# How Microwave Time Affects the Growth of Pinto Beans

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## ABSTRACT

The purpose of this study is to observe the effects of varying amounts of microwave time on the growth of the pinto bean (*Phaseolus vulgaris*). The researchers hypothesized that if a minimal amount of microwave time causes bean seeds to grow the fastest, then when measuring the growth of the beans in centimetres, the pinto bean seeds that are microwaved for shorter amounts of time or not at all will grow faster compared to the bean seeds microwaved for longer amounts of time. This was tested by microwaving pinto bean seedlings for 0 seconds (controls), 30 seconds, 60 seconds, 90 seconds, 120 seconds, 150 seconds, and 180 seconds and measuring the growth of each seed in centimetres for three weeks. A repeated measures one-way ANOVA and Tukey test were conducted using the data collected, and it was found that there was a significant difference ($p < 0.0001$). Pinto beans treated with shorter amounts of time, or not at all, showed higher amounts of germination compared to pinto beans treated for longer amounts of time. All treatments had significant results and an adjusted p-value of less than 0.05 except for three comparisons. The findings of this study contribute to the larger question of what the best factors are to improve the growth and health of plants.

## INTRODUCTION

An important area of research is understanding the environmental stress factors on seeds and how it correlates to the growth of plants. It is known that high-energy microwave radiation can break chemical bonds and alter the conformation of biomolecules, which ultimately leads to reduced germination rates (Soran et al., 2014). With the previous knowledge of how high energy microwave radiation affects biological structures, it is important to gain a better understanding of the effects of microwave time on plant performance. Previous studies have found that seed germination of oilseeds is decreased with larger power levels of microwave radiation for longer durations of time (Motallebi, 2016). Moreover, several studies have discovered that there is reduced growth of soybean seedlings when exposed to low levels of microwave radiation for extended amounts of time (Halgamuge et al., 2015; Wing & Alexander, 1975). In a study conducted by Jakubowski (2015), the effect of microwave radiation on the growth of certified

bean seeds, which are grown under strict certification standards, was determined. The results showed that 10 seconds of microwave radiation had a statistically significant positive impact on the growth of bean seeds, while 60 seconds of microwave radiation had a statistically significant negative impact (Jakubowski, 2015). Jakubowski (2015) suggested that this negative impact results from changes in the structure of amino acids, which affects the initial stage of plant development.

The purpose of this study was to determine how varying levels of microwave time affects the growth of pinto bean seeds. To gain a better understanding of the effects of different amounts of microwave time on the growth of pinto beans, the researchers measured the growth of beans without microwave radiation and with 30, 60, 90, 120, 150, and 180 seconds of 2450 MHz microwave time. The control group was three beans that were not microwaved at all. There were three samples in each treatment group and the bean growth was measured every other day in centimetres for three weeks. This procedure was completed by two students in their separate households. After collecting data for three weeks, Prism was used to conduct a repeated measures one-way ANOVA and Tukey test to gain a better understanding of how microwave time affects the growth of pinto beans. The researchers hypothesized that if a minimal amount of microwave time causes bean seeds to grow the fastest, then when measuring the growth of the beans in centimetres, the pinto beans seeds that are microwaved for shorter amounts of time or not at all will grow faster compared to the bean seeds microwaved for longer amounts of time. The findings in this study contribute to the larger question of what the best factors are to improve the growth and health of plants.

## METHODS

This experimental study was conducted by two students in their separate homes for a three-week period. Each student prepared and observed seven treatments: pinto beans microwaved for 0 seconds (control), 30 seconds, 60 seconds, 90 seconds, 120 seconds, 150 seconds, and 180 seconds. We both used microwaves with a reported frequency of 2450 MHz. For each treatment, we placed three Compliments brand pinto beans in a damp piece of paper towel, which was then folded and microwaved for the aforementioned time intervals. Then, we placed each folded paper towel with seeds into a ziplock bag, which was sealed, labelled, and placed by the same window to ensure consistent environmental conditions. Every two days, we used a ruler and a piece of string to measure the growth of each bean in centimetres (as shown in Figure 1) and recorded the data and observations in our lab notebooks. After the growth of each bean was recorded, we replaced the paper towels with new damp paper towels. We repeated this process throughout the entire three-week period. After three weeks, we used Prism to conduct ANOVA and Tukey tests to determine if microwave radiation has a statistically significant impact on the growth rate of pinto beans.

A B

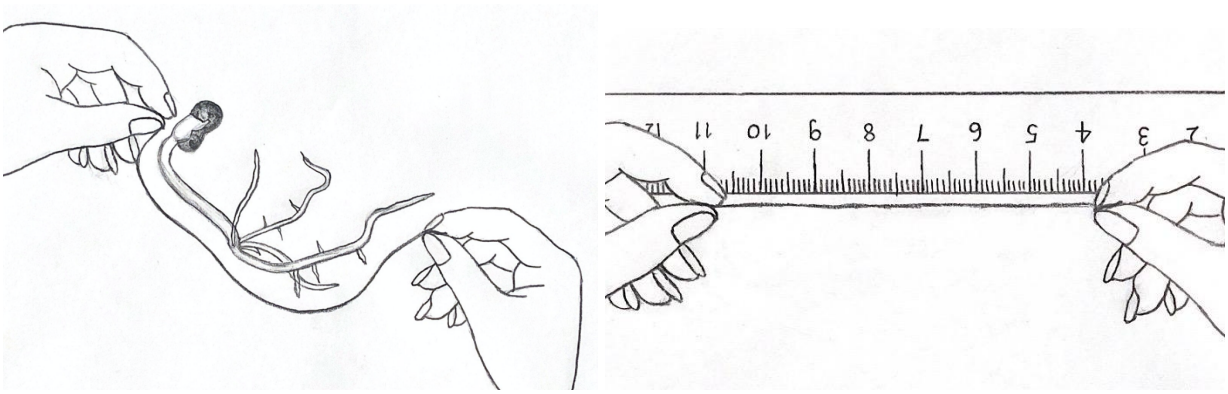

**Figure 1. How each sprouted pinto bean was measured.** (A) A string was used to measure the length of the sprouted pinto bean. (B) Then, the length of the string was measured with a ruler (in centimetres).

## RESULTS

ANOVA and Tukey tests were conducted using data from November 19, 2020, the last day of the 20-day experiment. Each of the seven treatments comprised a sample size of six beans (n=6), three from each student. Through a repeated measures one-way ANOVA test, the data was used to determine the mean growth of each treatment. Figure 2 shows the results for the repeated measures one-way ANOVA test, which yielded a p-value of $< 0.0001$. From Figure 2, it can be observed that the 90s, 120s, 150s, and 180s treatment groups showed minimal to no growth. Furthermore, it can be seen that as microwave time increased, the mean growth of each treatment significantly decreased.

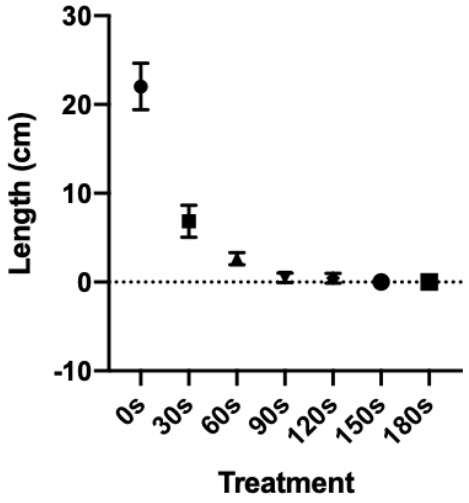


**Figure 2. The growth of pinto bean seeds by treatment.** The mean growth of each treatment (n = 6) is represented by a dot, and the range of lengths as given by the standard deviation is shown. Repeated measures one-way ANOVA testing found these results to be statistically significant ($p < 0.0001$).

Post-hoc comparisons using the Tukey test indicated that the all treatments had an adjusted p-value of $< 0.05$ except for 90s vs. 120s ($p = 0.9981$), 120 vs. 150s ($p = 0.5166$), and 120s vs. 180s ($p = 0.5166$) treatment groups. All comparisons of 0s vs. other treatment groups had an adjusted p-value of $< 0.0001$.

## DISCUSSION

From Table 1, it can be observed that the repeated measures one-way ANOVA test produced a p-value of $< 0.0001$, which shows that there is a significant difference between the growth of different treatment groups. Further analysis of these results using the Tukey test indicated that the pinto beans microwaved for 0 seconds (controls) showed p-values of $< 0.0001$ and the most significant growth when compared to all other treatment groups. Pinto beans microwaved for 30 seconds had the next smallest p-values, followed by the pinto beans microwaved for 60 seconds. Pinto beans microwaved for 90 seconds, 120 seconds, 150 seconds, and 180 seconds showed no significant growth. From these results, we can reject the null

hypothesis and accept the alternative hypothesis, which states that pinto bean seeds microwaved for shorter amounts of time or not at all will grow faster compared to the pinto bean seeds microwaved for longer amounts of time. This is consistent with previous studies which found that seed germination of oilseeds is decreased with larger power levels of microwave radiation for longer durations of time, resulting in decreased growth (Motallebi, 2016). Therefore, this suggests an inverse relationship between the germination rates of seeds and the duration of microwave time.

There may have been potential sources of errors in our experiment, which could have affected our results. Since this experiment was conducted in separate regions of British Columbia (White Rock and Victoria), there is likely to have been slight differences in the amount and intensity of sunlight that the beans were exposed to. Furthermore, each student used microwaves of different models and ages, which may have resulted in the beans being exposed to marginally different amounts of radiation. There may also have been human and instrumental errors in the measurement of the beans, since it was done independently and using different measuring equipment. Slight differences in measuring styles and attention to detail may have caused inconsistencies in the results. Also, the rulers used were only certain to one decimal place, which leads to less precise data collected from both students. It was also discovered that while one student ran the paper towels under the tap, the other student sprayed the paper towels with a spray bottle. The student with the more wet paper towels had more growth in all of their treatments.

## CONCLUSION

Using a repeated measures one-way ANOVA and Tukey test, it was found that there was a significant difference ($p < 0.0001$) between the growth of pinto beans between the different treatments of microwave time. Therefore, we are able to reject the null hypothesis in favour of the alternative hypothesis that pinto bean seeds that are microwaved for shorter amounts of time or not at all will grow faster compared to the pinto bean seeds microwaved for longer amounts of time. The results identify that shorter amounts of microwave time correlate to faster growth of pinto beans, and longer amounts of microwave time result in slower growth of pinto beans. The findings of this study contribute to the larger question of what the best factors are to improve the growth and health of plants.

## ACKNOWLEDGEMENTS

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## References


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## APPENDIX

| Table format: Column | | Group A | Group B | Group C | Group D | Group E | Group F | Group G |
|---|---|---|---|---|---|---|---|---|
| | | 0s | 30s | 60s | 90s | 120s | 150s | 180s |
| 1 | AP1 | 25.35 | 8.20 | 2.94 | 0.85 | 0.45 | 0 | 0 |
| 2 | AP2 | 23.50 | 8.30 | 2.58 | 1.15 | 0.90 | 0 | 0 |
| 3 | AP3 | 24.10 | 8.95 | 3.80 | 0.90 | 1.25 | 0 | 0 |
| 4 | AL1 | 19.76 | 5.46 | 1.97 | 0.00 | 0.00 | 0 | 0 |
| 5 | AL2 | 20.45 | 5.31 | 2.46 | 0.00 | 0.00 | 0 | 0 |
| 6 | AL3 | 19.01 | 4.97 | 2.06 | 0.00 | 0.00 | 0 | 0 |

**Figure 3. Complete raw data used for ANOVA testing.** Rows 1-3 represent the pinto beans used by A. Popham (AP), while rows 4-6 represent the pinto beans used by A. Liu (AL). The columns represent the different treatments. The growth of each pinto bean is recorded in centimetres.