Floral color and ecophysiology in *Castilleja coccinea (Orobanchaceae)*

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Introduction

- Scarlet paintbrush (*Castilleja coccinea*) is a biennial flowering plant typically found in mesic prairies across North America. It exhibits floral color polymorphism, with populations displaying either red or yellow floral bracts.
- Floral color polymorphism is typically attributed to pollinator mediated selection, but it can also be driven by abiotic environmental factors (1). In *C. coccinea*, it is associated with differences in soil moisture and light conditions. Particularly, red plants are found in shadier environments while yellow ones are found in open field environments (2).
- Light is an important limiting factor for plants as it provides the energy needed for photosynthesis. Plants who face environmental stress from insufficient light typically respond in two ways: shade avoidance or shade tolerance. Shade avoidance is generally associated with greater plasticity in physiological and morphological traits, while a shade tolerance response shows reduced plasticity but optimized light capture under shade (3).

Figure 1: Map showing the locations of the different *C. coccinea* populations used in this project, showing the yellow plants (A) in their open field environment (B) and red plants (C) in their shaded environments (D). In the common garden experiments, plants were assigned to a full sun treatment (E, F) or a shade treatment (G).

Objectives & Hypothesis

- **Objective:** This experiment focuses on studying the ecology and physiology of a restoration concern species, *C. coccinea*, as it is threatened in the eastern portion of its range due to habitat destruction and ecological succession. It also aims to provide us with a better understanding of the interaction between color and ecotypes of *C. coccinea*, to which end we investigated how light availability affects morphological and physiological traits of two varieties of *C. coccinea* across various populations.
- **Hypothesis**: We predict that plant physiology (photosynthesis and stomatal conductance) will depend on flower color and light treatment. There will be a significant difference in physiology as red plants are found in shadier environments and will perform better in shade conditions, and yellow plants will perform better in full sun conditions as they are found in open field environments.

Results

Photosynthesis

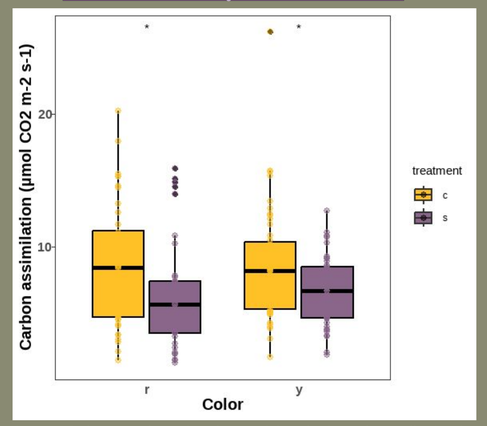

Figure 2: Carbon assimilation (µmol m-2 s-1), by color (r = red, y = yellow) and treatment (c = control, s = shade). Significance indicated by following notation: ns = p > 0.05, * = p < 0.05, ** = p <.005, *** = p <.005

We observed a significant effect of treatment on carbon assimilation (*A*) (F = 7.4896, p < 0.01). Full sun plants (mean = 8.64, SE = 0.48) demonstrated higher *A* than shade plants (mean = 6.53, SE = 0.38).

Stomatal Conductance

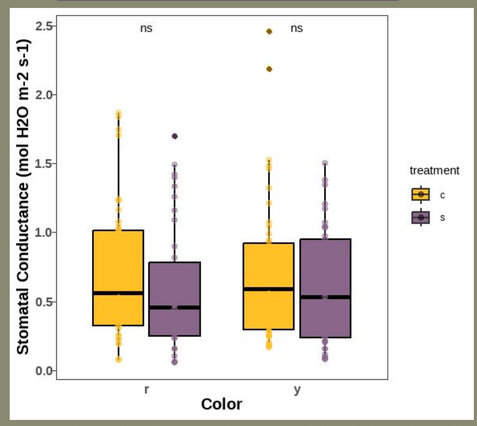

Figure 3: Stomatal conductance (mol H2O m-2 s-1), by color (r = red, y = yellow) and treatment (c = control, s = shade). Significance indicated by following notation: ns = p > 0.05, * = p < 0.05, ** = p <.005, *** = p <.005

We did not observe a significant difference in stomatal conductance by treatment, color or the interaction of treatment and color. (p > 0.05).

Water Use Efficiency

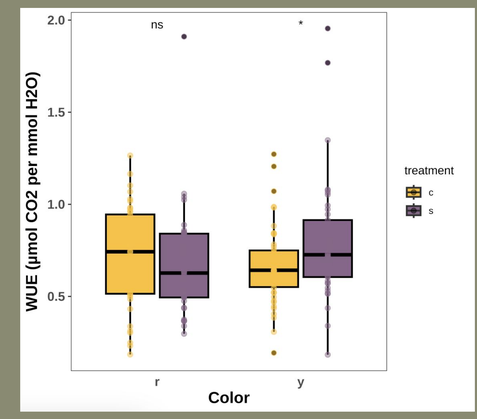

Figure 4: Water use efficiency (%), by color (r = red, y = yellow) and treatment (c = control, s = shade). Significance indicated by following notation: ns = p > 0.05, * = p < 0.05, ** = p <.005, *** = p <.005

We observed a marginally significant effect of a color by treatment interaction on WUE (F = 3.8254; p = 0.05). Yellow shade plants displayed higher WUE (mean = 0.80 SE = 0.051) over full sun plants (mean = 0.67 SE = 0.031).

Methodology

- The plants were arranged in a randomized complete block design across 12 blocks, with 24 plants in each block, 2 from each treatment.
- Physiology data is measured on the leaf level for a subset of plants (n = 144) using a LI-COR 6400XT Portable Photosynthesis System. (Licor Biosciences, Lincoln, NE).
- Data analysis: We performed general linear models and applied Type III two-way ANOVA, followed by Tukey's HSD post hoc tests using the emmeans package in R (6).

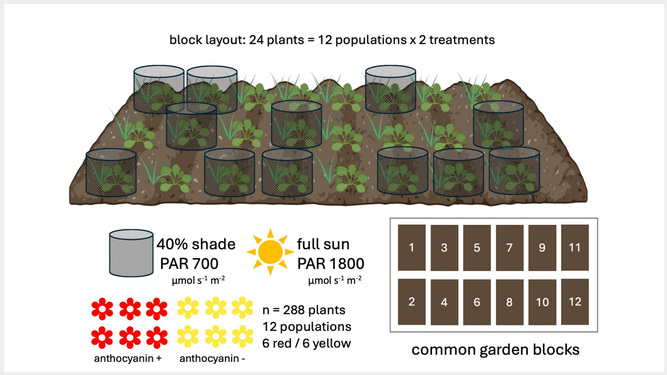

Figure 5: Image depicting the experimental setup at a common garden at the Chicago Botanic Gardens

LI-COR 6400XT Portable Photosynthesis System

Photosynthesis (*A*): the conversion of light energy to chemical energy by photosynthetic pigments using water and CO2. (4)

Stomatal conductance (gst) : measurement of the flux of water and carbon dioxide through the stomata and out of the leaf. (4)

WUE: the ratio of biomass produced per unit of water used, here measured by dividing the rate of photosynthesis (*A*) by the amount of water transpired (*E*). (5)

Figure 6: Image of the LI-COR 64000XT from Licor Biosciences, Lincoln, NE

Conclusion & Discussion

- While the results do not support our hypothesis that red plants would have a better performance in the shade treatments and yellow plants would have better performance in full sun, there was a significant effect of treatment on photosynthetic rate and a marginally significant effect of a color by treatment interaction on WUE. The results suggest some plasticity in yellow plants' response to shade treatment due to a higher WUE.
- The results improve our understanding of physiological diversity of *C. coccinea*, which can aid in future conservation and restoration efforts.
- Further research on responses to shade in *C. coccinea* could include measuring the chlorophyll a:b ratio to measure if a plant is exhibiting a shade tolerance or avoidance response. Another course of action could be RNA sequencing to compare the gene expression based on the light treatment.

Literature Cited

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