ESSAY #1 2007

Title: The success of photosynthesis in geranium leaves using visible light wavelengths obstructed by black paper, and red, blue, and green translucent filters.

I. Abstract

Photosynthesis is a process in which plants use light, water, and carbon dioxide to produce sugars, water and oxygen. Chlorophyll a and chlorophyll b, in the chloroplasts of a leaf, are responsible for absorbing wavelengths of light for use in photosynthesis with red and blue wavelengths being optimal. Testing for the most productive wavelength of light was done using four separate geranium leaves that were covered by red, green, and blue translucent filters, and black paper. The experimental areas of the leaves were compared to a control area that was left uncovered and a subjective rating from 0 to 5 was given to each area depending on the color seen after adding I_2KI solution to the leaf. I_2KI solution was used because this solution turns purple in the presence of starch. The red filter showed more starch content overall followed by blue, green, and black paper. The red filter was more successful because it transmitted red wavelengths that were better absorbed for photosynthesis, although the blue filter was also successful. The reasoning for the blue filter not being as successful as the red is not clear. The green filter was less successful because it transmitted light that chlorophyll usually reflects. The black filter was the least successful because it absorbed nearly all of the wavelengths and few were able to transmit into the leaf.

II. Introduction

Photosynthesis is the process that plants use to make food. Green plants use pigments called chlorophyll, located in chloroplasts, to absorb the incoming light and use it in the photosynthetic process (Massa, Carabella, & Fornasari, 1997). According to Lawlor (1987), there are two different types of chlorophyll: chlorophyll a and chlorophyll b, that collectively capture almost all of the visible light spectrum yet absorb blue (430-450 nm) and red (640-660 nm) most strongly. The end result of photosynthesis is starch and sucrose, which is used as an energy source for the plant (Massa, et al).

Light is an important factor in photosynthesis and the correlation between color and wavelength must be understood. When white light is put through a prism, it will break up into a spectrum of different colors. The spectrum is divided into wavelengths measured in nanometers and each color corresponds to a range of nanometers. Overheim and Wagner (1982) explain the colors we see as the wavelengths that were not absorbed by an object but were instead reflected back at our eyes. They further explain that a green object absorbs blue (400-500 nm) and red (600-700 nm) and reflects wavelengths in the middle of the spectrum that correspond with the color green. Similarly, blue absorbs green and red (560-700 nm) parts of the spectrum and reflects wavelengths that correspond to blue. Finally, red reflects the red end of the spectrum around 607 nm and absorbs the blue and green parts from 400-580 nm. Black absorbs almost all light and does not reflect or transmit wavelengths (Fehrman & Fehrman, 2004). So far, light can be absorbed or reflected, but it can also be transmitted or passed through the object. The transmitted light is colored as well and will be the colors that were not absorbed (Perkowitz, 1996).

In finding which wavelengths are the best for photosynthesis, this experiment will involve placing black paper and red, blue, and green filters over portions of four separate geranium leaves and letting them absorb white light for one week. The results of the control areas, where light was not filtered, will be compared to the results of the covered areas. Because a result of photosynthesis is the presence of starch, and according to Morgan and Carter (2005), starch turns purple in the presence of I_2KI solution, this will be the way that we determine how much starch is present in the leaves.

I predict that the geranium leaf with the red filter will have more starch present than those with the black paper or green and blue filters. After the addition of the I_2KI solution the leaf should turn a dark color if starch was made during photosynthesis. For the hypothesis to be supported, the leaf that had the red filter on it will have the darkest coloring. The hypothesis will not be supported if any other leaf has a darker coloring underneath their filters. The results of light absorption on spinach leaves performed by Vogelmann and Han (2000) showed that spinach chlorophyll absorbed red and blue light better than green. Wavelengths of blue will be transmitted through the blue filter and wavelengths of red will be transmitted through the red filter, but red is being chosen over blue because of the energy of each kind of light. Blue light has a shorter wavelength (400-500 nm) compared to red (600-700 nm). A short wavelength translates to high energy so the blue light will have a higher energy than the red light (Fehrman & Fehrman, 2004). A study of blue and red light absorption in algae (You & Barnett, 2004) found that high energy light increased the production of sugars, but when the light energy became too high the production decreased. If the same is true for geranium leaves, then the blue light might have too much energy and cause less starch production.

III. Materials and Methods

To test the effect of different wavelengths, we used methods described by Morgan and Carter (2005) and began with preparation of the plants. Geranium plants were obtained and determined to be usable if they had healthy looking leaves. There needed to be at least four leaves because each treatment had to be carried out on a different leaf. Rectangles were cut out of black paper, and red, green, and blue translucent filters measuring about 2.5 cm by 5 cm. They were then folded in half. Four different, healthy looking leaves of the plant were found that were similar in height. The paper and filters were attached to the leaves by sandwiching the leaf in between the two sides of each rectangle, and then loosely paper clipping it to the leaf. After the treatments were put on, the geranium plant was returned to bright light for one week.

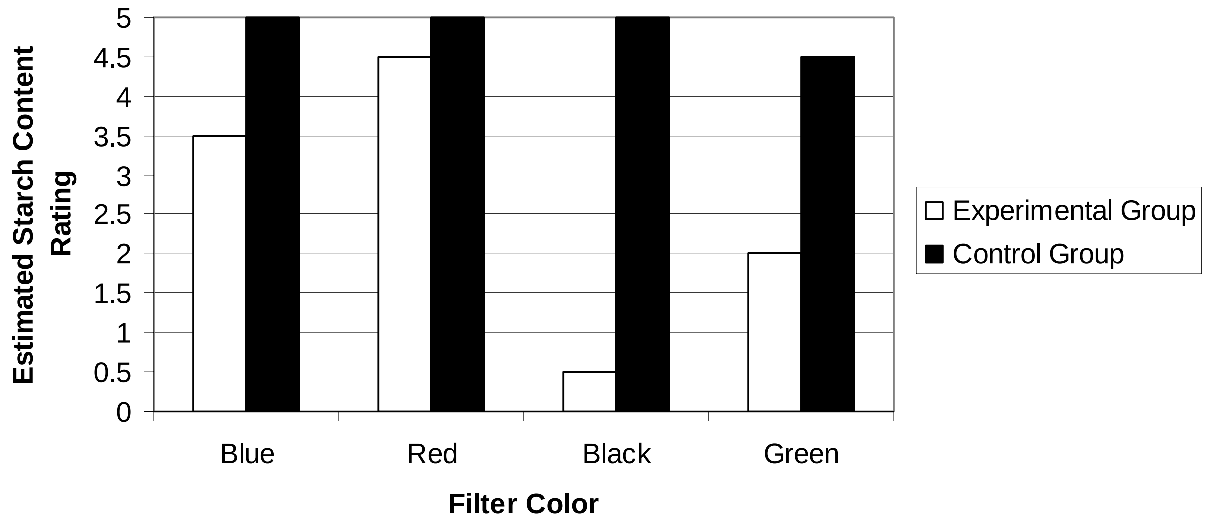
Each leaf with a treatment was pulled off the plant and distinct differences were made to each in order to tell the identity after the filters came off. Our identifying differences were the natural leaf size and petiole length. The identifying characteristics had to be made on areas of the leaf that were not covered by the paper or filters. The outline of each leaf was traced, and the filter locations were marked on the sketches. An alcohol bath was set up by putting 300 ml water into a 1,000 ml beaker. A 400 ml beaker was filled with 200 ml of ethyl alcohol and set into the 1,000 ml beaker. Both were placed on a hot plate and brought to a gentle boil. Once the water began to boil, the filters and paper were removed and set aside while each leaf was placed into the alcohol with forceps. The leaves were removed when they were almost white and placed into separate petri dishes. Distilled water was added to each dish, until the bottom of the dish was covered and the leaves were allowed to soak. Drops of I_2KI solution were added to the petri dishes. I_2KI solution was added until the outline of the paperclip could be seen on each leaf.

IV. Results

A subjective scale, from 0 to 5 was created to rate the colors found underneath and outside of the filters. The areas where the least amount of starch was found were amber and given the rating of 0, and areas where the most amount of starch was found were black and given the rating of 5. Our scale was applied to the results of one other group and the two sets of ratings were averaged.

The ratings for the experimental and control groups are shown in Figure 1. The leaf that had the blue filter showed high starch content in the control area as well as the experimental area. The control area was rated a 5 and the experimental area was rated a 3.5 (Fig. 1). The red filtered leaf was black in the control area and was rated a 5 and had the highest starch content rating in the experimental area of a 4.5 (Fig. 1). The leaf that had the green filter showed high starch content in the control area with a 4.5 and a low starch content in the experimental area with a 2 (Fig. 1). The leaf with the black paper showed two different, opposite ratings in the experimental region for our group and one rating for the group that we compared against. Our leaf was rated a 5 in the control area with parts of the experimental area being rated a 1 and other parts being rated a 5. In averaging the starch content in the black papered leaf, the 5 found in our group was thrown out because the other group's black paper leaf showed a rating of 0 in their experimental region. We used our rating of 1 and their rating of 0 to get a rating of 0.5 in the experimental area (Fig. 1).

Fig 1: A comparison of estimated starch content in geranium leaves in areas covered by filters and areas not covered by filters



V. Discussion

The darker areas that were left uncovered did the most photosynthesis because they were unimpeded in their light intake. Figure 1 shows that the uncovered area on the leaves that had the blue, red, and black filters had a rating of 5 and the leaf with the green filter had a rating of 4.5. The hypothesis is supported when the starch content rating of the control and experimental areas of the red filtered leaf are compared. The red filter, with a rating of 4.5 in its experimental region and a 5 for its control region, produced more starch than the other leaves (Fig.1). The red wavelengths that reached the area under the red filter were just as useful to the leaf as the broad spectrum of wavelengths that reached the uncovered area of the green filtered leaf. This is shown by their identical rating of 4.5 in starch content (Fig. 1). The red filter absorbed green and blue wavelengths and transmitted red wavelengths that the leaf was able to use for photosynthesis. Chlorophyll absorbs wavelengths of light when they are on either end of the light spectrum and the red filter allowed red light to come through (Vogelmann & Han, 2000).

The leaf with the blue filter was also productive in its process of photosynthesis. Its starch content rating was 3.5 in the experimental group which compared well with its rating of 5 in the control group (Fig. 1). The area underneath the blue filter was successful for the same reason that the area underneath the red filter was successful. The blue filter absorbed red and green light while it transmitted blue light that the leaf used for photosynthesis. Blue light as well as red light is absorbed well by chlorophyll and both colors are optimal for starch production (Lawlor, 1987).

The red and blue filters were close in their starch content ratings, but red light seemed to be the more optimal wavelength. A leaf can use both red and blue light for photosynthesis, but from the ratings, red light is better than blue light. This makes me think that either chlorophyll a or chlorophyll b is more prominent in absorbing wavelengths and using what they absorb. It would be interesting to know which chlorophyll absorbs blue and which one absorbs red light and why red is more productive in photosynthesis. Another question would be whether the light's energy has anything to do with photosynthesis. Although You and Barnett (2004) found that high energy light, such as blue light, could have too much energy for successful sugar production, this study was done using algae and not a green, leafy plant like geranium. Studying the effects of high energy light on higher plants might help to explain why the blue filter did not have as much starch present underneath it as the red filter did. If photosynthesis works best with certain wavelengths of light, it might also work best under certain energies of light. This experiment leaves me with two questions: which chlorophyll absorbs which wavelengths and what energies of light are optimal?

The leaves with the red and blue filters were the most productive, but the green filter had some starch underneath it too. The leaf with the green filter received a rating of 2 in the experimental region and 4.5 in the control region (Fig.1). The green filter absorbed red and blue light and reflected and transmitted green. Chlorophyll does not absorb green and yellow wavelengths and this is shown by the fact that we see reflected green wavelengths when we look at plants (Massa, Carabella, & Fornasari, 1997). Since chlorophyll does not absorb green light well, it was not able to make much use out of the available light and was not able to produce as much starch as the control or the blue and red filters. However, with a rating of 2, the leaf did use some of the light for photosynthesis. Green wavelengths are not the best but they were not completely useless in this geranium leaf either. There are pigments in the leaf other than chlorophyll that, when used in combination, absorb much of the light spectrum (Lawlor, 1984). This particular green that the filter transmitted may have been near the blue end of the spectrum where the plant could absorb it or was absorbed by the other pigments.

The fourth leaf with the black paper was somehow able to use light to produce starch in certain areas and not able to produce it in others. Our leaf had a rating of 5 in the control area and two different ratings in the experimental area of 1 and 5. We don’t know why the black paper enabled photosynthesis to happen and can only guess that the paper wasn’t secure enough and let some light through. With the 5 rating disregarded in the averaging of our results, the experimental area is left with an average rating of 0.5 (Fig. 1). Being close to a rating of 0, this area produced practically no starch and it’s safe to say that black is not a color that is successful at aiding photosynthesis. That would make sense seeing as how black absorbs all light (Fehrman & Fehrman, 2004). With all of the wavelengths being absorbed, there are none left to be transmitted into the leaf for photosynthesis.

VI. Literature Cited

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