Drought timing impacts on chlorophyll content and photosynthesis in New England trees

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Dr. Jay Wason III
Assistant Professor of Forest Ecosystem Physiology
University of Maine, School of Forest Resources, Orono, Maine

Abstract: Despite predictions for increased annual precipitation in New England, warming temperatures and variability in the timing and amount of rainfall in individual events is expected to lead to more extreme droughts. Furthermore, canopy disturbance can expose previously shaded trees to high light and dry air, triggering a drought response. However, most native forest trees in New England rarely experience drought and therefore may not be well adapted to future conditions. The goal of this project was to determine how rapid environmental changes drive physiological declines in trees native to New England. In the first study, we measured the physiological shock associated with rapidly exposing shade-acclimated *Picea rubens* trees to high light conditions and dry air by removing competing vegetation and tracking sapflow, water status, and leaf photosynthetic efficiency. In a related study (DroughtTIME: Drought Timing Impacts in Maine) at the University of Maine we simulated droughts occurring during different times of year on 288 saplings trees of *Betula papyrifera*, *Acer rubrum*, *Prunus serotina*, *Thuja occidentalis*, *Pinus strobus*, and *Juniperus virginiana*. Each sapling was individually irrigated to simulate one of four treatments: no drought, spring drought, summer drought, or late-summer drought. Throughout the study graduate and undergraduate students tracked height and diameter growth, soil moisture, plant hydration, leaf chlorophyll content, and leaf photosynthetic efficiency. These new data have provided insight into the physiological stress associated with rapid exposure to hot and dry air and drought conditions that help us better understand how New England forest trees may respond to future climate change.

Drought is a major driver of recent forest mortality (Allen et al. 2015). Despite predictions for increased annual precipitation in New England, the expected increase in temperatures as well as the high variability in the timing and amount of rainfall in individual events is expected to lead to more extreme droughts in the region (Vose et al. 2019). Importantly, most native trees are not well adapted to drought. Therefore, even moderate future droughts are expected to surpass the physiological thresholds of native trees in New England (Liénard et al. 2016). As climate continues to change, future conditions are expected to be beyond what our native plants have experienced in the recent past.

The *overall goal* of this research project was to determine **how drought and other rapid environmental changes drive physiological declines in trees native to New England.** To accomplish this goal, we conducted two separate experiments to simulate extreme conditions on trees. In the first experiment we tested how rapidly changing the light environment for mature red spruce trees (*Picea rubens*) from shaded understory conditions to high light conditions impacted water relations and photosynthesis. In the second experiment, we imposed an experimental drought on 288 sapling trees of six tree species native to New England (*Acer rubrum*, *Betula papyrifera*, *Prunus serotina*, *Juniperus virginiana*, *Pinus strobus*, and *Thuja occidentalis*). The New England Botanical Club supported this work by funding two important devices for rapidly estimating leaf chlorophyll content (CCM-200plus) and photosynthetic efficiency (PAR-FluorPen FP 110/D). In this report, we briefly highlight the key outcomes of this work that were facilitated by these measurements.

Despite the well-known benefits of thinning dense forests for the growth of the residual trees, the rapid change in environmental conditions can induce some negative effects. In this study, we tracked the physiology of large red spruce trees that were experiencing heavy competition from canopy trees. After removing that competition by thinning, we found a strong and consistent decline in photosynthetic efficiency of the shade grown needles that were not acclimated to the new high-light conditions (Figure 1). These results suggest that although thinning still overwhelmingly benefits residual trees, there are some negative effects of thinning

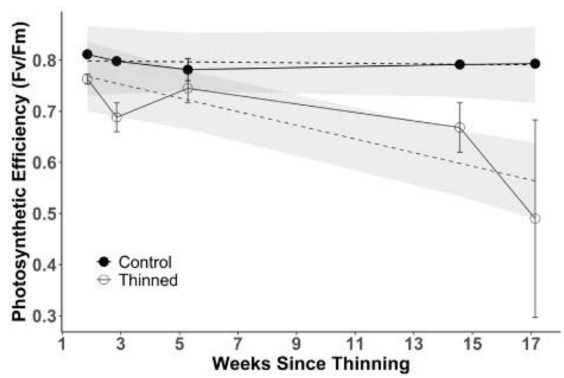

Figure 1. The immediate negative impact of removing competing trees on the photosynthetic efficiency of mature red spruce (*Picea rubens*). Trees that were initially suppressed in shade experienced consistent declines in photosynthetic efficiency when exposed to high light after thinning.

that may lead to reduced vigor and even mortality of the residual trees. In addition to the time required to grow new sun-acclimated needles, these negative effects on photosynthetic efficiency are likely part of the reason that it takes up to five years for trees to achieve maximum growth post-thinning.

In a separate study of sapling trees (DroughtTIME: Drought Timing Impacts in Maine), we found that simulated drought had profound effects on growth and physiology. For example, paper birch, was particularly sensitive to drought (Figure 2a) exhibiting rapid declines in estimated chlorophyll content within just five days of stopping irrigation (Figure 2b). These declines in chlorophyll content were followed by significant declines in photosynthetic efficiency of those leaves. Both of these changes were accompanied by strong reductions in plant water status and combined can provide insight into how water status and the ability to conduct photosynthesis respond to extreme drought.

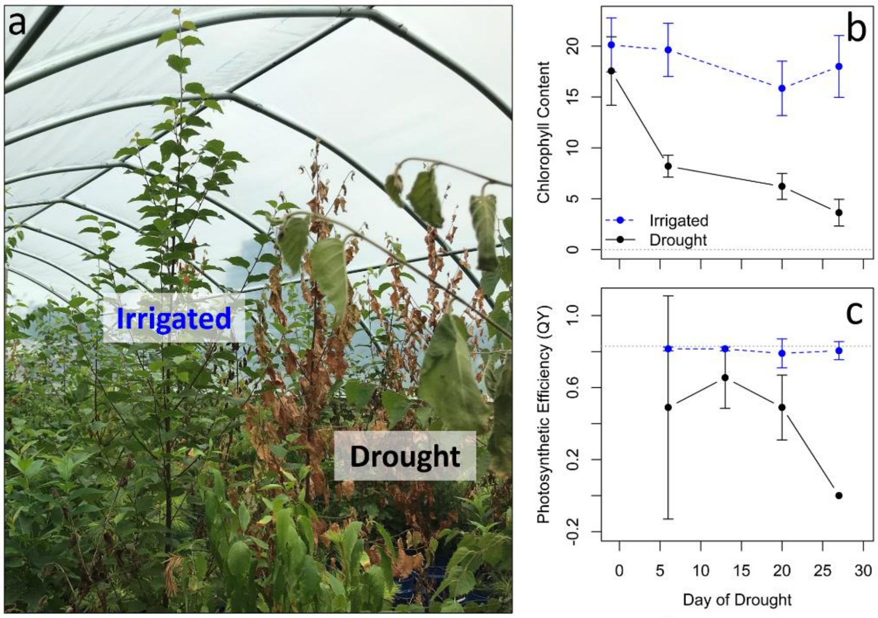

Figure 2. The impact of severe drought on paper birch physiology (*Betula papyrifera*; a). Drought resulted in severe declines in chlorophyll content (b) and photosynthetic efficiency (c).

The funding from the New England Botanical Club helped make this research possible. These data were collected by two graduate students at the University of Maine School of Forest Resources and are being incorporated into their final theses. The ability to quickly monitor chlorophyll content and photosynthetic efficiency of plants experiencing environmental stress will contribute to future research in my lab and provide direct benefits to the sustainable management and conservation of the flora of New England.

References

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