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Effect of UV-C light on the Growth of *Begonia dregei* and *Begonia arching* plants

Ishaan Saran[1] and Kevin DAmico[#]

[1]Thomas Jefferson High School for Science and Technology, Alexandria, VA, USA
[#]Advisor

ABSTRACT

Exposure to UV light can cause damage to DNA strands, but can also be used as a disinfectant. This study sought to investigate how UV-C light affected the growth rate of *Begonia dregei* and *Begonia arching*. The plants were split into 4 different treatment groups, with each group containing one *Begonia dregei* and one *Begonia arching*. Each group was treated with a certain amount of UV-C light time using a light box before they were allowed to grow under ideal conditions. Once the plants were done with treatment, they were grown in ideal indoor environmental conditions for 18 days. The data showed results proving that as UV-C light treatment time increased the growth rate of the plant decreased; however, it did not prove if the 15-second treatment group grew more or less than the 0-second group. Limitations in the potential of confounding variables and measurement errors could have interfered with the data, which is why definitive conclusions can not be drawn, but the experiment still contributes to the current body of knowledge on the vast subject. This study may set the ground for further research than can be conducted and practiced in the agricultural field.

1 Introduction

1.1 Pesticides

One of the biggest problems in today's era is climate change, which is partly caused by the use of pesticides in agriculture. The negative effects of climate change are well known including drastic changes to weather patterns and prolonged periods of extreme temperatures. Climate change affects countless animal species and populations all around the world, including humans, by destroying habitats and diminishing sources of food and water. The primary cause of climate change is the emission of greenhouse gases, particularly carbon dioxide, into the atmosphere. While pesticides are not the only cause of climate change, their impact on the atmosphere is significant. This is because pesticides release three harmful gases, carbon dioxide, methane, and nitrous oxide, while they are manufactured, transported, and used (Peterson, 2021). Besides climate change, pesticides also affect the water quality of different habitats. When pesticides make their way into water bodies, they make the water toxic which ends up affecting populations of animals in the water. A different method for disinfecting plants and crops may be more desirable for people and animals on the planet as a whole.

1.2 UV Light in Science

UV light has been a popular topic in recent sciences, as its practical uses are being researched and adopted. A couple of the most common practices of UV light, currently, are its use to analyze and change chemical structures (Holton et al., 2017). There are three different kinds of UV light: UV-A, UV-B, and UV-C; furthermore, UV-A has the lowest frequency and UV-C the highest. Early experiments have proven UV light's ability to cause breaks in DNA strands of organisms (Rastogi et al., 2010). Other experiments have shown that these breaks inhibit DNA replication which causes the cell cycle of organisms to also slow down, or even stop completely (Jiang et al., 2011). On the other hand, UV light can be used, with precision, to make intentional changes to DNA strands (Kovanda et al., 2012).

Another practice that recently became extremely popular was the use of UV light for disinfection. During the COVID-19 pandemic, people more commonly began to turn to UV light as a source of protection from bacteria and germs. Eventually, people started using UV light to disinfect their masks, gloves, phones, etc. Experiments were even conducted to investigate the effect of UV light on respiratory masks, with data showing positive results (Ontiveros et al., 2021).

If UV light can be used to disinfect masks, it may be possible to use this practice on plants. For example, shining UV-C light on plants may eradicate any harmful bacteria or germs. However, if a plant is shone with UV light, it will also go through negative effects such as DNA strand breaks, which won't let it grow.

1.3 Purpose

Shining UV light on plants would have positive effects: killing harmful bacteria/germs, and negative effects: DNA strand breaks. The study was focused on two different Begonia plants, *Begonia dregei,* and *Begonia arching*. Multiple plants were all treated with a certain amount of UV-C light before they were allowed to grow under ideal environmental conditions. The goal was to determine if the group of plants that were treated for only a short amount of time grew more than the group that was not treated at all. I hypothesized that the group of plants that were treated for the shortest amount of time (not 0 seconds) would grow the most because it would not undergo many if any DNA strand breaks, and some of the harmful bacteria/germs would be eradicated.

2 Methods

2.1 Overview of the Begonia Plants

Two different types of Begonia plants were used in this experiment: *Begonia dregei* and *Begonia arching*. *Begonia dregei* plants are not flowering plants compared to Begonia arching plants that produce white flowers; additionally, *Begonia dregei* plants tend to grow wider and not as tall as *Begonia arching* plants. The plants were split into groups based on their species to make comparisons more accurate. Both types of Begonia were a superior option to other plants as they possessed characteristics that complemented the experiment. For example, Begonias do not need a great amount of sunlight which allows them to be great indoor plants as long as they receive natural sunlight for a couple of hours every day. Because they can flourish indoors, countless confounding variables which can happen outside are disregarded.

2.2 Procedure

The plants were split by species, Group 1 consisted of only four *Begonia dregei* plants and Group 2 consisted of only four *Begonia arching* plants. Then, one plant from each group was placed in a level of treatment time. The process included treating the plants with a certain amount of UV-C light time, and then letting them grow for 18 days with a controlled amount of water, sunlight, and other environmental conditions. The levels of treatment times were 0 seconds, 15 seconds, 60 seconds, and 300 seconds. To do this, each group was placed in the UV-C lightbox, as shown in Figure 2, and treated for the desired time. The highest level of treatment time, 300 seconds, is the negative control; and, the lowest level, 0 seconds, is the positive control. All plants are measured for height, width, and physical appearance, every three days so that a pattern can be established. Height and width are measured to calculate growth rates, and physical appearance was observed to analyze qualitative results. The growth rate is calculated using the equation shown labeled Equation 1.

Equation 1. An equation to calculate the growth rate in cm/days of a plant, x_f is the final measurement, x_0 is the starting measurement, and t is the time in days.

$$growth\ rate = \frac{(x_f - x_0)}{t}$$

2.3 Instruments and Materials

UV-C light can be highly damaging to the recipient if seen directly (Holton et al., 2017); therefore, proper precautions need to be held when setting up the experiment. A light apparatus was used to irradiate the plants or treat the plants with UV-C light (Figure 1). The device included a shoe box (or any opaque box with a detachable lid) with a hole cut into the side, a UV-C light rod (preferably one that can be operated using a switch), and tape. To create the contraption firmly attach the UV-C light rod to the lid of the box using tape. The box needs a hole so that the scientist conducting the experiment can tell if the UV-C light is on without looking directly at it. The UV-C light used in the experiment was pluggable and operated using a switch for efficiency, as shown in Figure 1. Furthermore, the box used in the experiment measured 28.6cm x 16.5cm x 10.9cm. The other crucial components of the experiment are the plants. The experiment used *Begonias* for multiple reasons, as discussed in 3.1. To obtain the most accurate results, identical plants, or plants of the same genus, are ideal. If the experiment will be conducted indoors, scientists should consider plants that do not need high amounts of sunlight because that would be difficult to accomplish and may affect the outcome of the experiment.

Figure 1. UV-C lightbox with the lid off

Figure 2. UV-C lightbox with the light and lid on

2.4 Limitations

Although placing the plants inside protected the plants from outdoor conditions, there could have been some indoor variables that affected the experiment. Particularly, insects may have tampered with one or more plants or the soil of one plant may have been more nutritious than another; however, having multiple plants for each trial mostly offsets these possible scenarios. Furthermore, because plants grow in an S-shaped curve (Robinson, 2021), certain plants may have grown more because they were in a more maturing stage during the experiment.

3 Results

Table 1 displays the raw data that was measured using a ruler (cm) on all eight plants. Data from four groups of plants with different UV-C light treatment times are listed.

Table 1. Raw Data

UV-C Light Treatment Time	Plant Group	Plant Type	Time (Days)	Height (cm)	Width (cm)
0 seconds	1	Dregei	0	7.2	11.4
0 seconds	1	Dregei	3	8.7	12.1
0 seconds	1	Dregei	6	10.4	12.7

0 seconds	1	Dregei	9	10.9	14.3
0 seconds	1	Dregei	12	11.2	14.8
0 seconds	1	Dregei	15	11.6	15.1
0 seconds	1	Dregei	18	11.9	15.4
15 seconds	1	Dregei	0	6.6	11.1
15 seconds	1	Dregei	3	7.6	12.6
15 seconds	1	Dregei	6	8.4	13.8
15 seconds	1	Dregei	9	8.8	14.2
15 seconds	1	Dregei	12	9.1	14.8
15 seconds	1	Dregei	15	9.4	15.1
15 seconds	1	Dregei	18	10.6	15.9
60 seconds	1	Dregei	0	3.9	9.8
60 seconds	1	Dregei	3	4.1	10.5
60 seconds	1	Dregei	6	4.3	11.1
60 seconds	1	Dregei	9	4.8	11.3
60 seconds	1	Dregei	12	5.2	11.5
60 seconds	1	Dregei	15	5.5	11.8
60 seconds	1	Dregei	18	5.9	12.1
300 seconds	1	Dregei	0	3.8	7.5
300 seconds	1	Dregei	3	4.1	7.7
300 seconds	1	Dregei	6	4.2	7.9
300 seconds	1	Dregei	9	4.3	8
300 seconds	1	Dregei	12	4.3	8
300 seconds	1	Dregei	15	4.3	8
300 seconds	1	Dregei	18	4.3	8

0 seconds	2	Arching	0	11.6	13.5
0 seconds	2	Arching	3	12.3	13.6
0 seconds	2	Arching	6	13.4	13.7
0 seconds	2	Arching	9	14.2	14
0 seconds	2	Arching	12	14.9	14.2
0 seconds	2	Arching	15	15.7	14.3
0 seconds	2	Arching	18	16.4	14.4
15 seconds	2	Arching	0	14.5	12.5
15 seconds	2	Arching	3	15.2	12.6
15 seconds	2	Arching	6	15.6	12.7
15 seconds	2	Arching	9	16	13.1
15 seconds	2	Arching	12	16.5	13.3
15 seconds	2	Arching	15	16.8	13.5
15 seconds	2	Arching	18	17.8	13.8
60 seconds	2	Arching	0	12.7	13.6
60 seconds	2	Arching	3	13.1	13.9
60 seconds	2	Arching	6	13.3	14.5
60 seconds	2	Arching	9	13.7	16.1
60 seconds	2	Arching	12	14.1	16.4
60 seconds	2	Arching	15	14.4	16.7
60 seconds	2	Arching	18	14.8	17.4
300 seconds	2	Arching	0	7.5	9.4
300 seconds	2	Arching	3	7.6	9.6
300 seconds	2	Arching	6	7.9	9.8
300 seconds	2	Arching	9	8	9.9
300 seconds	2	Arching	12	8.1	9.9
300 seconds	2	Arching	15	8.1	10
300 seconds	2	Arching	18	8.1	10

Table 2 displays the growth rates in cm/days of the plants' height using Equation 1.

Table 2. Height Growth Rates

UV-C Light Treatment Time	Group #	Starting Height (cm)	Final Height (cm)	Time (days)	Growth Rate (cm/day)
0 seconds	1	7.2	11.9	18	0.261
15 seconds	1	6.6	10.6	18	0.222
60 seconds	1	3.9	5.9	18	0.111
300 seconds	1	3.8	4.3	18	0.028
0 seconds	2	11.6	16.4	18	0.267
15 seconds	2	14.5	17.8	18	0.183
60 seconds	2	12.7	14.8	18	0.117
300 seconds	2	7.5	8.1	18	0.033

Table 3 displays the growth rates in cm/days of the plants' width using Equation 1.

Table 3. Width Growth Rates

UV-C Light Treatment Time	Group #	Starting Width (cm)	Final Width (cm)	Time (days)	Growth Rate (cm/day)
0 seconds	1	11.4	15.4	18	0.222
15 seconds	1	11.1	15.9	18	0.267
60 seconds	1	9.8	12.1	18	0.128
300 seconds	1	7.5	8	18	0.028
0 seconds	2	13.5	14.4	18	0.05
15 seconds	2	12.5	13.8	18	0.072
60 seconds	2	13.6	17.4	18	0.211
300 seconds	2	9.4	10	18	0.033

The height growth rate of the plants is shown below in Figure 3, organized by group number.

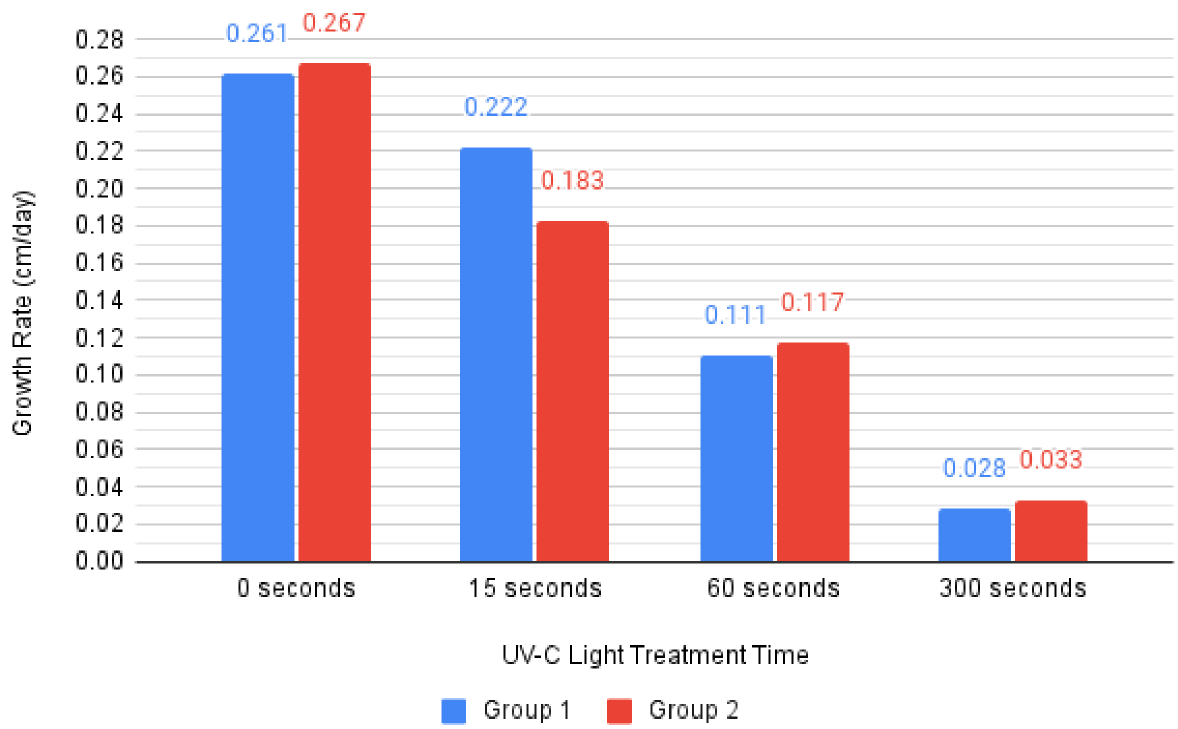

Figure 3. Height growth rate comparison between plants

The width growth rate of the plants is shown below in Figure 4, organized by group number.

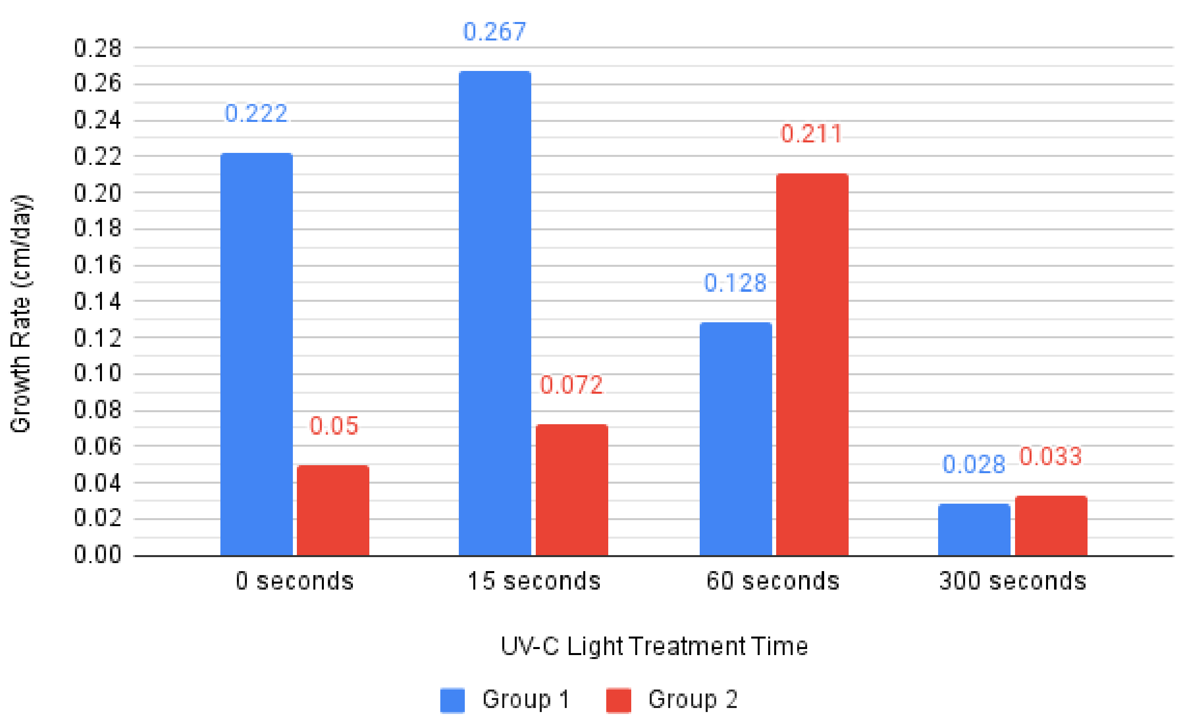

Figure 4. Width growth rate comparison between plants

Table 4 shows the changes in physical characteristics of the groups of plants over the 18 days.

Table 4. Changes in physical characteristics

UV-C Light Treatment Time	Group	0 days	18 days
0 seconds	1	Light green/dark green	Dark green
15 seconds	1	Light green	Dark green
60 seconds	1	Light green	Dark green, some weak brown areas
300 seconds	1	Light green	Brown, dead
0 seconds	2	Dark green	Dark green, 4 white flowers
15 seconds	2	Dark green, flower bud	Dark green, 7 white flowers
60 seconds	2	Dark green	Dark green, one small white flower
300 seconds	2	Dark green	Brown, dead

4 Discussion

4.1 Data Significance

Past studies have demonstrated results that signify the effects of UV light on slowing down the cell cycle process (Jiang et al., 2011). Therefore, it makes sense that when UV-C light irradiates the plants they tend to grow less, as the data implies. The data also shows that when the plants are irradiated for more extended periods of time (such as 300 seconds/5 minutes), they are unable to grow. This is likely because UV light causes breaks in DNA strands (Holton et al., 2017), inhibiting the DNA replication process. Without the DNA replication process, the plant cannot go through cell division; therefore, it is impossible for it to grow (Robinson, 2021). Figure 3 shows that the 15-second treated plants grew less than the 0-second treated, which is the opposite of Figure 4. This means that Figure 4 supports my hypothesis, whereas Figure 3 does not. Additional data may be necessary to determine if small amounts of UV-C light treatment time are beneficial to the plant.

4.2 Data Limitations

Measurements for height and width were done using a ruler. To get as accurate results as possible, using mass to measure growth rate could have also been a more reliable and efficient option. Furthermore, the data only showed the results on one genus of plants, results could differ on different plants. Lastly, the results cannot be used to draw definitive conclusions about UV light or disinfection on the plants' growth. The results can only show possible correlations.

5 Conclusion

The study was designed to investigate further the effect of UV-C light on the growth rate of plants. Data were taken from two different Begonia species: *Begonia arching* and *Begonia dregei.* All environmental factors were constant except for the amount of UV-C light treatment time the plants went through. The data did not show if short UV-C light treatment time was beneficial to the plant; however, it did show that extended treatment time was detrimental. UV-C light could also have major applications in the agricultural field. Table 4 shows that UV-C light can cause physical changes in plants, as also shown in other studies (Tevini, 1999). This can be extremely useful; for example, if UV light can be used to turn a plant from green to brown, without any negative effects, predators may leave the plant alone thinking it has decayed. Figure 4 suggests that a short amount of UV-C light treatment may be beneficial for the plant. This may be because of the disinfectant characteristics of UV light (Ontiveros et al., 2021). Perhaps if the plant goes through the correct amount of UV-C light treatment, it may get disinfected from harmful bacteria which could lead to positive effects on the growth rate. If this process is proven to work, UV light may be a better alternative to pesticides. Lastly, if future studies can prove that different plants have different UV-C light resistance, it can be used to kill invasive plant species or weeds. For example, if a fruit-bearing plant can resist up to one minute of UV-C light, but a weed can only withstand 30 seconds; then, a 30-second UV-C light treatment can be implemented to exterminate the weeds. The use of UV light in the agricultural field can be revolutionary, however, more research needs to be done to draw definitive conclusions.

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