Heat and drought impacts on tree seedling growth and survival

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Introduction

- Climate change stressors like heat and drought are increasingly threatening regeneration of trees in the northeastern US, particularly those at the southernmost limit of their ranges[1,2].
- First-year tree seedlings are likely extremely vulnerable to changes in climate[3].
- However, we have a very limited understanding of species-specific responses to climate, particularly the extent to which heat, drought, and heat combined with drought will impact survival and growth of first-year tree seedlings in the northeastern US.

Goal

Determine the extent to which heat, drought, and heat combined with drought impact the growth and survival of first-year tree seedlings and explore the physiological mechanisms underpinning their responses.

Methods

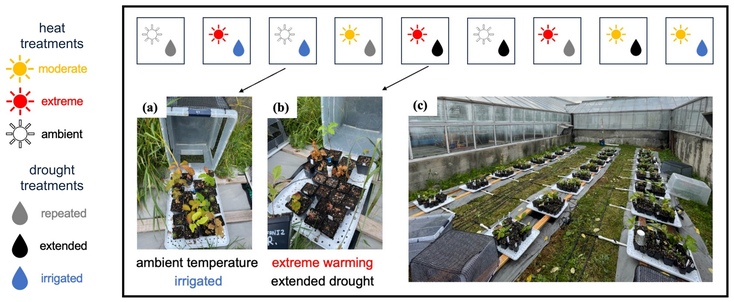

Figure 1. schematic representation of one experimental block with nine combinations of temperature and soil moisture conditions. Examples of (a) ambient, irrigated conditions and (b) extreme heat, extended drought conditions. 27 total chambers were used to replicate each unique treatment combination three times (c).

- We planted seeds of eight tree species individually in containers, which were divided among 27 treatment chambers.

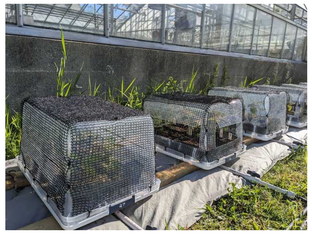

Figure 2. Chamber design used to heat the inside of chambers in both the moderate and extreme heat treatments (left) and ambient treatments (right).

Table 1. List of tree species.

Leaf type	Species
Evergreen needle-leaved species	balsam fir (*Abies balsamea*)
	red spruce (*Picea rubens*)
	eastern white pine (*Pinus strobus*)
	northern white cedar (*Thuja occidentalis*)
Deciduous broad-leaved species	red oak (*Quercus rubra*)
	red maple (*Acer rubrum*)
	sugar maple (*Acer saccharum*)
	black ash (*Fraxinus nigra*)

- Heat treatments lasted 90 days and were crossed with three soil moisture treatments lasting five weeks. Repeated drought chambers received no water for two weeks, which was repeated after a period of full irrigation. Extended drought plants were minimally irrigated for the duration of the treatment.
- We measured start- and end-of-treatment height and vigor. A subset of pots were weighed twice a week to monitor soil moisture. Species-level minimum epidermal conductance (g_{min}) and leaf mass per area (LMA) were measured after drought treatments concluded.

Preliminary Results

- **Survival was significantly lower for balsam fir and red spruce compared to the other species. Generally, we found that survival was lower in response to combined extreme heat and drought than either stressor alone (droughtxheat interaction p-value = 0.038)**

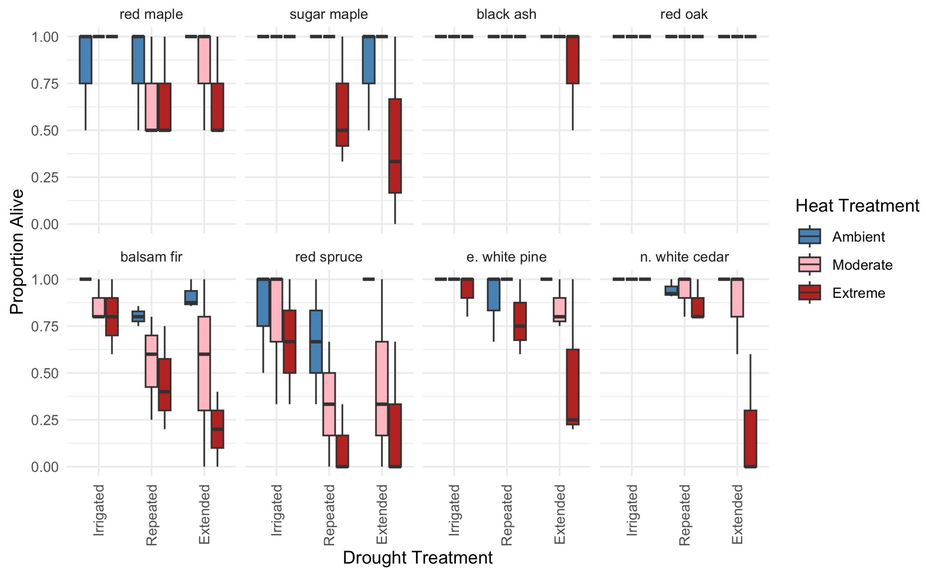

Figure 3. Proportion of surviving seedlings at the end of treatments averaged across chambers. Statistical significance was determined using linear mixed effect binomial model testing for effects of species, drought, and heat on survival.

- **For the seedlings that survived, we found that height differed significantly among species (p-value < 0.001). There were no significant effects of heat or drought on height.**

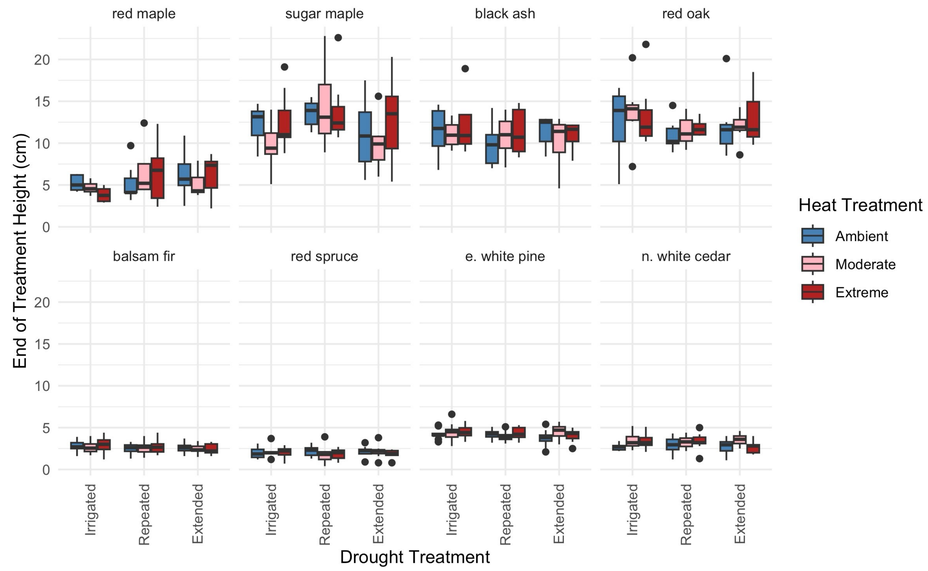

Figure 4. Total height at the end of treatments averaged across chambers. Statistical significance was determined using linear mixed effect model testing for effects of species, drought, and heat on height.

Preliminary Results cont'd

- **We found significant differences in LMA (p-value < 0.001) and gmin (p-value < 0.001) among species. g_{min} of red maple and red spruce were among the highest values, indicating leakier stomata, and the values for red oak and white pine were among the lowest. Generally, red maple and black ash had the lowest LMA, while red spruce and balsam fir had the highest LMA.**

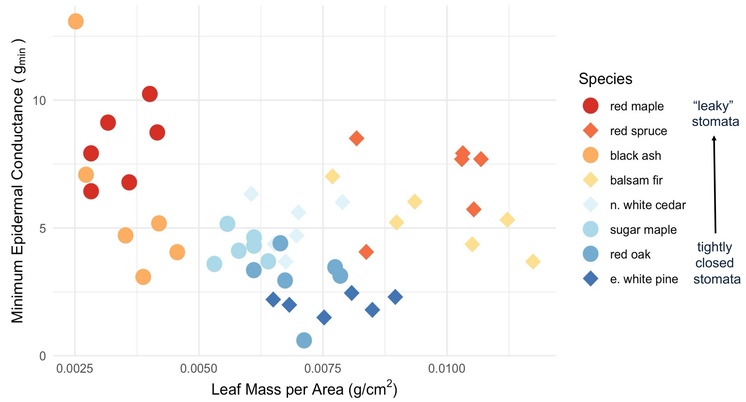

Figure 5. Leaf mass per area (LMA) and minimum epidermal conductance (g_{min}) of our study species. Linear mixed effect model testing was used to determine differences among species. Species are listed according to average g_{min} values.

Discussion

- Boreal conifers were most sensitive to heat and drought effects, and combined drought and heat had more negative effects than either treatment applied independently.
- Drought and heat did not reduce height growth, suggesting that surviving first-year seedlings are able to grow across a range of conditions.
- These results suggest that land managers may want to consider the potential of compounded stressors when there is concern regarding tree regeneration. Additionally, heat waves and higher baseline temperatures associated with climate change may not pose a threat to most first-year seedlings of most species, so long as they have access to adequate soil moisture.
- Next steps:
  - biomass and root:shoot analysis
  - other drought tolerance metrics (e.g., turgor loss point)

Acknowledgements

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