The relationship between drought tolerance traits and germinant seedling establishment in three Pacific Northwest conifer species

Kelly L. Kerr[1], Kate A. McCulloh[1], Frederick C. Meinzer[2], David R. Woodruff[2]

[1]Forest Ecosystems and Society, Oregon State University, [2]USDA Forest Service, PNW Research Station

Background

Research Question

- **Investigate how physiological parameters are affected by altered water and light regimes at the seedling life stage**
- **Advance understanding of mechanisms involved in seedling establishment and how species-specific responses to limiting environmental factors affect species distribution patterns**

Seedling establishment might be the most important determinant of tree species distributions[1]. Water availability and solar irradiance have significant effects on seedling growth and survival[2]. In the Pacific Northwest, distributions of three conifer species (*Pinus ponderosa, Tsuga heterophylla* and *Pseudostuga menziesii;* Fig.1) have been shown to be growth limited under drought[3,4,5]. These species maintain wide geographic ranges across varying precipitation regimes. Plant species distributions have been linked to rainfall regimes[6]. Thus, populations within a species from contrasting precipitation regimes could exhibit different establishment mechanisms. Climate change projections predict increases in temperature and drought events, which are expected to alter the distribution patterns of many plant species[7]. Understanding physiological mechanisms behind conifer seedling establishment, especially under variable environmental conditions, will improve our ability to predict future species distributions.

Figure 1.
From left to right, seedlings of : *Pinus ponderosa, Tsuga heterophylla* and *Pseudostuga menziesii.*

Hypotheses and Assumptions

Hypotheses

1) The ontogenetic timing of development of mechanisms for desiccation resistance determines drought tolerance during the seedling stage.

2) Different populations within a species exhibit different drought resistance strategies that correlate to the seed source.

3) The climate of a species' ecological distribution is strongly correlated to first-year seedling traits that facilitate establishment.

Assumptions

- The ecological distribution of a tree species can be correlated with climate
- Soil moisture level, solar irradiance and anatomy affect xylem development and functioning

Methods

Study Design

- Experimental study
- Compare physiological responses between and within species to two limiting environmental factors: water and light
- Seedlings of three conifer species:
  - ponderosa pine (*Pinus ponderosa*)
  - western hemlock (*Tsuga heterophylla*)
  - Douglas-fir (*Pseudostuga menziesii*)
- Two seed sources from contrasting precipitation regimes (Fig.3 for seed source locations)
- Seed were sown into raised soil beds located in Corvallis, OR in March 2013 following a randomized block planting design (Fig.2)
- Randomly selected blocks will receive one of two light treatments: full or 25% sunlight
- Randomly selected beds will receive one of two water treatments: well-watered or drought

Figure 2. *Left panel:* Schematic of randomized block planting design in a soil bed. PIPO = *Ponderosa pine*, PSME = *Pseudostuga menziesii*, TSHE = *Tsuga heterophylla*. A 1 denotes a "Wet" population and 2 denotes a "Dry" population. *Right panel:* Field crew sowing seed.

Sampling

- Seedlings sampled randomly
- Regular sampling intervals throughout the growing season (approx. May - September)
- 3-5 replicate seedlings per measurement
- Water potential, gas exchange, hydraulic conductance, biomass, cuticular development, xylem anatomy and development, and isotopic analysis
- Construct hydraulic vulnerability curves, assess rates of carbon gain, and observe developmental changes in anatomy
- Data analysis will allow us to estimate the phenotypic plasticity of these measured traits

Interpretation

Scope of Inference

Causal inferences can be drawn as this is a designed experiment. Inferences are restricted to the three conifer species examined, but results will provide information about seed sources beyond those used in this study. Results may also inform future studies.

Expected Outcomes

- Seedling populations from drier precipitation regions will be more drought tolerant and will develop mechanisms earlier for desiccation resistance at the seedling stage
- The importance of mechanisms involved in seedling establishment will be species-specific
- Results from this study will correlate to the climate of a species' ecological distribution

Broader Significance

This research will contribute knowledge of germinant conifer seedling physiology and the mechanisms associated with conifer seedling survival. Results will advance our understanding of how species-specific responses to drought affect species distributions, and will allow for more accurate predictions of distribution patterns under future climate change.

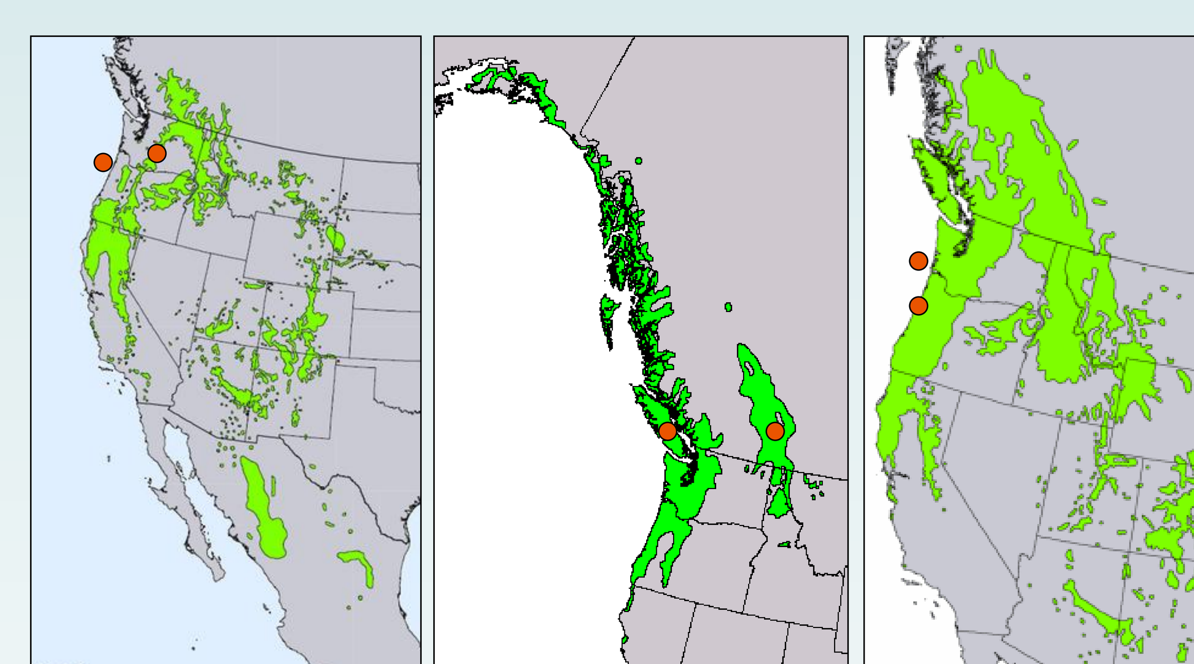

Figure 3. Current distribution patterns of (from left to right): *Pinus ponderosa, Tsuga heterophylla* and *Pseudostuga menziesii*. Approximate seed source locations for this study are indicated by an orange dot. *Pinus ponderosa*: west (wet) and east (dry) of the Oregon cascades; *Tsuga heterophylla*: Washington coast (wet) and northern Idaho (dry); *Pseudostuga menziesii*: along a precipitation gradient on west side of Oregon cascades. Images from plants.usda.gov.

References

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