**SUMMARY OF RESEARCH PROPOSAL**

Temperate and boreal forests are closely linked to temperature, a critical factor in regulating the boundaries of trees’ seasonal activity. Human-induced climate change has led to a global rise in temperatures, resulting in the lengthening of the growing season in numerous ecosystems. Shifts in plant’s phenology —the study of recurring life history events— have already been observed and are expected to continue with warmer temperature. Since spring arrives earlier and autumn is delayed, trees could take advantage of these extra days to fix and store more carbon and nutrients. Extended spring and autumn events could affect the next growing season, though this is rarely tested. Given this understanding, what will be the response of different tree species in the following growing season to an extended growth period and autumn nutrient supplements? I hypothesize that the extended growing season influences trees' storage pools, and species capable of utilizing this opportunity may exhibit growth increments in the subsequent year. Consequently, species with the ability to absorb nutrients after leaf coloration might also demonstrate increased growth in the following year.

To assess trees' capacity to extend their activity schedule, determine nutrient absorption after leaf coloration, and investigate if increased carbon storage translates into growth increment during the subsequent growing season, I will conduct controlled experiments manipulating spring and autumn temperatures across nine tree species. Among these, seven will be deciduous trees, and two will be conifers. The four treatments include spring warming, autumn warming, both, and a control. Nutrient enrichment will be applied to trees under warmer and regular autumn temperatures. In 2024, I will monitor radial growth and track phenology. In fall 2025, after trees have grown in ambient temperature, I will assess growth on the individual level and the cellular level.

**RESEARCH PROPOSAL**

**Context:** In temperate and boreal forests, temperature plays a crucial role in setting the boundaries for the 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 10.8 days (Körner et Basler, 2010 ; Menzel et Fabian, 1999). Plants have tracked this through shifts in phenology—the study of recurring life history events—which are expected to continue with increasing temperatures (Wolkovich *et al.*, 2012). In particular, trees have shifted earlier in the spring, and may use this opportunity to fix more carbon and grow more during the current growing season (Keenan *et al.*, 2014 ; Wang *et al.*, 2020). Trees have also delayed autumn events (e.g., leaf senescence) but the impacts on tree fitness are not well understood. Both extended spring and fall events are likely to affect the next growing season, though this is rarely tested.

**Research Question:** In the context of a changing climate, what will be the following growing season's response of different tree species to prolonged growth periods and nutrient supplementation?

**Hypothesis :** I hypothesize that an extension of the growing season could modify a tree’s capacity to fill carbon and nitrogen storage pools (Chapin *et al.*, 1990 ; Lawrence et Melgar, 2018). Trees that use this opportunity by fixing more carbon may experience increased growth in the subsequent growing season (Landhäusser *et al.*, 2012 ; Martens *et al.*, 2007). Thus, species capable of accumulating nutrients, like nitrogen, after leaf senescence, might exhibit growth increment in the following growing season (Schott *et al.*, 2013).

**Objectives:** First, I aim to assess the trees’ innate 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 nine different tree species under controlled conditions. For deciduous trees, I will select seven species characterized by fast and short-life strategies (e.g., *Alnus rubra*) as well as slow growth and longer lifespan species (e.g., *Quercus macrocarpa*). Since phenological monitoring is more difficult and trends are less likely to be observed for evergreen trees, only two of the nine species will be conifers (Jönsson *et al.*, 2010). I plan four treatments: spring or autumn warming, or both, and a control. For the nutrient enrichment treatment, liquid nutrients will be administered to the treatment trees with regular and warmer autumn temperature. Given the variability in phenological responses, I plan on having a minimum of 10 replicates per species, adhering to the standards in tree phenological monitoring, which generally require 5-10 replicates (Siegel, 2009).

Throughout the summer of 2024, I will continuously monitor radial growth using magnetic micro-dendrometers and track phenology every 2-3 days. In fall 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).

**Research outreach:** Given the widespread implications of climate change on ecosystems, understanding how forest communities respond to prolonged growing seasons is crucial. Observing the reactions of various species to extended growth periods and nutrient supplementation can reveal potential benefits for some species and harm for others. These shifts are likely to influence forest stand dynamics across North America.

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