What are the effects of differing herbal infusions (chamomile, linden, oregano, and sage) on the photosynthesis rate of the plant elodea (*Elodea canadensis*)?

Biology HL

Word Count: 3298

Table of Contents

Introduction

Research Question

What are the effects of differing herbal teas on the photosynthesis rate of the plant elodea (*Elodea canadensis*)?

Background

Herbal teas have been used by humans for a variety of purposes like treating illnesses or general wellbeing since they have been discovered in the early ages. A known fact about herbal teas is that they are known to have many benefits on physical and mental health of humans. Some herbal tea types are known to contain sedative compounds that tranquilize the consumer whereas some contain psychoactive compounds such as caffeine. Despite being known as “teas”, herbal teas do not actually contain tea (*Camellia sinensis*). They are technically herbal infusions. However, since they are prepared in a similar way when compared to teas, they have gained the nick name “tea”.

Herbal infusions can be made with any part of a plant; including their stems, dried or fresh flowers, fruits, leaves, seeds or roots. They are usually made with the dried components of plants since these parts are easy to soak up water and can release the nutrients that are wanted to be released. In some cases, sweeteners such as honey or spices such as cinnamon are added to the infusion for further taste or health properties. Therefore, herbal teas are easy to access and prepare. The most common way to prepare herbal tea is to infuse the part of the plant that is wanted with usually a cup of hot or cold water and then the infusion is left to steep for a short period of time.

Elodea is a part of the genus of eight species of aquatic plants. Elodea is most commonly used as aquarium vegetation and also for some research to observe cellular activities. Elodea is a common lake plant that is easy to access, making it easy to do research based on aquatic vegetation. Aquatic plants such as elodea (*Elodea canadensis*) have ooptimal conditions that they require to continue living. Elodea (*Elodea canadensis*) has an optimal water temperature of 15°C to 22°C. In the range of this optimal temperature, the plant grows most efficently and the rate of photosynthesis is at its maximum rate. Other than temperature, different aquatic plants live in different forms of water. Some plants live in salt water and some plants live in fresh water such as elodea. Furthermore, Elodea is a navive plant to America but some of its species have been transported to other continents such as Europe, Asia, Africa and is considered to be a noxious weed in these continents since it experiences rapid growth for five to six years then its growth slows down ince the nutrients of the soil are used up. Elodea is a key to aquatic wildlife since it provides habitat for aquatic invertebrates which are animals that do not have a spine either by not developing one or not retaining one.

In this extended essay, I will be observing the effect of differrent store-bought herbal teas (chamomile, linden, oregano and sage) to the photosynthesis rate of the elodea plant by adding the plant into a mixture of herbal infusion and lukewarm water.

Literature Review

Ever since herbal infusions have been found and utilized, there have been experiments that have researched the effects of the antioxidant and nutritional properties on human bodies. This situation can be researched as a fertilizer option for plants in general. There are many natural and home-made options for fertilizers such as a banana compost which is usually prepared as, similarly to an herbal infusion, the infusion of the outside layer, the peel, of the banana with water and this infusion is left to steep in room temperature water filled container which is left in a dark environment for one to two weeks before it is utilized. Since I was a child I have been observing the ways in which my mom, who is an agricultural engineer, used natural and home-made options of fertilizer to use for the many plants that we have been growing in our house, these methods are usually drastically cheaper and easier to prepare and access compared to store-bought fertilizers. However, I have never came up to any research in which actual herbal infusions are used as fertilizers or as supplements to make the photosynthesis rate increase in aquatic plants when I was looking for optional sources to when I would conduct the experiment.

Method

Experimental Procedure

This experiment will be conducted to observe the changes in photosynthesis rate depending on the type of the herbal infusion. The experiment will be conducted as the following steps:

1. The varying herbal infusions (chamomile tea, linden tea, oregano tea and sage tea) will be infused in 250 milliliters of boiling water (the tea bags will be added to separate cups, then boiling water will be added as instructed)
2. The herbal tea infusions will then be left to cool down to 22°C since it is the optimal water temperature for the plant.
3. Five different elodea roots of the same size will be added to 500 ml beakers.
4. 250 ml of water at 23 degrees celcius will be added to each beaker.
5. The time (30 minutes) that the herbal infusions cool down to the optimal temperature equal amounts (250 ml) will be added to each group
6. One control group will be left without any herbal infusions and will only be added 500 mL of water.
7. A root will then be picked and cut to make it 10 centimeters.
8. Each root will be individually put into the beaker and the tip of the root will be cut off by a small portion to promote photosynthesis.
9. They will be observed by test tube and funnel apparatus method and the bubbles around the tube will be counted for thirty seconds after five minutes have passed after the apparatus had been set up.
10. Step seven, eight and nine will be repeated until all infusions and the control group are tested with five roots of elodea.

Variables

The independent variables in this investigation are the varying herbal infusions, which are; chamomile tea, linden tea, oregano tea and sage tea. There will also be a control group of only tap water included in the experiment. The dependent variable in the experiment will be the bubble number, which will indicate the photosynthesis rate directly show change depending on the type of herbal infusion.

Data Analysis

	Water	Oregano	Sage	Chamomile	Linden
Trial 1	15	2	2	4	0
Trial 2	14	1	4	5	1
Trial 3	17	3	4	6	0
Trial 4	19	0	3	5	0
Trial 5	22	4	2	6	2

Table 1: Table showing the raw data of the herbal infusions and the control group.

	Water	Oregano	Sage	Chamomile	Linden
Mean	17.4	2	3	5.2	0.6
Standard deviation	3.21	1.58	1	0.84	0.89

Table 2: Table showing the mean and the standard deviation of the herbal infusions and the control group.

The results indicate that infusions from herbs have a significant effect on *Elodea canadensis'* photosynthesis rate, and varying degrees of inhibition are noted for varying infusions. Control group in which only water was present recorded the highest rate of photosynthesis throughout the observation of the bubbles that have formed around the test tube, and a significant reduction in oxygen bubble formation was noted with infusions from chamomile, linden, oregano, and sage. Among all infusions, linden tea was most inhibitory, with photosynthetic activity being virtually eliminated since 60% of the trials showed no signs of photosynthesis. These results point to certain elements in infusions from herbs inhibiting the plant's ability to perform photosynthesis through most likely chemical interactions with chloroplast function or gas exchange. Differences in levels of inhibition indicate that each tea from herbs has a different chemical composition and hence a different effect on photosynthesis.

Analysis of Variance (One-Way)

Descriptive Statistics

Groups	*Sample size*	*Sum*	*Variance*	*Std Dev*	*Mean*	*95% Confidence Interval**

	1	5	87,0000	10,3000	3,2094	17,4000	13,4151	21,3849
	2	5	10,0000	2,5000	1,5811	2,0000	0,0368	3,9632
	3	5	15,0000	1,0000	1,0000	3,0000	1,7583	4,2417
	4	5	26,0000	0,7000	0,8367	5,2000	4,1611	6,2389
	5	5	3,0000	0,8000	0,8944	0,6000	-0,5106	1,7106
Total		25		40,9067	6,3958	5,6400		

Confidence intervals are calculated using individual standard deviations.

ANOVA

Source of Variation	d.f.	SS	MS	F	p-value	F crit	Omega Sqr.
Between Groups	4	920,5600	230,1400	75,2092	9,1943E-12	2,8661	0,9223
Within Groups	20	61,2000	3,0600				
Total	24	981,7600					

Bonferroni

Alpha/N	0,0050				
Group vs. Group (Contrast)	*Difference*	*95% Confidence Interval*		*Test Statistic*	*p-value*
1 vs 2	15,4000	11,9113	18,8887	13,9197	9,4708E-11
1 vs 3	14,4000	10,9113	17,8887	13,0158	3,1927E-10
1 vs 4	12,2000	8,7113	15,6887	11,0273	5,9634E-9
1 vs 5	16,8000	13,3113	20,2887	15,1851	1,9189E-11
2 vs 3	-1,0000	-4,4887	2,4887	0,9039	1,0000
2 vs 4	-3,2000	-6,6887	0,2887	2,8924	0,0901
2 vs 5	1,4000	-2,0887	4,8887	1,2654	1,0000
3 vs 4	-2,2000	-5,6887	1,2887	1,9885	0,6061
3 vs 5	2,4000	-1,0887	5,8887	2,1693	0,4229
4 vs 5	4,6000	1,1113	8,0887	4,1578	0,0049

To understand the statistical differences among experimental groups, one way ANOVA test was conducted. As summarized, The Anova test results revealed that there were clear differences between specific group comparisons.

Descriptive statistics

The means and standard deviations for each group were calculated for conducting the ANOVA test. Group 1 had the highest mean value. The order was group 1,5,2,3,4 in descending order. These differences showed a potential variation in the biological responses measured in the research. Descriptive statistics The means and standard deviations for each group were calculated for conducting the ANOVA test. Group 1 had the highest mean value. The order was group 1,5,2,3,4 in descending order. These differences showed a potential variation in the biological responses measured in the research.

ANOVA Test Results

The ANOVA test has resulted in several statistically significant results. Specifically, comparisons of *group 1 vs. group 2*, *group 1 vs. group 3*, *group 1 vs. group 4, and group 1 vs. group 5* yielded p-values of *0.0*, indicating extremely strong significance since the p value is less than 0.05. This suggests that the biological responses in Group 1 showed significant differentiation from those in the other groups.

Further post-hoc tests were conducted to identify where the significant differences occurred. The *2 vs. 4 comparison ($p = 0.008451$)* also demonstrated statistical significance, indicating that Group 2 exhibited a clear different response compared to Group 4.

However, comparisons *2 vs. 3 ($p = 0.375852$), 2 vs. 5 ($p = 0.218957$), and 3 vs. 4 ($p = 0.059334$)* were not as statistically significant, as their p-values exceeded the 0.05 limit.

Interpretation of Findings

The results indicate that Group 1, the control group, had an obvious different response compared to other groups, which is an expected response since group 1 is the control group. Additionally, Group 2 and Group 4 also had differences, suggesting potential underlying chemical properties of the infusions affecting their responses.

The non-significant comparisons suggest that, despite variations in mean values, the differences observed between those groups were likely due to random variation rather than a true effect of the experimental conditions.

Conclusion of the ANOVA Test Results

The ANOVA test results support the hypothesis that there are significant differences in biological responses among some of the experimental groups. The findings show the importance of further investigating the factors influencing these variations, especially in Group 1, which differed the most.

Future research could explore the specific mechanisms driving these differences through additional experimental trials and more detailed statistical analyses.

Evaluation

The test successfully showed that herbal infusions have a significant effect on the rates of *Elodea canadensis*' photosynthesis, with individual infusions having a more severe effect than others. The introduction of a control sample made only from plain water created an accurate reference point against which to compare, allowing differences in the results to be attributed to the presence of herbal content within the test groups. Statistical analysis by the ANOVA test confirmed there to be statistically significant differences between the groups, and as a result, supported the hypothesis that herbal infusions have a significant effect on suppressing rates of photosynthesis. While trends showed an obvious result, there were a number of key limitations built into the test methodology that must be taken into account.

One major issue in the present research relates to the methodology used to determine the rate of photosynthesis. While the technique involving counting bubbles is mostly used in pedagogical contexts because it is simple to perform, it is unsuitable where quantification is required with more accuracy. This technique is based on visual counting, and as a result, is susceptible to errors in counting and variability between measurements. The use of a more accurate technique, e.g., an oxygen probe or dissolved oxygen meter, would provide quantitatively better results and compensate for possible biases. Another drawback in the study was the sample size used. The experimental setup only used five repetitions per group, which, although convenient to determine trends, is not large enough to represent behavior in a large population. More repetitions would increase the strength of the statistical analysis and ensure that results are not an artifact caused by random errors. Moreover, although a certain level of control was maintained over the temperature by heating the infusions beforehand before their interaction with Elodea canadensis, other environmental variables, e.g., light intensity and pH variation, remained uncontrolled. Light is an important factor in the process of photosynthesis, and slight variation may have effects on the results. Likewise, no pH measurements on the herbal infusions were made, which may be an important variable affecting the process. Some plants contain basic or acidic components that may destabilize the aqueous environment, and consequently affect enzymatic activities in the plant. Future studies should include pH measurements and a controlled light source to reduce extraneous variables that may affect the validity of the results.

The preparation of the herbal infusions represented an uncontrolled variable in the experiment. While the results showed that the herbal infusions inhibited photosynthetic processes, the exact compounds responsible for inhibiting them have not yet been identified. Different herbal teas contain tannins, flavonoids, alkaloids, and other phytochemicals, any one of which may interfere with chloroplast activities or gas exchanges. Performing a chemical analysis on the components found in every infusion would provide more insight into how individual components contribute to the effect.

In addition, infusion concentrations did not change throughout the experiment; however, one should recognize that these concentrations can vary, and as a result, their inhibitory effects may change. Higher concentrations may have a greater inhibitory effect, and diluted infusion may reduce their effect. Future studies could investigate how differing infusion concentrations affect the rates of photosynthesis, and so increase our understanding of how these substances contribute to plant physiological processes.

Weaknesses

One important limitation of the study is related to the research methodology used. As earlier explained, the bubble counting technique is subjective and prone to errors, making it less reliable compared to other methods that could have been used for measuring oxygen levels. In addition, while using *Elodea canadensis* as the test plant, the study failed to determine if the effects caused by herbal infusions would show consistency across various plant species. This limitation negatively affects the external validity of findings, especially in consideration of the fact that other plant species could respond differently to the chemical compounds present in herbal teas.

The test parameters showed certain discrepancies. Though the technique used to infuse the herbal teas was done uniformly, variation in steeping times and in temperature could have had an effect on the range of chemical components extracted. In addition, there was no investigation regarding the time scale of the inhibitory action. One can only speculate as to whether the effect on the rate of photosynthesis is only a temporary effect, or prolonged exposure may lead to permanent damage to *Elodea canadensis*.

One of the identified limitations is related to the lack of exploration of recovery mechanisms. The study only measured the photosynthetic rate immediately after the infusion treatment, without determining if *Elodea canadensis* has the ability to recover and restore to its original level of photosynthesis if exposed again to pristine conditions. Another study could be designed to test the recovery ability of the plant over a given timeframe, thus providing valuable insight into the reversibility or irreversibility of the infusion-induced damage.

Conclusion

This research has produced significant results with respect to the effect of herbal infusions on *Elodea canadensis*'s rate of photosynthesis, showing that regularly used plant infusions negatively influence the health of aquatic plants. The results showed a significant reduction in oxygen bubbles produced, which is directly related to a decrease in the level of photosynthesis. Out of the range of herbal infusions tested, the most significant effect was that of linden tea, greatly suppressing visible photosynthesis in most experiments. Chamomile, oregano, and sage infusions also showed inhibitory effects, though to varying degrees. The control experiment, which only used plain water, showed the highest level of production in all experiments, thus supporting the case that herbal infusions hinder natural photosynthetic activities.

The strong statistical significance found in the results from the ANOVA confirmed that the differences identified could not have been due to chance, but rather truly reflect the direct effects of the herbal infusions. This was supported by the post-hoc Bonferroni tests, where the control only showed significant differences compared to all the experimental groups, thus confirming that certain infusions had very distinct effects compared to others. From the inference, the chemical compounds found in herbal infusions have an important role to play in determining their effects on the process of photosynthesis. The exact ways in which these inhibitions take effect, though, are vague and more research is required. One viable explanation for the inhibitory effects observed in this study relates to the bioactive compounds present in the infusions. Many plant species contain polyphenols, flavonoids, tannins, and essential oils, which have the potential to interfere with chloroplast performance, enzymatic activities, or gaseous exchange processes in aquatic plants. Some of these compounds have antimicrobial or antifungal activities, potentially disrupting the sensitive balance between cellular processes within the organism. Additionally, certain herbal infusions have been found to alter the pH level of the surrounding medium, thereby affecting the plant's ability to absorb nutrients or to establish homeostasis. Inasmuch as pH change was not measured in the present study, it is possible that chemical alteration to the surrounding environment was responsible for the reduction in plant performance.

Ecologically, the findings of this study elicit important questions about the potential environmental effects caused by herbal infusions when introduced into aquatic environments. Given the fact that herbal teas are normally consumed and then drained through household plumbing systems or discharged into external environments, residual components may accidentally find their way into natural water sources. If these compounds causing inhibition of photosynthesis remained active in these aquatic systems, they might become harmful to aquatic plant communities. An incidence could therefore destabilize complete ecosystems, as aquatic plants play important ecological roles by producing oxygen, supporting habitats for aquatic fauna, and providing a nutritional resource to herbivores. More studies are required to determine if herbal infusions affect other aquatic plant populations to the same extent and if these effects are temporary or permanent.

Another important consideration is the relevance of these findings outside of *Elodea canadensis*. This species was selected due to its availability and the prevalence of documentation regarding its use in photosynthesis studies; however, it is still possible that other aquatic plants would respond differently to herbal infusions. Some species may be more resistant to the chemical effects of these infusions, while others may be significantly more sensitive. Investigating a wider range of aquatic plant species would help to determine if this is a species-specific phenomenon or reflective of a more pervasive environmental problem.

Furthermore, the experiment is an avenue to explore potential uses of herbal infusions in agricultural and aquatic plant control. For example, if certain herbal extracts are confirmed to consistently reduce photosynthesis, they may be tested as natural ways to contain the spread of unwanted aquatic plants in areas where it causes ecological imbalances. Alternatively, other studies may reveal certain phytochemical components that enhance photosynthesis, opening the door to the development of green fertilizers or plant supplements.

Despite the obvious inhibitory effects reported in this study, the exact interactions between plant compounds and the process of photosynthesis are still uncertain. Future research studies should aim to determine the particular phytochemical components responsible for these effects by means of chemical analysis techniques including chromatography or spectrophotometry. Additionally, it would be helpful to conduct long-term experiments to determine if exposure to herbal teas causes permanent physiological change in *Elodea canadensis*, or if the organism is able to recover when returned to favorable conditions.

In conclusion, while herbal infusions have long been recognized for their potential therapeutic benefits to humans, their effects on plant organisms, and especially aquatic plants, represent a largely untapped area of research. The current research has shown that herbal infusions substantially inhibit the process of photosynthesis in *Elodea canadensis*, with certain infusions having more significant effects than others. The exact mechanisms underlying these inhibitory effects have yet to be fully established; however, they are likely to be due to chemical interactions affecting chloroplast function, aqueous chemistry, or cellular respiration pathways. These findings have important implications for both plant biology and environmental science, highlighting the need for further research into the effects of plant-derived chemicals on ecosystems. A more complete understanding of these interactions could allow for better environmental management practices, foster more sustainable agricultural systems, and enhance appreciation of the interdependent relationships between plants and their environment.

Bibliography

Azab, Mohamed. “Effects of Herbicides on Aquatic Plant (Elodea Canadensis) Vorgelegt von Mohamed Azab.” *Effects of Herbicides on Aquatic Plant (Elodea Canadensis) Vorgelegt von Mohamed Azab*, 2000.

Simpson, Philip Stanley. “Photosynthesis and Respiration in Elodea Canadensis Michx.” *Photosynthesis and Respiration in Elodea Canadensis Michx*, University of Liverpool, 1981.