

## **MEASURING PLANT HYDRAULIC CONDUCTANCE AND XYLEM VULNERABILITY UNDER CLOSE TO NATURAL CONDITIONS**

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# INTRODUCTION

#### WHY DO WE CARE ABOUT PLANT HYDRAULICS?

- To take up CO2 and transpire, plants need to transport water from soil to leaves
- Plant hydraulics explains plant water transport under tension
- Hydraulic failure assumed to cause drought stress and eventually plant death
- Different plant hydraulic traits enable plants to survive in different environments

 $\rightarrow$  By looking at all these traits, best plant functional types for given environment can be chosen





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## **PLANT HYDRAULICS**

COHESION-TENSION THEORY AND PLANT HYDRAULIC TRAITS

> As water evaporates from the leaves through transpiration, it generates a capillary force, which is an adhesive force between the water and plant. The capillary force reduces the pressure at the top of the plant, leading to a large enough pressure gradient between the leaves and the roots. This tension generates water flow through a small network of tubes along the entire height of the plant called xylem [Dixon, 1914].



Cohesion-tension





# QUANTIFY PLANT HYDRAULIC VULNERABILITY



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The first method is bench dehydration, where plants are deprived of water until cavitation occurred naturally. The plant material is dried to various pressures, measured via a pressure chamber.

**CURRENT METHODS** 



The second method is centrifugation. Centrifugation consists of placing a twig in a centrifuge and rotating it to apply known negative pressures to the xylem. The conductivity is then measured following both of these methods. And the output is a vulnerability curve that characterizes a plants response to cavitation by plotting the loss of conductivity vs the pressure that was applied.

Alder et al. [1997]



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# **PROBLEMS WITH** STATE-OF-THE-ART



- Experiments performed on dead plant segments
- <u>Conditions to induce cavitation far away</u> • from naturally experienced conditions
- Methods do not differentiate between • different cavitation mechanisms

 $\rightarrow$  The main goal for this research is to replicate more natural conditions

Introduction

- Quantify plant hydr-aulic vulnerability
- Problems with the state-of-the art



#### SOLUTION I THE SETUP

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# SOLUTION I

**SPONTANEOUS FAILURE AFTER 21H** 



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## SOLUTION I

le-8

11.1

15:00

18:00

21:00

03:00

00:00

22-Jun

Time

06:00

09:00

1.4

1.2

1.0

0.8

k (in *m*<sup>2</sup>)

#### **SPONTANEOUS FAILURE AFTER 21H**



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**Perforation plate** – The remains of the end walls between two adjacent vessel elements in a vessel of xylem, forming an opening between the cells. – *http://botanydictionary.org/perforation-plate.html* 



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### SOLUTION I ROLE OF PERFORATION PLATES

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Perforation plates are located at characteristic lengths along the xylem (7cm in this case). One twig long enough with a perforation plate in each vessel and one short enough to have at least one vessel without a plate were chosen.

### SOLUTION I EXPERIMENTAL RESULTS







- As the bubble reached the longer twig, the flow stopped and the pressure gradient (difference between red and green line) increased until the system failed.
- As the bubble reaches the shorter twig, the pressure gradient increases and flow is maintained. This means that cavitation without perforation plates does not inhibit flow
- Perforation plates prevent air from moving up or down even if this prevents flow

bubble

passing

through

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## SOLUTION I EXPERIMENTAL RESULTS



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The permeability of the long twig showed a slow reduction until the bubble reached the bottom of it and conduction stopped with the flow.

 For the short twig, the reduced permeability could be due to blocked vessels that have perforation plates, meaning flow only continues through vessels without.

#### Issues with the setup

- The system collapsed at the upper membrane for each experiment
- The pressure of the system could not be lowered enough to induce the other forms of cavitation

# **SOLUTION II**



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#### AVOIDING AIR ENTRY AT UPPER MEMBRANE



#### SOLUTION II PRELIMINARY RESULTS





## CONCLUSIONS



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• Experimental device enables monitoring rapid responses of flow and hydraulic conductance to forced cavitation and pressure changes

• Able to create near natural conditions for water flow through a twig and control the pressure of the system

• Cannot yet produce all 3 types of cavitation reliably

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## **FUTURE WORK**



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- Understand the current setup more
  - Reproduce preliminary experiments
  - Induce cavitation in twigs of different species
  - Reduce pressure further to induce other types of cavitation
- Compare results with literature
- Measure diameters of water-filled and embolised vessels with microscope



REFERENCES

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