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Impact of drought and fertilizer use on the photosynthesis rate of cucumber and sweet corn under ambient and elevated atmospheric CO_2 conditions

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Introduction

Past research shows that elevated CO_2 levels are beneficial to plant growth and increase photosynthesis rates, which encourages faster plant growth and higher levels of food production.[1] Despite that, drought conditions and increased temperatures have been shown to mitigate the positive impacts, including reduced biomass and lower nutrient content in agricultural products.[2] Additionally, other consequences of climate change such as natural disasters, soil degradation, and precipitation changes are additional challenges plants must overcome to see any potential positive impacts.[3] The intersection of agriculture, food security, and nutrition is understudied in the realm of climate change research. To help overcome this gap in research, this study aims to simulate two scenarios that are expected to become more common as climate change continues: high fertilizer use and drought conditions.

- Current CO_2 concentration = 415 ppm
- Projected 2050 CO_2 concentration = 685 ppm

$$6\,CO_2 \text{ (Carbon dioxide)} + 12\,H_2O \text{ (Water)} \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 \text{ (Glucose)} + 6\,O_2 \text{ (Oxygen)} + 6\,H_2O \text{ (Water)}$$

Methods

- 30 plants of each species were planted one inch deep inside a 50:50 mix of peat and vermiculite
- Grown in the St. John's University Melancon Greenhouse to control for temperature and sunlight
- All plants received the same treatment for two weeks and were watered until saturation 2-3 times per week. They were split up into experimental groups after two weeks.
- All plants grew for approx. seven weeks total

Fertilizer Group

- After two weeks of grow time, these plants received 1/8 tbsp of Miracle-Gro once every week, per package instructions.
- The plants received the same quantity of water as the control group

Drought Group

- After five weeks, the drought experimental condition began. The control plants were weighed after being watered and the drought plants received 30% (by weight) of the water given to the control group.

Data Collection

- A LICOR 6400 was used to measure photosynthesis rate of the plants and expose them to varied levels of CO_2
- Data was recorded after the photosynthesis rate was stable for one minute

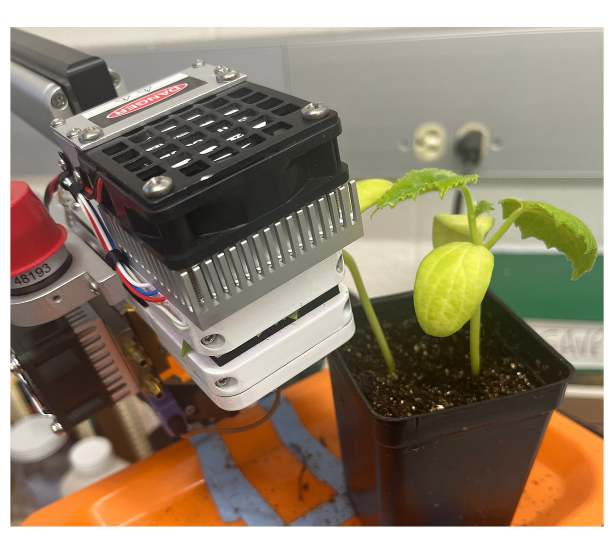
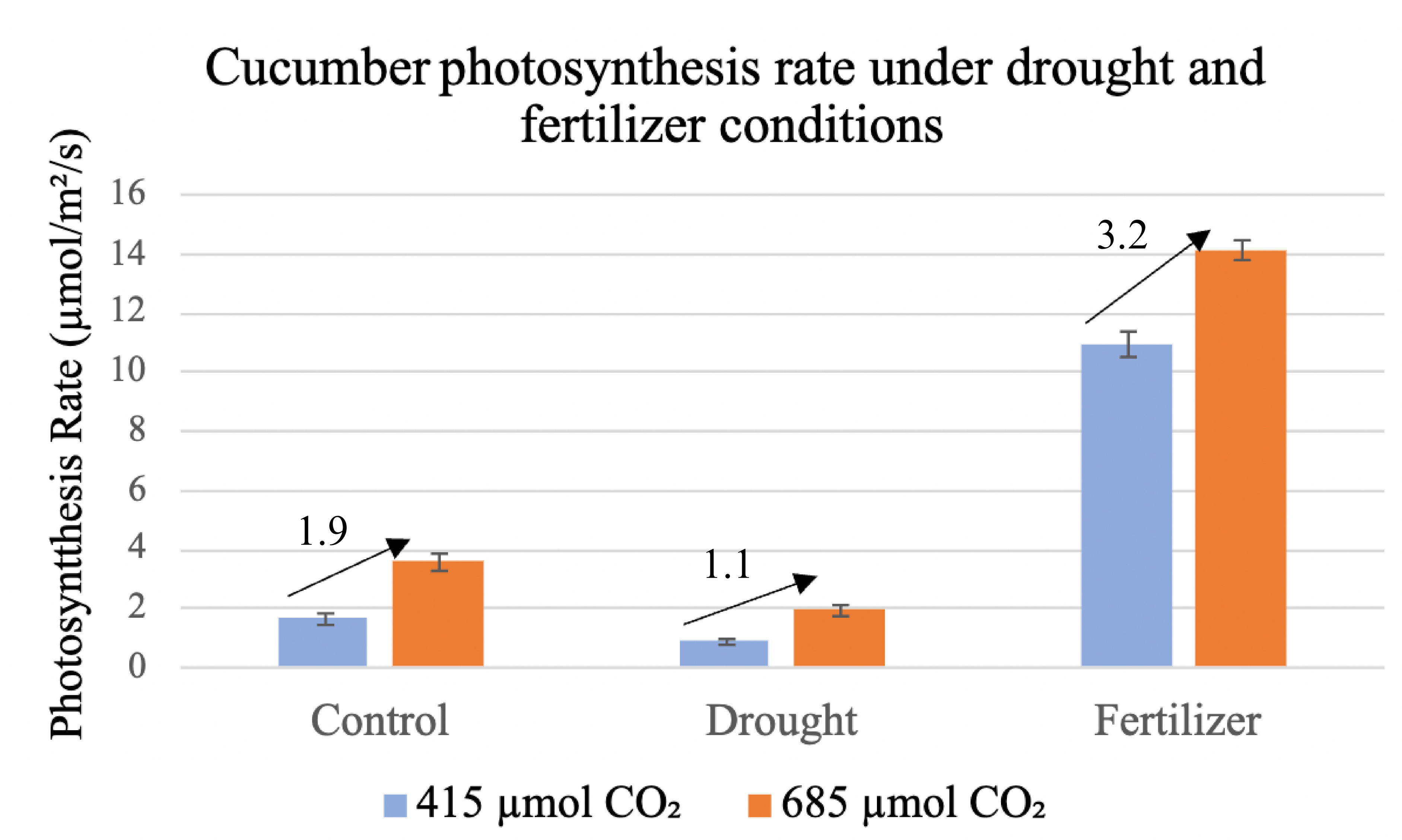


Figure 1. LICOR-6400 measuring the photosynthesis rate of a cucumber plant

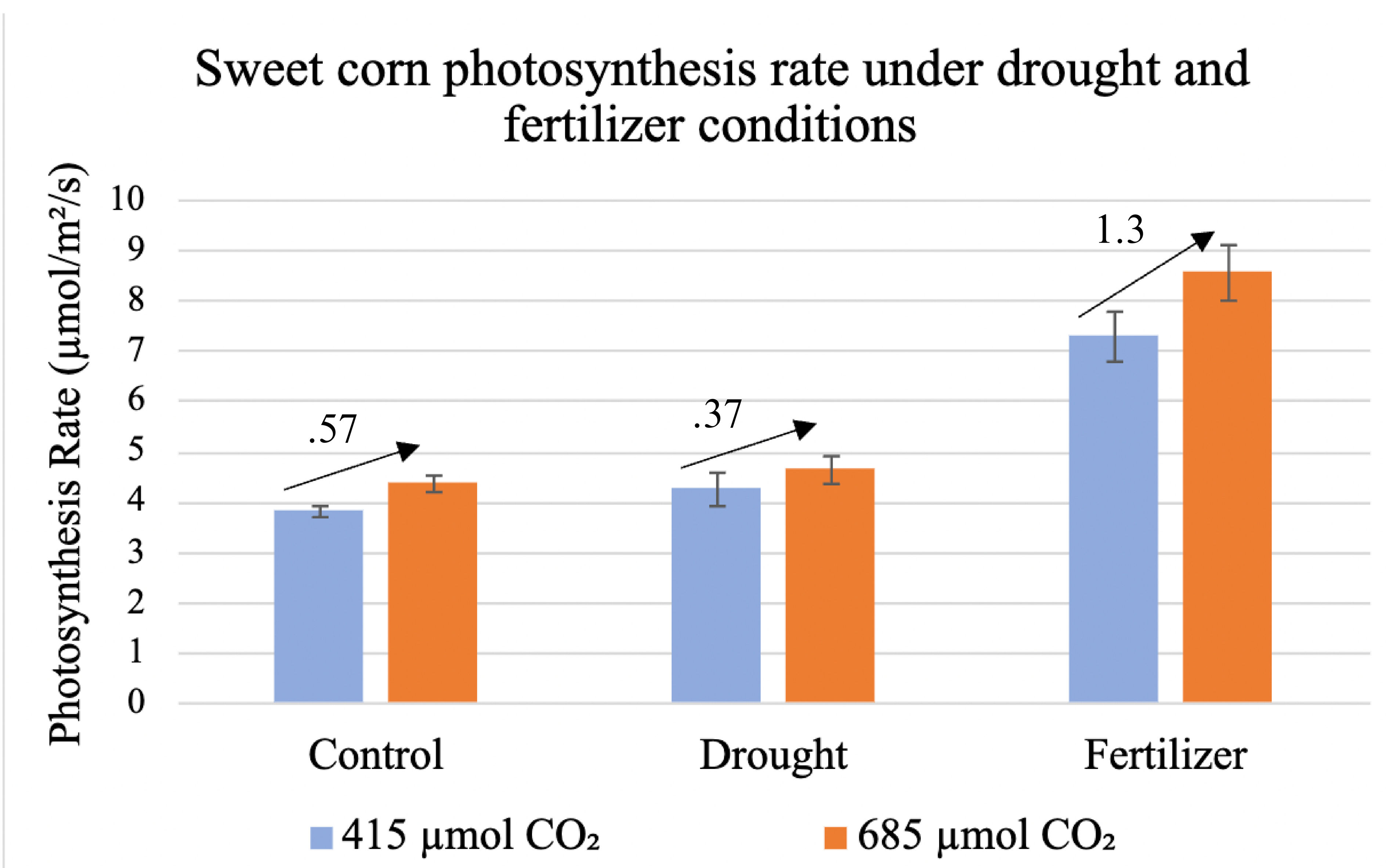
Figure 2. Cucumber and corn plants during week two of growth.

Results

The study expected that higher CO_2 levels would result in increased photosynthesis rate. The research examines whether plants grown in different conditions are able to take advantage of that potential increase in photosynthesis rate.



- 66% increase between the gains seen by the fertilizer and the control groups
- 84% decrease between the gains seen by the drought and the control groups
- Error bars represent the standard deviation of the mean



- 120% increase between the gains seen by the fertilizer and the control groups
- 55% decrease between the gains seen by the drought and the control groups
- Error bars represent standard deviation of the mean

Discussion

The gain that cucumber plants lost between the control and drought groups was statistically significant. While it was not for corn plants, the same trend is still observed. One possible reason for the differences between species is because they photosynthesize differently, as cucumber is a C3 plant and corn is a C4 plant. C4 plants photosynthesize more efficiently because they have a different method of carbon fixation.

- C3– cucumber, soybean, rice, tomatoes, and wheat
- C4– corn, sugarcane, cabbage, broccoli, and turnip

The results from this study show that the predicted benefit from elevated CO_2 as climate change progresses may be lower than anticipated. As shown by the experiment, fertilizer has the ability to help overcome some of the negative impacts that drought can cause. Although this is true, fertilizer should not be used as the only solution, particularly because society must consider how fertilizer use impacts waterways, soil erosion, and its other negative environmental impacts.[4] In context of food security for the rising global populations, some of the possible ways to overcome these challenges might include investments in climate resilient genetically modified crops, efforts to reduce food waste, and expanding aquaculture.

Limitations

- This study did not analyze the relationship between drought and fertilizer groups together
- Small sample size (n=9 or 10)
- Plants only grew for seven weeks and these results cannot be extrapolated onto a plant's lifetime

Future Research

- Repeat research with a larger sample size
- Compare C3 plants or C4 plants to each other, instead of C3 plants to C4 plants
- Analyze nutritional content of the resulting fruits and vegetables after growth in different conditions

References

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