# Do Sugar Snap Peas Have a Critical Growth Period?

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## ABSTRACT

It is a known fact that humans have a critical development period in which external environmental conditions have long lasting effects [1]. In this study, I investigate the question of whether or not *Pisum sativum 'Macrocarpon Group'* (sugar snap peas) have a critical development period. In this experiment, sugar snap peas were grown in acidic soils or untreated soils for 20 days, with some being transplanted on day 10. This is done to investigate if when the plants are grown in their optimal pH of 6.0-7.0 matters. Throughout the experiment, the plants had individual heights and leaf counts measured every day, with the goal being to determine how changing optimal pH conditions affects germination, growth, and leaf count. After conducting the experiment for 20 days, it's shown that germination and growth are affected by pH and when plants are placed in certain conditions, while leaf count is not impacted. Peas grown in optimal pH conditions in their early period of growth that were then transplanted into acidic soil grew taller than plants first grown in acidic conditions before being transplanted into optimal ph soil, showing that sugar pea plants do have a critical growing period from planting to early growth after germination.

## Introduction

Humans have a critical development period, where we are most susceptible to our outside environment. This often occurs when humans are extremely young. However, the presence of a critical development period has not been demonstrated in plant growth. In humans, we know that this period has long-lasting implications for language and other mental functions. In plants, they may have a period where external factors are most important to their own development.

This experiment was conducted to determine if plants and when had a critical growth period where they were affected by their surrounding soil pH the most. pH was chosen to be the experimental variable in this experiment since it has been proven that the pH of growing soils affects plant growth.

We used *Pisum sativum 'Macrocarpon Group'* (sugar snap peas) as a model species to answer this question. Sugar snap peas can survive in a broad range of pHs and have an ideal pH, making it easy to grow different groups across different pHs the peas can survive in. Sugar snap peas' ideal pH is from 6.0 - 7.0, but can survive in conditions much lower up with pH from 5.0-6.0 being acidic, suboptimal pH that results in less growth [2].Lower soil pHs usually result in decreasing nutrient availability, usually through nutrient leaching. [3].Sugar snap peas are also legumes, a plant from the *fabaceae* family with pods that cover seeds and have a symbiotic relationship with rhizobia, bacteria that fix nitrogen. It has been found that lower soil pHs inhibit the survival of rhizobia, which should lead to lower pea plant nutrient availability and growth [3]. Another study on pea plants and pH found that pea plants absorb nutrients more efficiently in neutral soils than under acidic conditions [4]. Finally, it has been found that sugar snap peas have found that soil with 4.5 pH limits root nodulation [5]. The previous research on acidic soil in relation to sugar snap pea growth indicates that sugar snap peas should see less growth when grown in acidic soil and more growth in neutral pH soil.

# Materials and Methods

## Materials

The sugar snap peas used were from Burpee, as pea plants have a quick germination time of 5-10 days, allowing the experiment to be conducted in a timely manner. They were grown in planters with dimensions of 8.5” x 3.3” x 7.9”, with ten planters being used in total. All soil used in the experiment came from Fremont, California city soil, which the city describes as fine-loamy and being somewhat poorly drained. For lighting, a 4 head growing LED light from GHOdec was used to simulate the effect of sunlight. Finally, digital pH probes from Kensizer were used to measure the pH daily.

To create the acidic soil, a large pot of Fremont city soil was gathered, and for two weeks, its pH was lowered with a mixture of white distilled vinegar (pH = 2.8), and water in a ratio of 1 quart water to ½ cup vinegar, with the mixture having a pH of 3.5. Over the next two weeks, the pH of the soil was lowered to 5.0.

## Methodology

The experiment was conducted in an enclosed room with minimal outsight light. The plants were exposed to a 12 hour night-day cycle with an LED growing light. Four groups were used to organize the plants: group 1 was in acidic soil for 20 days, group 2 was placed in acidic soil for the first ten days then transplanted into neutral pH soil, group 3 was first grown in neutral pH soil for ten days then transplanted into acidic pH, and group four was grown in neutral pH for all 20 days (Figure 1).

For all treatments, 8 seeds were planted into each planter, with groups 1 and 2 starting with soil of pH 4.8 made from the procedure above, while groups 3 and 4 were planted in Fremont city soil with a pH of 6.9, inside the peas’ optimal pH range. Planters were rotated under the LED light every two days to minimize outside factors, and planters with acidic soil were watered with an acidic solution of 1 cup water and 1/16 cup vinegar every five days, while planters with neutral pH soil were watered with just water. Height, leaf count, pH, and moisture of planters were recorded daily. After 10 days, plants in groups 2 and 3 were transplanted into neutral pH and acidic soil respectively, with groups 1 and 4 staying in their initial soil. The procedure continued for 10 more days, with the watering solution for groups 2 and 3 being switched. Groups 1 and 2 were conducted before Groups 3 and 4, resulting in a lack of leaf data until Day 10.

| Group 1 (all acidic) | Group 2 (acidic → normal) | Group 3 (normal → acidic) | Group 4 (all normal) |
|---|---|---|---|
| Planter 1 & 2 | Planter 3, 4, & 5 | Planter 6 & 7 | Planter 8, 9, &10 |

**Figure - 1:** Planters by Group

## Data Analysis

Results of the experiment were analyzed in R studio [6], which was also used to create the graphs used in displaying the results. ANOVA was used to test the effects of the different groups on the total height, germination day, and leaf count at the end of the 20 days. A total of 11 plants were excluded from height and leaf count data analysis and graphs. Outliers were determined based on the total plant heights being bimodal, shown in Figure 2. Due to ANOVA only being applicable to normal data, plants that did not grow to a minimum of 14.4 centimeters by the end of 20 days were excluded. These outliers came from planters that started in acidic soil as well as optimal pH soil. 28% (8/28) of plants from acidic soil were excluded, and 33% (3/9) plants from neutral soil were excluded as outliers. This shows height limits of these outliers are likely a result of the seed itself being potentially defective, not a result of soil pH.

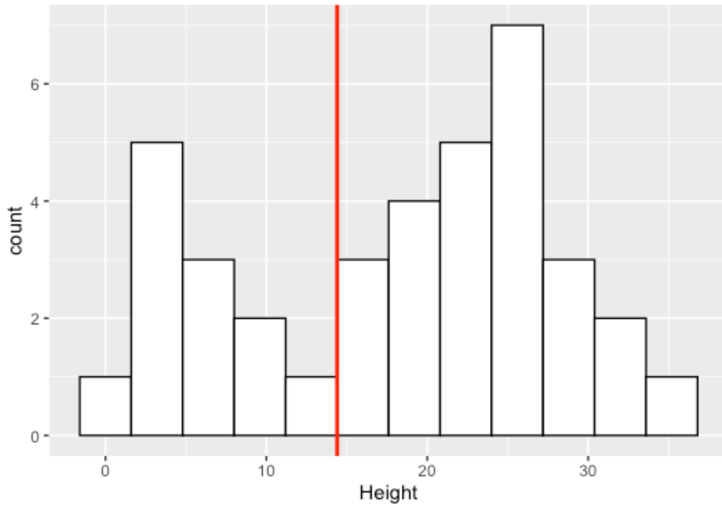


**Figure - 2**: Plant Height Histogram (plants left of red line are considered outliers)

## Results

### Height

Results on height data of the different plants at day 20 given in Figure 3a. The data show that plants grown first in neutral pH soil before being transplanted into acidic pH soil grew higher on average than plants first grown in acidic pH soil that were then transplanted into neutral pH soil, indicating a critical growth period. However, the results were not statistically significant ($p = 0.1946$) and further research would be necessary to confirm this finding. A scatter plot is also shown of the data (Figure 3b), showing that the plants grown in normal soil first grew higher on average, but due to the small sample size, the data is not conclusive for efficacy of the different treatments.

The growth trends of the different treatments are shown in Figure 4. This data shows faster germination in plants that started in acidic soil, but faster overall growth through the first ten days in plants that started in normal soil. Plants transplanted from normal soil to acidic soil (Group 3) had an extremely high initial growth, but had their growth almost immediately halted after being transplanted into acidic soil. Plants grown in neutral pH soil for 20 days show standard growth of pea plants under optimal pH circumstances for 20 days. This data is more informative than the other two figures, as even with the low sample size from Groups 3 and 4 it still shows growth trends. It shows growth trends within groups are similar, suggesting the different treatments impacted overall growth.

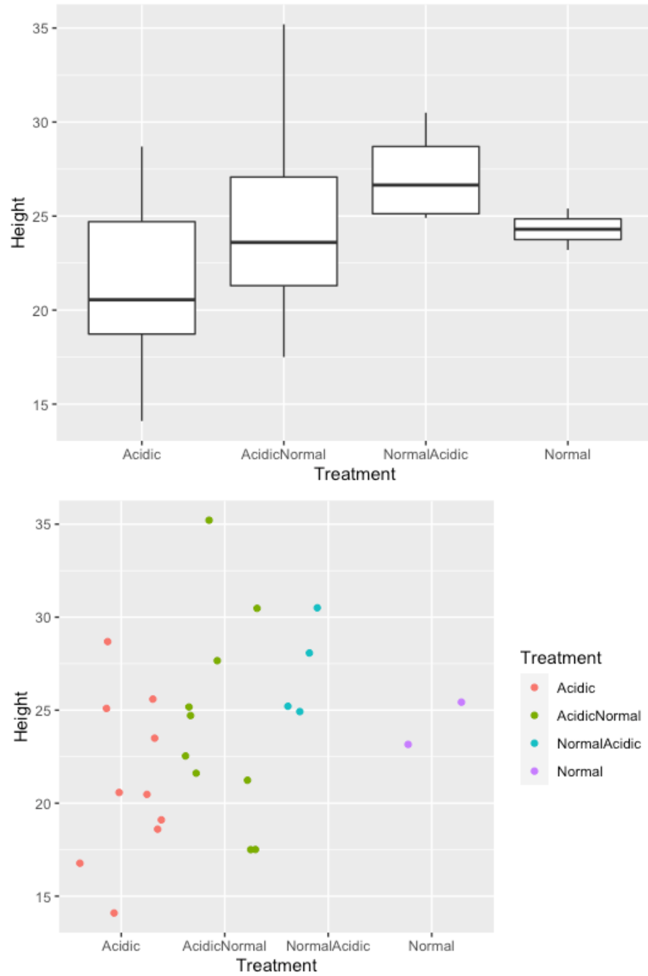


**Figure 3a (top):** Plant height boxplot of different treatments on Day 20

**Figure 3b (bottom)**: Plant height scatter plot of different treatments on Day 20

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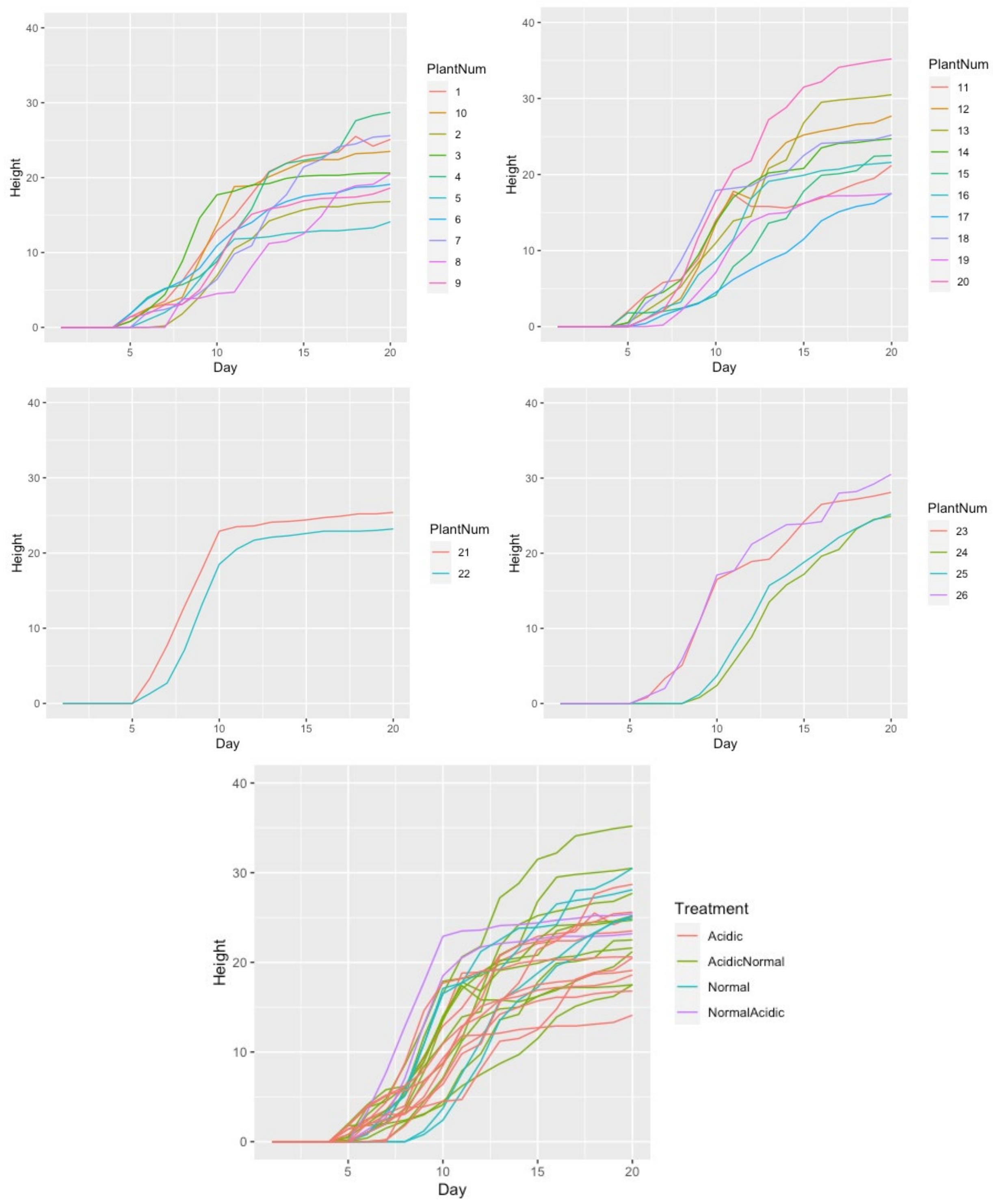



**Figure 4:** Graphs of plant growth over the 20 days separated by Treatment: Figure 4a (top left) shows the growth trends in plants grown in acidic soil for 20 days. Figure 4b (top right) shows the growth trends in plants first grown in acidic soil that were transplanted into neutral pH soil. Figure 4c (middle left) shows growth trends in plants first grown in neutral pH soil that were transplanted into acidic soil. FIgure 4d (middle right) shows growth trends in plants grown in neutral pH soil for 20 days.

## Germination Data

Another factor to note is the germination percentage and time needed for germination in the plants that started in normal soil. For germination data, outliers were included, since while those plants grew to a low height, they still germinated similarly to other plants. Data for days needed to germinate were plotted and shown in Figure 5. Plants were grouped together by the soil they started in as either acidic or neutral pH. All plants germinated before transplantation, so only initial soil pH needs to be accounted for. While 28 of the 40 planted seeds in initial acidic soil germinated (70%), only 9 of the 40 seeds planted in initial neutral pH soil germinated (22.5%). While the seeds in both groups had the same mean germination time, the seeds in the acidic group had a smaller third and first quartile, meaning that their germination time was shorter than the plants that started in neutral pH soil. After running an ANOVA test on germination data, it's shown that there is a germination difference between plants that started in acidic soil and plants that started in neutral pH soil (p=0.03471).

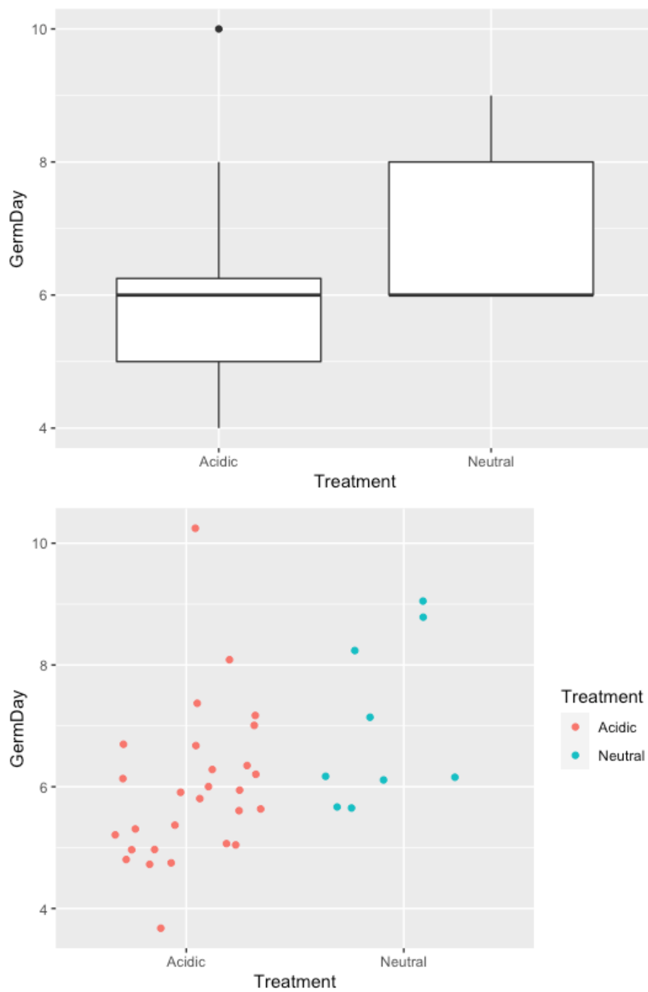
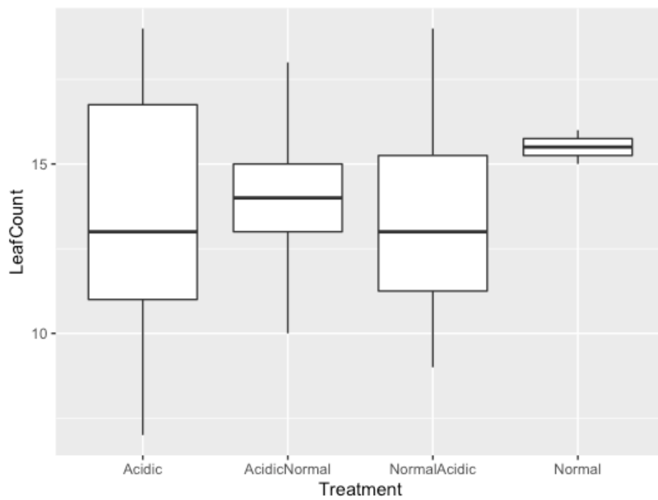



**Figure 5a (top)**: Average Germination Day by Initial Treatment Boxplot

**Figure 5b (bottom)**: Average Germination Day by Initial Treatment Scatterplot

### Leaf Count

While leaf count was also recorded through the experiment, after analysis it was found that leaf count data is not conclusive between the four groups. It appears the amount of leaves individual plants grew depended mostly on the individual plant, not the growing solution ($p = 0.8879$). The box plot and scatter plot are included below in Figure 6.



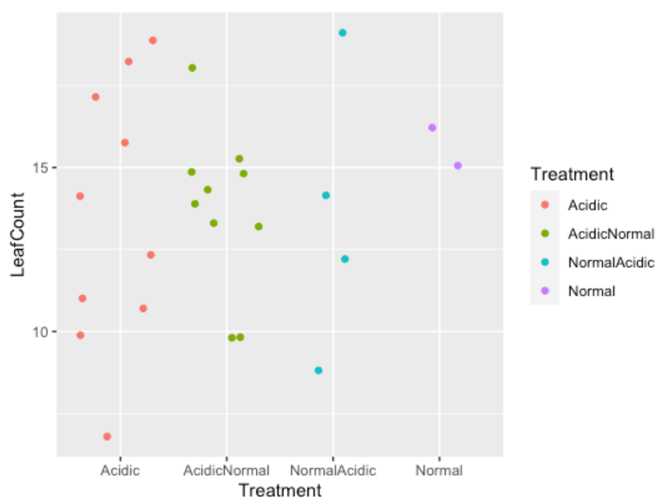




**Figure 6a (top):** Boxplot of Leaf Count

**Figure 6b (bottom)**: Scatterplot of Leaf Count

## Discussion

Our results show that soil pH treatment does have an impact on overall height. Neutral pH soil resulted in taller growth overall, and plants that were transplanted from neutral pH soil to acidic soil grew taller on average than plants that were transplanted from acidic soil to neutral pH soil. One potential explanation is that soil pH changes nutrient availability in the soil. Pea plants need high amounts of phosphorus and potassium to grow, and phosphorus and potassium amounts diminish as pH drops [3]. Another explanation is that many nutrients originally present leached out during the acidification process. In a study on acidic rainfall, it was found that bases and other nutrients, such as calcium, magnesium, and phosphorus leach out [7]. Given that the initial soil acidifying process could resemble acidic rainfall, this is another possible explanation. In another study regarding how plants respond to nutrient deficiencies, it was found that when plants have deficiencies in essential nutrients such as phosphorus, nitrogen, and potassium, they store most of their nutrients in roots and leaves [8]. This could explain why the plants in acidic soil grew shorter in general, as phosphorus, potassium, magnesium, and other essential nutrients were less available at acidic pHs.

Expanding on the biomass accumulation concept can help explain Groups 2 and 3's growth pattern. Plants in Group 2 started with nutrient deficiencies, resulting in biomass accumulation in roots and slower initial growth. When placed into neutral pH soil with high amounts of nutrients, biomass accumulated in stalks, resulting in more growth after the transplant. For Group 3, after being transplanted into soil with less nutrients, the plants may have allocated most of their generated biomasses into leaves and stems, resulting in minimal stalk growth during the second half of the experiment and high leaf count. However, given the ANOVA test score on leaf count data and high p score, the leaf data from this experiment is still inconclusive.

The results also show that initial soil pH has a significant effect on germination time. This may be because acid breaks down the seed's outer coating. In a study done on the effect of vinegar on germination, it was found that vinegar expedites the sprouting process in eggplant seeds by breaking down the outer layer of seeds [9]. This may have occurred in this experiment, with the acetic acid in the acidic soil breaking down the outer layer of seeds planted in Groups 1 and 2, allowing seedlings to absorb nutrients faster, resulting in faster germination overall. While many nutrients' plants need to germinate, such as nitrogen, phosphorus, etc. are less available at lower pHs, the faster absorption of these nutrients result in a faster germination time overall [5].

## Conclusion

Despite the fact that height data is not statistically significant, given the trends shown, it can be seen that sugar snap peas grown in suboptimal pH soil yields lower height, and it seems peas are more sensitive to the pH difference very early after germination as opposed to a few days after. To further study this phenomenon, an experiment can be conducted by adding lost nutrients to acidic soil to observe if the lower growth was due to lack of nutrients or another factor associated with lower pH. This experiment's results may be useful in seed planting in the future, as seeds can be placed in paper towels wetted with slightly acidic solution before planting to increase germination speed. Furthermore, this experiment's investigation on pH in regards to legumes can be helpful to further research in the future.

## Limitations

One important factor that limited the efficacy of research and statistical significance of data was the limited amount of germination (37.25% total yield). This is likely due to seed rotting, a phenomenon that occurs to seeds in waterlogged soil. According to Fremont's city website, Fremont's soil is poorly drained. Sugar snap peas need high drainage, and combine that with slight overwatering, as plants were watered every 5 days instead of the recommended 7, likely resulting in seed rotting. According to an article in *Soil and Tillage Research*, pea plants are especially susceptible to root rot caused by Aphanomyces Euteiches Drechs in soil with poor drainage [10]. However, both starting soils had poor drainage, and seed rotting fungi prefer acidic soil, meaning it is hard to explain what caused this result [11]. In further study, seed rotting and moisture and drainage are factors that need to be further controlled, as they severely limit the amount of usable data.

## Acknowledgements

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