Gas exchange of sugar maple and bur oak populations under warming and drought

Colleen R. Ritter[1], Kerrie M. Sendall[2], Artur Stefanski[3], Raimundo Bermudez Villanueva[3]

[1]Rider University, Department of Geological, Environmental, and Marine Sciences, [2]Rider University, Department of Biology and Behavioral Neuroscience, [3]University of Minnesota, Department of Forest Resources

Introduction

Understanding tree species' responses to climate change is integral for the continued success of forest ecosystems. Boreal Forest Warming at an Ecotone in Danger (B4WarmED) is a long-term ecological experiment in Minnesota examining the effects of experimental warming, drought, and their combined effect on temperate and boreal species. Gas exchange is one aspect of plant physiology that is affected by changing climate conditions, and can be used as a proxy for estimating future growth of forests under different climate scenarios.

Species and Site Descriptions

This study looked at populations of bur oak seedlings from Minnesota, Oklahoma, and Illinois, and sugar maple seedlings from northern, southern, and central locations relative to Minneapolis, MN. All seedlings were planted together at the University of Minnesota's established B4WarmED experimental site in Cloquet, Minnesota. Seedlings were grown under the following conditions:

- ambient temperature/ambient rainfall
- ambient temperature/reduced rainfall
- +3.4°C warming/ambient rainfall
- +3.4°C warming/reduced rainfall

Data Collection

Gas exchange was measured in early August 2023, using a Li-COR 6400XT on randomly-selected individuals of species in each of 24 plots (n = 6 per treatment). Measurements were taken between approximately 9:00 AM and 3:00 PM; leaves measured were exposed to the following conditions: CO_2 concentration of 400 ppm, relative humidity between 40 and 80%, PAR of 1200 µmol m^{-2} s^{-1}, and temperature varied but generally stayed between 25 and 30°C.

Photosynthesis Data

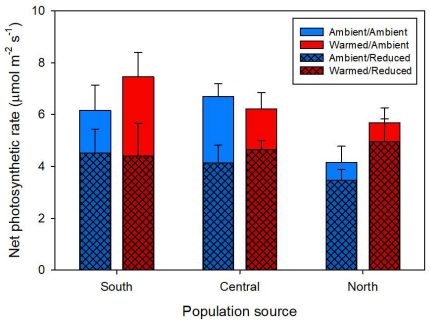

Figure 1. Photosynthetic rates of sugar maple populations sourced from southern, central, and northern locations relative to Minneapolis, MN. Seedlings were planted together at the B4WarmED experiment in MN. Measurements were taken on seedlings exposed to each combination of warming/rainfall treatments (n = 6 measurements per treatment, per population).

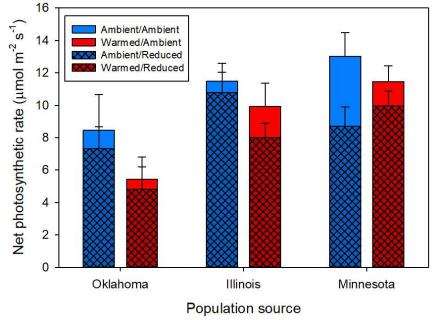

Figure 2. Photosynthetic rates of bur oak populations sourced from Oklahoma, Illinois, and Minnesota. Seedlings were planted together at the B4WarmED experiment in MN. Measurements were taken on seedlings exposed to each combination of warming/rainfall treatments (n = 6 measurements per treatment, per population).

Results

We found that photosynthetic rates of both sugar maples and bur oaks varied depending on source ($p < 0.05$). For maples, northern populations generally had reduced photosynthetic rates and southern populations had increased photosynthetic rates in the warmed plots relative to locally-adapted populations ($p < 0.05$; Figure 1). Bur oak populations had decreased photosynthetic rates the further south from MN they were sourced ($p < 0.05$; Figure 2). Photosynthetic rates of sugar maples were typically enhanced by warming (except for locally-adapted populations), while all populations of bur oak were negatively affected by warming ($p < 0.01$). All groups had reduced photosynthetic rates in drought conditions compared to ambient rainfall ($p < 0.05$).

Conclusions

These findings suggest that both warming temperatures and changes in precipitation patterns will impact photosynthetic rates under future climate change. We predicted that species moved from warmer, southern locations would respond most positively to warming, but this was not the case for bur oak seedlings, suggesting that assisted migration of common tree species from populations located further south in their ranges may be beneficial for the long-term success of some, but not all, species under future climate conditions.

References

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