) and soil water content (SWC).



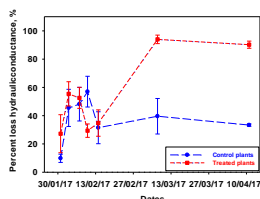
Results



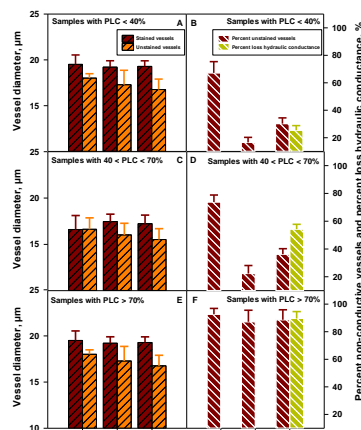
Relationship between leaf predawn water potential and the soil water content. Progressive decrease in Ψ_w with drying soil.



Predawn water potential over time for control and treated plants. Ψ_w dropped within the 15 days since the water withholding of the treated plants



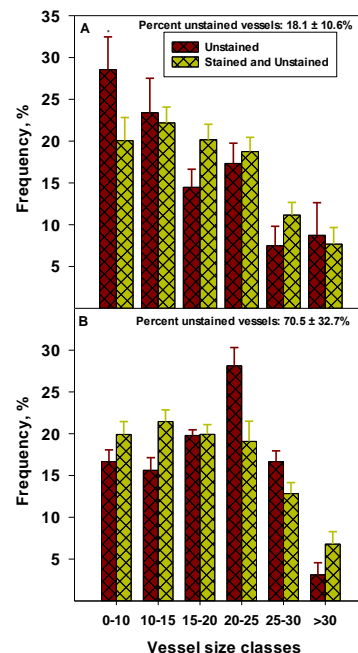
Pattern of percent loss hydraulic conductance for control and treated saplings versus time. Even high, the rate of native embolism (PLC) was similar for both the control and treated plants during the fortnight after the onset of the experiment. But thereafter, PLC for treated plants rose sharply to more than 90% while PLC levelled off for control plants.



Location within the cross-sectional area
Left panel - Mean \pm SE diameter of stained and unstained vessels in different sections of the xylem (inner and outer sapwood) in differently embolized plants. There was no significant difference in the mean size of stained and unstained vessels (Tukey's test, $p < 0.05$).
Right panel - Percent of unstained vessels in inner and outer portion of sapwood in plants with different degree of PLC. Proportion of unstained vessels was high in all plants (even control plants). It increased steadily in the inner area along the drying steps while this proportion remained low in the outer part when PLC was lower than 70% but increased sharply for highly stressed plants.



Percent loss hydraulic conductance (hydraulic method) was highly correlated with percent stained sapwood area (staining method).
 $y = -0.8305x + 92.7196$; $r^2 = 0.80$



Upper panel - Size distribution of unstained vessels in plants with low proportion of embolized vessels was significantly different from that expected by chance and, the highest deviation was in the lowest vessel size range (Chi² test, $p < 0.05$).
Lower panel - Size distribution of unstained vessels in plants with high proportion of embolized vessels followed the expected vessel size distribution of the entire sapwood area (Chi² test, $p < 0.05$).

Conclusions

- We found that the mean native embolism rates were similar for all the plants during the 15 days after the onset of the water stress treatment. PLC was very variable, from 15% up to 71% in some individuals, irrespective of the treatment. This could be a matter of the high proportion of the embolized vessels: high in the inner but variable in the outer section of the sapwood area.
- We came to a good correlation between PLC (hydraulic method), the proportion of stained sapwood area and the percent of unstained vessels (staining methods). Based on the mean size of the vessels, embolism occurred randomly in the sapwood. Indeed, the sensitivity of the study Eucalypt species was not a matter of vessel diameter.
- When considering the vessel diameter distribution, we also observed a significant increase in the probability of embolism occurrence in the smallest vessel range for plants with a relatively low proportion of unstained vessels only.
- Besides, it rose from our study that saplings of *E. camaldulensis* could recover from a severe water-stress unless their percent loss hydraulic conductance was lower than 77%. Anyhow, no post-drought recovery occurred when the PLC is equal or greater than 85%.

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