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Investigating photosynthetic activity in response to increased atmospheric CO_2 levels and increased leaf level temperatures in *Ravenea rivularis*

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ABSTRACT

The *Ravenea rivularis* response to increasing global CO_2 concentrations coupled with increased leaf level temperatures was explored in a three-part study evaluating real time photosynthetic responses to changing environmental elements facing the plants in today's climate. In the first segment of the research, controls for the experiment were a temperature setting of 26°C, and a CO_2 of 400 ppm, per the current global average. The vapor pressure deficit was set at 1.4 units. The palms were individually exposed to 15 separate light levels ranging from 0, or, absolute darkness, to 2000 μmol mol^{-1}. In each test, the palms began to decrease photosynthetic activity near the 1800 μmol mol^{-1} mark. The data I recovered from the LI 6800F indicated the palms were the most productive between 1400 μmol mol^{-1} and 1600 μmol mol^{-1} ppm. Because of this, I used 1500 μmol mol^{-1} for the second stage of testing. Stage two of the project was to determine the CO_2 saturation level for the *Ravenea rivularis*. In stage two, the light setting of 1500 μmol mol^{-1} was used as a control as well as the temperature of 26°C, and a controlled vapor pressure deficit of 1.4 units. The established climate controls were applied individually to each palm. The second stage showed the *Ravenea rivularis* ability efficiently sequester CO_2 at the 1500 μmol mol^{-1} light level. The third and final stage of the experiment utilized data from last two segments of the experiment, the controls were set at 1500μmol mol^{-1}, 400ppm CO_2, with the 1.4 VPD. This time temperatures were increased at the leaf level. Beginning with 24°C, I increased the temperature by 4°C until I had a range of 24-40°C. Each of the five palms responded in a comparably positive manner. With each increase in the temperature, the palms continued to fix more and more CO_2 nearly doubling the amount of CO_2 sequestration for each specimen by the 40°C temperature mark from an average of 4.9 to around 10.3.

KEYWORDS: *Ravenea rivularis, Carbon Fixation, IPCC, Photosynthesis, Licor 6800F*

INTRODUCTION

Since the IPCC first published its report on climate change in 1990, they conclusively noted concentrations of atmospheric carbon dioxide levels had increased by around 40 percent since the start of the Industrial Revolution (IPCC, 2018). Current predictions suggest CO_2 levels and temperature extremes will become more common and increasingly dangerous for individuals already living in areas affected by extreme climate conditions. Extended periods of drought, extreme heat, and severe cold, have also become more frequent across the globe.

While some insist that increased carbon dioxide in the air will increase plant productivity, there are others who believe that several other factors must be accounted for. Strong evidence showing upper canopies of all forest types are showing a decline in photosynthetic activity due to increased upper canopy leaf level temperatures. Tropical forests are showing the greatest amount of canopy in operation under higher than optimal temperature conditions. (Mau, Reed, Wood, and Cavaleri, 2018.)

Increased atmospheric CO_2 levels are being accompanied by rising temperatures and, as a result, these temperatures can dramatically affect plant growth and development. Tropical tree species may be more sensitive to increasing temperatures than temperate species. (Mau, Reed, Wood, and Cavaleri, 2018.)

Tropical and temperate forests account for a large portion of the world biomass. Tropical forests account for over 60% of the terrestrial global carbon. (Mau, Reed, Wood, and Cavaleri, 2018.) Forests have the ability to offset the effects of climate change by sequestering CO_2, Currently, projections for future atmospheric CO_2 levels are expected to reach 900 parts per million by the year 2100, (IPCC 2018). As with the rise in CO_2 levels from the past, this will be accompanied by more increases in mean temperatures as well. Global average temperatures are currently approaching a 10ºC increase from 1900. (IPCC 2018). Increasing global temperatures could reach a point in which forests could switch from net carbon sequesters to producers. (Mau, Reed, Wood, and Cavaleri, 2018.)

The understanding of leaf-level processes, such as photosynthesis, respiration, and transpiration, are vital to understanding how the continuous increase of global CO_2 levels accompanied by increased annual temperatures will impact the growth of future vegetation.

Plants act as the main entity in CO_2 removal from the atmosphere in our environment, therefore, in my experiment I established a thermal threshold by referencing data obtained by models in the IPCC report as well as using the LI 6800F.

Researchers were able to project numbers for increases in estimated CO_2 ppm, average annual temperature, and several other climatic factors, I chose a point in time from the model increased CO_2 ppm combined with other environmental factors such as increased heat, could become detrimental to the palm's ability to sequester CO_2 from the atmosphere and produce more breathable CO_2 for mammals.

MATERIALS AND METHODS

The subjects are five Majestic Palm Trees, (*Ravena rivulris*). My subjects were purchased at the Lowes in Salina, Kansas. They were originally housed in an outdoor garden area. The palms were all chosen with the idea of keeping them as close to the same size and shape as possible and also should appear to be in good health visually.

The local average temperature and humidity was not a factor due to the climate-controlled environment within the lab. In addition to the climate-controlled nature of the laboratory, the LI 6800F has the capability to control the environment inside of the leaf testing chamber.

All measurements were made with an LI 6800F portable photosynthesis system (LICOR, Lincoln, NE U.S.A.), I measured gas exchanges at the leaf level. I ran a prewritten program designed by Licor to establish both carbon dioxide and light response curves.

During the program the LI 6800F independently controlled light intensity, humidity, leaf temperature, and CO_2 ppm. All of the data was then transferred to a combination of spreadsheets and graphs. The goal of the experiment to record and measure the leaf's responses to increased leaf temperature at four controlled levels of CO_2 ppm in an attempt to see when increases in either range could affect the *Ravenea rivularis* ability to efficiently process CO_2.

For the initial phase of the experiment, I attempted to identify an optimal light level for the Majesties to use as a control.

Previous research on the Majesty had already established an ideal temperature range between 25°C to 29°C. However, the data does suggest that they do best in at least 26°C for maximizing photosynthetic performance. Therefore, I have chosen to control the temperature at 27°C.

The current global average of around 400ppm CO_2 will also be used as a control. The Majesties natural habitat is typically within the tropical zone where average humidity levels are around 40%, for this reason that was my control for the humidity level. This allowed me to compile the data to generate a light response curve that helped me to determine the specific light compensation point where respiration rates and photosynthesis were balanced. (100 μmol mol⁻¹).

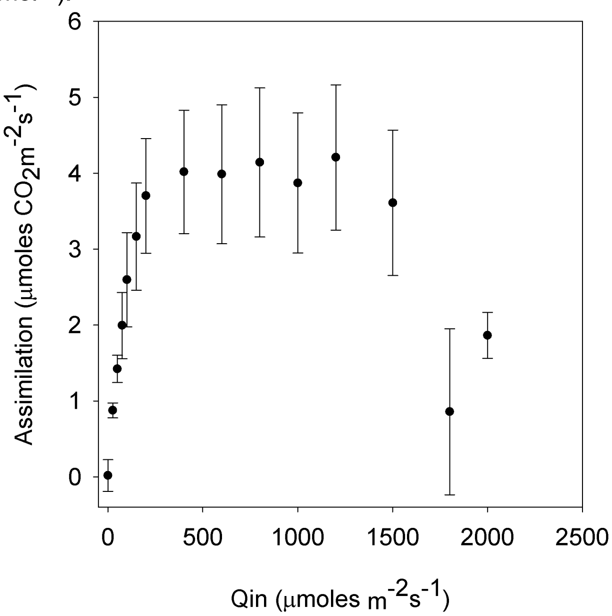

Figure 1. Light Response Curve Data for photosynthesis of *Ravenea rivularis* at 400 CO_2 ppm with increasing light intensity from 0 - 2500 μmol mol^{-1}. Each point is the average between 5 specimens. The vertical bars represent the standard error for each average.

The light compensation curve also indicated the optimal light intensity which the *Ravenea rivularis* are most photosynthetically productive. (1500 μmol mol^{-1}) This data helped me to ensure that the palms achieved maximum efficiency for the second stage of the experiment. With the light compensation curve established, I was able to use the data recorded to begin the second stage of tests.

In this portion of the experiment, I was using the same controls as the first one, and the newly established optimal light level (1500 μmol mol^{-1}), to establish a CO_2 compensation curve. The CO_2 compensation curve informed me when CO_2 assimilation was equal to respiration, (100 μmol mol^{-1}) and also when it was the most efficient at producing oxygen. (600 μmol mol^{-1})

The program began by slowly increasing the CO_2 inside of the leaf chamber recording the gas levels at the reference and sample sides. The Licor simultaneously calculated the differences between the two readings. All of the real time measurements were completed simultaneously within the LI 6800F system.

With the results from the CO_2 compensation curve and the Light Compensation curve test, I chose to select a point in time based on models ran in the IPCC survey.

Sample Measurements were taken on all 5 subjects in the same session. Assimilation rates at increasing leaf temperatures were recorded on all five subjects within the same series of experiments every day that test was performed.

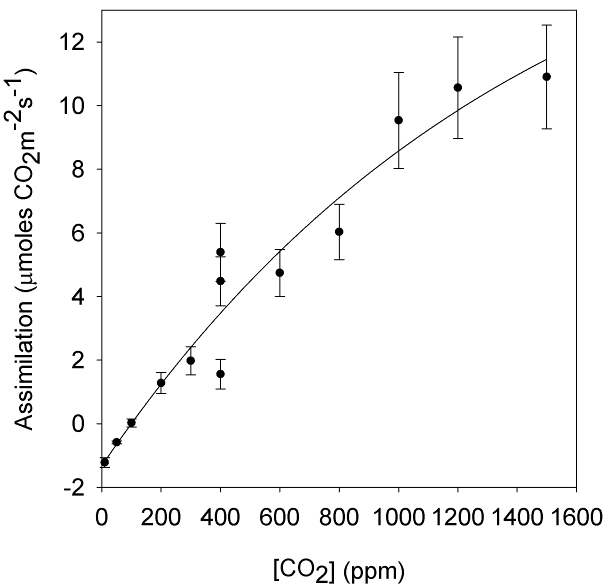

Figure 2. CO_2 response curve data for assimilation rates of CO_2 in *Ravenea rivularis* at 1500 µmol mol⁻¹ with increasing CO_2 ppm from 0-1600 CO_2 ppm. Each point represents the average between 5 specimens. The vertical bars indicate a standard error range in the average.

RESULTS

In each test, the palms began to decrease photosynthetic activity near the 1800 µmol mol^{-1} mark. The data I recovered from the Licor indicated the palms were the most productive between the 1400 µmol mol^{-1} – 1600 µmol mol^{-1}. Because of this I decided that 1500 µmol mol^{-1} which allowed me to begin the second stage of testing.

In this segment of the project the goal was to determine the CO_2 saturation level for the *Ravenea rivularis*, in this stage the light setting of 1500 µmol mol^{-1} was used as a control as well as the temperature of 26°C, and a controlled vapor pressure deficit of 1.4. The established climate controls were applied individually to each palm. The test appears to demonstrate, that under ideal temperature and light conditions, the palms would increase CO_2 sequestration far beyond the projected 900 ppm in the year 2100.

After establishing the *Ravenea rivularis* ability to do well at the 1500 µmol mol^{-1} measurement, I was able to run the third and final stage of the experiment. Using data from last two experiments, the controls were set at 1500µmol mol^{-1}, 400ppm CO_2, with the 1.4 VPD. This time temperatures were increased at the leaf level. I started with 24°C, then increased the temperature by 4°C until I had a range of 24-40°C. The palms all responded positively to the increase in temperature nearly doubling the amount of CO_2 sequestration for each specimen by the 40°C. temperature mark.

DISCUSSION

I expected the palms photosynthetic capacity to fall off much earlier on during the light response curve portion of the testing. I decided to test all the palms in the dark to measure their respiration rates along with the assimilation figures. I estimated around 1000-1200 µmol mol^{-1} would be when the Majesties would become light stressed. The palms began to decrease photosynthetic activity near the 1800 µmol mol^{-1} mark, Interpreting the data with sigma plot showed me the palms were the most productive between the 1400 µmol mol^{-1} – 1600 µmol mol^{-1} ppm. I decided to use 1500 µmol mol^{-1} as my light control for the second stage of testing.

In this segment of the project the goal was to determine the CO_2 saturation level for the *Ravenea rivularis*, again using the light setting of 1500 µmol mol^{-1} as well as the temperature of 26°C, and a controlled vapor pressure deficit of 1.4 units. The established climate controls were applied individually to each palm while increasing the concentration of CO_2 ppm from 400 up to 1500 ppm. The test appears to demonstrate, that under ideal temperature and light conditions, the palms would increase CO_2 sequestration far beyond the projected 900 ppm in the year 2100. After establishing the *Ravenea rivularis* CO_2 saturation point, I was able to run the third and final stage of the experiment.

Using data from last two experiments, it was easy to see the palms could handle a significant increase in both light and an increase in atmospheric CO_2 levels. I decided to increase the controls to 1500 µmol mol^{-1}, 1500ppm CO_2, with the 1.4 VPD. to simulate an extreme climate shift. Just as in the previous experiments the leaf level temperatures were increased to get the most accurate measurements. I started with 24°C, then increased the temperature by 4°C until I had a range of 24-40°C.

The palms all responded positively to the increase in temperature, nearly doubling the amount of CO_2 sequestration for each specimen by the 40°C. Temperature mark. This is not surprising at all because plants CO_2, the *Ravenea rivularis* thrives in warm humid climates, and all plants thrive in CO_2 rich environments.

While my test does not indicate that an increase in CO_2 by even 100 percent combined with an increased temperature of 16°C would have negative effects on the growth and health of the *Ravenea rivularis*, it does

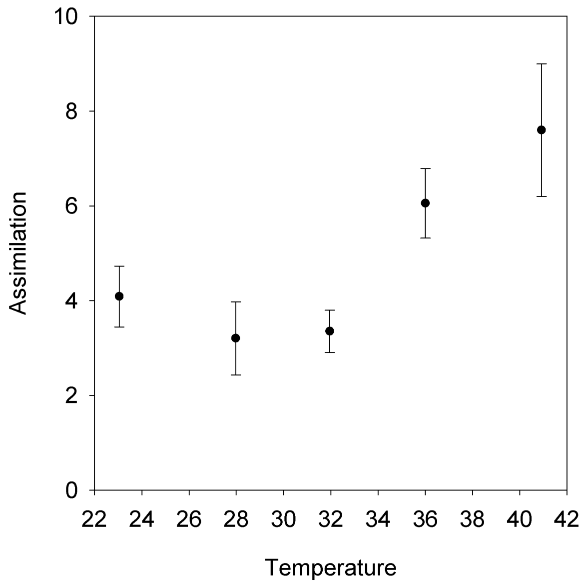

Figure 3. Temperature response curve data for CO_2 Assimilation with increased temperatures from 24-42°C. Each point represents the average responses by all 5 specimens. The vertical bars represent the standard error range in the averages.

not take into account the numerous changes that would accompany such dramatic shifts in the Earth's atmospheric composition. The increased temperatures alone would have drastic effects on weather patterns across the globe. The *Ravenea rivularis* location is in tropical regions located around the equator. These tropical regions rely heavily on the oceanic gyres that help drive the wind currents which are the source of rainfall promoting the cycle of growth. These trade winds and jet streams are also major catalysts in the distribution of hot and cold air across the continents.

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