Seedling Physiology: Lifting, Storing , Planting and Surviving in a Winter-less World

Dr. Lisa Samuelson

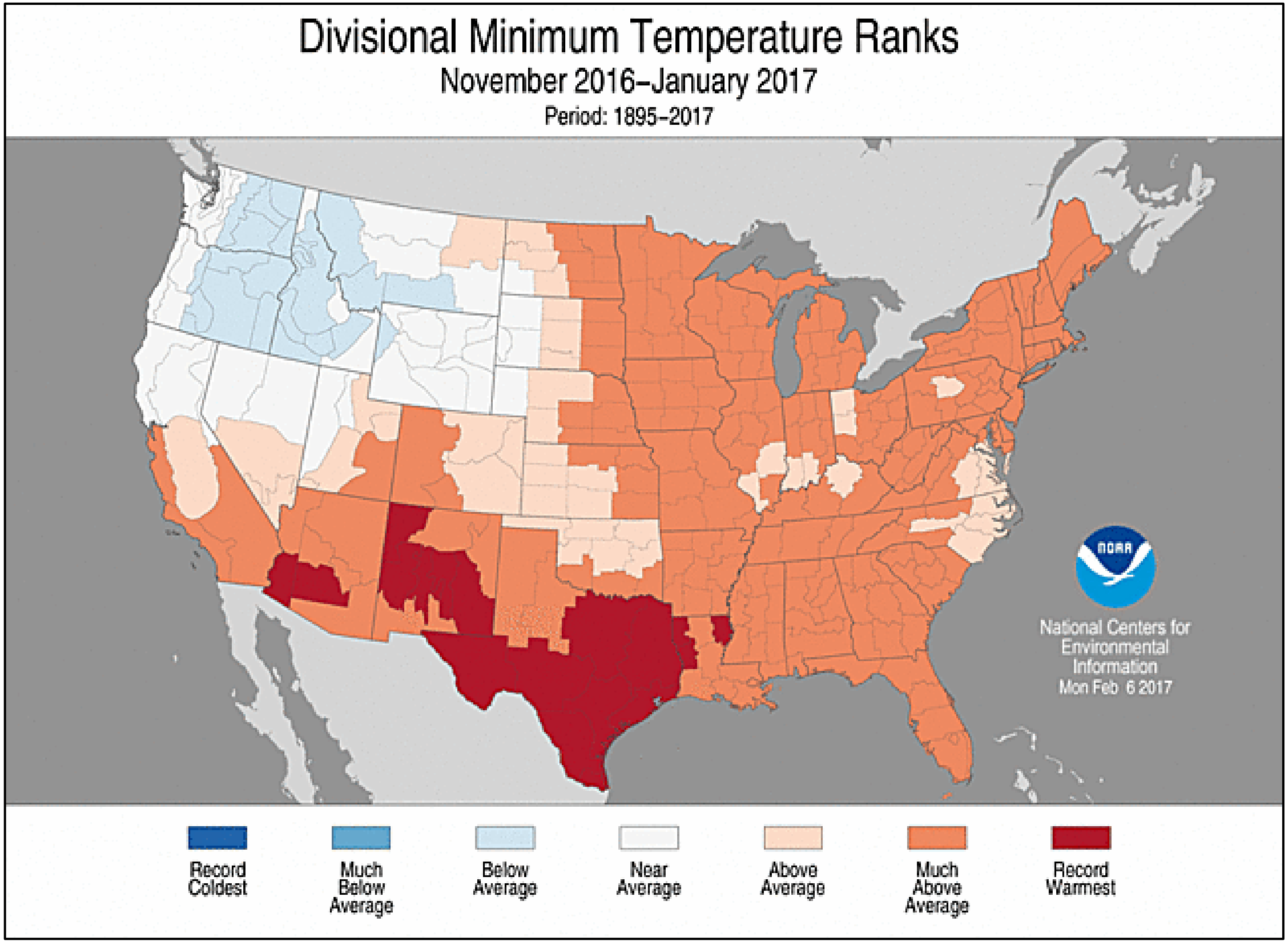
Luce Professor of Forestry

SFWS, Auburn University

AUBURN UNIVERSITY

SCHOOL OF FORESTRY AND WILDLIFE SCIENCES

Most Seedlings Lifted Dec-Feb…



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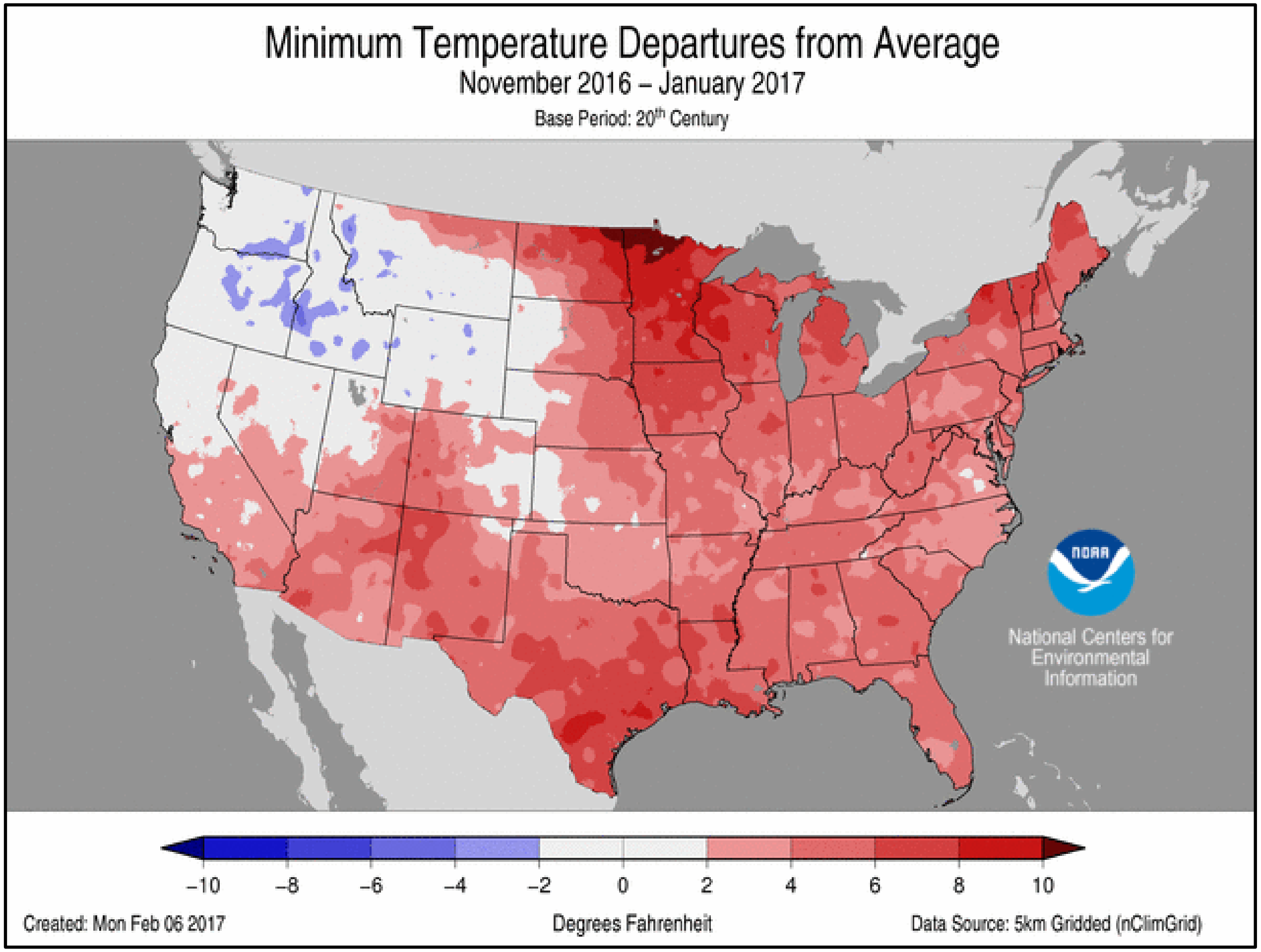
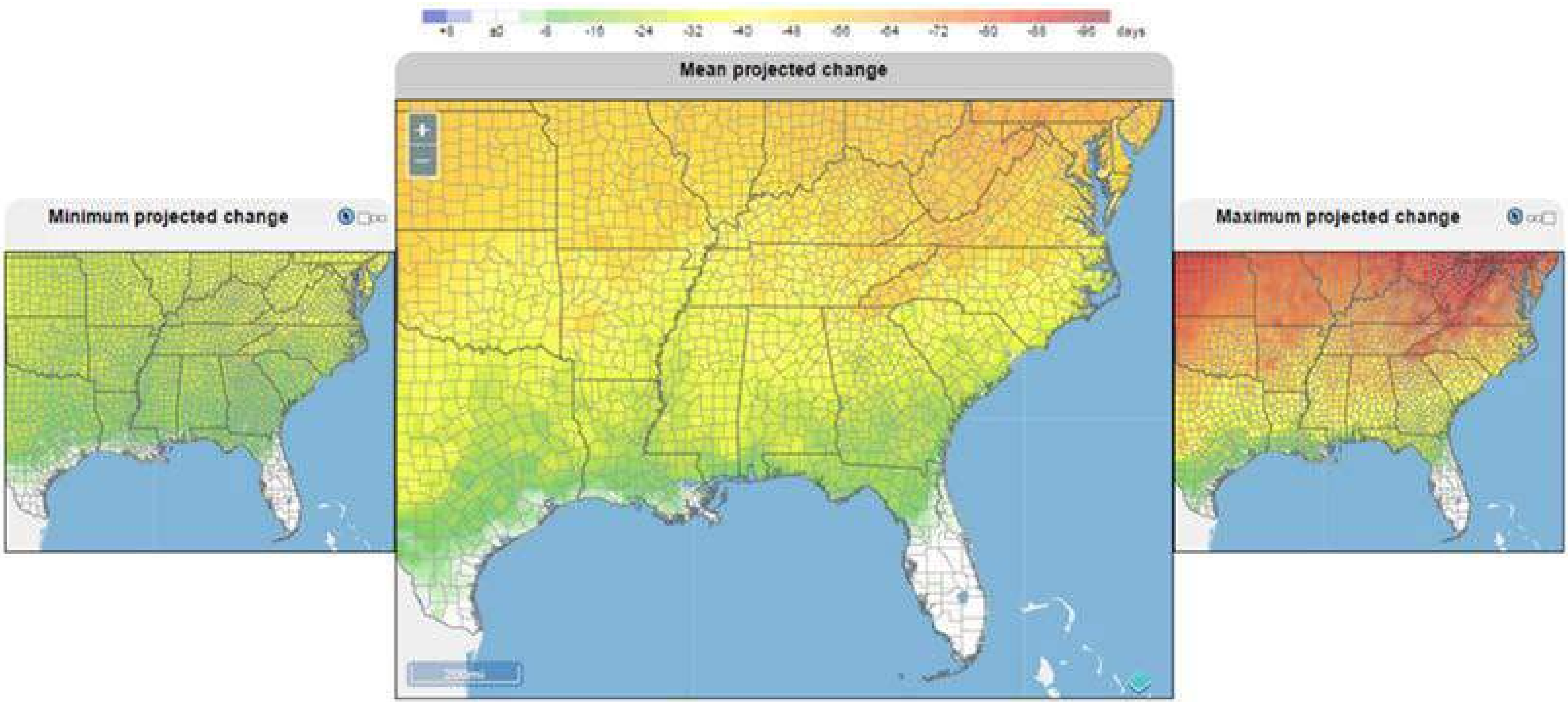


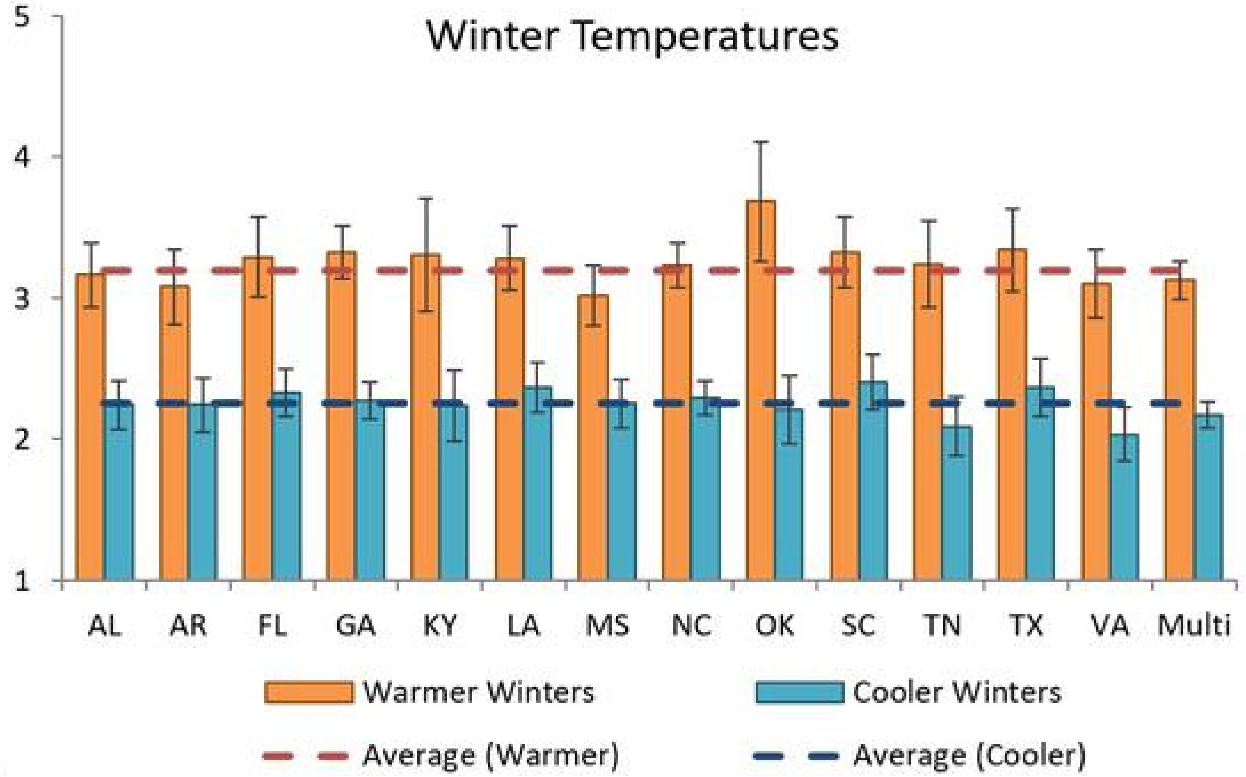
Loblolly Pine Desired Chilling hours: 32-46°F for 182-400 hours

Projected change in the number of days per year with minimum temperatures <32°F for 2080–2099 for the intense warming scenario (RCP 8.5). Figures preliminary and provided by the State Climate Office of North Carolina.



McNulty et al. (2015)

Southern Foresters Report Warmer Winter Temperatures



1=never; 5=very frequently

Tree Phenology-the Basics

- Temperate trees use temperature and night-length as information to regulate cessation and onset of shoot growth and removal of cold hardiness.
- Trees also have an internal ontogenetic rhythm that partially regulates these processes regardless of the environment.

Physiological Mechanisms That Perceive and Respond to Chilling?

- Reported changes in gene expression before, during and after budburst.
- How do plants sense and remember environmental conditions?
- Studies with birch and poplar: short days promote production of an enzyme which blocks transfer of chemical signals into cells that promote shoot growth.

Harrington and Gould (2015)

Cold Hardening/Acclimation

- First stage of hardening induced by night length alone and second stage by temperatures below 5°C.
- In southern pines, long nights can induce hardening.
- Hardening occurs to its maximum extent when there is a progression and sequence from warm short nights, to warm long nights, to cool longer nights.
- Cooling must occur at a particular time relative to increasing night length in order to achieve maximum hardiness.
- *This synchronization is likely to be disturbed by climatic warming. Seedlings may not be at maximum hardening when lifted.*

Saxe et al. (2001)

Physiological State of Buds During Winter

- Buds are capable of responding to thermal forcing when full chilling has not been achieved (Landsberg 1974).
- If warmer temperatures become more common in late winter, seedlings can break bud early and then be exposed to frosts.
  - Earlier planting may increase risk of frost damage.
  - Later planting to avoid frost risk may increase risk of drought damage.

Physiological States of Buds During Winter

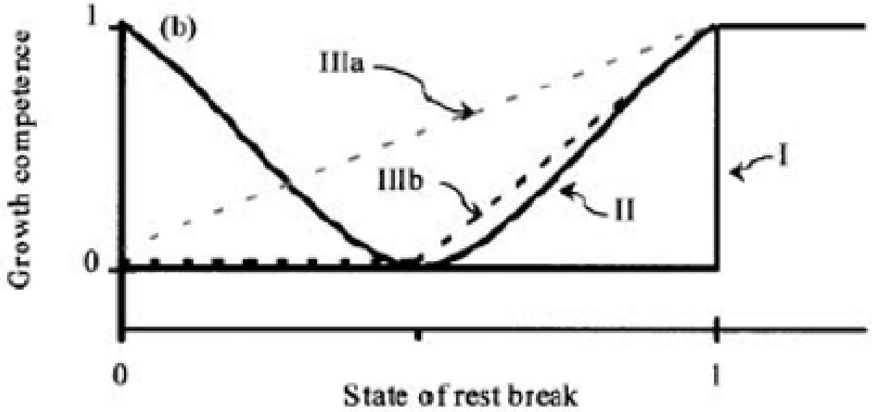
1. **Rest (Dormancy)**
    - Buds most dormant when cell division and growth cease and bud development is complete.
    - Broken by exposure to chill temperatures, short nights can substitute for chilling when buds have received little chilling in southern pines.
    - Loss of rest involves changes in balance between internal growth promoters and inhibitors and poorly understood biochemical processes.
    - *There is considerable uncertainty about the relationship between chill temperatures and the rate of rest break.*

Saxe et al. (2001)

Physiological States of Buds During Winter

2. Growth Competence (Ability to grow)

- Defines ability of buds to grow in response to warm temperatures
- High degree of uncertainty concerning patterns (linear versus threshold response)



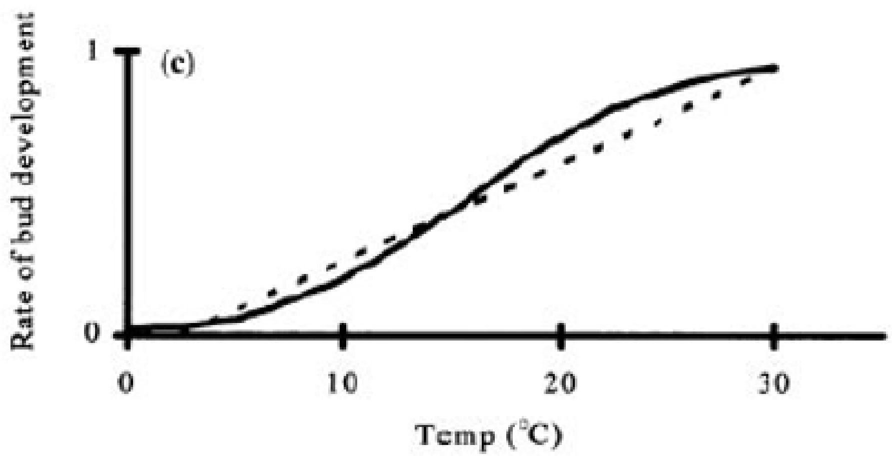
0=maximal rest
1=maximum potential growth rate at warmer temperatures

Saxe et al. (2001)

Physiological States of Buds During Winter

3. Bud growth and development

- Defines the visible change in size of buds as cell division and enlargement progress in warm temperatures.
- Slope depends on the growth competence.



Saxe et al. (2001)

Cold Hardiness and Stress Resistance

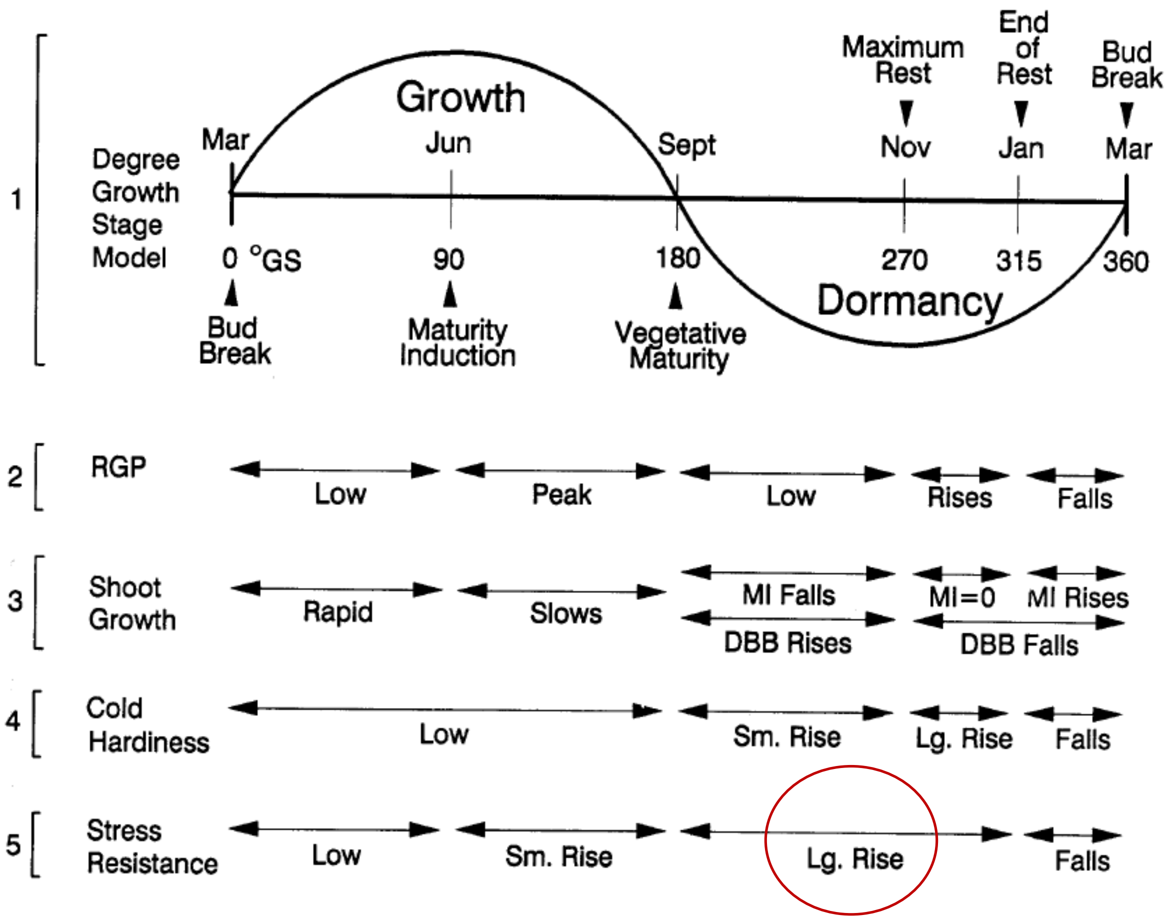


Figure 7.1—*A Degree Growth Stage model (Fuchigami and Nee 1987, Fuchigami et al. 1982) representing one complete annual cycle, with changes in root growth potential (RGP), shoot growth (MI = mitotic index, DBB = days to bud break), cold-hardiness, and stress resistance during the cycle.*

- *Less hardiness = a less stress resistant seedling*

Burr (1990)

Dehardening

- Driven mainly by temperature and can occur at 0.5-1.5^{o}C per day, much faster than hardening.
- Warm minimum temperatures decrease hardiness after a few days.
- Low minimum temperatures can slow, halt or reverse dehardening.
- Fluctuating warmer temperatures promote development towards budburst.
- *Once budburst begins, shoots can no longer harden in response to cool temperatures*.

Saxe et al. (2001)

Budbreak

- Southern pine seedlings require natural-light chilling to develop tolerance to a -6^{0}C freeze (South 2013).
- After budset, a 14 hour photoperiod can partially substitute for chilling requirement for budbreak (Garber 1983).
- *If chilling requirement is satisfied, temperature is overriding factor causing budbreak and short days can’t forestall budbreak.*

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.

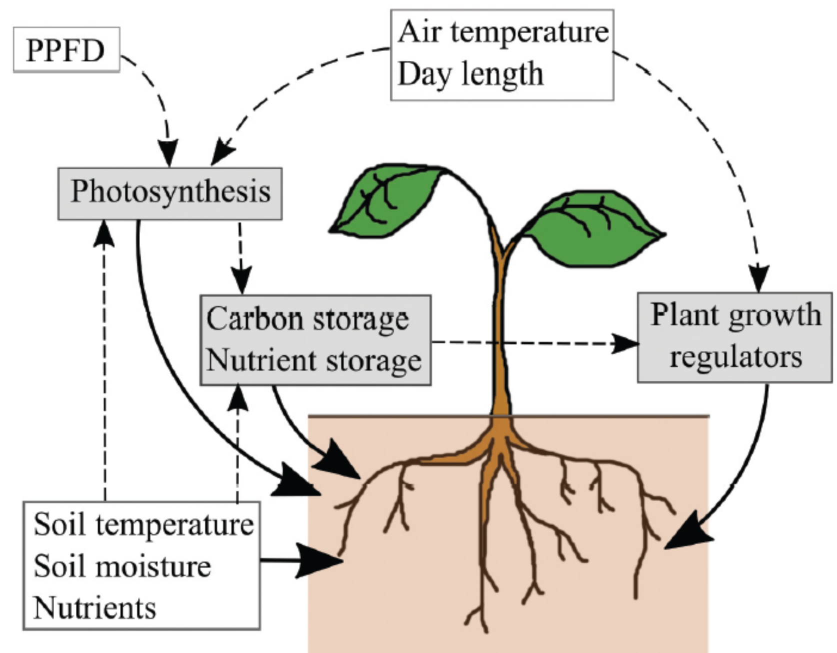


Fig. 1. Potential controls over root phenology. Solid lines indicate direct controls and dashed lines indicate indirect controls on root phenology. Gray boxes represent endogenous controls; and white boxes represent exogenous controls. PPFD is photosynthetically active flux density.

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

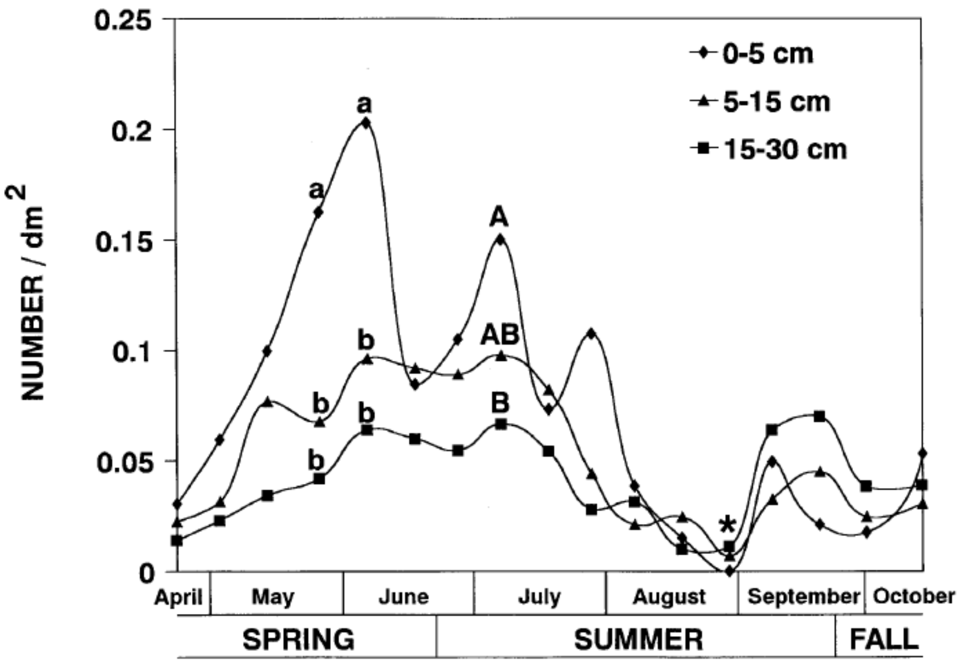
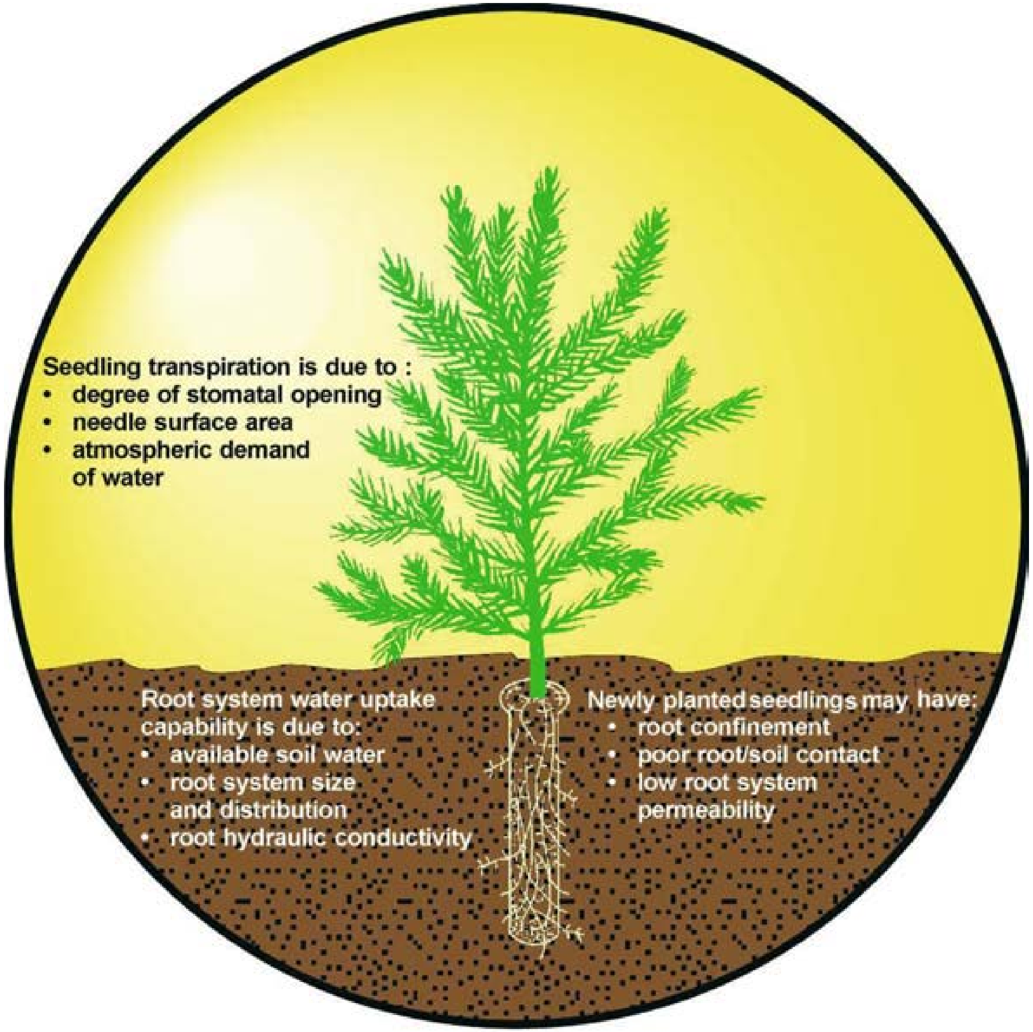


Figure 4. Mean number of roots dm^{-2} initiated at 0–5, 5–15 and 15–30 cm in rhizotrons during April through September 1993. Within measurement intervals, means associated with the same letter are not significantly different by the LSD test at $P < 0.05$ (lower case), and $P < 0.10$ (upper case). The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

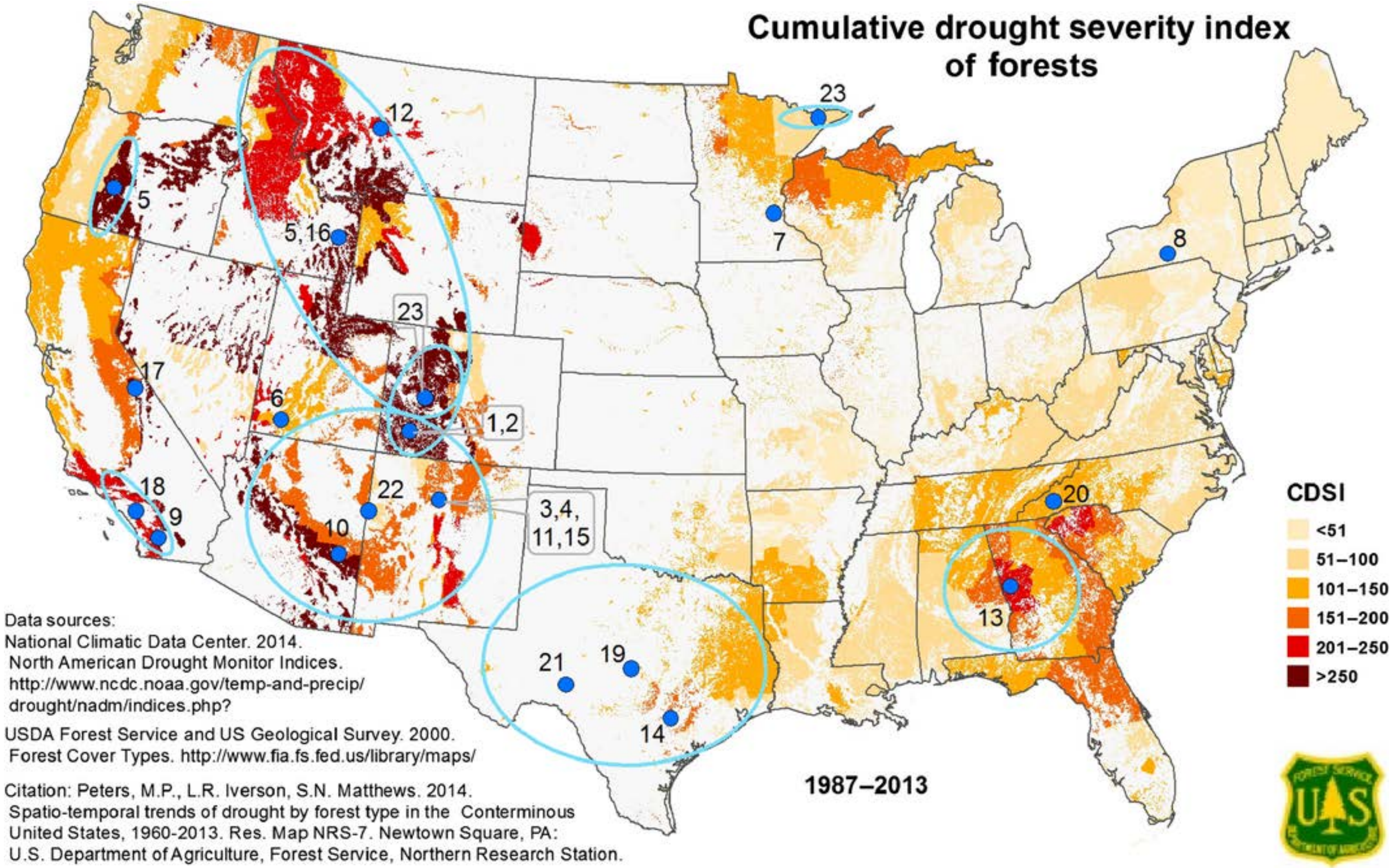
Sword et al. (1996)

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

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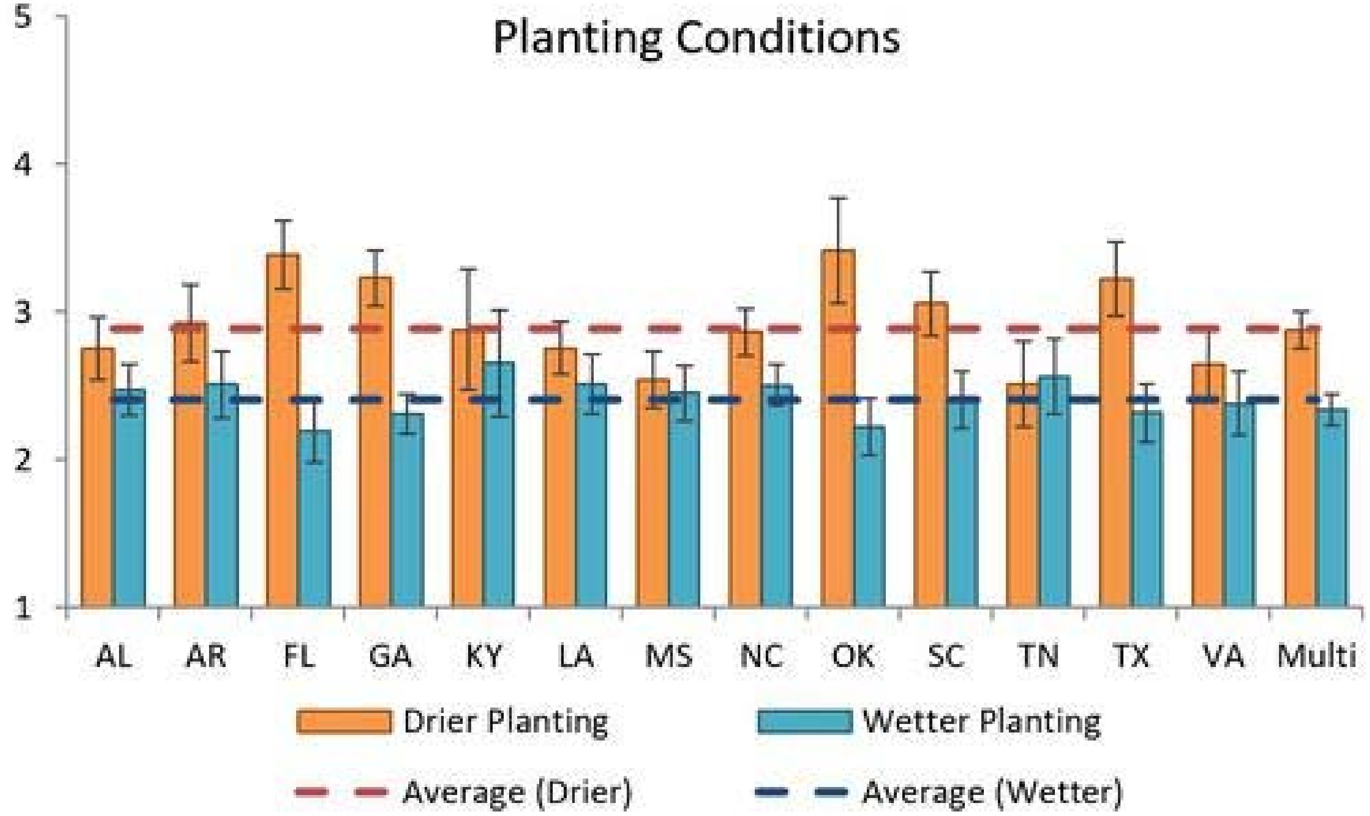
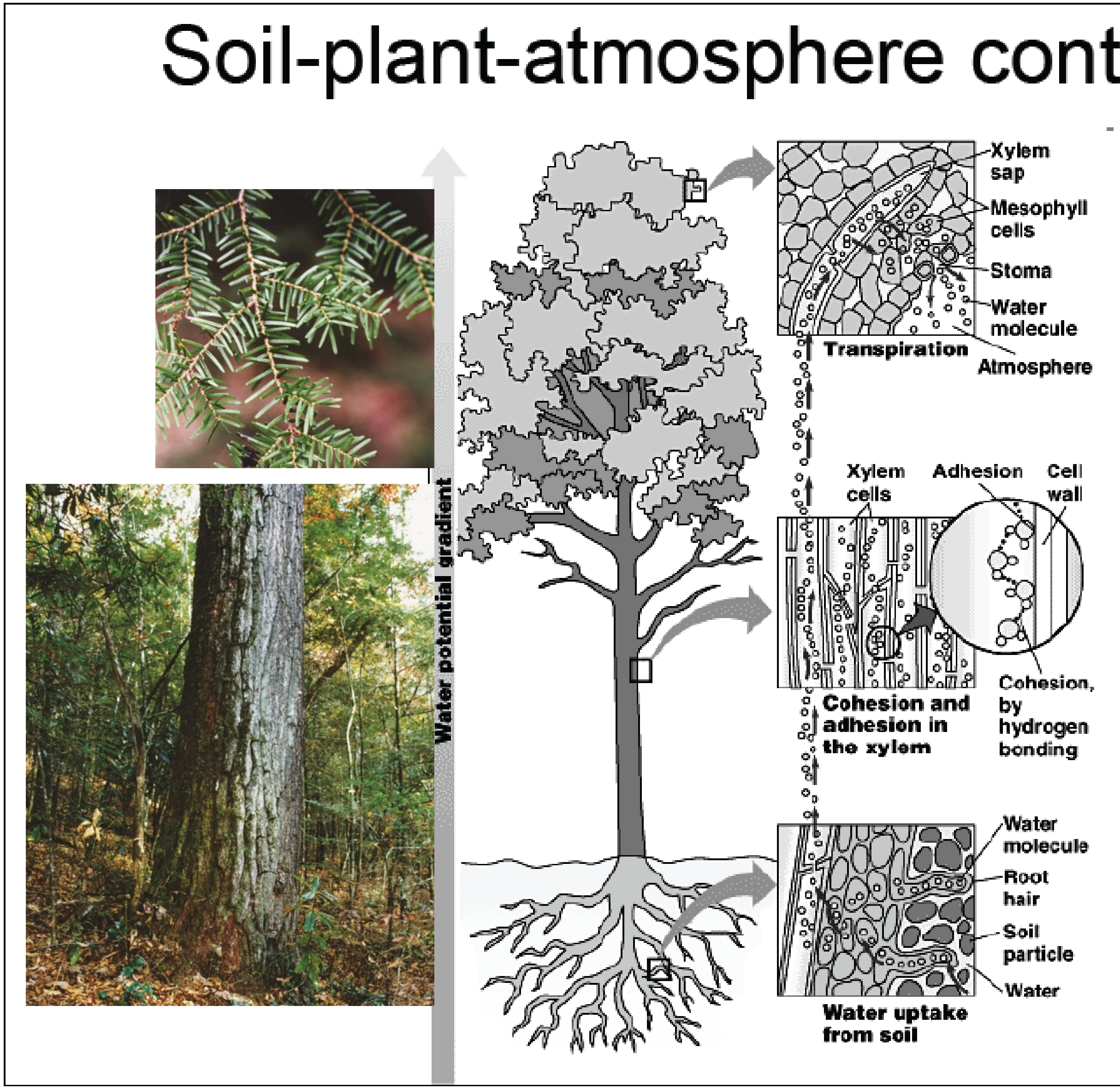
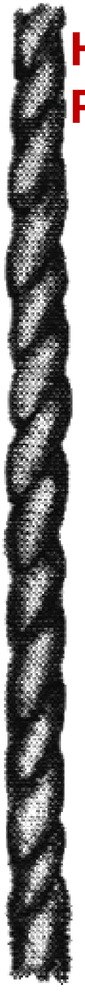
http://onlinelibrary.wiley.com/doi/10.1111/gcb.13160/full#gcb13160-fig-0008

Southern Foresters Report Drier Planting Conditions



Water Movement in Trees-the Basics





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.

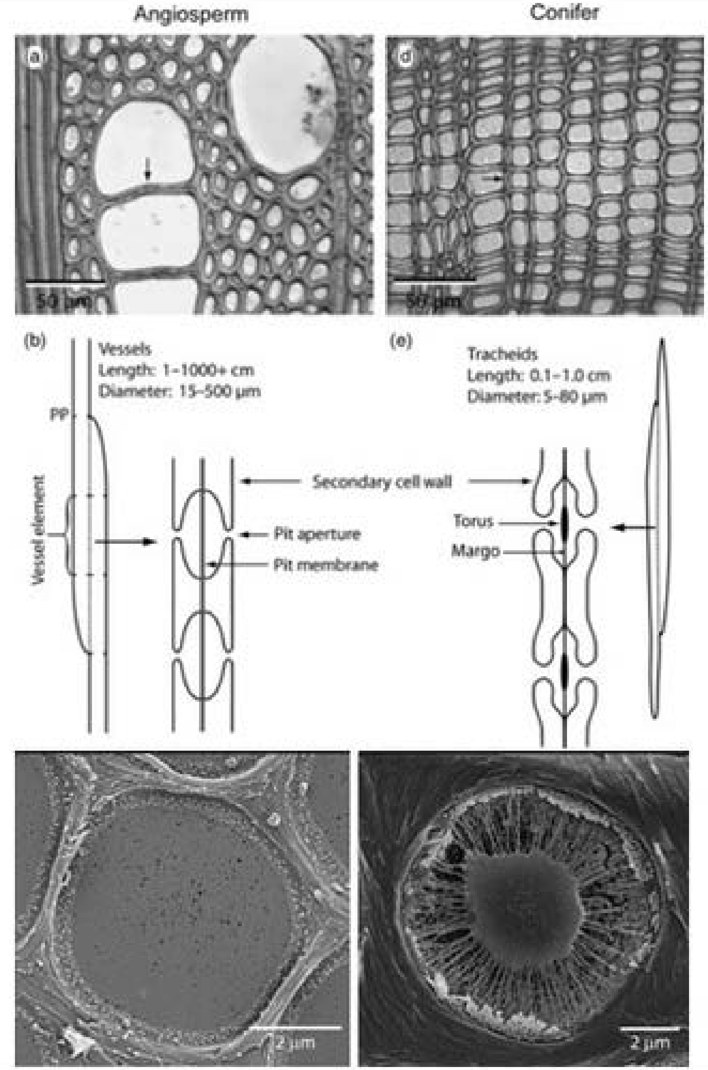


Figure 6: Comparison of different types of wood from flowering and cone-bearing plants.
This features wider conduits from flowering plants (top), a cartoon reconstruction of vessels, tracheids and their pit membranes (middle), which are also shown in SEM images (bottom).

McElrone et al. (2013)

How Embolisms Spread

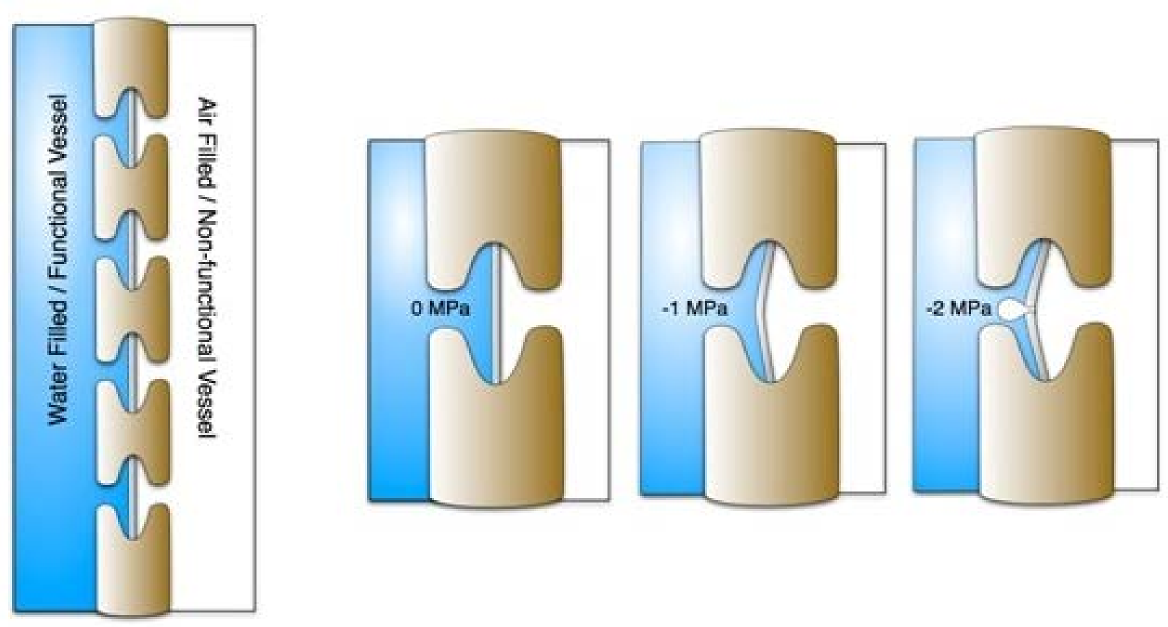


Figure 9: Air seeding mechanism.
Demonstrates how increasing tension in a functional water filled vessel eventually reaches a threshold where an air seed is pulled across a pit membrane from an embolized conduit. Air is seeded into the functional conduit only after the threshold pressure is reached.

McElrone et al. (2013)

Embolism Repair

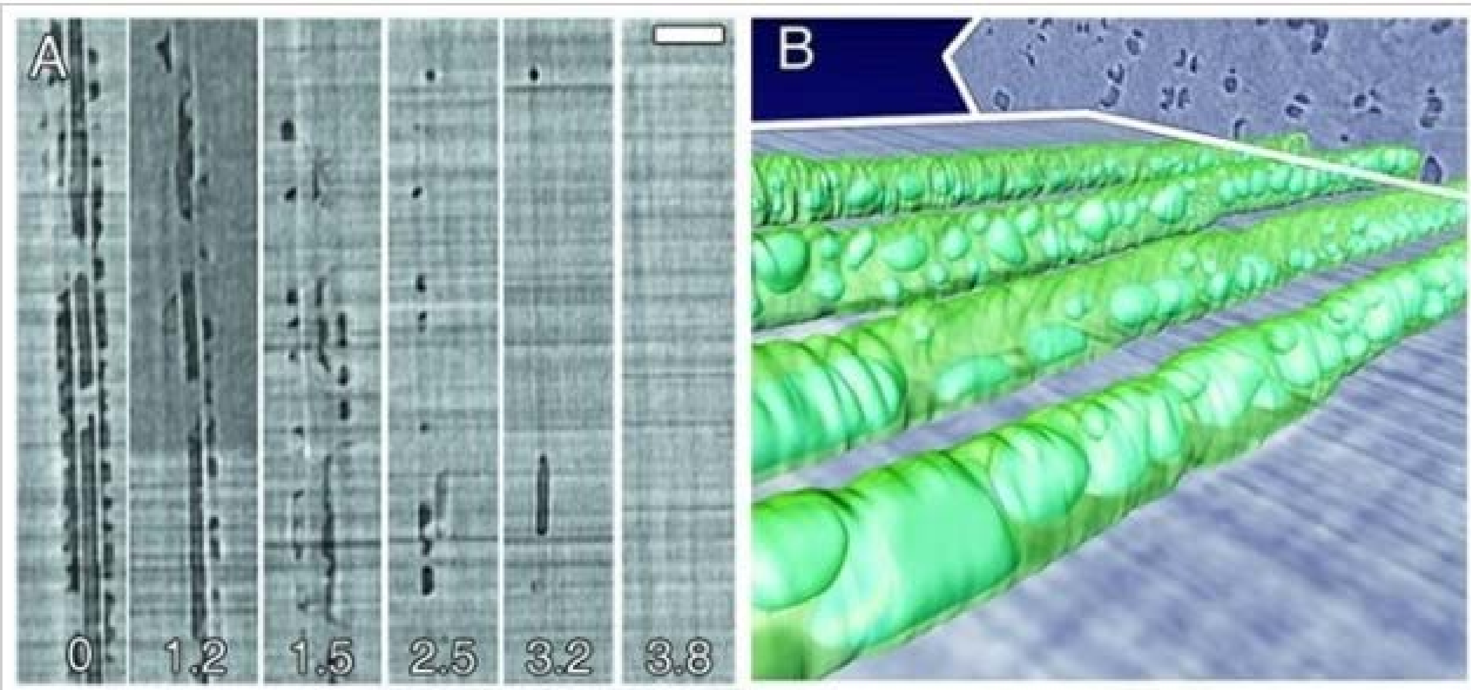
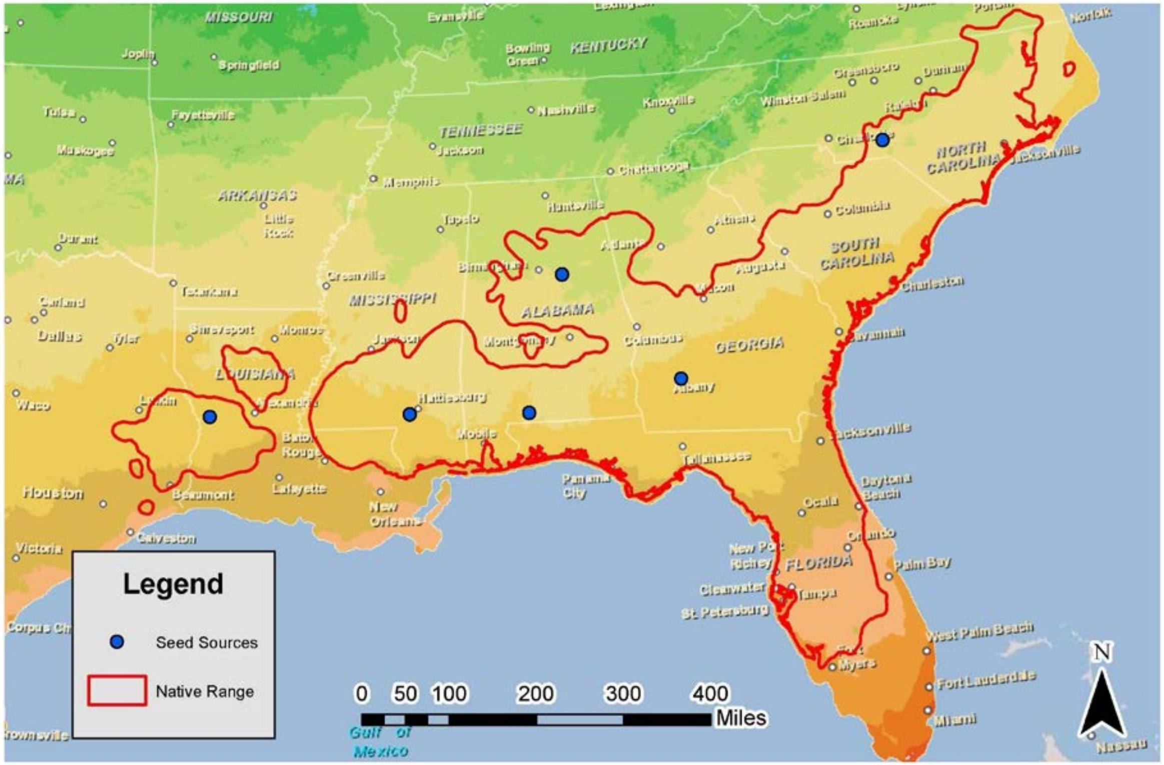


Figure 10: Embolism repair documented in grapevines (*Vitis vinifera* L.) with X-ray micro-CT at the ALS facility at Lawrence Berkeley National Lab CA, USA.
(A) Longitudinal section showing a time series of cavitated vessels refilling in less than 4 hrs; (B) 3D reconstruction of four vessel lumen with water droplets forming on the vessel walls and growing over time to completely fill the embolized conduit.

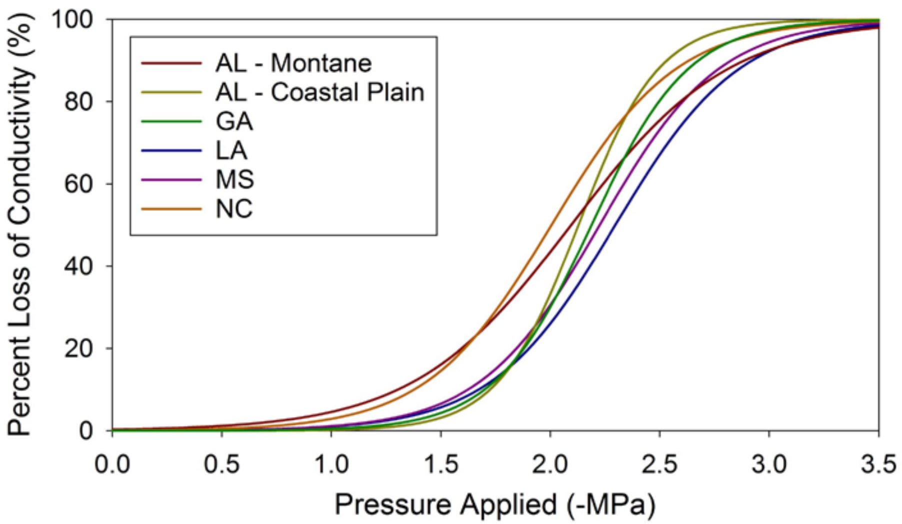
- Ray parenchyma
- Aquaporins

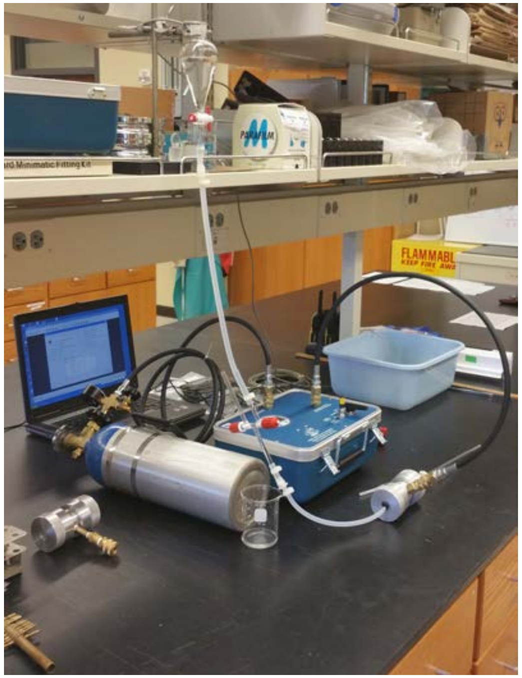
McElrone et al. (2013)

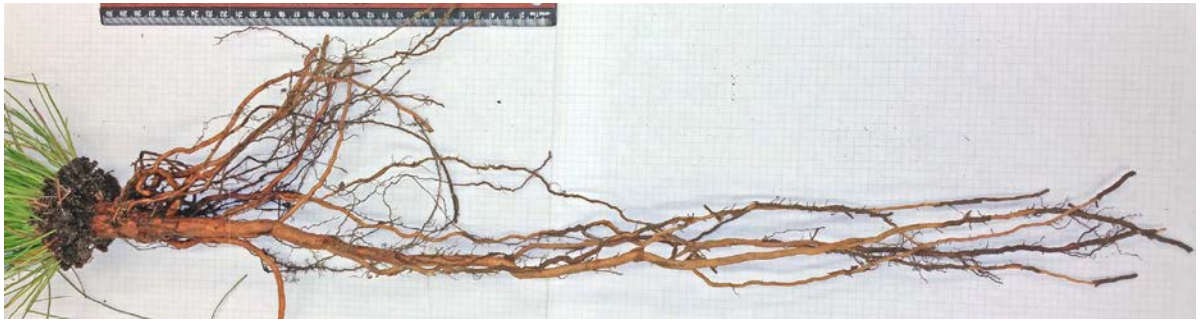
Root Vulnerability to Cavitation in Longleaf Pine Seedlings



Hydraulic Vulnerability Curves on Lateral Roots





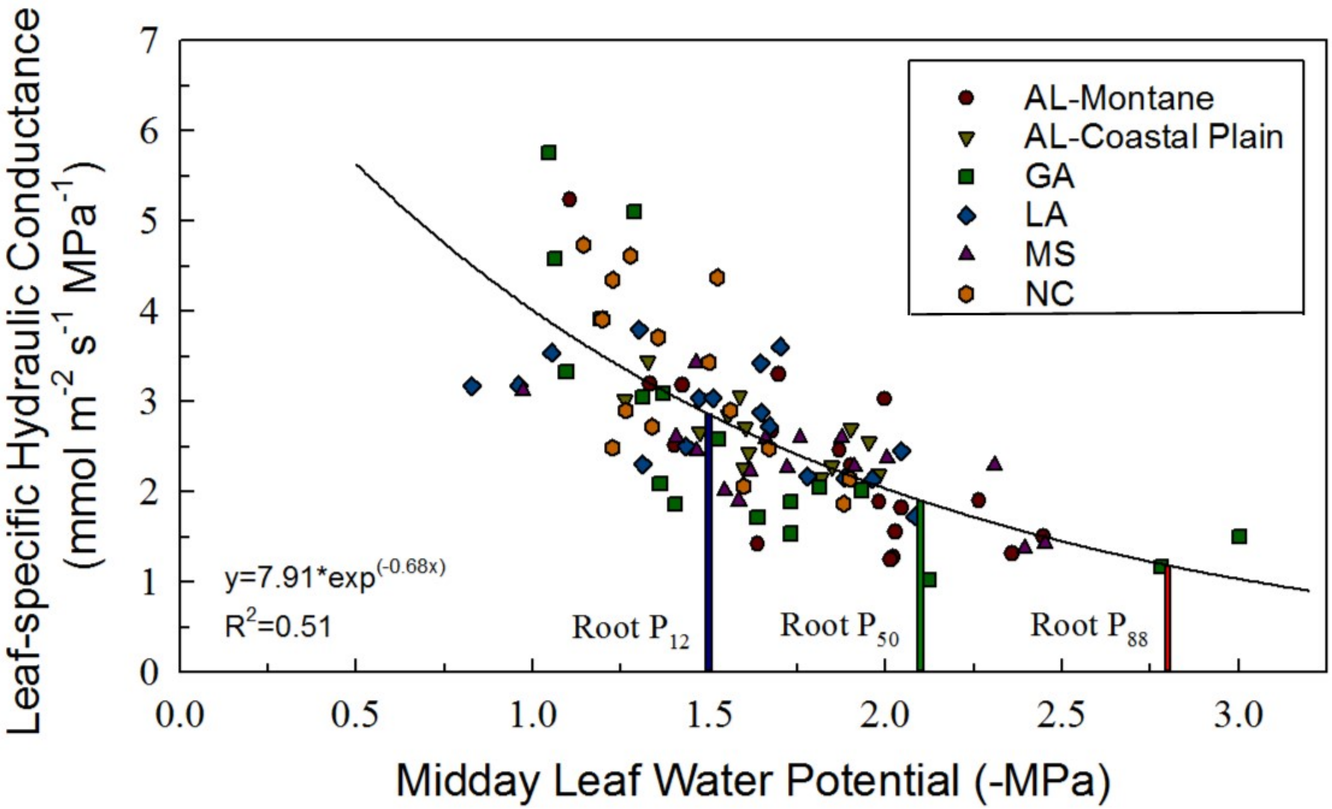


Embolism Resistance in Pines

- 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

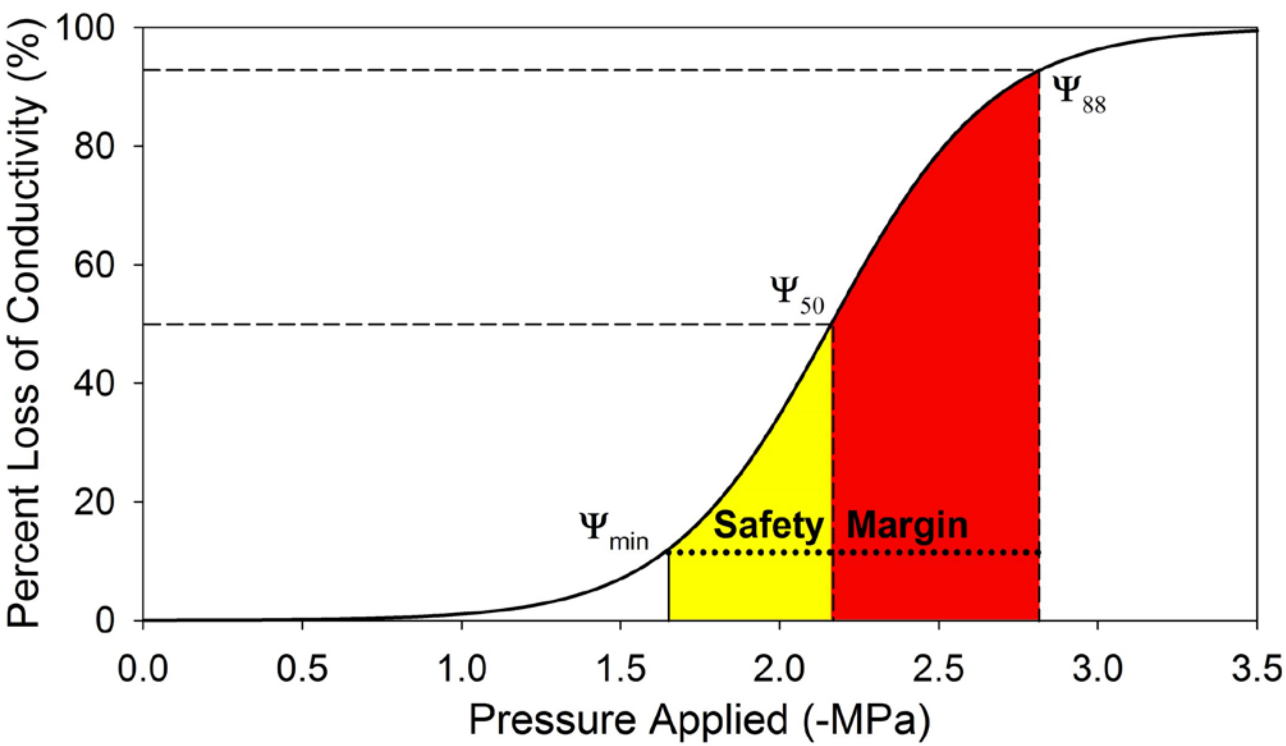
- Measure of how efficiently water is transported through the seedling as water stress increases



- 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.
- Seedlings may not be as hardened in a warmer winter. Shallow hardening may influence stress resistance (i.e. storage times, containers versus bareroot).
- Lifting and planting windows may need to narrow because of later or less hardening and earlier budbreak.
- *Because of climate, the seedling stress "buffer" will be less than it has been in the past.*
  - *Seedling care during storage and planting*
  - *Proper planting depth*
  - *Planting conditions*
  - *Lifting window*

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