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The Final Paper: The Effect of Different Types of Soil on the Growth of Habanero Peppers

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Abstract:

This experiment was used to determine if there was a significant difference between the masses of habaneros produced by plants that were grown in different types of soil. The experiment was conducted with 18 plants: 3 groups of 6 grown in soil, 5 parts soil to 1 part ash and 5 parts soil to 1 part sand. Data was collected weekly in the form of the masses of individual habaneros produced for a total of 6 weeks. The resulting data was then analyzed using an Anova test and following T-Tests to determine where the significant differences lie. There were two groups of findings for this experiment depending on if damaged and bitten habaneros counted in the data set. If they did, then all populations of habaneros were significantly different from one another. If they did not, then all the populations of habaneros were not significantly different from one another. However, the quantities of habaneros produced suggest that sand was the most productive as it produced the most, followed by ash and then soil. The final conclusion that was drawn was that there was not a significant difference with the individual masses of the habaneros, but that the one with sand was the most productive. In the future, more experiments that relate to the soil content of plants should be conducted. This way gardeners have data that they can form their own conclusions on soil content based on the trends they identify.

Introduction

All plants need soil and each plant therefore has its own preference of soil conditions. The plant that is the focus of this experiment is the habanero chili pepper. This pepper as well as most other peppers prefer soil conditions to be slightly acidic and for the soil to drain well (Damask). The approximate pH value that the habaneros work best in is a value of 6-6.8 (Damask; How to Get Hotter Peppers Just by Adjusting Your Soil). This pH value will also affect the perceived spiciness of the peppers produced by the plant (*How to Get Hotter Peppers Just by Adjusting Your Soil*). These peppers also require full sun and only need to be watered when the soil is dry (*Growing Habanero Peppers*).

Historically, the habanero originates from south and central America and as a result carries the aforementioned growing constraints (*History of the Habanero Pepper*). They also must be started before the final frost for the fruit to be ready in the summer (Grant.). If they are started after the first frost, they may have to deal with frost heave, sunscald and their cells will freeze (Frost Heave ; Effects Of Cold In Plants: Why And How Plants Are Affected By Cold ; Sunscald of Woody Plants).

The objective of this experiment was to determine the effect of sand and ash in soil on the growth of habanero peppers in the central, coastal New Jersey area where the soil that the plant is grown in is the independent variable. The research hypothesis for this experiment states that there will be a significant difference in the total biomass of habaneros produced in different types of soil.

The reason the prediction was as such was because the mass of a single pepper was not significantly different as long as the pepper had not been affected by factors such as insect bites. Insect bites are not typically common on peppers because the insects are preyed upon by other organisms and there are typically better fruits nearby (Barbercheck). However, the habaneros were the only available fruits when the plants moved from outside to inside and as a result, caterpillars were forced to eat the habaneros to survive. In addition, aphids had no predators and their population increased exponentially (Aphid Pests). The only way to get rid of them would be to cut off all the leaves, but that was not a possibility at the given time (Chambers).

The independent variable, the mixtures of soils, consisted of 3 conditions. One being the control, two being 5 parts soil to one part ash and three being 5 parts soil to 1 part sand. These

variables were picked because variable 3 affects the drainage of the plant and two affects the pH. The dependent variable is the growth of the habaneros and this has been defined as the masses of the produced fruits

Over the course of the study, soil was mixed such that they represent the different variables and habanero seeds will be planted in them. Over the next 2 or so weeks, the seeds germinated and sprouted. In the weeks following germination, the plants continued to grow and were watered when needed. They eventually flowered and produced fruits. At this point, data collection began. Data collection consisted of weighing habaneros, marking what plant they came from and the date it was picked for 6 weeks.

Materials and Methods

Preparing Buckets

Required for this process are 18 two gallon buckets, a sharpie, a ruler, a screwdriver, about 10 square feet of screen mesh used for windows, a drill and a $\frac{1}{2}$ in drill bit. First, the center of the bottom of the bucket was marked using the sharpie and dots were then drawn according to the pattern **shown below**. Following that, the screwdriver was placed over the dots and punctured the plastic by pressure applied with a hand. Next, holes were drilled into the plastic at the spots marked. Finally, a 9x9in sheet of screen was placed at the bottom of the bucket.

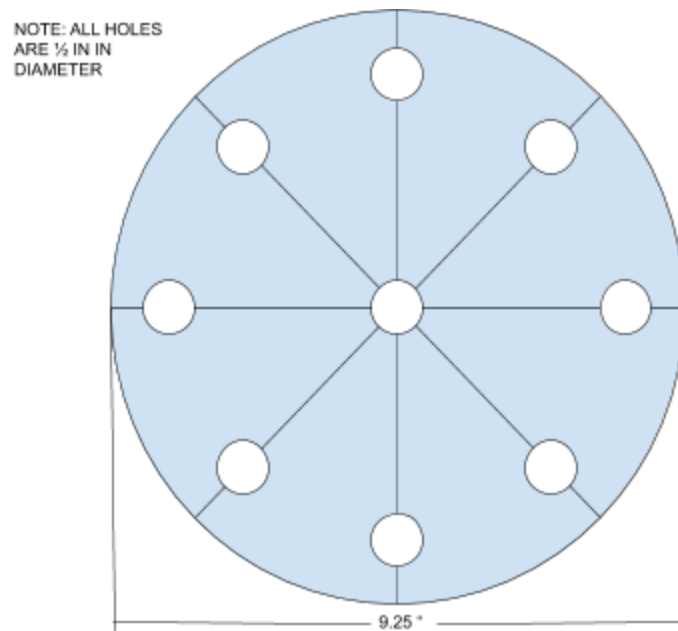


Figure 1: Layout of Holes on Bucket Bottom

This diagram shows the positioning of the holes drilled into the bottom of the buckets.



Figure 2: Holes on Bucket Bottom

This picture shows the positioning of the holes drilled into the bottom of a bucket.

Preparing Soil

Required for this process are 32 gallons of soil, 2 gallons of ash, 2 gallons of sand, a wheelbarrow, a 2 gallon bucket, the 18 prepared buckets, a sharpie and a shovel. 6 buckets were marked for each condition. The labeling system utilized had SA for sand, S for Soil and A for ash. After the letter, they were numbered 1-6. To fill the control buckets marked S, nothing was done to the soil. It stayed unmodified. For the sand mixture (SA), one bucket full of sand and 5 buckets of soil were poured into the wheelbarrow and mixed as if mixing cement. Once homogenous, the mixture was then distributed among the six buckets marked SA. The final mixture: Ash followed the same steps as sand, but sand was replaced by ash.

Sowing Seeds

Required for this process are 36 habanero seeds, the filled buckets and a watering can. A finger was stuck into the soil and made 2 holes a quarter to one half inch deep. They were about 2 inches apart and close to the center (See Figure 3). Next, 1 seed was placed in each hole and the holes were filled with the soil pushed out of the hole when creating them. The bucket was watered with the watering can and checked to make sure that the seeds were covered. This process was repeated for the remaining 35 buckets.

NOTE: HOLES
ARE $\frac{1}{4}$ TO $\frac{1}{2}$ IN
DEEP

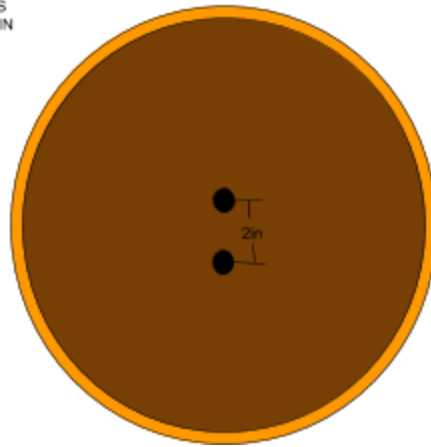


Figure 3: Positioning of Seeds in Soil

This diagram shows the positioning of seeds planted in the buckets.



Figure 4: Positioning of Seeds in Soil (Birds Eye View)

This picture shows the positioning of seeds planted in the buckets from a top view.



Figure 5: Positioning of Seeds in Soil (Isometric)

This picture shows the positioning of seeds planted in the buckets from an isometric view.

Maintenance of Plants Before Fruit is Produced

Required for this process are habanero plants that have at least 6 leaves excluding cotyledons and have not yet produced fruit, a hose with a connection to a water line, miracle grow and a 2 gallon watering can. First, two scoops of Miracle Grow (3 tbsp) were poured into the two gallon watering can before putting in the water. Next, water was put in using a hose that had the spigot turned all the way left. The reason for the hose to be at max flow was so that the water was mixed with the Miracle Grow. Finally, the solution was distributed evenly among the plants (it was about 8 seconds of water each using the watering can).

Taking Plants Inside

Required for this process are a tarp, habanero plants, grow lights and a wet paper towel. First, the tarp was placed down (it was laid down in the basement) and the grow lights (two Monios - L T5 LED 4ft full spectrum sunlight grow lights were used) were hung. Next, the bottoms and sides of the buckets were wiped until the dirt was gone. Finally, the plants were placed below the grow lights.



Figure 6: Positioning of Grow Lights

This picture shows the positioning of grow lights in the basement.



Figure 7: Mounting of Grow Lights

This picture shows the mounting mechanism of grow lights in the basement.

Data Collection

Required for this process are a scale(I used a pocket gram scale with the word contact on its cover), a pen and a piece of paper. The plants were checked for ripe fruit. Once found, the date was written down as well as the plant number and mass of the pepper found using the scale. This process was repeated for the next six weeks.

Analysis Methods

Google Sheets was used to analyze the data. Two Anova tests were done; the first test included the damaged samples and the second test did not. The first sample set which included the damaged fruits was then further analyzed using T-Tests to determine between which populations, the significant difference layed.

Results

Table 1 : The Raw Data Table for the Mass of Undamaged Habaneros Harvested by Soil Type in Grams Per Week (Quantitative)

The Raw Data Table for the Mass of Habaneros Harvested by Soil Type in Grams Per Week (Quantitative)				
Weeks	Dates	Soil with Ash (g)	Soil with Sand (g)	Soil (g)
1	10-25-2020	0.00	16.36	0.00
2	11-1-2020	9.72	44.57	0.00
3	11-8-2020	42.5	37.06	8.88
4	11-15-2020	17.53	31.57	0.00
5	11-22-2020	29.05	17.31	5.91
6	11-29-2020	14.1	26.62	0.87

This table depicts the total amount of habaneros produced weekly by each of the three levels.

Table 2 : Raw Data Table for The Weights of Individual Peppers by Soil Type

The Raw Data Table for The Weights of Individual Peppers by Soil Type		
SOIL (CONTROL)	ASH	SAND
0.87	3.04	10.04
2.45	0.56	13.12
3.63	3.42	0.49
2.80	2.34	7.33
3.77	3.09	9.03
5.91	4.53	7.47
	6.18	7.86
	5.87	6.16
	6.78	5.57
	5.15	5.30
	4.96	6.03
	5.96	6.18
	5.73	5.32
	5.84	6.71
	5.79	4.64
	6.31	4.58
	5.67	5.77
	5.79	7.14
	5.49	5.63
	2.78	5.68
	5.88	8.25
	5.44	3.47
		5.59
		6.39
		6.00
		3.66
		5.12
		4.96

This table depicts the individual pepper masses including the masses of the damaged peppers.

Table 3 : Raw Data Table for The Weights of Individual Peppers by Soil Type w/o Bad Fruit

Weights of Individual Peppers by Soil Type w/o Bad Fruit		
SOIL (CONTROL)	ASH	SAND
3.77	2.34	0.49
5.91	2.78	3.47
	3.09	3.66
	3.42	4.58
	4.53	4.64
	4.96	4.96
	5.44	5.12
	5.49	5.30
	5.67	5.32
	5.73	5.57
	5.79	5.59
	5.79	5.63
	5.84	5.68
	5.87	5.77
	5.88	6.00
	5.96	6.03
	6.18	6.16
	6.31	6.18
	6.78	6.39
		6.71
		7.14
		7.33
		7.47
		7.86
		8.25
		9.03
		10.04
		13.12

This table depicts the individual pepper masses without the masses of the damaged peppers.

Table 4: The Summative Data Table for the Mass of Habaneros Harvested by Soil Type in Grams (Quantitative)

The Summative Data Table for the Mass of Habaneros Harvested by Soil Type in Grams (Quantitative)			
	Soil With Ash	Soil With Sand	Soil
mean	4.845	6.196	3.238
SD	1.596	2.270	1.673
VAR	2.549	5.153	2.799
n	22	28	6

This table depicts the mean, standard deviation, variance and number of samples of the Raw Data Table for The Weights of Individual Peppers by Soil Type.

Table 5: The Summative Data Table for the Mass of Habaneros Harvested by Soil Type in Grams w/o Bad Fruit (Quantitative)

The Summative Data Table for the Mass of Habaneros Harvested by Soil Type in Grams w/o Bad Fruit (Quantitative)			
	Soil With Ash	Soil With Sand	Soil
mean	5.150	6.196	4.840
SD	1.292	2.270	1.513
VAR	1.669	5.153	2.290
n	19	28	2

This table depicts the mean, standard deviation, variance and number of samples of the Raw Data Table for The Weights of Individual Peppers by Soil Type w/o Bad Fruit.

Table 6: The Summative Data Table for the Mass of Habaneros Harvested by Soil Type per Week in Grams (Quantitative)

The Summative Data Table for the Mass of Habaneros Harvested by Soil Type per Week in Grams (Quantitative)			
	Soil With Ash	Soil With Sand	Soil
mean	22.580	28.915	5.220
SD	13.243	11.100	4.049
VAR	175.365	123.208	16.397
n	6	6	6

This table depicts the mean, standard deviation, variance and number of samples of The Raw Data Table for the Mass of Undamaged Habaneros Harvested by Soil Type in Grams Per Week (Quantitative).

Table 7: The Statistical Data Table for the P-Values of the Mass of Habaneros Harvested by Soil Type per Week in Grams (Quantitative)

The Statistical Data Table for the P-Values of the Mass of Habaneros Harvested by Soil Type per Week in Grams (Quantitative)			
	Sand vs Soil	Soil vs. Ash	Ash vs. Sand
P-Value	0.005123228627	0.03971809639	0.02205472926
P-Value for Undamaged Peppers	0.4166997368	0.7527069499	0.0761819422
P-Value vs. Alpha	< 0.05	< 0.05	< 0.05
P-Value for Undamaged Peppers vs. Alpha	0.05 >	0.05 >	0.05 >

This table depicts the different P-Values for the 2 tailed T-Tests conducted between the different pepper populations.

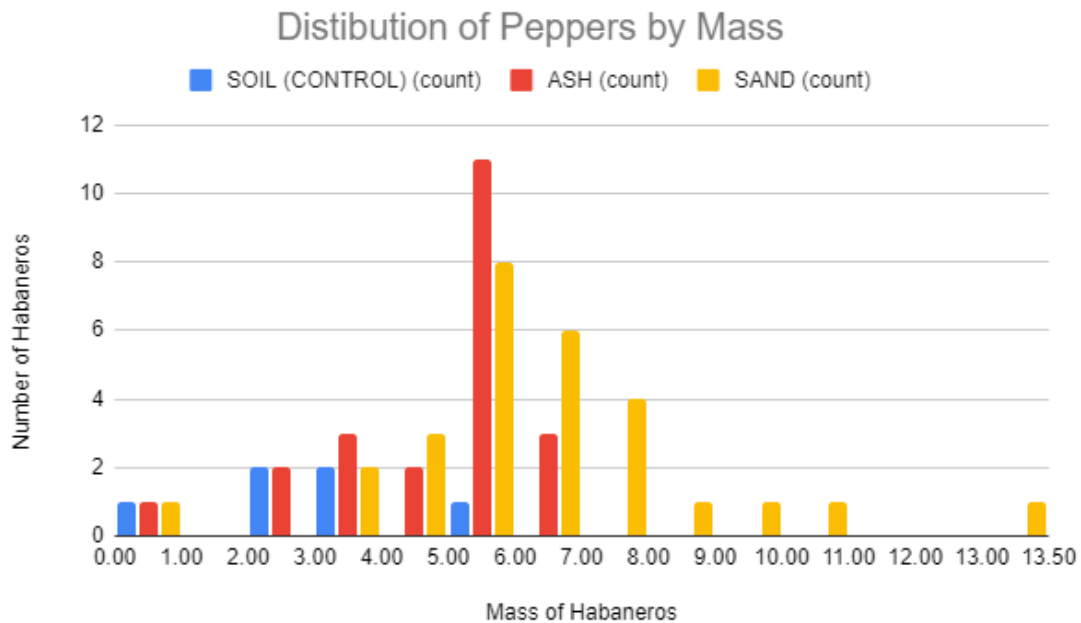


Figure 8: Distribution of Peppers by Mass

The data presented shows the distribution of pepper masses.

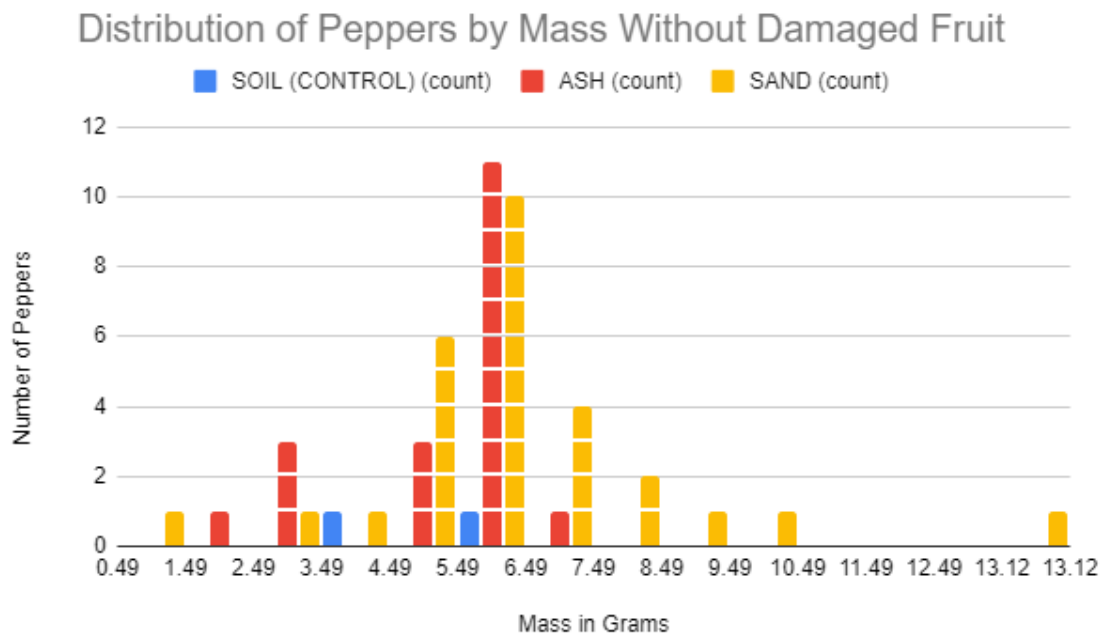


Figure 9: Distribution of Peppers by Mass Without Damaged Fruit

The data presented shows the distribution of undamaged pepper masses.

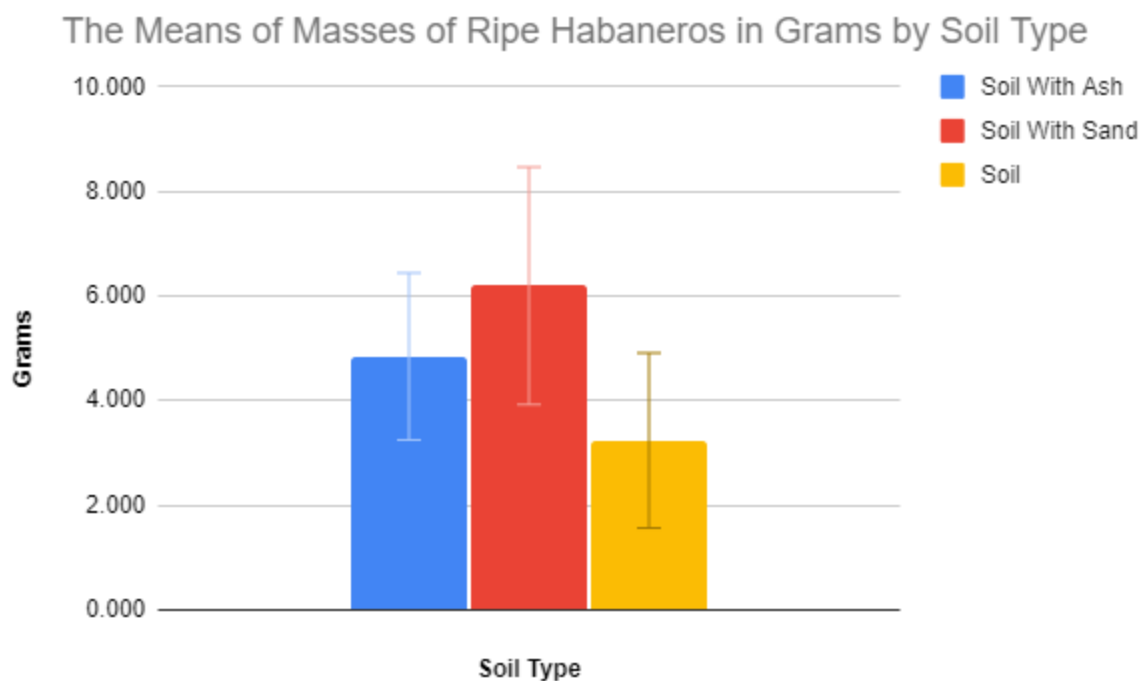


Figure 10: The Mean Masses of Habaneros in Grams by Soil Type

The data presented is a bar graph with the mean masses of habaneros per soil type.

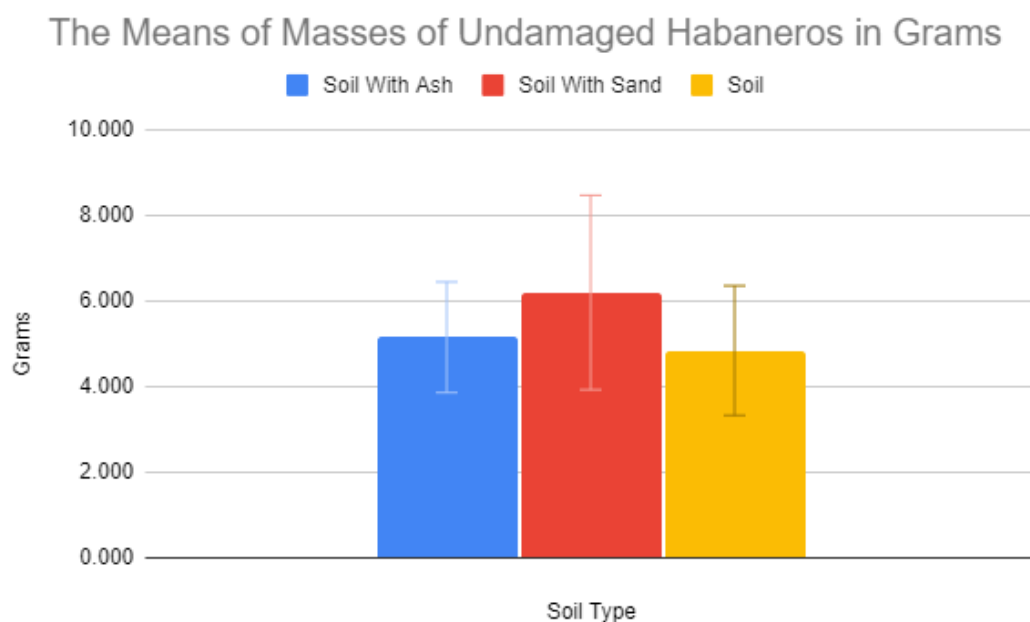


Figure 11: The Mean Masses of Undamaged Habaneros in Grams by Soil Type

The data presented is a bar graph with the mean masses of undamaged habaneros per soil type.

Discussion

When analyzing the data to test the hypothesis, *There will be a significant difference in the total biomass of habaneros produced in different types of soil*, the independent and weighted anova test returns a value of $2.205 * 10^{-2}$ which is less than the alpha of 0.05.

Therefore:

- Reject the null hypothesis.
- Support the alternative hypothesis.
- The data do support that there is a significant difference between the weights of Soil and Ash habaneros.

Since the Anova was successful, T-Tests were conducted.

The first hypothesis was: *There is a significant difference between the weights of Soil and Ash habaneros*.

After conducting the T-Test, a P-Value of $3.972 * 10^{-2}$ was returned.

Therefore:

- Reject the null hypothesis.
- Support the alternative hypothesis.
- The data do support that there is a significant difference between the weights of Soil and Ash habaneros.

The second hypothesis was: *There is a significant difference between the weights of Soil and Sand habaneros*.

After conducting the T-Test, a P-Value of $5.123 * 10^{-3}$ was returned.

Therefore:

- Reject the null hypothesis.
- Support the alternative hypothesis.

- The data do support that there is a significant difference between the weights of Soil and Sand habaneros.

The third hypothesis was: *There is a significant difference between the weights of Ash and Sand habaneros.*

After conducting the T-Test, a P-Value of 2.205×10^{-2} was returned.

Therefore:

- Reject the null hypothesis.
- Support the alternative hypothesis.
- The data do support that there is a significant difference between the weights of Ash and Sand habaneros.

However, when the data that excludes the damaged fruit was analyzed to test the hypothesis, *There will be a significant difference in the total biomass of habaneros produced in different types of soil*, a P-Value of 1.626×10^{-1} was returned, which is greater than the alpha value of 0.05.

Therefore:

- Fail to reject the null.
- Do not support the alternative.
- The data do not support that there will be a significant difference in the total biomass of habaneros produced in different types of soil.

Depending on if the damaged fruit are considered in the analysis, there will or there will not be a significant difference. If they are counted then there is a significant difference between all soil types, but if they are excluded, the data will get anova greater than 0.05 and fail.

The data should be analyzed without the damaged fruit because those fruits do not represent the general population. The damaged fruit were also significantly lighter than the rest and skewed the data as a result.

One reason the sample sizes may be so low is because the seeds were sown in early June which pushed the data collection into the Fall. As a result of this later collection time, the plants needed to be moved inside to avoid the frost and had to adjust to the temperature and light schedule of the basement.

Another side effect of moving the plants inside was the uncontested growth of the plants' aphid population. While outside, the aphids are kept in check by other insects such as ladybugs. However, the basement was devoid of ladybugs and other aphid predators, so the population flourished. The population did not have a significant effect on the plants during data collection, but it was clear that they would cause harm in the future.

Although the weights of the peppers were not significantly different, there was most certainly a difference in growth if the quantity of peppers produced is the metric. The sand population had 14 times the amount of good peppers produced compared to the soil and ash only produced a little more than half of the peppers that sand did.

Based on the conclusion above, there is a difference in the amount of habaneros produced, just not a significant difference in the masses of the individually produced habaneros.

Future Studies and Research Impact

Many additional questions have been raised as a result of this experiment. Even though they all faced the same conditions with the exception of the soil type, some plants had darker leaves than others. The first hypothesis on this was that the amount of light they were exposed to was different, but they were exposed to the same amount of light. Another question as a result of this experiment was why the taste of the young leaves was different than that of the older leaves. Maybe it is to do with the allocation of plant resources and how it may prioritize the younger rather than the older. It would also be interesting to see if the soil type related to the plants aphid resistance since it seemed like certain plants got infested before others. Being able to easily measure the capsaicin in a pepper would allow researchers to determine if the soil type makes a difference.

Although many experiments have been done related to soil type, it would be interesting to see a common location with data for common plants in an organization system like the tables here. Having specific data samples for many plants would allow gardeners to further optimize the soil for their individual plants based on trends they can discern from the data. More levels of the experiment would be beneficial to this cause because it would allow for even more precision on the best suitable content of a soil for a specific plant. The findings of this experiment are only the beginning of this rabbit hole related to soil conditions.

Acknowledgements

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- Flowers may drop because of temperature changes, improper pollination, amount of water, nitrogen levels. Regulate these to fix issues.