Evaluation of Banana and Cocoa Waste Management Techniques in The Humid Tropics


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2. Abstract

Natural resource management, defined as the way humans use natural resources such as land, plants, soil, and water, is a very crucial topic in terms of food security. With 2 billion more people expected to be on Earth by 2050, it is essential to protect and manage resources wisely in order to maintain food security for future generations. That being said, many countries are developing policies and initiatives to effectively manage natural resources in a more sustainable way. Research institutions, including EARTH University in Costa Rica, are also conducting projects that deal with new and innovative ways to manage natural resources.

One of the main topics that is focused on when dealing with natural resource management is the closed-loop system. This system is obtained when waste or by-products of a production system are repurposed to benefit or "meet the demand of" another component of the same system. For example, many homeowners around the world compost food waste to use as a fertilizer for their garden. After eaten, the crops in the garden will eventually turn into food waste, and the cycle repeats itself. This paper will explain an investigation happening at EARTH University looking to evaluate a potential commercial fertilizer and closed production system option for cacao and banana plantations. The investigation involves the application of *lixiviados*, or leachates, of banana rachis and cocoa pods to four types of plants: celery, green lettuce, purple lettuce, and parsley.

3. Personal Introduction

3.1 World Food Prize Experience

In my bedroom, I have a world map that covers the whole ceiling. When I was younger, I used to look up at it and wonder what it would be like to live in a different country. In my Human Geography class in high school, I enjoyed discussions about global food security and studying pictures of people's homes in different countries showing the distinction between living conditions. From helping and learning more from my dad on the family farm, I also was interested in studying agriculture. When I first heard about the World Food Prize by another student in the fall of my junior year, I was uncertain if I would be able to write the 5-page paper to participate in the Iowa Youth Institute. With so many academic and extra-curricular activities, I was worried it would be difficult to find time to write the paper. Since I was interested in global studies and agronomy, I knew that writing this paper would expand my knowledge and open up new opportunities in both of these fields. Because of that, I decided to write it.

For my paper, I wrote about child labor and how it has affected the educational sector in Ivory Coast. After discussing this issue with other students and mentors at the Iowa Youth Institute, I felt more confident and determined to make an impact in terms of world food security. When I listened to Ambassador Quinn speak at the institute, I was introduced to the relationship between food security and STEM, which stands for science, technology, engineering, and math. In the same speech, I also was introduced to sustainable agriculture, which was a concept that applied STEM to serve the present and future generations of people. From that speech, I knew that writing the paper was the right decision.

When I heard that I had moved on to the Global Youth Institute, I was ecstatic. Not only would I be able to meet world-renown researchers, but also get the opportunity to apply for the Borlaug-Ruan Internship. Before participating in the GYI, I remember reading each interns' reports on the World Food Prize website and thinking how awesome it would be if I could do the same thing as them. Once I listened to the interns' presentations at the GYI, I knew that this internship would be the perfect opportunity for me.

3.2 Application Process

I started the application process in late November to make sure I didn't procrastinate. The cover letter and resume were definitely time-consuming, but worth the extra time and effort. After I sent in my application, it was difficult to avoid checking my e-mail to see if I moved on to the interview stage even though we wouldn't hear back until early February. I finally heard that I moved on during a show choir competition at my high school.

During the interview, I discussed past experiences that pertained to my interest in sustainable agriculture. I also talked about my interest in Latin American culture and learning Spanish as a foreign language. My goal was to show the World Food Prize that I was passionate for something and that I desired to make a difference in it.

Another month of constantly checking my e-mail went by until one Thursday afternoon in early March. I got home and checked my e-mail for probably the tenth time that day and found one from Lisa Fleming. I quickly opened it and scanned for any important information. My hands started sweating and my mouth turned dry. After a couple seconds, I finally found the bold sentence that stated that I would be a 2017 Borlaug-Ruan International Intern!

About a month later, I was informed that I would be travelling to EARTH University in Guácimo, Costa Rica to work on an integrated organic farm. Finally, on the early hours of June 10th, I excitedly boarded the plane and began a life-changing journey.

4. Research Center Background

4.1 EARTH University

In the early and mid 1980s, political and social unrest was commonplace in Central America. The effect of the Cuban revolution in the 1960s and the overthrow of Chilean president, Salvador Allende, in 1973 gave rise to new revolutions in other Central American countries. The civil war in Guatemala between the indigenous Mayans and the Guatemalan government continued to worsen. Another civil war in El Salvador broke out between the very powerful oligarchy and the opposition of the common people (Gould & Eichstedt).

In an effort to avoid future conflict, a group of Costa Ricans got together with USAID, the W.K. Kellogg Foundation, and the Costa Rican government in 1986 to create a non-profit international university which came to be known as EARTH.

EARTH University, or *La Escuela de Agricultura de la Región Tropical Húmeda*, is located on the eastern half of Costa Rica near a small town known as Guácimo. The campus, being 8,342 acres, includes many academic farms and places where students can learn hands-on and apply what they have learned in the classroom. These places include an integrated livestock farm, Food Processing Laboratory, a forest reserve, an Ethnobotanical Garden, and a Peri-Urban garden. The campus also has an 800-acre commercial banana plantation and packing plant where bananas are directly sent to the Whole Foods enterprise in the United States ("EARTH Facts").

At the moment, there are approximately 431 students from 41 different countries who study at EARTH. Around 60% of these students receive scholarships from foundations such as USAID or the Howard G. Buffett Foundation ("EARTH Facts").

4.2 EARTH's Academic Model

EARTH University has a strong academic model that is based off of four critical components ("EARTH Facts"):

1.) Technical and scientific knowledge – Like any other university that is promoting higher education, students must be provided with a technical background in order to be successful after graduation. At EARTH, each student works towards the same bachelor's degree in "Agronomic Engineering" or *Licenciatura en Agronomía.*
2.) Social and Environmental Responsibility – Students are taught the importance of protecting the environmental and natural resources through experiential learning and community projects.
3.) Ethics and Positive Values – To be able to create positive change, it is necessary to have certain values that make you a strong leader. Some of the values that are taught include teamwork, respect, tolerance, and self-awareness. With EARTH being a very "multicultural environment", respect for others and their beliefs is a very important value that students learn both inside and outside of class.
4.) Entrepreneurship – This component is intended to give students knowledge on how to think creatively and make responsible decisions. The entrepreneurship program at EARTH is a three-year activity that allows students to construct and operate their own businesses on campus.

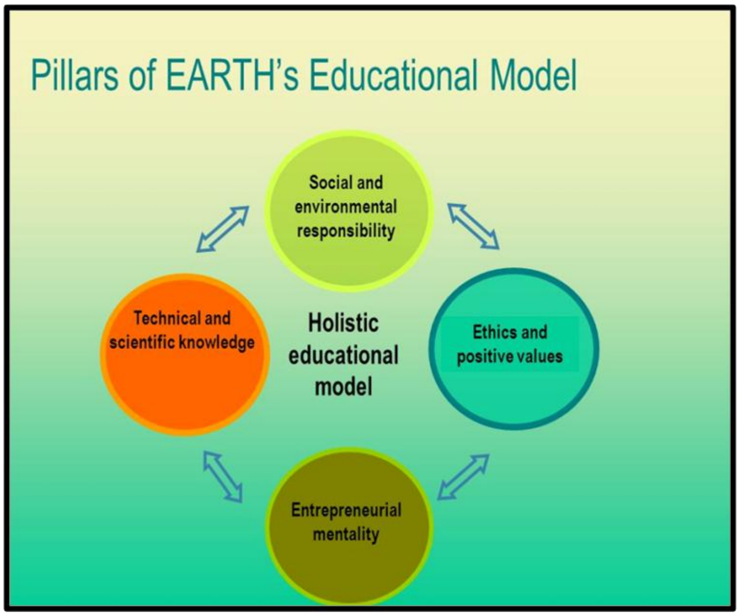

Figure 1 - Visual of EARTH's Academic Model (Zaglul, 2007)

4.3 Integrated Organic Farm

The integrated organic farm, or *finca integrada orgánica (FIO), is* where my internship took place over the summer. Created in 1995, this farm was created by a few faculty members who had a mission to "create a completely auto-sustainable farm that was exclusively organic" ("Crazy Idea That Grew"). Furthermore, they wanted to create a model farm that would replicate what students will return to after they graduate from EARTH.

FIO is located approximately three miles south from the main campus. The farm, being around 45 acres, includes a chicken coop, a pig barn, a bio-intensive farming system, a seed bank, a compost station, an artificial drier and fermenting place for cacao production, and two functioning bio-digesters. There are also many varieties of crops currently being grown at FIO, including yucca, corn, cacao, bread fruit, chile beans, bananas, sugar cane, and peppers ("Crazy Idea That Grew").

4.4 Daily Routine

A typical day for my internship involved waking up at 5:15 A.M. to go to breakfast at 5:30 a.m. The bus that went to FIO left a few minutes before 6, so I had to scarf down my food and quickly make my way to the bus stop behind the cafeteria. The bus ride was around five minutes to FIO each morning, including a few stops to pick up other passengers.

When I arrived to FIO, I made my way to the break room where I met the rest of the workers. Our first task was to feed and collects the eggs from the chickens. Then, we fed the pigs and cleaned out their corals. We usually finished these tasks by 8 o'clock, which was the start of a 15-minute break for the workers.

The 15-minute break was a great time for me to practice spanish and wake up a little with some rich Costa Rican coffee.

By the time break was over, we started to work on different projects happening at FIO. In the first few weeks of my internship, we worked on building a bio-digester, which is a large plastic tank that digests pig and cow waste to create methane gas. The methane gas can then be used to start ovens for cooking or for electricity. On other days, I helped plant yucca, corn, or other plants with some of the workers. Whichever task they gave me, I often enjoyed it because it involved getting my hands dirty.

This was my daily routine for Mondays, Tuesdays, Thursdays, and Fridays. On Wednesdays and Saturdays, I participated in *expriencia de trabajo,* or work experience, with the first, second, and fourth year students. The first and second year students are assigned a place to work on campus, whether it be FIO, the animal farm, organic banana farm, agro-forestry farm, or Peri-Urbana. The fourth-year students are the *jefes*, or bosses, that supervise the work and teach students why certain tasks are carried out. On those days, I helped create compost piles at the compost station, patched up holes in a bio-digester, and harvested cocoa. I also worked on an experiment with a fourth-year student from Ecuador named Steeven León. While my tasks varied greatly each day, this experiment became the main focus of my research as part of the internship.

5. Research

5.1 Bananas

Bananas, a perennial crop found in the *Musaceae* family, have always been a very familiar fruit in the human diet. According to study done in 2014, bananas are the leading fruit in terms of production. Around 114 million metric tons of bananas were produced that year, with watermelons and apples trailing not far behind (“World Production”). Furthermore, around 76% of the bananas produced go to directly to humans (“Surprising Science”).

Banana production also plays a valuable role in the Costa Rican economy. In fact, banana production represents around 30% of the gross domestic product (GDP) within the country’s agricultural sector. On top of that, about 19.6% of the total GDP goes to agriculture (Hernandez & Witter). Back in 2013, Costa Rica ranked 12th globally in banana production, producing over 1.9 million metric tons. Today, the small Central American country continues to be a powerhouse in banana production, especially through exportation. As of May 12, 2017, Costa Rica is the 3rd largest exporter of bananas, selling around 996.8 million dollars worth of bananas to other countries (Workman).

5.2 Cocoa

Similar to bananas, cocoa is another fruit that is in constant demand in the global market. Cocoa is the main crop associated with the production of chocolate. According to gourmethealthychocolates.com, around “1 billion people eat chocolate every day.” Additionally, the average American consumes 12 pounds of chocolate each year” (Klein). That’s about 44 Hershey chocolate bars! Not only is it a major food in America, but globally as well. One study found that “more than $75 billion worldwide is spent on chocolate annually” (Klein).

Most of cocoa production can be found in Western Africa, which accounts for “66% of the average annual production of cocoa between 1993 and 2013” (“facts and figures”). Based on a study done on cocoa production in 2013, four of the top five cocoa producing countries in the world lie in Africa. Also, four of the top ten lie in Latin America (Mattyasovszky). You may recall earlier in this paper that there are over 400 students from 41 different countries that attend EARTH University. Besides the United States and Belgium, all the countries that are being represented at EARTH are in Africa and Latin America. As a result, EARTH University has put a lot of emphasis on cocoa research in order to teach students proper agronomic practices for this crop that they can bring back to their home country.

5.3 Background & Objective

With an increasing demand for both cocoa and bananas on a global scale, it is becoming more and more important to ensure the sustainability of both of these sectors. Therefore, some of the research that people at EARTH University have focused on is the waste material that come with cocoa and banana production. In particular, students and professors have begun to utilize “banana stalks to produce and sell banana paper in an on-campus paper-making factory” (“Sustainability”). Plastic bags and cord are also being re-used at the banana packing plant on EARTH’s campus (“Sustainability”). When the banana trees at the commercial farm are re-planted, workers use compost made from banana stalks and non-marketable bananas to provide more nutrients readily available to the plant (“benevolent bananas”).

The experiment that I worked on was designed to evaluate the effectiveness of two types of plant leachates as a natural fertilizer on four types of plants. If proven effective, using decomposed plant material as a fertilizer could be a great alternative to synthetic fertilizer on small-scale farming operations. Not only would it decrease the cost of fertilizer for the farmer, but also would create a sustainable, closed-loop production system.

The two types of plant material used in this experiment were the cocoa pod and banana rachis. The cocoa pod is the outer shell of cocoa beans which are used to produce chocolate. Banana rachis is “the stem of the inflorescence” that sits between the male flower and the cluster of bananas (Véniza & Baena). Figures 1 and 2 show the material used in the experiment. Both the cocoa pod and banana rachis have no specific use after the beans and the bananas are harvested. Because of this, new research is being conducted to find a use for the leftover material. So far, many cocoa plantations are placing cocoa pods in large piles to compost (“Harvesting Cocoa”). Although little research has been conducted with the use of banana rachis, EARTH University has started to use it as compost material from the commercial banana plantation on campus. The rachis is mixed with sawdust and calcium carbonate to level out the pH and balance out moisture levels.

Figure 2 – Cocoa Pods (“Cacao pods, 2010)

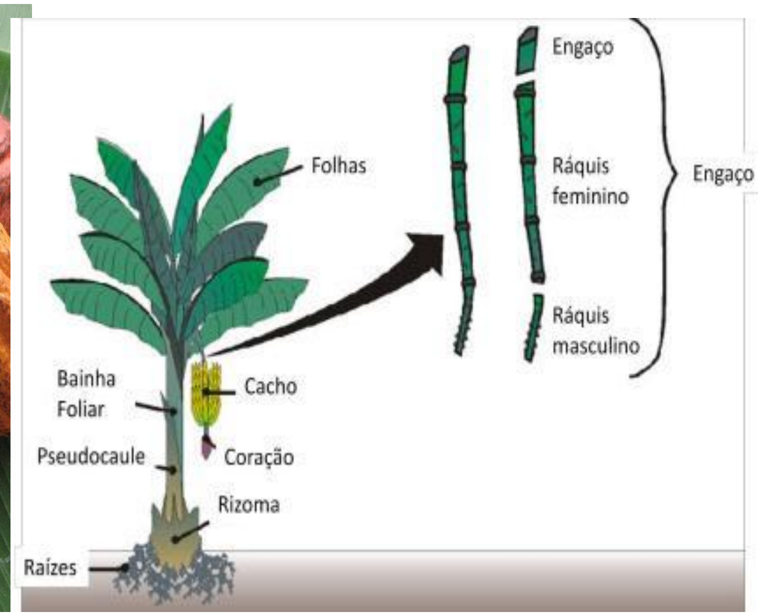

Figure 3- Rachis (ráquis in Spanish) on Banana Tree (Rodrigues Cardoso, 2011)

5.4 Leachates

Although both can be used as compost material, students and professors at EARTH University are beginning to investigate the *lixiviado*, or leftover leachate, of both the cocoa pod and banana rachis after the decomposition process. The leachate is a “liquid that is produced in the decomposition of organic matter” (Ramirez 2-3). The organic matter in our situation was two types of “vegetative material”, the cocoa pod and banana inflorescence (Ramirez 3). To harvest the leachate, the plant matter is first chopped or crushed into smaller pieces and then placed on an inclined chamber to decompose. A certain amount of water (around 10% of the weight of the plant matter) is added to the chamber to collect the leachate from the decomposing plant matter. The liquid with the extracted leachate then flows down the inclined chamber by gravity into a jug at the base. A 100% impermeable plastic cover is placed under the plant matter so no liquids escape from the chamber. Figures 4,5, and 6 seen below show the decomposition chambers with the decomposing leachates inside. After the leachate is collected in the jug, it can be applied as a fertilizer (Ramirez 5-6).

Figures 4,5,6 - Decomposition Chambers and Harvesting of Cocoa (4,6) and Banana (5) Leachates

5.5 Hypothesis

This experiment was driven by four hypotheses, all dealing with how effective the leachates are. To be able to test their effectiveness on plants, we decided to measure variables that corresponded with plant growth and development. The hypotheses are listed below.

1st hypothesis (H_o) – Both leachates will have no significant impact on plant growth.

2nd hypothesis (H_a) – The banana leachate will have a larger impact on plant growth compared to the cocoa leachate.
3rd hypothesis (H_a) – The cocoa leachate will have a larger impact on plant growth compared to the banana leachate.
4th hypothesis (H_a) – Both leachates will have a significant impact on plant growth.

5.6 Methodology

When both cocoa pod and banana rachis undergo decomposition after the fruit is collected, certain compounds break down into vital nutrients for soil health and plant growth. These nutrients are specifically nitrogen, phosphorus, potassium, calcium, magnesium, and other elements in smaller amounts. With natural decomposition, there is only a certain proportion of nutrients that can be collected from both the pod and rachis. Therefore, it was important for us to identify the optimal concentration of leachate fertilizer that would promote the greatest overall development between each plant. So, five different concentrations of leachate were tested for both types.

T1	Control	Cocoa Pod Leachate
T2	20%	
T3	40%	
T4	60%	
T5	80%	
T6	100%	
T7	Control	Banana Rachis Leachate
T8	20%	
T9	40%	
T10	60%	
T11	80%	
T12	100%	

Figure 7: Leachate Treatments with Assigned Concentrations

We obtained a better overall sample of their effect on plant growth by developing five different concentrations of leachate. Each concentration was then applied to four types of plants: celery, purple lettuce, green lettuce, and parsley. Twelve treatments were developed representing a control group and the five concentrations of leachate. Figure 7 on the right shows all treatments from 1-12 and the concentration assignment given to each. To again get a better overall representation of data, all twelve treatments were used in four repetitions for each plant, besides green lettuce which was 3 repetitions. Therefore, there were 48 celery, parsley, and purple lettuce plants, along with 36 green lettuce plants.

Each plant was placed on long metal tables in a greenhouse set up as a semi-controlled environment. The three controlled factors in this experiment were the amount of water, the soil:compost ratio, and the amount of soil for each plant to grow out of. All plants were watered around the same amount (about five seconds of watering by hose for each) daily by workers at the organic farm. The two control groups (T1, T7) were only watered daily and fertilizer was never applied to them. The plants were planted in small pots with a proportional amount of dug-up earth and compost, 2 part soil:1 part compost.

5.7 Data Collection Process and Harvesting

Different measurements were taken into consideration for each plant. For both celery and parsley, the number of leaves and plant height were measured. For green and purple lettuce, plant height, width and length of the largest leaf, and the number of leaves were measured. The wet and dry weight was also measured for each plant. The intention of measuring biomass was to identify the actual weight of the plant itself. This gave us an idea on plant

and Banana Leachate

yield and root development for each treatment. It also gave us a more accurate alternative measurement compared to, for example, the height and width of the largest leaf.

Data was collected for seven weeks from June 21 to August 9. The leachates were applied each Saturday during work experience so other students could help out. Figure 8 on the previous page shows

Figure 9: Weighing lettuce leaves and roots

f increasing concentration. The brown-colored leachate on the left is the banana rachis and the black-colored leachate is the cocoa pod. Data was recorded every Wednesday following the leachate application. The lettuce was harvested a week early because it began to suffer from a disease known as Anthracnose leaf blight. This disease is a fungus that forms small yellow spots across the entire leaf of a lettuce plant. One of the main causes of the fungus is the buildup of water on leaves from improper irrigation. Since we didn’t take the disease into consideration when watering the lettuce plants, this could be the reason why it formed. After harvesting the lettuce, we obtained the biomass of each plant by measuring the fresh and dry weight on an electronic balance. The biomass was collected for both the plant and its roots. This was done by separating the roots from the plant and cleaning out all soil particles stuck in the roots. After each were seperated and weighed, they were placed in labelled sacks and set in an oven to dry out over a week. Then, the dry weight was measured for each. Figure 9 on the left shows me weighing and bagging up the leaves and their roots to be placed in the oven in the right side of the picture.

5.8 Results/Analysis

All of the data was placed in an excel document with each plant, week, repetition, and variable included. The results of the data are shown below the bibliography on page 18 as line graphs with the treatments listed on the x-axis and the variable being tested on the y-axis. All the data is represented as the average of the first three weeks of leachate application for all variables except the biomass of each plant. The data was based on the first three weeks because we knew that the plants were becoming mature after the third week and were most unlikely to absorb the applied nutrients for growth. Based on all the graphs for cocoa, there doesn’t seem to be any correlation between the amount of leachate being applied to the development of the plant. Most of the trendlines for cocoa show a slope of less than 0.2, suggesting that no correlation exists between the cocoa leachate and plant growth. Some of the plants reacted similarly to each other, like green and purple lettuce. This does make sense because they have a very similar physiological make-up and both suffered from leaf blight in the middle of the experiment.

As for the banana leachates, there seems to be either a strong negative or strong positive

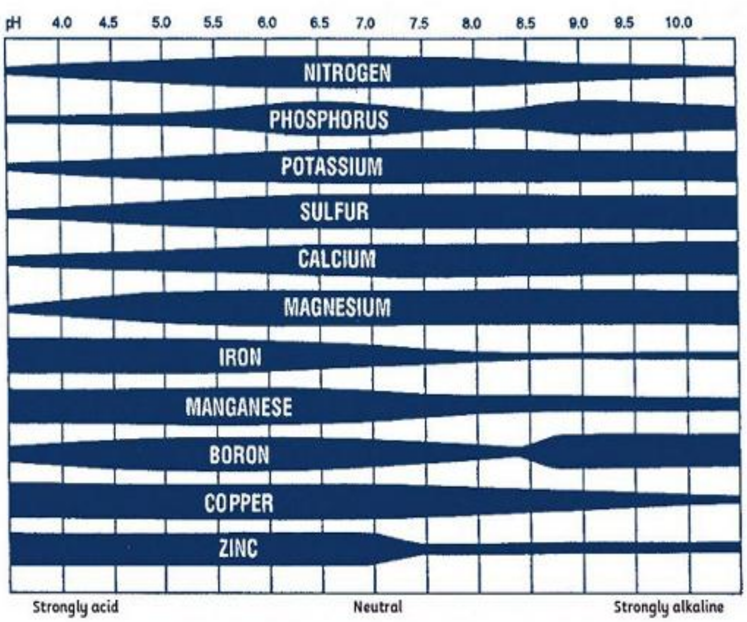

Figure 10: Plant Nutrient Availability Chart (Silveira, 2013)

correlation between the leachate concentration and the variable dealing with plant growth. The strong negative correlation is what pops up the most.

There could be a number of factors that cause this. One of the factors could be pH and its impact on nutrient availability. As seen in the chemical analysis table below, the pH of the banana leachate is 4.58. The figure just above the chemical analysis table is another analysis of the soil at the same research location. The analysis was conducted for a similar research project that evaluated the effect of pineapple and banana leachates on six different varieties of cocoa. Based on the table in figure 12, the pH of the soil at the research location was 5.42. Although we were unable to conduct a soil analysis like the 2014 study, we assumed that the pH of the

IDENTIFICATION	P	K	Ca	Mg	Fe	Cu	Zn	Mn	Nitrates	pH	Elect. Cond.
	ppm										dS/m
Banana Leachate	65.7	3024	607	245	54.6	0.45	1.31	3.83	64.64	4.58	9.679
Cocoa Leachate	157.6	6275	211	159	*	0.58	0.57	*	*	8.36	13.22

Figure 11: Chemical Analysis of Banana and Cocoa leachates (Avila & León, 2017)

soil we used in the flower pots was very similar. The low pH values for both the soil and the banana leachate could have caused the negative correlation between concentration levels and plant development variables.

Identificación	pH/ agua	Ac. Ext.	K	Ca	Mg	P	Fe	Cu	Zn	Mn
		------------cmol+/kg---------				--------------mg/kg-----------------				
Plantación Agrocacao	5,42	0,70	0,97	6,55	3,91	5,56	188,39	10,71	3,00	64,20

Figure 12: Soil Analysis for a Research Project at FIO in 2014 (Ramirez 2014)

When a fertilizer with a low pH is added to a low pH soil, the soil's pH will decrease even further. When this happens, important plant nutrients like phosphorus become insoluble and are unavailable to the plant. Looking back at the chart in figure 10, other nutrients like iron and manganese thrive in low pH soils. While important, these nutrients can be toxic to the plant when in excess. The plants that were being fed the banana fertilizer may have suffered from a lack of phosphorus since they were being tied-up by other nutrients. The chart in figure 13 shows this process in a little more detail. As the pH of the soil becomes more acidic, the

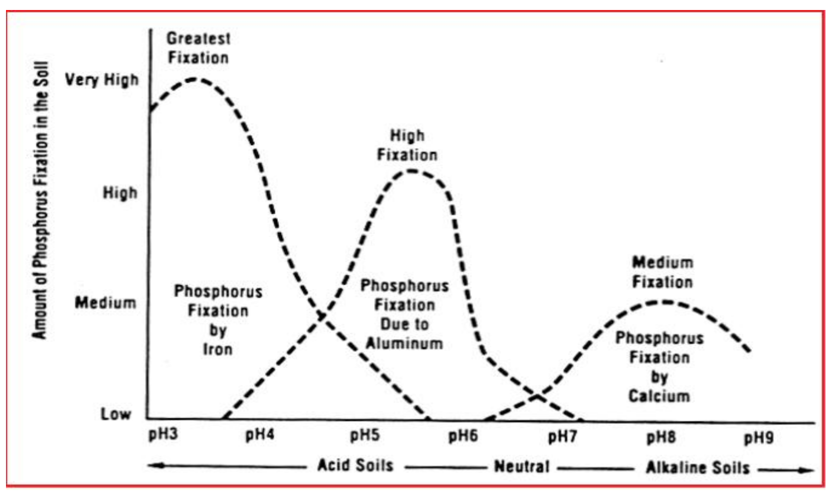

Figure 13: Phosphorus Availability to Plants (Soil Phosphorus - Soil Quality Kit)

amount of phosphorus being fixated by iron and aluminum increases. Therefore, the more banana leachate that's applied, the less phosphorus will be available to plant (Silva).

The lack of correlation with the cocoa leachate may have been caused by other factors rather than pH. The pH of the cocoa leachate is 8.36, while the pH of the soil is around 5.5. When the leachate is added to the soil, the soil pH will rise to a number between it's own pH and the pH of the leachate. For that reason, the soil's pH should have been adjusted to a level where more nutrients are available and accessible. Another potential factor could be the very low nitrate concentration of the cocoa leachate. Nitrates are soluble anions that plants take up as a source of nitrogen. Similar to phosphorus, nitrogen is a macronutrient that's an essential component to plant functions and development. Without it, plants can't photosynthesize as well as they could with an optimum supply of nutrients (Buchholz). In the case of the cocoa leachate, there was no nitrogen being added to the soil. Although other nutrients were being added in large amounts like phosphorus and potassium, the lack of access to nitrogen could've held the treated plants back from growing any larger than the controlled plants.

The third and final factor could have been salt accumulation of the leachate or water being added. The electric conductivity in figure 11 determine the amount of salts that are presents in the leachates measured in Deci Siemens per meter. The higher the value the, more salts like sodium, calcium, magnesium, and potassium cations are present in the leachate. Different plants have different responses to salt concentrations in liquid additives. Some plants are more sensitive to high salt concentrations compared to others. Plants like lettuce and celery are moderately sensitive salinity, or electric conductivity. The chart in figure 14 shows relative crop yield as a function of crop yield. According to the chart, moderately sensitive crops are generally not affected by salinity until the value jumps over 5 dS/m. In our case, the banana leachate had an electric conductivity value of 9.679 and the cocoa leachate had a value of 13.22 (Figure 11). According to figure 14, the relative crop yield at both EC values would be significantly lower than 100% if the leachates are added to the plants we used in our experiment. Although we didn't test the EC value for the water that we used to water the plants, it could've also been a factor with the lack of, or strong negative, correlation between leachate concentration and plant growth.

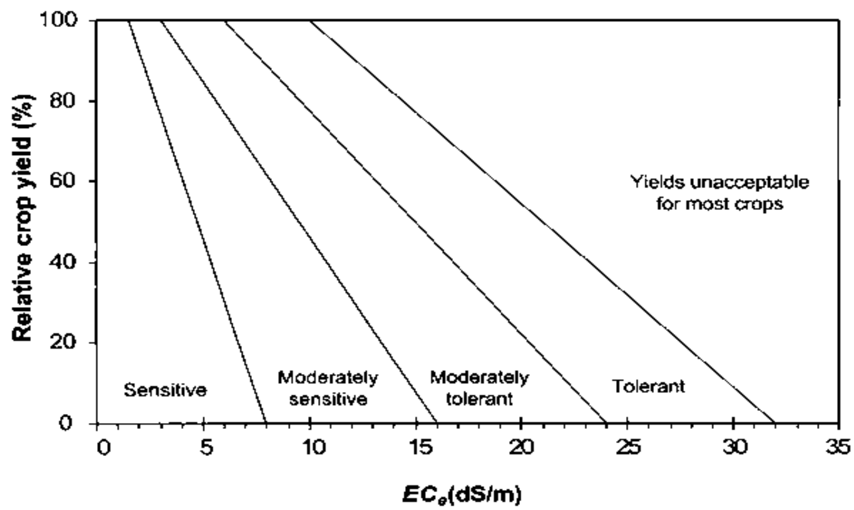

Figure 14: Relative Crop Yield vs. Electric Conductivity ("Crop Salt Tolerance Data")

5.9 Conclusion

Both of the leachates didn't perform as well as we wanted. For that reason, we concluded that the 1st hypothesis was the best answer. Some of the root causes behind the low performance could've been pH, nitrate concentrations, and electric conductivity. The only leachate concentrations that seemed to perform better than the ones that didn't receive fertilizer were 20% and 40%. Therefore, these two concentrations would be the best option if both the cocoa and banana leachate are produced and sold commercially. However, a lot more research still needs to be conducted before both leachates can become marketable products.

To improve the results of the experiment, I would recommend starting the experiment with the seedlings of the plants being used. This would be beneficial because, in general, a fertilizer is most effective when it is applied at earlier stages of plant growth. Since we applied the fertilizer after the seeds had germinated and the plants were already forming leaves, the nutrients that were added may have not been utilized as efficiently as it could have been if applied earlier in the plants' growth stages. I also would suggest analyzing the soil and water used for physical and chemical properties so we could compare it to the chemical analysis of the fertilizers.

6. Personal Experience

6.1 Overcoming Language Barrier

From all the experiences that I had, it's been very difficult for me to put it into words when trying to describe it all to someone else. However, the most important thing that I got out of this opportunity is to live life to the fullest. Whether that meant speaking Spanish to other students and professors, participating in the Romería, or learning how pineapple is produced commercially, I realized that taking advantage of opportunities and being optimistic about the outcome is the best way to live.

Since I only worked at the organic farm until noon every day, a lot of my experiences were on the cultural side. Some of my most memorable experiences were playing on a 3 vs. 3 basketball team, In high school, I was often the shy kid in class who didn't like to share his thoughts. After participating in the World Food Prize programs in my junior year, I was more confident in myself and willing to go out of my comfort zone. By the time I was heading back to the U.S. after the internship, anything that meant going out of my comfort zone was exciting to me. I was no longer afraid of what other people thought of me. I rather was more willing to get to know them and find out what they were interested in. One of the biggest factors that influenced my self-confidence was overcoming the language barrier. In high school, I took four years of Spanish. In those four years, I definitely expanded my vocabulary, memorized different tenses and conjugations, and learned about Latin American culture, but didn't have much practice with actually speaking to someone else. When I first got to the university and someone started speaking Spanish to me, I had a mini-panic attack. 'Would I be able to handle this?' I remember thinking.

It got a lot better once I started forcing myself out of my comfort zone. Rather than laying in my bed pondering what to watch on Netflix on the night I arrived, I practiced speaking Spanish by getting to know my roommate. I found out we had similar interests, including playing soccer and listening to rock music. He was really flexible with my broken Spanish and I really appreciated that.

6.2 Soccer & Basketball

On the Monday after my first day on the job, I decided to walk around and check things out. When I was walking, I saw a pick-up soccer game that was about to start at the soccer fields. Since I like soccer and thought I could maybe learn some new skills from some of the players, I decided to make my way over and join the game. At first, it was a little intimidating since a lot of them were older and I didn't know if they were talking about me. I then started to pick up on a few words that I remember learning way back in freshman year of high school like *aqui* (here), *corre!* (run!), and *vamos!* (let's go!). I had a diverse Spanish vocabulary and could recognize what signs said, but it was difficult for me to register what other people were saying because they spoke so fast. I left the soccer game feeling a little more confident knowing I could understand a few of the words that were being said.

In the weeks following, I tried to find any opportunity to get out of the dorm room I was staying at. After eating dinner, I often went to the game room and played ping-pong or pool with my roommate and his friends. I also participated in the EARTH games, which is a large one-day sporting event held every year over the summer. Some of the sports that I participated in included soccer, basketball, and soccer-volley. Around the 4th week of my internship, I joined a basketball team for a 3 vs. 3 tournament. There were three other people on my team. One was from Somalia, another was from Haiti, and the third was from Mexico. Playing on a team with diversity and different backgrounds was an awesome experience.

6.3 Romería

One of the most eye-opening experiences was the Romería. A really good friend I met at EARTH University named Julio told me about a 15-mile pilgrimage to a beautiful basilica east of Costa Rica's capital known as *La Basilica de Nuestra Señora de Los Ángeles*. Around 50-75 students form EARTH were planning on participating in the pilgrimage, so Sarah and I decided to join Julio and take on the adventure. Around 2 million Catholics from all over Central America come to this annual event to "ask for blessings, favors, or forgiveness" ("La Negrita"). This made it important for us to stay together while walking. We arrived in the capital, San José, around midnight and started walking east to Cartago where the basilica was at. Needless to say, walking 15 miles from midnight to 4 in the morning wasn't the most entertaining part of my whole experience, but it did make me realize the dedication and faith to the Catholic church that many people in Latin America hold on to. When we finally made it to the basilica around 5, it was so cool to see all the excited faces not only about making it there, but also how beautiful the basilica. If you go inside it, you have to go down on your knees and crawl until you reach the altar in order to forgive and repent. I'm a Catholic myself, so it was interesting to see the different practices that make up the Catholic church in Latin America.

We were going to church on Sundays in a small town called Pocora right outside of EARTH University. Much of what happens in mass is the same as my church back at home. The only big difference is that it was all in Spanish and I had to translate in my head. I was able to get the gist of most of it, especially the parts that I was familiar with.

6.4 Lessons Learned

Having gone out of my comfort zone to get to know other people and overcome the language barrier was the best decision I made. It also humbled me knowing that many of the people I met grew up underprivileged and had a passion to learn and give back to their communities. Most of the students that I met from Africa were fluent in multiple languages, including French, a native Creole language, English, Spanish, and Arabic. I will never forget the begs from other students for me to come visit them in their own country.

Another big component of my personal experience was freedom and independence. Being able to play soccer, eat, or go to the swimming pool anytime of the day was something that I wasn't used to. Having that freedom and independence helped me transition into a whole new stage of life, especially knowing that I would be a freshman at Iowa State University in a few months. Being able to make my own decisions was a little scary at first, but as time went by during the internship, I began to really appreciate it.

6.5 Relation to Food Security

Food security means different things to different people. It could mean having a small garden to feed your family to developing a hybrid corn product that will feed millions of people. The research that I conducted helped me broaden my knowledge of the different components that tie into food security, one of them being waste management in food production. It's not all about the quantity of food you create, it's about how the food constructs healthy and sustainable communities. The research that I conducted did not directly feed people who struggle from food insecurity, but I knew deep down that this work will eventually help maintain food production in areas where the climate is favorable for crops like bananas and cocoa.

I also knew that my research could potentially benefit the students that are currently attending EARTH University. Because a large population of students at EARTH are originally from Africa and cocoa is a main cash crop for many countries there, these students can bring this research back to their communities and make a small difference. It's also impactful for Costa Rica knowing the fact that they aim to become the first carbon-neutral country in the world. Carbon-neutral is when the amount of carbon dioxide being released into the atmosphere is equal to the amount of carbon dioxide being sequestered from the atmosphere ("carbon neutral"). To be able to do this, it will be important for Costa Ricans to manage solid waste material effectively in order to limit the amount of carbon dioxide emissions from them. This means avoiding build-up of waste in landfills by re-cycling, composting, etc. Bananas also play a huge role in food security within Costa Rican communities. If large banana plantations or small banana farmers will be unable to produce as much as they are able to now, other nations will start to feel the harsh reality of food insecurity within their own communities.

6.6 Reflection

A famous author named Robert Swan once said, "The greatest threat to our planet is the belief that someone else will save it." If everybody on this planet had this mindset, it would be tough to say where we would be now in terms of global food security. I'm guessing it wouldn't be as pretty as what we might think. Today, a vast majority of the population still thinks like this. The students that attend EARTH University are different. They want to save the planet, and they know that relying on somebody else to do it won't foster any progress. They all have a passion to make a difference, whether it be back in their communities or around the globe. It was easy for me to notice this with all the time and effort they put into their school work and the questions they asked during work experience.

Protecting the environment and ensuring food security through development of sustainable cropping systems is something that I'm deeply passionate about. By studying Agronomy and Global Resource Systems at Iowa State University, I can gain technical knowledge on sustainable agronomic management techniques and apply it back to real-word issues on a global level. This internship was a perfect fit for my future plans. Being able to relate my own passion to other people from around the world and the same age as I was invaluable. I might not be able to visit some of the students, but I will definitely keep in touch with them to see the difference that they make. By the time I'm out of college and starting a career tackling food security issues, I want to be able to look up at the map on my ceiling at home and not only realize that I've been to a certain country, but also made a difference there whether it be directly related to food insecurity or not.

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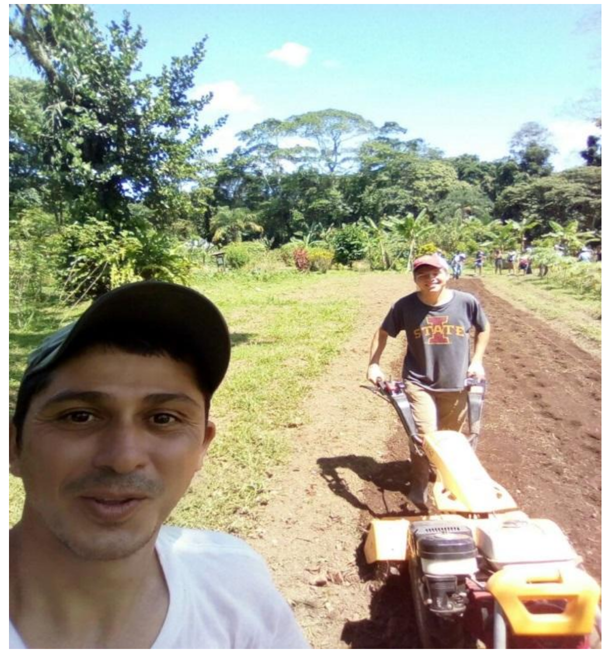
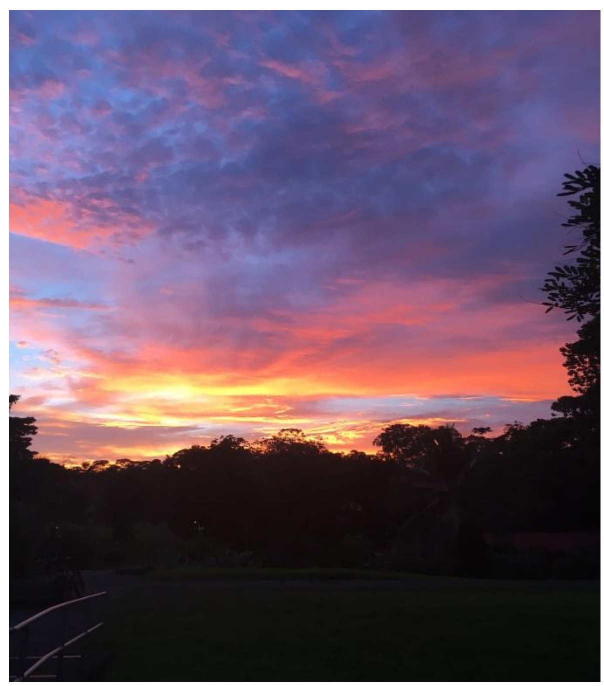
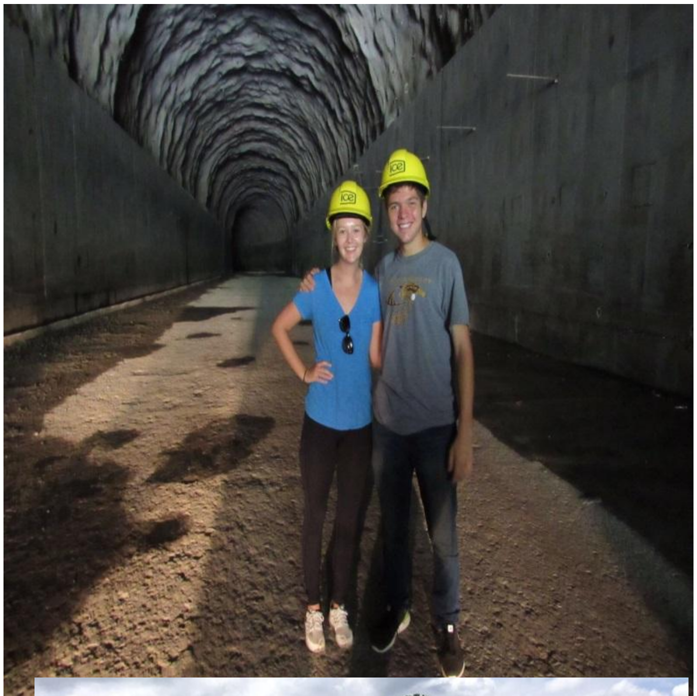
Zaglul, José . EARTH University. N.p.: Wilfrid French, 5 June 2007. PPT. **(Figure 1)**

Pictures







Plant Growth Time-Lapse

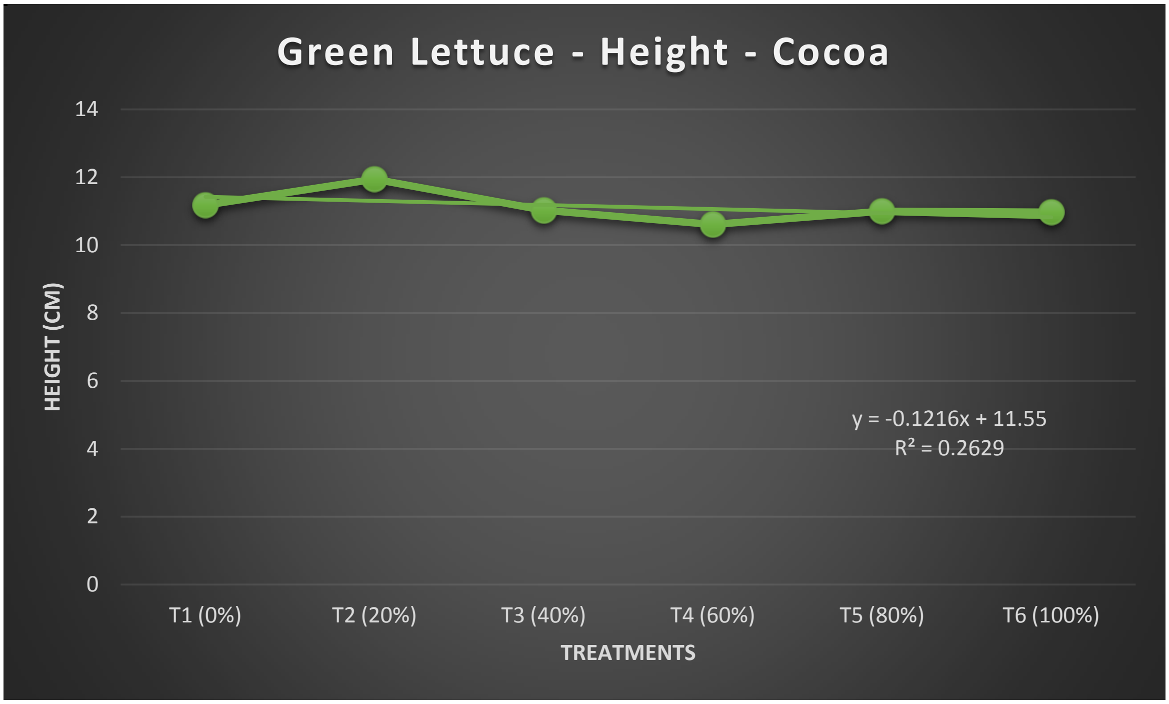
July 1 (Week 2)

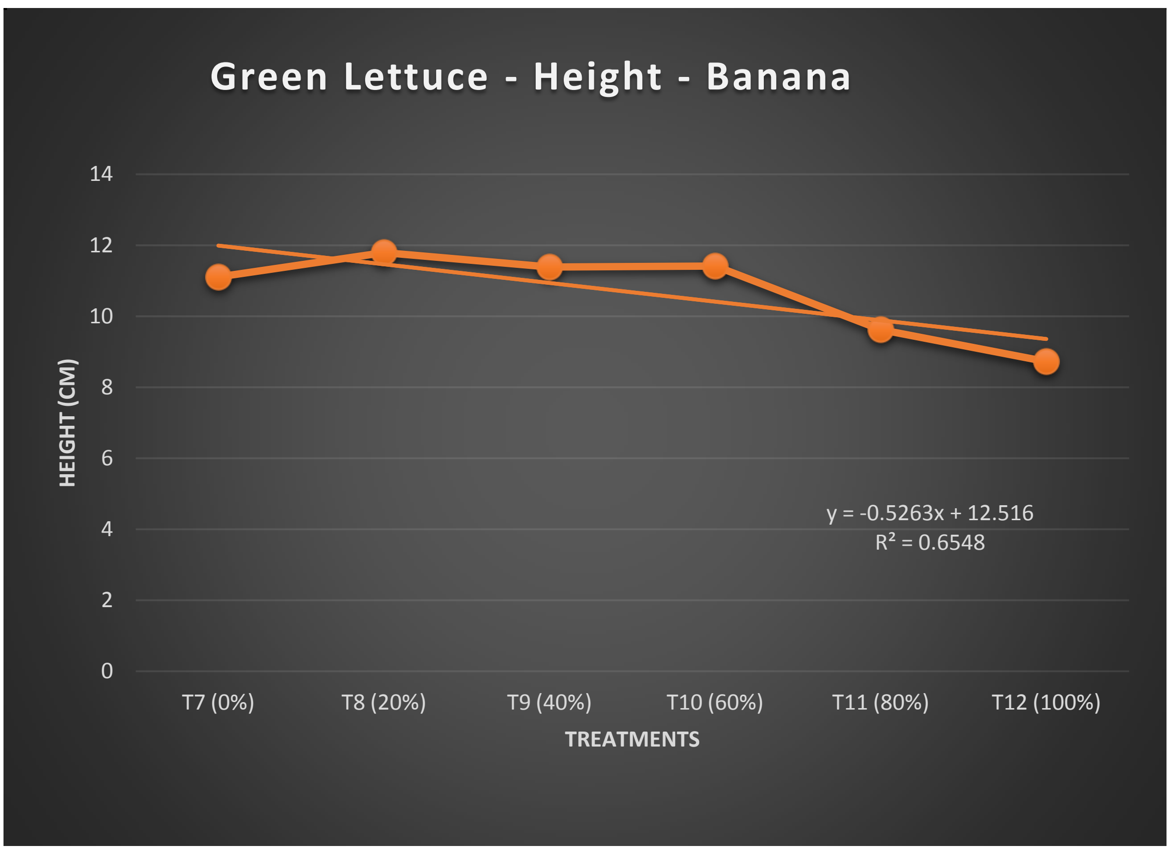
July 19 (Week 4)

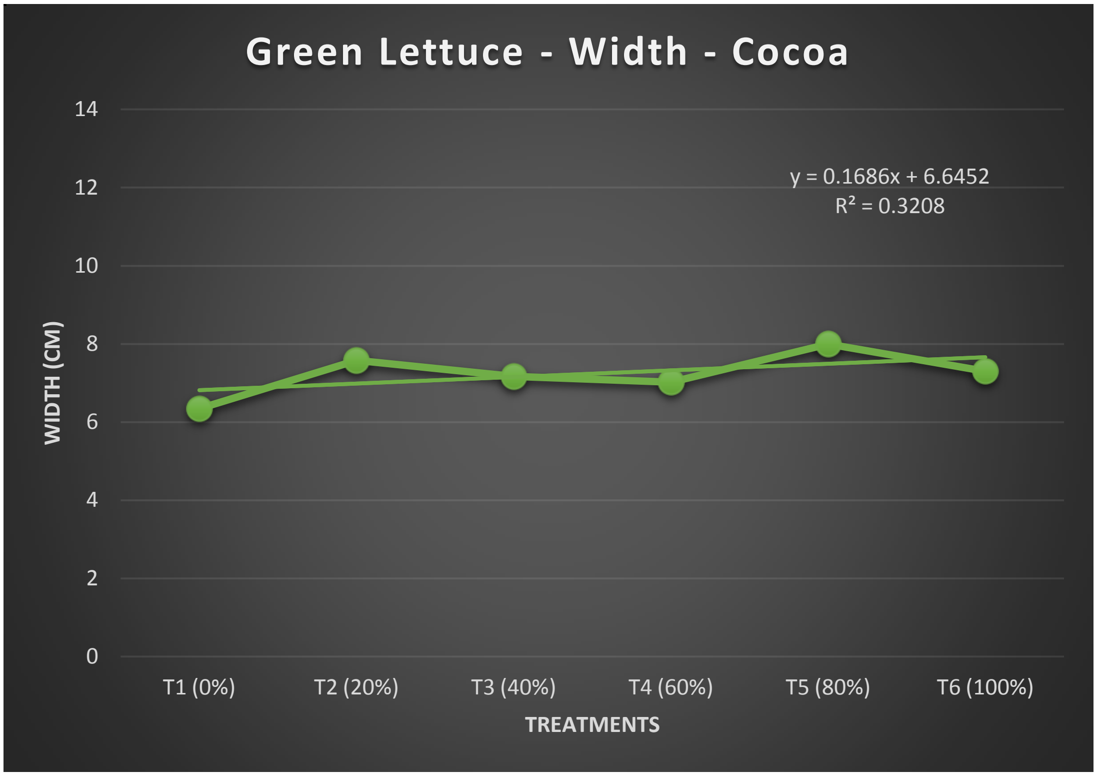
July 28 (Week 5)

August 7 (Week 7)

Graph Analysis


Green Lettuce - Height - Cocoa
HEIGHT (CM)
14
12
10
8
6
4
2
0
y = -0.1216x + 11.55
R² = 0.2629
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS


Green Lettuce - Height - Banana
HEIGHT (CM)
14
12
10
8
6
4
2
0
y = -0.5263x + 12.516
R² = 0.6548
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS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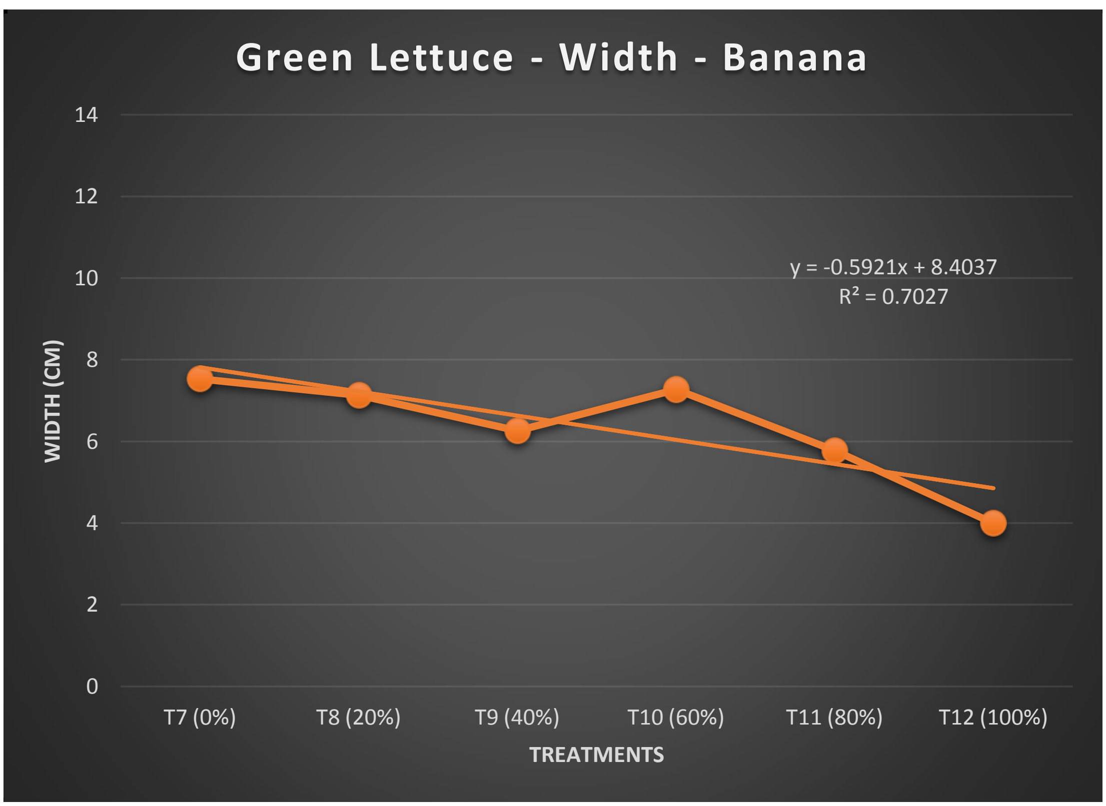
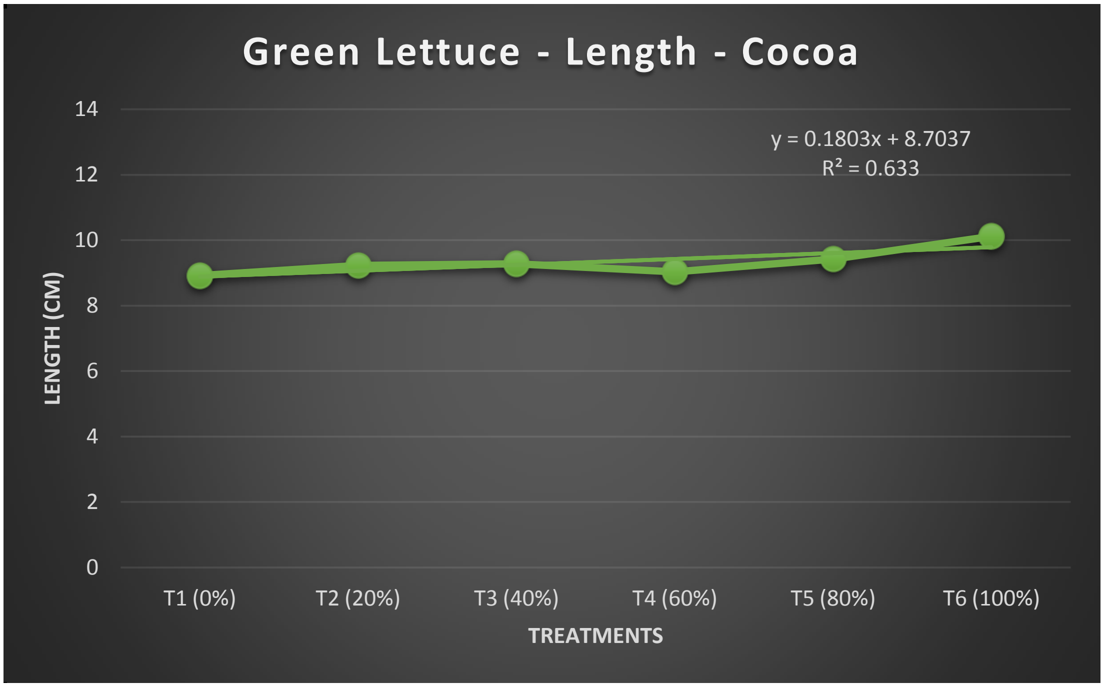
y = 0.1686x + 6.6452
R² = 0.3208
WIDTH (CM)
14
12
10
8
6
4
2
0
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS


Green Lettuce - Width - Banana
y = -0.5921x + 8.4037
R² = 0.7027
WIDTH (CM)
14
12
10
8
6
4
2
0
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS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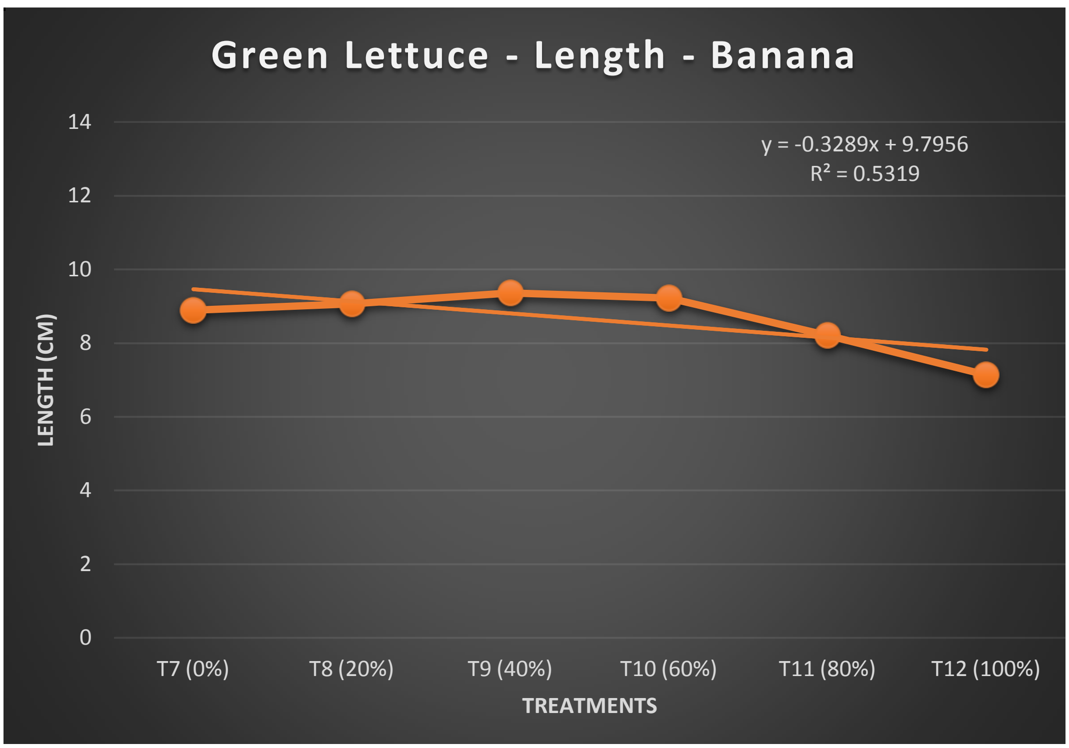
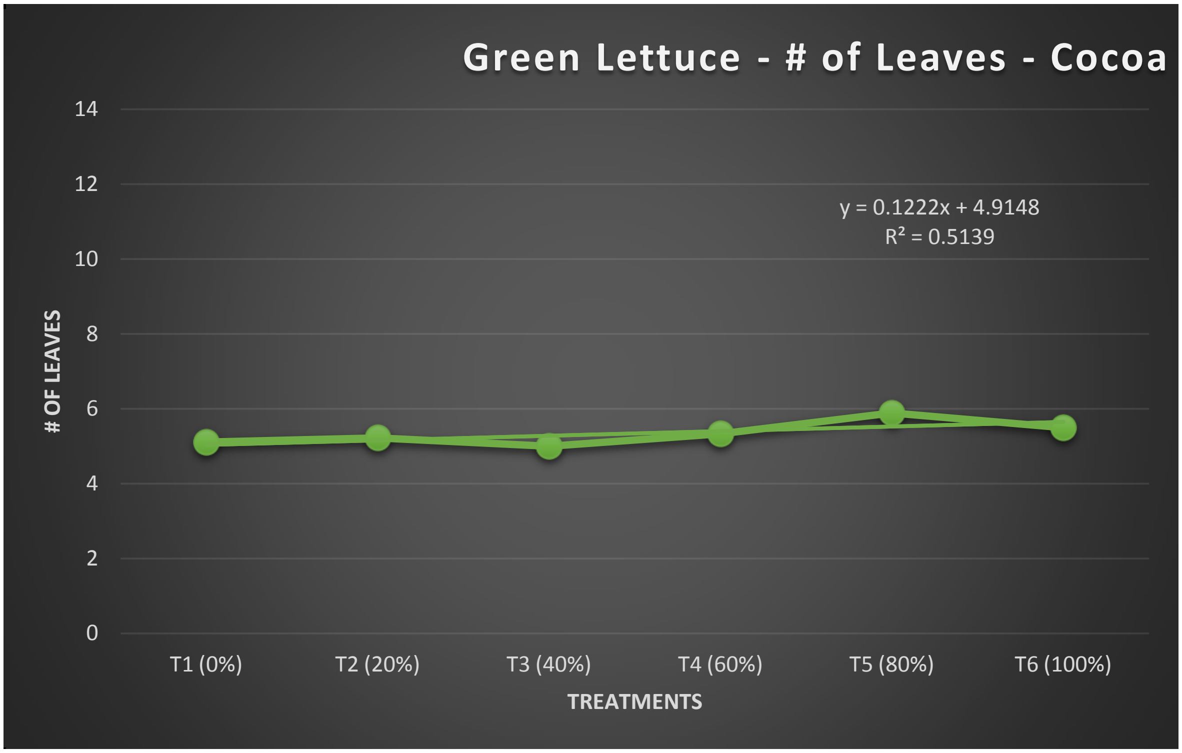
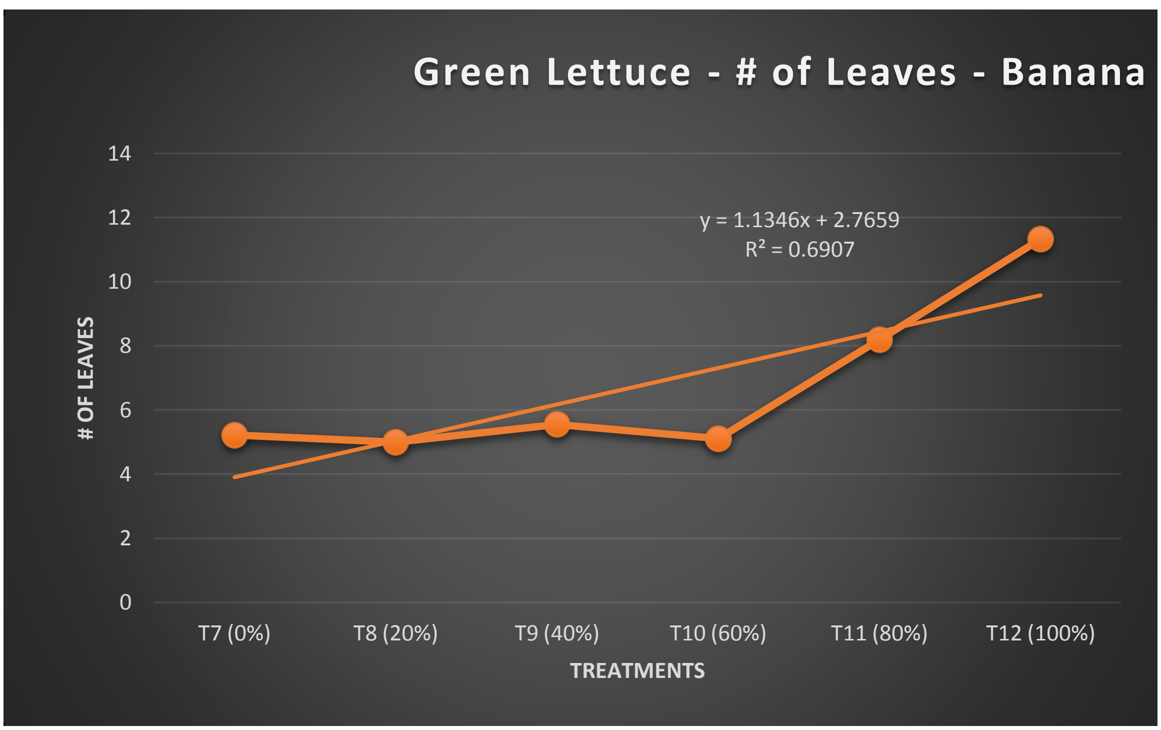
y = 0.1803x + 8.7037
R² = 0.633
LENGTH (CM)
14
12
10
8
6
4
2
0
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

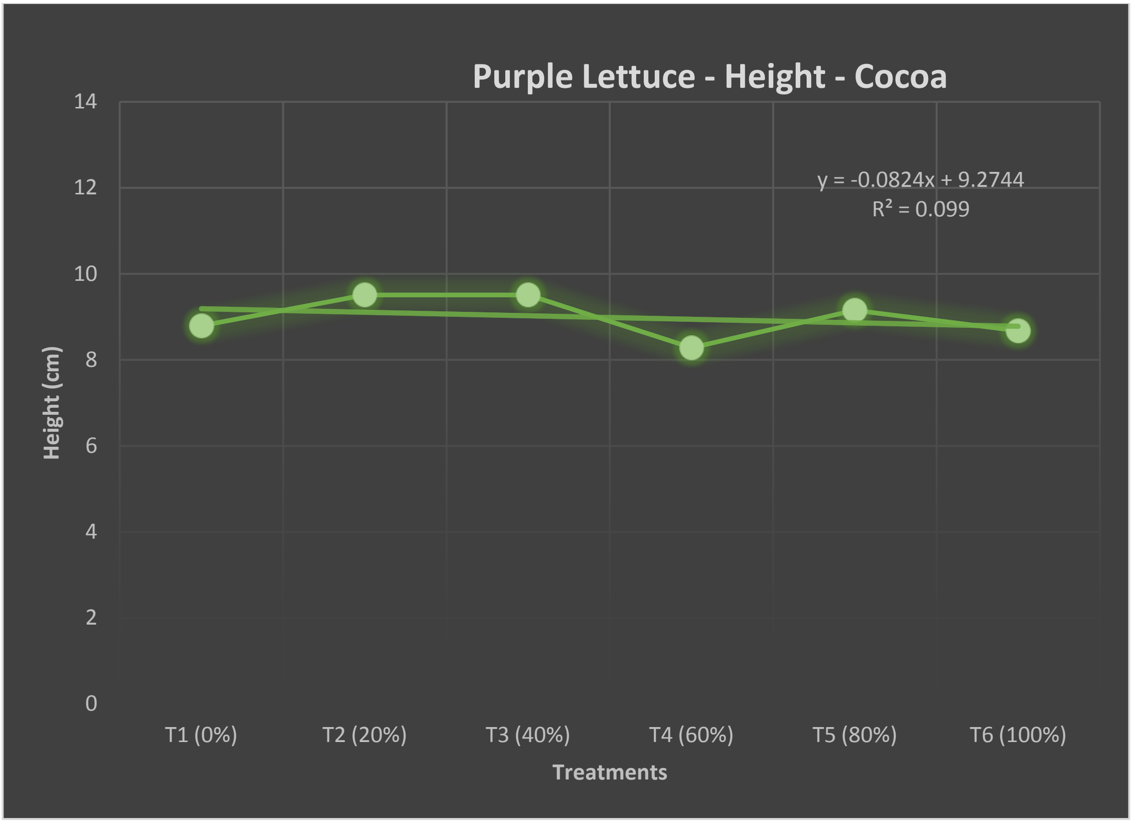

Green Lettuce - Length - Banana
y = -0.3289x + 9.7956
R² = 0.5319
LENGTH (CM)
14
12
10
8
6
4
2
0
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS

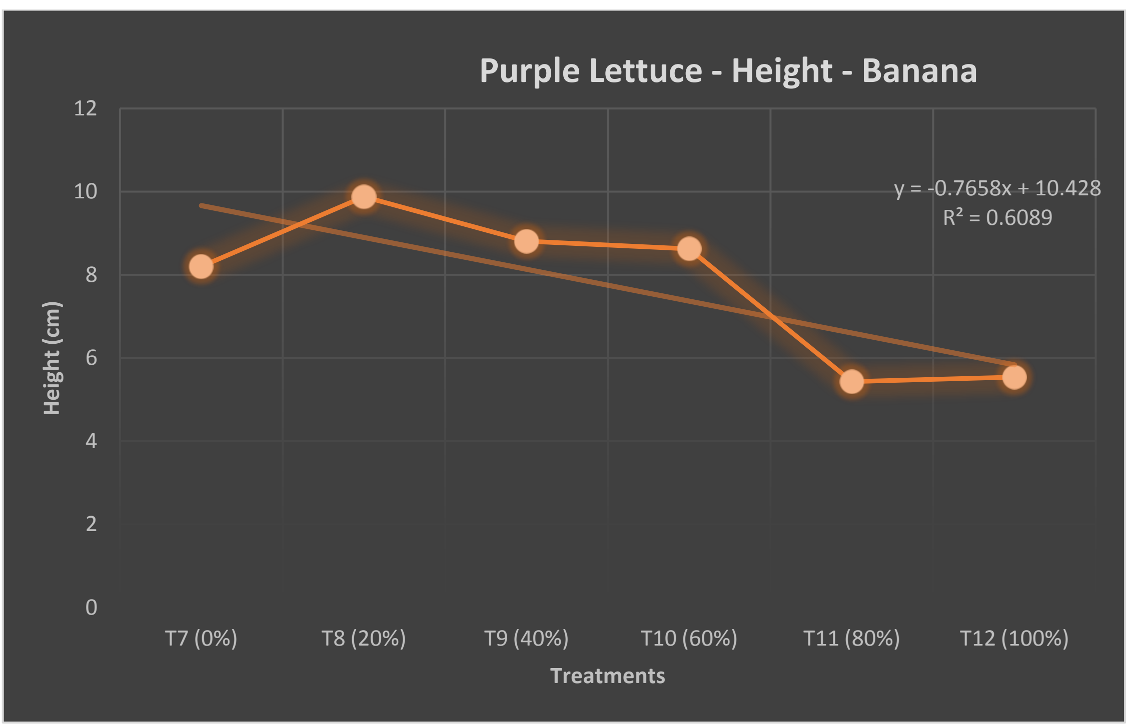


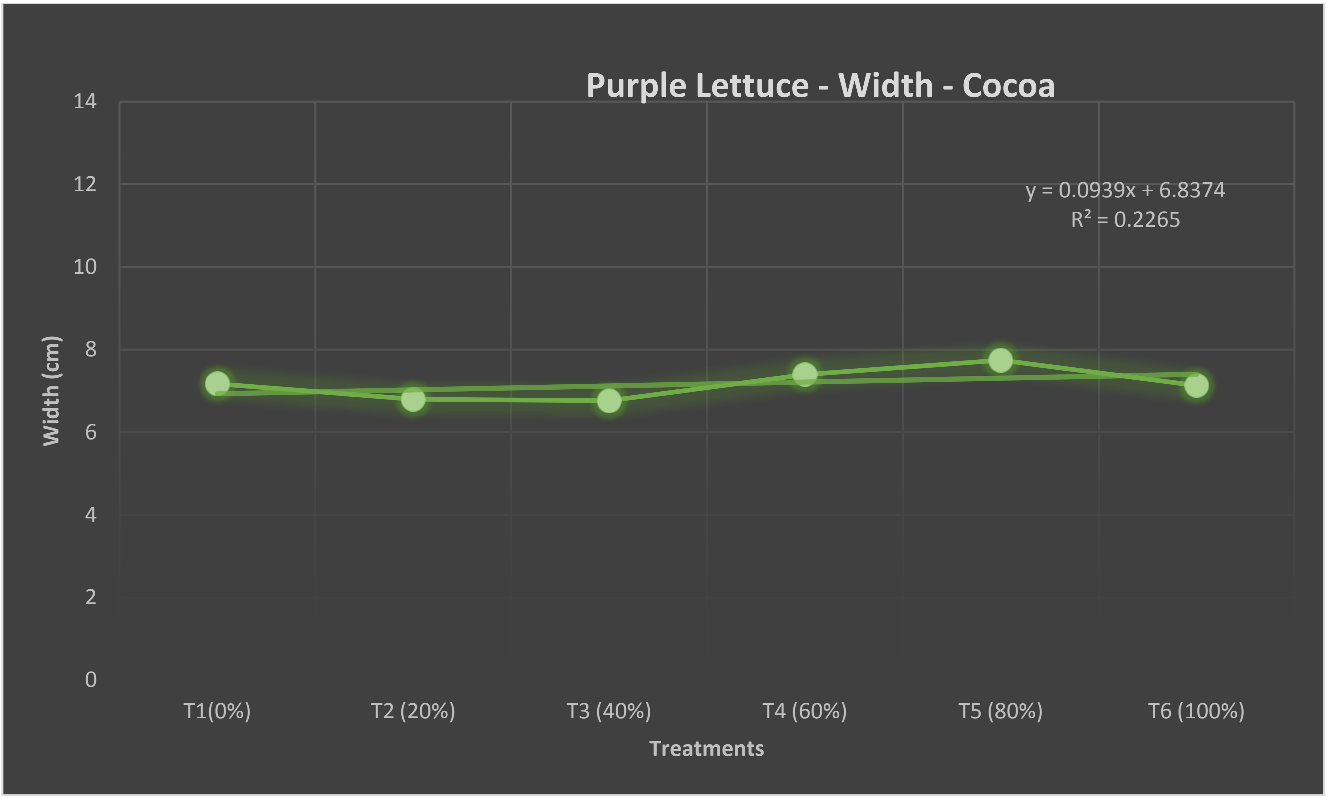
Green Lettuce - # of Leaves - Cocoa
14
12
10
8
6
4
2
0
# OF LEAVES
y = 0.1222x + 4.9148
R² = 0.5139
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

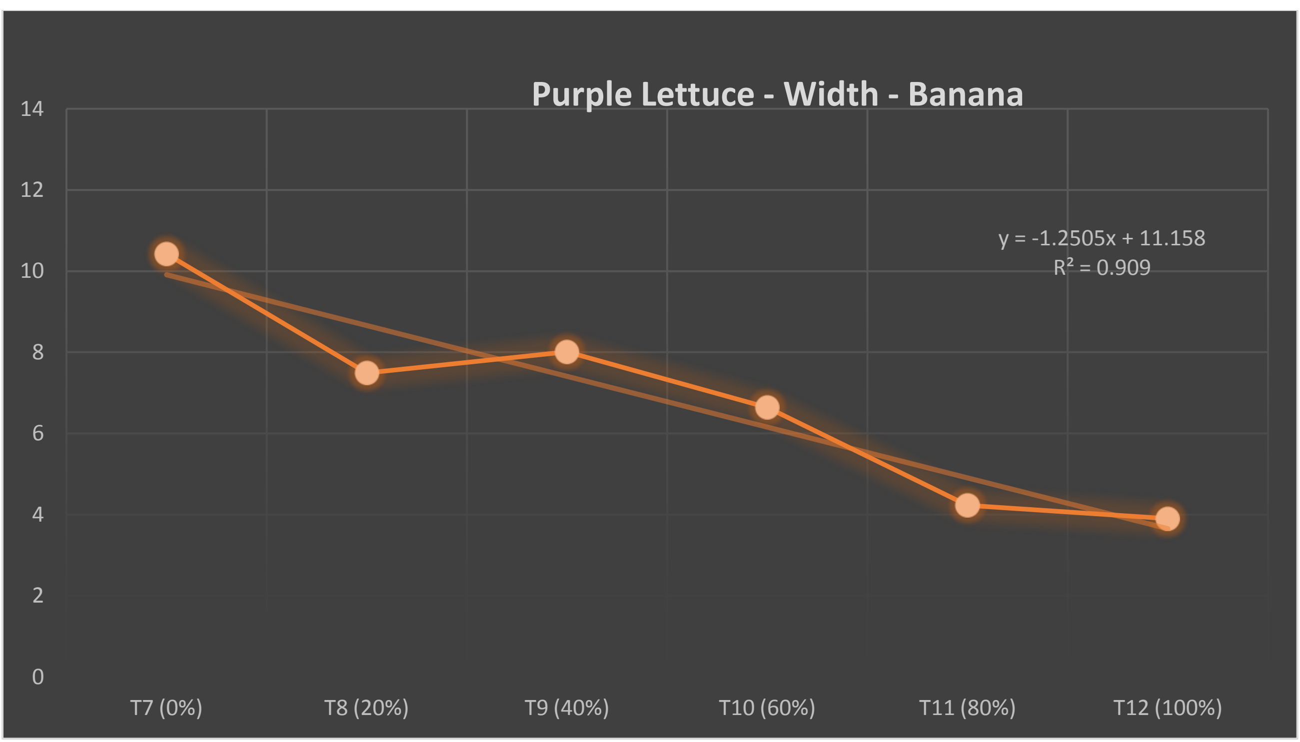


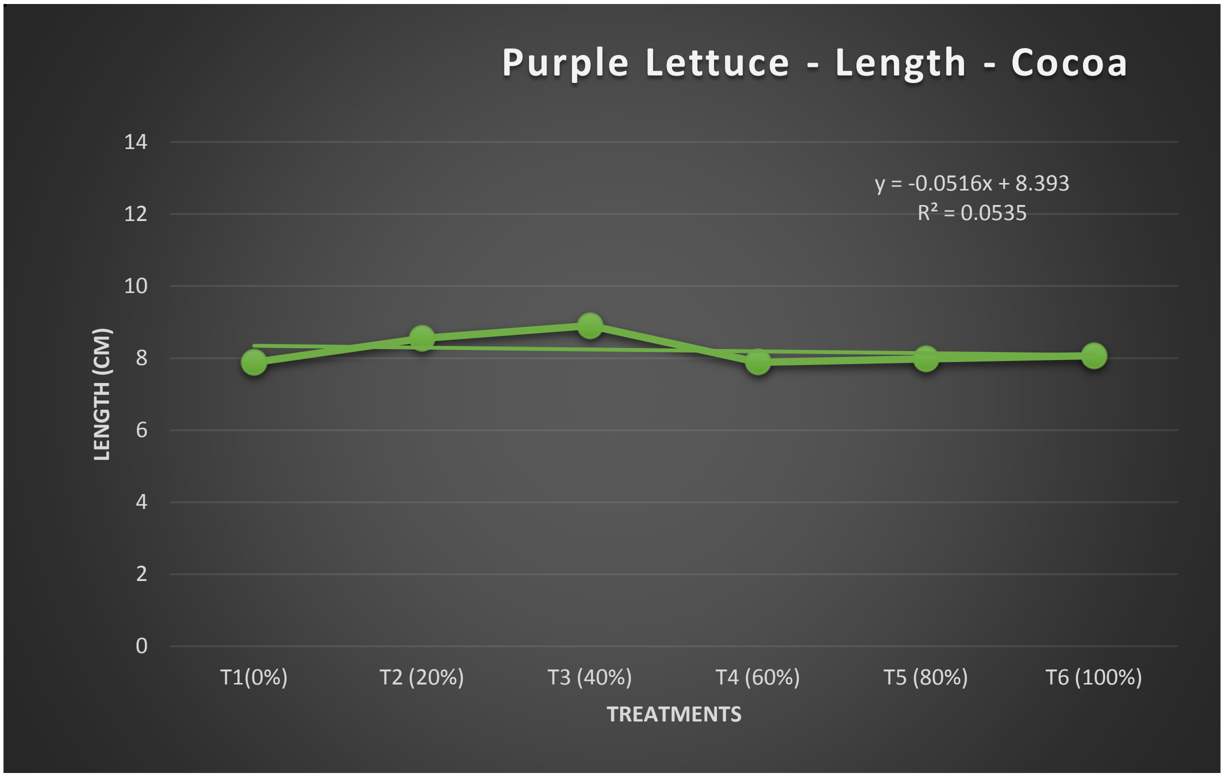
Green Lettuce - # of Leaves - Banana
14
12
10
8
6
4
2
0
# OF LEAVES
y = 1.1346x + 2.7659
R² = 0.6907
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS

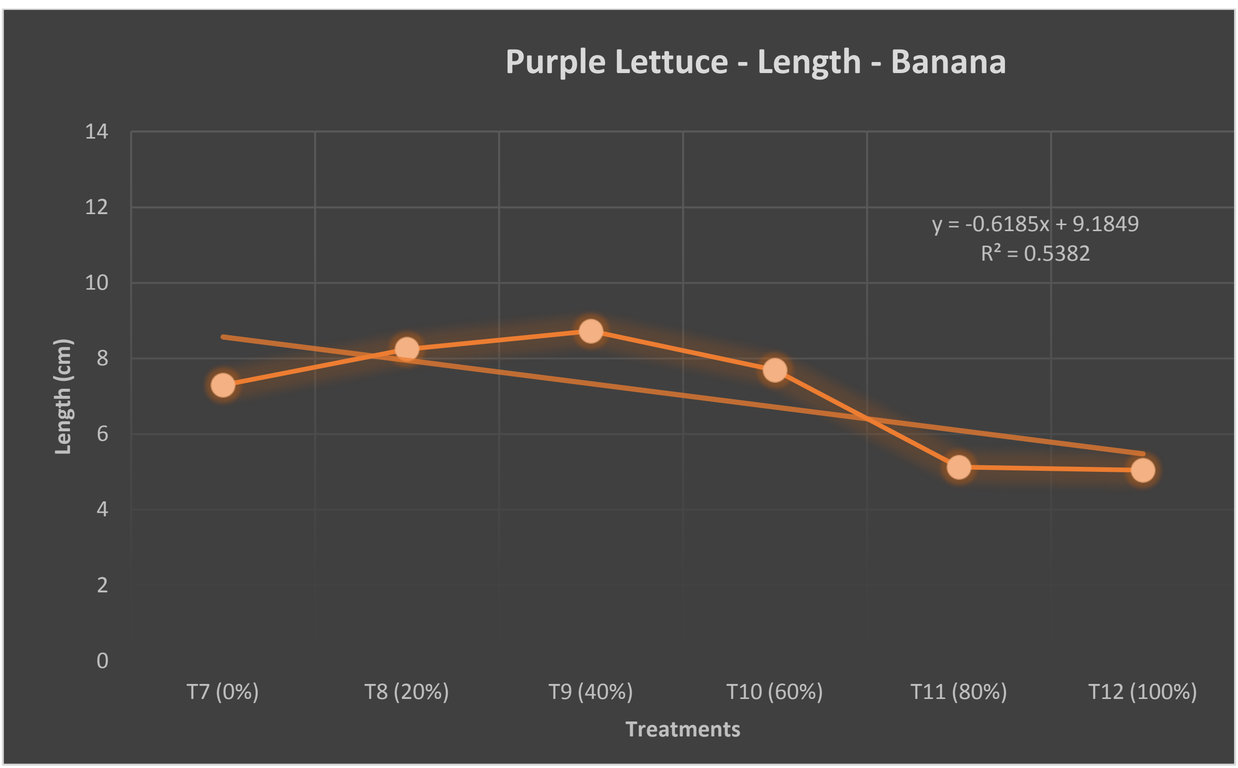

Purple Lettuce - Height - Cocoa
y = -0.0824x + 9.2744
R^2 = 0.099
Height (cm)
14
12
10
8
6
4
2
0
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
Treatments

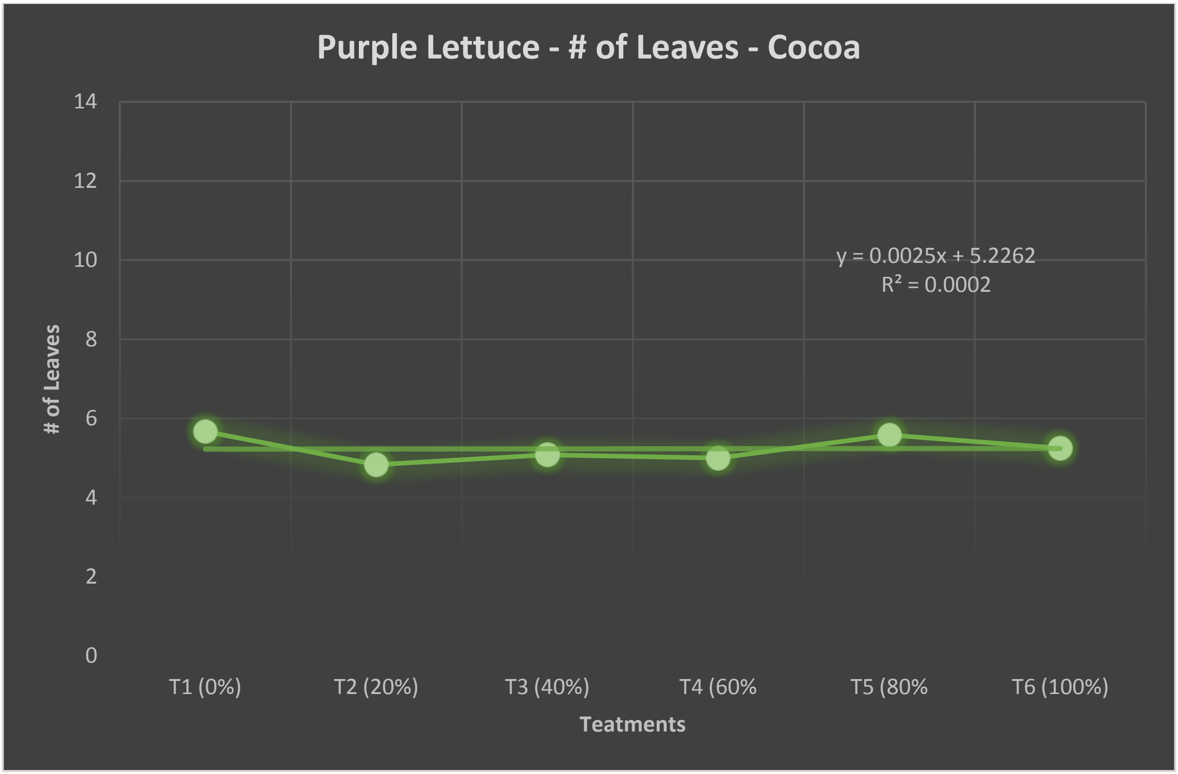

Purple Lettuce - Height - Banana
y = -0.7658x + 10.428
R^2 = 0.6089
Height (cm)
12
10
8
6
4
2
0
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
Treatments

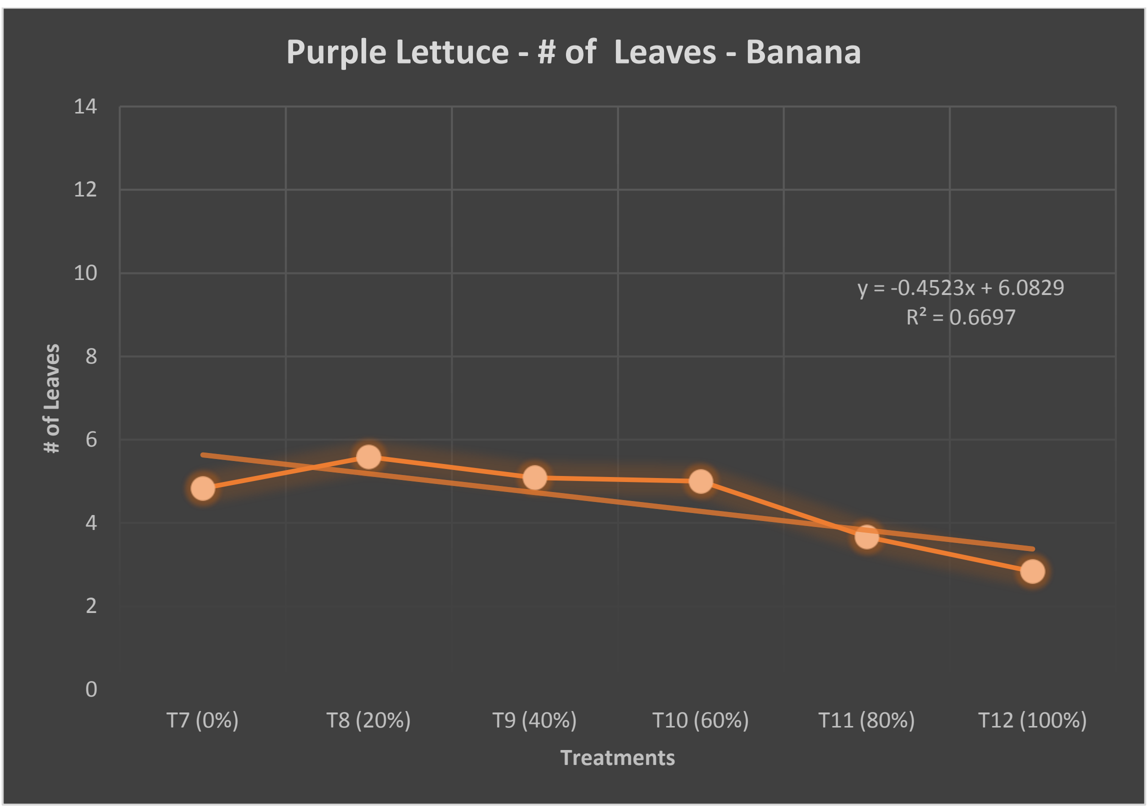

Purple Lettuce - Width - Cocoa
y = 0.0939x + 6.8374
R² = 0.2265
Width (cm)
14
12
10
8
6
4
2
0
T1(0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
Treatments

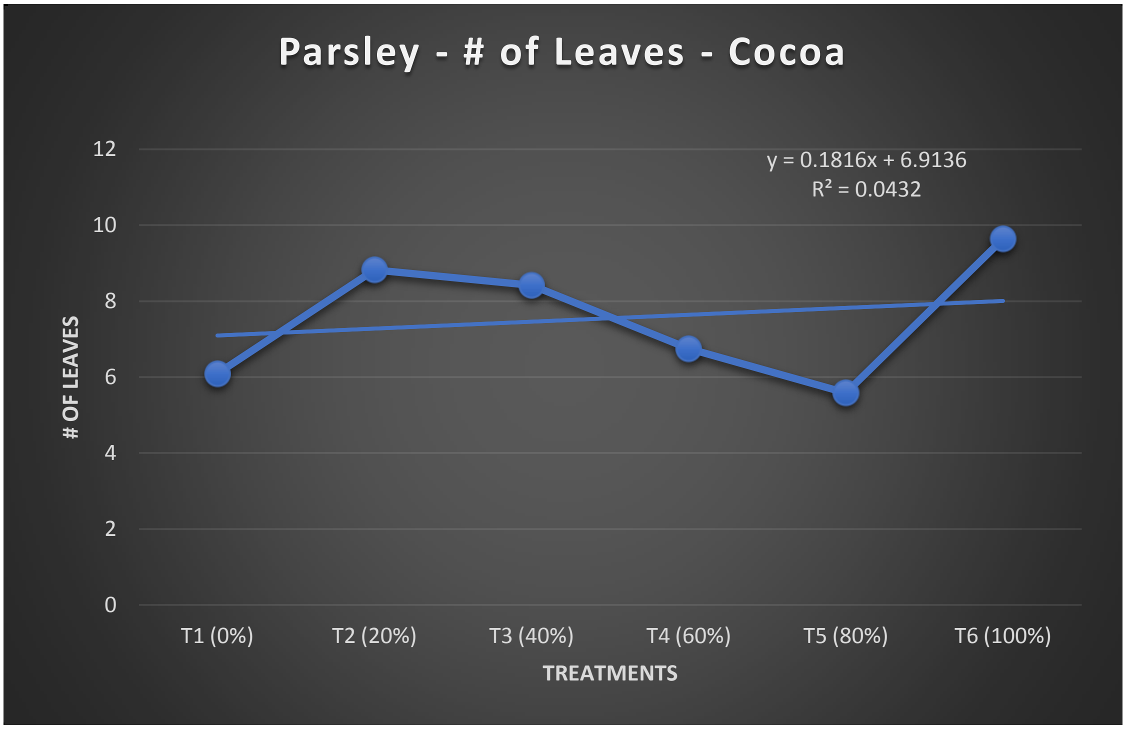

Purple Lettuce - Width - Banana
y = -1.2505x + 11.158
R² = 0.909
14
12
10
8
6
4
2
0
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)

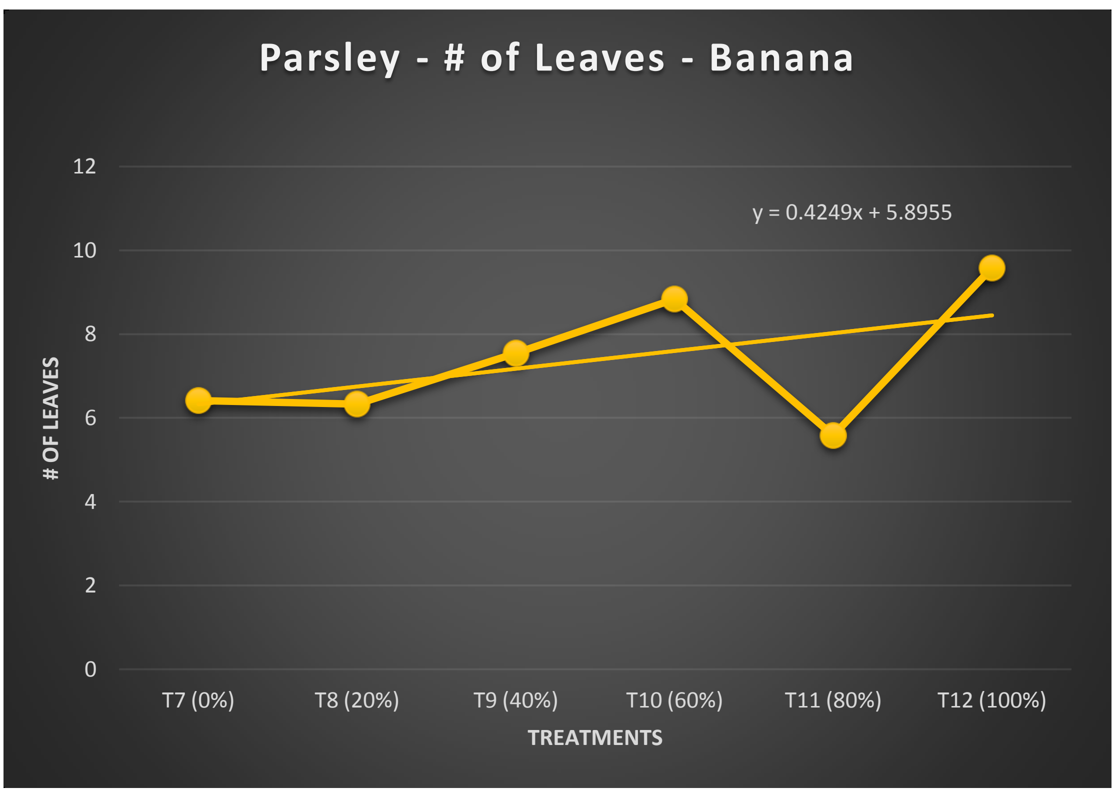

Purple Lettuce - Length - Cocoa
y = -0.0516x + 8.393
R² = 0.0535
LENGTH (CM)
14
12
10
8
6
4
2
0
T1(0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

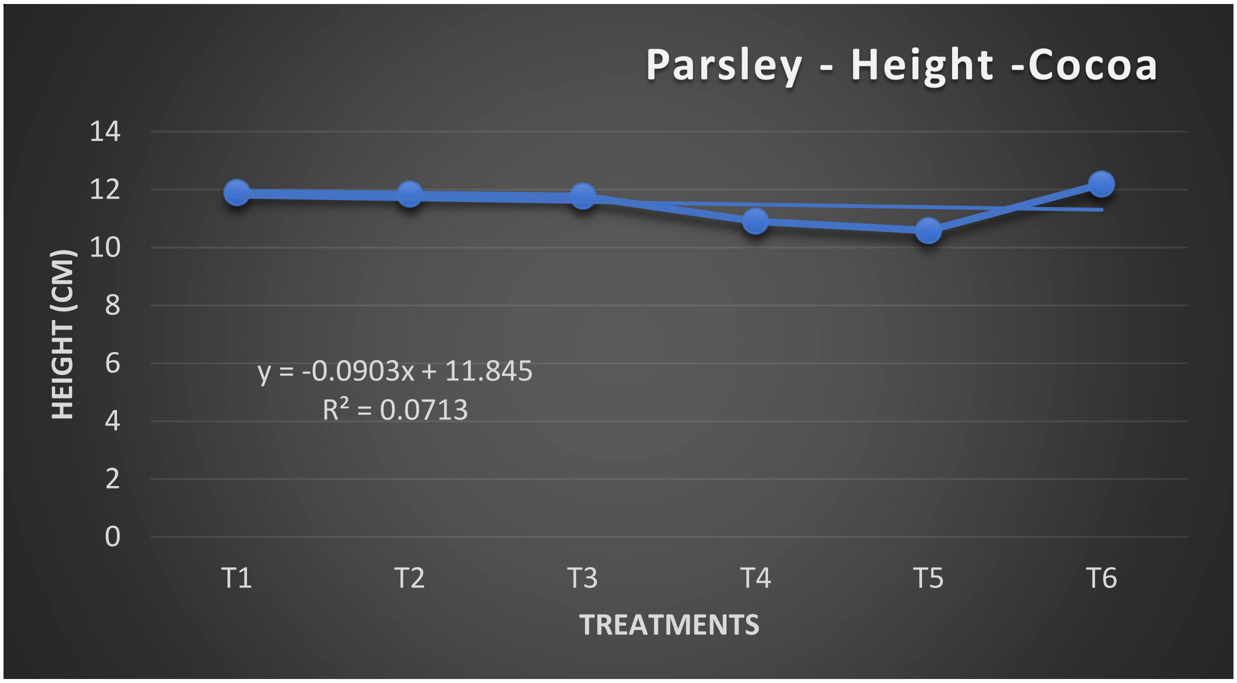

Purple Lettuce - Length - Banana
y = -0.6185x + 9.1849
R² = 0.5382
Length (cm)
14
12
10
8
6
4
2
0
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
Treatments

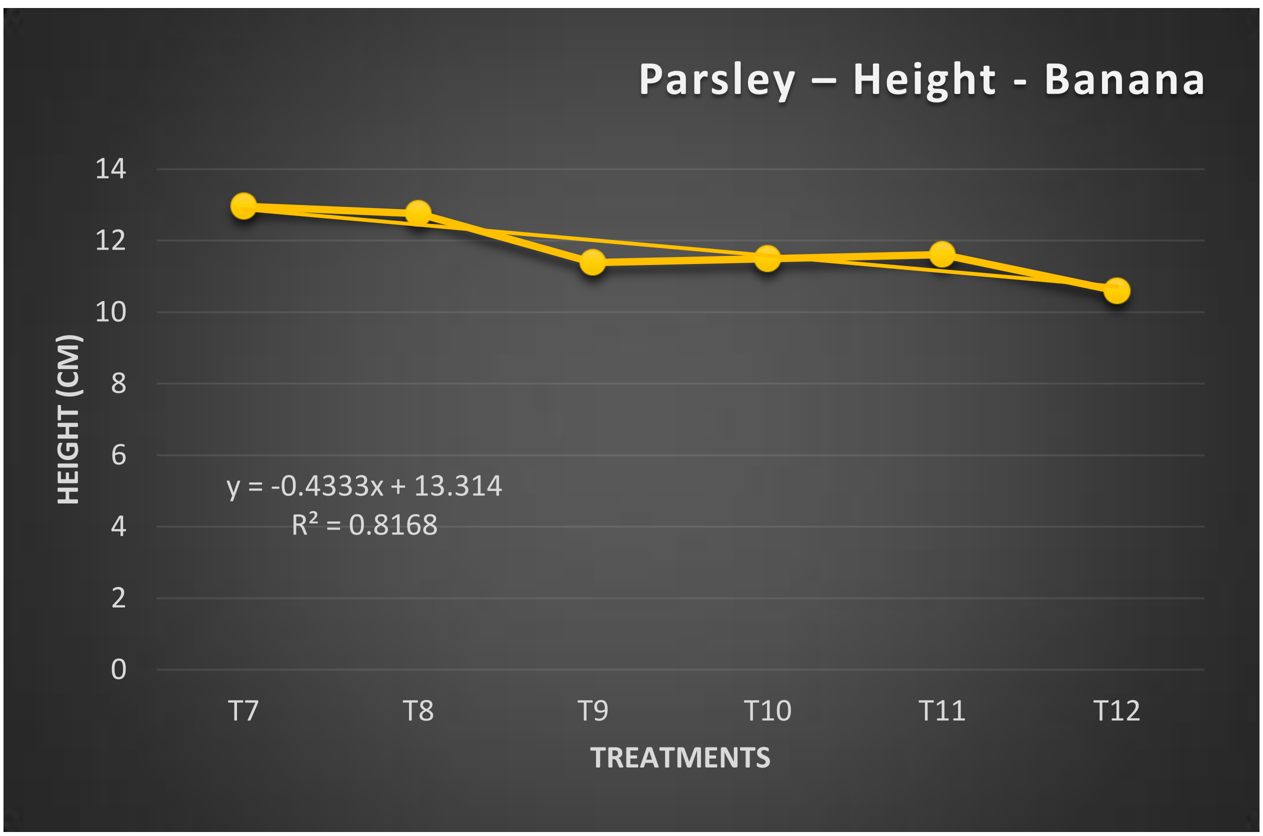

Purple Lettuce - # of Leaves - Cocoa
14
12
10
8
6
4
2
0
# of Leaves
y = 0.0025x + 5.2262
R² = 0.0002
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%
T5 (80%
T6 (100%)
Teatments

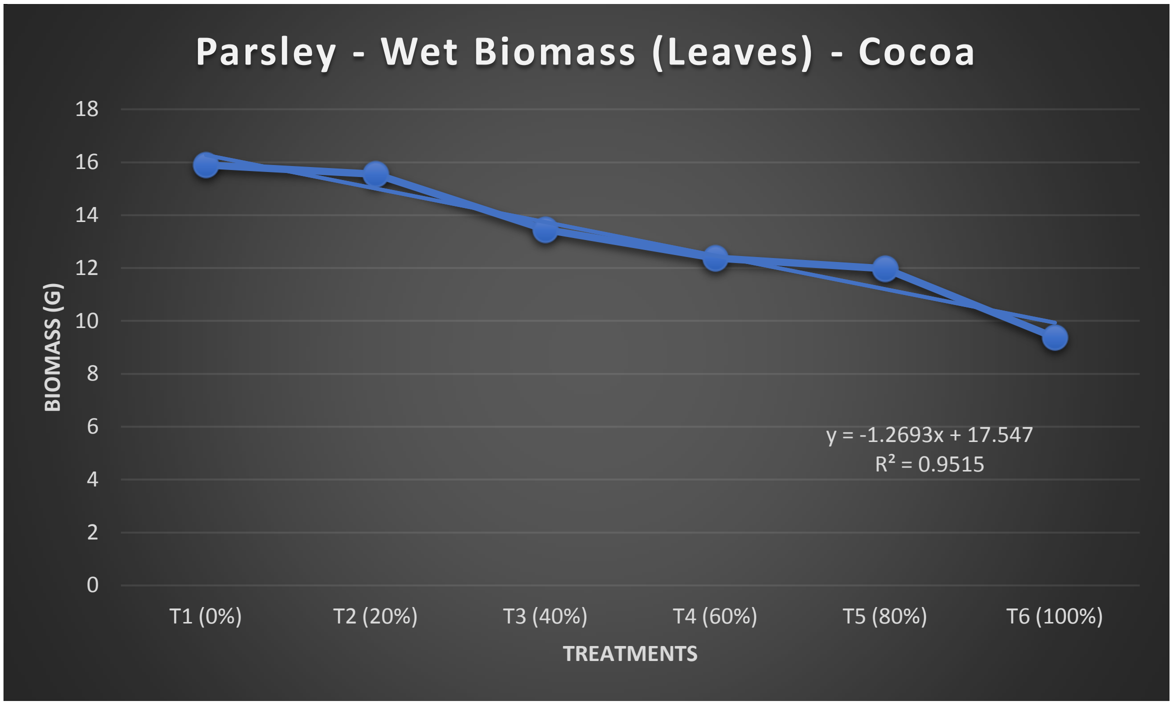

Purple Lettuce - # of Leaves - Banana
14
12
10
8
6
4
2
0
# of Leaves
y = -0.4523x + 6.0829
R² = 0.6697
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
Treatments

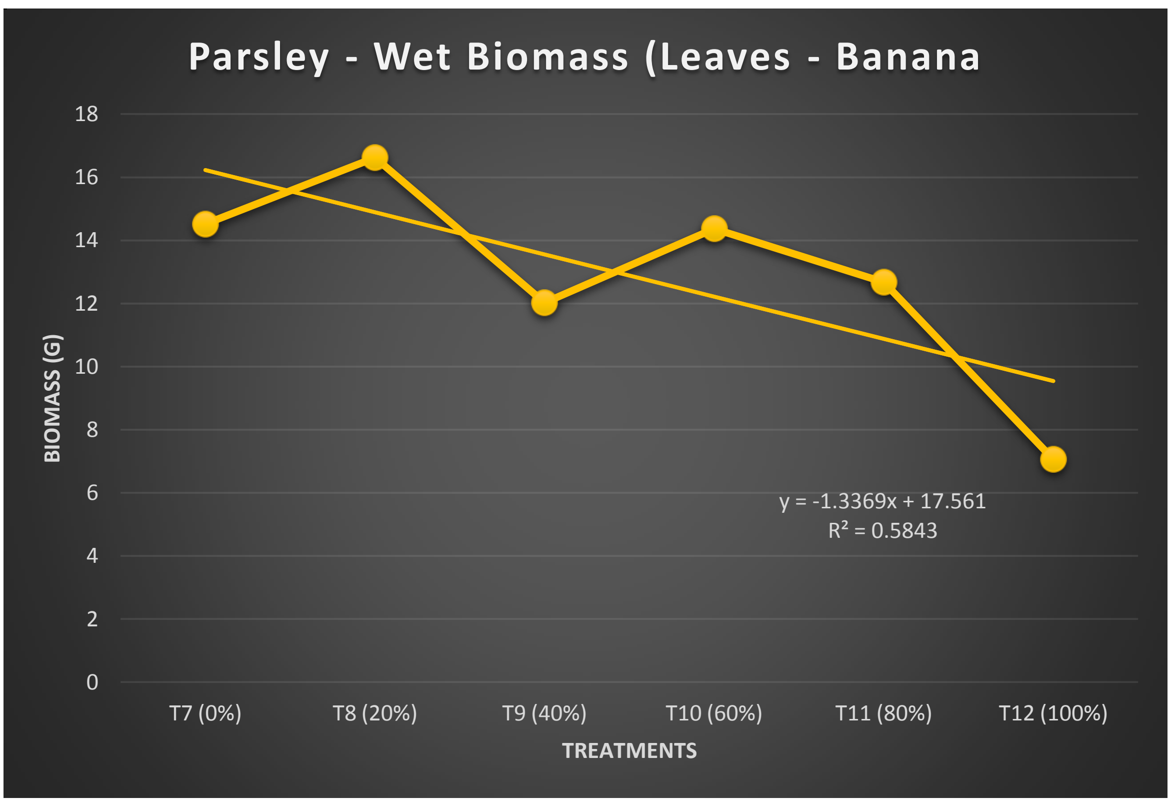

Parsley - # of Leaves - Cocoa
y = 0.1816x + 6.9136
R² = 0.0432
# OF LEAVES
12
10
8
6
4
2
0
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

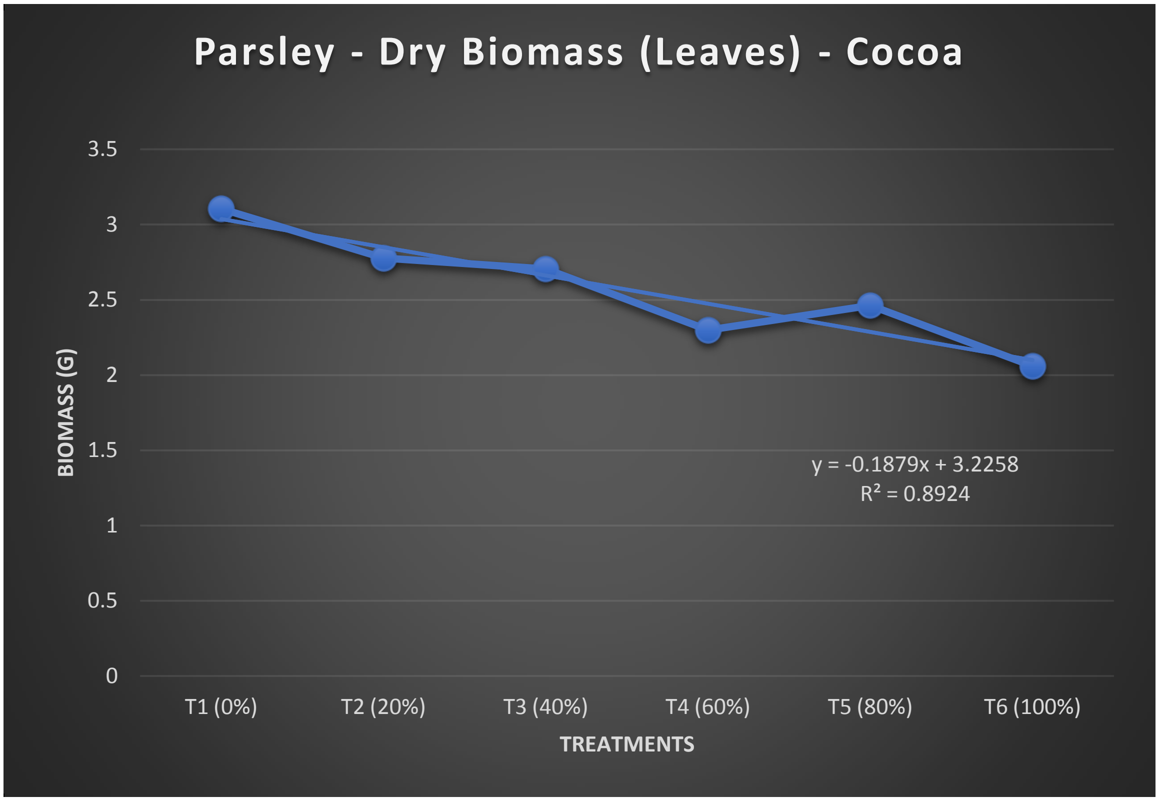

Parsley - # of Leaves - Banana
y = 0.4249x + 5.8955
# OF LEAVES
12
10
8
6
4
2
0
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS

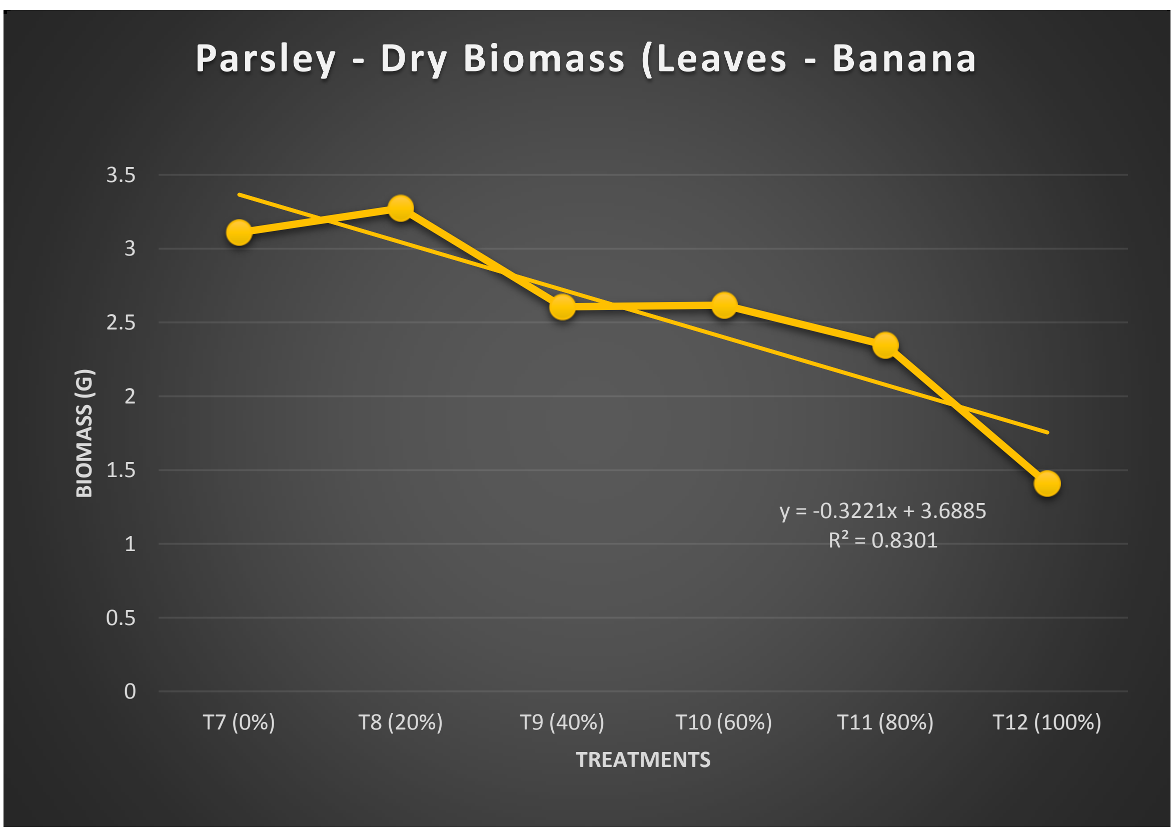

Parsley - Height -Cocoa
14
12
10
8
6
4
2
0
HEIGHT (CM)
y = -0.0903x + 11.845
R² = 0.0713
T1
T2
T3
T4
T5
T6
TREATMENTS

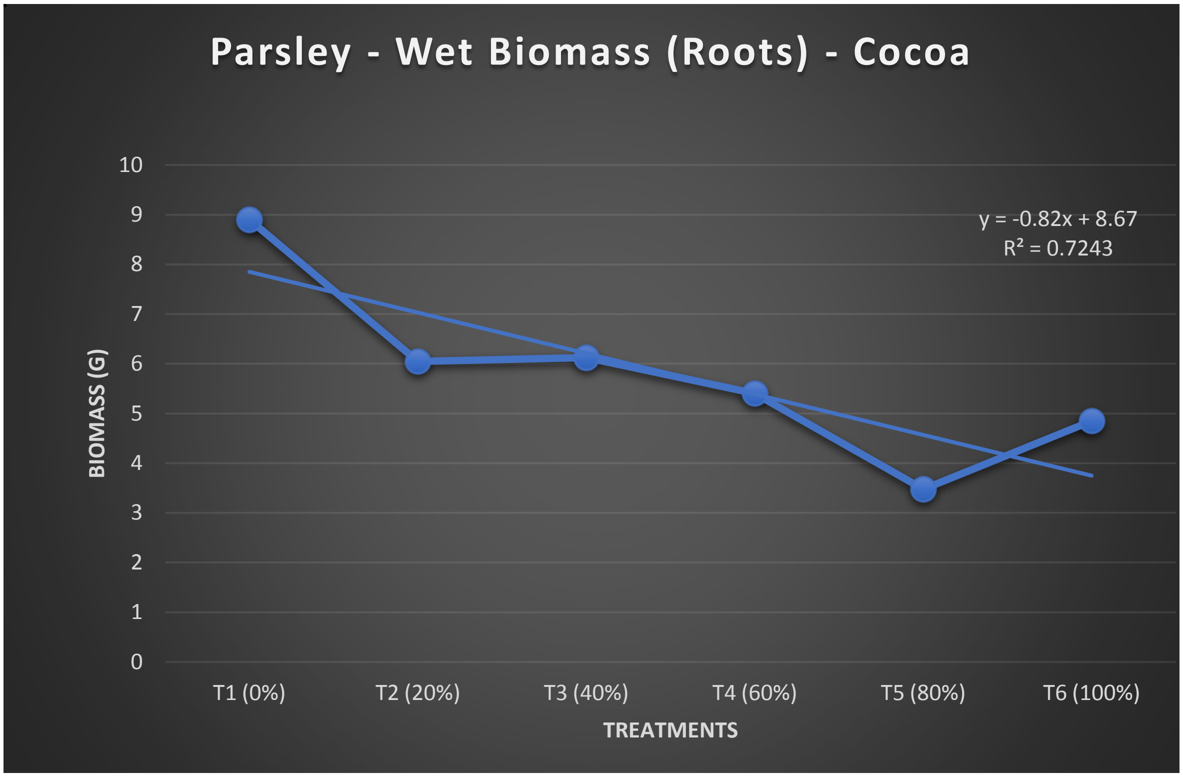

Parsley – Height - Banana
14
12
10
8
6
4
2
0
HEIGHT (CM)
y = -0.4333x + 13.314
R² = 0.8168
T7
T8
T9
T10
T11
T12
TREATMENTS

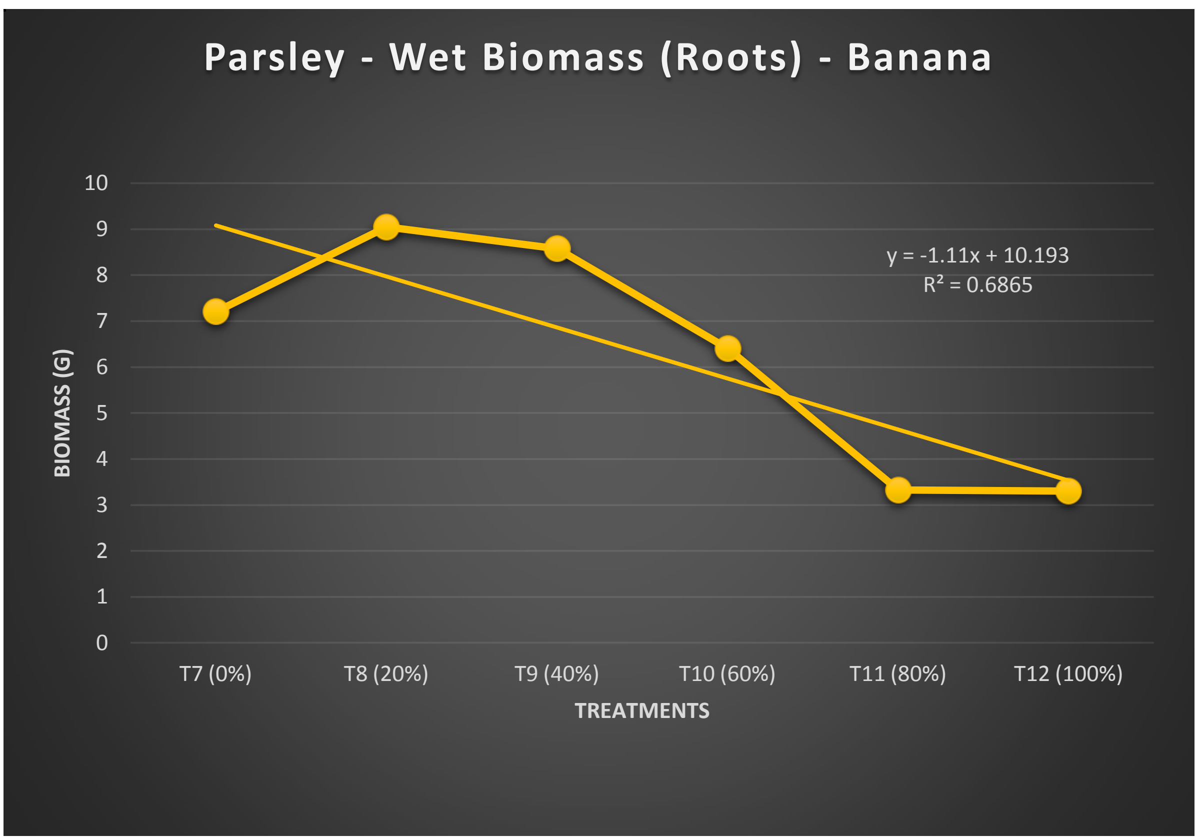

Parsley - Wet Biomass (Leaves) - Cocoa
BIOMASS (G)
18
16
14
12
10
8
6
4
2
0
y = -1.2693x + 17.547
R² = 0.9515
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

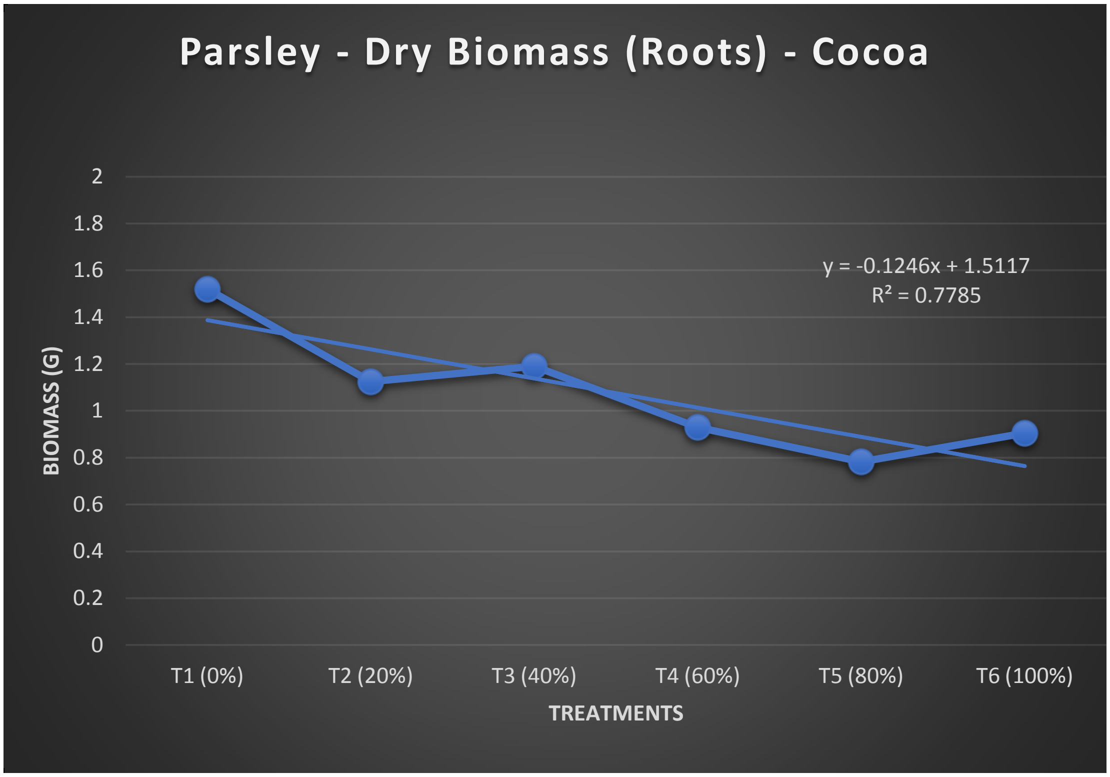

Parsley - Wet Biomass (Leaves - Banana
BIOMASS (G)
18
16
14
12
10
8
6
4
2
0
y = -1.3369x + 17.561
R² = 0.5843
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS

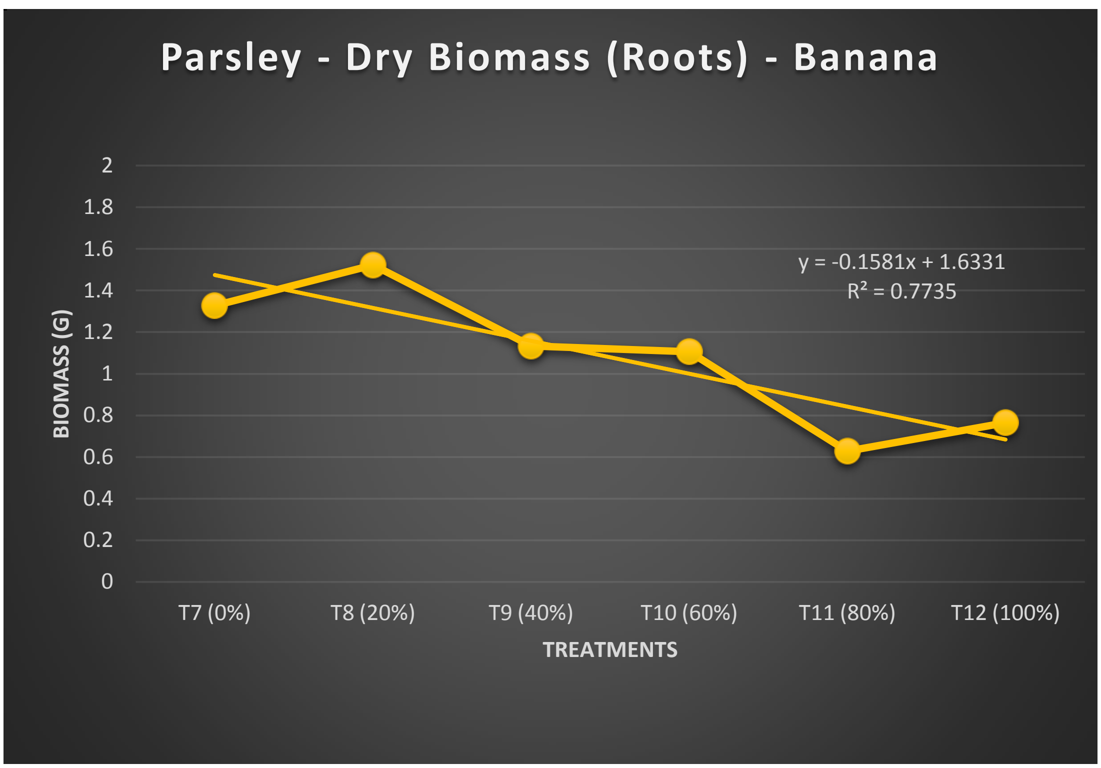

Parsley - Dry Biomass (Leaves) - Cocoa
BIOMASS (G)
3.5
3
2.5
2
1.5
1
0.5
0
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS
y = -0.1879x + 3.2258
R² = 0.8924

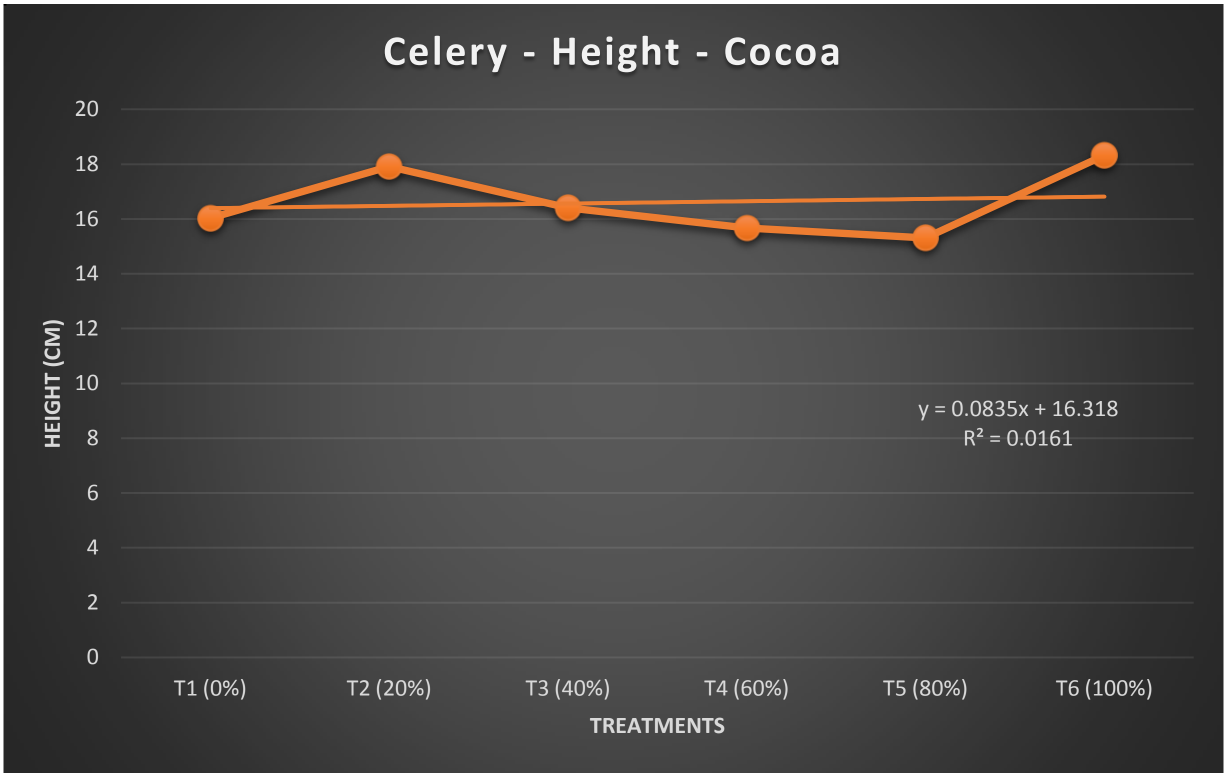

Parsley - Dry Biomass (Leaves - Banana
BIOMASS (G)
3.5
3
2.5
2
1.5
1
0.5
0
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS
y = -0.3221x + 3.6885
R² = 0.8301

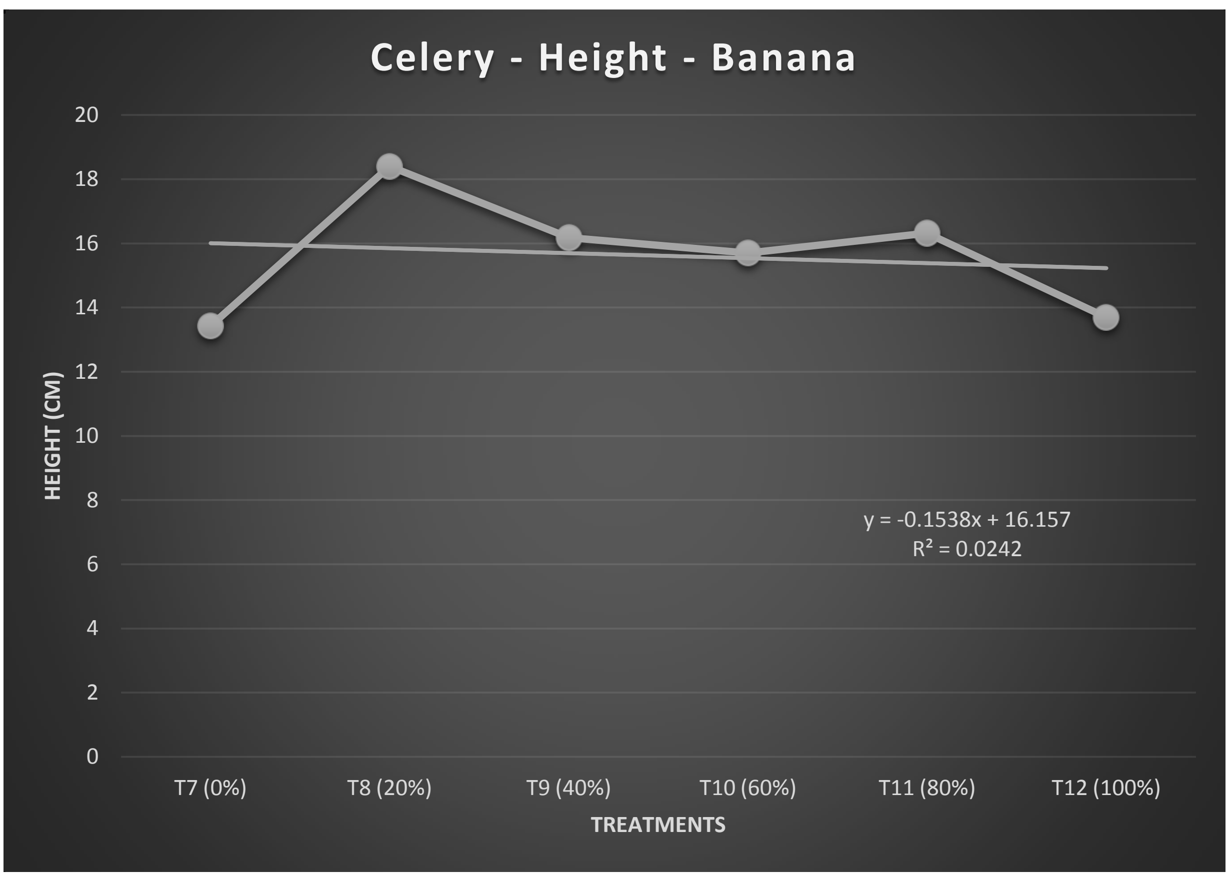

Parsley - Wet Biomass (Roots) - Cocoa
BIOMASS (G)
10
9
8
7
6
5
4
3
2
1
0
y = -0.82x + 8.67
R² = 0.7243
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

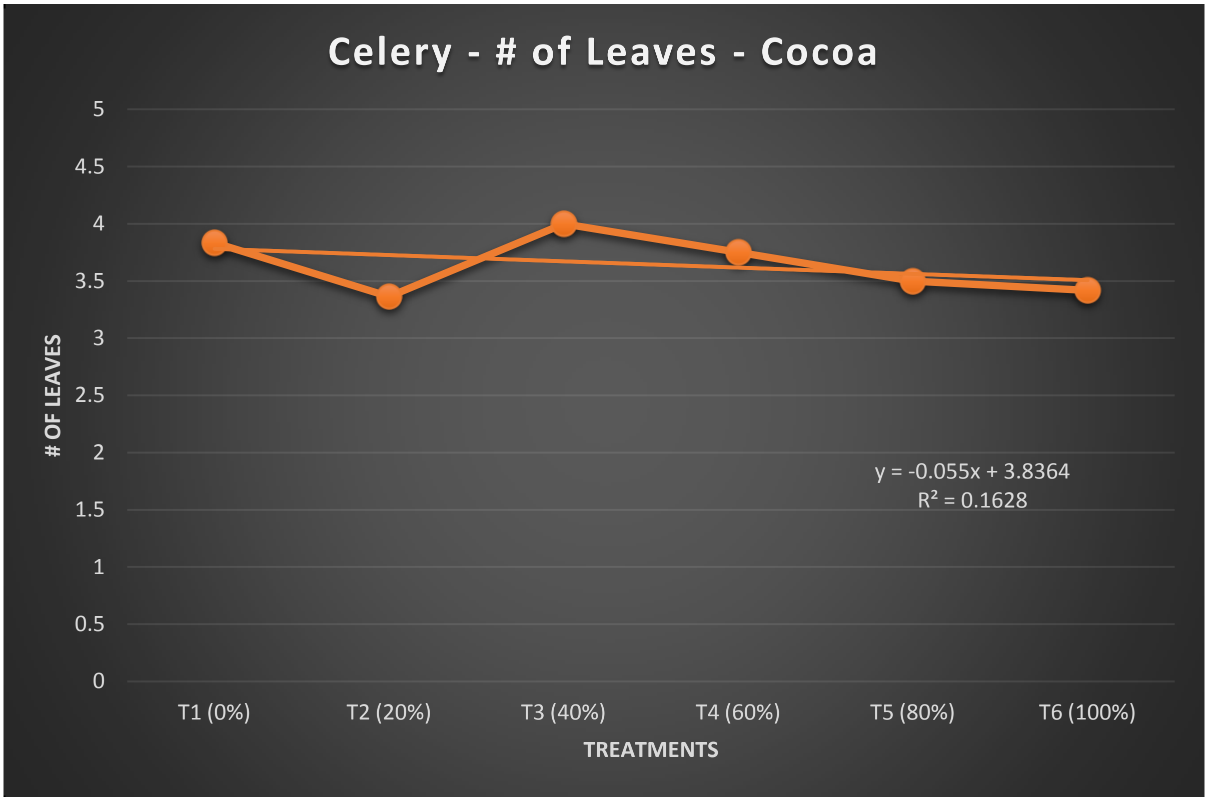

Parsley - Wet Biomass (Roots) - Banana
BIOMASS (G)
10
9
8
7
6
5
4
3
2
1
0
y = -1.11x + 10.193
R² = 0.6865
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS

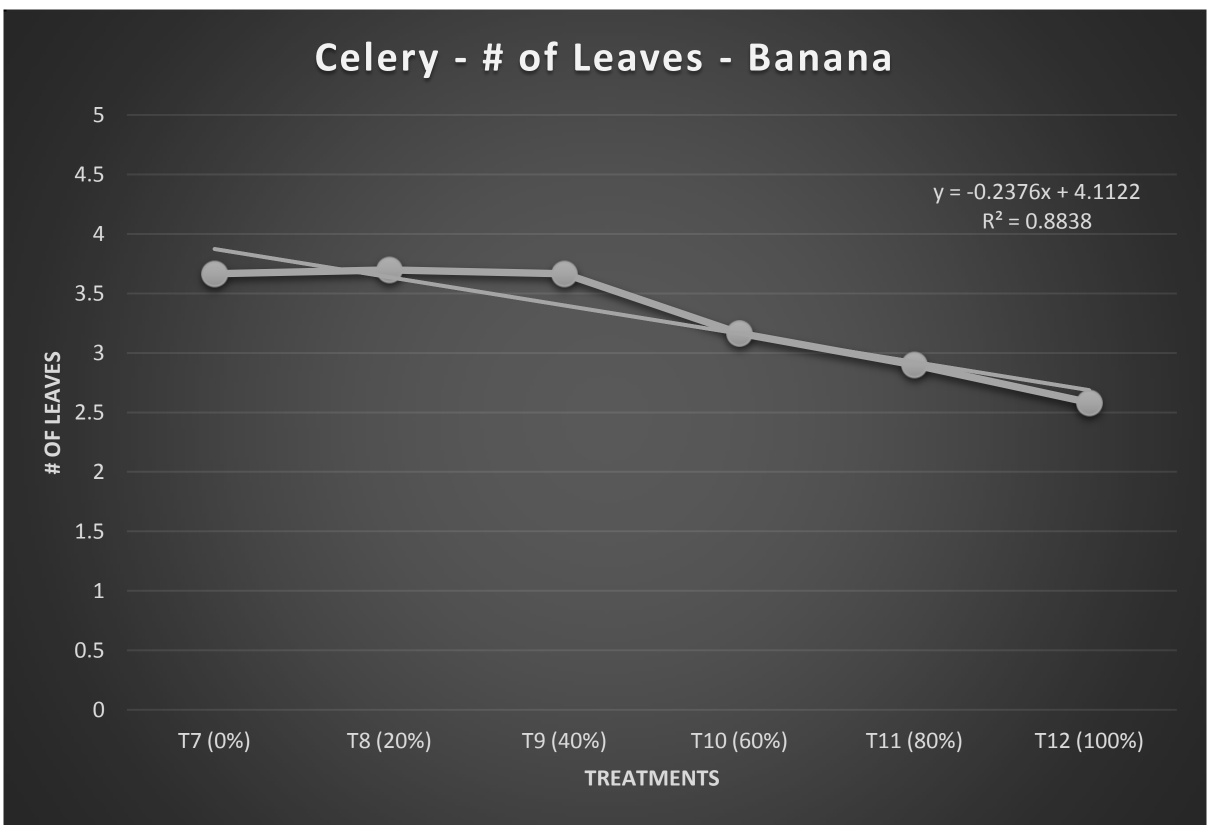

Parsley - Dry Biomass (Roots) - Cocoa
y = -0.1246x + 1.5117
$R^2 = 0.7785$
BIOMASS (G)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

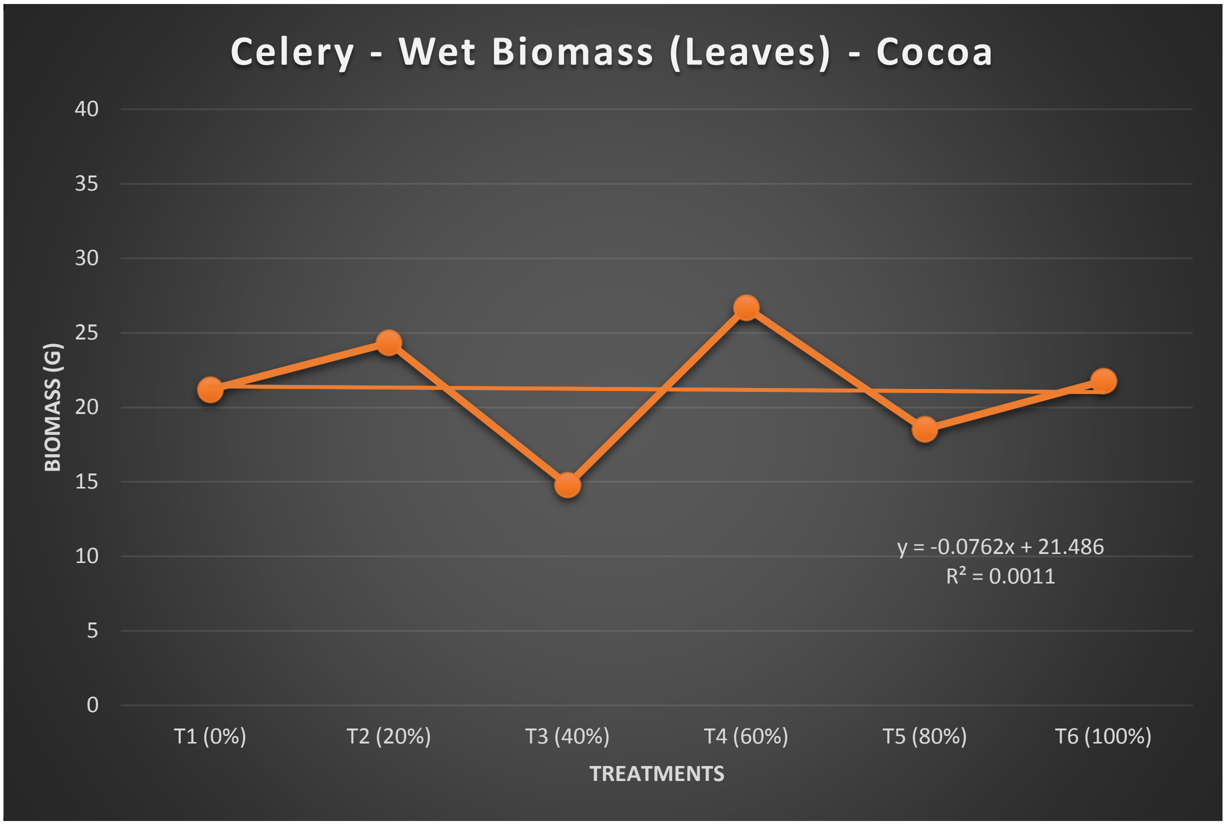

Parsley - Dry Biomass (Roots) - Banana
y = -0.1581x + 1.6331
$R^2 = 0.7735$
BIOMASS (G)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS

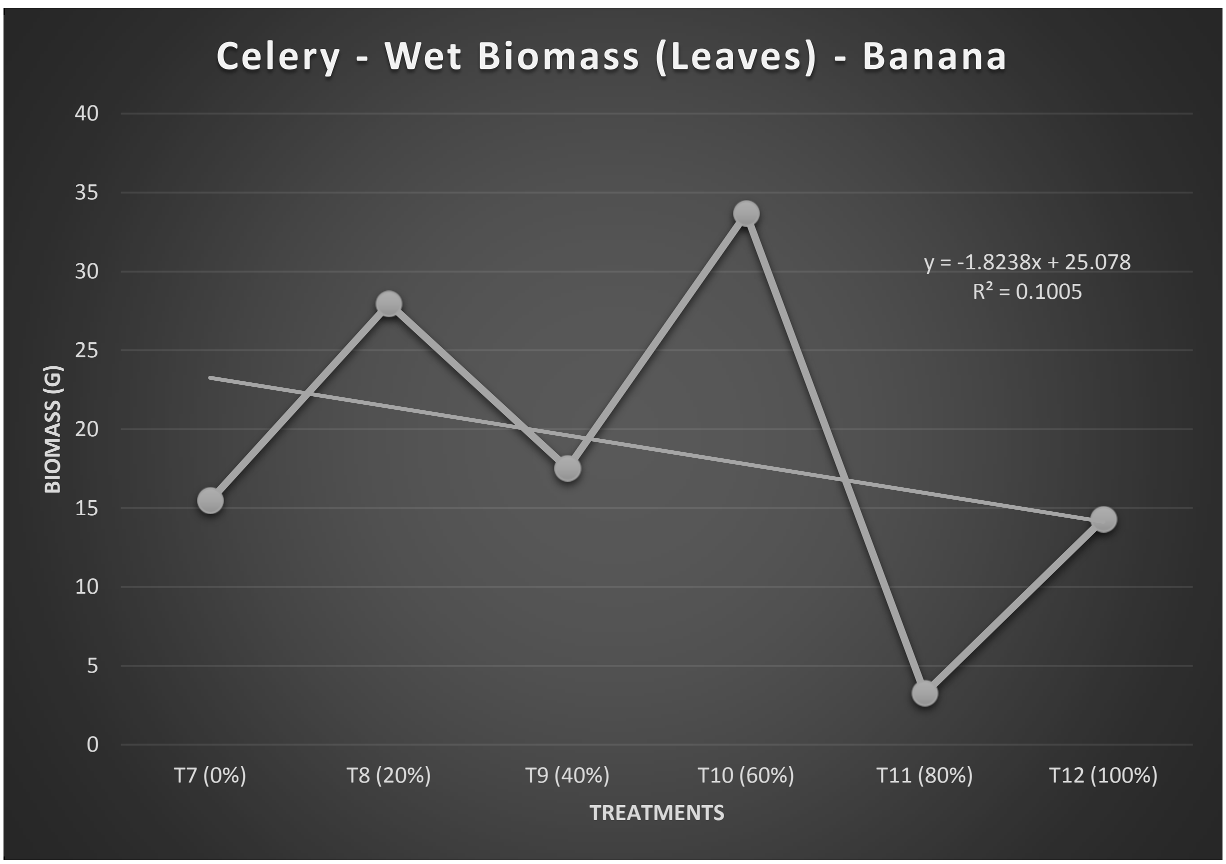

Celery - Height - Cocoa
HEIGHT (CM)
20
18
16
14
12
10
8
6
4
2
0
y = 0.0835x + 16.318
R² = 0.0161
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

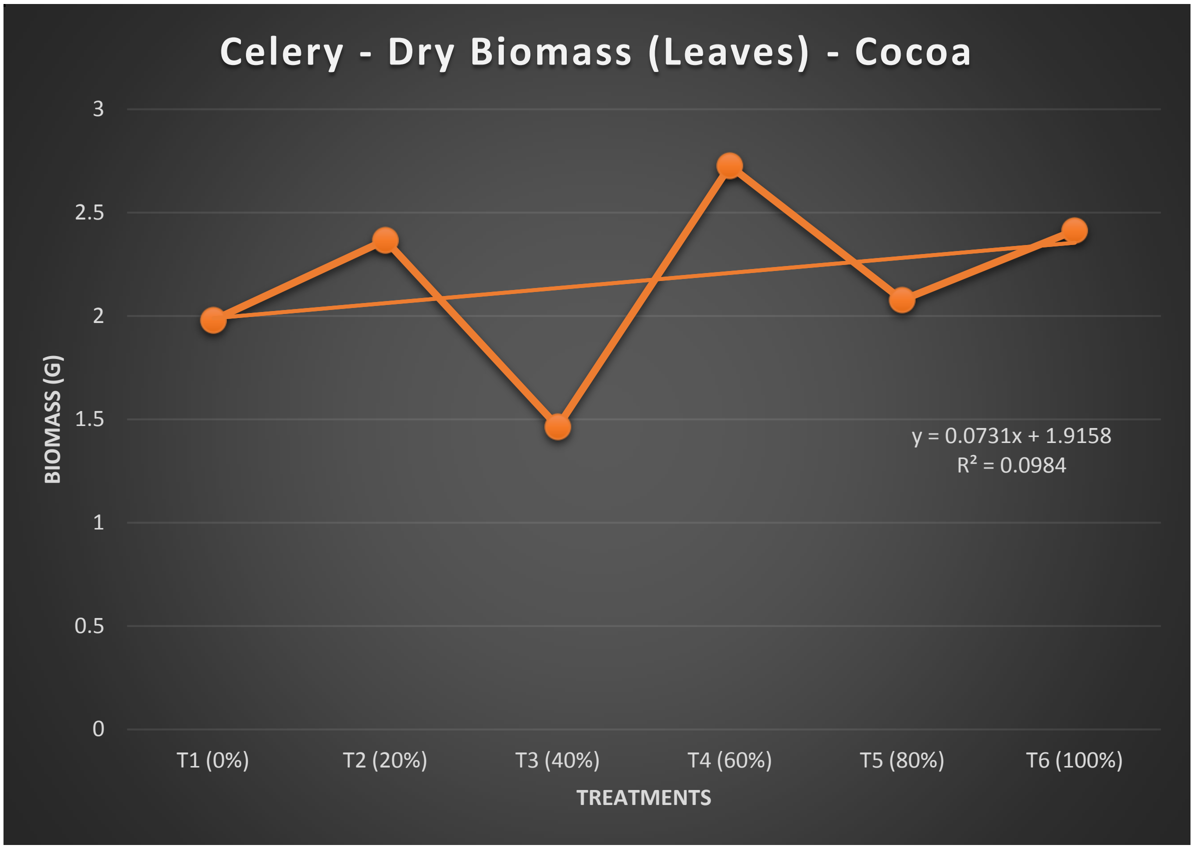

Celery - Height - Banana
HEIGHT (CM)
20
18
16
14
12
10
8
6
4
2
0
y = -0.1538x + 16.157
R² = 0.0242
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS

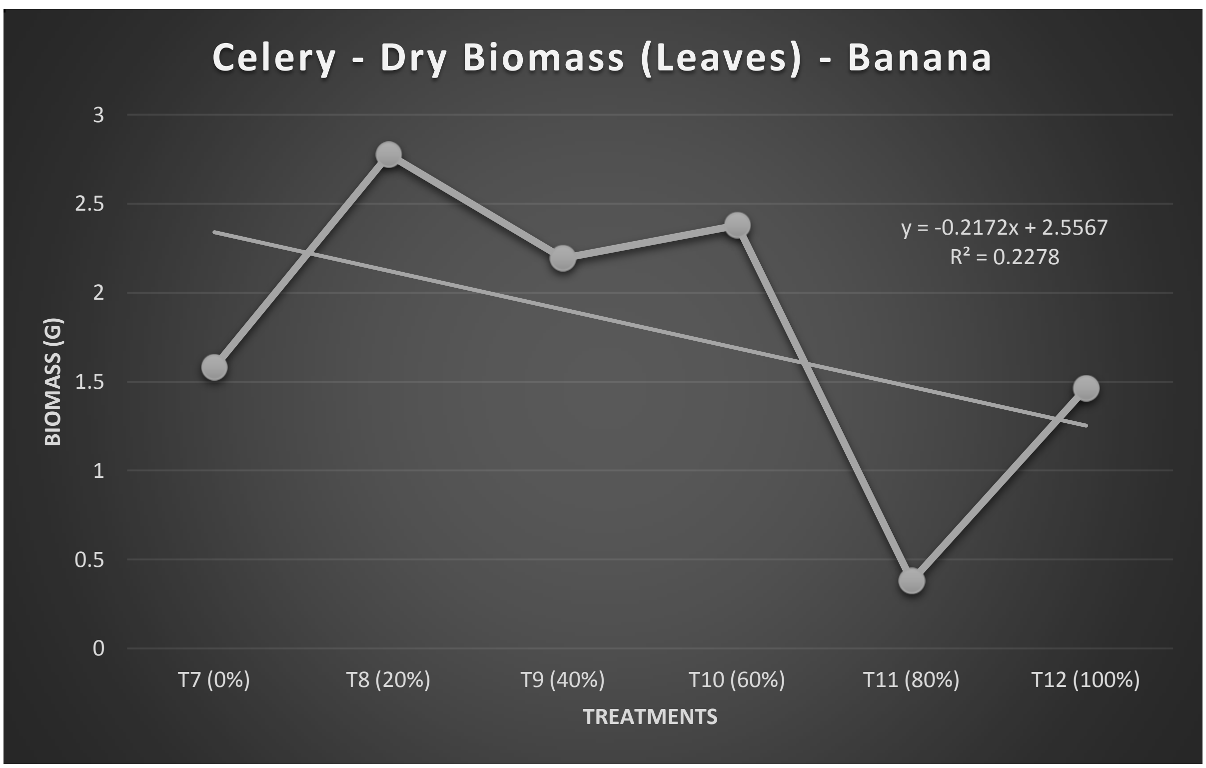

Celery - # of Leaves - Cocoa
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
# OF LEAVES
y = -0.055x + 3.8364
R² = 0.1628
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

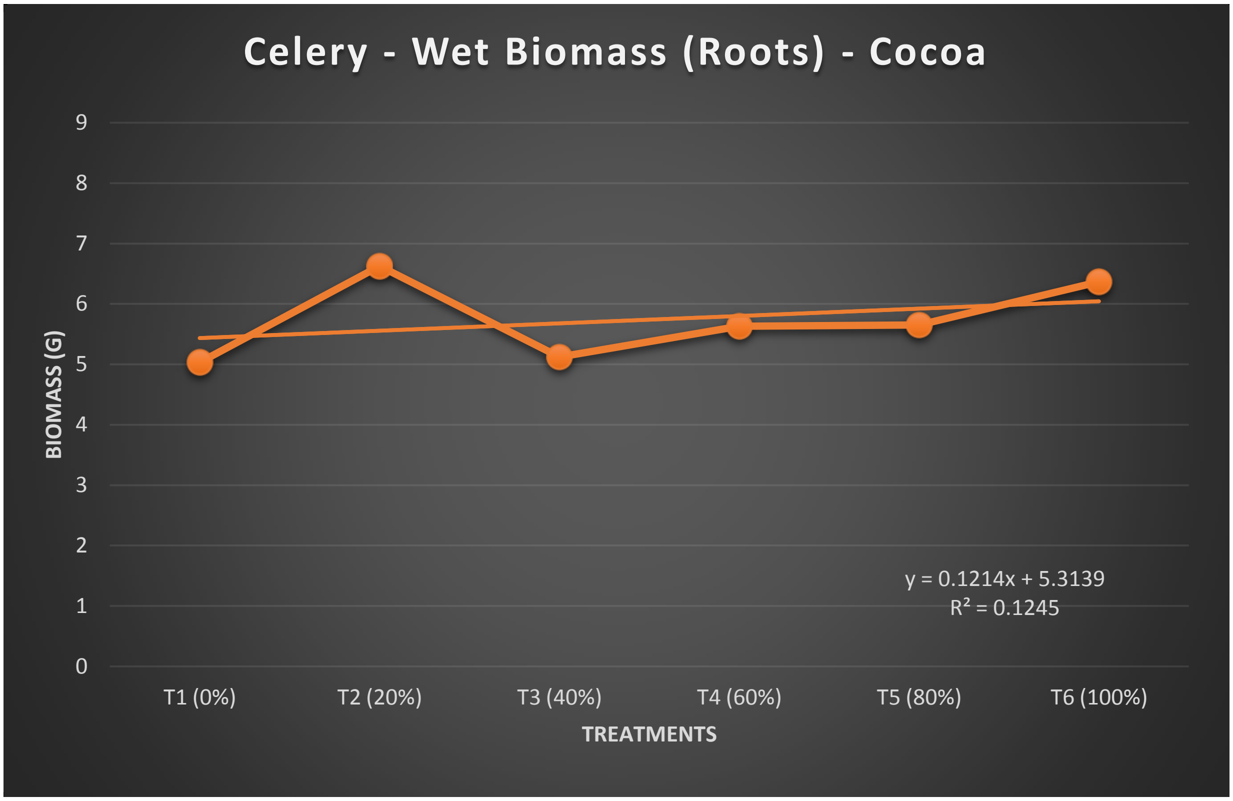

Celery - # of Leaves - Banana
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
# OF LEAVES
y = -0.2376x + 4.1122
R² = 0.8838
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS

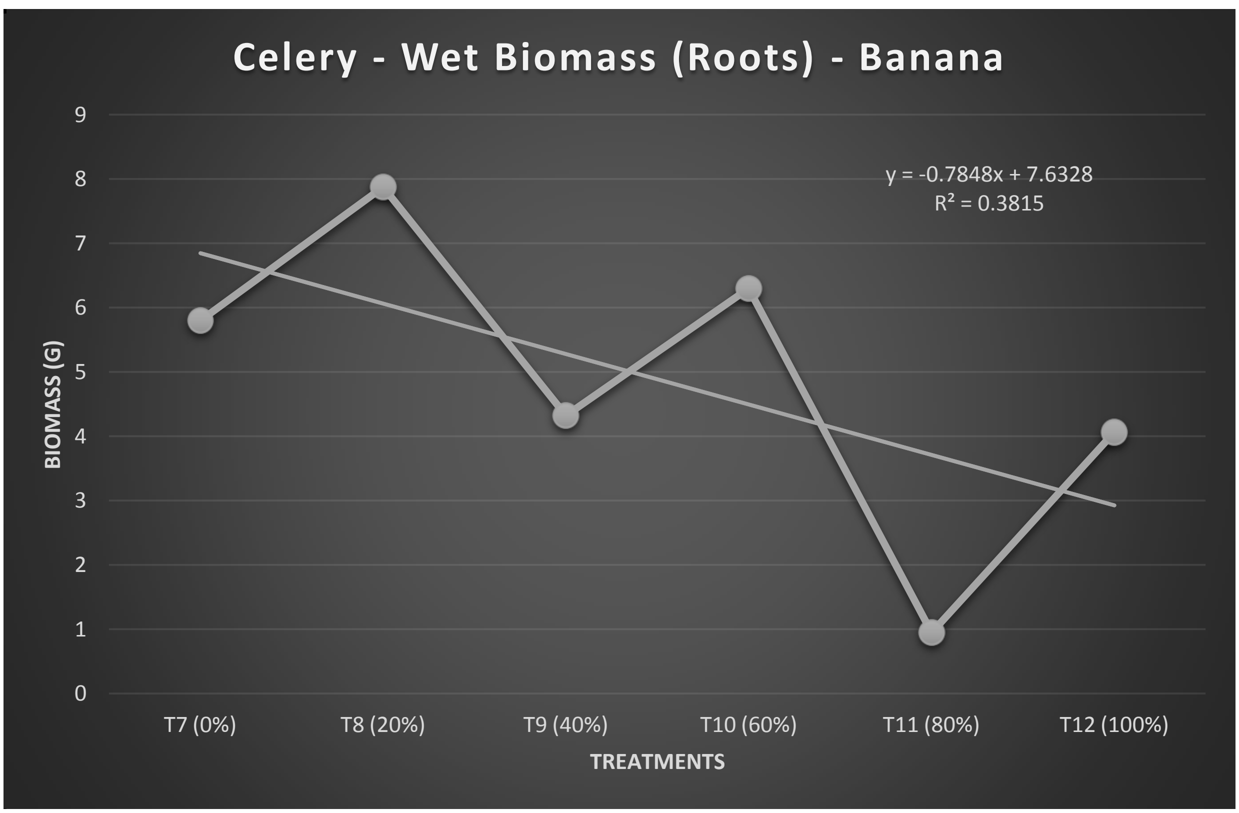

Celery - Wet Biomass (Leaves) - Cocoa
40
35
30
25
20
15
10
5
0
BIOMASS (G)
y = -0.0762x + 21.486
R² = 0.0011
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS

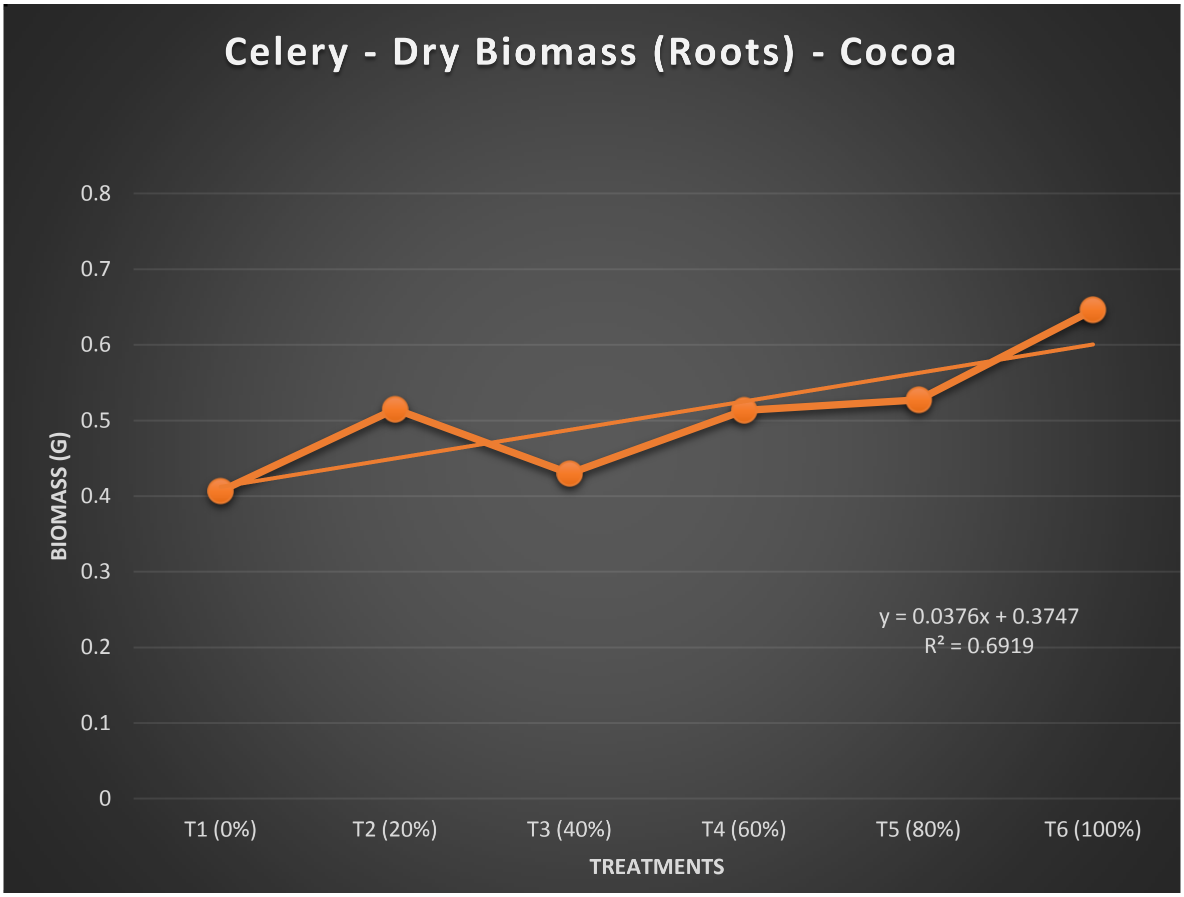

Celery - Wet Biomass (Leaves) - Banana
40
35
30
25
20
15
10
5
0
BIOMASS (G)
y = -1.8238x + 25.078
R² = 0.1005
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS

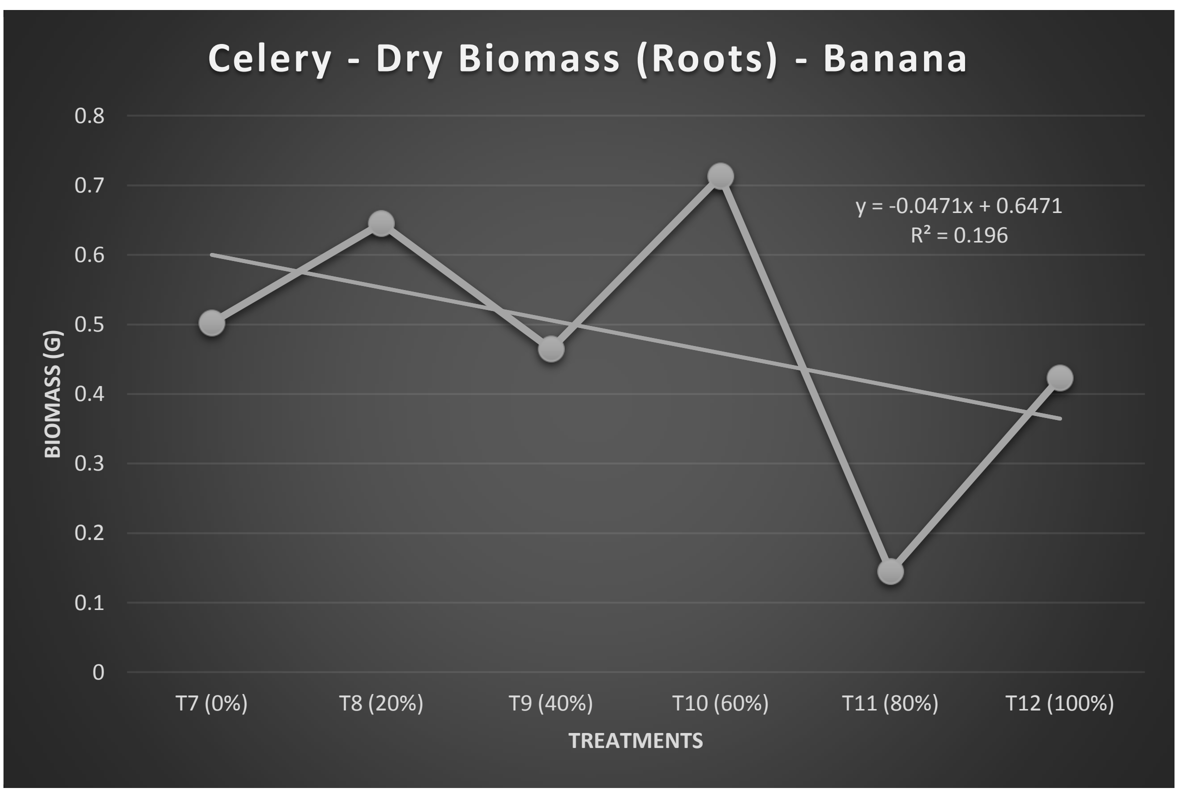

Celery - Dry Biomass (Leaves) - Cocoa
3
2.5
2
1.5
1
0.5
0
BIOMASS (G)
y = 0.0731x + 1.9158
R² = 0.0984
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS


Celery - Dry Biomass (Leaves) - Banana
3
2.5
2
1.5
1
0.5
0
BIOMASS (G)
y = -0.2172x + 2.5567
R² = 0.2278
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS


Celery - Wet Biomass (Roots) - Cocoa
BIOMASS (G)
9
8
7
6
5
4
3
2
1
0
y = 0.1214x + 5.3139
R² = 0.1245
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS


Celery - Wet Biomass (Roots) - Banana
BIOMASS (G)
9
8
7
6
5
4
3
2
1
0
y = -0.7848x + 7.6328
R² = 0.3815
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS


Celery - Dry Biomass (Roots) - Cocoa
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
BIOMASS (G)
y = 0.0376x + 0.3747
R² = 0.6919
T1 (0%)
T2 (20%)
T3 (40%)
T4 (60%)
T5 (80%)
T6 (100%)
TREATMENTS


Celery - Dry Biomass (Roots) - Banana
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
BIOMASS (G)
y = -0.0471x + 0.6471
R² = 0.196
T7 (0%)
T8 (20%)
T9 (40%)
T10 (60%)
T11 (80%)
T12 (100%)
TREATMENTS