# Experimental evaluation of the theoretical acclimation response of $C_3$ and $C_4$ grasses to temperature and carbon dioxide ($CO_2$)

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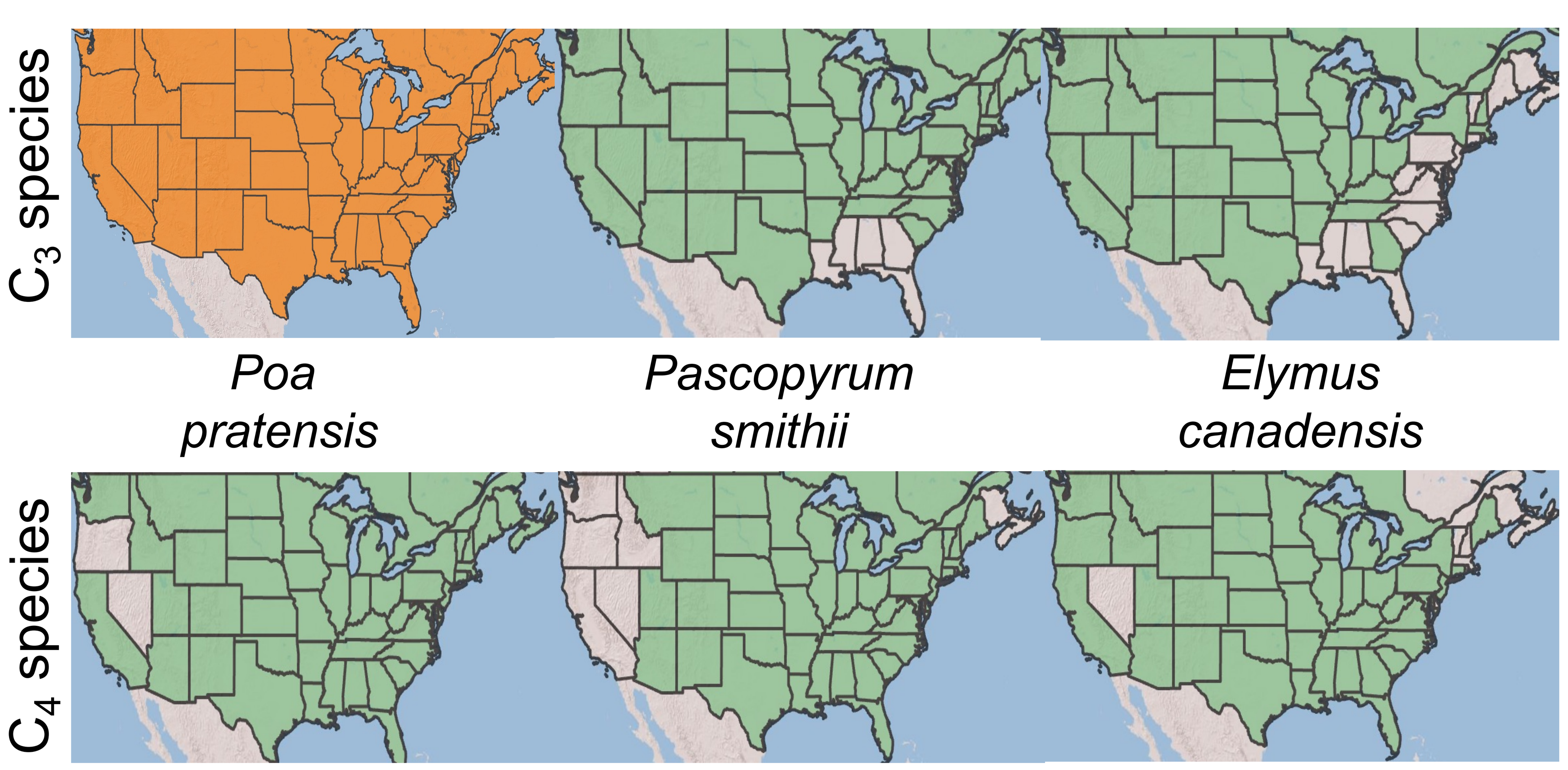
## INTRODUCTION

- Earth system models are sensitive to the representation of photosynthetic processes and photosynthetic acclimation in particular.
- Photosynthetic acclimation is a change in the instantaneous response of stomatal functioning and photosynthetic biochemistry to an environmental driver that improves carbon uptake and resource use efficiency.
- **Acclimation responses are expected to differ between $C_3$ and $C_4$ plants, but these responses are not well tested.**
- We used a temperature-by-$CO_2$ manipulation experiment to test whether acclimation responses to temperature and $CO_2$ differ between coexisting $C_3$ and $C_4$ species.
- Experiment results will be used to test predictions from a recently developed $C_4$ optimality model (Scott and Smith 2022).

## EXPERIMENTAL DESIGN

We compared photosynthetic acclimation responses between six coexisting $C_3$ and $C_4$ species.

Plants were grown under two temperature (day/night: 20/10°C and 35/25°C) and two $CO_2$ treatments (420 ppm and 1000 ppm) in a full-factorial design.

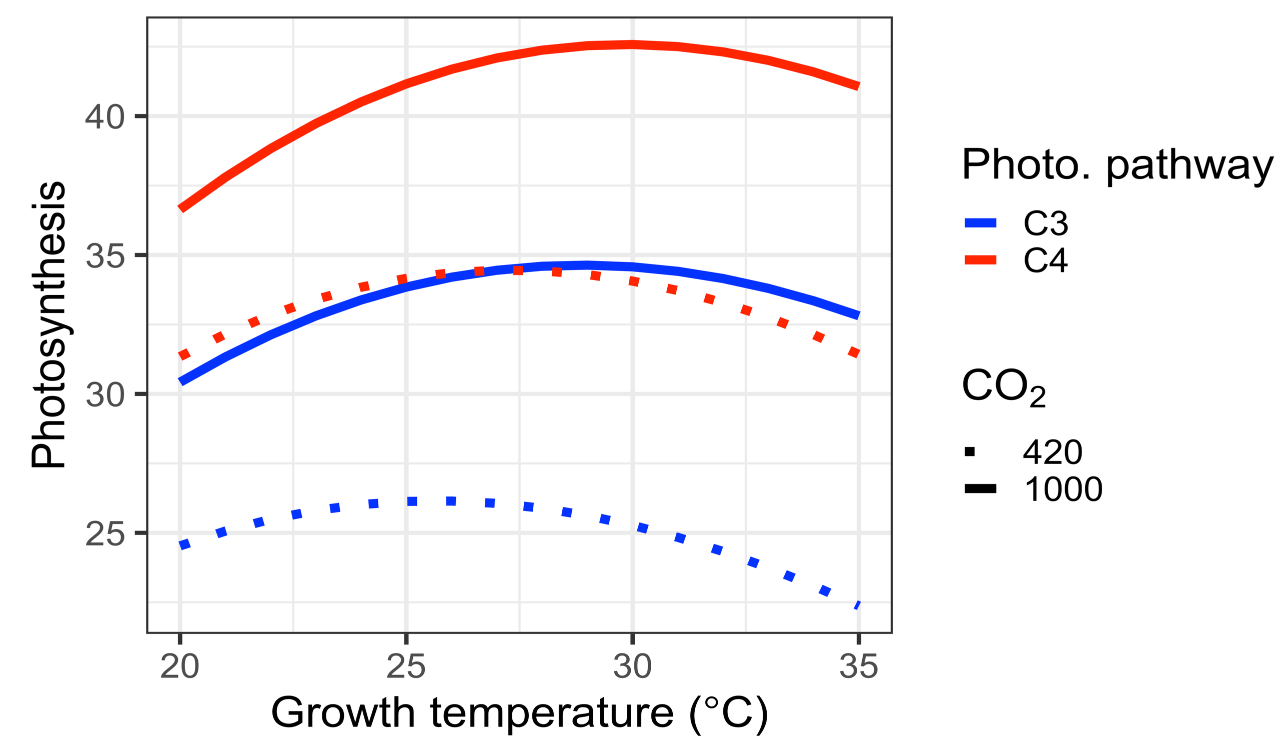


$C_3$ species: *Poa pratensis*, *Pascopyrum smithii*, *Elymus canadensis*

$C_4$ species: *Sorghastrum nutans*, *Schizachyrium scoparium*, *Bouteloua curtipendula*

## THEORETICAL EXPECTATIONS

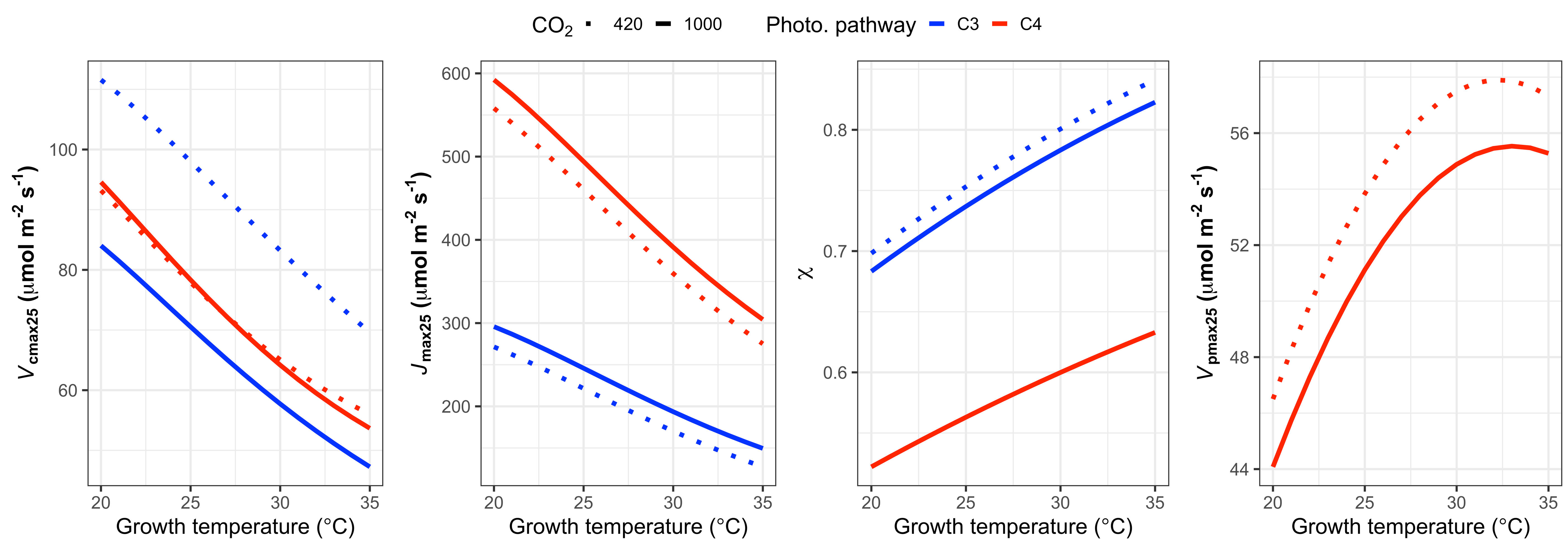
All data from theoretical model described in Scott and Smith (2022).




$C_4$ species will have greater acclimated photosynthetic rate than $C_3$ species, but this effect diminishes under increased $CO_2$ and lower temperatures (see table).

| | 420 ppm | 1000 ppm |
|---|---|---|
| 20°C | 22% | 17% |
| 35°C | 29% | 20% |

Percent advantage in photosynthetic carbon assimilation rates for $C_4$, relative to $C_3$ plants. $C_4$ is always expected to have an advantage over $C_3$ plants, but the advantage decreases under increasing $CO_2$ (shade of green is proportional to the relative advantage of C4 over C3 photosynthesis).




In both plant types, $V_{cmax25}$ decreases with temperature, but decreases with $eCO_2$ in only $C_3$ species

$J_{max25}$ decreases with temperature and increases with $eCO_2$ in both plant types, but the temperature response is greater in $C_4$ species

The ratio of intercellular to atmospheric $CO_2$ ($\chi$) increases with temperature similarly between plant types but decreases with $eCO_2$ only in $C_3$ species

$V_{pmax25}$ decreases with $eCO_2$ and increases with temperature

## FUTURE WORK

The outcome of this project will be used to enhance the representation of acclimation in ESMs. Subsequently, the refined acclimation processes will be integrated into an ESM framework, specifically the Community Earth System Model. We will model the influence of acclimation on plant community dynamics, with a particular focus on grassland ecosystems where $C_3$ and $C_4$ species coexist. This integration will likely improve carbon storage and climate change predictions in ESMs. `

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