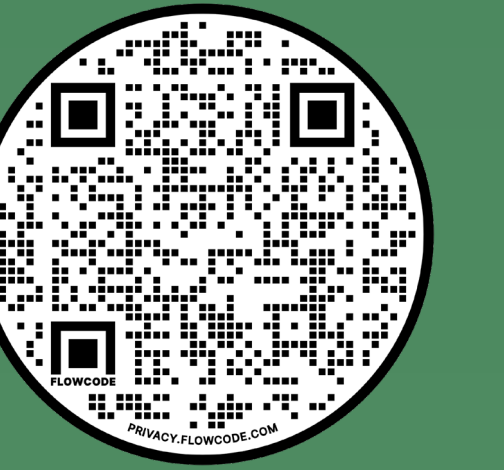


# Light and Moisture Content as Determinants of Photosynthetic Activity in Southern Appalachian Mosses from Open and Shaded Habitats



## BACKGROUND

- Mosses are pioneers in ecological succession, prevent erosion, retain soil moisture, store and filter nutrients, and serve as refugia for fauna.
- Mosses are poikilohydric and ombrotrophic; they quickly desiccate and remain metabolically active only when sufficiently hydrated.
- They tolerate a wide range of light levels, from shady understory habitats to open-field habitats.
- Mosses reach peak photosynthesis ( $A$ ) at intermediate water contents, before  $A$  declines as tissues further desiccate.
- There are *no studies* on moss ecophysiology in the Southern Appalachian Mountains (SAM); understanding responses to changes in moisture content and light will be crucial for predicting climate change impacts.

## OBJECTIVES

To compare open-habitat to forest understory moss species to understand how they differ physiologically in response to varying light and moisture levels.

## HYPOTHESES

- Open-habitat acrocarpous species, growing in clump formations, will maintain physiologically suitable water contents longer than understory pleurocarpous (feather) mosses, extending their time for positive photosynthesis.
- Mosses in understory low light habitats will have higher chlorophyll contents and lower a:b ratios than open-habitat mosses, but differences may be less in winter when understory habitats experience higher light levels.
- Open-habitat mosses will undergo less stress from prolonged exposure to high light than those from shady forest understories.

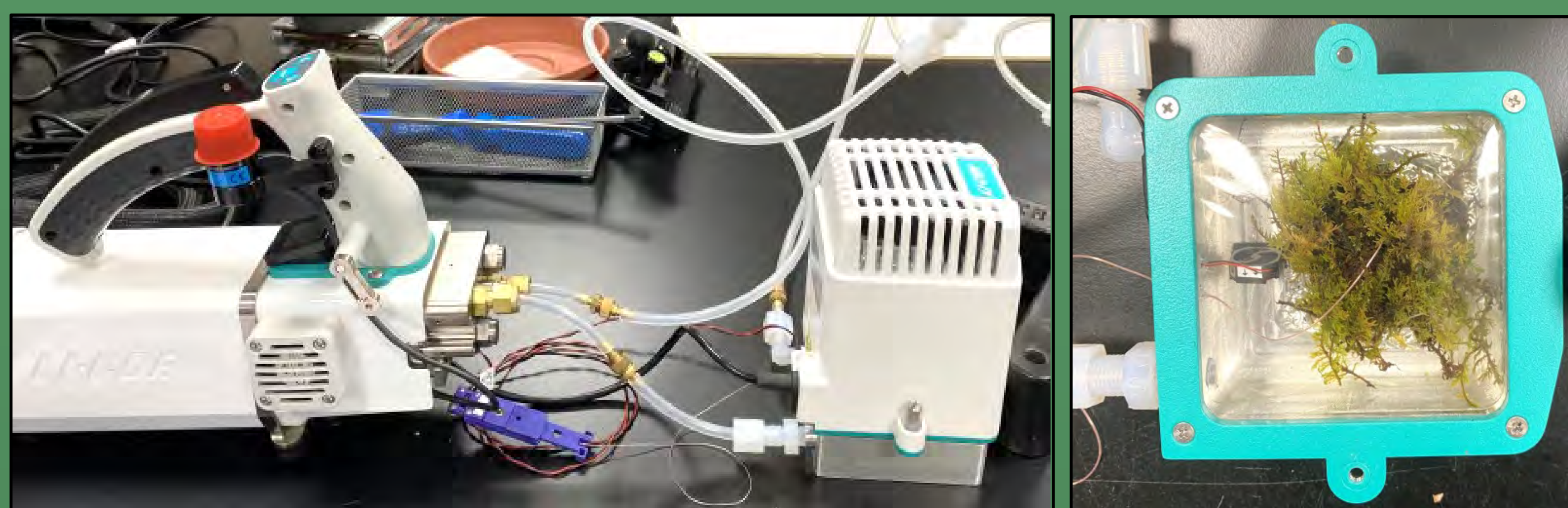
## METHODS

### Moss Species

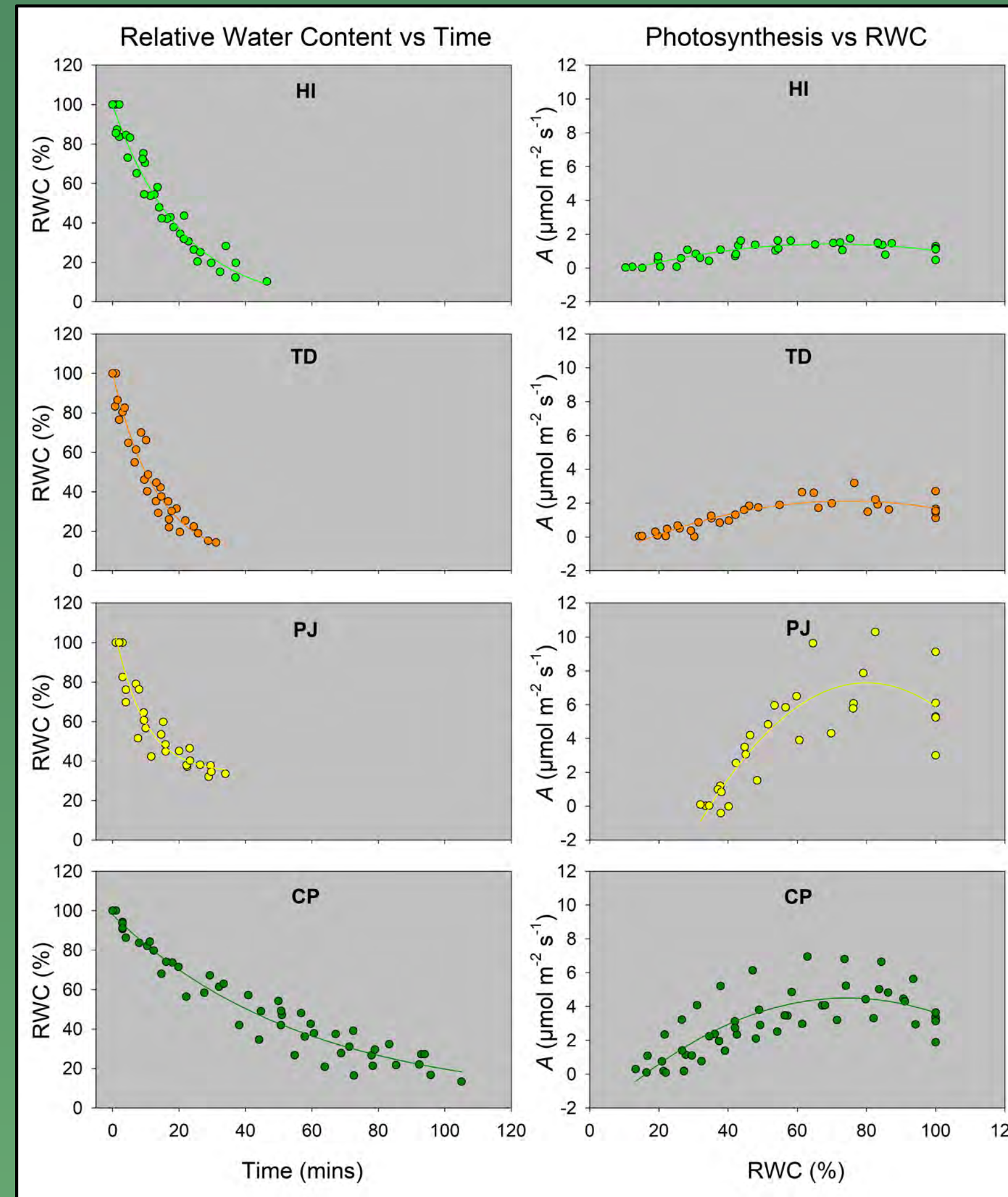
- Open-Habitat:** *Ceratodon purpureus*, CP; *Polytrichum juniperinum*, PJ
- Forest Habitat:** *Thuidium delicatulum*, TD; *Hypnum imponens*, HI

### Physiological Measurements

- Determined **chlorophyll contents** in winter and summer using DMF extraction.
- Measured **light responses of photosynthesis** ( $A$ ) using Li-6800 and LED light source with custom-built cuvette, allowing better control of RH (**Fig. 1**).
- RWC** calculated as:  $(\text{Fresh Wt} - \text{Dry Wt}) * 100 / (\text{Turgid Wt} - \text{Dry Wt})$ .
- Measured **diurnal changes in RWC** in the field for a 3-day period following a rain event. Mosses were saturated at the start of the measurements.
- Built **drying curves** to determine relationship between  $A$  and RWC.
- Calculated **Water Use Efficiency** when  $A \geq 90\%$  of  $A_{\text{max}}$  as: Ratio of water lost to total carbon assimilation over this time interval.
- Measured dark-adapted **chlorophyll fluorescence** after 1 hr exposures at varying levels of PAR (15, 500, 1000, 2000  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ).



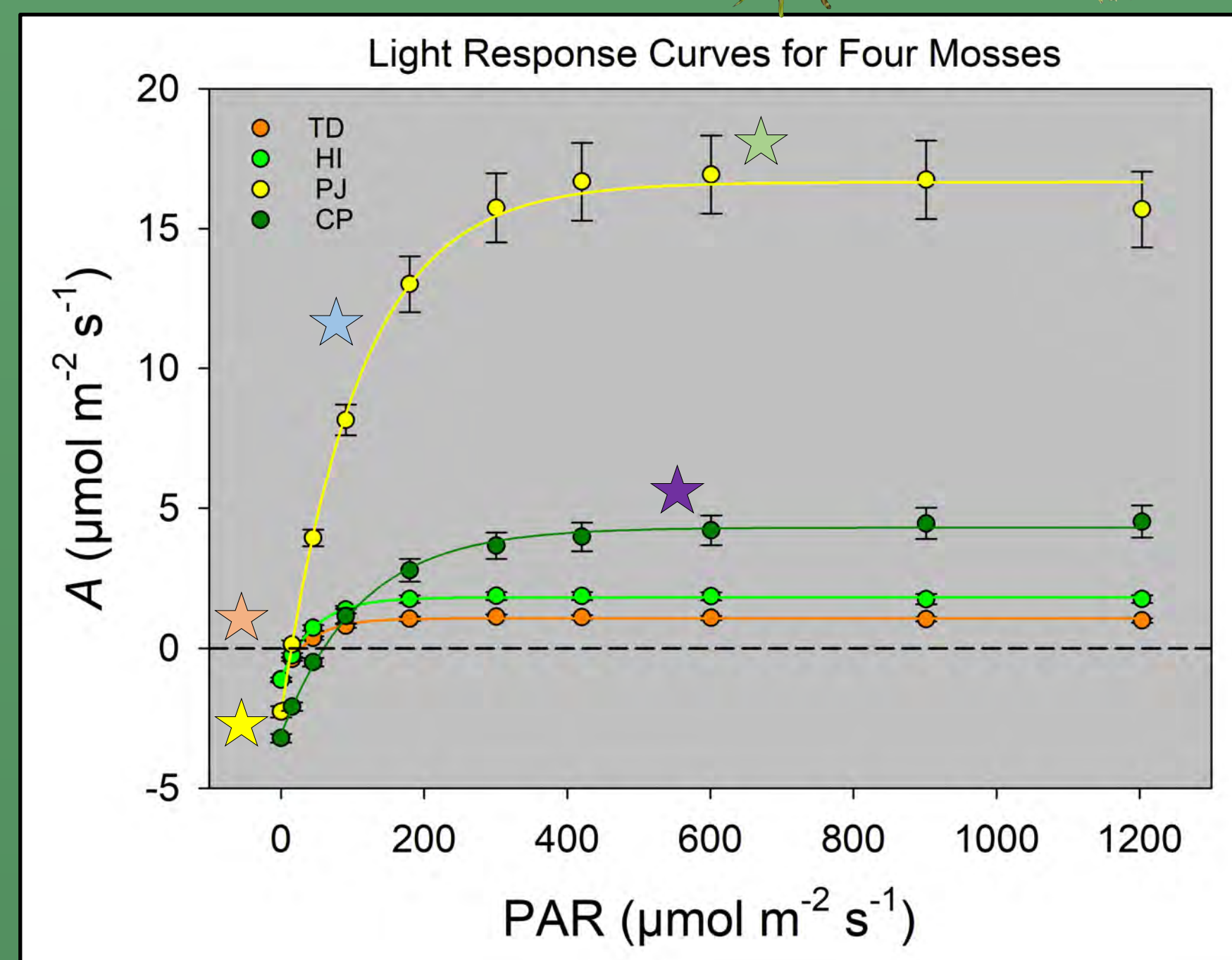
**Figure 1. Left:** Li-6800 system with LED light source and Nafion drying tubes. **Right:** Custom-built moss cuvette with thermocouple for temperature measurement and a small cage fan to stir the air.



**Figure 2. Left Column:** RWC vs Time ( $n = 5$ ); **Right Column:** Photosynthesis ( $A$ ) vs RWC ( $n = 5$ ).

### Take Home Messages:

- Mosses dry in exponential decay fashion with time.
- CP, a cushion moss, dries the slowest of all four mosses.
- $A$  for all mosses peaks between 65-80% RWC.
- $A$  becomes negligible below 20% RWC for all mosses except PJ, which has a higher threshold of 40% RWC.
- $A$  higher in PJ and CP (open habitat mosses) and lower in HI and TD (forest habitat mosses).



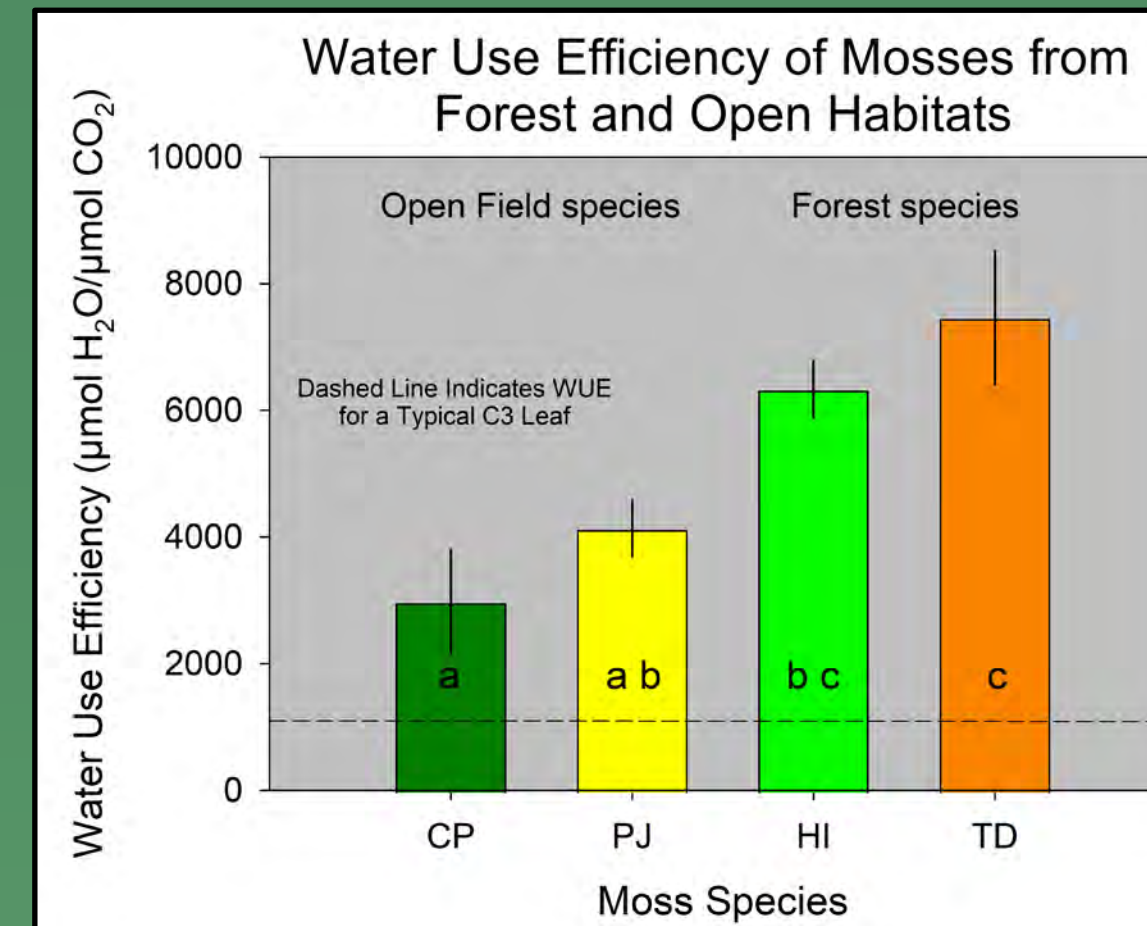
**Figure 3: Top:** Light Response Curves. Parameters derived from light response curves marked by stars and linked to graphs on the right. Differences significant at  $p \leq 0.05$  ( $n = 10$ ).

Rd = dark respiration; LCP = light compensation point; AQE = apparent quantum efficiency; LSP = PAR where  $A$  saturates;  $A_{\text{max}}$  = highest  $A$  observed.

### Take Home Messages:

- Open-grown mosses (CP and PJ) have higher Rd rates than forest mosses.  $A_{\text{max}}$  and AQE trend higher in open-grown mosses.
- CP has highest LCP and LSP than other mosses.
- PJ has significantly higher AQE and  $A_{\text{max}}$  than other mosses.

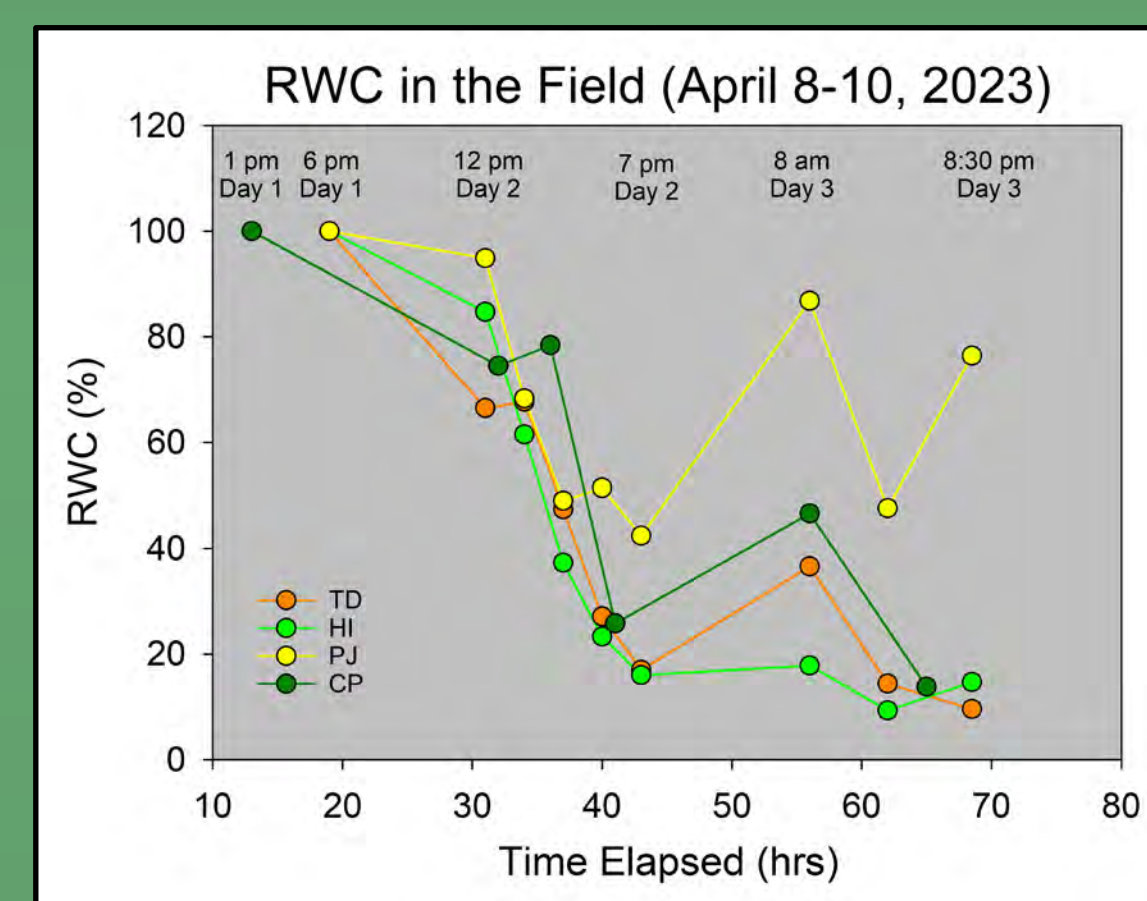
## RESULTS



**Figure 4. WUE of Mosses ( $n = 10$ ).**

### Take Home Messages:

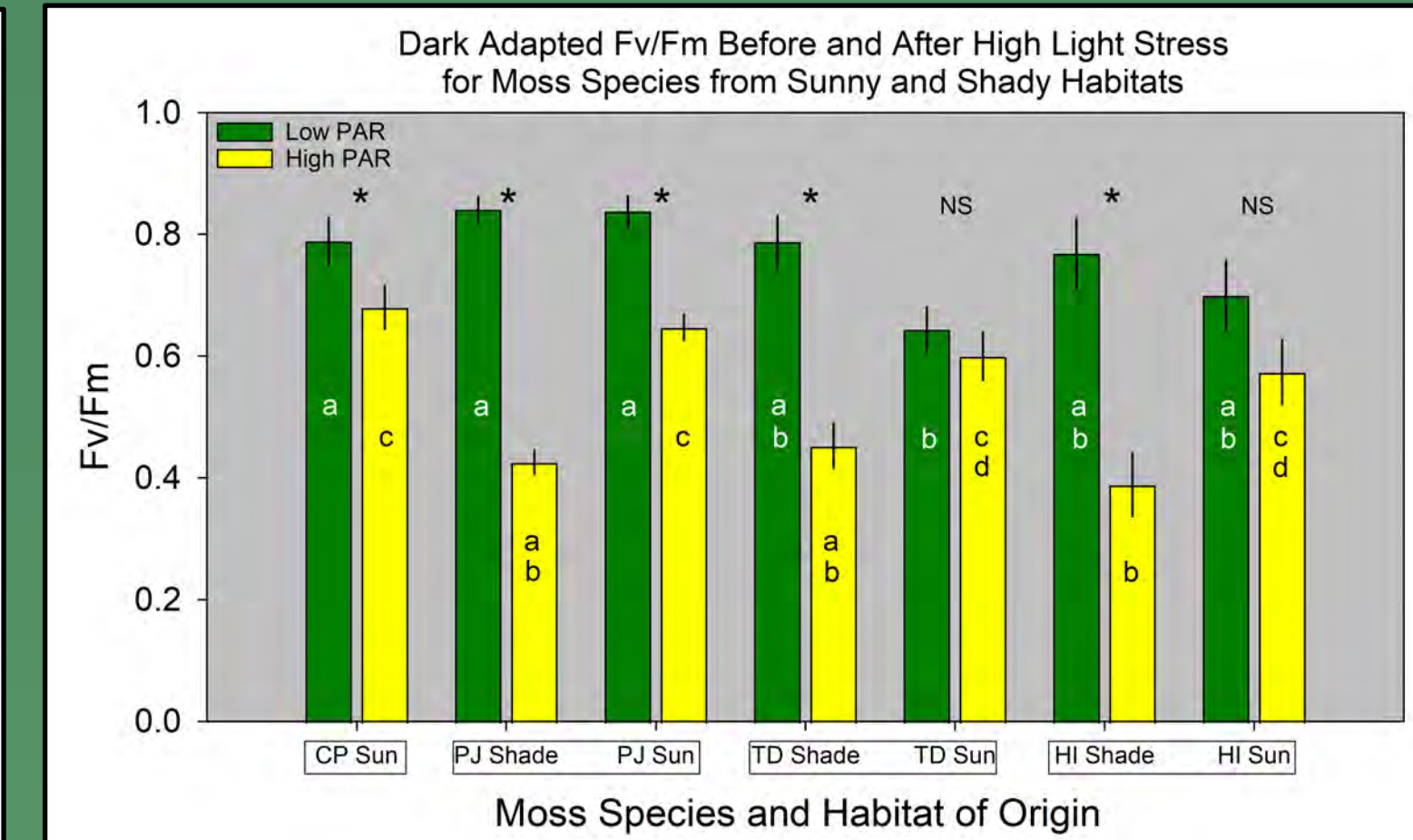
- CP and PJ have higher water use efficiency and HI and TD lowest.
- WUE higher for acrocarpous mosses compared to pleurocarpous mosses.
- Mosses lose ~2X to 7X as much water per  $\text{CO}_2$  absorbed compared to a typical leaf from a C3 plant.



**Figure 5. Field RWC vs Time ( $n = 10$ ).**

### Take Home Messages:

- Mosses dried at moderate rates over two days and had RWC that would support positive  $A$  over this interval.
- Increases in RWC on Day 3 due to hydration from fog and/or dew.



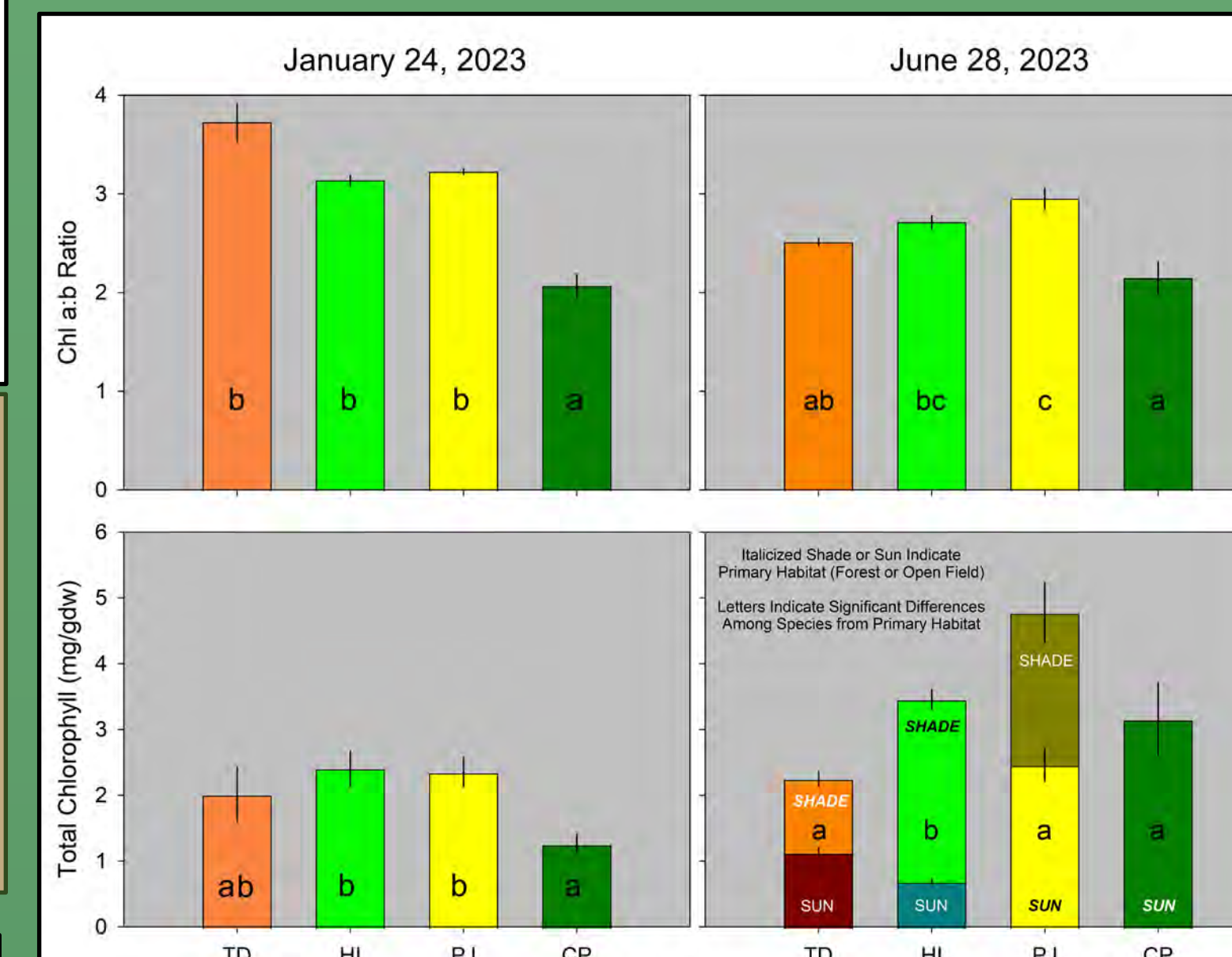
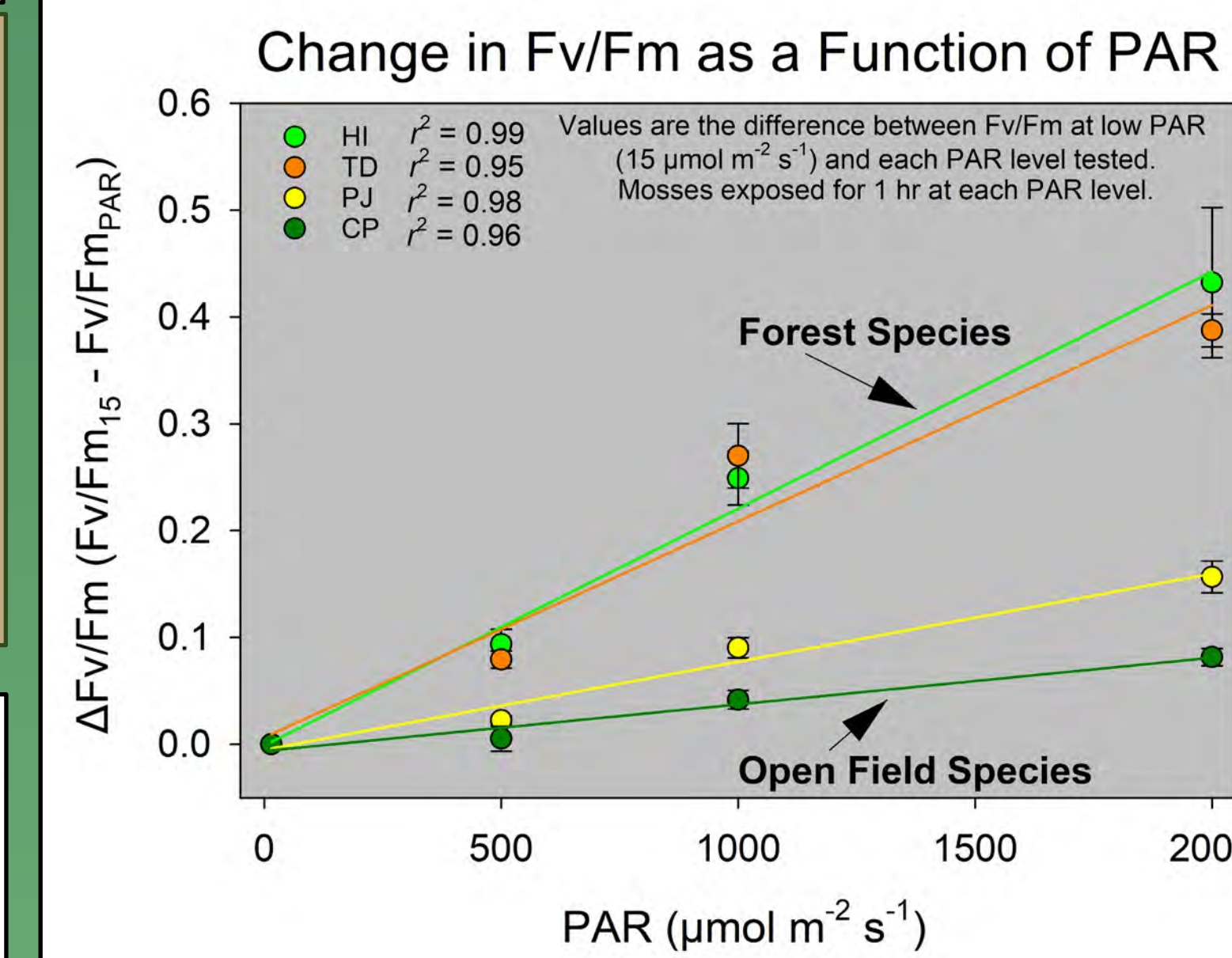
**Figure 6. Top Left Graph:** Dark-adapted fluorescence ( $Fv/Fm$ ) from sunny and shady habitats.

**Bottom Left Graph:** Linear regressions of differences between  $Fv/Fm$  from low and higher PAR after 1 hr exposure.

Letters indicate differences within light treatment ( $n = 5$ ); Low and High PAR: 15 and 2000  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ; Asterisks indicate differences in  $Fv/Fm$  between low and high PAR within a moss category.

### Take Home Messages:

- $Fv/Fm$  at low PAR (green bars) similar for all mosses grown in shade but lower for TD when grown in sun.
- High light stress (yellow bars) reduces  $Fv/Fm$  under all conditions except for HI and TD grown in sunny habitats.
- Stress is greater (low  $Fv/Fm$ ) when mosses are grown in shady habitats.
- Stress increases linearly (lower graph) with increasing exposure to stress PAR.
- The slope of increasing stress with higher PAR is greater for mosses from forest habitats compared to those that are from open-field habitats.



**Figure 7. Total chlorophyll contents and chl a:b ratios of mosses from January and June 2023 ( $n = 10$ ).**

### Take Home Messages:

- Total Chl similar in Jan and Jun.
- When grown in high-light habitats, total chlorophyll amounts are lower (lower right panel, bars marked as sun).
- Chl a:b ratios lowest in CP and do not change substantially from Jan to Jun.

## CONCLUSIONS

- Photosynthetic rates peak at intermediate water contents before declining as the moss dries. Positive  $A$  maintained to 20% RWC except in PJ, where it is 40%.
- RWC may be a proxy for determining when SAM mosses are photosynthetically active, although prolonged exposure to high PAR may further reduce  $A$ .
- Habitat origin has a substantial impact on sensitivity to light stress: mosses grown in high light are less sensitive to light stress than those from low light habitats, irrespective of their primary habitat of origin (i.e., forest vs open-field).
- Open-habitat moss species may be more tolerant of warming and precipitation alterations due to climate change, because they are subject greater light and moisture stress than understory habitat moss species.
- With additional modeling, it should be possible to predict daily and annual carbon uptake by SAM mosses and predict impacts of future climate change on their productivity.

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