Root health and hydraulic conductivity and its importance to outplanting success

Ryan Nadel and Lisa Samuelson

Southern Forest Nursery Management Cooperative

Root Phenology

- Aboveground phenology is typically separated into discrete events such as budburst and leaf senescence.
- Onset and progression of root phenology do not simply track aboveground phenology.
- Unlike shoots, roots do not experience winter dormancy.

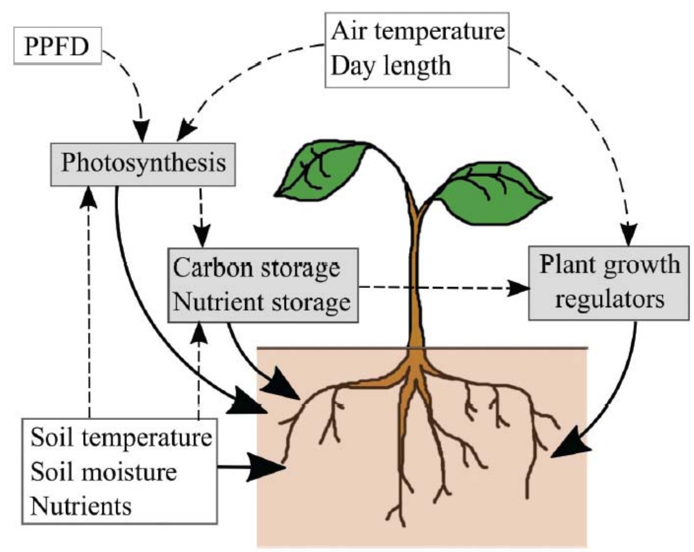


Fig. 1. Potential controls over root phenology. Solid lines indicate direct controls and dashed lines indicate indirect controls on root phenology. Gray boxes represent endogenous controls; and white boxes represent exogenous controls. PPFD is photosynthetically active flux density.

Radville et al. (2016)

Root Phenology in a Changing Climate

- Drivers of autumn root phenology not well understood.
- Root growth may slow as soil temperature and plant carbohydrate availability decrease.
- Photoperiod not a strong control.
- Root growth can occur year round if conditions favorable.
- In southern US, seedlings in nursery beds can increase RCD and root growth in winter. *Unsuberized roots more vulnerable to mechanical injury and dessication.*

Radville et al. (2016)

Loblolly Pine Root Growth

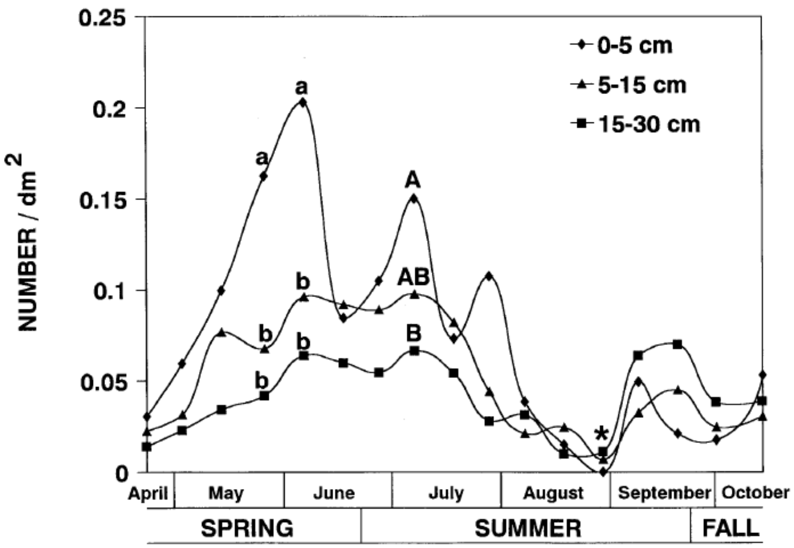


Figure 4. Mean number of roots dm^{-2} initiated at 0–5, 5–15 and 15–30 cm in rhizotrons during April through September 1993. Within measurement intervals, means associated with the same letter are not significantly different by the LSD test at $P < 0.05$ (lower case), and $P < 0.10$ (upper case). The asterisk between August and September data denotes: 0–5 cm (b), 5–15 cm (ab) and 15–30 cm (a).

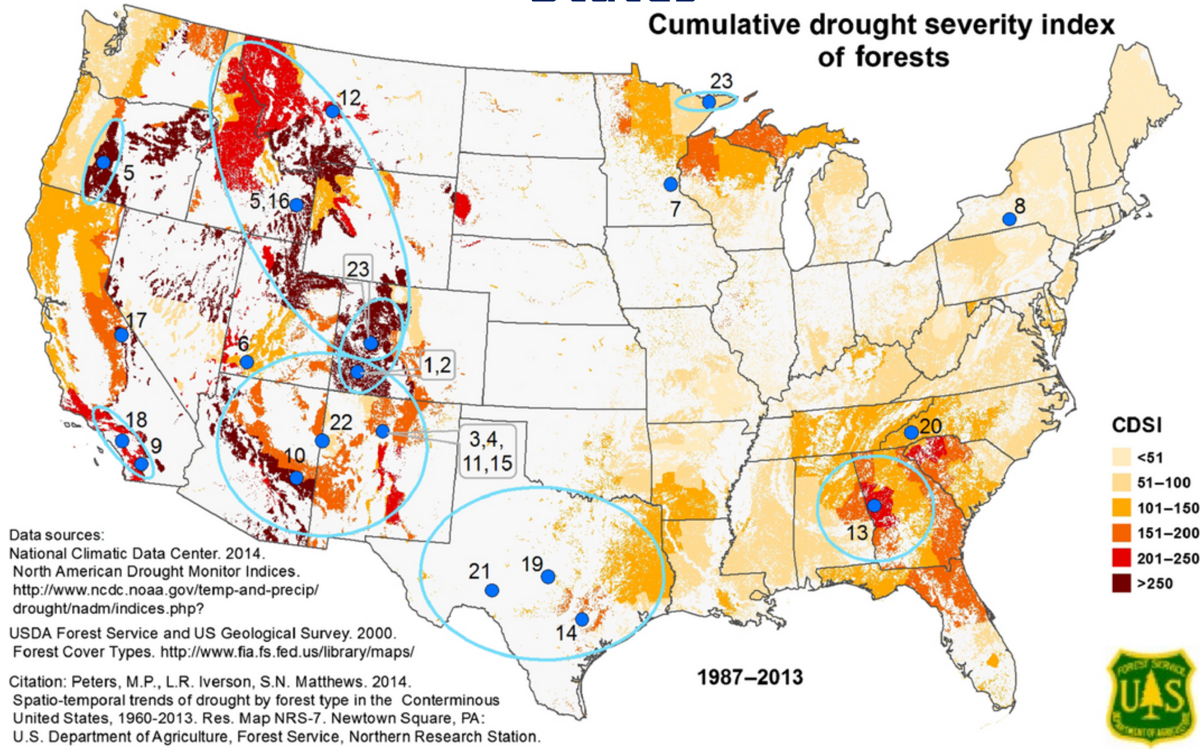
- Root phenology patterns related to photosynthate availability

Sword et al. (1996)

Surviving Drought

Grossnickle (2005)

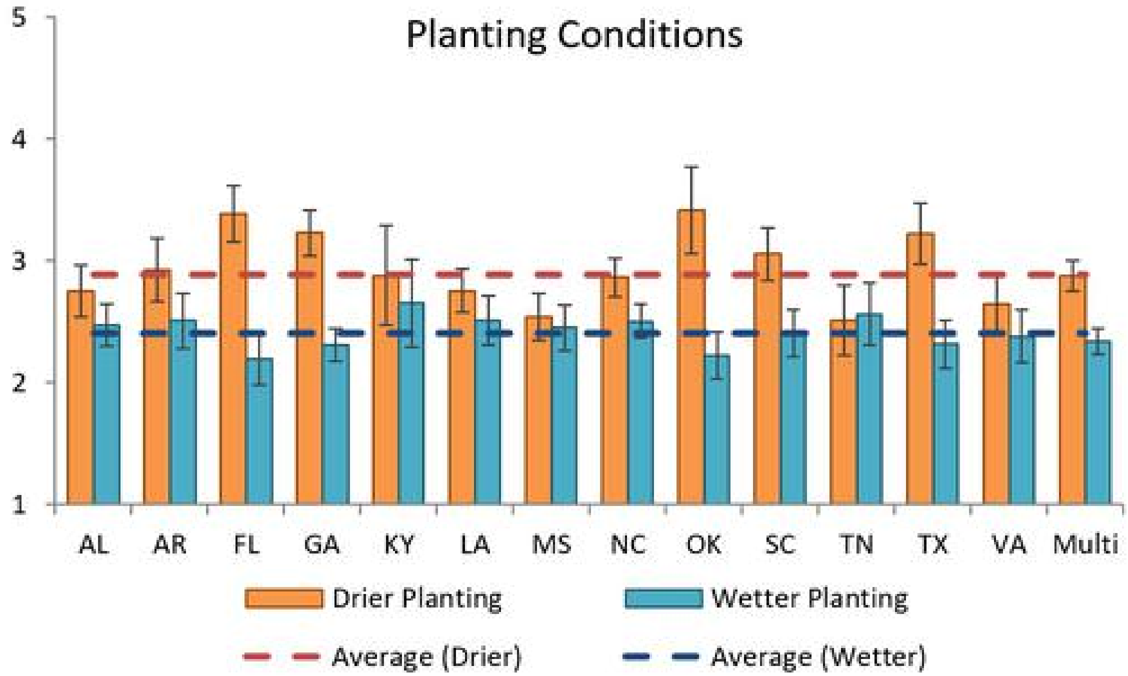
The Impacts of Increasing Drought on Forest Dynamics, Structure, and Biodiversity in the United States

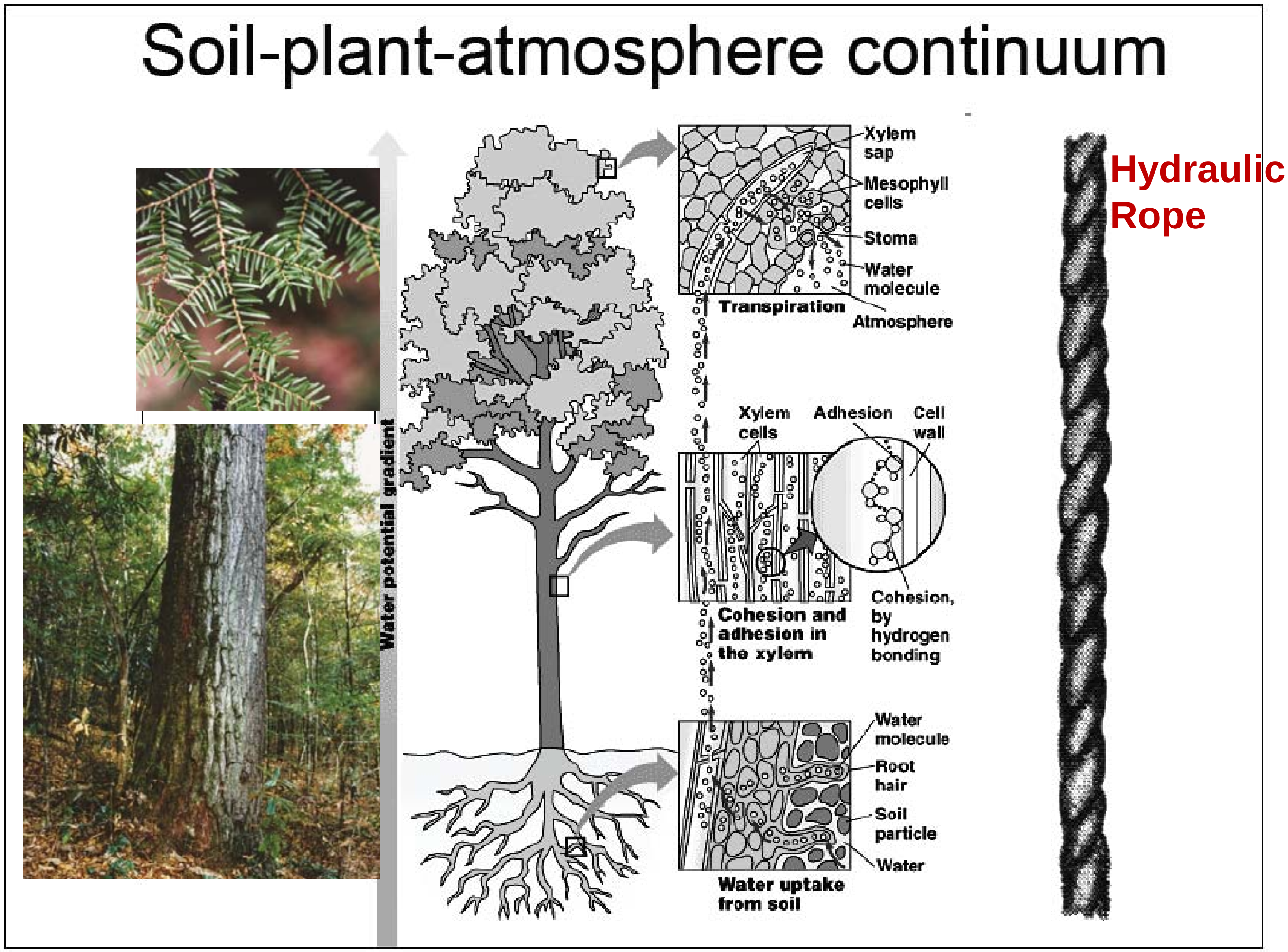


Cumulative drought severity index (CDSI) for forested lands from 1987 to 2013, (modified from Peters *et al*., 2014), with selected locations of drought- and heat-induced tree mortality indicated by blue circles

Global Change Biology
Volume 22, Issue 7, pages 2329-2352, 21 FEB 2016 DOI: 10.1111/gcb.13160
http://onlinelibrary.wiley.com/doi/10.1111/gcb.13160/full#gcb13160-fig-0008

Southern Foresters Report Drier Planting Conditions




Soil-plant-atmosphere continuum
Water potential gradient
Xylem sap
Mesophyll cells
Stoma
Water molecule
Transpiration
Atmosphere
Xylem cells
Adhesion
Cell wall
Cohesion and adhesion in the xylem
Cohesion, by hydrogen bonding
Water molecule
Root hair
Soil particle
Water
Water uptake from soil
Hydraulic Rope

Xylem Cavitation and Embolism

- Breakage of the xylem water column due to water stress or injury.
  - Entry of air into the xylem conduits.
  - Embolisms move primarily through the pit membranes.
- Species and individuals differ in their vulnerability to cavitation – trade-offs between vulnerability and water flow.
- Size, structure and number of pits important traits.

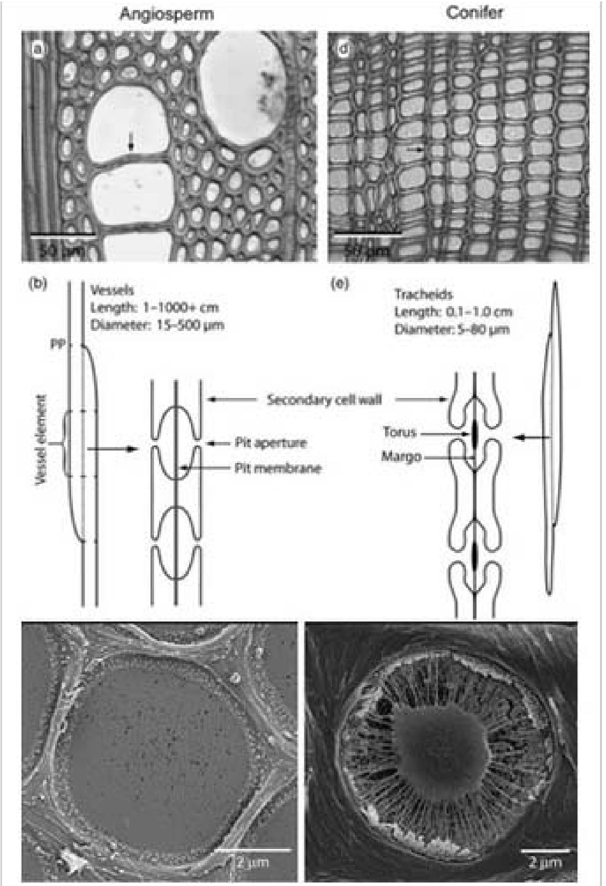


Figure 6: Comparison of different types of wood from flowering and cone-bearing plants.
This features wider conduits from flowering plants (top), a cartoon reconstruction of vessels, tracheids and their pit membranes (middle), which are also shown in SEM images (bottom).

McElrone et al. (2013)

How Embolisms Spread

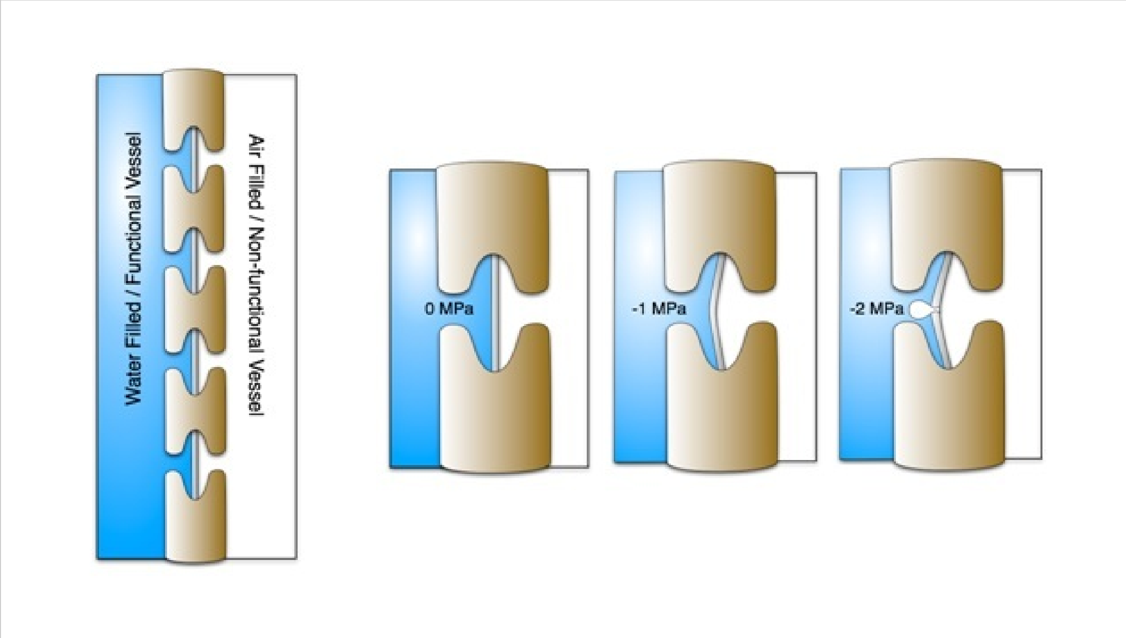


Figure 9: Air seeding mechanism.
Demonstrates how increasing tension in a functional water filled vessel eventually reaches a threshold where an air seed is pulled across a pit membrane from an embolized conduit. Air is seeded into the functional conduit only after the threshold pressure is reached.

McElrone et al. (2013)

Embolism Repair

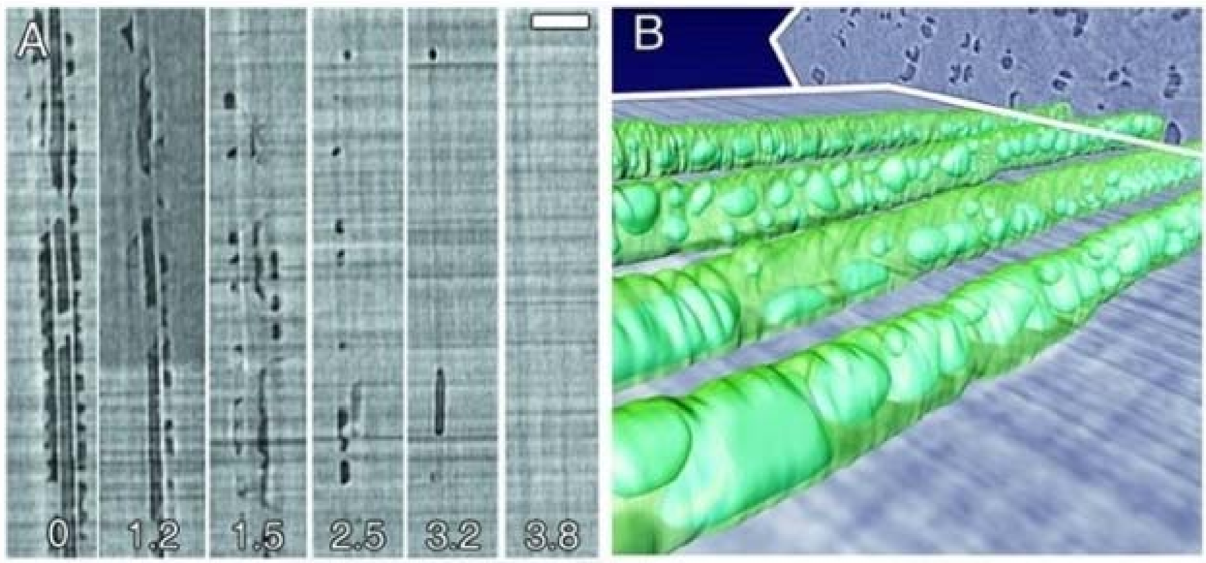


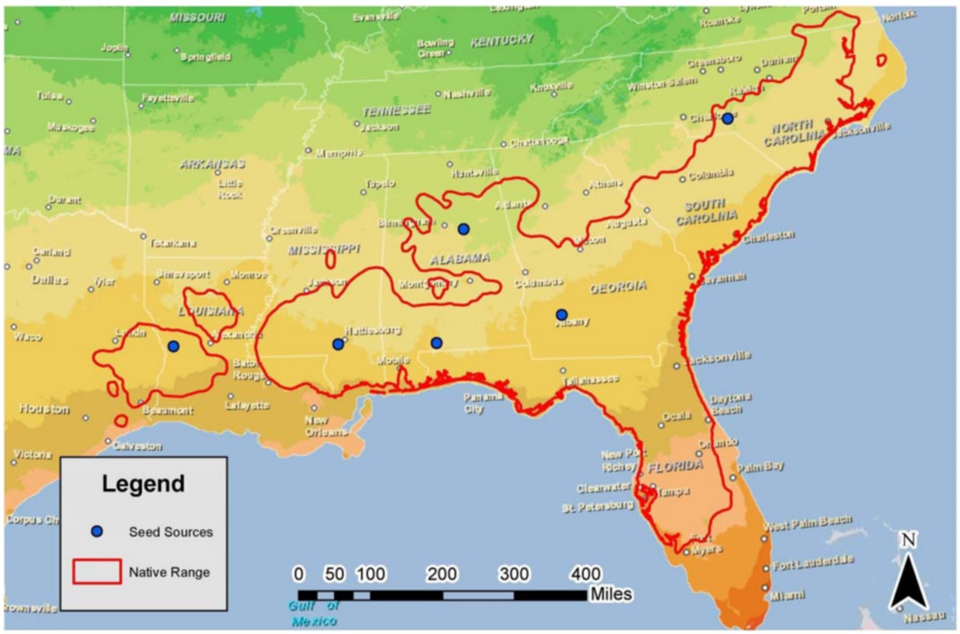
Figure 10: Embolism repair documented in grapevines (*Vitis vinifera* L.) with X-ray micro-CT at the ALS facility at Lawrence Berkeley National Lab CA, USA.

(A) Longitudinal section showing a time series of cavitated vessels refilling in less than 4 hrs; (B) 3D reconstruction of four vessel lumen with water droplets forming on the vessel walls and growing over time to completely fill the embolized conduit.

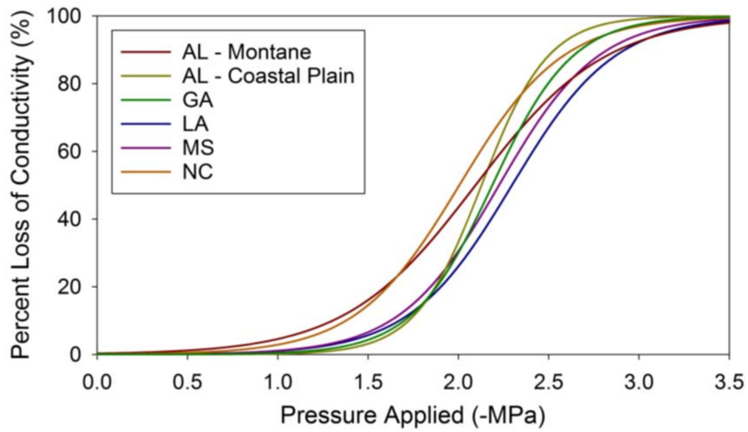
- Ray parenchyma
- Aquaporins

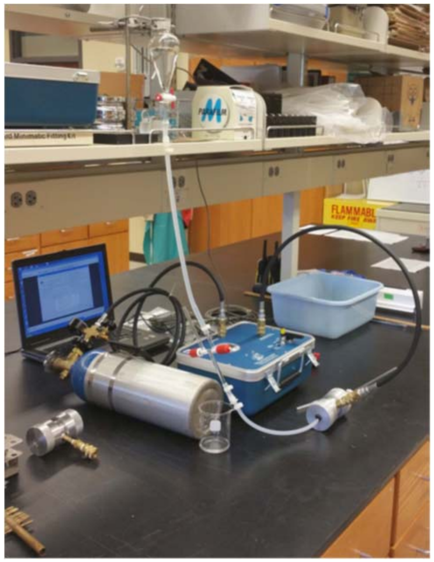
McElrone et al. (2013)

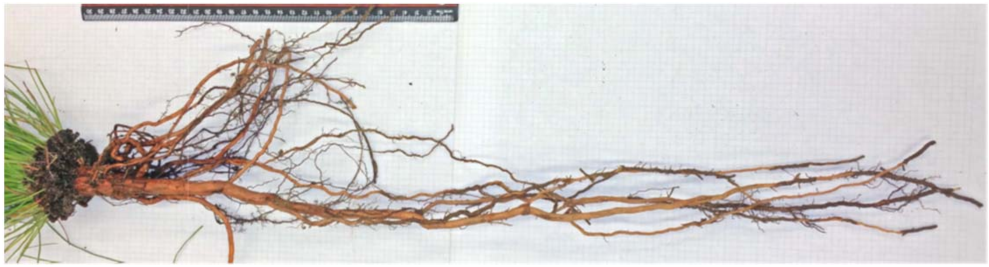
Root Vulnerability to Cavitation in Longleaf Pine Seedlings



Hydraulic Vulnerability Curves on Lateral Roots





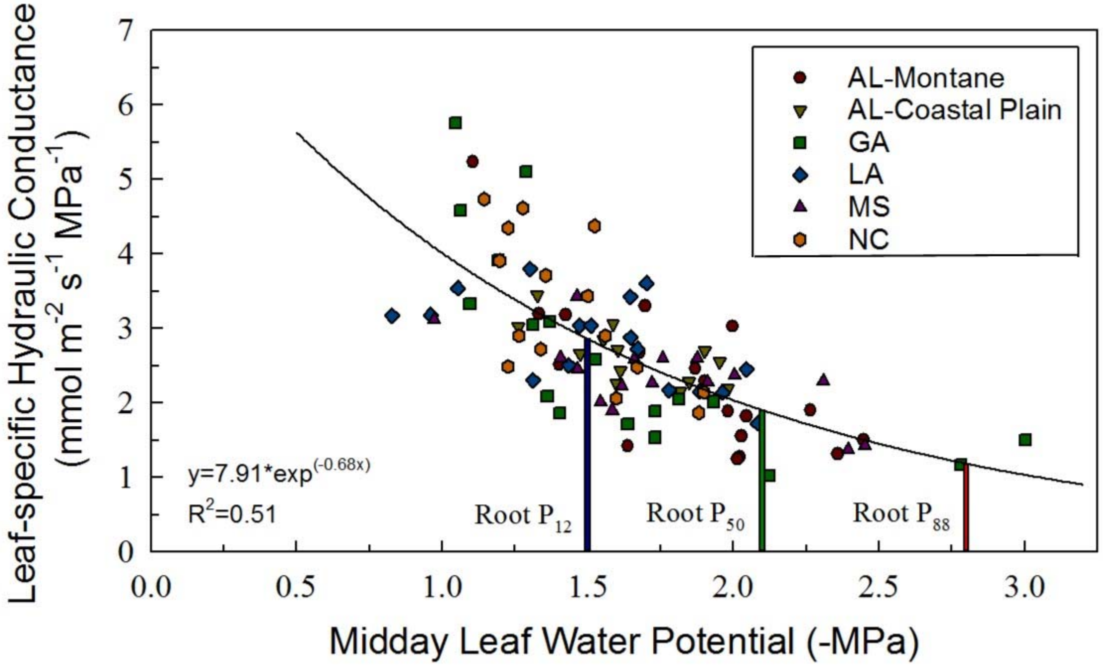


Embolism Resistance in Pines

- Studies of other southern pines (mostly mature trees) indicate moderate embolism resistance.
- Longleaf pine seedlings appear to be in the group of more embolism resistant pines, meaning they can tolerate lower water potentials (more water stress) before reaching 50% loss of conductivity.
- No direct species comparisons at the seedling stage on the same site.

Seedling Hydraulic Conductance

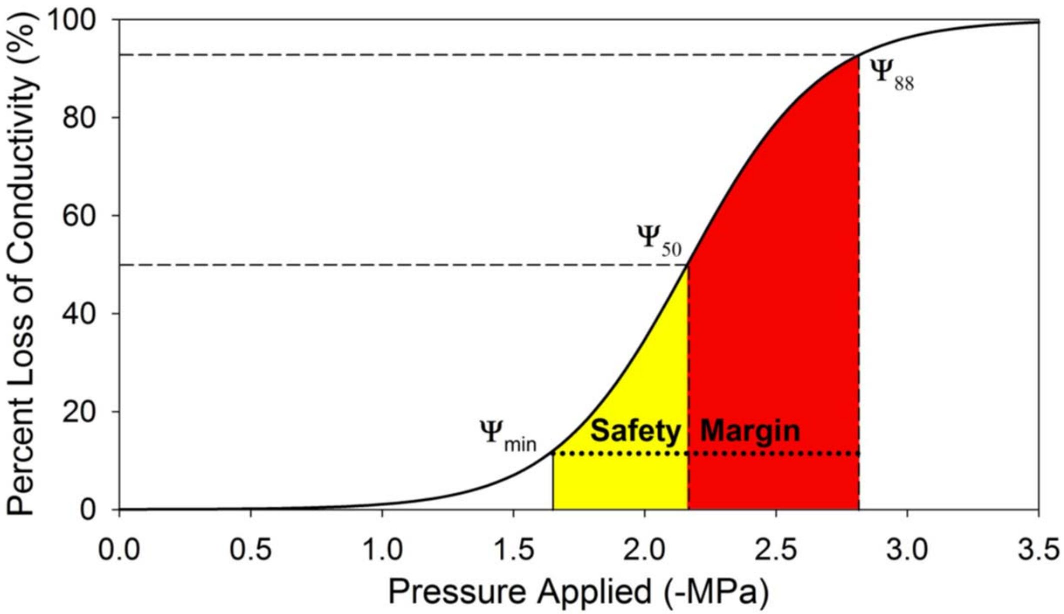
- Measure of how efficiently water is transported through the seedling as water stress increases



- Average leaf-specific hydraulic conductance reduced 50% near root P_{50}.
- *Root embolism a significant control on whole plant water transport in longleaf pine seedlings.*

Hydraulic Safety Margins

- Longleaf pine seedlings have a small hydraulic safety margin and high risk of hydraulic failure under extreme drought, as shown for other *Pinus* species.
- Little within species plasticity in hydraulic architecture and integrated traits such as P_{50}, as shown for other pines.



Applications

- Root health and root hydraulic conductivity important to outplanting success.
- Embolized roots will increase drought vulnerability of outplanted seedlings.

Loblolly seedlings from Bastrop, Texas
Source: Lady Bird Johnson Wildflower Center, University of Texas