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# The Effect of Radiant Energy on Radish Seed Germination

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## Summary

**As mankind becomes increasingly dependent on technology, scientists are discovering through experimentation the influence of technology over the natural world. The following study was conducted in order to determine if exposure to microwave radiant energy influences the process of radish seed germination. The results show that energy emitted from microwaves influences radish seed germination. Radish seeds exposed for four minutes in the microwave experienced almost 150% greater seed germination over the course of six days compared to a control group and a group of radish seeds microwaved for one and one-half minutes. These data demonstrate one example of how the natural world reacts to radiant energy emitted by man-made objects.**

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## Introduction

Seed germination is essential to both human and animal life. Seeds that are consumed by humans and animals make up more than 70% of the world's caloric intake (1). As a result, seed germination is becoming more and more important in the fight to combat poverty and world hunger. Therefore, by studying seed germination, scientists can figure out how different seeds react to different environmental factors.

The process of seed germination occurs when a seed is exposed to water, its coat breaks, and a plant begins to emerge (2). In addition to water, studies have shown that other environmental factors regulate seed germination. Both temperature and the amount of light can influence seed germination (3). Previous work has shown that exposing seeds to temperatures of 20-40°C results in germination, with optimal germination occurring at 30-40°C (3). Seeds were also found to germinate in twelve-hour periods of alternating light and dark exposure as well as in constant dark conditions. Other researchers found that sodium chloride concentrations between 0-200mM affect seed germination and that placing seeds on the soil surface results in better germination than burying seeds at an increased depth (4).

Everyday technologies, such as communication devices (cellphones and laptops), microwaves, and X-ray machines from hospitals, may have a biological effect on living organisms. Many people use technology and have no idea what harm it may cause living organisms. By studying the relationship between microwaves and physical variables such as seed germination, scientists can discover how one aspect of technology influences the natural world (5). Previous studies have shown that radiant energy can influence the process of a seed's ability to sprout into a plant. For example, germination of radish seeds is delayed and reduced by low-power microwave exposure (6).

The objective of this study was to determine whether radiant energy would affect radish seed germination. Two experimental groups of radish seeds were subjected to microwave times of 1.5 minutes or 4 minutes and allowed to germinate alongside a control, non-exposed group of radish seeds at 21-22°C in constant dark conditions. After a period of six days, the total length of germination was measured in millimeters.

## Results

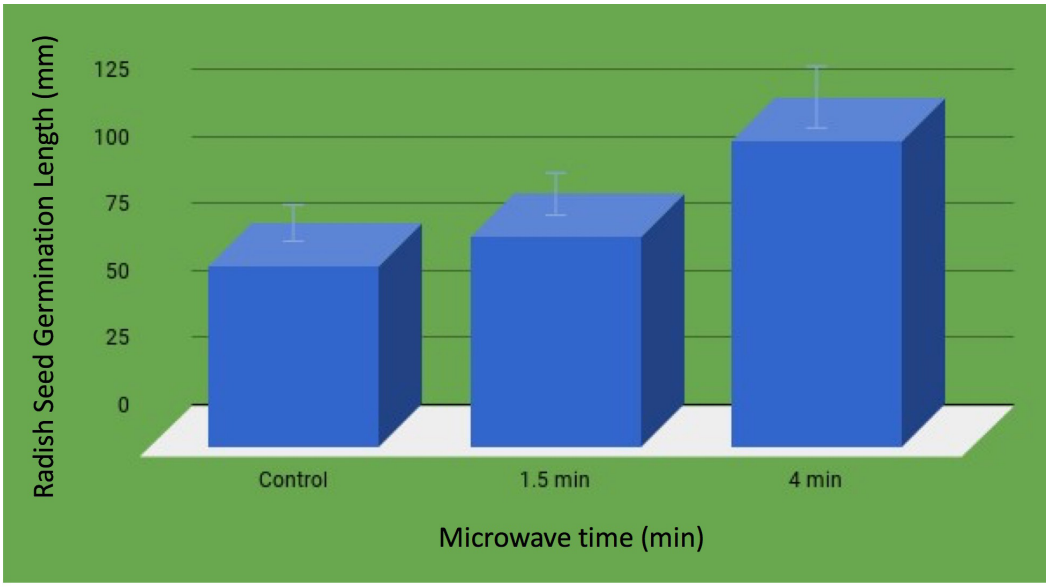
In order to investigate the effect of radiant energy on radish seed germination, we conducted a controlled experiment using a sample size of twenty radish seeds per experimental group as well as a control group. In this experiment, the radish seeds were exposed to radiant energy from a microwave oven. Two experimental groups were exposed to different degrees of microwave radiation: one group of radish seeds received a total exposure time of 1.5 minutes in the microwave while the second experimental group of radish seeds received a total exposure time of 4 minutes. A control group of radish seeds was not subjected to any time in the microwave. After six days, we measured the germination length, in millimeters, between the root tip and cotyledon of each seedling using a metric ruler. We also conducted a second experiment on a different day. After collecting the data, the average radish seed germination length

was determined by taking the sum of the radish seed germination lengths for each group and dividing by 40 (the total number of seeds).

Results of this experiment indicate that seed exposure to microwave technology longer than 1.5 minutes may influence radish seed germination. The control and 1.5-minute microwave groups germinated at an average of 67.8 mm (control) and 78.6 mm (1.5-minute microwave) while the seeds that were in the microwave for 4 minutes germinated an average of 114.8 mm, roughly 1.5 times longer than either the control or the 1.5-minute microwave group (**Figure 1**).

In ANOVA statistical testing between all three experimental groups, the *F* value was 12.12 and the *F* critical value was 3.07. Since the *F* value is greater than the *F* critical value, we were able to reject the null hypothesis and concluded that a significant difference was seen between the three radish seed groups based on exposure time in a microwave. We also ran a *t*-test between the control and each distinct experimental group. There was no statistical difference between the germination of the control group and the 1.5-minute microwave group of radish seeds ($p = 0.231$). As the null hypothesis cannot be rejected, the 1.5-minute exposure time does not appear to have influenced radish seed germination. However, according to the *t*-test between the control group and the 4-minute microwave group of radish seeds, there was a strong statistical difference between these two groups ($p = 0.000042$). This means that the germination ability of the radish seeds was influenced somewhere between the 1.5 and 4 minutes of exposure to radiant energy while in a microwave. We conclude that radish seed exposure of up to 4 minutes in a microwave results in over 1.5 times longer seedling lengths after a 6-day germination time period.

Since multiple factors can influence the germination process, we repeated the experiment on an additional day in order to investigate experimental variability. We found similar germination lengths within the same experimental groups despite conducting the experiments on different days (**Table 1**). Between experiments 1 and 2, the control radish seeds germinated on average 62 mm vs. 73 mm, the 1.5-minute microwaved radish seeds germinated on average 80 mm vs. 77 mm and the 4-minute microwaved seeds germinated on average 112 mm vs. 117 mm. We conclude that the reproducibility in experimental results between radish seed groups demonstrates a well-controlled experiment and a high degree of accuracy for assessing the effect of radiant energy on seed germination.




| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Control Group | 40 | 2711 | 67.8 | 1934.2 |
| 1 1/2 Minute Microwave | 40 | 3144 | 78.6 | 1286.9 |
| 4 Minute Microwave | 40 | 4590 | 114.8 | 2742.1 |

**Figure 1: Average seed germination length after six days.** Germination data is averaged over experiments 1 and 2.

**Table 1:** Average radish seed germination length after six days, by experiment.

| Experimental Group | Experiment #1 (n=60) | Experiment #2 (n=60) |
|---|---|---|
| Control | 62.4 mm | 73.15 mm |
| 1.5 Minute Microwave | 79.75 mm | 77.45 mm |
| 4 Minute Microwave | 112.3 mm | 117.2 mm |

## Discussion

The objective of this experiment was to determine if radiant energy from a microwave would affect the length of radish seed germination over a period of six days. As shown in **Figure 1**, the control group (n=40) germinated at an average of 67.8 mm while the seeds that were in the microwave for 1.5 minutes (n=40) germinated similarly, on average, at 78.6 mm. However, the seeds that were in the microwave for 4 minutes (n=40) germinated almost 1.5 times longer, at an average of 114.8 mm. We conclude that radish seed exposure of four minutes to radiant energy in the microwave enhances seedling length after six days of germination.

A factor which served as a limitation in this experiment was the difficulty in measuring the length of radish seed germination. This happened because some

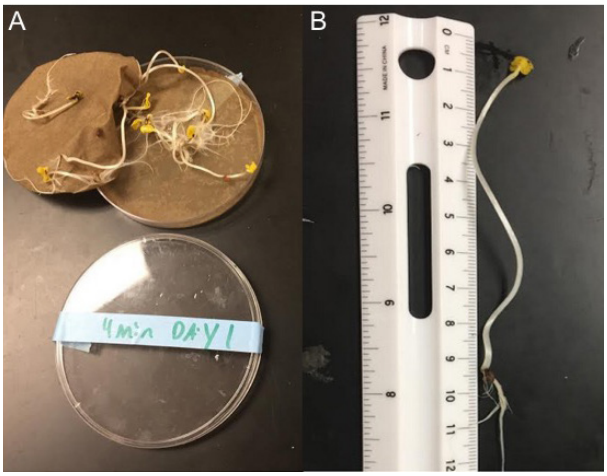



**Figure 2: Experimental limitations of radish seed measurement.** A) Entanglement of roots due to germination seedlings. B) Difficulty while measuring length because of a natural curl in seedlings.

of the seedlings broke as a result of handling during measurement. The seedlings tangled into one another after the six-day germination period (**Figure 2A**) and also presented with a natural curl (**Figure 2B**) that made it difficult to spread each seedling straight for accurate length measurement. This resulted in root breakage during handling and possibly inaccurate calculations of germination length. For future studies, instead of measuring germination by length in mm, we suggest measuring the biomass at the beginning (seeds) and the end (seedlings) of the experiment, in grams, using an electronic balance. This method should eliminate the difficulty that comes with measuring seedling length in millimeters.

A question remains as to when specifically between 1.5 and 4 minutes microwave technology ultimately influences the germination capabilities of a radish seed. In addition, at what exposure time in the microwave beyond 4 minutes will radiant energy inhibit and/or destroy the germination process? To prolong and improve this experiment, the experimenters would like to subject a similar population of radish seeds to microwave times of 1.5 minutes, 2.5 minutes, 4 minutes, 7 minutes, and 10 minutes. In future experiments, we would also like to expose a separate experimental group of radish seeds to an alternative heat source (e.g. radiator, hot water bottle, or incubator) for the same amount of time. This would allow us to determine whether the effect on radish seed germination was due to the heating or to other aspects of microwave radiant energy.

This experiment relates to previous studies by showing how additional factors other than water, such as radiant energy from a microwave, affect radish seed germination. We conclude that the germination process of radish seeds was enhanced somewhere between a 1.5- and 4-minute exposure to radiant energy from a microwave. It is possible that, in this time, the heat energy from the microwave influenced the quality of the seed coat. Perhaps the heat energy from the microwave caused the radish seed coat to break down faster, thereby allowing more water, as well as other nutrients (carbon dioxide and sunlight), to penetrate and/or soften the seed coat. In doing so, the germination and photosynthetic process for the radish seedlings could more easily begin.

Exposure of seeds to one type of radiant energy (microwave) parallels the exposure of seeds in the wild to alternative forms of radiant energy, such as solar energy, lighting, cellular phones, and power lines. Both scenarios involve an exposure to radiant energy. However, we do not believe that this experiment was an accurate representation of the total amount (and types) of radiant energy that seeds are ultimately exposed to in the wild. Although additional studies to explore the types of radiant energy that most crops are exposed to

as seeds would enhance the understanding of this topic, one conclusion that can be drawn from this experiment is that direct exposure to radiant energy can positively influence the germination process. Studies involving the effect of radiant energy over seed germination are beneficial to humans. Data from these studies can reveal how the natural world reacts to heavily used man-made objects that emit radiant energy and may potentially lead to future short- and long-term scientific studies of economic value.

## Materials and Methods

### Materials

In this experiment, the following materials were used: 6 Petri dishes, 120 radish seeds (*Raphanus sativus*), paper towels, scissors, 1 beaker of tap water, and a liquid dropper. In addition, other materials were used including tape, a marker, a Sharp Carousel II Convection 1200 W Microwave Oven (Model #R-9H71), and a metric ruler.

### Specimen Handling

The experiment began with microwaving 20 radish seeds for 1.5 minutes and then another twenty seeds for four minutes. A total of six Petri dishes were obtained: two of these contained ten radish seeds/dish (n=20), each microwaved for 1.5 minutes, and two contained ten radish seeds/dish (n=20) that were microwaved for 4 minutes. Finally, the other two Petri dishes with ten, non-microwaved radish seeds each were prepared as the control group (n=20).

### Preparation of Petri Dishes

The experimenters first cut out two evenly cut circles of paper towel with scissors in order to ensure proper alignment with the Petri dish. After removing the control group radish seeds, a paper towel circle was placed inside the bottom of two open Petri dishes. Using a liquid dropper, roughly 25 drops of tap water were added so that the bottom of each towel became saturated with water. Ten control seeds were then evenly dispersed throughout each Petri dish (**Figure 3A**). Finally, a second paper towel was placed on top of the ten radish seeds within each Petri dish. Using a liquid dropper, roughly 15 drops of tap water were added to the top paper towel and light pressure was applied by hand so that a saturated "seed sandwich" was created between the paper towels (**Figure 3B**). Then, the Petri dishes were covered with a lid and sealed with tape. These steps were repeated for the two additional experimental groups (**Figure 3C**). The seeds of all six Petri dishes were then collected to germinate for six days inside of a dark drawer at a room temperature of 21-22°C. During this time, the seeds were watered twice with roughly 15 drops of tap water from a liquid dropper, and care was taken to evenly saturate each of the three groups of seeds with tap water.

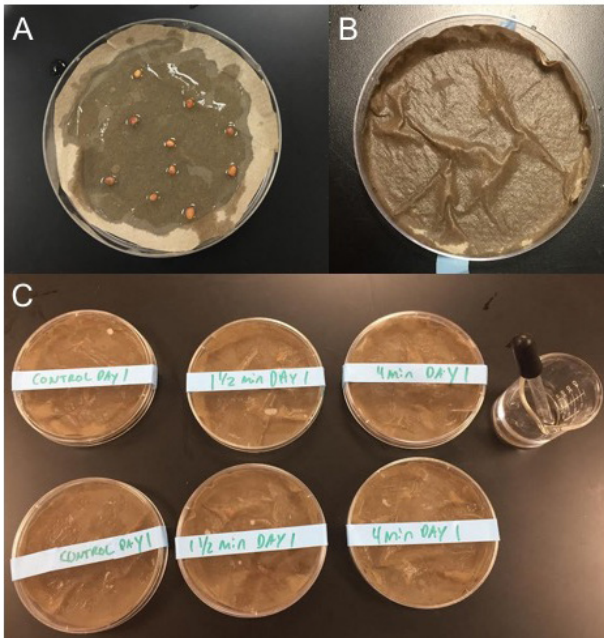



**Figure 3: Experimental Setup.** A) Placement of seeds. B) Creating a seed sandwich. C) Labeling of petri dishes.

### Data Collection

After a total of six days, the length of radish seed germination was measured with a metric ruler in millimeters. The experimenters took measurements of each seedling by measuring between the end of the root tip and the top of the seedling's cotyledon. Any root tip or cotyledon that broke off of a seedling during handling was still included in the seedling's final measurement. The radish seeds that did not germinate were counted as zero millimeters. The results of the average seed germination for the 20 seeds in the 1.5 microwave group, 4-minute microwave group, and the control group were calculated and recorded.

The entire experiment was repeated on an additional day, using a second group of 60 radish seeds from the original seed packet. In order to be consistent with the previous trial, the second group of radish seeds were placed into the same Petri dishes that were used during the first germination trial. Room temperature remained between 21-22°C over the course of a six-day period.

### Statistical Analysis

Upon recording the germination data, both ANOVA and T-test statistical analysis were performed using Microsoft Excel (2013).

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## References

1. Nambara, E., Hiroyuki N. “Seed Biology in the 21st Century: Perspectives and New Directions”. Plant Cell Physiology. Volume 53, No.1:1-4 (2012): p. 165.
2. Campbell, N.A. Neil., 2004. Biology Exploring Life. Pearson Education Inc. New Jersey p. 445.
3. Kroger, C., Reddy, K., Poston, D. “Factors Affecting Seed Germination, Seedling Emergence, and Survival of Texasweed (Caperonia palustris)”. Weed Science Society of America. Volume 52, No. 6 (2004): p. 989.
4. Awan, T., Chauhan, B. & Cruz, P. “Influence of Environmental Factors on the Germination of Urena lobata L. and Its Response to Herbicides”. PLoS ONE. Volume 9, No. 3 (2014) e90305.
5. Ragha, L, Mishra, S., Ramachandran, V., Singh-Bhatia, M. “Effects of Low-Power Microwave Fields on Seed Germination and Growth Rate”. Journal of Electromagnetic Analysis and Applications. Volume 3, No. 5 (2011): pp. 165-171.
6. Scialabba, A., Tamburello, C. “Microwave Effects on Germination and Growth of Radish”. Acta Botanica Gallica. Volume 149, No. 2 (2002): p. 113.