Chlorophyll Fluorescence Imaging: Monitoring Growth, Morphology, and Physiology of Hydroponic Lettuce in Response to Photosynthetic Photon Flux Density

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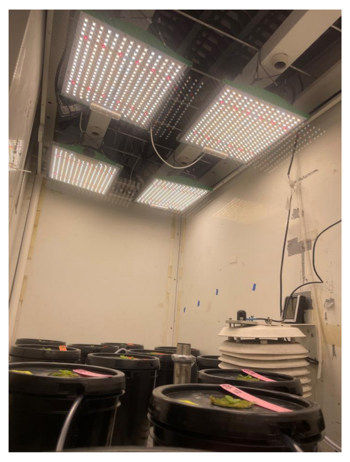
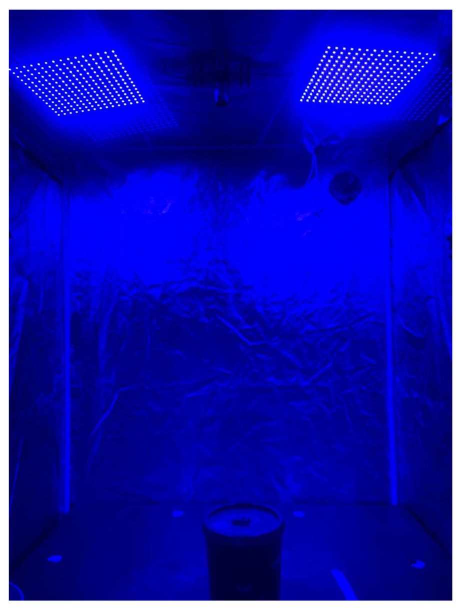
Introduction

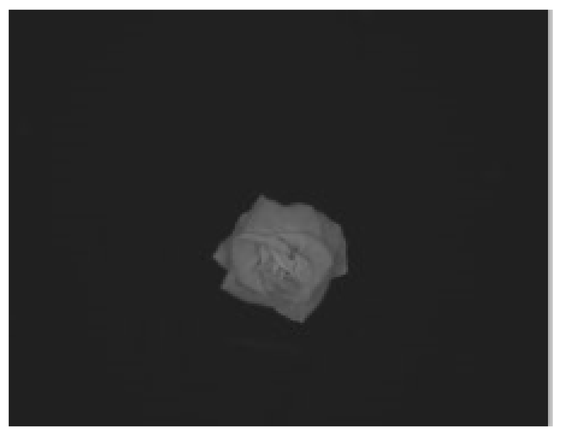
- The electricity cost to provide lighting in controlled environment agriculture is high
- Efficient use of light is critical for profitable crop production
- Crop growth depends on the **amount of light captured by the canopy** and **light use efficiency** (LUE)
- The effect of different photosynthetic photon flux densities (PPFD) on lettuce growth, morphology, light capture, and light use efficiency is not well understood



CFI Analysis

- Chlorophyll fluorescence accounts for a small fraction of the absorbed light (1–2%) and occurs at wavelengths of 650 to 730 nm, with a peak near 690 nm
- CFI visualizes only plants, not the background, by capturing fluorescence emission from chlorophyll





Hypotheses

- Increasing PPFD increases growth by increasing total incident light, despite a decrease in LUE
- Plant morphology under low PPFD changes to increase light capture

Materials and Methods

Plant Material

- Lettuce 'Rex' (*Lactuca sativa*) grown in a growth chamber under 16-h photoperiod

Treatments

- Grew lettuce under different PPFDs (from 201 to 413 $\mu mol \cdot m^{-2} \cdot s^{-1}$, DLI of 11.6 to 23.8 $mol \cdot m^{-2} \cdot d^{-1}$)
- Sole-source white LED light

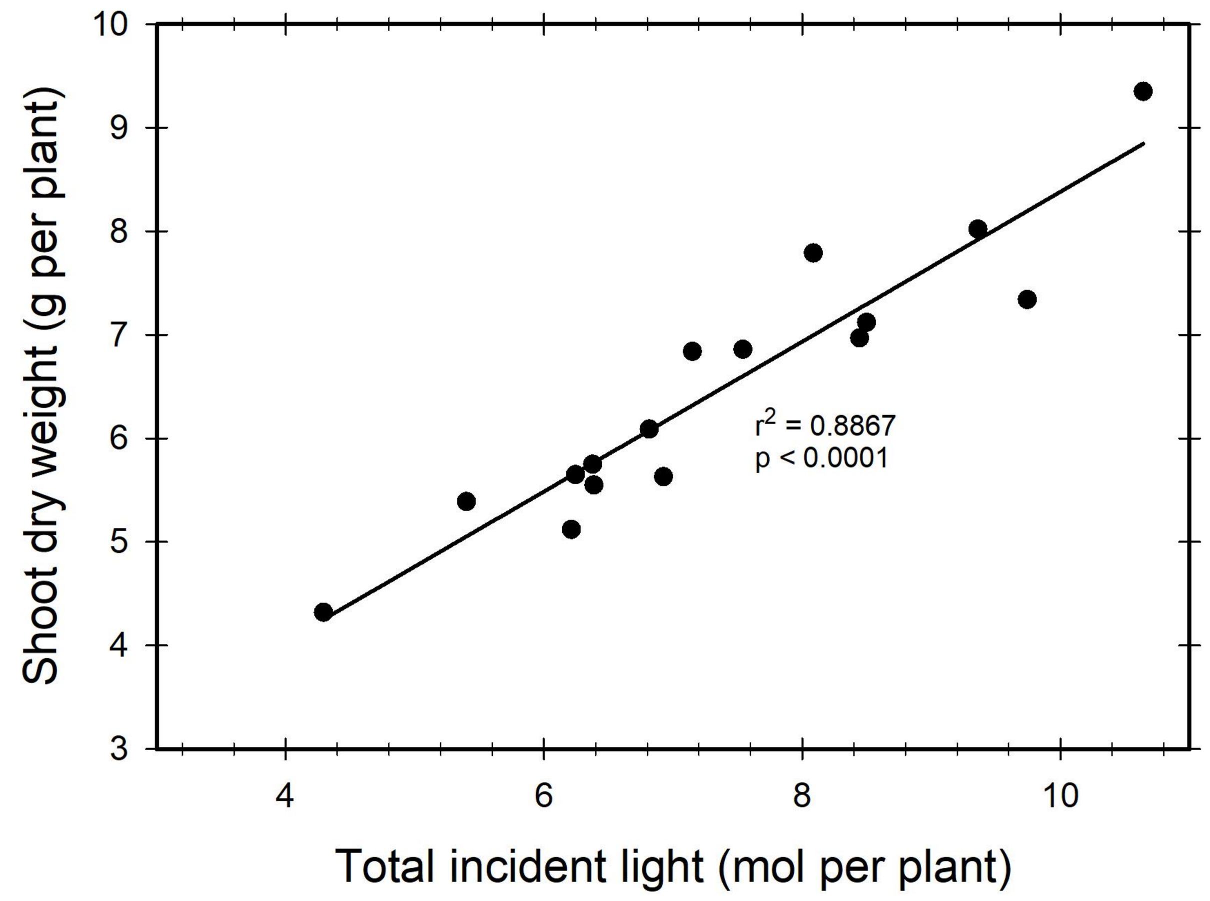
Measurements

- Projected canopy size throughout the growing cycle (used to calculate incident light), dry & fresh root and shoot weight

Calculations

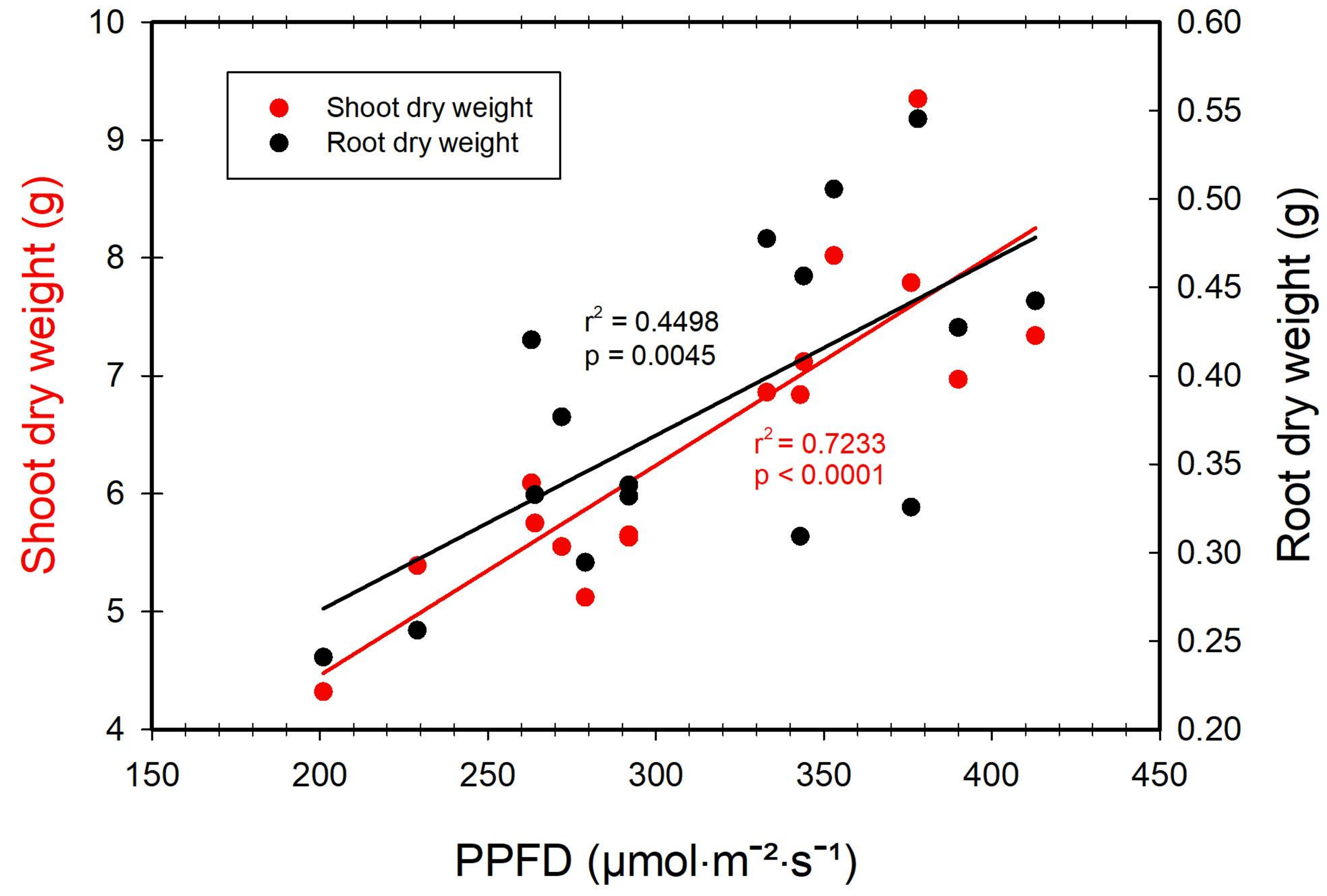
- Total incident light = ∫ DLI x projected canopy size
- Specific leaf area (leaf area/shoot dry weight)
- LUE = plant dry weight/total incident light

Results

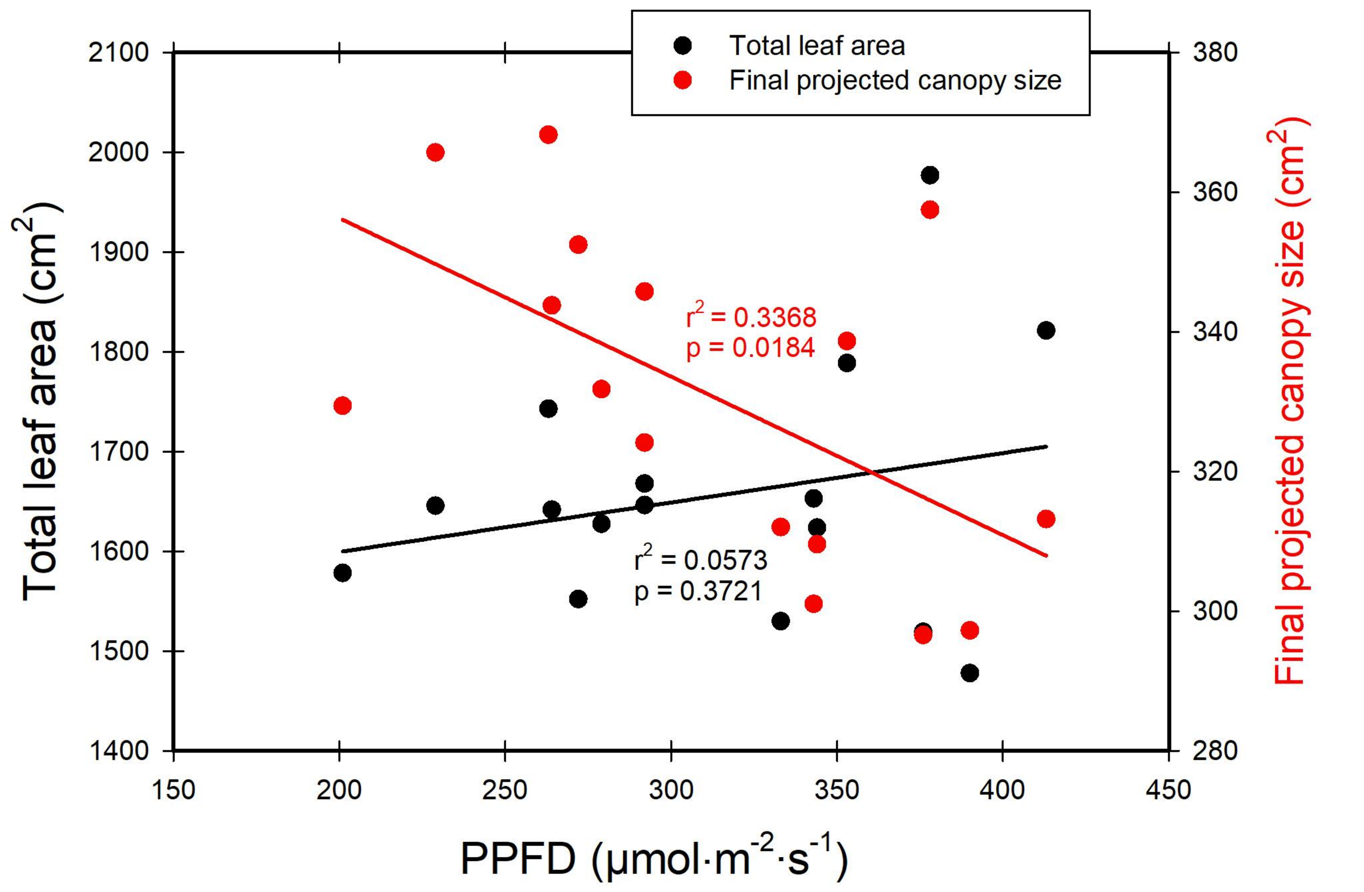


- High PPFD increases incident light (not shown)
- Total incident light strongly correlated with shoot dry weight
- Light use efficiency not affected by PPFD (0.89 ± 0.07 g/mol) (mean ± std.dev.)

Results



- Root and shoot dry weight increase under higher PPFD
- Fresh weight responded similarly



- With increasing PPFD, SLA decreased
- Plants grown under lower PPFD had a larger projected canopy size

Conclusions

- **Under lower PPFD, plants increase SLA and projected canopy size to increase light capture**
- **LUE was not an important factor in determining growth**
- **Growth and total incident light are strongly and positively correlated**

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