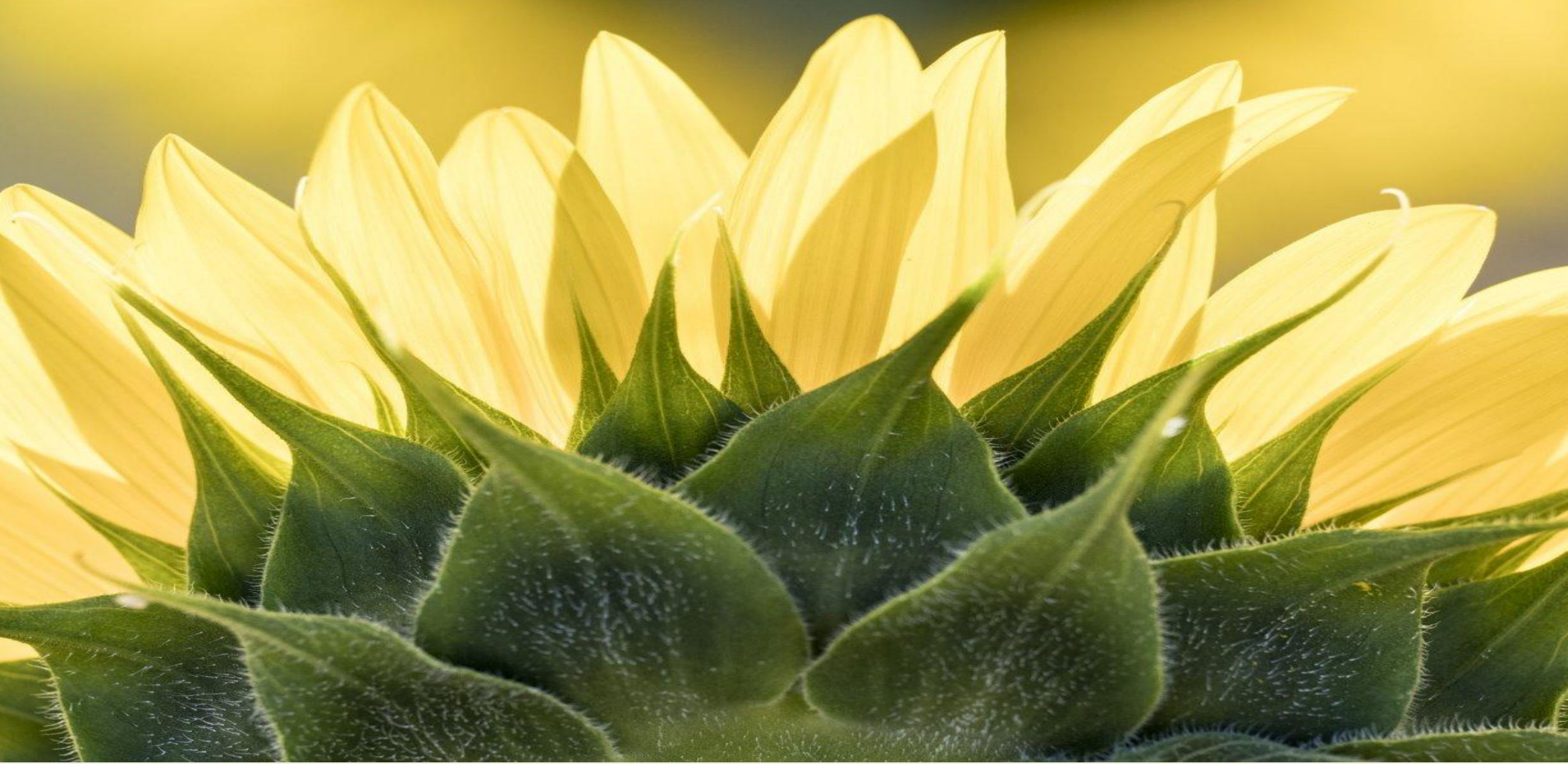

Reduced light intensity decreases photosynthesis and shifts resource allocation towards the shoot in sunflower plants (*Helianthus annuus*)

Sofia Amaral and Adrianna Gonzalez

1. Defining the Question
2. Forming a Hypothesis
3. Methods
4. Experimental Results
5. Discussion

How would *Helianthus annuus* (sunflowers) survive if their light source was greatly reduced?

This experiment is studying:

- The relationship between light intensity and photosynthetic rates
- The correlation between light intensity and resource allocation in sunflower plants.

This study is important for:

- Understanding how plants, especially crop plants, react to changing environments. This can improve agricultural practices and informing strategies for crop management in areas with changing light availability

Background

- **Photosynthesis:**
  - Process by which plants convert light energy into chemical energy. Light is a critical factor in this process as it drives the reaction that produce energy for growth and development.
- **Plasticity:**
  - Ability for plant’s to adjust their growth based on environmental conditions. This helps them maximize resource uptake.
- **Resource Allocation:**
  - Plants distribute energy and nutrients between different parts such as roots and shoots. In response to environmental changes, plants may prioritize certain areas over others to maximize their survival or growth.
- **Sunflowers:**
  - C3 plants: require ample light for optimal photosynthesis

1. Defining the Question
2. **Forming a Hypothesis**
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Hypothesis

If sunflower plants are only exposed to low light intensity then they will have lower photosynthetic rates and display physical characteristics that differ from plants grown in direct light.

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SET UP

Preparation

- Approximately 20 sunflower seeds were potted and left in a greenhouse. The sunflower seeds were left to grow for approximately 4 weeks. Once large enough they were repotted into larger pots. They were watered 3 days a week. During the repotting and at week 3 fertilizer was added (Miracle Gro)

Experiment: 16 *Helianthus annuus* tested

- **Control:** 8 sunflower plants were placed in direct sunlight. Rocks were added around the plants to ensure harsh weather didn't disrupt them.
- **Treatment:** 8 sunflower plants were placed in the shaded environment.
    - 2 sheets were placed over a foldable table and held down with rocks. This provided constant shade for the group.


Treatment Group


Control Group

LI-COR 6400

Preparation:

- The LI-COR 6400 was prepared before any measurement were taken.

Experiment:

- A **log file** was opened before obtaining any measurements as well as matching IRGAs.
- The **chamber was clamped** onto 1 leaf of the sunflower plant. The stability and photosynthetic rate were monitored to ensure the stability read 3/3 and the photosynthetic rate was positive.
- The **data was recorded** once the conditions were stable and the steps were repeated for 1 leaf per plant.

Stomatal Peel

A stomatal peel is a technique used to create an impression of a leaf's stomata so it can be viewed underneath a microscope. In our experiment the stomatal peel is required to calculate stomatal density and guard cell diameter.

1. **Prepare the leaf:** One healthy leaf was collected from all 16 plants.
2. **Create the peel:** A small amount of clear nail polish was added to the underside of the leaves. The leaves were left to dry in a fume hood for 20 minutes. Once dry a piece of tape was stuck to the nail polish and gently peeled off.
3. **Mount the peel:** The peel was added to a microscope slide with the sticky side facing up.
4. **Observe**: All 16 peels were examined underneath a digital microscope.

Water Content and Dry Mass of Sunflower Root and Shoot

This technique involves measuring the fresh and dry weights of sunflower roots and shoots. In our experiment, this was required to calculate their water content percentage.

1. **Uprooting the Plant:** Each sunflower plant was gently removed from its pot while carefully loosening the soil to avoid damaging the root system.
2. **Cleaning the Plant:** The remaining soil was gently rinsed and then the plant was patted dry.
3. **Separating and Weighing:** Each plant was cut into root and short portions, weighed separately and their fresh weights were recorded.
4. **Drying and Storing:** The root and shoot portions were placed into labeled paper bags and placed in an incubator to dry.

Softwares Used

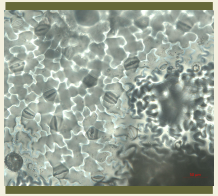
Stomatal Peel

Digital Microscope

A digital microscope is used to to inspect and analyze various objects. Images at the microscopic level can be achieved using the microscope. In this experiment the microscope was used to retrieve images of the stomata from the stomatal peel.

ZEISS Software

The ZEISS Software is used for image acquisition.



and analysis. In this experiment the software was used to determine stomatal density and guard cell diameter. Stomatal density was determined by counting the number of stomata in the microscope image and dividing it by the area.

Analysis

Stat Cat

StatCat is a statistical software used to perform various analyses of our data. In our experiment, StatCat was used to perform regression analysis and two sample independent tests on our data.

ImageJ

ImageJ is an image analysis software used to measure and analyze various properties in the images. In our experiment, it was used to determine leaf area, stomatal density, and guard cell diameter

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Figure 1.

Photosynthetic rates of plants under average light intensity (control) and low light intensity (treatment) over four weeks. The x-axis represents time (weeks 1–4), and the y-axis represents photosynthetic rates (μmol CO_2 m^{-2} s^{-1}). The control group maintained higher photosynthetic rates compared to the treatment group across all time points.

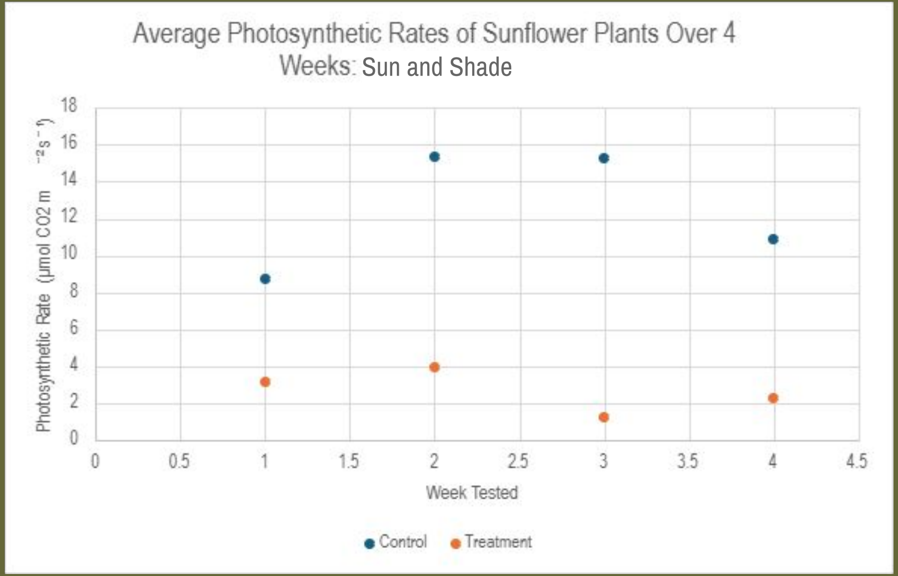

Figure 1.

Figure 2.

The relationship between photosynthetic rates and stomatal conductance in the control group (direct sunlight) and treatment group (indirect sunlight). There was a significant difference in photosynthetic rates between control and low intensity treatments (F= 53.879, P< 0.05, N = 64).

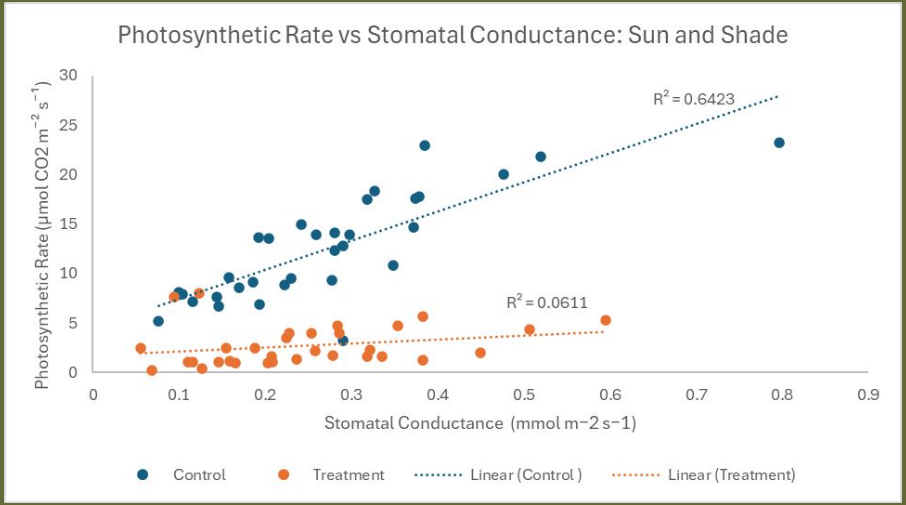

Figure 2.

Figure 3.

Contingency table showing the number of rough and smooth leaves in control (average light intensity) and treatment (low light intensity) groups. A contingency table analysis was performed to analyze the association between leaf texture and light intensity conditions, resulting in $\chi^2 = 55.082$, $p = 1.2 \times 10^{-13}$. These results indicate that leaf texture was dependent on light intensity conditions.

Contingency Table

	Control (Sun)	Treatment (Shade)
Rough	35	0
Smooth	13	48
Total	48	48

Figure 3.

Figure 4.1

Average dry weight (in grams) of sunflower roots and shoots grown under control (average light intensity) and treatment (low light intensity) conditions. When comparing root weights, the control groups had significantly higher average dry weight compared to the treatment group ($T=4.45537$, $p<0.05$). However, when comparing shoot weights, there was no significant difference between the control and treatment groups ($T= 0.82077$, $p>0.05$) .

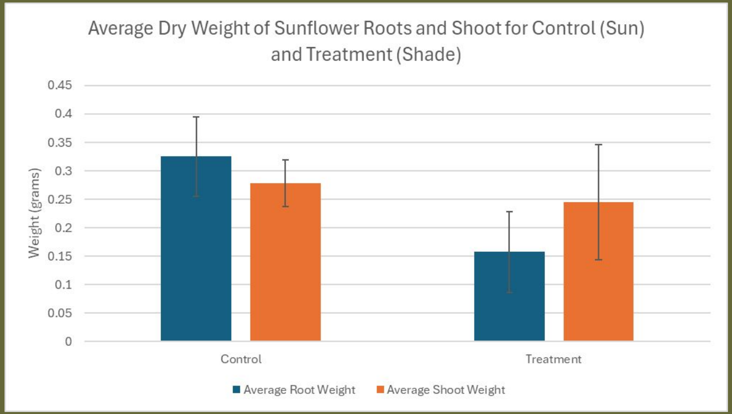

Figure 4.1.

Figure 4.2

Average water content (as a percentage) of sunflower roots and shoots grown under control (average light intensity) and treatment (low light intensity) conditions. For roots, there was no significant difference in water content between the two groups($T=0.2665$, $p>0.05$). For shoots, there was no significant difference in water content between the two groups ($T=-1.8631$, $p>0.05$).

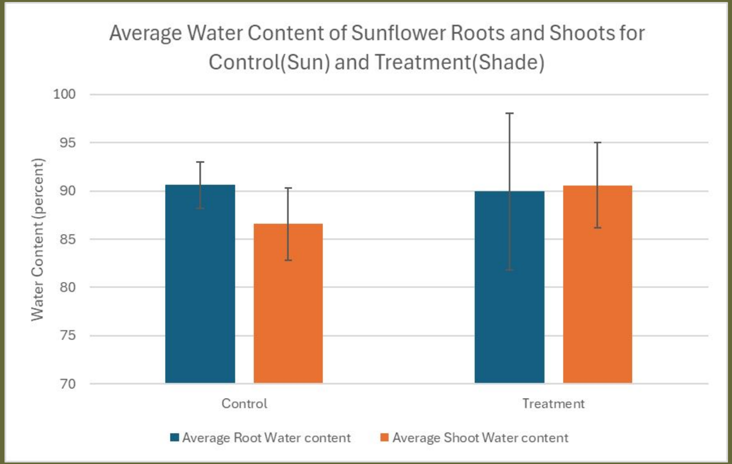

Figure 4.2.

Stomatal Density and Guard Cell Diameter

Average Stomatal Density (Control):

- 19.95

Average Guard Cell Diameter (Control):

- 12.42 µm

Average Stomatal Density (Treatment):

- 18.02

Average Guard Cell Diameter (Treatment):

- 15 µm

1. Defining the Question
2. Making Observations
3. Methods
4. Experiment Results
5. **Discussion**

Findings

Photosynthesis and Light Intensity

Lower Photosynthetic Rates:

- Plants in low light had lower photosynthetic rates (Figure 1) likely due to limited energy for ATP and NADPH production
-

Leaf Morphology:

- Treatment group had a smoother texture than control group (Figure 3). Improves light capture efficiency.

Photosynthesis and Stomatal Conductance

- The stomatal conductance of the control group and treatment group stayed relatively the same even as photosynthetic rates increased.
- Other factors are determining the photosynthetic rates in these plants.
  - Adverse weather conditions
  - the plants' efficiency of light absorption.
- This proven by the similar stomata densities and guard cell diameters between the treatment group and control group.

Light Intensity and Resource Allocation

Biomass Allocation:

- Under low light, plants shifted resources toward shoot growth while roots had reduced dry weight (Figure 4.1). Helps maximizes light capture.

Water Content:

- Despite biomass changes, water content remained stable for both groups (Figure 4.2). Suggests that light intensity did not affect water regulation mechanisms

Other Scientific Articles

1. The effects of drought on soybean plants under different light conditions

This study found that plants grown in low light environments were able to cope with additional stress compared to plants grown in direct light. The low light plants were able to within stan the additive stress because they had different structural characteristics such as thinner and larger leaves (Zhang et al., 2016).

2. Examining the impacts of shade and drought on the biomass allocation of shade tolerant woody seedlings.

They discovered that light stress affected biomass allocation. In light stress environments the seedlings would reallocate resources towards leaf growth to optimize their light capturing ability (Sack and Grubb, 2002).

3. Studies canopy plants' photosynthetic rates and resource distribution.

He discovered that over time canopy plants acclimate to low light environments by increasing their leaf area and chlorophyll content (Niinemets, 2007).

Further Studies

Stomatal Behavior and Photosynthesis Efficiency:

- Research how stomatal behavior under different light conditions impacts CO_2 uptake and water loss.
- Can help optimize crop irrigation practices

Light Stress and Crop Growth

- Study how crop plants, such as sunflowers, respond to different light conditions
- Lead to better agricultural practices in regions with varying sunlight availability

Work Cited

Niinemets, Ü. (2007). Photosynthesis and resource distribution through plant canopies. *Plant, Cell & Environment*, *30*(9), 1052–1071. https://doi.org/10.1111/j.1365-3040.2007.01683.x

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