

Fueling Next Year's Growth of Trees with Carbon and Nitrogen

Context: In temperate and boreal forests, temperature plays a crucial role in setting the boundaries for seasonal physiological activity. Thus, with rising temperatures from anthropogenic climate change, the climatically possible growing season has lengthened in many ecosystems worldwide by up to 11 days^{4,8}. Plants have tracked this through shifts in phenology—the study of recurring life history events—which are expected to continue with increasing temperatures¹². In particular, trees have shifted earlier in the spring and may use these extra days to fix more carbon and increase growth during the current growing season^{3,11}. Also, autumn events in trees (e.g., leaf senescence) have been delayed but the impacts on their fitness are not well understood.

Earlier spring and delayed fall events are likely to affect the next growing season, though this is rarely tested given most studies of this use adult tree growth where many factors effecting growth co-vary. Using saplings and an extended experiment would allow a mechanistic test of this critical hypothesis.

Research Question: How do extended growing seasons affect tree growth across different species both immediately (in the same year as the extended season) and in subsequent years?

Hypothesis: I hypothesize that an extension of the growing season could modify a tree's capacity to fill carbon and nitrogen storage pools^{1,6}. Trees that use this opportunity by fixing more carbon may experience increased growth in the subsequent growing season^{5,7}. Thus, species capable of accumulating nutrients after growth cessation while going through leaf senescence might exhibit growth increment in the following growing season⁹.

Objectives: First, I aim to assess the tree species' potential to prolong or stretch their activity schedule. Second, I will determine whether trees can absorb nutrients beyond their theoretical growing season. I will also examine if increased carbon storage pools translate into growth increment in the following growing season. Finally, I will investigate potential variations in these responses across deciduous and evergreen tree species, aiming to discern whether different patterns emerge within these distinct groups.

Methodology: To investigate the impact of manipulated spring and autumn temperatures on phenological responses, I will conduct experiments across seven different tree species under controlled conditions, including species that span both fast and short-life strategies (e.g., *Populus balsamifera*) and slow growth and longer lifespan species (e.g., *Quercus macrocarpa*) and including both deciduous and evergreen species². I plan a full factorial experiment of spring and fall warming with two levels each (control/warmed) resulting in four treatments: spring or autumn warming, or both, and a control. To test that responses are not limited by nutrient depletion later in the season, I plan two additional nutrient enrichment treatments (6 total treatments across the whole experiment). I plan on using 15 replicates per species per treatment¹⁰ resulting in 630 individual trees. During the growing season of 2024, phenological events were tracked weekly from the start of the spring treatments through the end of the fall treatments. During the growing season of 2025, the same measurements will be performed. In autumn 2025, after the trees have grown in ambient temperatures for the season, I will assess growth on the individual (total biomass) and the cellular level (number of cells and their characteristics), using dendrochronological methods.

Research outreach: Given the widespread impacts of climate change on ecosystems, understanding how forest communities respond to prolonged growing seasons is crucial. Observing the reactions of deciduous and conifer species to extended season and nutrient supplementation may reveal potential benefits for some species and harm for others. These shifts are likely to

influence forest stand dynamics across North America.

References

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