Combined Effect of Light and Heat on Leaf Function

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USDA REEU Program

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About Me

Internship Overview

Project was conceived and data was collected during the 2024 USDA REEU grant with the help of graduate students Eduardo Barragan and Karli Miller.

All plant material was collected at the California Botanic Garden (Claremont, CA).

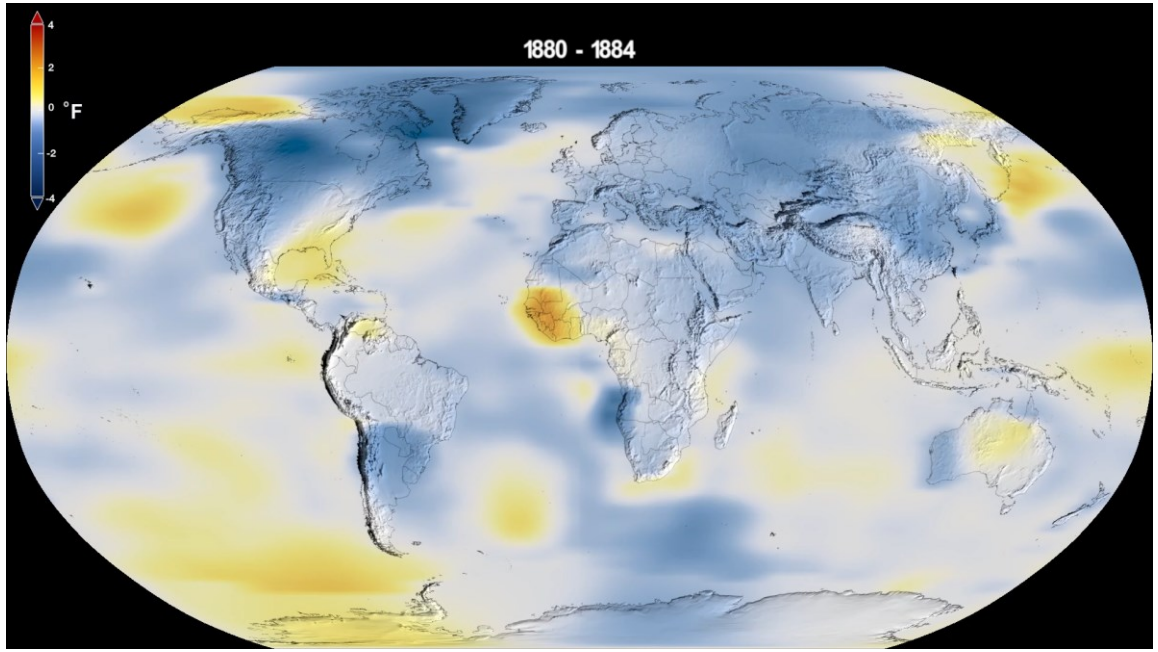
Focus: Investigating plant responses to combined environmental stressors of light and heat

Objective

- Determine the combined impact of light and temperature stress on leaves of five native California species.
- Refine methods for leaf thermal studies.

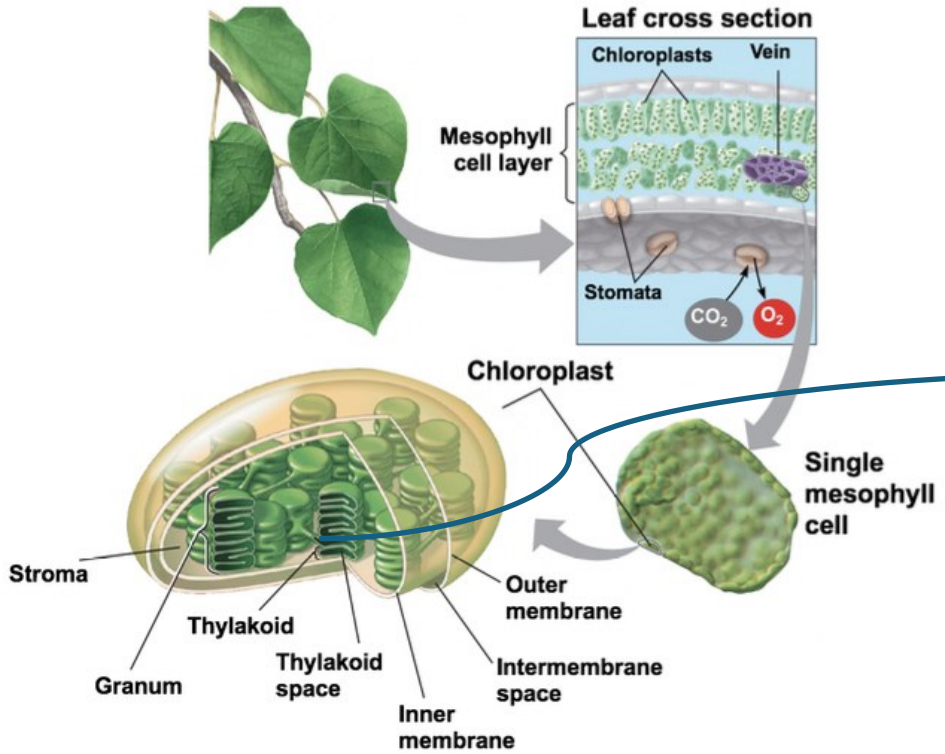
Climate Extremes

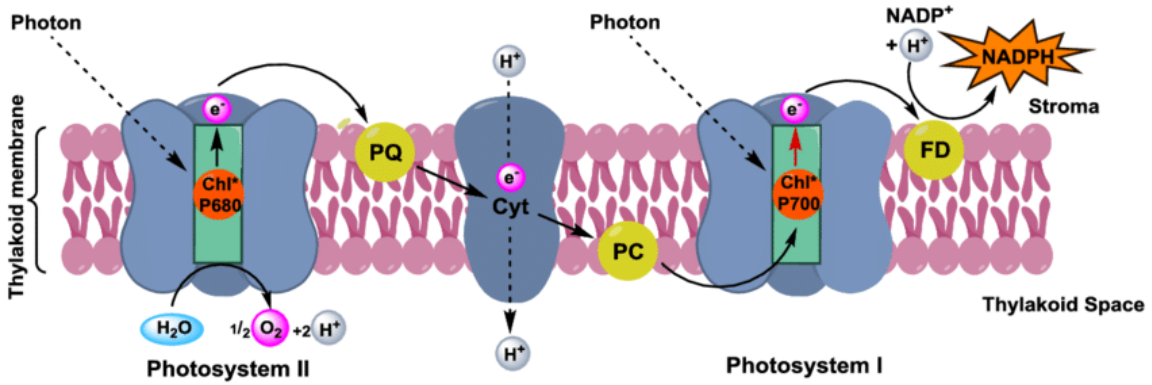
- Average global temperatures have increased by ~1.17°C (2.11°F) since the late 19th century (NASA/GISS, 2023).
- Residents think winters are colder due to increased severe weather from climate change and El Niño (Aggie, 2024).
- California's mean temperatures have risen by 1.8°F with nighttime temperatures (2.3°F) increasing the fastest (OEHHA, 2018).



Background

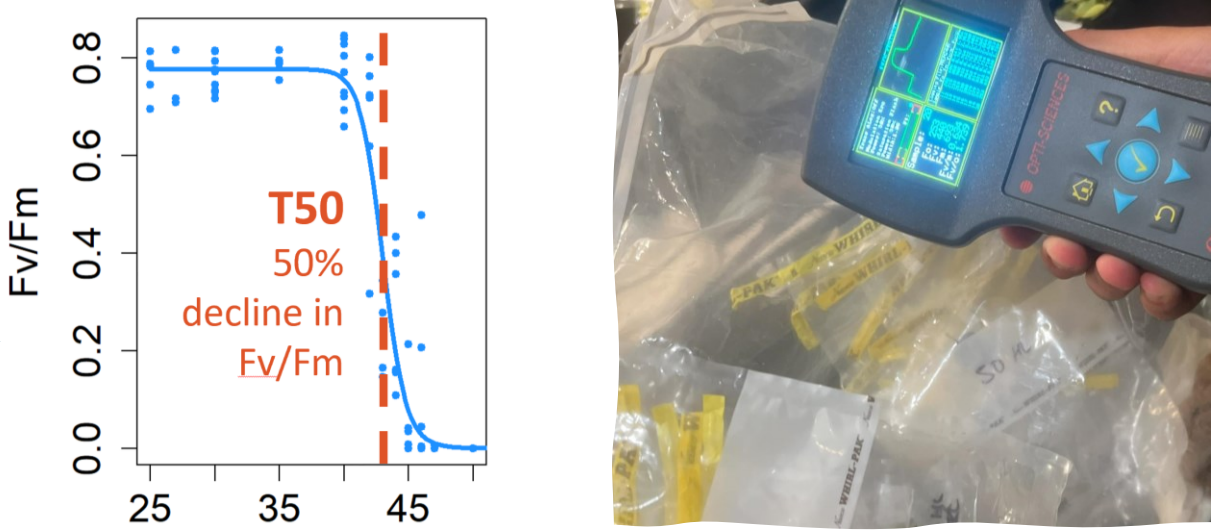
- Both light and heat stress disrupt the thylakoid membranes in protein complexes called photosystems.
- Both photosystems are thermally vulnerable. Especially photosystem II (PSII), the first unit involved in light capture.
- Photosystem II (PSII) is the protein complex typically used to determine thermal tolerance.

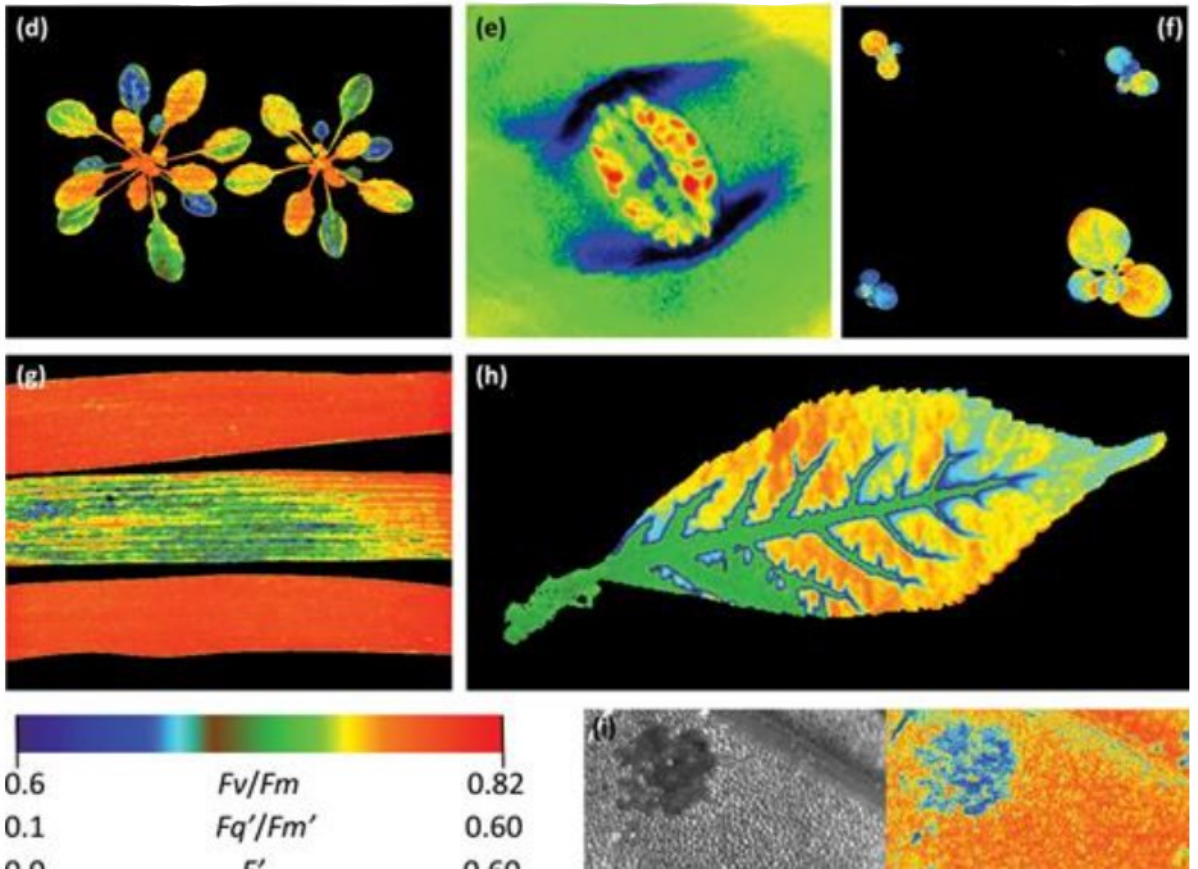




Background

- Fv/Fm ratio measures PSII efficiency using chlorophyll fluorescence; healthy plants score ~ 0.82
- Heat sensitivity stress heightens energy loss as heat or fluorescence, affecting PSII efficiency.
- Krause et al. (2010) Water Bath Protocol. T50 – 50% loss of efficiency





Focal California Native Species

Salvia apiana

White Sage

Cercocarpus betuloides

Mountain Mahogany

Ceanothus leucodermis

Chaparral Whitethorn

Prunus fremontii

Desert Apricot

Comarostaphylis diversifolia

Summer Holly

Methods

- Goal 1: Assess the combined effects of light and temperature stress on plant vitality.
- I constructed thermo-sensitivity curves for each species under two light conditions:
    - Low Light: <10 µmol m^(-2) s^(-1)
    - High Light: >1500 µmol m^(-2) s^(-1)

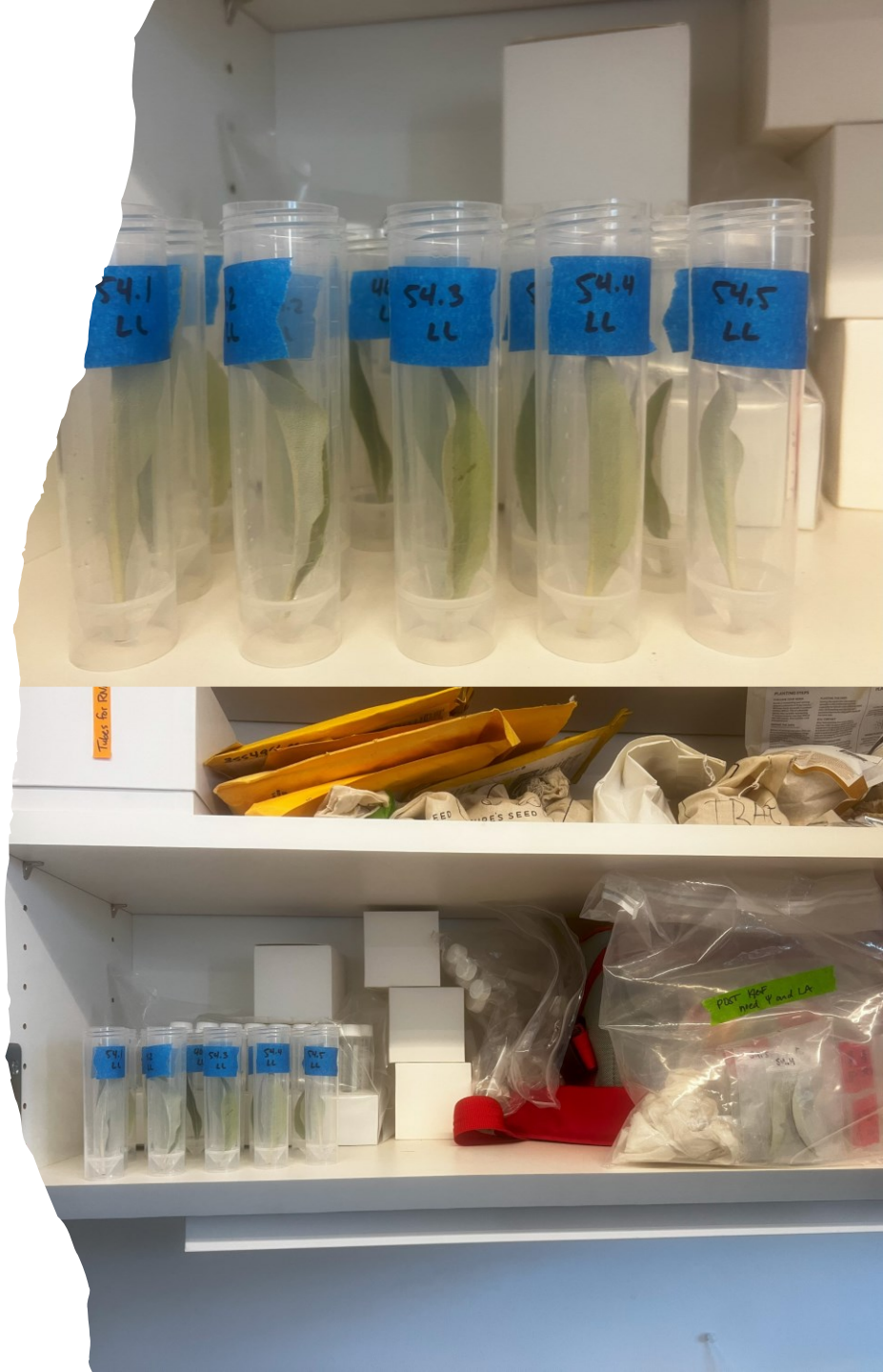
Leaves were exposed to 8-10 temperature treatments (ranging from 30-58°C) and Fv/Fm was quantified after 24h recovery from the heat exposure.

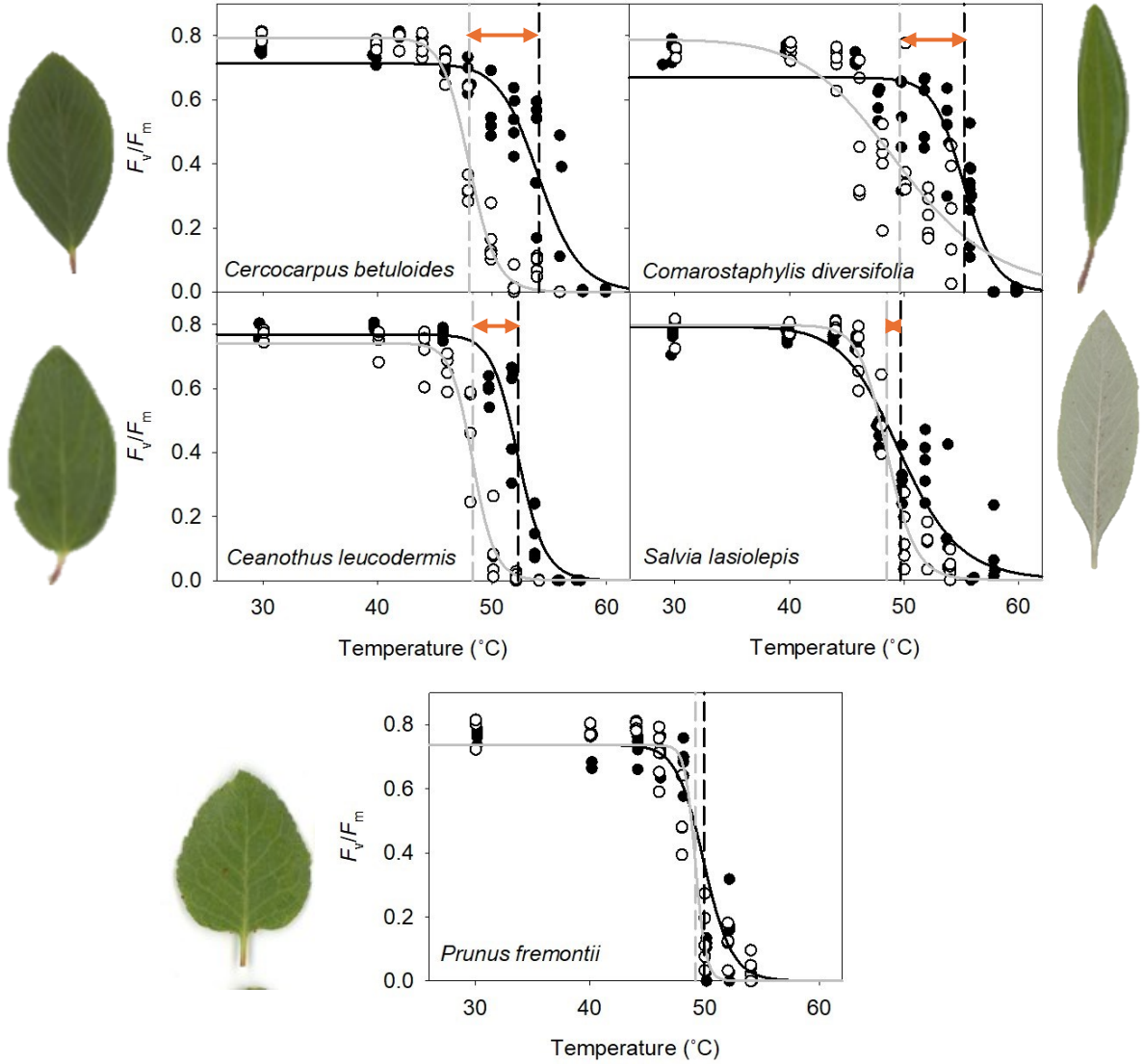
A logistic function was fit through the points and the T50 value and its confidence intervals for each species under each light treatment was calculated.

Methods

Goal 2: Improve protocols for thermal recovery in leaves.

- Standard Recovery Protocol: Typically, leaves recover in a bag in the dark at room temperature for 24h. Low oxygen levels in the bag could impede recovery by reducing energy processes.
- Species Tested: *Cercocarpus* and *Salvia*.
- Post heat treatment, three different recovery methods were tested under laboratory temperatures:
    - Leaves are placed in a humidified sealed bag (“bag”).
    - Leaves are placed in an open bag with moist paper towels (“Open”).
    - Leaf petioles are placed in water, with moist paper towels around (“Water”).



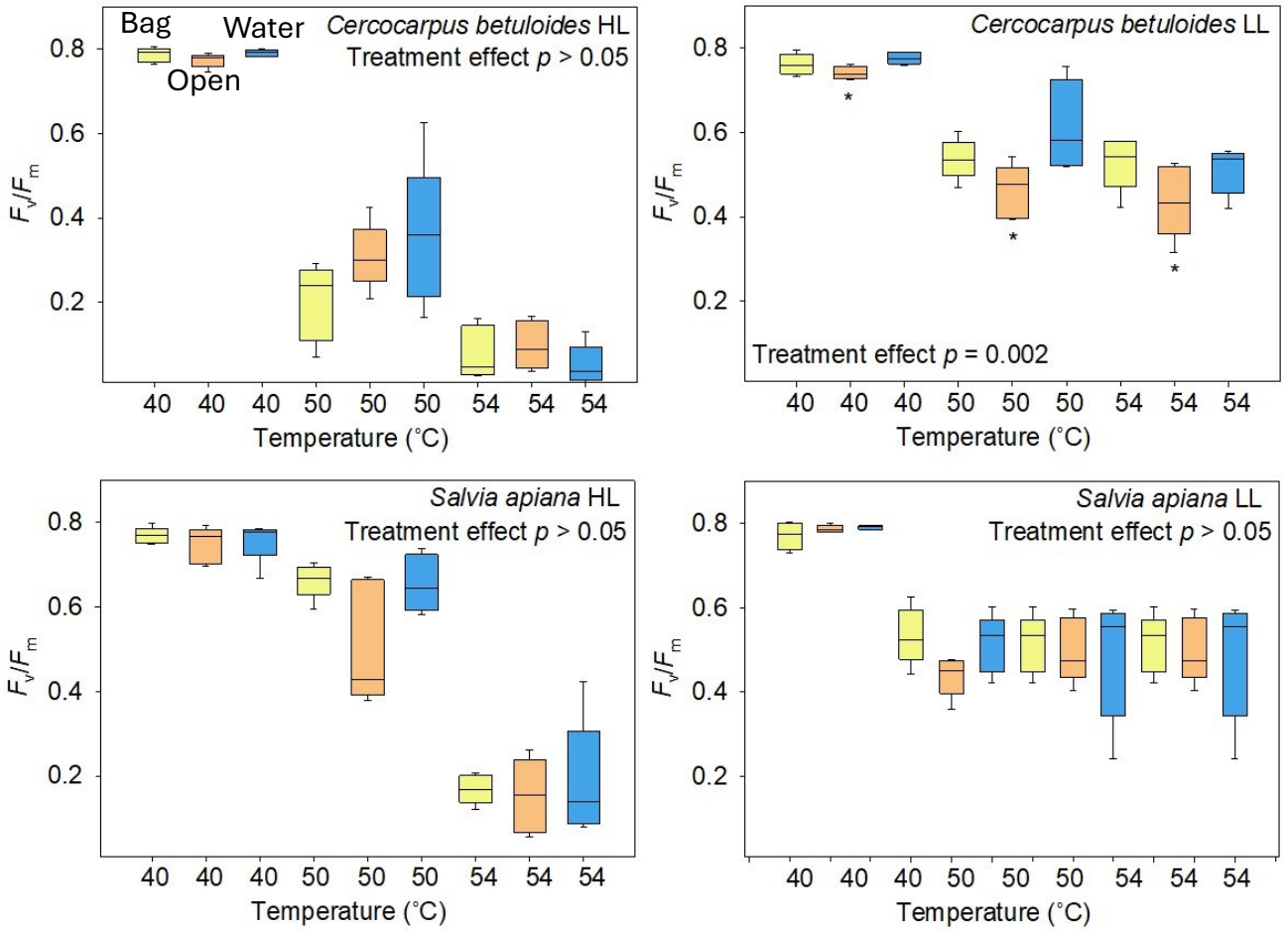


Results: light effect

- In 4 out of 5 species studied, the 95% confidence internals between the two light treatments did not overlap, indicating a significant light effect
- As such, T_{50} values were 1 to 6°C lower under high light conditions compared to low light, indicating a significant impact of light on heat tolerance.
- Only *Prunus fremontii* showed no significant difference (95% confidence intervals in T50 overlapped) in thermal tolerance between light conditions.

Results: Refining methods

- The recovery treatments had little impact on Fv/Fm values across temperatures and light treatments (two way ANOVA).
- In *Cercocarpus* under low light, a significant treatment effect was found, driven by lower Fv/Fm values of leaves that recovered in open bags.



Discussion of Findings

Sensitivity to Conditions:

- Certain species are more heat sensitive when exposed to high light, suggesting past studies in the dark may overestimate thermal tolerance. The combination of high light and heat may increase the production of reactive oxygen species, hindering protein repair (Yamamoto 2016, Frontiers in Plant Sciences).
- Future studies should assess thermal tolerance under natural light conditions.

Variable Light Effects:

- Not all species showed a significant light effect. Further research is needed to explore species-specific biochemical and anatomical factors affecting light and heat response.

Refining methods:

- Data indicate that recovery in sealed bags for 24 hours does not hinder PSII recovery, suggesting oxygen levels may not significantly impact the repair of damaged PSII units. However, for one species we found that placing leaves in open bags led to lower recovery values, suggesting dehydration occurred. Thus, we recommend either sealed moist bags, or placing leaf petioles in water.

Implications for Climate Change:

- Considering rising nighttime temperatures due to climate change, further investigation is needed into recovery dynamics under warmer conditions compared to laboratory settings.

Professional and Personal Development

- Provided firsthand experience in both lab and fieldwork.
- Strengthened my public speaking and research skills through presentations.
- Motivated me to contribute to climate change efforts, with aspirations to work for organizations like the USDA to support environmental sustainability.

Thank you!

- **Appreciation**: Thank you all for your attention and engagement during this presentation.
- **Open for Questions**: I am open to any questions you may have. Let's discuss further!