The Germination of an Experimental Study Indulging Strawberries

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Introduction

Strawberries are a commonly grown fruit amongst farmers due to the resilience of their roots and their ability to sustain themselves during colder conditions. (Rohr, 2022, p.1) As a result, industrial farmers who hope to gain a lucrative advantage using these berries often employ chemical fertilizers to assist the development of strawberries; this can have detrimental influences on a wide variety of people. (EPA, 2022, p.1) This issue sets the foundation of my research project, which is to address the question "How does the addition of exogenous sugars that consist of primarily monosaccharide components into the water of strawberry roots influence their growth during the winter?" Ultimately, my purpose is to explore a potential alternative to using chemical fertilizers which are integrated in the growth of the strawberry plants, and can improve their development and compatibility with the environment. To determine if there is a significant difference between the inclusion of monosaccharides into the strawberry roots, the growth rate of the roots is required. To obtain this data for further statistical analysis, I will be conducting an experimental study that collects the numerical measurements of the roots as the monosaccharide treatment is added to the water of the plants. In this study, "exogenous sugars" refer to sugars that enter strawberry from an external source and "monosaccharides" are the monomers of carbohydrates. The concentrated form of monosaccharides that I will be adding to the plants is honey and for this experimental design. I will only be using honey and strawberry roots that are non-GMO and non-enhanced soil, essentially organic.

Significance of the Issue

While the research I am conducting will aid farmers regarding their environmental concerns with the nurturing of their strawberries, it will also assist surrounding communities and the soil used to grow the crops. Previous studies examining chemical fertilizers have shown that they affect surrounding communities through runoff by waterways such as “rivers, ponds, lakes and even coastal areas”. (Reddington, 2009, p.1) Along with contaminating areas through various bodies of water, the chemical fertilizers also leak into the soil sustaining the strawberry plants, and the fertilizers reach the groundwater underneath. Not only do they cause “changes in bacterial community structure” (Bai et al., 2020, p.1) by killing microorganisms abetting the germination of the strawberry plants but they also “leach to groundwater” (Keena et al, 2022, p.5), which is used for consumption purposes. If nearby populations, unaware of these implications, use this heavily contaminated water as sustenance, it could lead to severe health problems for current and future generations, such as cancer. By using honey, a natural source of carbohydrates, the contamination concern with the chemicals in fertilizers could potentially decrease through the replacement.

Literature Review

Finding the Juxtapositions: Organic vs. Chemical Fertilizers

In order to implement a more environmentally efficient method of assisting strawberry plants during the winter, it is necessary to avoid using fertilizers that contain harsh chemicals and find aid from natural sources instead. Alisha Patil, writer at Earth.Org, has suggested the use of organic fertilizers as they have the potential to “transform agricultural practices and improve environmental sustainability” (Patil, 2023, p.1) while containing carbon-to-carbon chains that are familiar to the environment. To reinforce this idea, Doctor Weiwei Lin and his colleagues conducted an experimental study where they analyzed the effects of organic fertilizers and chemical fertilizers on tea orchards and their rhizosphere soil. They found that the organic fertilizers decreased the amounts of heavy metals in the soil, which made the environment healthier for the tea orchards. (Lin et al., 2019, p. 13) However, the results of the experiment also illustrated that the nitrogen concentration levels “were not significantly different” in the two treatments, indicating that the organic fertilizers stimulated the same amount of nitrogen in the soil as the chemical fertilizers. A major issue with chemical fertilizers is the excess of nitrogen fused with hydrogen to create liquid ammonia, the main component in these fertilizers. While nitrogen is an essential chemical element for plants, a plethora of nitrogen becomes a weapon and transforms into a pollutant for crops through the form of chemical fertilizers (Pradhan, 2020, p.1). Not only can they damage the integrity of the crops, but they are also a significant contributor to global warming, as excess nitrogen in the soil can continuously raise the temperature of the atmosphere. If organic fertilizers contain the same amount of nitrogen as chemical fertilizers, there is no tangible improvement to environmental sustainability.

The idea of nitrogen proliferating through the use of organic fertilizers is also supported by the content analysis that Professor Yi Wang and his colleagues conducted. From their data, they deduced that the organic fertilizer “significantly increased the soil carbon and nitrogen” of their vegetation. (Wang et al., 2023, p.2) This study concluded that organic fertilizers emulate the same effects that chemical fertilizers have on the environment, supporting the idea that organic fertilizers are equally as damaging. In contrast, the research that I will be conducting uses raw honey, a natural source, that consists primarily of monosaccharides, “17% to 20% of water” (Kamal and Klein, 2010, p.1), and only 0.003% of nitrogen. Since honey contains very little nitrogen compared to known organic fertilizers and chemical fertilizers, it demonstrates the capability of honey being a potential environmentally friendly alternative to using existing fertilizers. Through the integration of this carefully selected natural substance, I plan to address the gap concerning the lack of environmentally sustainable fertilizers that include little to no harsh chemicals affecting the structure of the plant.

The Versatile Functions of the Monosaccharides

Strawberries may not exhibit a positive effect with the addition of monosaccharides externally, but the importance of these carbohydrates is displayed through their variety of functions. Strawberries are able to grow and withstand tough environmental conditions due to high amounts of antioxidants in their system. The purpose of these antioxidants is to allow the strawberry to respond to external conditions and preserve its homeostasis, enabling it to thrive in colder temperatures. (Pineli et al., 2011, p.2) While antioxidants are important, they can only be made through the use of NADPH, an electron carrier used in the process of photosynthesis to make glucose. This metabolite not only provides reducing agents for cellular processes but also acts as an electron donor that is essential for making these antioxidants. (Arese et al, 2012, p.2) Looking further into the composition of NADPH, it is seen that NADPH is not made specifically for durability purposes but made as a byproduct. As glucose is being converted into pentosephosphates, the process "produces reducing power in the form of NADPH". (Kasote et al., 2015, p.4) Fundamentally, the strawberry's ability to survive comes from the functions and the composition of glucose; not only does glucose modify into a source of usable energy by the mitochondria, but it also generates substances that are necessary for the strawberry to develop. In addition to glucose, another monosaccharide provides important sustenance for the strawberry's endurance. Dr. Tahir Mahmood and his fellow researchers administered a content analysis where they analyzed the amount of different types of sugar at various maturity stages in strawberries. From their study, they found fructose rates to be significantly higher than glucose and sucrose during all of the stages, making it the main source of sugar for the plant. (Mahmood et al., 2012, p.5) Fructose is another form of energy source for the plant; if it were found in larger amounts compared to other sugars, then it would be the most integral source of metabolic energy used for the development of strawberry seeds. Without the presence of fructose, these plants would be nearly devoid of the ability to mature into fruit. As the value of monosaccharides in strawberry plants is prominent in these sources, there is a lack of research on the effect of exogenous monosaccharides. The experimental study that I will be conducting has the potential to differ since it includes honey, a substance consisting primarily of monosaccharides, subsequently filling in the gap of an external source of monosaccharides.

The Lurking Detriments of Sucrose

While some researchers have measured the effects of various solutions on strawberry plants, other researchers have decided to go completely natural and insert raw sucrose into the berries. Sucrose is a form of a carbohydrate that exists as a disaccharide and is often found in strawberry plants, but not in abundance. To demonstrate the effects of sucrose on strawberry growth, researcher Ya Luo and her associates performed an experiment where they grew strawberries in a controlled environment and sprayed the berries with different concentrations of sucrose. Through observations and their data, the researchers concluded that sucrose was able to "promote strawberry fruit ripening" (Luo et al., 2019, p.2) by assisting in the processes regulating strawberry ripening. By showing statistically significant differences between the control group and the experimental group, the team was able to justify that sucrose concentration directly correlates with the measurements of the dimensions of the strawberries; the strawberries were significantly bigger compared to the control group.

Intrigued by the potential of exogenous sucrose, Professor Dong Li and his fellow researchers executed a similar experiment, but they used the same concentration of sucrose for the experimental group and doused the control group in mannitol to see the effects of sucrose on post-harvest strawberry fruit. At the end of the study, the group found that sucrose had a positive effect on the plants and stimulated anthocyanin levels, which are metabolites that play "vital roles in plant defence" (Li et al., 2019, p.6) and maintain the structure of strawberries after they are harvested. Both studies indicated that the addition of sucrose into the plants significantly enhanced the plants' endurance; regardless of the concentration levels, the plants were able to show remarkable improvements compared to the strawberries in the control groups. However, the conclusions found in Dr. Shilun Gao and his peers' study demonstrated that sucrose was detrimental to vegetation. Instead of conducting a study using strawberries as the experimental unit, Gao and his colleagues focused their research on examining the effects of sucrose on the sugarcane plant. They discovered that even though the sugarcane did grow and demonstrate better survival features than the sugarcane without sucrose, the carbohydrate ultimately slowed down photosynthesis rates because the energy needed to break down the sucrose was being removed from photosynthesis; the sugar was just acting as an alternative source of food for the plants. (Lobo et al., 2015, p.5) Gao also suggested that this may be the same case for other types of plants because the basic functions of photosynthesis are the same in all varieties of crops. Therefore, adding a large amount of exogenous sucrose may disrupt the functions of strawberry plants and decrease its production of antioxidants; preventing the crop from surviving during colder temperatures. The variability in these results from the peer-reviewed journals show a greater need for research to be conducted in this area; while the studies conducted by Ya Luo and Dong Li solely highlight the benefits of exogenous sucrose, Dr. Goa's project demonstrates that adding sucrose to strawberry plants is a multifaceted process and is not entirely advantageous. To conduct further research about sucrose and its relation to plant growth, researchers need to make assumptions using reliable studies and cannot do so if there are irregularities in current conclusions; therefore hindering any advancements regarding agricultural techniques to efficiently grow strawberry plants. A feasible option to address this issue would be to analyze the effects of a substance that has the same fundamental composition of sucrose but a more basic version: monosaccharides. My data-collection method is not designed to render the inconsistencies in sucrose research but has the potential to discover another technique to growing strawberry plants through the addition of a helpful substance without hindering the photosynthesis process, effectively addressing an existing gap.

Methods

The Experimental Design

Addressing the Environmental Issue

A significant concern surrounding the inclusion of fertilizers in the growth of strawberry plants is the health issue that they pose to humans and microorganisms residing in the soil. (Bai et al., 2020, p.1) Naturally, strawberries are able to sustain themselves in the wild because they have adapted to the conditions in the environment and have a sufficient amount of resources to continue to grow and thrive. When farmers introduce fertilizers into the system of the strawberries to expedite their growth during the winter, it can influence the nature of the plants and have the potential to harm the health of those who come into contact with these strawberries (*Statewide IPM Program*, 2023, p.4). Therefore, I hope to explore a new method of planting these fruits that has the potential to stem the growth of strawberries during the winter months through the addition of a natural source of monosaccharides into their water.

Justification of the Method

In order to detect a difference, I will be conducting an experimental study that recognizes any potential change in the experimental group when the treatment is implemented. The advantage of an experimental design is to directly suggest or reject hypotheses by isolating a specific variable, making the results less inconspicuous. Furthermore, I am able to make various hypotheses pertaining to different statistical tests appropriate for experiments and make a judgment on these hypotheses depending on the values I receive from the study.

In this experiment, there are two different hypotheses that I will be testing for through statistical methods. The first hypothesis is if honey, a substance that contains primarily monosaccharide components, is added to the water used to grow the strawberry roots, then the growth rate will statistically significantly increase. This hypothesis can only be suggested if I am able to reject the null hypothesis, which states that any variation in the rate of growth of the strawberry roots in the experimental group is due to chance.

Commencing the Growth of the Strawberry Roots

Materials

In the initial stage of my experiment, I decided to include 22 Everbearing Strawberry roots as the observational units due to the amount of space I had available, the cost of all the materials needed and the location of the plants; these roots also grow the quickest. Due to time constraints, I initiated the study with 22 plants as it would take around 1-2 weeks for more roots to arrive, considering they needed to be transported in specific conditions. However, this smaller sample size may lead to undercoverage bias, where the population of the study is not entirely represented. I used local soil that was identified as clay loam with a pH of 6, as strawberry roots prefer slightly acidic conditions. (*University of Minnesota*, 2021, p.1) For the pots, I purchased plastic ones that were 5 inches wide at the top, 5 inches long, and 4.5 inches at the base. They also arrived with domes with holes at the top, which prevented excess moisture from escaping the soil. The honey I purchased was also from a local farm that was raw and non-genetically modified, ensuring that it consisted primarily of monosaccharides.

Preparation Phase

To start, I added dry soil into plastic bags and mixed them with water until the liquid reached the bottom; I then left it outside for the excess moisture to evaporate. Once the soil was dry enough, I began preparing my roots. I gently separated the roots of the plants and placed them on a paper towel and once they were no longer entangled, I soaked them in lukewarm water one hour prior to planting. During this time, I measured 1.5 pints of the dry soil using a measuring cup and placed it into a pot; repeating this step for 22 pots. Once an hour had passed, I took the roots out of the water in a random order and placed them on a paper towel, labeling each root from 3-22. I then randomized the roots into the experimental group and the control group, through simple random sampling, and planted each root into a pot and labeled the pot with the corresponding number and EG/CG (EG stands for experimental group and CG stands for control group) for convenience. I then set the majority of pots inside a large aluminum tray to avoid any water from trickling to the ground, organizing the experimental groups on one side and the control groups on the other side, and put the rest that did not fit on a separate tray. I placed the two trays outside in the same location and situated the domes on top of each plant, allowing the plants to retain their water.

Germination Phase

For obtaining the proper amounts of water and honey used to grow, I used the first two roots as the trial plants, #1 was for the experimental group and #2 was for the control group. To determine the amount of water, I ended up with 90 mL of water since it is around 10% of the amount of soil for each plant and would be adequate until the time I watered it again, and established it as a constant variable. The honey was more difficult to quantify because there is a lack of experiments that add honey to water used to grow the strawberry roots; therefore, I had to use my judgment to decide the measurement of the honey. To ensure that I did not disrupt the turgor pressure of the plants and maim any of their cell structures, I decided the amount of honey was to be 1% of the amount of water added, which became 0.9 mL.

The procedure for the roots in the control group was simple, I measured 90 mL of water using a measuring cup and watered a root, repeating this process for each root in this group. For the experiment group, I used a weighing scale to measure 0.9 mL of honey and 45 mL of water. I mixed these two substances for 30 seconds and it was able to properly dissolve (when the honey was no longer distinguishable). I then measured another 45 mL of water and mixed it with the previous honey-and-water solution to make a new 90.9 mL of the honey-and-water solution and watered each root in the experimental group with this mixture. Using the same procedures for the two groups, I watered each plant on the Monday and Friday of each week to give enough time for the plant to access the water and measured the height of each plant using a ruler.

Inclusion of Specific Procedures

Certain aspects of the design of my experiment were based on techniques that authors used in peer-reviewed journals to come to conclusions that addressed their purpose. I decided to use the blocking method as Laure Olazcuaga and her colleagues did when examining the metabolism of various fruit depending on the species of flies ingesting it; this method allowed for more precision in their results as they were able to identify the specific process that some flies used to convert the fruit into energy (Olazcuaga et al., 2023, p.4). By blocking my experimental units and having one specific strawberry type, I am able to more effectively eradicate any lurking variables that follow different strawberry types which insinuate more unambiguous conclusions. At the same time, incorporating this technique has the potential to address the small sample size and the undercoverage bias in my experiment. Additionally, the basis of my dependent variable, the height of the strawberry roots in the control and experimental groups, comes from the technique Yixiong Bai and her team equipped when identifying the association between barley genes and their height and tiller number (Bai et al., 2021, p.2). In this experiment, plant height was quantified because it is an important phenotypic parameter. These specific dimensions serve as an indicator for plant growth and plant health; a rapid increase or decrease in the rate of growth for plants can indicate a system change within their cell structure. Combining the procedures of blocking and the evaluation of plant height will ultimately lead to more consistency in my results, as I can properly identify a plausible influence through the simplification of two approaches in my study.

Data Collection and Analysis

Description of the Data

The specific data that I will collect are the heights of all the plants in the experimental group and the control group. Using a ruler, I will be measuring the distance from the crown (the base of the stem) to the tallest point of the stem and recording these values on a table everyday. As the strawberry roots progress in their development, they also progress in the growth of their height; therefore, by obtaining the height each day, I can observe if the treatment has any significant influence on the experimental group compared to the control group. The collected data is also identified as a quantitative continuous variable, as they are numerical values, representative of the strawberry roots and are subject to decimal points. Furthermore, numerical data allows for the analysis of the specific effect of the honey on the strawberry roots as numbers permit for a more definite explanation of the influence rather than a quantitative description of the roots. The independent variable is the amount of honey being added to the roots (0 mL vs. 0.09 mL) and the dependent variable is the height of each plant in centimeters. The variables kept constant between the two groups are the amount of water, the type of pot and dome, the amount of soil, the type of soil and the location of the plants. In this experiment, the varying initial heights of the plants do not pose an issue because the values I am using for statistical analysis are the slopes of the experimental group and the control group. Therefore, larger values in height do not necessarily equate to more significant values in my statistical tests.

Statistical Tests Used for Analysis

The three tests I will be conducting are linear regression, 2 sample t-Tests and a visual description of the average slopes of the control group and the experimental group. In beginning the analysis, I will be calculating the slope of each plant along with the R and R^2 values to justify the use of the slope. Then, I will use a 2-Sample t-Test to conclude if the means of the slopes of the experimental group differ from the means of the slopes of the control group. After calculating the t-value, I will compute the cumulative distribution function for the t-distribution on the right tail of the graph and compare it to the significance level of 0.001. If the p-value is less than 0.001, I will be able to reject the null hypothesis and suggest there is a difference between the means of the slopes in the experimental group and the control group. Using the results from the two tests, I will make a graph with the average slope of the experimental group and the control group and visually compare the two; if there is a difference between the two means of the group and the experimental group has a steeper slope, then I can suggest that the honey has a positive influence on the rate of growth of the strawberry roots. If there seems to be no difference between the means, I will need to retain my null hypothesis and conclude there needs to be further testing done in order to determine an accurate description of the influence of honey on the growth of strawberry roots.

Results

Table 1: Slopes, R Values, and R^2 Values of Each Plant

Plant #	Slope	R	R^2
1	0.1399719888	0.9749867696	0.9505992009
2	0.0583473389	0.9745812376	0.9498085886
3	0.1626890756	0.9616253586	0.9247233303
4	0.1724089636	0.9685304562	0.9380512446
5	0.1624089636	0.9613954684	0.9242812466
6	0.0699159664	0.9663971065	0.9339233675
7	0.1518487395	0.9690463857	0.9390508976
8	0.1836694678	0.9730066629	0.9467419661
9	0.1200280112	0.942203268	0.8877469982
10	0.2376190476	0.980618731	0.9616130955
11	0.0719887955	0.9803629079	0.9611114312
12	0.0705602241	0.9632558279	0.9278617899
13	0.1640616246	0.9728606662	0.9464578759
14	0.1224369748	0.9376174525	0.8791264873
15	0.0807563025	0.9951461307	0.9903158215

16	0.0816806723	0.9946410937	0.9893109052
17	0.1961344538	0.9777364248	0.9559685165
18	0.0726610644	0.9728251841	0.9463888387
19	0.0995798319	0.9947003367	0.9894287599
20	0.180140056	0.9893364728	0.9787866563
21	0.0907002801	0.9798122327	0.9600320113
22	0.1617927171	0.9824124944	0.9651343092

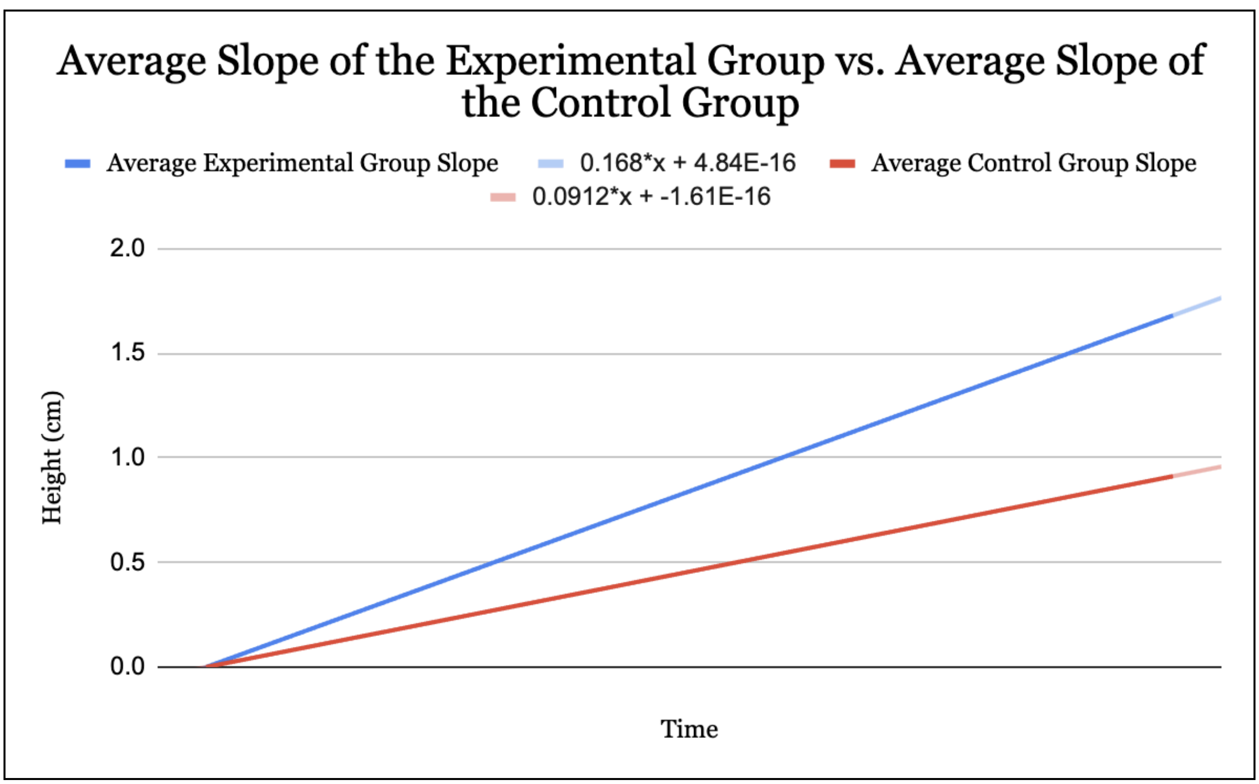
The table displays the slopes, the R values and the R^2 values of each plant in the study; red being the plants from the control group and green being the plants from the experimental group. The slope of each plant was calculated from the linear regression test, with the height of the plant being the response variable and the day being the explanatory variable; it represents the change in height as the days progress and this can be evaluated as the growth rate for the roots. The R value corresponds to the strength of the correlation between two variables. Here, an R value closer to 0 shows a weak correlation and advises a linear relationship is not suitable while an R value closer to 1 shows a stronger correlation between the height of the plant and the day/time. The R^2 value reflects the percentage of variability in the response variable that is accounted for by the explanatory variable; a number closer to 0 indicates a large percent of the variation is not accounted for and a number closer to 1 suggests that a majority of the variation in the height of the plant is accounted for by the day.

Table 2: Average Slope, SD, Test Statistic, and P-Value for the Two Groups					
Group	Average Slope	Standard Deviation	Alpha Level	t-Value (From 2 Sample T-Test)	P-Value
Experimental	0.16802393684	0.00107967755			

Group			0.001	180.6363083	$4.162776266e^{-33}$
Control Group	0.0911942959	0.00090787519			

Once the slopes were calculated for each plant, I took the average and determined their standard deviation through the addition of all the average means subtracted from the slopes and divided by the sample size. I decided to use a more stringent alpha level to decrease the possibility of receiving a Type 2 error: when my null hypothesis is true, but I mistakenly reject it due to the evidence presented. Using the 2 Sample t-Test, I entered the average slope for each group, their respective standard deviation and sample size and received a t-value of 180.64, which is the test statistic for any t-Test. The p-value obtained expressed how likely the observed results are due to sampling error given that the null hypothesis is true.

Graph 1: Average Slope of the Experimental Group and Control Group



This graph shows the average slopes of both groups, with the experimental slope being blue and the slope of the control group being red. In a visual perspective, the slope of the experimental group is steeper than that of the control group, suggesting that the former has a faster rate of growth compared to the latter.

Discussion

Observing the values from Table 1, it appears that all the plants showed high R values, with all of them being between 0.9 and 1. This indicates a strong correlation between the height of the plant and the day. The same pattern was observed in the R^2 values, with the exception of Plants #9 and #14; their R^2 values were between 0.87 and 0.9. These values also indicate a high percentage of the variability in the plant height is accounted for by the day. The calculations from the 2 Sample T-test using the average slopes of the plants showed a test statistic of 180.64 and a p-value of $4.16e^{-33}$, essentially zero. Since the p-value is lower than the alpha level, I am rejecting my null hypothesis; it is unlikely that the observed results are due to sampling error. From these results, there is strong evidence to suggest that the experimental group had a faster growth rate compared to the control group.

Initially, I hypothesized that if honey, a substance that contains primarily monosaccharide components, is added to the water used to grow the strawberry roots, then the rate of growth will significantly increase. The values from Table 1 showed a strong correlation between the height of the plant and the day; the tables in Appendix A show the numerical increase per day while Appendix B shows the visual representation of the growth of each plant. The slopes, the R values, the R^2 values and the values from the 2-Sample T-test confirmed the rate of growth increased; therefore, I am able to accept my original hypothesis. My results showed statistically conclusive evidence and I was able to accept that honey was found to accelerate the growth of strawberry plants and. To address my original research question of “How does the addition of exogenous sugars that consist of primarily monosaccharide components into the water of strawberry roots influence their growth during the winter?”; honey as an exogenous sugar with primarily monosaccharides have a positive influence on the growth of strawberry roots during the winter.

Limitations

Even though the evidence compiled is in support of my initial prediction, the limitations also influence how applicable my conclusions are in the broader context. I only collected data from a small sample size of 22 plant roots and solely used one type of strawberry to grow, this limited my ability to generalize my results to the larger population. My conclusions can only be applied to the Everbearing Strawberry, and there is still potential for variation in my results due to the smaller sample size. However, the type of root I used was unavoidable because I had a limited amount of time to grow my strawberries; therefore, I needed to designate the root that was able to grow the fastest to demonstrate quantifiable results. Additionally, there was restricted accuracy in my measuring materials as the computed slopes were between the tenth and hundredth of a centimeter and the ruler I used only measured in the tenths of centimeters. Had the precision in my ruler increased to include millimeters and I increased the time range of my experiment, there would have been greater validity in my results. At the same time, the results may have been varied and the new data could have supported or refuted my initial hypothesis prior to method execution.

Future Research

While there was consistency in my research, there were evident gaps considering the limitations of my study. To enhance my method, future researchers could allot more time to grow and collect data of the strawberry roots while also using multiple concentrations of honey. With more data, there is greater confidence in results and by using different concentrations, researchers could identify the amount of honey added that would induce the greatest rate of growth for the root. Furthermore, I suggest researchers use a bigger sample size and grow the roots in sandy loam soil, as strawberries grow most efficiently in this matter. With the benefit of a bigger sample size, the variability in the results is decreased along with the probability of any undercoverage bias influencing the conclusions. A larger group also increases the power of the test and decreases the probability of making a Type 2 error. The power indicates the probability that the researcher correctly rejects a false null hypothesis and if there are more experimental units available for data, the researcher has a greater chance of making an accurate conclusion. Subsequently, the power is the Type 2 error in the study subtracted from 1 and if power increases, a more precise interpretation could be made regarding the results obtained from a better experimental design.

Implications

In my study, my results concluded that honey had a positive effect on the growth rate of the strawberry roots. Since honey is both naturally occurring and environmentally friendly, it could be more easily integrated into the farming methods of agricultural farms. These are farms that prioritize human health, and employ practices that address environmental sustainability to protect land use for future generations. However, my method did not compare the effect of chemical fertilizers to the effect of honey on the plant roots and there is no evidence to suggest that honey is as effective as chemical fertilizers; therefore, there is a lower chance of honey being used in industrial farms that are concerned about profits.

Currently, my results could initiate a profound change in the food and agriculture industry, prioritizing both the economic perspectives of business owners and the environmental concerns of scientists and agricultural farmers. Through the combination of my research and future endeavors in this field, the locations of which honey could be implemented can increase; thereby slowing the deterioration of Earth and preserving human health.

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Appendix A. Recorded Height of Root Each Day

Plant 1:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	5	13	6	25	7.4
2	5	14	6.1	26	7.6
3	5.1	15	6.3	27	7.8
4	5.1	16	6.5	28	8.1
5	5.1	17	6.5	29	8.3
6	5.1	18	6.6	30	8.5
7	5.2	19	6.6	31	8.7
8	5.2	20	6.7	32	9
9	5.3	21	6.9	33	9.3
10	5.5	22	7	34	9.7
11	5.6	23	7	35	10
12	5.8	24	7.2		

Plant 2:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	6.5	13	6.8	25	7.7
2	6.5	14	6.9	26	7.7
3	6.5	15	6.9	27	7.8
4	6.5	16	7	28	7.8
5	6.6	17	7	29	8
6	6.6	18	7	30	8
7	6.6	19	7	31	8
8	6.6	20	7.1	32	8.2
9	6.7	21	7.3	33	8.3
10	6.7	22	7.3	34	8.3
11	6.7	23	7.4	35	8.3

12	6.8	24	7.6		

Plant 3:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	6.5	13	7.3	25	9.2
2	6.6	14	7.6	26	9.5
3	6.6	15	7.7	27	9.8
4	6.6	16	7.7	28	10
5	6.6	17	7.9	29	10.2
6	6.6	18	8	30	10.4
7	6.7	19	8	31	10.9
8	6.7	20	8.2	32	11.3
9	6.8	21	8.3	33	11.6
10	7	22	8.5	34	12
11	7.1	23	8.7	35	12.1
12	7.2	24	8.9		

Plant 4:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	8.5	13	9.3	25	11.6
2	8.5	14	9.5	26	11.7
3	8.6	15	9.6	27	12.1
4	8.6	16	9.7	28	12.4
5	8.7	17	9.9	29	12.5
6	8.7	18	10	30	12.7
7	8.7	19	10.3	31	13
8	8.8	20	10.4	32	13.3
9	8.8	21	10.5	33	13.8
10	9	22	10.8	34	14.2

11	9.1	23	11	35	14.3
12	9.1	24	11.3		

Plant 5:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	3.3	13	4.3	25	5.9
2	3.3	14	4.4	26	6.2
3	3.3	15	4.5	27	6.3
4	3.3	16	4.6	28	6.7
5	3.4	17	4.6	29	6.9
6	3.4	18	4.7	30	7.3
7	3.5	19	4.9	31	7.7
8	3.5	20	5	32	7.9
9	3.6	21	5	33	8.4
10	3.7	22	5.3	34	8.9
11	3.7	23	5.6	35	8.9
12	4.1	24	5.7		

Plant 6:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	6.2	13	6.8	25	7.5
2	6.2	14	6.8	26	7.5
3	6.3	15	7	27	7.6
4	6.3	16	7	28	7.6
5	6.3	17	7	29	7.8
6	6.3	18	7	30	8
7	6.5	19	7.1	31	8.2
8	6.5	20	7.1	32	8.3
9	6.6	21	7.2	33	8.5

10	6.6	22	7.2	34	8.7
11	6.6	23	7.3	35	8.9
12	6.6	24	7.4		

Plant 7:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	3.5	13	4.3	25	6.2
2	3.5	14	4.5	26	6.3
3	3.5	15	4.7	27	6.7
4	3.5	16	4.9	28	6.7
5	3.6	17	4.9	29	6.9
6	3.6	18	5	30	7.1
7	3.6	19	5.2	31	7.4
8	3.6	20	5.2	32	7.7
9	3.7	21	5.2	33	8.2
10	4	22	5.4	34	8.6
11	4	23	5.5	35	8.8
12	4.2	24	5.8		

Plant 8:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	9.6	13	10.5	25	12.9
2	9.7	14	10.9	26	13.3
3	9.7	15	11	27	13.5
4	9.7	16	11	28	13.6
5	9.8	17	11.2	29	13.6
6	9.8	18	11.6	30	13.9
7	9.8	19	11.8	31	14.4
8	9.9	20	11.9	32	14.7

9	9.9	21	12	33	15.2
10	10	22	12.3	34	15.7
11	10	23	12.3	35	15.9
12	10.3	24	12.5		

Plant 9:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	7.2	13	7.7	25	8.9
2	7.2	14	7.9	26	9.2
3	7.2	15	7.9	27	9.5
4	7.3	16	7.9	28	9.9
5	7.3	17	7.9	29	10
6	7.3	18	8	30	10.3
7	7.5	19	8.2	31	10.5
8	7.5	20	8.2	32	10.9
9	7.5	21	8.4	33	11
10	7.6	22	8.6	34	11.3
11	7.6	23	8.7	35	11.3
12	7.7	24	8.8		

Plant 10:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	6.8	13	8.5	25	11.2
2	6.8	14	8.7	26	11.6
3	6.9	15	8.7	27	11.9
4	6.9	16	8.7	28	12.3
5	6.9	17	8.8	29	12.6
6	6.9	18	9	30	12.8
7	7.1	19	9.3	31	13.2

8	7.2	20	9.7	32	13.5
9	7.3	21	10	33	13.7
10	7.3	22	10.3	34	14.2
11	7.4	23	10.5	35	14.3
12	7.8	24	10.9		

Plant 11:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	4.7	13	5	25	6
2	4.7	14	5	26	6.2
3	4.7	15	5.2	27	6.2
4	4.8	16	5.4	28	6.3
5	4.8	17	5.5	29	6.3
6	4.8	18	5.5	30	6.5
7	4.8	19	5.7	31	6.6
8	4.8	20	5.8	32	6.7
9	4.9	21	5.8	33	6.9
10	4.9	22	5.9	34	6.9
11	4.9	23	6	35	7
12	4.9	24	6		

Plant 12:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	4.4	13	4.9	25	5.5
2	4.4	14	4.9	26	5.6
3	4.4	15	5	27	5.7
4	4.4	16	5	28	5.9
5	4.5	17	5	29	6
6	4.5	18	5.1	30	6.2

7	4.6	19	5.1	31	6.3
8	4.6	20	5.3	32	6.5
9	4.6	21	5.4	33	6.7
10	4.7	22	5.4	34	6.9
11	4.7	23	5.4	35	6.9
12	4.8	24	5.5		

Plant 13:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	0.7	13	2	25	3.4
2	0.7	14	2.2	26	3.7
3	0.7	15	2.3	27	4.2
4	0.7	16	2.3	28	4.4
5	0.7	17	2.5	29	4.4
6	0.8	18	2.6	30	4.8
7	1	19	2.6	31	5.1
8	1	20	2.7	32	5.4
9	1	21	2.7	33	5.7
10	1	22	2.8	34	6.2
11	1.1	23	2.9	35	6.3
12	1.6	24	3.2		

Plant 14:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	7.3	13	7.9	25	9.1
2	7.4	14	8	26	9.3
3	7.4	15	8.1	27	9.6
4	7.4	16	8.2	28	10
5	7.4	17	8.2	29	10.3

6	7.4	18	8.3	30	10.4
7	7.5	19	8.3	31	10.6
8	7.5	20	8.4	32	10.8
9	7.5	21	8.4	33	11.2
10	7.6	22	8.5	34	11.6
11	7.6	23	8.6	35	11.7
12	7.7	24	8.9		

Plant 15:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	7	13	7.9	25	8.7
2	7	14	7.9	26	8.8
3	7	15	8	27	8.9
4	7.1	16	8	28	9.1
5	7.1	17	8.1	29	9.1
6	7.1	18	8.1	30	9.2
7	7.4	19	8.1	31	9.4
8	7.5	20	8.2	32	9.4
9	7.5	21	8.5	33	9.5
10	7.6	22	8.5	34	9.6
11	7.7	23	8.6	35	9.6
12	7.7	24	8.7		

Plant 16:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	2.2	13	3.1	25	4.1
2	2.3	14	3.1	26	4.2
3	2.3	15	3.4	27	4.2
4	2.3	16	3.5	28	4.4

5	2.3	17	3.6	29	4.4
6	2.4	18	3.6	30	4.4
7	2.6	19	3.6	31	4.5
8	2.6	20	3.8	32	4.6
9	2.8	21	3.9	33	4.7
10	2.8	22	3.9	34	4.8
11	2.9	23	4	35	4.8
12	2.9	24	4.1		

Plant 17:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	3.6	13	4.4	25	7.2
2	3.6	14	4.4	26	7.5
3	3.6	15	4.7	27	7.8
4	3.7	16	5	28	8.1
5	3.7	17	5.4	29	8.4
6	3.7	18	5.8	30	8.7
7	3.8	19	6	31	8.9
8	3.9	20	6.1	32	9
9	4	21	6.1	33	9.3
10	4	22	6.3	34	9.5
11	4.2	23	6.5	35	9.6
12	4.3	24	6.9		

Plant 18

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	2.5	13	3	25	3.7
2	2.5	14	3	26	3.9
3	2.5	15	3.2	27	4

4	2.5	16	3.2	28	4.2
5	2.6	17	3.2	29	4.3
6	2.6	18	3.2	30	4.4
7	2.7	19	3.3	31	4.6
8	2.7	20	3.4	32	4.6
9	2.7	21	3.4	33	4.8
10	2.7	22	3.5	34	4.9
11	2.9	23	3.5	35	4.9
12	3	24	3.6		

Plant 19:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	7	13	8.1	25	9.2
2	7.1	14	8.1	26	9.2
3	7.1	15	8.4	27	9.3
4	7.2	16	8.5	28	9.5
5	7.2	17	8.5	29	9.6
6	7.2	18	8.7	30	9.7
7	7.6	19	8.8	31	9.9
8	7.7	20	8.8	32	10
9	7.7	21	8.9	33	10.2
10	7.8	22	9	34	10.4
11	7.9	23	9	35	10.5
12	7.9	24	9.1		

Plant 20:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	4.3	13	5.5	25	8
2	4.3	14	5.9	26	8.2

3	4.4	15	6	27	8.6
4	4.4	16	6	28	8.7
5	4.4	17	6.1	29	8.9
6	4.6	18	6.4	30	9.3
7	5	19	6.7	31	9.4
8	5.2	20	6.9	32	9.6
9	5.2	21	7	33	9.7
10	5.3	22	7.2	34	9.8
11	5.3	23	7.5	35	9.9
12	5.3	24	7.8		

Plant 21:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	2.9	13	3.5	25	4.5
2	2.9	14	3.6	26	4.7
3	2.9	15	3.7	27	4.9
4	3	16	3.7	28	5
5	3	17	3.8	29	5.1
6	3	18	3.9	30	5.3
7	3.2	19	3.9	31	5.3
8	3.2	20	4	32	5.5
9	3.2	21	4.2	33	5.8
10	3.3	22	4.3	34	5.9
11	3.3	23	4.3	35	5.9
12	3.4	24	4.4		

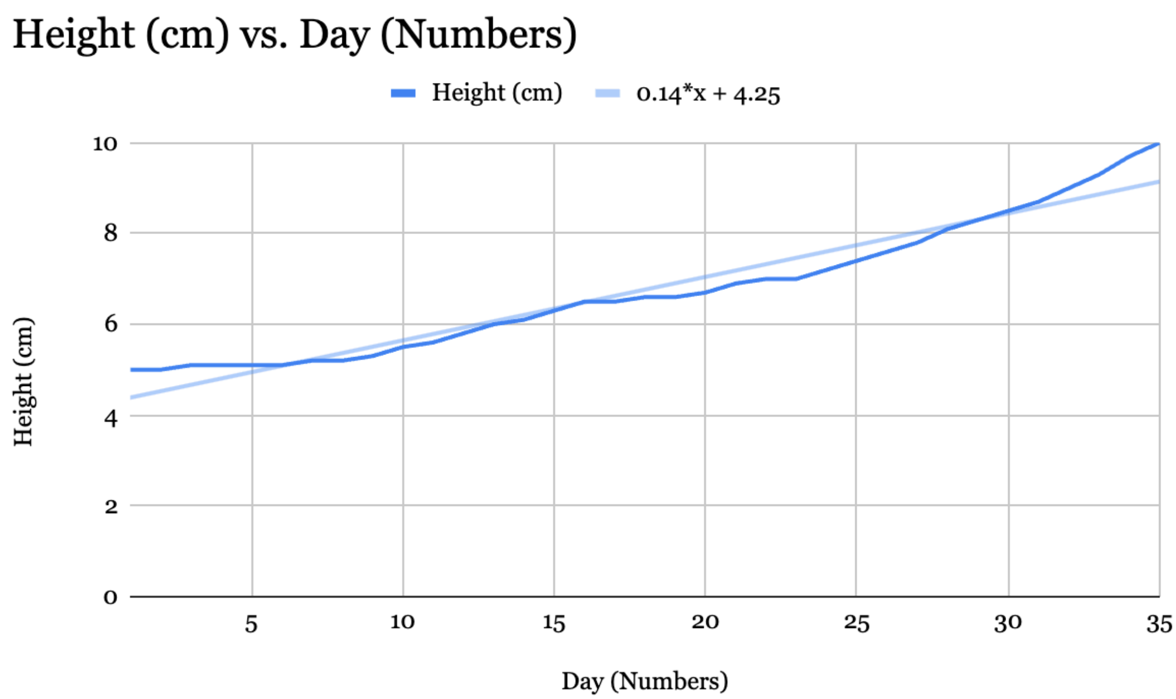
Plant 22:

Day	Height (cm)	Day	Height (cm)	Day	Height (cm)
1	5.1	13	5.9	25	8.3

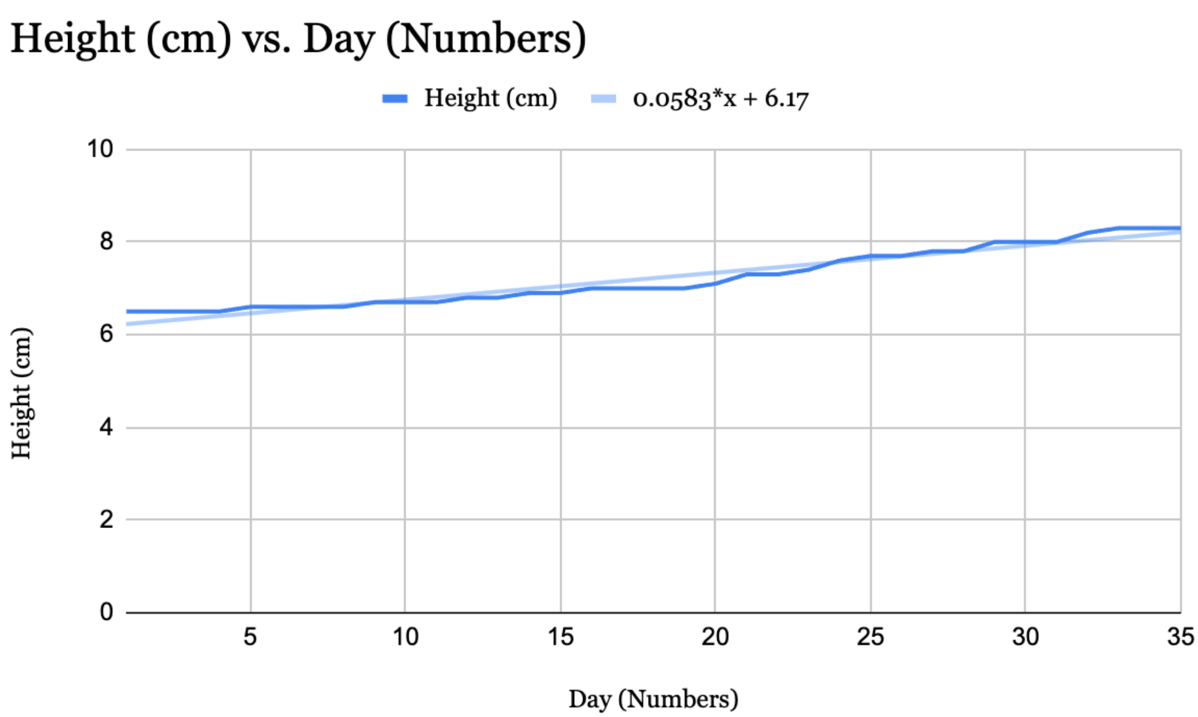
2	5.2	14	6.1	26	8.4
3	5.2	15	6.3	27	8.6
4	5.2	16	6.5	28	8.9
5	5.2	17	6.6	29	9.1
6	5.3	18	6.8	30	9.3
7	5.3	19	7	31	9.4
8	5.4	20	7.1	32	9.6
9	5.4	21	7.4	33	9.7
10	5.4	22	7.7	34	10
11	5.7	23	7.8	35	10.2
12	5.7	24	8		

Appendix B. Graphical Representation of Growth Rate of Each Root

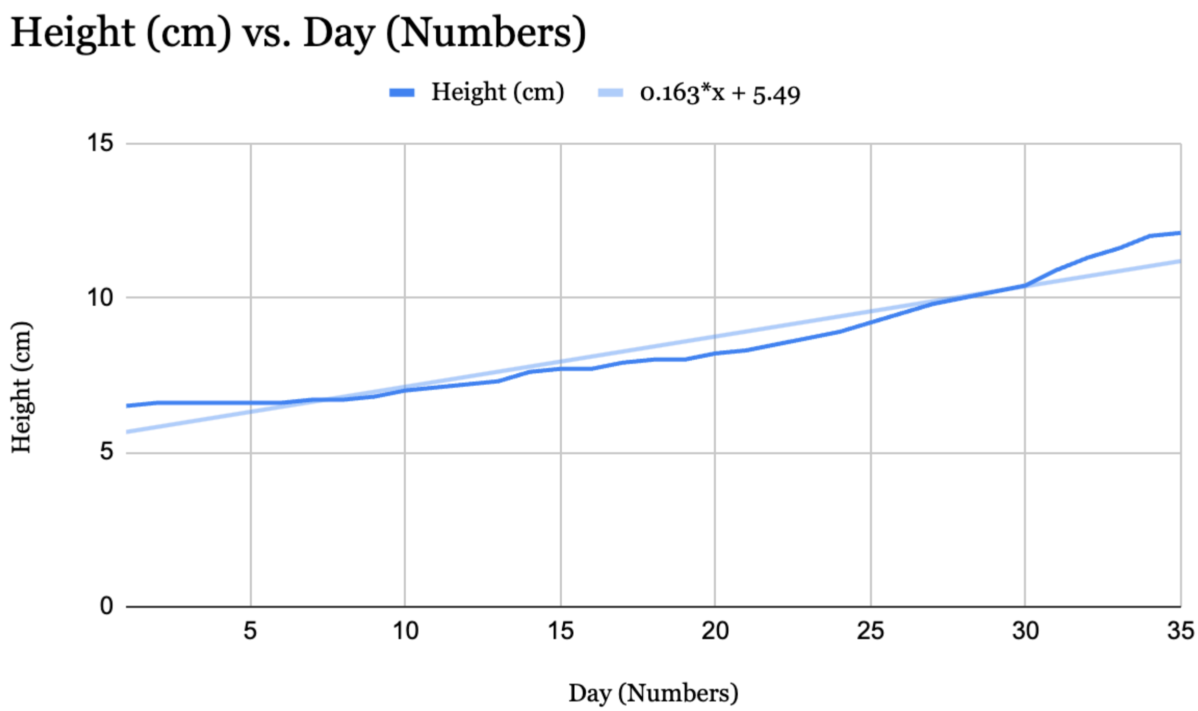
Plant 1:



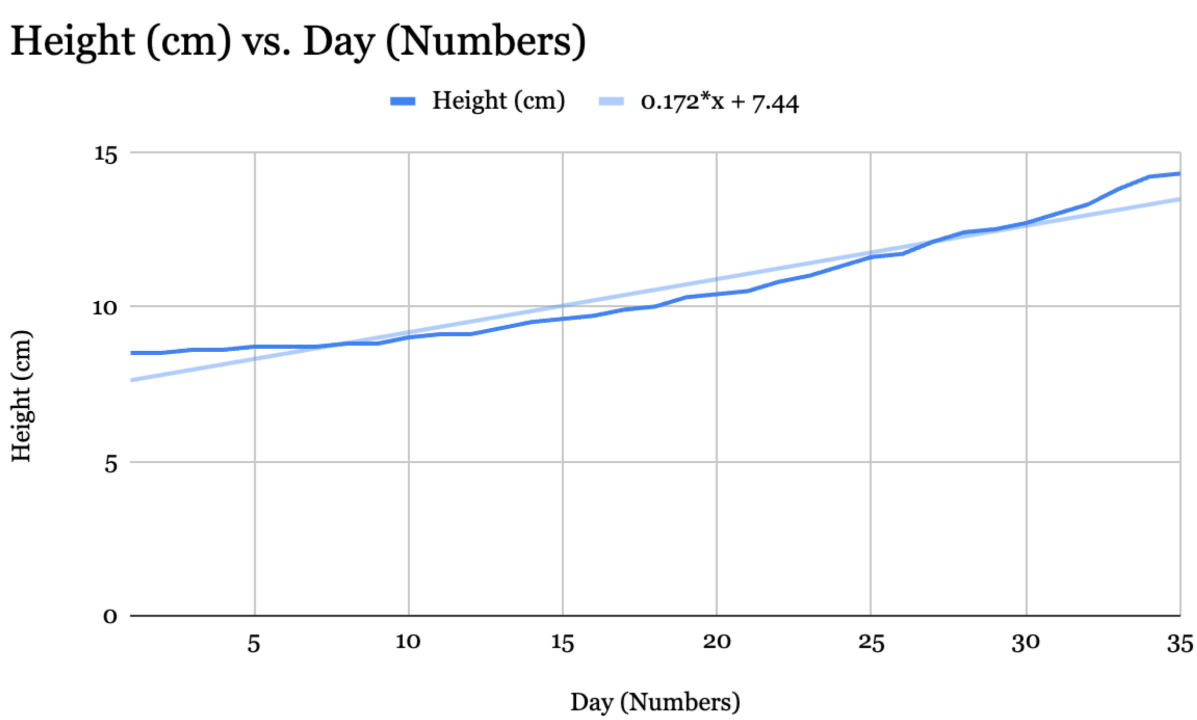
Plant 2:



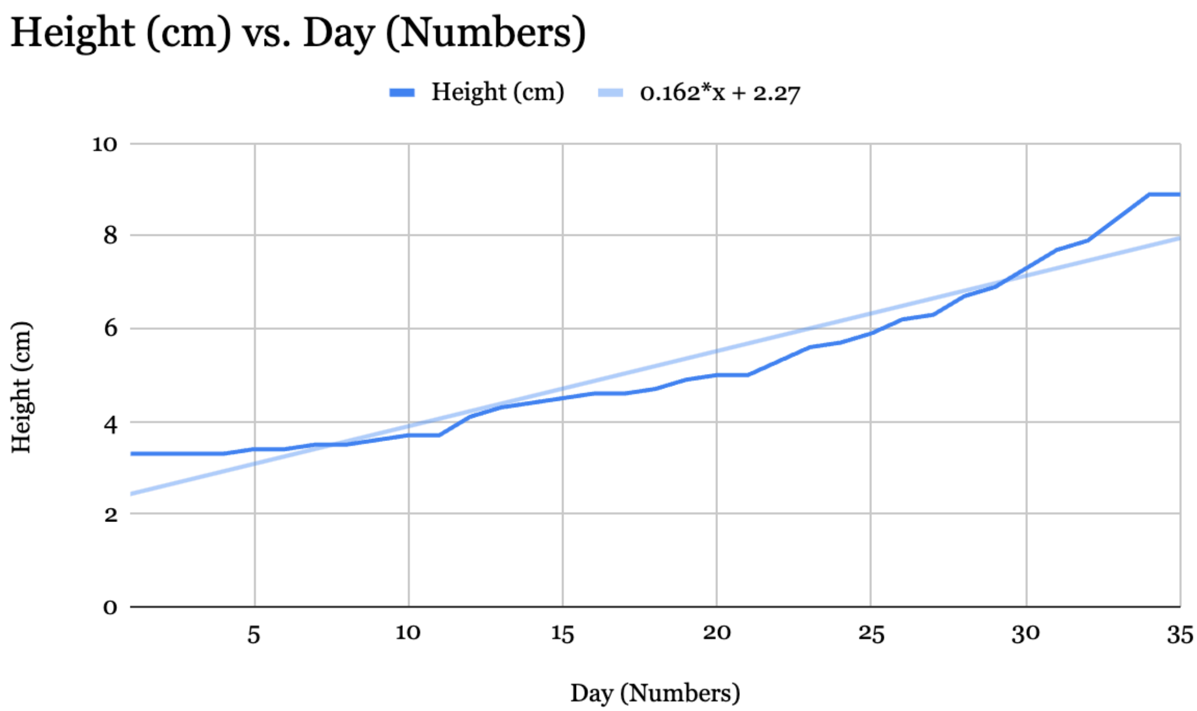
Plant 3:



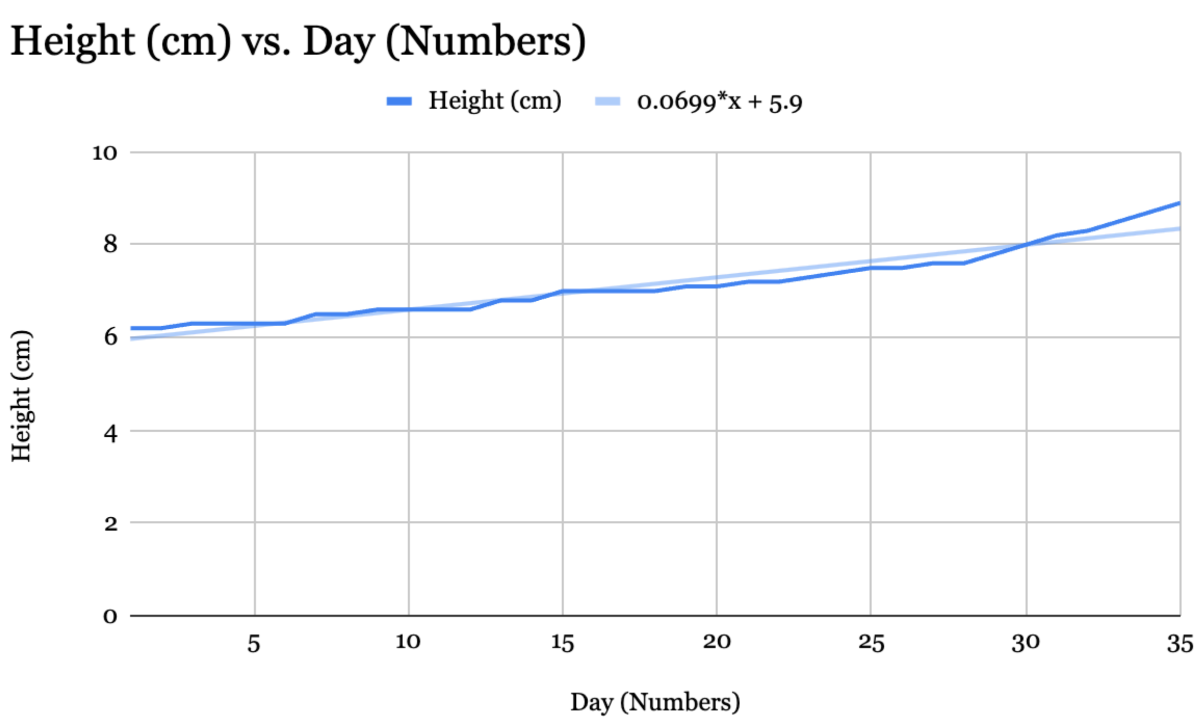
Plant 4:



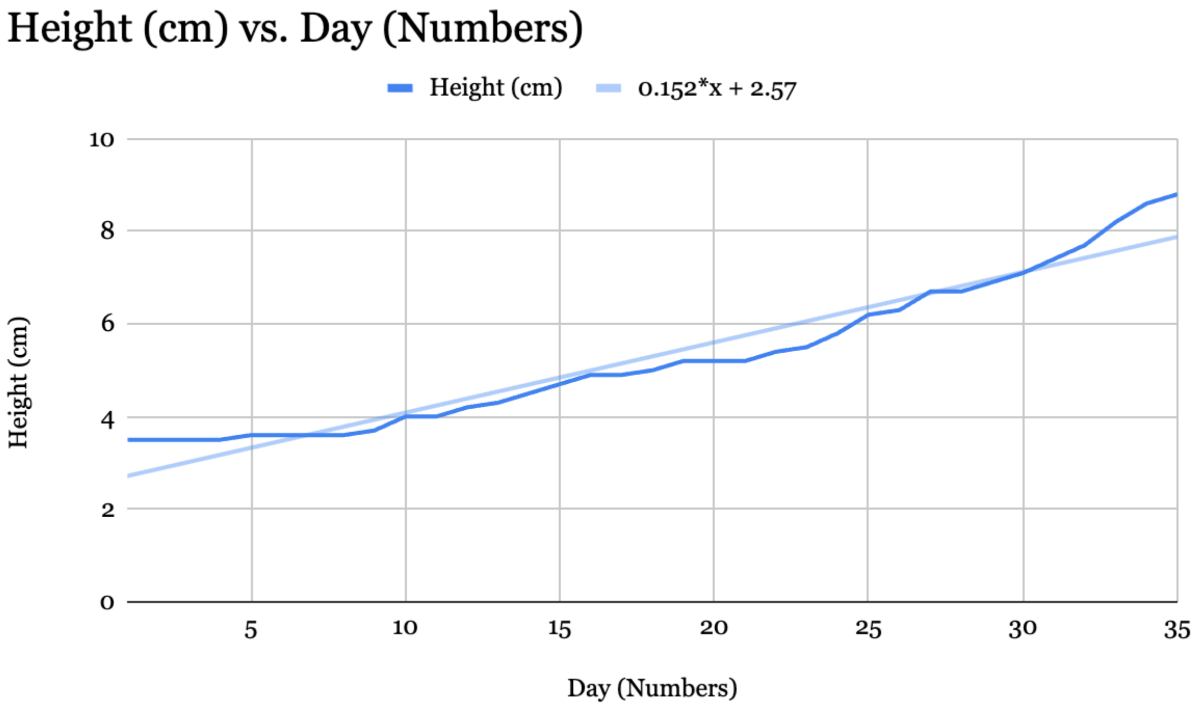
Plant 5:



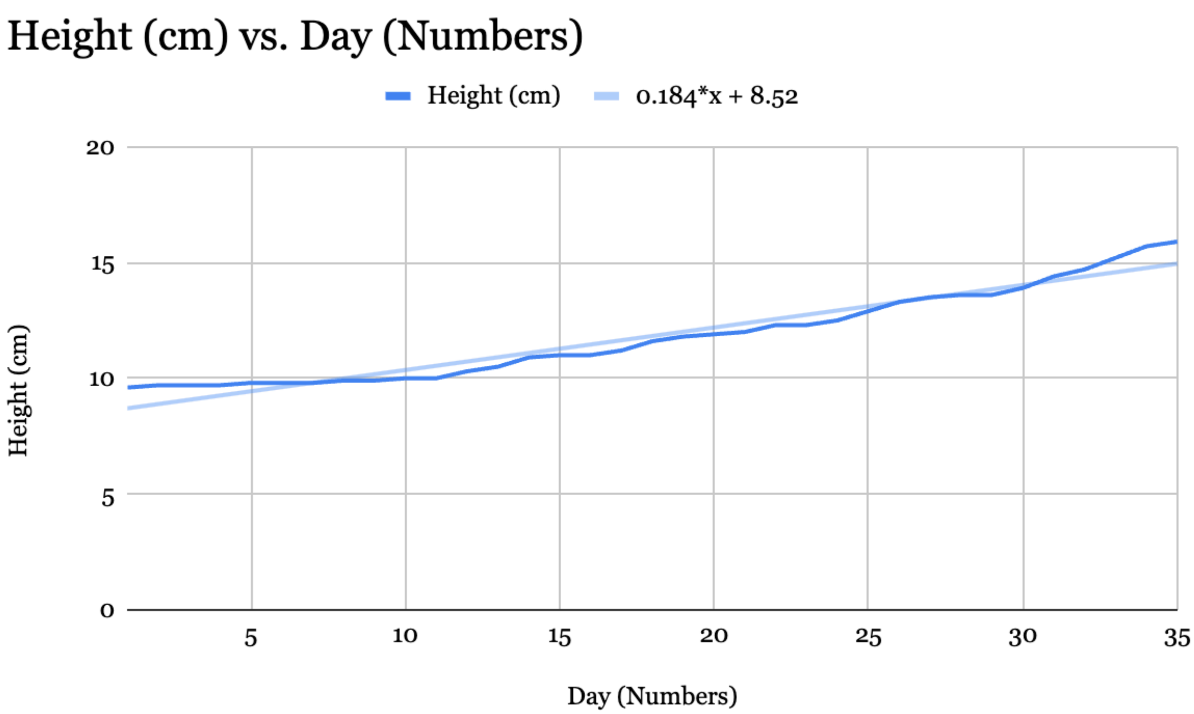
Plant 6:



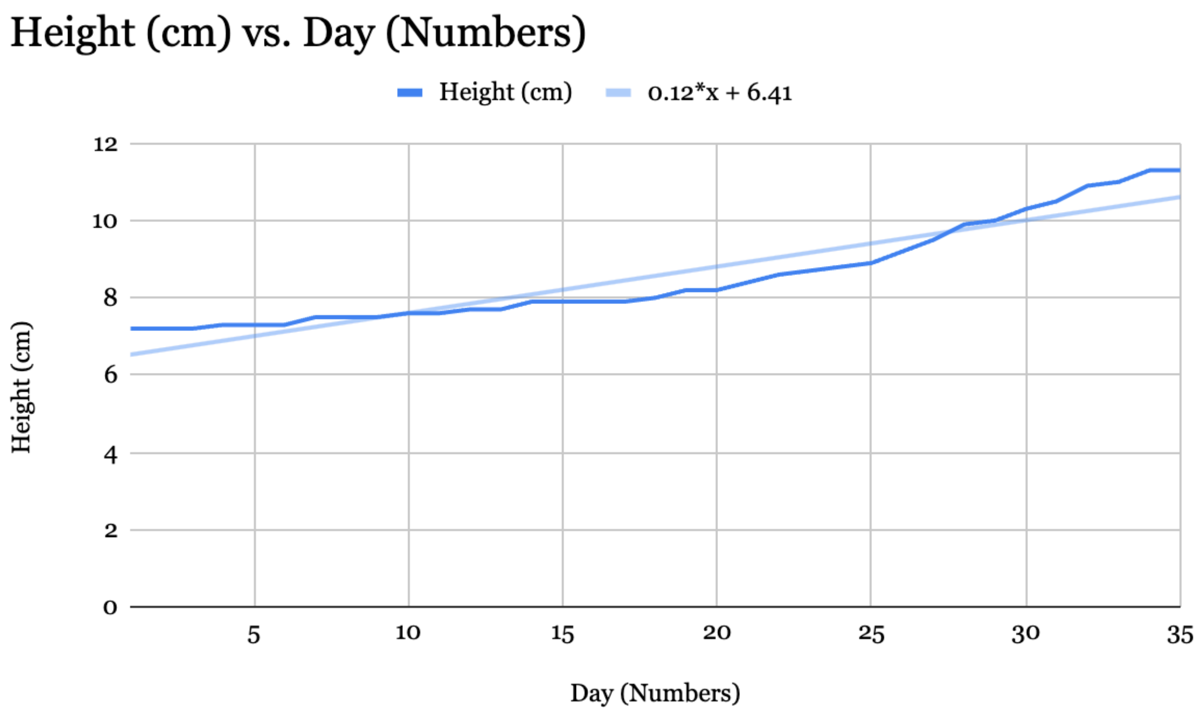
Plant 7:



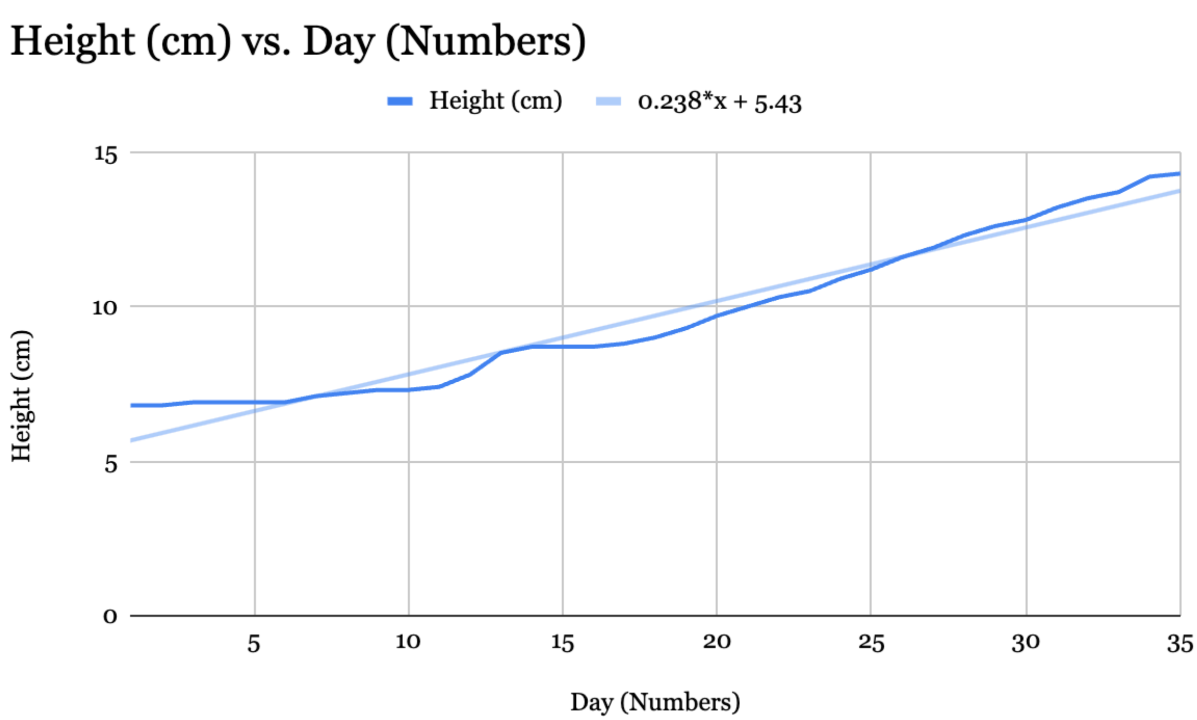
Plant 8:



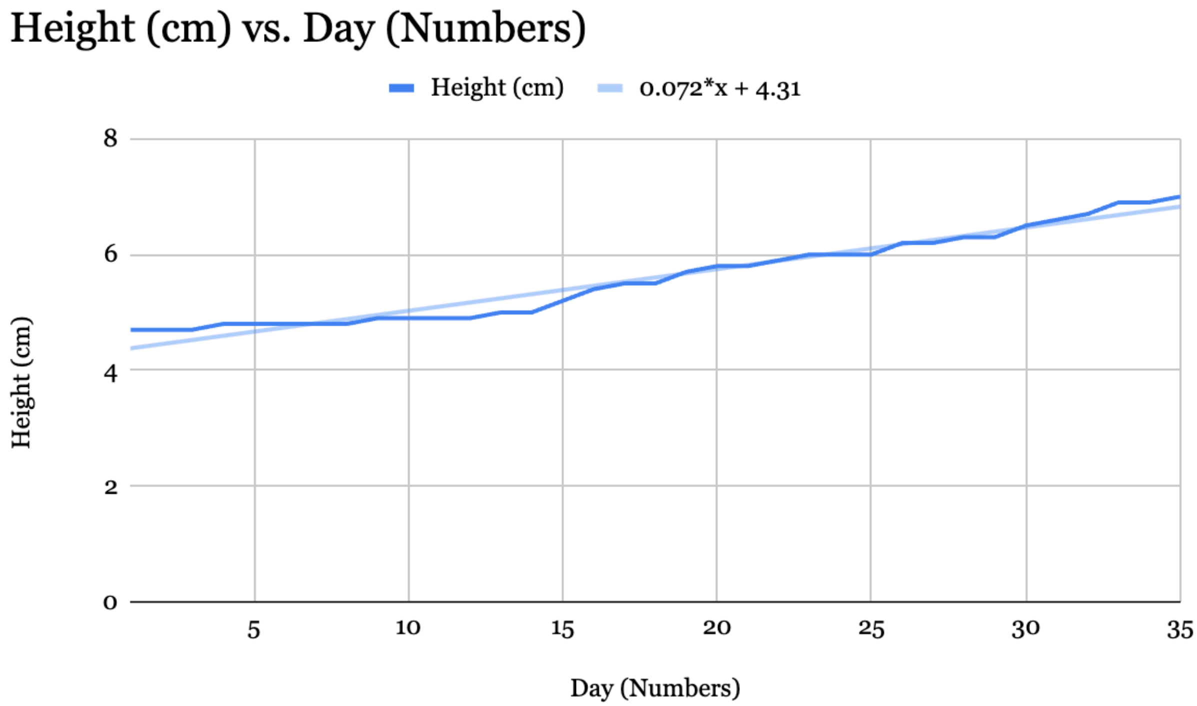
Plant 9:



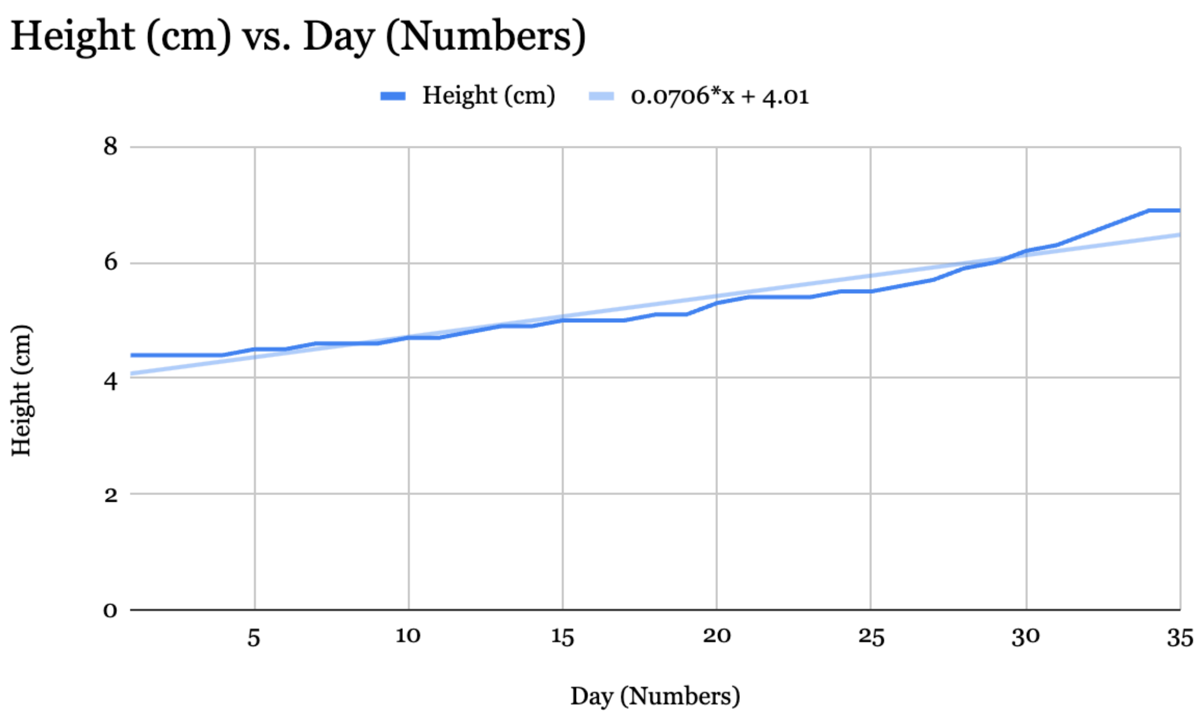
Plant 10:



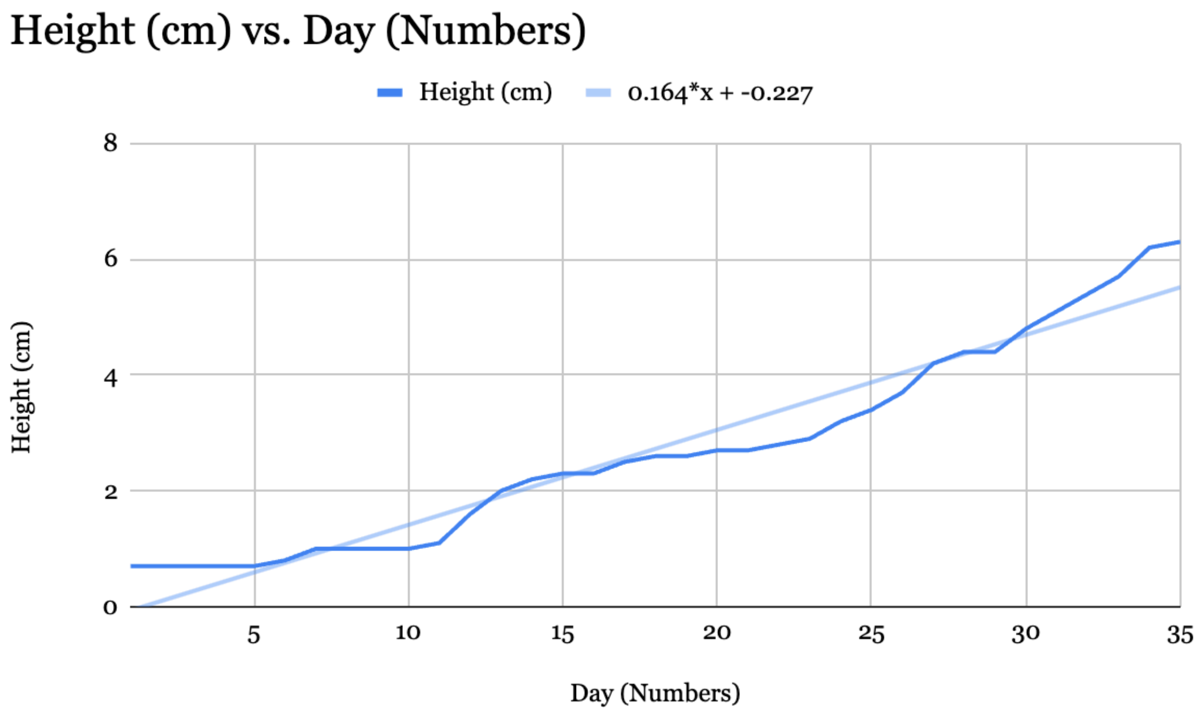
Plant 11:



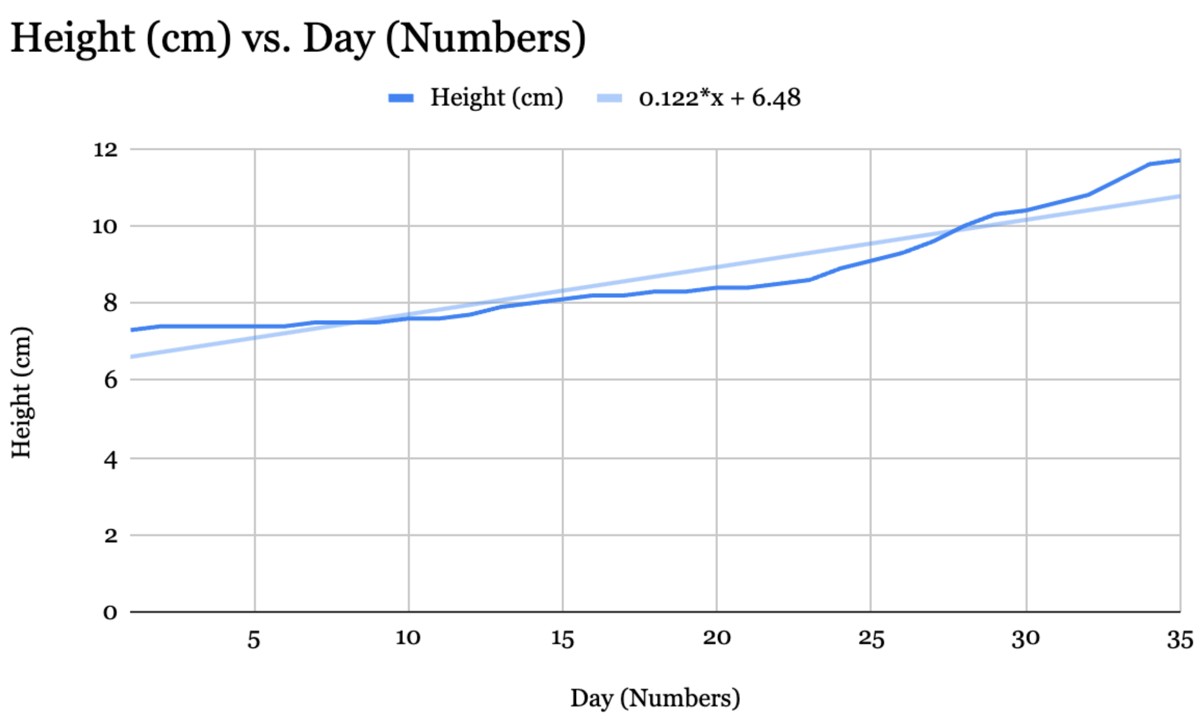
Plant 12:



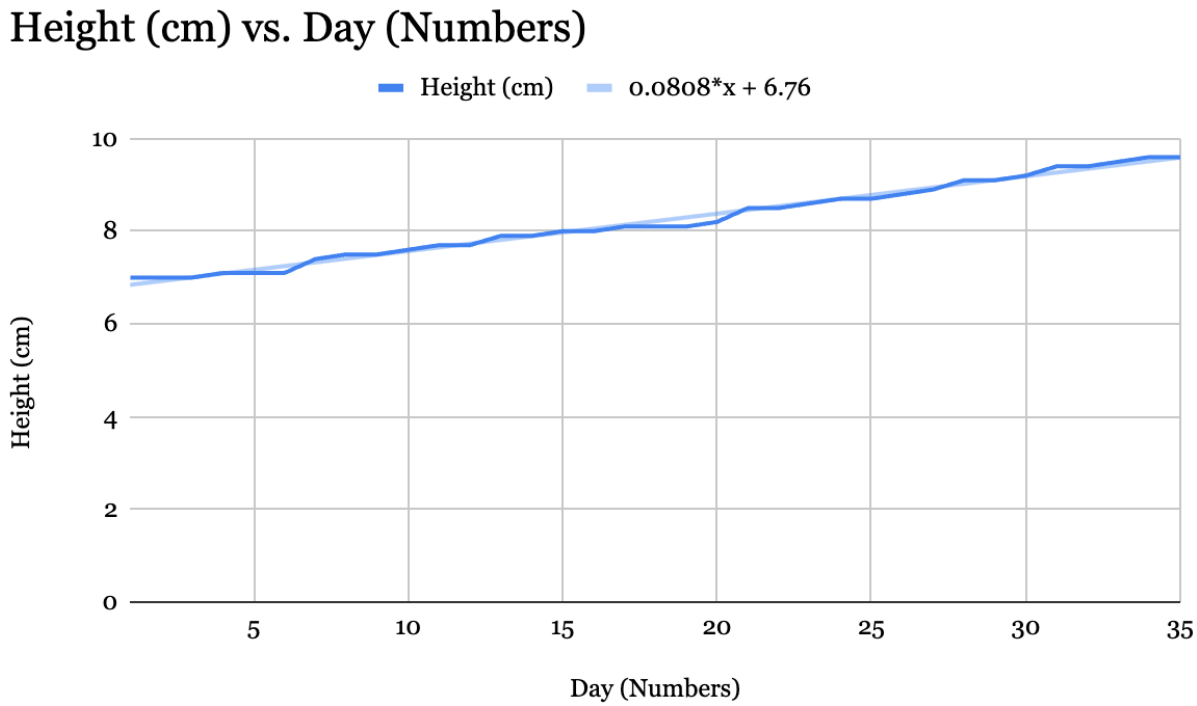
Plant 13:



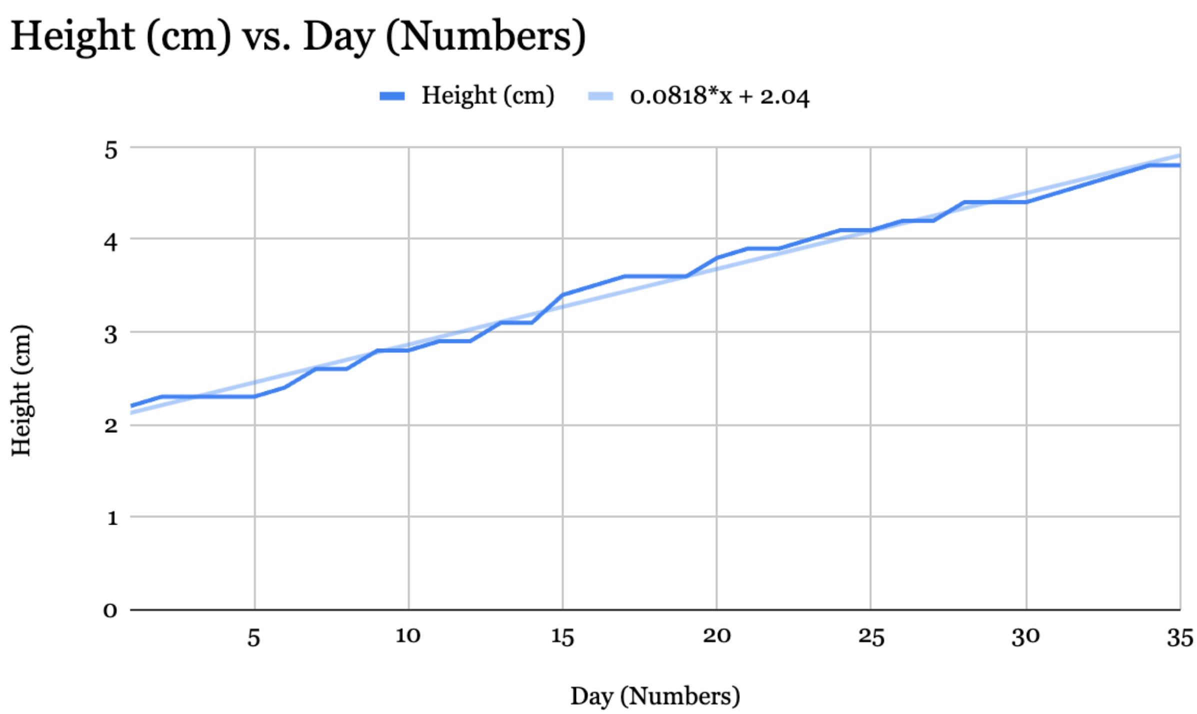
Plant 14:



Plant 15:



Plant 16:



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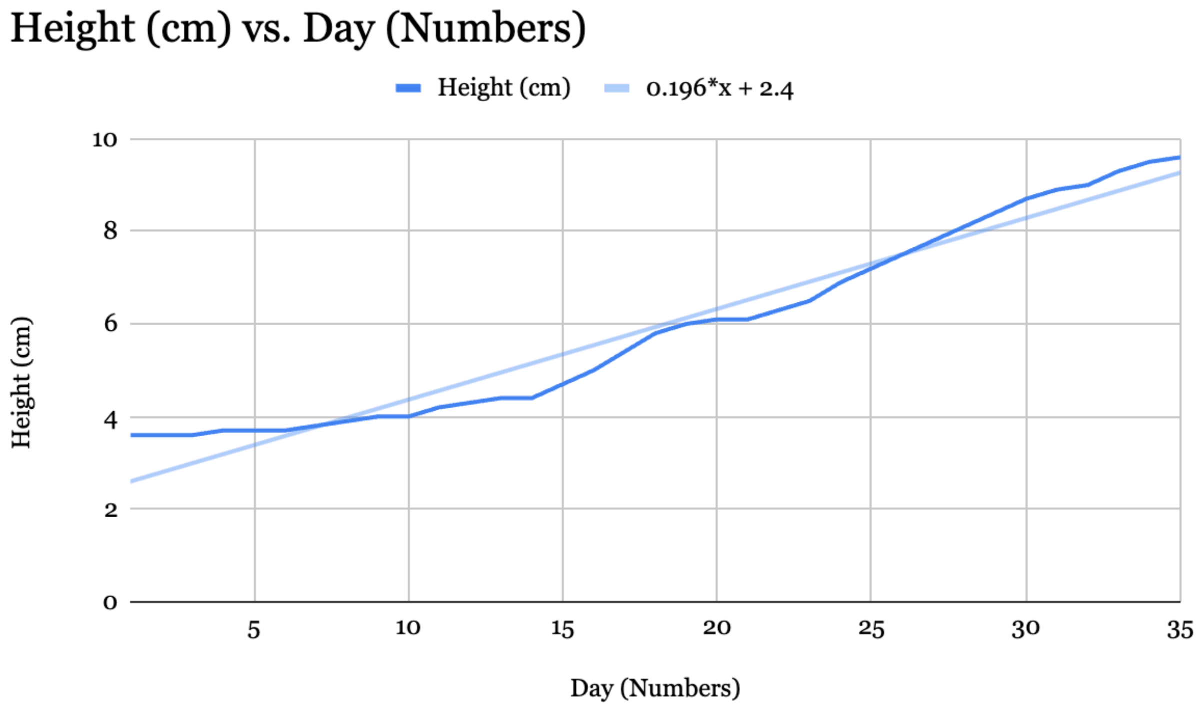

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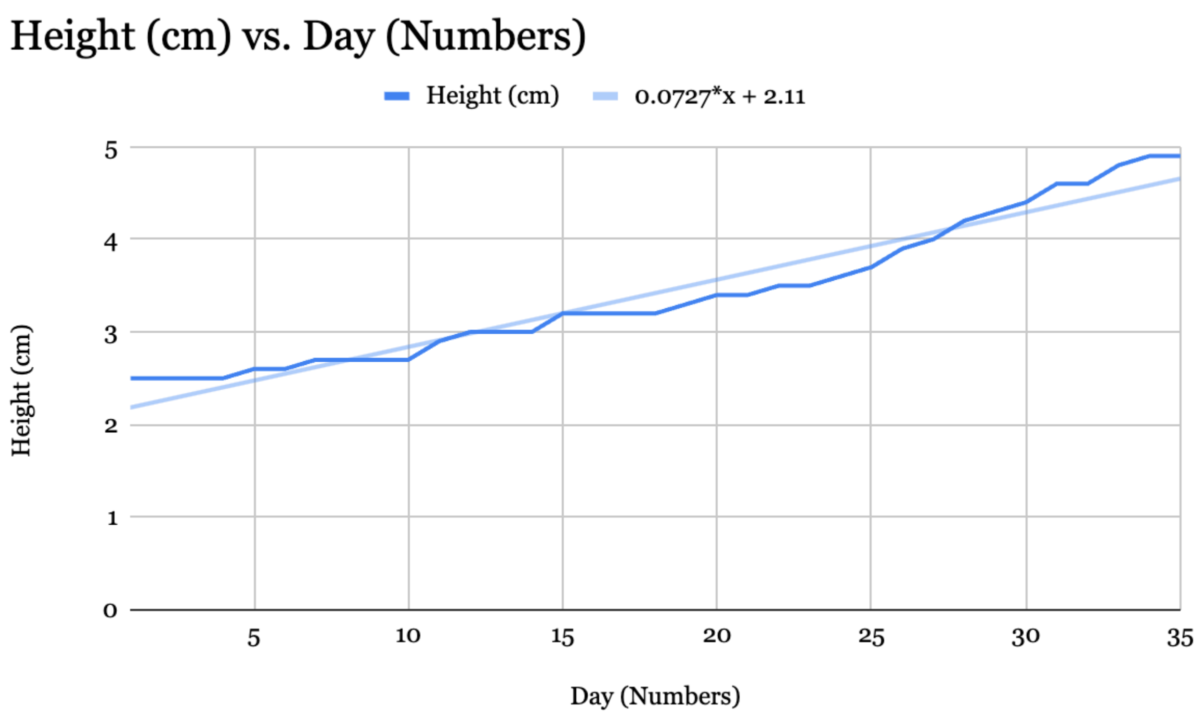

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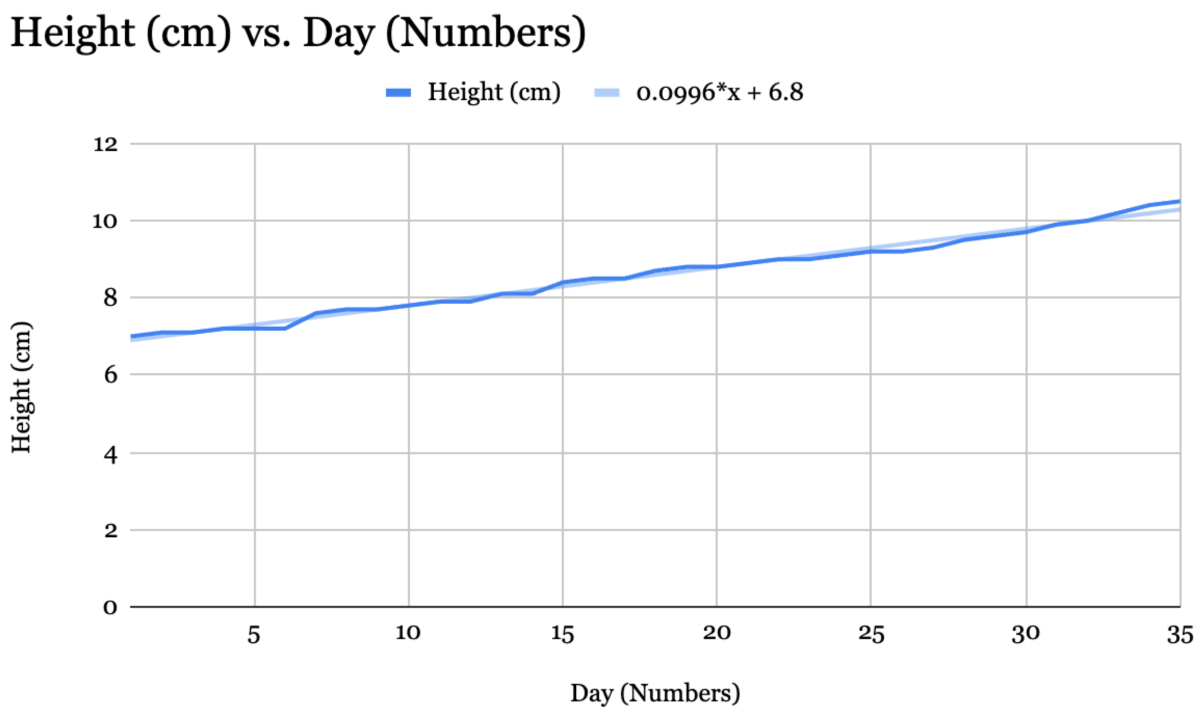

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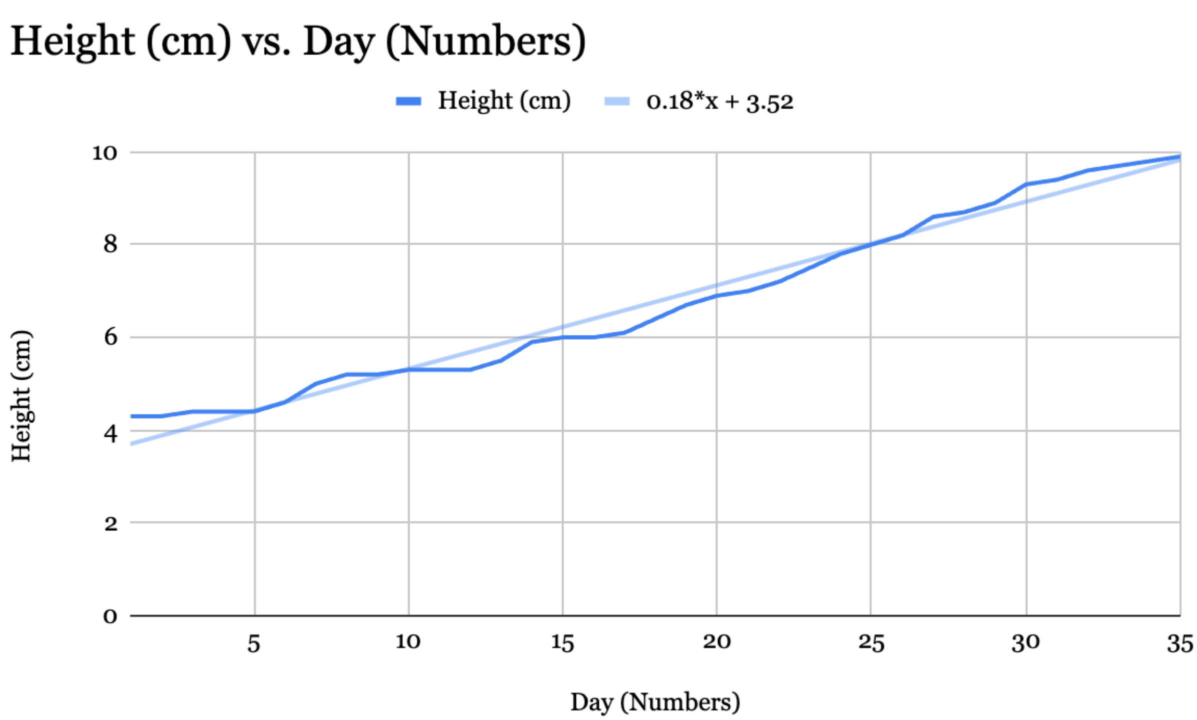

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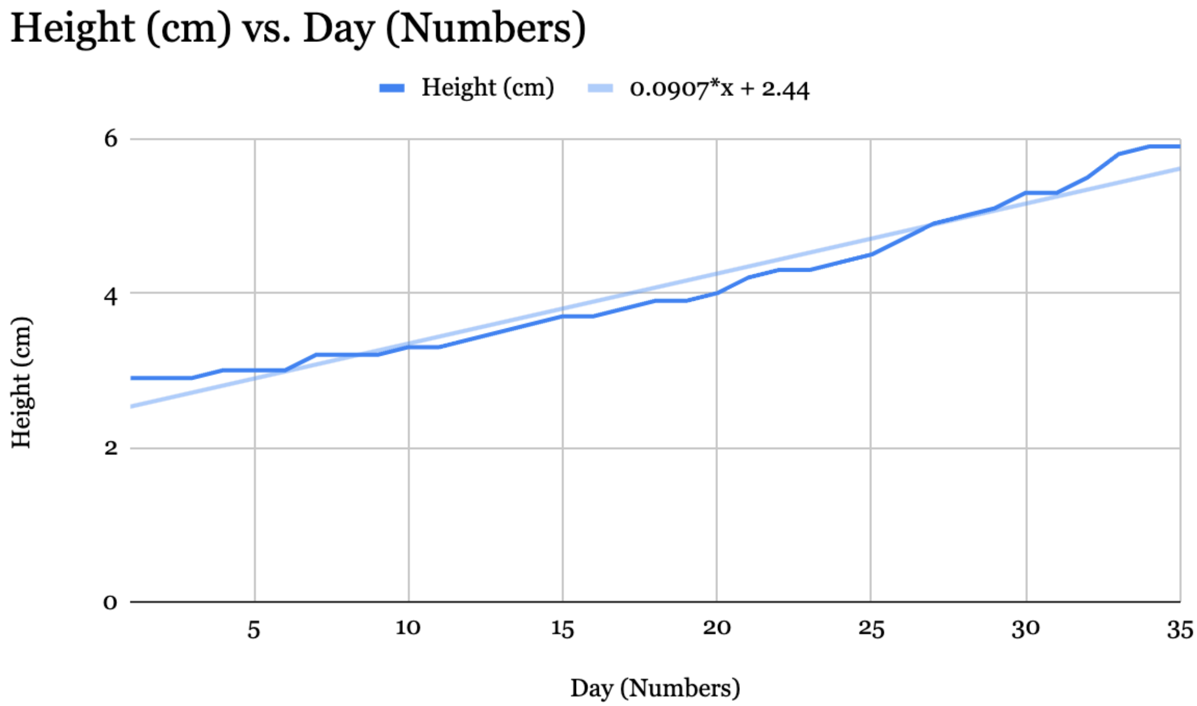

Plant 22: