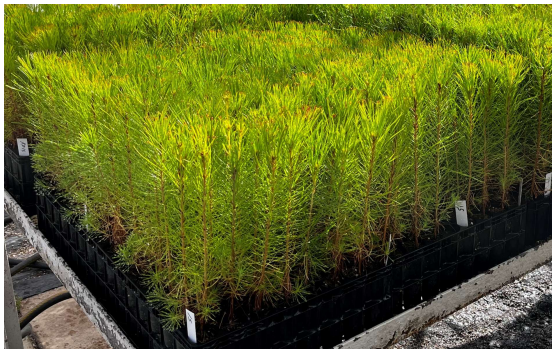
Southern Forest Nursery Management Cooperative



Physiological Impacts of Drought Conditioning Practices on Loblolly Pine

Tom Stokes

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Introduction

- Seedlings grown in nursery under optimal growing condition
  - Irrigation
  - Fertilization
  - Competition control
  - Etc.

- Outplanting in harsh environmental conditions
  - Physiology
  - Morphology
  - Anatomy

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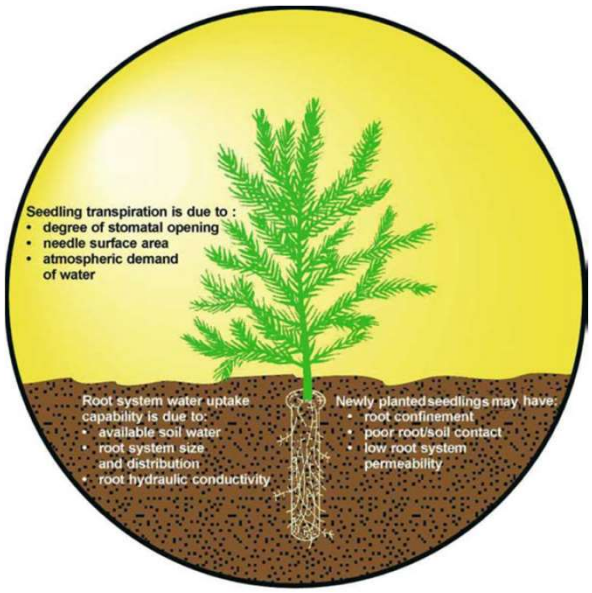
Introduction

- Surviving Drought
  - Water loss through transpiration
  - Root water uptake capability
  - Overcome newly planted conditions



Grossnickle (2005)

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Introduction

- Drought conditioning seedlings
  - To intentionally limit irrigation during the growth phase in a nursery
    - This practice began in the 1st half of the 20th century in an arid region in the pacific northwest.
    - Became more prevalent after a graph was published in 1974 indicating greater survival of drought stressed seedlings.
    - Some studies have shown greater survival with drought conditioned seedlings.
    - However, many recent studies have shown that survival does not increase with reductions in irrigation in many bareroot Pinus species.

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Introduction

- Benefits of Drought Conditioning
  - Increased root to shoot ratio
  - Decrease in succulent foliage
  - Increase in soluble sugars
- Risks of Drought Conditioning
  - Depletion of stored carbohydrates
  - Increase in cavitated xylem conduits
  - Predispose to future stress events (legacy effects).

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Introduction

- To understand the physiological effects of drought conditioning we must:
  - Understand how water moves through a plant
  - How cavitation and embolisms occur
  - How embolisms spread
  - How embolized xylem MAY be repaired

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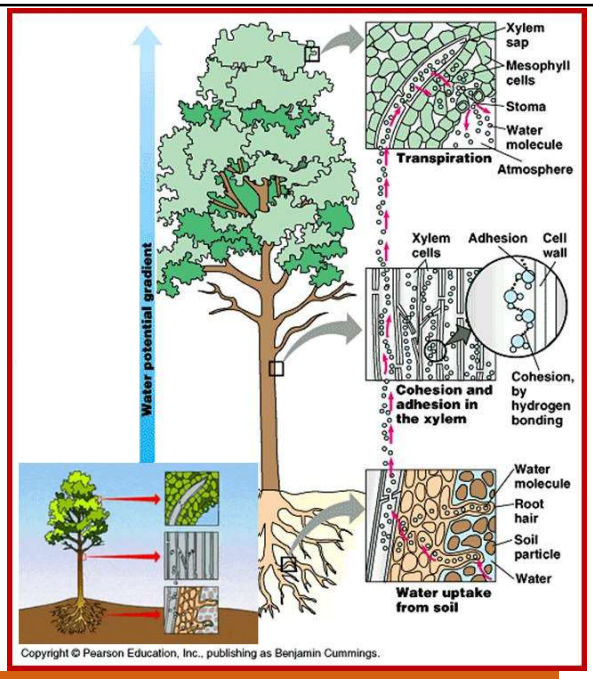
Introduction

- How water moves through a tree.
  - Transpiration
    - Water moves out of stomata
    - Water moves down concentration gradient which creates negative pressure
    - Water is replaced by water from xylem
  - Cohesion and adhesion in the xylem.
    - Xylem water column is maintained by the cohesion of water and adhesion to the cell walls
  - Water uptake from soil
    - Water is pulled from root cortex into xylem cells
    - Water is pulled from the soil into the roots



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Introduction

- How embolisms spread
  - Air seeding
    - Air bubble moves from air filled xylem into water filled xylem across the pit membrane when a threshold pressure is reached

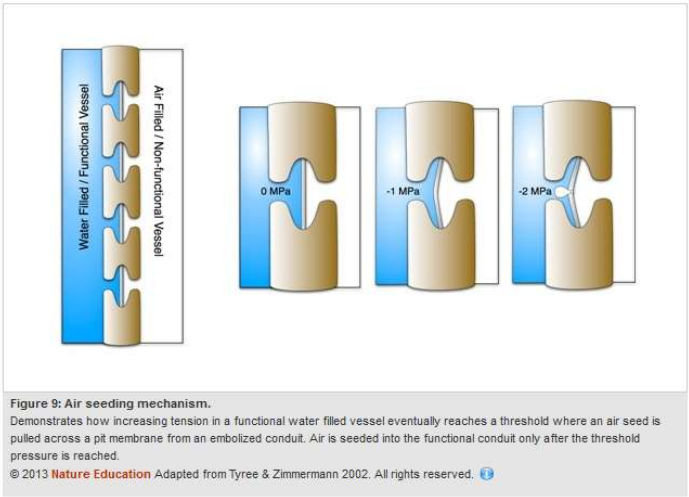

Figure 9: Air seeding mechanism.
Demonstrates how increasing tension in a functional water filled vessel eventually reaches a threshold where an air seed is pulled across a pit membrane from an embolized conduit. Air is seeded into the functional conduit only after the threshold pressure is reached.

McElrone et al. (2013)

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Introduction

- Embolism repair
  - Some species have shown the ability to rapidly repair embolized xylem conduits
    - For refilling of xylem conduits either:
      - Freeze-thaw cycles –which will dissolve the gas back into water, or
      - Positive root pressure – from movement of solutes to the roots.
  - Several recent studies, especially with conifers, have shown a lack of a mechanism to refill embolized xylem conduits.
    - New xylem will have to be made – significant carbon cost to the plant.

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Introduction

- Vulnerability to embolism within a plant

Roots → **Needles** → **Branches** → **Stems**

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Methods

- Treatment Phase
  - Randomized complete block
    - 4 replications of 3 treatments (3 genetic families)
  - Treatments
    - Control – No drought conditioning
    - DCWP – Drought conditioning based on 3 progressive steps of pre-dawn water potentials
    - DCCW – Drought conditioning based on 3 progressive steps of container weights

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Methods

- Drought Phase
  - Randomized complete block
    - 4 replications of 3 treatments (3 genetic families)
    - Outplanted in outdoor stress facility
  - Drought
    - All trees were watered daily for 3 weeks after outplanting
    - Watering was cut to every three days during the 4th week after outplanting
    - Water was withheld for 29 days starting the 5th week after outplanting




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Methods

- Recovery Phase
  - After 29 days without water, seedlings will be kept well watered during the growing season




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Methods

- Measurements
  - Treatment Phase
    - Initial RCD and Height
    - Pre-dawn water potential
    - Container weights
    - End of treatment stem embolism
  - Drought Phase
    - Initial outplanting RCD and Height
    - Soil moisture
    - Chlorophyll fluorescence
    - Beginning and ending stem embolism
  - Recovery Phase
    - Final RCD and height
    - Stem embolism
    - survival

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Results

- RCD and Height
  - There was a measurement date main effect on both RCD and height
  - Both RCD and height significantly increased from before treatment phase to being outplanted
  - There were no treatment differences in RCD and Height

Effect	RCD	HEIGHT
Date	<0.001	<0.001
TRT	0.462	0.808
Date*Trt	0.573	0.088

Date	RCD (mm)	Height (cm)
Before Trt	3.3	27.4
Before Outplanting	3.76	33.9

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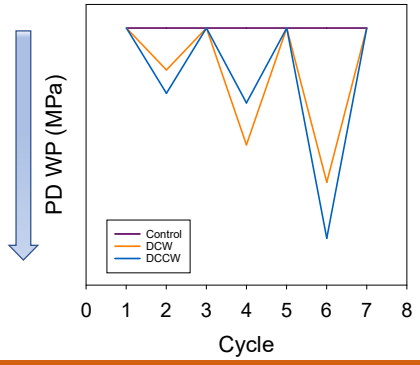
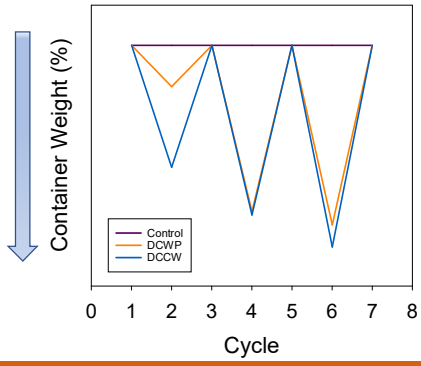
Results

- Treatment Phase
  - During the last cycle of drought conditioning:
    - PDWP was -0.35, -0.68, and -0.80 for the control, DCWP and DCCW treatments, respectively
    - Container weights were 100%, 55.2% and 49.7% of saturation for the control, DCWP and DCCW treatments, respectively





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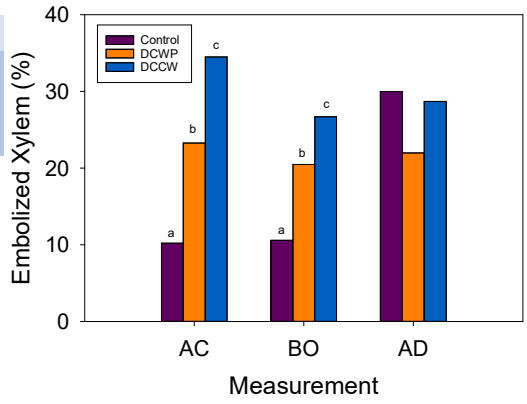
Results

Effect	Embolized Xylem (%)
Date	0.019
Trt	<0.001
Date*trt	0.002

- Stem Embolism
  - There was a date*trt interaction with percent stem embolism
  - Both, after drought conditioning and before outplanting resulted in DCCW with increased percent embolized xylem followed by DCWP then Control
  - No significant differences after the drought between treatments with average percent embolized xylem of 25.5%



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Discussion

- Three different levels of drought conditioning were evident in terms of water stress in both predawn water potentials and stem embolisms
- During the drought phase, seedlings with no drought conditioning significantly increased in percent xylem embolized while both the DCWP and DCCW treatments had little change
  - Loblolly pine has been shown to have tight stomatal control over water stress
  - Since DCWP and DCCW seedlings were already stressed when the drought phase began, these seedlings probably shut down (no carbon gain) to avoid further water stress
  - Control seedlings were not stressed at the beginning of drought, so they probably kept higher levels of photosynthesis which resulted in increased embolisms.
    - End of growing season growth measurement should help explain this.

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In Progess

- Second drought?
  - We will consider a late season second drought when evaporative demand is high to determine legacy effects
- Recovery
  - We will measure end of year growth to determine drought conditioning success on seedling performance
  - We will measure end of year embolisms to determine if loblolly pine can refill embolized xylem
  - We will look at survival

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Questions?