Title: Simulation Tomato Leaf Lab

To compare the effect of light quality (blue, red, and white color filters) on the photosynthetic rate in a Lycopersicon esculentum (Tomato) plant using an online simulation lab

Background

The Bahamas is a country that imports most of what it needs. Imports in The Bahamas averaged 668.72 million Bahamian Dollars from 2002 until 2015 (Trading Economics, 2016). The Bahamas does not have the capacity to make large scale items like furniture, however, it does have the capacity to farm. If the country were to invest further in farming, the country would save about 93 million dollars (Trading Economics, 2016). There are farms present already; in 2006 there were 24 vegetable crops reportedly grown in the Bahamas (Heed, 2011). This is a good starting point, but in order to reach a level beyond subsistence farming, methods have to be improved. If methods improve and more Bahamians are aware that there is success in growing vegetable crops, then this figure should definitely increase.

There is not a large portion of fertile land, but modern technology can improve the conditions that the crops experience. Hydroponics and greenhouses are uses of technology that may prove to be useful. "Becoming ever more popular with the farming community are 2 highly specialised technologies; greenhouse production and hydroponics" (Heed, 2011). Greenhouses are glass buildings in which plants grow. Greenhouses are one way to ensure the growth of plants despite weather conditions. The Bahamas is generally very sunny all year round, so the plants won't need protection from cold weather. However, it would be useful to know which color of light stimulates the highest photosynthetic rates in plants. In recent improvements to greenhouse options, different colored plastic covers are now available and can be used in greenhouses. "...there is an enormous variety of options available in terms of the thickness of plastic materials and of course, the color of plastic that you might choose for your greenhouse" (Segura, 2011). So, that is why this lab will specifically look at the effect of different colors, in order to determine if there may be a specific color of plastic that will stimulate higher photosynthetic rates. The red filter will reflect only red light on the plant and the blue filter will do the same. The white filter will allow all wavelengths of light to be shone on the plant.

It is not feasible to attempt to test all 24 vegetable crops, so the tomato crop will be tested. The tomato was chosen because it has been grown since 1978 and was in the top 20 crops for 2004 and 2006 (Hedden, 2011). It would be very valuable to improve already established methods of growing this crop. It is farmed on an island called Abaco, but it would definitely have to be expanded further to reach its "potential."

A simulation is the imitation of a real-world process. The use of a simulation is advantageous because this model predicts the effect of light quality on photosynthetic rate before implementation. This simulation lab will examine the effect of three colors on the photosynthetic rates of a tomato plant. This leads to the question: Which color filter will produce the highest photosynthetic rate in a C3 tomato plant? In the first step of the Calvin cycle, C3 plants produce "two 3-carbon molecules of 3-phosphoglyceric acid (3-PGA)" (Georgia State

University, 2016). The light intensity will be increased in increments of 200µmol/m^2/s. The visible light spectrum contains a number of colors that have differing wavelengths. Not all colors have the same effect on stimulating photosynthesis in plant leaves. This investigation will help determine the most efficient colored plastic to use on the greenhouse for growing tomato plants. Tomatoes are C3 plants, so it grows best in cool, wet climates. It would be useful to determine the optimal light intensity value(s) from this investigation as C3 plants have their stomata open during the day. The plants lose water because the stomata are open during the day, so it is important to minimize this effect.

Null Hypothesis
There is no correlation between photosynthetic rate and light quality.

Alternative Hypotheses
There is a positive correlation between photosynthetic rate and light quality. Furthermore, one can hypothesize that either the blue or red filter will have the highest photosynthetic rates in the tomato plant. This is because C3 plants have chlorophylls, found in the chloroplasts, that absorb mostly blue and red light. C3 plants have the disadvantage that in hot dry conditions their photosynthetic efficiency suffers because of a process called photorespiration (Vermaas, 2011). Photorespiration is "a light-dependent process in some plants resulting in the oxidation of glycolic acid and release of carbon dioxide that under some environmental conditions (as high temperature) tends to inhibit photosynthesis" (Merriam-Webster, 2015). It is important to identify the optimum light intensity for the plant under the different color filters.

Variables

Independent: light quality (color filters)
Blue, red and white color filters will be used. One color filter will be chosen in each trial.

Dependent: photosynthetic rate - μmol/m^2/s ±1
The photosynthetic rates of the plant will change as the light intensity increases and different color filters are used.

Controlled:

gas flow level of O_2	This variable will be measured in ml per min. It will be controlled by setting the gas off and keeping it off throughout all trials.
temperature	This variable will be measured in centigrade. This will be set to 25°C at the start of each trial.
CO_2 level	This variable will be measured in ppm. This will be set to 350 ppm at the start of each

	trial.
C3 tomato plant used in simulation	Once the C3 tomato is chosen at the beginning, it will remain throughout all of the trials.

Materials

- online Pearson simulation lab

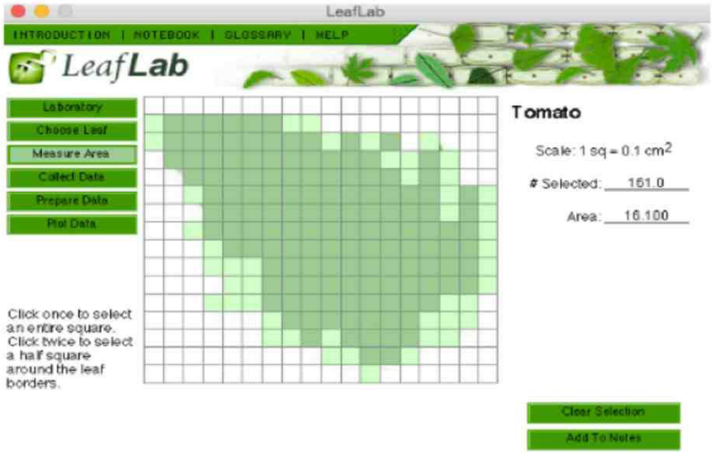
Method

Precautions: There are no safety, ethical or environmental precautions to note.

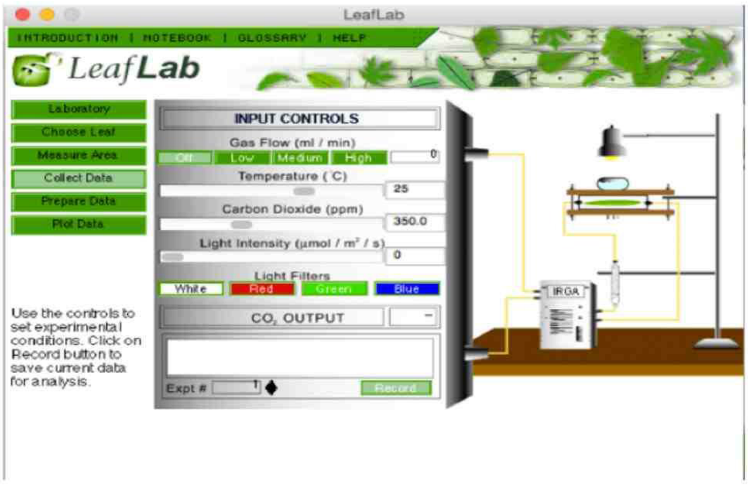
1. Go to Biology labs on-line.
2. Choose Leaf Lab.
3. Choose C3 tomato.
4. Measure the area of the leaf given.
    a. Select an entire square when the square is entirely covered by the leaf.
    b. Select half of a square when a portion of the square is covered by the leaf.
5. Set the CO_2 level to the default value.
6. Set gas flow to high.
7. Set temperature to 25°C.
8. Set the light filter to white and measure photosynthesis for light values from 0 to 2000 in increments of 200μmol/m^2/s.
    a. Before increasing to the next light value, ensure that the light value number is not changing.
9. Complete step 8 three times.
10. Record the CO_2 output value shown.
11. Repeat steps 8-10 for the blue and red filters.

Screenshots from the simulation

Area measurement of tomato plant:



The experimental results were given here:



Data

Raw Results

	CO_2 Output ± 0.1(ppm)											
Light Intensity µmol/m²/s ± 1	White Filter				Red Filter				Blue Filter			
	Trials				Trials				Trials			
	1	2	3	Average Trial	1	2	3	Average Trial	1	2	3	Average Trial
0	350.6	350.6	350.6	350.6	350.6	350.6	350.7	350.6	350.6	350.6	350.6	350.6
200	347.4	347.3	347.4	347.4	349.6	349.7	349.6	349.6	349.3	349.3	349.4	349.3
400	345.2	345.3	345.3	345.3	348.6	348.5	348.6	348.6	348.1	348.2	348.1	348.1
600	344.2	344.2	344.3	345.2	347.7	347.8	347.8	347.8	346.9	346.9	346.8	346.9
800	343.8	343.8	343.9	343.8	346.9	346.8	346.9	346.9	346.1	346.2	346.2	346.2
1000	343.3	343.4	343.3	343.3	346.3	346.3	346.4	346.3	345.3	345.3	345.4	345.3
1200	343.2	343.2	343.1	343.2	345.7	345.8	345.7	345.7	344.8	344.8	344.8	344.8
1400	343	343.1	343.1	343.1	345.1	345.2	345.2	345.2	344.3	344.4	344.3	344.3
1600	343.0	343.0	343.1	343.0	344.7	344.7	344.7	344.7	344.0	344.1	344.0	344.0
1800	342.8	342.7	342.8	342.8	344.4	344.4	344.4	344.4	343.8	343.7	343.8	343.8
2000	342.7	342.6	342.6	342.6	344.2	344.3	344.2	344.2	343.5	343.5	343.4	343.5

Calculations

The lab simulation gave each equation calculated below. All were needed in order to calculate the photosynthetic rates.

CO_2 Consumption

CO_2 Consumption = (CO_2 in 350.0 ppm) - (CO_2 out ppm)

CO_2 Consumption (ppm)			
Light Intensity Value μmol/m^2/s ± 1	White Filter	Red Filter	Blue Filter
0	-0.6	-0.6	-0.6
200	2.6	0.4	0.7
400	4.7	1.4	1.9
600	4.8	2.2	3.1
800	6.2	3.1	3.8
1000	6.7	3.7	4.7
1200	6.8	4.3	5.2
1400	6.9	4.8	5.7
1600	7.0	5.3	6.0
1800	7.2	5.6	6.2
2000	7.4	5.8	6.5

Compute CO_2 consumption into μmol per liter using temperature

(CO_2 Consumption ppm) (1 mol gas ÷22.42 L gas)(273°K÷T, 25°C + 273°K) = μmol/L

CO_2 Consumption (μmol/L)			
Light Intensity Valueμmol/m^2/s ± 1	White Filter	Red Filter	Blue Filter
0	-0.03	-0.03	-0.03
200	0.106	0.016	0.029
400	0.192	0.057	0.078
600	0.196	0.09	0.127
800	0.253	0.127	0.155
1000	0.274	0.151	0.192
1200	0.278	0.176	0.212
1400	0.282	0.196	0.233
1600	0.286	0.217	0.245
1800	0.294	0.229	0.253
2000	0.302	0.237	0.266

CO_2 exchange rate from gas flow

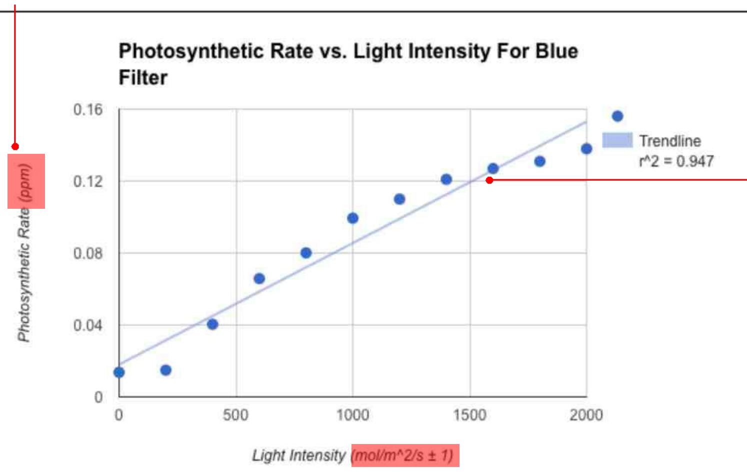
(CO_2 μmol/L) (5000, ml/min) (1 min/ 60s) (1 L/ 1000 ml) = μmol/s

CO_2 exchange rate μmol/s			
Light Intensity Value μmol/m^2/s ± 1	White Filter	Red Filter	Blue Filter
0	-0.0022	-0.0022	-0.0022
200	0.0089	0.0013	0.0024
400	0.016	0.00475	0.0065
600	0.0163	0.0075	0.0106
800	0.021	0.0106	0.0129
1000	0.0228	0.0126	0.016
1200	0.023	0.0147	0.0177
1400	0.0238	0.0163	0.0194
1600	0.024	0.0181	0.0204
1800	0.025	0.0191	0.0211
2000	0.0252	0.0198	0.0222

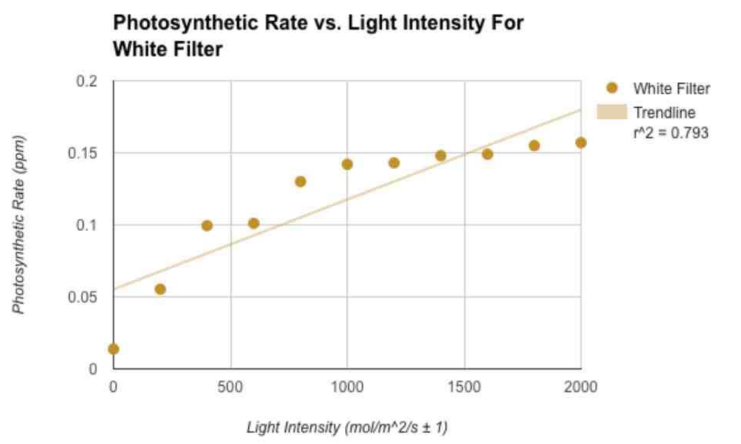
Compute photosynthetic rate per unit leaf area

(CO_2 exchange rate μmol/s) (1/16.1 cm^2) (100 cm/1 m)^2 = P μmol/m^2/s

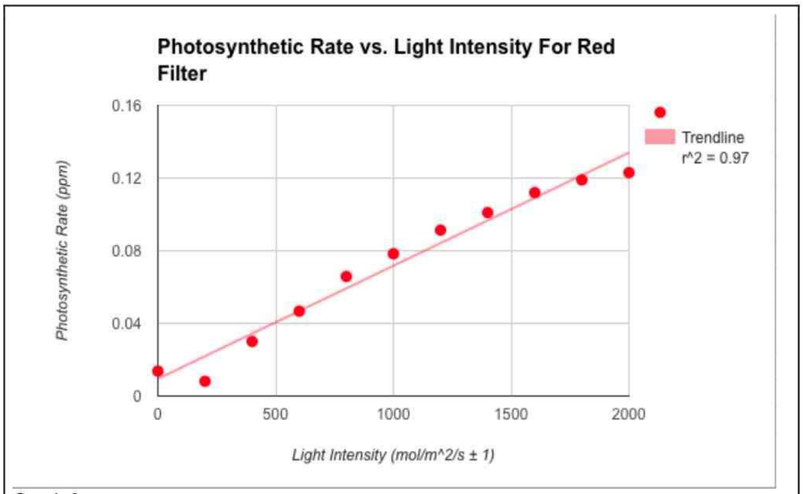
Photosynthetic rates (μmol/m^2/s)			
Light Intensity Valueμmol/m^2/s ± 1	White Filter	Red Filter	Blue Filter
0	0.0137	0.0137	0.0137
200	0.0553	0.0081	0.0149
400	0.0994	0.03	0.0404
600	0.101	0.0467	0.0658
800	0.130	0.0658	0.0801
1000	0.142	0.0783	0.0994
1200	0.143	0.0913	0.110
1400	0.148	0.101	0.121
1600	0.149	0.112	0.127
1800	0.155	0.119	0.131
2000	0.157	0.123	0.138



Graph 1



Graph 2



Graph 3

Data Analysis/Discussion

The data shows that the white filter has the highest photosynthetic rates in the tomato plant. Overall, there is a positive correlation between an increase in light intensity and an increase in photosynthetic rate. This could mean that the sunny climate of the Bahamas is not a threat to the growth of C3 tomato plants. Since the white filter was found to produce the highest photosynthetic rates, this would mean that direct, natural sunlight can work and colored plastics are not needed for the greenhouses.

As the graph doesn't plateau at the higher light intensity it may mean that the plant could undergo efficient photosynthesis processes at even higher light intensities.

The Pearson Coefficient Correlation coefficient (R) was calculated for all three graphs using Google Sheets. The R value was calculated by taking the square root of each R^2 value generated from Google Sheets. Graph 1 has a calculated R value of 0.9732, graph 2 has a calculated R value of 0.891, and graph 3 has an R value of 0.985. All of the graphs have strong positive correlations, however, graph 3 had the highest R value. Graph 3 is the red filter, so the red filter has the strongest correlation. This means that the higher the light intensity, the higher the photosynthetic rate.

The p value was calculated using an online Pearson calculator (Stangroom, 2016). The summary of p values are as follows at a significance level of 0.05: Graph 1(Blue) - P-Value is < 0.00001; Graph 2(White) - The P-Value is 0.00054; Graph 3(Red) - The P-Value is < 0.00001. Therefore, the null hypothesis is rejected because the p values are less than 0.05, which indicates strong evidence against the null hypothesis.

Conclusion

This investigation showed that the highest photosynthetic rate in the Lycopersicon esculentum plant was produced with the white filter. This disproves the hypothesis because neither the blue or red filters had the highest photosynthetic rates. There was, however, a positive correlation between light quality and photosynthetic rate. It can be concluded that no colored plastics should be put on the greenhouses, if they were to be implemented in the Bahamas.

Evaluation

Limitations	Improvements/ Extensions
These variables were controlled in the simulation: CO_2 level, temperature and gas flow. However, these variables are difficult to control in a real world application.	Model simulations that are more representative of the conditions the plant would experience. The CO_2 levels could be varied, for example, instead of keeping it constant.
Mineral composition of the soil was not taken into consideration. This may affect the rate of growth.	Determine the mineral composition from a sample of Bahamian soil. Find an online simulation that allows you to mimic this [illegible] or conduct a practical lab.
This lab was not able to test the thickness of the colored plastic. The light filter represented the color of the plastic, but the thickness was not tested in this online simulation.	Complete a practical lab that looks at the effect (if any) of thickness of plastic filters on photosynthetic rates.
The simulation only had generic capabilities. There was a limited selection of plants to choose from and specific tomato species were not available to be chosen from.	Design a simulation lab that will take into consideration all of the biotic and abiotic factors specific to The Bahamas.

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