

Abstract:

The Seed in Space project endeavors to unravel the mysteries surrounding the effects of space environments on seed germination, inspired by the Sakura in Space incident ([Lemonick, 2014](#)). This project systematically explores the impacts of different, known space components, including extreme temperatures, vacuum conditions, microgravity, microwave radiation, UV radiation, electromagnetic field radiation, and helium environments on a seed's biology. Through experimentation, surprising findings emerged, revealing the delicate balance between radiation benefits and risks. Microwave and UV radiation exposure facilitated seed coat cracking and germination, yet excessive exposure led to vulnerability to water and negative mutations, underscoring the complex interplay between radiation dosage and seed viability. Intriguingly, seeds exposed to helium atmospheres exhibited accelerated germination, challenging conventional notions of seed response to inert gasses and suggesting potential benefits for space agriculture. Furthermore, the project uncovered puzzling phenomena, such as two plants sprouting from a single seed under the south end of electromagnetic field radiation, pushing the boundaries of my understanding of plant genetics and mutations. These findings not only shed light on the resilience and adaptability of seeds to extreme conditions but also offer promising implications for future space exploration and habitation. By advancing this understanding of how seeds respond to space environments, research can pave the way for innovative approaches to cultivating crops in space for sustenance, addressing global challenges such as food scarcity, enhancing agricultural practices both on Earth, and even aiding us to uncover the mysteries in the space environment.

Purpose:

In 2008, astronauts carried 265 cherry pits from a 1,250-year-old holy tree, whose seeds have never sprouted, to the International Space Station, where—upon return to Earth—they unexpectedly sprouted, one seed even had a six times faster germination rate, and displayed unique characteristics such as five petals instead of thirty on each flower. ([Lemonick, 2014](#)) This event sparked my curiosity, leading to the exploration of how individual components of the space environment affect seeds.

The Seed in Space project aims to systematically test the impact of outer space components—extreme temperatures, vacuum conditions, microgravity, electromagnetic radiation, magnetic fields, and hydrogen/helium plasma—on seed germination ([Sear, 2016](#)). Drawing from existing knowledge and related studies, the project seeks to deepen our understanding of space's influence on seed structure. By

conducting controlled experiments and supplementing with research, this project aims to theorize outcomes when direct testing is challenging.

Significance:

Advancing Space Exploration: By studying how seeds react to space conditions, the project contributes to space exploration and habitation. Insights gained may aid in safer transportation of organisms and mitigate potential hazards to astronauts.

Challenging Existing Theories: The project serves as a testing ground for current theories about space's impact on biological entities. If results deviate from expectations, it may prompt reconsideration of established theories.

Addressing Global Issues: Beyond space exploration, the project may offer solutions to global challenges. Identifying factors that accelerate seed growth, as seen with the cherry blossom, could have implications for addressing food scarcity.

Approach:

The project involves systematic testing of each space component with individual controls and mini-lab reports. The cumulative findings from these experiments, with relevant research, will form the basis for the final conclusion. This project allows for adaptability, where if certain conditions cannot be directly tested, informed inferences will be drawn from available resources to form a theory.

Background Research:

Known Space Components:

The space environment is characterized by various components, each contributing to its unique conditions ([Experiment - International Space Station - JAXA, n.d.](#)). These include:

Nearly Perfect Vacuum ([Roth, 1990](#)):

- Space has a couple of hydrogen atoms per cubic meter ([Sears, 2016](#))
- Microgravity creates an environment with almost no buoyancy, allowing for uniform mixing of light and heavy materials.
- Defect-free crystal structures can be formed.
- Materials can be held without using a melting pot, minimizing contamination ([Experiment - International Space Station - JAXA, n.d.](#)).

Microgravity:

- Almost no buoyancy exists in the space environment.
- Light and heavy materials can be mixed uniformly.
- There is almost no weight or depth pressure.
- Defect-free crystal structures can be formed.
- Materials can be held without using a melting pot, reducing contamination impurities ([Experiment - International Space Station - JAXA, n.d.](#)).

Low Density of Particles:

- The space environment has a low density of particles, enhancing visibility and allowing electromagnetic radiation to travel great distances ([Durrer, 2008](#)).

Extreme Temperatures:

- Fluctuating temperatures, from freezing to burning, present unique challenges in space ([Experiment - International Space Station - JAXA, n.d.](#)).

Predominantly a Plasma of Hydrogen and Helium:

- The space environment is composed mainly of a plasma of hydrogen and helium ([Durrer, 2008](#)).

Electromagnetic Radiation:

- Encompasses a wide spectrum, including radio, microwave, infrared, visible, UV, X-ray, and Gamma radiation ([Why Space Radiation Matters - NASA, 2017](#)).

Ionizing Radiation:

- Includes X-ray, gamma, alpha, and beta radiations/particles.
- The space radiation environment consists of various types of particles, including a radiation belt and galactic radiation generated by solar flares ([Why Space Radiation Matters - NASA, 2017](#)).

→ Study for these in future research
(I did study but haven't completed formally)

Electromagnetic Fields:

- Exist in the space environment ([Wikipedia Contributors, 2019](#)).

Neutrinos: ([Sears, 2016](#)) ← seed not tested for this

Dust: ([Sears, 2016](#)) ← seed not tested for this

Cosmic Rays: ([Sears, 2016](#)) ← seed not tested for this

Space Features and Characteristics:

The features of the space environment provide unique conditions for scientific exploration ([Experiment - International Space Station - JAXA, n.d.](#)):

Microgravity and Vacuum:

- Microgravity, coupled with a high level of vacuum, allows the production of pure materials from the melted state with unprecedented purity.
- ISS, situated 400 km from the ground, experiences a vacuum level 100th millionth of the pressure on the ground ([Experiment - International Space Station - JAXA, n.d.](#)).

Primary effects of microgravity	With gravity	In a microgravity environment	New materials generation under microgravity (examples)
			
			Semiconductor with no crystal defects ↓ Excellent semiconductor elements and sensors
			High-purity infrared transparent glass ↓ Excellent optical materials
			Porous crystal ↓ Densified crystal structure

([Experiment - International Space Station - JAXA, n.d.](#)).

Excellent Visibility:

- The absence of atmosphere and meteorological effects near Earth ensures excellent visibility (except for dust).

- Abundant, constant, and high-density solar energy is available ([Experiment - International Space Station - JAXA, n.d.](#)).

Space Radiation:

- Space is full of ionized and solar radiation, including gamma rays, X-rays, and ultraviolet rays.
- The radiation environment consists of various particle types, such as protons and galactic radiation with multiple nuclei ([Why Space Radiation Matters - NASA, 2017](#)).

Temperature Variation:

- The temperature of outer space is measured based on the kinetic activity of gas, differing from the temperature of radiation ([Spitzer, 1948](#))
- Gas temperatures in outer space vary widely, from 1 K in the Boomerang Nebula to millions of degrees in the solar corona ([Katsu, 2021](#))([Withbroe, 1988](#)).

Electromagnetic Fields:

- Exist in the space environment, and magnetic fields have been detected around just about every class of celestial object:
 -
- Star formation in spiral galaxies can generate small-scale dynamos, creating turbulent magnetic field strengths of around 5–10 μG .
 -
- Ordered magnetic fields exist in several nearby galaxies.
 -
- Magneto-hydrodynamic processes in active elliptical galaxies produce their characteristic jets and *radio* lobes.
 -
- Presence of magnetic fields among the most distant, high-*z* sources detected
 - Thru *Non-thermal radio sources*

([Beck & Wielebinski, 2005](#))

Space Radiation and Its Implications:

Space radiation, a critical aspect of the space environment, has significant implications for human space exploration ([Why Space Radiation Matters - NASA, 2017](#)):

Composition of Space Radiation:

- Space radiation results from atoms where electrons have been stripped away, leaving only the nucleus as the atom approaches the speed of light.
- Three main types: particles trapped in Earth's magnetic field, solar particle events, and galactic cosmic rays ([Why Space Radiation Matters - NASA, 2017](#)).

Ionizing Radiation Effects:

- Astronauts are exposed to ionizing radiation, including high-energy protons and heavy ions, representing ionizing radiation.
- Effective doses range from 50 to 2,000 mSv, with potential health effects, including radiation sickness, increased cancer risk, and central nervous system effects ([Why Space Radiation Matters - NASA, 2017](#)).

Non-Ionizing vs. Ionizing Radiation:

- Radiation can be non-ionizing (low energy) or ionizing (high energy).
- Ionizing radiation has enough energy to completely remove an electron from its orbit, creating a more positively charged atom.
- Examples include alpha particles, beta particles, gamma rays, X-rays, and galactic cosmic radiation ([Why Space Radiation Matters - NASA, 2017](#)).

Previous experiments and research, including information from them.

1. Mutation Breeding:

- **Definition:** Mutation breeding involves breeding through mutational changes.
 - E.g. exposure to radiation
 - a crucial keyword for ongoing project
 - ([Seeds Undergo Radiation in Space to Explore Biology and Genetics for Enhanced Food Security, 2023](#))

2. Evolutionary Basis of Organisms:

- **Spontaneous Mutations:** Environmental conditions drive spontaneous mutations, forming the basis of evolution.

- **Joint FAO/IAEA Centre Involvement:** *IAEA and FAO have a history of supporting countries in developing crop varieties using radiation-induced mutagenesis techniques.*
- **Species Selection:** Arabidopsis and sorghum seeds were chosen due to extensive genetic knowledge, aiding analysis and comparison.
- ([Seeds Undergo Radiation in Space to Explore Biology and Genetics for Enhanced Food Security, 2023](#))

3. Historical Perspective on Mutation Breeding:

- **Joint FAO/IAEA Centre's Contribution:** Over 60 years, the Centre has accelerated plant breeding research, resulting in 3,400+ new varieties across 210 plant species.
- **RADSEED Project:** NASA's ongoing project focusing on radiation-induced genetic variation.
- ([Seeds Undergo Radiation in Space to Explore Biology and Genetics for Enhanced Food Security, 2023](#))

4. Dry Seed Survival in Extreme Conditions:

- **Environmental Challenges:** Dry seeds can withstand extreme temperatures, vacuum conditions, and various types of radiation.
- **Species Variation:** Survival varies between species, demonstrated by examples from Aizoaceae and Brassicaceae families.
- **Ultraviolet Exposure:** Limited knowledge on dry seed survival after exposure to UV radiation in outer space.
- ([Extreme Survival of Seeds on Earth and in Space | Kew, n.d.](#))

5. IAEA's Experiment with Arabidopsis and Sorghum Seeds:

- **Selection of Seeds:** Arabidopsis and sorghum chosen for exposure to *cosmic radiation and extreme temperatures* on the ISS.
- **Purpose:** To identify genetic mutations *beneficial in addressing climate change-induced environmental stresses.*
- **Global Efforts:** Similar projects in China's wheat variety development highlight *the global interest in radiation-induced mutagenesis.*
- ([Mutated Space Seeds Could Be the Answer to Feeding Our Warming World, 2023](#))

Plant Hormones:

(*Growth and Plant Hormones*, 2020)

- **Genetic Regulation:**

Enzymes, critical in plant metabolism, are primarily synthesized locally in minute quantities.

Genetic information also controls the production and transport of hormones, which regulate various physiological processes.

- **Plant Hormones:**

Hormones are organic compounds synthesized in one plant part and transported to target tissues.

Major hormone groups include auxins, gibberellins, ethylene, cytokinins, and abscisic acid.

- **Auxins:**

Indoleacetic acid (IAA) stimulates cell elongation and fruit development.

Synthetic auxins like NAA and 2,4-D are utilized in rooting, fruit enlargement, and weed control.

- **Gibberellins:**

Stimulate elongation growth, used in agriculture for fruit enlargement and seed germination.

- **Functions:**

Primarily stimulate elongation growth in plants.

Influence various developmental processes including stem elongation, leaf expansion, and flowering.

- **Regulation of Plant Growth:**

Act in conjunction with other hormones to regulate plant growth and development.

Interplay with auxins, cytokinins, and other hormones influences various physiological responses in plants.

- **Ethylene:**

Gaseous hormone regulating fruit ripening and leaf abscission, applied commercially for fruit ripening.

- **Cytokinins:**

Promote cell division, vital for tissue culture and lateral bud growth.

- **Absciscic Acid:**

Inhibits other hormones, involved in seed and bud dormancy, and stomatal closure during drought.

- **Other Growth Regulators:**

Utilized in agriculture and horticulture for growth inhibition and shaping purposes.

- **Plant Movements:**

Respond to environmental stimuli through tropisms (directional) and nastic movements (non-directional), regulated by water pressure changes in specific cells.

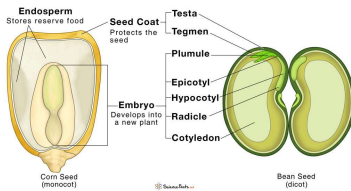
- **Seasonal Responses:**

Photoperiodism influences processes like flowering and bud dormancy, crucial for optimizing agricultural practices and enhancing crop yield.

Parts of a Seed

(*Parts of Seed*, 2023)

Parts of a Seed with Functions



Seed is fertilized ovule. After fertilization, ovules are converted into seeds, and the integument of the ovule forms a seed coat. The seed is the reproductive unit of plants that contains all the necessary components to initiate the growth of a new plant.

Parts of Seed

A seed comprises essential components crucial for plant growth and reproduction. It is structured with distinct parts, including the **seed coat**, **embryo**, **endosperm**, and occasionally the perisperm. The seed coat plays a pivotal role in safeguarding the seed and facilitating its dispersal. Within the embryo, specialized tissues contribute to the formation of the root, stem, and leaves, paving the way for the development of a new plant. The endosperm functions as a nutrient reservoir, supporting the growth of the developing embryo. In cases where present, the perisperm serves as an additional tissue for nutrient storage. Together, these components orchestrate the intricate processes involved in seed germination and subsequent plant establishment.

Seed Coat

The seed coat provides protection and helps in the dispersal of seeds. The seed coat is made up of two layers: the outer test and the inner tegmen. The **testa** is tough and protective, and it prevents mechanical damage and the entry of pathogens. The **tegmen** is thin and delicate and it provides a protective covering for the embryo from physical damage, pathogens, and dehydration.

Embryo

The embryo contains the important tissues that give rise to the root, stem, and leaves of the new plant. The embryo consists of the epicotyl, the hypocotyl, the plumule, the radicle, and the cotyledons. The **plumule** is the embryonic shoot, and the **radicle** is the embryonic root. The **epicotyl** gives rise to the shoot system above the ground, including the leaves and stem. The **hypocotyl** connects the epicotyl and the radicle. Dicot seeds have two cotyledons. In monocot seeds, only one cotyledon is present

towards the lateral side of the embryonal axis which is known as 'scutellum' in the grass family of monocots.

Endosperm

The endosperm is a tissue that stores nutrients, mainly starch, which serves as a food source for the developing embryo during germination. In some seeds, it is absorbed by the cotyledons as the embryo grows.

Cotyledons

Cotyledons are the seed leaves that store and provide nutrients to the developing embryo during germination. In monocotyledonous plants, there is only one cotyledon, while in dicotyledonous plants, there are two.

Radicle

The radicle is the embryonic root that emerges first during germination. It is responsible for anchoring the plant and absorbing water and nutrients from the soil to support the growing seedling.

Plumule

The plumule is the embryonic shoot that develops into the above-ground parts of the plant, including stems, leaves, and eventually flowers. It becomes active after germination and starts the process of photosynthesis.

Conclusion

A seed embodies remarkable complexity with its specialized components, each bearing vital significance in the plant's life cycle. Profound comprehension of these parts and their functions is imperative for ensuring successful germination and fostering the growth of robust plants. This understanding forms the bedrock of agricultural practices, plant breeding endeavors, and initiatives aimed at ecological preservation.

(Parts of Seed, 2023)

Experiments:

Table of Content:

Note: All plants are only observed for this project until the 30 day mark in order to keep all testings consistent.

Growth Environment Notes

For all ([How to Build a Microclimate for Your Tropical Plants, n.d.](#))

Background Research:

For bean plants to best thrive =

- Sensitive to frost!
 - Temperature between 15-21° C
 - but no more than 35° C
 - ([Home Garden Green Beans, n.d.](#))
 - Soil at 15-27° C
 - ([How to Grow Beans - Part 2, n.d.](#))
 - ([Home Garden Green Beans, n.d.](#))
 - Soil pH level 6.5
 - ([How to Grow Beans - Part 2, n.d.](#))
 - Relative Humidity of 75 - 80%
 - but too much heat and humidity can harm
 - ([Beans, Haricot Vert | FreshPoint, 2021](#))
 - minimum of 8 hrs of sunlight
 - ([How to Grow Beans - Part 2, n.d.](#))
 - easily die to frost and cold
 - ([Home Garden Green Beans, n.d.](#))
 - ([How to Grow Beans - Part 2, n.d.](#))

Where:

In a COOS BAY Walk in Mini Greenhouse covered, from top, with a thin blanket

- Greenhouse: 144.78L x 73.66W x 195.58H cm, made of Polyethylene (PE) covering and Alloy Steel frames
 - <https://a.co/d/agXJ9lV>

Location:

- In my garage

Management:

- Have a device that turn off and on all the managements below based on

the preset needed temperature and humidity

Temperature Management:

- Small Heater with use of management device to set proper temperature → set to 21° C

Humidity management:

- Humidifier and bowl of water with use of management device to set proper humidity → set at 80%

Sunlight management:

- Using indoor plant growing (stimulates sunlight) lamp because too many variables if try to use direct sunlight, as hard to control
→ set to 8 hrs per day

Cup/ Pot:

- size: 6.6675 cm height x 7.62 cm top diameter [7.62π cm circumference] x 4.445 cm bottom diameter [4.445π cm circumference]
- Clear Plastic Cups from dollarama
- Each pot = 2 cups stacked on top
 - 1st cup has soil and seeds, has 3 holes (made by the same pin)
 - For drainage
 - 2nd cup under the first → empty
 - Purpose to catch any soil drops or water from 1st cup

Planting Notes:

1. Add potting soil to the clear plastic cup until it is 2 cm away from the top
2. Mark the 2.5 cm point from the surface of the soil
3. Attach the label made by using a teal sharpie on translucent tape
4. Create 3 holes at the bottom of the cup using the a heated pin
5. With tweezers → place the seed at the middle and 2.5 cm deep from the surface
 - a. Use the marking as guidance
6. Cover up the seed's hole
7. Place the cup in the same type of second cup
8. Feed the soil 5 mL of water
9. Place all the cups on a paper plate
10. Place them all in the greenhouse
 - a. Make sure the “sunlight” (lamp that mimics sunlight rays) is reaching the seeds

Microwave Testing:

Purpose:

This experiment aims to investigate the impact of microwave radiation on seeds and their germination, assessing the extent and nature of this influence.

Hypothesis:

I hypothesize that seeds exposed to microwave radiation for fifteen and thirty seconds will exhibit earlier germination compared to the control group, while seeds subjected to one minute of radiation will experience delayed growth or may fail to sprout altogether. This prediction is based on the premise that microwave radiation tends to impact organic structures it encounters. In the case of seeds, the initial effect is on the seed coat, potentially aiding the embryo's emergence. However, prolonged exposure, especially beyond thirty seconds, may result in damage to the internal structures of the seed. Considering the typically thin seed coat of garden beans, it is anticipated that one minute of exposure could facilitate the embryo breaking through the seed coat prematurely, leading to potential internal damage and hindered germination.

(Szopińska & Dorna, 2021) (Microwave Plant Experiment: Radish Seed Germination | Science Project | Education.com, n.d.)

Duration:

December 9 2023 (1 day long)

Background Research:

Microwave Testing accelerated germination process on strength of your microwave oven and seeds. ([Microwave Plant Experiment: Radish Seed Germination | Science Project | Education.com, n.d.](#))

- Seeds which are not microwaved at all should germinate in a couple of days.
- Treatment durations: 15, 30, and 60-Seconds seed exposed to microwave radiation.
- Parameters evaluated on impact of organic structure, initial effect is on seed coat, potentially aiding the embryo's emergence. Sometimes it may result in damage to the internal structure.
- Microwave radiation breakdown seed coat, promoting positive plant development
- It takes short time to sprout microwave seed as those seeds have a slightly opened coats, allowing water in and starting the germination process sooner
- Seeds microwaved longer periods did not germinate as fast because water in the seeds boiled away during the excessive exposure to microwave radiation.
 - A dried seed cannot germinate even if we add water at a later stage.

- Microwave ovens damage the essential fats the seed needs to grow.
- ([Microwave Plant Experiment: Radish Seed Germination | Science Project | Education.com, n.d.](#))
 -
- Microwave radiation stimulates the formation of hydrogen (H⁺) and hydroxyl (OH⁻) ions in seeds([Primandari et al., 2023](#))
 - These ions play a crucial role in the oxidative stress cycle during seed germination. ([Primandari et al., 2023](#))

Safety:

Wear proper equipment

- lab coat
- Thick long sleeves
- Eyewear
- Sunglasses
- Gloves
- Keep away from heat, Sparks, Open Flames and hot surfaces.

Materials:

- 2 (11 π cm $\approx$ 34.56cm base's circumference x 17cm height) microwavable mugs
- Water
- 8 Golden Garden Beans seeds
- 2 Overall seeds + 1 control overall seeds
 - 2 containers
 - Aluminum foil
- Microwave
- Syringe (in mL measurements)
- 8 plastic cups
- Potting mix
- Ruler (cm)
- Permanent marker

Procedure:

1. Fill all the plastic cups with the potting mix.
2. Mark a line where the dirt is 2.5 cm away from the surface with the marker.

3. Also, label every 2 cups either “Microwave Control, Microwave 15 seconds, Microwave 30 seconds, or Microwave 1 minute.”
4. Split the 8 seeds into 4 groups, “control, 15s, 30s, and 1m.” (each one has 2)
5. Place the 2 control seeds in the middle and 2.5 cm deep of the plastic cups (each with their own cup) labeled “Microwave Control,” using the marked line as guidance.
6. Fill 1 of the microwavable cups with cool water until it is 1.5 cm away from the surface.
7. Place the 15s seeds in the other microwavable cup.
8. Place both cups in the microwave, water cup to your right and seeds cup to your left.
9. Microwave for 15 seconds (as the name suggests).
10. Once 15s have passed, take both mugs out, pour out the water from the water cup and fill new cool water.
11. Take the seeds out from the seed cup and plant them in the middle and 2.5 cm deep of the plastic cups (each with their own cup) labelled “Microwave 15 seconds,” using the marked line as guidance.
12. Repeat 6-11 with the 30 seconds seeds and 1 minute seeds. Make sure to set microwave time according to the label (30s for 30 second group and 1m for 1 minute group).
13. After all the seeds have been planted, pour – using a syringe for exact measurements – 5 mL of water into each cup, making sure the water is spread out.
14. Place all the plastic cups in the designated control area set up, such as a greenhouse
15. Observe germination and growth daily. Don’t forget to water plants properly.

Overall:

Place Overall Control seed in 1 empty container and seal it

For the 2 overall seeds, do steps 6 - 10 and microwave it for 15s

- As 15s shows best result in he inspired testing
 - (Microwave Plant Experiment: Radish Seed Germination | Science Project | Education.com, n.d.)

For microgravity, they revolve at 15 rpm for 3 days

For UV radiation, one seed exposure at

For Vacuum → 37% vacuum

For Electromagnetic → one seed placed North for 1 hr, other South for 1 hr
 Take the seeds and place them in the other empty container and seal it
 Wrap both containers in aluminum foil
 - No sunlight effect or most other possible variables
 Place it away for next testing

Photos:

Observation:

Watering Table:

Date and day	How much water (mL)
Dec 9 2023 - day 1	3 mL
Dec 11 - day 3	5 mL
Dec 12- day 4	10 mL
Dec 16 - day 7	20mL
Dec 17 - day 8	3 mL
Dec 21- day 12	3 mL
Dec 22- day 13	3 mL
Dec 23- day 14	All dissolved, only watering 3mL to the growing control
Dec 24 - day 15	Last control died, no more watering needed

Weekly Germination Table:

Date and day #	Picture	Growth observation and anything else
Dec 9 2023 - day 1		Just set seeds right after testing Gave them 5 mL of water using a syringe drop by drop

Dec 16 2023 - day 7	Remove photos due to too big	No sign of plant Fed them 20 mL of water Weirdly plotting mix wasn't taking water <i>at first</i> → water looked like mercury when placed on a surface
Dec 18 2023 (day 9)		On Dec 18 2023 (day 9) First plant appear on surface from Control seed but a lot more skinny (not healthy and deformed) Too much water was added by accident (even double to the other control seed)
Dec 23 2023 - day 14		Tried to check if seeds were alright but all (except the one that sprouted) had dissolved!!! Though the other control dissolved in a different way → slimy texture, no crumbs, weird odor. Rest dissolved leaving crumbs and smelled fine. This could mean that the dissolving wasn't just because of too much water but also the microwave radiation had something to do with it.

Analysis and Discussion:

The primary objective of this experiment was to investigate the impact of microwave radiation on seed germination. The initial hypothesis was that lower levels of microwave radiation might aid in the breakdown of the seed coat, promoting positive plant development. Conversely, higher doses of microwave radiation were expected to pass the seed coat and potentially harm the embryo and slow germination, if not causing outright failure. However, an unexpected result emerged from my watering errors during the experiment, shedding light on the seeds' heightened sensitivity to water following exposure to microwave radiation.

In this testing, the batch of microwaved seeds was subjected to slightly elevated water levels, including one control group receiving nearly triple the standard amount. Consequently, only the other control with a weak stem exhibited sprouting, while the others remained unresponsive. Upon digging to assess seed condition, it was discovered that the seeds had disintegrated, the control which received triple the water had left behind an unusual odor and a slimy texture, which was common in plants. Intriguingly, the microwaved seeds also disintegrated, but without the characteristic odor and sliminess observed in the control. Instead, clumps of the seed were dispersed throughout the soil, even though the microwaved seeds had received a comparable amount of water to the control that successfully sprouted.

This observation led to the hypothesis that microwave radiation, while effective in breaking the seed coat, renders the seeds more sensitive to water. Unlike the control group, the microwaved seeds did not exhibit the same degradation upon contact with excess water. Instead, the water seemed to interact differently with the microwaved seeds, resulting in the formation of seed clumps in the soil. This suggests that the microwave radiation impacting the seed coat also influences the seeds' protection, making it more vulnerable.

In conclusion, the unintended watering variations in the experiment unveiled an intriguing connection between microwave radiation, seed vulnerability, and water sensitivity.

Redo Microwave Testing:

Purpose:

This redo experiment also aims to investigate the impact of microwave radiation on seeds and their germination, assessing the extent and nature of this influence.

Hypothesis:

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the seed coat prematurely, leading to potential internal damage and hindered germination. (Szopińska & Dorna, 2021) ([Microwave Plant Experiment: Radish Seed Germination | Science Project | Education.com, n.d.](#))

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December 27 2023 (1 day long)

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11. Repeat 6-11 with the 30 seconds seeds and 1 minute seeds. Make sure to set microwave time according to the label (30s for 30 second group and 1m for 1 minute group).
12. After all the seeds have been planted, pour – using a syringe for exact measurements – 5 mL of water into each cup, making sure the water is spread out.
13. Place all the plastic cups in the designated control area set up, such as a greenhouse
 - a. Observe germination and growth daily. Don’t forget to water plants properly.

Overall:

Place Overall Control seed in 1 empty container and seal it

For the 2 overall seeds, do steps 6 - 10 and microwave it for 15s

- As 15s shows best result in the inspired testing
 - (Microwave Plant Experiment: Radish Seed Germination | Science Project | Education.com, n.d.)

Take the seeds and place them in the other empty container and seal it

Wrap both containers in aluminum foil

- No sunlight effect or most other possible variables

Place it away for next testing

Observation:

Weekly Photos (Monday 7:00 pm)/ When something new comes saved on phone

Daily checks

Watering Table

Date and day	Amount in mL
Dec 28 - day 1	5 mL
Dec 29- day 2	7 mL
Jan 1- day 5	5 mL
Jan 2 - day 6	5 mL
Jan 3- day 7	5 mL
Jan 4 - day 8	5 mL
Jan 5 - day 9	5 mL
Jan 6 - day 10	5 mL
Jan 7 2024 - day 11	5 mL
Jan 8 2024 - day 12	3 mL
Jan 9 2024 - day 13	5 mL
Jan 10 2024 - day 14	5 mL
Jan 11 2024 - day 15	3 mL
Jan 12 2024 - day 16	5 mL
Jan 13 2024 - day 17	3 mL
Jan 14 2024 - day 18	3 mL
Jan 15 2024 - day 19	5 mL
Jan 16 2024 - day 20	5 mL

Weekly Germination Table

(front to back order)

Control 1

Height (cm)	Date and day	Didn't sprout!
-------------	--------------	----------------

Control 2

Height	Date and day
Sprout at 0.5 cm	Jan 02 2024 - Day 6
2 cm	Jan 03 2024 - Day 7
16 cm	Jan 06 2024 - Day 10
31 cm	Jan 08 2024 - Day 12
35 cm	Jan 11 2024 - Day 15
36 cm	Jan 16 2024 - Day 20
36cm >36cm	Jan 26 2024 - Day 30

15s Seed 1

	Date and day
Sprout at 1 cm	Jan 02 2024 - Day 6
2.5 cm	Jan 03 2024 - Day 7
20 cm	Jan 06 2024 - Day 10
31 cm	Jan 08 2024 - Day 12
36 cm	Jan 11 2024 - Day 15
37 cm	Jan 16 2024 - Day 20
35cm (withered L) >32cm	Jan 26 2024 - Day 30

15s Seed 2

Height(cm)	Date and day
Sprout at 1 cm	Jan 01 2024 - Day 5
3 cm	Jan 03 2024 - Day 7

11 cm	Jan 06 2024 - Day 10
26 cm	Jan 08 2024 - Day 12
20 cm -> Top Leaves withered	Jan 11 2024 - Day 15
34 cm	Jan 16 2024 - Day 20
34cm >32cm	Jan 26 2024 - Day 30

30s Seed 1

Height(cm)	Date and day
Sprout at 1 cm	Jan 01 2024 - Day 5
4 cm	Jan 03 2024 - Day 7
15 cm	Jan 06 2024 - Day 10
20 cm	Jan 08 2024 - Day 12
21 cm	Jan 11 2024 - Day 15
22 cm	Jan 16 2024 - Day 20
28cm >27cm	Jan 26 2024 - Day 30

30s Seed 2

Height(cm)	Date and day
Sprout at 1.5 cm	Jan 01 2024 - Day 5
5 cm	Jan 03 2024 - Day 7
17 cm	Jan 06 2024 - Day 10
29 cm	Jan 08 2024 - Day 12

37 cm	Jan 11 2024 - Day 15
33 cm	Jan 16 2024 - Day 20
40cm >38cm	Jan 26 2024 - Day 30

60s Seed 1

Height(cm)	Date and day
Sprout at 1 cm	Jan 01 2024 - Day 5
1.5cm	Jan 03 2024 - Day 7
16 cm	Jan 06 2024 - Day 10
22 cm	Jan 08 2024 - Day 12
25 cm	Jan 11 2024 - Day 15
22 cm	Jan 16 2024 - Day 20
30cm	Jan 21 2024 - Day 25
24cm(Leaves Withered) >23cm	Jan 26 2024 - Day 30

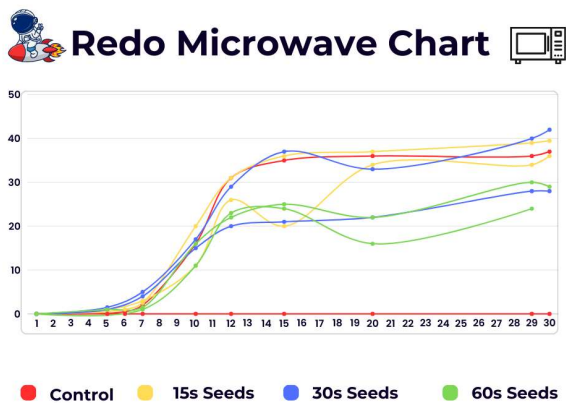
60s Seed 2

Height(cm)	Date and day
Sprout at 1 cm	Jan 03 2024 - Day 7
11 cm	Jan 06 2024 - Day 10
23 cm	Jan 08 2024 - Day 12
24 cm	Jan 11 2024 - Day 15

16 cm	Jan 16 2024 - Day 20
11cm(half of it died top)	Jan 26 2024 - Day 30

Summary Table And Germination Chart:

Time Microwaved 1200 watts (jules/sec)	Notes on Growth (no major difference in appearances)
0 seconds 0 jules (Control)	Had a steady predictable germination rate
15 seconds 18000 jules	Seeds exposed this level had, averagely, the fastest germination rate
30 seconds 36000 jules	Seeds exposed at this level either had a faster germination rate or slower, depending on the seeds' strength
1 minute 72000 jules	All seeds exposed to this level had the slowest germination rate.



Note: I was not able to add it but the *vertical axis is the plant's measurement in cm*, and *the horizontal line is the day* (e.g. 1st day is when it is planted so the day the testing finishes).

Analysis and Discussion:

The primary objective of this experiment was to investigate the impact of redo microwave radiation on seed germination. The initial hypothesis was that lower levels of microwave radiation might aid in the breakdown of the seed coat, promoting positive plant development. Conversely, higher doses of microwave radiation were expected to pass the seed coat and potentially harm the embryo and slow germination, if not causing outright failure.

In this testing, the batch of microwaved seeds were exposed to microwave radiation for different timing Control, 15s, 30s, and 1 minute. Consequently, 15s and 30s exposed microwave radiation germinate similar to control whereas seeds exposed to 1 minute of microwave radiation germinate slowly. Reason behind Seeds microwaved for a longer period did not germinate as it caused water in the seeds to boil away during the process. A dried seed cannot germinate even if we add water at a later stage. Microwave ovens damage the essential fats the seed needs to grow.

Upon digging to assess seed condition, it was discovered that Hydrogen and Hydroxyl Ions: Microwave radiation stimulates the formation of hydrogen (H^+) and hydroxyl (OH^-) ions in seeds. Microwave EMF radiation modifies or reduces specific chemical reactions within seeds. Changes in chemical reactions positively influence key biochemical pathways associated with germination. These ions play a crucial role in the oxidative stress cycle during seed germination.

This observation led to the hypothesis that redo microwave radiation, while effective in breaking the seed coat, renders the seeds more sensitive to water. Unlike the control group, the microwaved seeds did not exhibit the same degradation upon contact with excess water. Instead, the water seemed to interact differently with the microwaved seeds, resulting in the formation of seed clumps in the soil. This suggests that the microwave radiation impacting the seed coat also influences the seeds' protection, making it more vulnerable.

In conclusion, based on this experimental setup and testing, redo microwave radiation has a different impact on seeds for timing when it is exposed. If it is over exposed to microwave radiation for a longer period it does not germinate as it cause water in the seed to boil away, which damage the seed and germination process is either slow or it does not germinate at all. A dried seed cannot germinate at all once water is boiled. So

proper expose to microwave radiation will aid in the breakdown of the seed coat, promoting positive plant development and better result.

Temperature Testing:

Purpose:

This experiment aims to investigate the impact of extreme temperatures on seeds and their germination, assessing the extent and nature of this influence

Hypothesis:

I hypothesize that the seeds exposed to higher temperatures would undergo a faster germination process. This is based on the notion that the warm environment not only has the potential to soften the seed coat but also aligns with the preference of bean plants for warmer conditions. The seeds are expected to be well-suited to handle the heat, promoting a quicker germination. Additionally, increase in temperature allows some processes and organelles to speed up because of the increased energy, such as the mitochondria, aiding in a faster germination.

Meanwhile, I anticipate that the seeds exposed to colder temperatures will demonstrate a slower germination rate. This projection stems from the bean plant's extreme sensitivity to frost and cold temperatures. However, it's worth noting that if bean plants were not vulnerable to frost, the cold-exposed seeds might have had an accelerated germination . In this scenario, a thin layer of frost formed around the seed during exposure to cold conditions would, when planted in a room temperature environment, melt, providing the seed with additional moisture and facilitating a more favorable environment for sprouting.

Duration:

December 16 - 17 2023

Materials:

- 2 large plastic containers (8x8x8 cm) with lids
- 2 smaller plastic containers (4x4x4 cm)
- 6 Provider Bush Bean Seeds
- 2 Overall seeds (+1 control)
- Thermometer (one that can measure both high and low temperatures).

- Ice packs or ice cubes.
- Hot water or heating pad.
- Insulating materials (e.g., foam board or thick blankets)
 - Aluminum foil

Procedure:

1. Prepare the Containers:

- Place one container (4x4x4 cm) inside the other (8x8x8 cm) to create a double-walled chamber
 - Leave some space between the inner and outer containers

2. Insulate the Chamber:

- Surround the space between the inner and outer containers with 2 layers of aluminum foil
 - helps maintain temperature extremes

3. Create a Cooling Environment:

- Place ice cubes on top of the foil (- 3°C)
 - Use enough to achieve -3° C low temperature
 - I placed the containers in the freezer (-3° C)
 - Alongside the ice placed inside

3. Create a Heating Environment:

- Use a boiling water (95°C)
- Place the boiling water on top of the aluminum foil
 - Used enough to achieve 95° C high temperature
 - I placed the container near warm stove to help maintain the heat

4. Measure Temperatures:

- Place a thermometer inside the chamber to monitor the temperature
 - Ensure the thermometer can record high and low temperatures

5. Place Pairs of Seeds:

- For each environment place 2 seeds in the inner container
 - Ensure there are 2 control seeds in a container with the same setup except no ice or boiling water in it (empty)

6. Seal the Chamber:

- with a lid
 - minimize heat exchange with the external environment.

7. Plant the seeds after 24 hrs,

Observation:

Watering Table:

Date and day	Water quantity in mL
Dec 17 2023 - Day 1	5 mL
Dec 18 2023 - Day 2	5 mL
Dec 19 2023 - Day 3	3 mL
Dec 21 2023 - Day 5	5 mL
Dec 22 2023 - Day 6	3 mL
Dec 23 2023 - Day 7	5 mL
Dec 24 2023 - Day 8	5 mL
Dec 27 2023 - Day 11,	5 mL
Dec 28 2023 - Day 12	5 mL
Dec 29 2023 - Day 13	7 mL
Jan 1 2024 - Day 16	5 mL
Jan 2 2024 - Day 17	5 mL
Jan 3 2024 - Day 18	5 mL
Jan 4 2024 - Day 19	5 mL
Jan 5 2024 - Day 20	5 mL
Jan 6 2024 - Day 21	5 mL
Jan 7 2024 - Day 22	5 mL
Jan 8 2024 - Day 23	3 mL
Jan 9 2024 - Day 24	5 mL
Jan 10 2024 - Day 25	5 mL
Jan 11 2024 - Day 26	3 mL
Jan 12 2024 - Day 27	5 mL
Jan 13 2024 - Day 28	5 mL
Jan 14 2024 - Day 29	3 mL
Jan 15 2024 - Day 30	5 mL

Weekly Germination Table :

Control

Height in cm	Date - day
Sprout at 1 cm	Dec 24 2023 - day 8
11 cm	Dec 27 2023 - day 11
20 cm	Dec 29 2023 - day 13
22 cm	Jan 1 2024 - day 16
23 cm	Jan 3 2024 - day 18
24.5 cm	Jan 8 2024 - day 23
27 cm	Jan 11 2024 - day 26
24 cm (leaves withered)	Jan 15 2024 - day 30

Hot 1

Height in cm	Date - day
Just sprout at 2 cm	Dec 21 2023 - day 5
20cm	Dec 27 2023 - day 11
25 cm	Dec 28 2023 - day 12
26 cm	Jan 1 2024 - day 16
27 cm	Jan 3 2024 - day 18
28 cm	Jan 6 2024 - day 21
30 cm	Jan 8 2024 - day 23
26 cm (leaves withered)	Jan 11 2024 - day 26
26 cm	Jan 16 2024 - day 31

Hot 2

Height in cm	Date - day
Can see a long piece that goes back in	Dec 26 2023 - day 10
same as above	Jan 1 2024 - day 16
definitely growing because roots are expanding but growing inwards	Jan 3 2024 - day 18
Died	Jan 15 2024 - day 30

Cold 1

Height in cm	Date - day
Sprout at 1 cm	Dec 24 2023 - day 8
9 cm	Dec 27 2023 - day 11
9 cm	Dec 28 2023 - day 12
10cm	Jan 1 2024 - day 16
11 cm	Jan 3 2024 - day 18

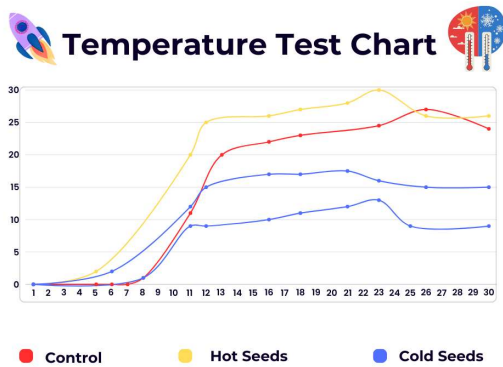
12 cm	Jan 6 2024 - day 21
13 cm	Jan 8 - day 23
9 cm (withered)	Jan 11 - day 25
9 cm (withered)	Jan 15 - day 30

Cold 2

Height in cm	Date - day
Sprout at 2 cm	Dec 22 2023 - day 6
12 cm	Dec 27 2023 - day 11
15 cm	Dec 28 2023 - day 12
17 cm	Jan 1 - day 16
17 cm	Jan 3- day 18
17.5 cm	Jan 6 - day 21
16 cm (withering)	Jan 8 - day 23
15 cm (withering)	Jan 11 - day 26
15 cm	Jan 16 - day 30

Summary Table And Germination chart

Type:	Growth rate	Appearance and extra
Control	Had a steady and predictable germination rate.	Normal appearance
Cold	Had the slowest germination rate for both seeds.	One seed grew a weaker plant with a thin stem. Otherwise, have all normal features.
Hot	The one seed that grew outwards had the highest germination rate.	One seed sprouted inwards but was still growing → could it be from the heat exposure?



Note: I was not able to add it but the vertical axis is the plant's measurement in cm, and the horizontal line is the number of days (e.g. 1st day is when it is planted so the day the testing finishes).

Analysis and Discussion

In this experiment, I investigated the impact of extreme temperatures on the germination of gold garden bush bean seeds, considering the inherent variability among plants. My hypothesis was that elevated temperatures might accelerate germination by potentially softening the seed coat through the steam generated from the boiling water or due to the higher temperatures. Additionally, bean seeds, being acclimated to warmer conditions, could respond positively to elevated temperatures. Conversely, cold temperatures would slow down germination due to the bean plant's sensitivity to frost ([How to Build a Microclimate for Your Tropical Plants, n.d.](#)).

The experimental results offered partial support to the initial hypothesis. Notably, the seeds exposed to higher temperatures exhibited a slightly accelerated germination compared to the control group. While this aligns with the hypothesized impact of elevated temperatures, the observed growth margin was relatively modest. It is possible that the minimal difference in growth could be attributed to the inherent strength of the seed itself, as suggested by the narrow growth differential between the experimental and control groups. This subtle variation falls within the general range of gold garden bush bean seeds' typical germination, leaving room for the consideration of seed strength as a contributing factor.

Furthermore, the experiment successfully demonstrated the expected deceleration in germination under cold temperatures, aligning with the hypothesized sensitivity of bean plants to frost. These outcomes emphasize the complexity of the germination process and suggest the need for further investigation between temperature, seed resilience, and other types of plant's seeds effect.

Helium Experiment:

Purpose:

This experiment aims to investigate the impact of a helium environment on seeds and their germination, assessing the extent and nature of this influence.

Hypothesis:

I predict that exposing the seed to helium will likely have no effect. This expectation is based on the protective role of the seed coat, which shields the embryo from direct contact with the surrounding environment. Given that the seed coat acts as a barrier, an alteration in the atmospheric composition, such as introducing helium, is unlikely to significantly impact the seed coat and, consequently, the seed itself.

Duration:

December 17 - 19 2023

Background Research:

Impact of Low-Vacuum Helium Cold Plasma on Oilseed Rape ([Brassica napus L. cv. Zhongshuang 9](#))

- examine the effects of 15-second exposure to low-vacuum helium cold plasma (0–120 W) on oilseed rape germination, growth, and yield.

Optimal Conditions:

The 100 W treatment positively affect germination, growth, and yield:

- **Enhanced Germination:** Cold plasma treatment improved germination metrics, including rate, vigor indices, and emergence uniformity.
- **Physiological Shifts:** Increased seed conductivity and water uptake suggest improved permeability.
- **Surface Changes:** Reduced apparent contact angle indicates enhanced seed wettability.
- **Positive Growth Effects:** Increased plant height, stem diameter, and shoot/root weights.

- **Improved Yield Components:** Enhanced pod numbers per plant and 1000 seed weights.
- **Significant Yield Increase:** 28.20%.

Mechanistic Insights:

Low-vacuum helium cold plasma enhances seed permeability by potentially *breaking the seed coat*, as evidenced by increased water uptake and improved germination.

Materials:

- 6 Provider Bean Bush seeds
- 2 Overall seeds (+1 control)
- 1 bottle of Ultra Hi-Float
 - Mixture made out of Water, Polyvinyl Alcohol, and Dextrose Monohydrate
 - Helps balloon stay inflated with helium for 2-3 days
- 6 clear balloons (1 extra in case)
 - (make sure they are tied so they can be untied)
- 1 helium tank (outsource from a shop)
 - Has 96% helium and 4% nitrogen
- 5 Strings
- Chair
- 6 pots/cups ready for planting

Procedure:

1. **Split the 6 seeds into groups of 2** and label each group as *Helium group*, *Hi-Float group*, *Control group*
2. Place the Helium group, Hi-Float group, and Overall seeds **inside the dark blue balloons**
3. **Fill up** the balloons with helium **from the tank** and tie it up with a string
 - a. For Hi-float group add 2 pumps (~ 4 mL) of Ultra Hi-float mixture
4. **Place all of the seeds (even if in a balloon) close to each other on a chair.** Make sure they stay in a controlled environment with the least amount of variables.
5. Let them **sit there for 24hrs**
6. Afterwards, pop the helium group balloons, remove **1** control seed and **plant all of the them in their respected cups with labels**
7. Repeat 5./6. for Hi-Float balloons and the other control seed

8. Place them with all the other seeds and **observe** any changes or details as they grow.

Observation:

Watering Table:

Date and day	Amount of water (mL)
Dec 19 2023, day 1	5 mL
Dec 21 2023 , day 3	5 mL
Dec 22 2023, day 5	3 mL
Dec 23 2023, day 6	5 mL
Dec 24 2023, day 7	5 mL
Dec 27 2023, day 10	5 mL
Dec 28 2023, day 11	5 mL
Dec 29 2023, day 12	7 mL
Jan 1 2024, day 15	5 mL
Jan 2 2024, day 16,	5 mL
Jan 3 2024, day 17	5 mL
Jan 4 2024, day 18	5 mL
Jan 5 2024, day 19	5 mL
Jan 6 2024, day 20	5 mL
Jan 7 2024, day 21	3 mL
Jan 8 2024, day 22	5 mL
Jan 9 2024, day 23	3 mL
Jan 10 2024, day 24	5 mL
Jan 11 2024, day 25	5 mL
Jan 12 2024, day 26	5 mL
Jan 13 2024, day 27	5 mL
Jan 14 2024, day 28	5 mL
Jan 15 2024, day 29	3 mL
Jan 16 2024, day 30	3 mL

Weekly Germination Table:

Control 1

Height in cm	Date - day
Sprouted at 2 cm	Jan 5 2024 -day 19
6 cm	Jan 6 2024 - day 20
7 cm	Jan 8 2024 - day 22
9 cm	Jan 11 2024 - day 25
11 cm	Jan 16 2024 - day 30

Control 2

Height in cm	Date - day
Sprouted at 1 cm	Dec 20 2023 - day 3
25 cm	Dec 28 2023 - day 11
28 cm	Jan 1 2024- day 15
28 cm (had a 1.5 cm growth at least)<—leaf top chopped off !!!! Don't know how or why and can't find the top leaves	Jan 2 2024 - day 17
29.5 cm	Jan 6 2024 - day 20
30 cm	Jan 8 2024 - day 22
32 cm	Jan 11 2024 - day 25
26 cm (leaves dried)	Jan 16 2024 - day 30

Normal 1

Height in cm	Date - day
Sprouted at 1.5 cm	Dec 21 2024 - day 4
27 cm	Dec 28 2023 - day 11
30 cm	Jan 1 2024 - day 15
32 cm	Jan 3 2024 - day 17
34 cm	Jan 6 2024 - day 20
34 cm	Jan 8 2024 - day 22

34 cm	Jan 11 2024 - day 25
35 cm	Jan 16 2024 - day 30

Normal 2

Height in cm	Date - day
Can't tell it sprouted but something came up, and it was covered in white, fuzzy mold. Probably withered.	Dec 28 2023 - day 11
same as above	Jan 1 2024 - day 15
same as above	Jan 3 2024 -day 17

Hi- float 1

height in cm	Date - day
Sprouted 2 cm	Dec 19 2023 - day 2
30 cm	Dec 28 2023 - day 11
33 cm	Jan 1 2024 - day 15
34 cm	Jan 3 2024 - day 17
35 cm	Jan 6 2024 - day 20
36 cm	Jan 8 2024 - day 22
33 cm (leaves dried)	Jan 11 2024 - day 25
35 cm	Jan 16 2024 - day 30

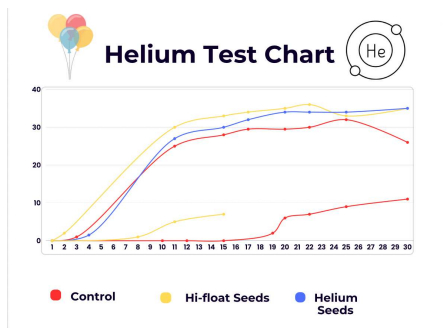
Hi- float 2:

Height in cm	Date - day
Sprouted 1 cm	Dec 23 2023 - day 8
5 cm but died sadly (withered)	Dec 28 2023 - day 11
dead 7 cm	Jan 1 2024 -day 15

Summary Table And Germination Chart:

Type:	Growth rate (similar appearance features)
Control	Controls where steady but one seed was faster than the usual growth rate, and the other seed was slower

HiFloat	1 of the Hi Float seeds died but the other had the highest growth rate but dropped and ended with the same height as the normal exposed seed.
Normal	Only one of the seeds sprouted, but that one did well. Better than the control and same as the Hi float one.



Note: I was not able to add it but the vertical axis is the plant's measurement in cm, and the horizontal line is the day (e.g. 1st day is when it is planted so the day the testing finishes).

Analysis and Discussion:

This experiment aimed to unravel the impact of helium and helium with Hi-Float chemical on the germination of Golden Garden Bush Bean seeds, recognizing three pivotal factors influencing seed germination: temperature, light, pH, and soil moisture. Seed germination is a complex process dependent on various environmental conditions, and exploring novel agents such as helium and Hi-Float could provide insights into optimizing germination rates and overall seedling development.

Comparing helium exposure for one day to Hi-Float exposure for two days revealed similar germination outcomes that are both faster than the control seed's germination, suggesting a potential equivalence in their effects on seed germination. Despite Hi-Float initially outperforming helium in the early stages, the final germination results converged, implying that the sticky nature of Hi-Float might influence the germination process but does not significantly alter the end outcome. This raises possibilities, hinting that extended helium exposure, slightly breaking the seed coat from the change in the environment and facilitating increased water uptake, could potentially yield improved germination results.

Consistent watering schedules across all groups, including control, helium, and Hi-Float helium, indicated that water availability did not substantially impact

germination patterns. However, the distinct impact of helium on seed germination, as evidenced by the chart, underscores its potential as a catalyst for germination improvement.

In conclusion, based on the experimental setup and analysis, helium emerged as a notable positive influence of seed germination. The growth rate and appearance of helium-exposed seeds differed significantly from the control group, showcasing the positive impact of helium exposure. Both helium and Hi-Float-treated seeds demonstrated superior germination compared to the control group, aligning with existing research hypotheses. Helium's ability to release and penetrate the seed coat, facilitating moisture absorption and seed emergence, contributed to its efficiency in enhancing germination.

This experiment serves as a preliminary exploration, suggesting that helium exposure warrants further investigation, particularly in prolonged exposure scenarios and with different seed varieties. A more comprehensive understanding of plant responses to helium could pave the way for innovative approaches to optimize seed germination and enhance overall agricultural practices.

Microgravity:

Purpose:

This experiment aims to investigate the impact of microgravity on seeds and their germination, assessing the extent and nature of this influence.

Hypothesis:

I hypothesize that a microgravity environment will have minimal influence on seed germination. While seeds lose their perception of gravity as they spin, upon planting, they easily reorient and regain a sense of direction aligned with the reestablished gravity. This hypothesis is grounded in the instant adaptability of plants to gravity changes, explaining why continuous rotation is needed for simulating microgravity conditions.

Duration:

Dec 22 - 24 2023

Material:

- ☐ Vex IQ made clinostat
- Made with
- Vex IQ brain,

- battery for brain
- 1 Vex IQ motor
- 1 V5 Smart cable
- 11 VE IQ pin (lime one on chart)
- 4 square plates (white one on chart)
- 1 S large beam (orange one on chart)
- 1 L large beam (white one on chart)
 - 2 S beams (blue one on chart)
 - 1 S/M beam (orange one on chart)
 - 1 M beam (pink one on chart)
 - 2 M connectors (yellow one on chart)
- (* Add photo of material and building process (rebuild) and overall look)



- ☐ USB-C to Micro USB cable
 - the brain in VEX IQ uses Micro USB
- ☐ Mac Book (my laptop)
 - ☐ Vex IQ (block code) app
 - with codes:
 - rpm = revolutions per minute
- ☐ 3 clear, ($2\pi \approx 6.28\text{cm}$ bottom circumference x 3cm height x $2.5\pi \approx 7.85\text{cm}$) plastic container
- ☐ 1 extra VEX IQ pin
- ☐ Double sided tape
- ☐ Dongle
- ☐ Red USB to micro USB cable
- ☐ 3 Golden Garden Bush Bean seeds
 - 1 control
 - 2 microgravity seeds

Clinostat building Procedure:

To create main motor:

1. Attach motor to brain using the V5 smart cable
2. Also, attach the same brain to your computer (MacBook Air) using a dongle and the red USB to micro USB cable
3. On the computer, download VEXcode IQ.pkg and connect the brain to the program by connecting the computer and the brain using the USB to micro USB cable (and dongle).
4. Once connected, set it so the codes are connected to the motor (by clicking on the motor feature) and code in the codes:



rpm = revolutions per minute

→ These codes will make the motor spin forward at 15 rpm once the code is activated on the brain, meaning the code has been pre-coded into the brain.

5. Now, you can save and unplug your computer from the brain.
 - a. Make sure to test if the code is properly working on the brain

To build base:

1. Align the 4 square plates to create a larger square.
2. Attach the S large beam in the middle using 4 pins.
3. Attach 2 S beams to each side of this larger square using 2 pins each to make the base more stable.
4. On the side, attach the S/M beam on top of the M beam, secure with 2 pins. This part will be used later.
5. Flip the large square around, and attach the 2 connectors on the edge so that they are sticking out of the big square.
6. Attach the M beam from step 4. under the part of the connector sticking out
 - a. This ensures the base can fit the brain on it
7. Attach the L large beam to the 90° portion of the connectors.
8. Add a pin to the outer side of the L large beam (not facing the large square), and attach the motor.
9. Place the brain on the large square, and allow the wire to wrap around the L large beam.

Procedure:

1. Using a small strip of double sided tape and attach the 2 microgravity seeds to one side of the clear, plastic container.
2. Do the same for the overall seeds and make sure to add a purple marking from a marker on either ends of the overall seeds' side.
3. Place the control seed in another clear container and wrap it in aluminum foil.
4. Do the same for the control overall seed.
5. Wrap the container with the microgravity seeds in aluminum foil.
 - a. To avoid variations such as light differences
6. Take the same container and tape the extra VEX IQ pin on, using heavy layers of double sided tape to make sure it is secured.
 - a. Make sure the pin is in the exact center of the container in order to make sure it doesn't spin at an angle.
7. Attach the pin with the container stuck to it onto the VEX IQ created clinostat.
8. Start the pre-coded VEX IQ brain and keep it in an controlled environment
9. After 3 days, take all the seeds out and only plant the microgravity and control seeds using the planting guide. Make sure to place all overall seeds back into their assigned containers (1 overall container and 1 control overall container) and wrap it in aluminum foil.
10. Observe the plants growth and give them regular water.

Observations:

Watering table

Microgravity watering schedule

Date and day	Amount (mL)
Dec 21 2023, day 1	5 mL

Dec 22 2023, day 2	3 mL
Dec 22 2023, day 3	3 mL
Dec 24 2023, day 5	5 mL
Dec 27 2023, day 8	5 mL
Dec 28 2023, day 9	5 mL
Dec 29 2023, day 10	7 mL
Jan 1 2024, day 13	5 mL
Jan 2 2024, day 14	5 mL
Jan 3 2024, day 15	5 mL
Jan 4 2024, day 16	5 mL
Jan 5 2024, day 17	5 mL
Jan 6 2024, day 18	5 mL
Jan 7 2024, day 19	5 mL
Jan 8 2024, day 20	3 mL
Jan 9 2024, day 21	5 mL
Jan 10 2024, day 22	3 mL
Jan 11 2024, day 23	3 mL
Jan 12 2024, day 24	3 mL
Jan 13 2024, day 25	5 mL
Jan 14 2024, day 26	5 mL
Jan 15 2024, day 27	3 mL
Jan 16 2024, day 28	5 mL
Jan 18 2024, day 29	5 mL
Jan 19 2024, day 30	5 mL

Weekly Germination Table:

Control

Height in cm	Date - day
Sprout at 1 cm	Dec 25 2023 - day 6
5 cm	Dec 28 2023 - day 9
26 cm	Jan 1 2024 - day 13
26.5 cm	Jan 3 2024 - day 15
28 cm	Jan 6 2024 - day 18
29 cm	Jan 8 2024 - day 20

29 cm	Jan 11 2024 - day 23
28 cm	Jan 18 2024 - day 30

Microgravity 1

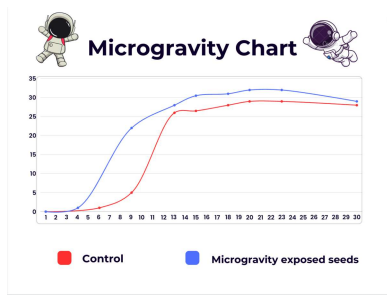
Height in cm	Date
Didn't Sprout	N/A

Microgravity 2

Height in cm	Date - day
Sprouted at 1 cm	Dec 23 2023 - day 4
22 cm	Dec 28 2023 - day 9
28 cm	Jan 1 2024 - day 13
30.5 cm	Jan 3 2024 - day 15
31 cm	Jan 6 2024 - day 18
32 cm	Jan 8 2024 - day 20
32 cm	Jan 11 2024 - day 23
29 cm	Jan 18 2024 - day 30

Summary Table And Germination Chart:

Type:	Growth rate	Appearance and extra
Control	- Growth was steady and predictable	
Microgravity exposed	- Similar growth as Control - At the beginning, there was a jump but, afterwards, it was a steady growth.	Both had very similar appearances to the control plant.



Note: I was not able to add it but the vertical axis is the plant's measurement in cm, and the horizontal line is the day (e.g. 1st day is when it is planted so the day the testing finishes).

Analysis and Discussion

This experiment's objective was to explore the impact of microgravity on seed germination, specifically golden garden bush bean seeds. My hypothesis proposed minimal influence on seed germination in a microgravity environment, taking in consideration the adaptability of seeds to gravity changes. The experiment utilized a custom-built clinostat with a Vex IQ kit to simulate continuous rotation, mimicking microgravity conditions.

As my hypothesis stated, the results indicate that a microgravity environment had a limited effect on the germination of seeds most likely because plants' statoliths, starch-filled plastids, inside the statocytes, gravisensing cells, move alongside the change of gravity ([Levernier et al., 2021](#)); therefore, it recovers a sense of gravity once it stopped spinning. This theory also explains why clinostats have to continuously spin to simulate microgravity as if it stops the seed will once again regain a sense of gravity.

The control group exhibited steady and predictable growth, showcasing typical germination patterns. While there was an initial jump in growth for one of the microgravity-exposed groups, the seed subsequent development mirrored that of the control group.

The watering schedule was consistent for both the control and microgravity-exposed groups, indicating that water availability did not significantly influence the observed germination patterns.

In conclusion, based on this experimental setup and testing, microgravity did not exert a prominent influence on either the appearance or germination of these exposed seeds. The growth rates and appearances of the control and microgravity-exposed groups were notably similar, suggesting that the adaptability of seeds to gravity changes may extend to microgravity conditions as well. Further exploration into the effects of

prolonged exposure and different seed varieties may contribute to a more deeper understanding of plant responses to microgravity.

UV:

Purpose:

This experiment aims to investigate the impact of ultraviolet radiation on seeds and their germination, assessing the extent and nature of this influence.

Hypothesis:

I hypothesize that exposure to UV light likely enhances seed germination. This is attributed to the UV light's strength, which could penetrate the seed coat, creating a pathway for the plant to initiate sprouting. Additionally, the UV exposure may contribute to an increase in the seed's temperature, potentially accelerating the activity of cellular organelles, such as mitochondria, involved in energy production and metabolism

Duration:

December 21 - 23 2023

Background Research:

1. Ultraviolet LED Treatment on Seeds:

Ultraviolet (UV) LED treatment applied to seeds in the UV radiation zone.

- Treatment durations: 5, 10, and 15 minutes with an average illumination energy of 3.137 W/m².
- Parameters evaluated include growth strength, laboratory germination, shoot height, primary root length, and root rot infestation.
- Positive effects observed for
 - winter wheat
 - winter triticales
 - oats
 - Thick seed coat

- winter wheat:
 - Notable results with UV radiation dose of 1882 J/m² (10-minute treatment) enhancing growth strength and germination
 - Improved shoot height and root length noted with 5-minute irradiation at 941 J/m².

Overall, the ultraviolet treatment proposed to enhance hydroponic feed production technology.

→ Consideration given to modern requirements for energy conservation and environmentally friendly product development.

- ([Kondrateva et al., 2020](#))

2. Dosage Effects of UV Light:

- Research Insight: Smaller doses of UV light are beneficial, while larger doses can be harmful ([Bless, 1937](#))
- Positive Impact of UV Light: UV light has positive effects on plant ([Noble, 2002](#))
- Positive effects observed in winter wheat, winter triticale, and oats, with considerations for energy conservation, rest demonstrated negative effects with a decrease of speed in the germination process. ([Kondrateva et al., 2020](#))

Safety:

- Wear proper equipment
 - lab coat
 - Thick long sleeves
 - Eyewear
 - Sunglasses
 - Gloves
- Have a sterile environment
 - reduce contamination

Material:

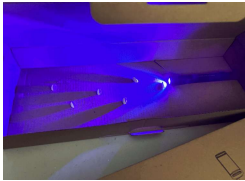
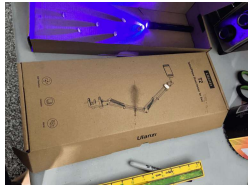
- ☐ 4 Provider Bean Bush seeds
- ☐ 2 Overall testing seeds (and 1 control)
- ☐ 1-2 UV lamp or flashlight

- ☐ 3 similar cardboard box (l:w:h → 80:20:6) with a lid on each
- ☐ Sterile tweezer (move seeds)
- ☐ UV light meter -Sponsored by Mr. Jang-
- ☐ 9 Pots with soil
- ☐ 1 Sunglasses
→ (depending on how many people conducting test)
- ☐ Full sleeves clothing

Procedure:

1. Split the seeds into 3 groups, **1 control, 1 UV seed group, 1 darkness group.**
2. Place each group in one of the **3 similar boxes** (80x10x6)
3. Arrange each group in the same pattern where they are **4 cm apart and not blocking each other by their shadows.**
4. Place the **UV flashlight/lamp** in the UV group box (25 cm away from other side) and make sure the **light is only in that side of the box**
 - **Make sure the UV light is on each of the UV seeds.**
5. **Close the lid for the dark group box.** Be careful not to move the seeds positioning.
6. **Measure the level of UV radiation for each seed in the UV light group** and document it
 - a. 1 cm away from UV flashlight, $506\text{-}508\ \mu\text{W}/\text{cm}^2$
 - b. 9 cm away from UV flashlight, $130\ \mu\text{W}/\text{cm}^2$
 - c. 18 cm away from UV flashlight, $71\ \mu\text{W}/\text{cm}^2$
 - d. 21 cm away from UV flashlight, $12\ \mu\text{W}/\text{cm}^2$
7. Leave it like that for **24 hours** (in case anything happens have extra material on hand)
8. After the 24 hours, **gradually close the UV light, remove the cover of the dark group section** (try to do in a darker environment), **and plant all the seeds (keep in same environment)** following the proper planting procedure

9. As they grow record **any observation or differences between the three groups**

		
<i>UV light set up</i>	<i>Dark set up</i>	<i>Control set up</i>

Observations:

Watering Table:

Date and day	Amount of water (mL)
Dec 24 2023, day 1	5 mL
Dec 27 2023, day 4	5 mL
Dec 28 2023, day 5	5 mL
Dec 29 2023, day 6	7 mL
Jan 1 2024, day 9	5 mL
Jan 2 2024, day 10	5 mL
Jan 3 2024, day 11	5 mL
Jan 4 2024, day 12	5 mL
Jan 5 2024, day 13	5 mL
Jan 6 2024, day 14	5 mL
Jan 7 2024, day 15	5 mL
Jan 8 2024, day 16	3 mL
Jan 9 2024, day 17	5 mL
Jan 10 2024, day 18	3 mL
Jan 11 2024, day 19	3 mL
Jan 12 2024, day 20	3 mL
Jan 13 2024, day 21	5 mL
Jan 14 2024, day 22	5 mL
Jan 16 2024, day 24	5 mL

Jan 17 2024, day 25	5 mL
Jan 18 2024, day 26	5 mL
Jan 19 2024, day 27	3 mL
Jan 20 2024, day 28	3 mL
Jan 21 2024, day 29	5 mL
Jan 22 2024, day 30	5 mL

Weekly Germination Table:

Control

Height in cm	Date - day
Sprouted at 2 cm	Dec 28 2023 - day 5
29 cm	Jan 1 2024 - day 9
32 cm	Jan 3 2024 - day 11
34 cm	Jan 6 2024 - day 14
35 cm	Jan 8 2024 - day 16
38 cm	Jan 11 2024 - day 19
33 cm (withered leaves)	Jan 16 2024 - day 24
34 cm	Jan 22 2024 - day 30

Dark 1

Height in cm	Date - day
Sprouted at 2 cm	Dec 28 2023 - day 5
31 cm	Jan 1 2024- day 9
34 cm	Jan 3 2024- day 11
35 cm	Jan 6 2024 - day 14
36 cm	Jan 8 2024 - day 16
37 cm	Jan 11 2024 - day 19
33 cm (withered leaves)	Jan 16 2024 - day 24
35 cm	Jan 22 2024 - day 30

Dark 2

Height in cm	Date - day
Sprout at 1 cm	Jan 3 2024 - day 11
11cm	Jan 6 2024 - day 14

17 c m	Jan 8 2024 - day 16
19 cm	Jan 11 2024 - day 19
19 cm	Jan 16 2024 - day 24
22 cm	Jan 22 2024 - day 30

503-506 $\mu W/cm^2 \rightarrow$ 1 cm away from UV light

Height in cm	Date - day
Sprout at 0.2 cm	Dec 28 2023 - day 5
13 cm	Jan 1 2024 - day 9
22 cm	Jan 3 2024 - day 11
30 cm	Jan 6 2024 - day 14
31 cm	Jan 8 2024 - day 16
32 cm	Jan 11 2024 - day 19
35 cm	Jan 16 2024 - day 24
37 cm	Jan 22 2024 - day 30

130 $\mu W/cm^2 \rightarrow$ 9 cm away from UV light

Height in cm	Date - day
Sprout at 1 cm	Dec 28 2023 - day 5
20 cm	Jan 1 2024 - day 9
24 cm	Jan 3 2024 -day 11
28 cm	Jan 6 2024 - day 14
30 cm	Jan 8 2024 - day 16
33 cm	Jan 11 2024 - day 19
36 cm	Jan 16 2024 - day 24
37 cm	Jan 22 2024 - day 30

7 $\mu W/cm^2 \rightarrow$ 17 cm away from UV light

height in cm	Date - day
Sprout at 1.5 cm	Dec 28 2023 - day 5
30 cm	Jan 1 2024 - day 9
34 cm	Jan 3 2024 - day 11
35 cm	Jan 6 2024 - day 14
38 cm	Jan 8 2024 - day 16
40 cm	Jan 11 2024 - day 19
42 cm	Jan 16 2024 - day 24

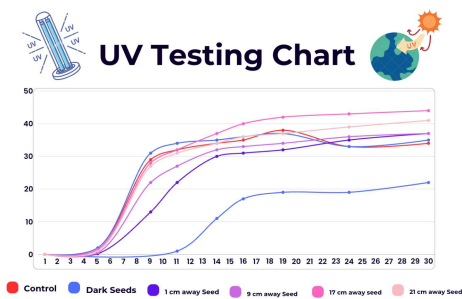
44 cm	Jan 22 2024 - day 30
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$2 \mu W/cm^2 \rightarrow 21 \text{ cm away from UV light source}$

Height in cm	Date - day
Sprout at 1 cm	Dec 28 2023 - day 5
27 cm	Jan 1 2024 - day 9
31 cm	Jan 3 2024 - day 11
34 cm	Jan 6 2024 - day 14
36 cm	Jan 8 2024- day 16
37 cm	Jan 11 2024 - day 19
39 cm	Jan 16 2024 - day 24
40 cm	Jan 22 2024 - day 30

Summary Table And Germination Chart

Level exposed to UV radiation (or if in darkness) For 1 day	Notes on Growth (all of them looked almost identical)
0 $\mu W/cm^2$ (Control)	Mostly had a steady and predictable growth rate except for the end where the height had decreased due to some withering
Dark	1 seed had almost identical growth rate as control. Other seed were slower but most likely because of the seed itself.
503-506 $\mu W/cm^2$ (1 cm away from source)	grew just slightly faster then control
130 $\mu W/cm^2$ (9 cm away from source)	Had the same germination rate as the 1 cm away UV light seed.
7 $\mu W/cm^2$ (17 cm away from source)	Had the best results with the fastest germination → power of balancing amount
2 $\mu W/cm^2$ (21 cm away from source)	Germination rate was between 17 and 9 cm away seeds and 7 cm away seed. (2nd fastest)



Note: I was not able to add it but the vertical axis is the plant's measurement in cm, and the horizontal line is the day (e.g. 1st day is when it is planted so the day the testing finishes).

Analysis and Discussion:

This experimental analysis UV radiation and seed germination relation. Despite my initial hypothesis anticipating a straightforward correlation between increased UV exposure and enhanced germination, the data introduces another, similar, theory.

Seeds exposed to $17 \mu W/cm^2$ or $2 \mu W/cm^2$, situated 17 or 24 cm from the UV light source, exhibited accelerated and robust germination, aligning with the anticipated effect of UV light accelerating germination by breaking the seed coat and creating a path for the embryo to sprout from. However, complications emerged at higher exposure levels ($503-506 \mu W/cm^2$, $130 \mu W/cm^2$), resulting in a slower germination rate compared to the control group. This hints at a potential negative impact on the embryo, underscoring the necessity for precise UV exposure parameters for optimal germination. Additionally, $2 \mu W/cm^2$ seed had a slower germination rate than $17 \mu W/cm^2$ seed, still faster than the control seed, indicating that too low levels of UV radiation wouldn't be able to pierce thru the seed coat.

The experiment underscores the importance of fine-tuning UV exposure conditions to identify an optimal threshold for seed coat removal without harming the embryonic development. The dark seeds' relatively slower growth and UV exposed seeds' mixed growth indicates the importance of sunlight in a plant's early stages as it helps the plant break out of its seed coat. The relatively slower germination observed in the control and dark groups, despite signaling the positive influence of UV exposure, emphasizes the need for a customized rather than a one-size-fits-all UV treatment approach if we want to use this as a method of growing our crops faster.

Vacuum:

Purpose:

This experiment aims to investigate the impact of a vacuum environment on seeds and their germination, assessing the extent and nature of this influence

Hypothesis:

I hypothesize that the vacuum's impact will be minimal because, while the seeds are subjected to an airless environment, the vacuum is not entirely devoid of substances, an environment impossible to achieve. Additionally, the primary influence of this environment is expected to be on the seed coat, which is inherently designed to withstand various challenges and should endure the conditions presented. In essence, the vacuum, being not completely empty, is likely to have limited effect on the seeds' germination, particularly considering the protective nature of the seed coat.

Duration:

December 27 - 28 2023

Materials:

- 4 golden wax garden bean seeds
- Overall testing kit
 - 2 overall golden wax garden bean seeds
 - + 1 control golden wax garden bean seed
 - 2 plastic cups
- 4 similar Mason Jars
 - Base: $6\pi \approx 18.84$ cm
 - Height: 6 cm
 - 2.1 cm to screw on screw band
 - 2 for overall seeds
- 4 similar sealing compound for mason jars
 - Base: 6.5π cm ≈ 20.42 cm
 - Height: ≈ 0.2 cm
- 4 similar screw bands for mason jars
 - Base: $7\pi - 5.5\pi = 1.5\pi \approx 4.17$ cm with a $5.5\pi \approx 17.28$ cm hole
 - Height: ≈ 1.6 cm
- OXLIMKEE Electric Mason Jar Vacuum Sealer
 - Material: Acrylonitrile Butadiene Styrene
 - Colour: Black
 - Dimensions: 10.2L x 7.6W x 10.2H cm
 - Power source: Corded Electric
 - Operation mode: Automatic
 - Wattage: 4 watts
 - <https://a.co/d/hZWjzIt>

Procedure:

1. **Split the 4 seeds into groups** of two—a control group and a vacuum group.
2. **Place the control group together** in 1 empty mason jar, **close the jar** by placing both the sealing compound and screw band on.
3. **Wrap** the control group's jar with one layer of aluminum foil.
Make sure not to vacuum seal it at all.
4. **Place the vacuum group** in the other mason jar and **place the sealing compound**. Then, attach the **vacuum sealer on and start it**.
5. After **200 seconds**, write the **vacuum level (42%)** and **remove** the vacuum sealer.
6. Then, **screw on the screw band** and **wrap** it in one layer of aluminum foil.
7. Finally, **place all jars in a controlled environment**— not in use closet— and let it sit for **24 hrs**.
8. After **24 hrs**, **remove** the control and vacuum group seeds and **follow the planting procedure**.

Overall Seed Procedure:

1. Do **steps 1-6** for the overalls' control and tested seeds
 - a. Both with **vacuum level of 38%**
2. After **24 hrs**, place the seeds back into their designated containers and **wrap** it with aluminum foil.

Observations:

Watering Table:

Day and date	Amount of water (mL)
Jan 1 2024, day 1	5 mL

Jan 2 2024, day 2	5 mL
Jan 3 2024, day 3	5 mL
Jan 4 2024, day 4	5 mL
Jan 5 2024, day 5	5 mL
Jan 6 2024, day 6	5 mL
Jan 7 2024, day 7	5 mL
Jan 8 2024, day 8	3 mL
Jan 9 2024, day 9	5 mL
Jan 11 2024, day 11	5 mL
Jan 12 2024, day 12	5 mL

Weekly Germination Table:

Control

Date and day	Height (cm)
Jan 6 2024 - day 6	Sprout at 1.5 cm
Jan 8 2024 - day 8	7 cm
Jan 11 2024 - day 11	17 cm
Jan 16 2024 - day 16	20 cm
Jan 25 2024 - day 25	23 cm
Jan 30 2024 - day 30	25 cm

Control

Date and day	Height (cm)
Jan 8 2024 - day 8	Sprout at 3 cm
Jan 11 2024 - day 11	16 cm
Jan 16 2024 - day 16	22 cm
Jan 25 2024 - day 25	24 cm
Jan 30 2024 - day 30	26 cm

Vacuum (42%) 1

Date and date	Height (cm)
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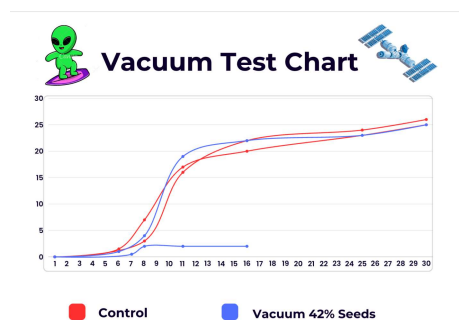
Jan 7 2024 - day 7	Sprout at 0.5 cm
Jan 8 2024 - day 8	2 cm
Jan 11 2024 - day 11	2 cm → withered
Jan 16 2024 - day 16	2 cm → Died

Vacuum (42%) 2

Date and day	Height (cm)
Jan 6 2024 - day 6	Sprout at 1 cm
Jan 8 2024 - day 8	4 cm
Jan 11 2024 - day 11	19 cm
Jan 16 2024 - day 16	22 cm
Jan 25 2024 - day 25	23 cm
Jan 30 2024 - day 30	25 cm

Summary Table And Germination Chart:

Type of Seed:	Growth rate (similar appearances)
Control	Growth was steady and predictable
Vacuum (42%) Exposed	One seed was weak and died early. The other one had almost the same growth rate as the control seeds.



Note: I was not able to add it but the vertical axis is the plant's measurement in cm, and the horizontal line is the day (e.g. 1st day is when it is planted so the day the testing finishes).

Analysis and Discussion:

This experiment aimed to assess the impact of a vacuum environment on the germination of golden wax garden bean seeds. The initial hypothesis suggested a minimal effect due to the seeds' protective nature and the incomplete vacuum conditions. The testing involved control and vacuum-exposed groups, with an OXLMKEE Electric Mason Jar Vacuum Sealer utilized for creating the vacuum environment.

Similar to the hypothesis, the results indicate that exposure to a vacuum did not have a prominent effect on either the appearance or germination of the golden wax garden bean seeds at this level. The control group displayed a steady and predictable growth rate, consistent with typical germination patterns for these seeds. The vacuum-exposed groups, both at 42%, did not exhibit clear distinctions in germination outcomes compared to the control.

While the first vacuum-exposed seed showed some stunted growth and seed withering, the second seed displayed a recovery and growth trajectory similar to the control. The observed variations not only suggest that the first vacuum-exposed seed may have shown such results because of sources of errors, such as a weak seed, but also that the vacuum level, at 42%, did not consistently impact seed germination. These findings are supported by how routinely sealing seeds and legumes mason jars don't have any detrimental effects because the seed's coat is able to withstand and protect it from that level of vacuum.

In conclusion, based on this testing, there is no major discernible effect of a vacuum environment on either the appearance or germination of golden wax garden bean seeds at 42% vacuum level. This experiment proves that, under the conditions explored, exposure to vacuum does not significantly alter the germination process. It's worth noting that further investigation may be warranted to explore potential effects at higher vacuum levels, though at this stage, the observed impact is inconclusive.

Magnetic Testing:

Purpose:

This experiment aims to investigate the impact of magnetic field's radiation on seeds and their germination, assessing the extent and nature of this influence.

Hypothesis:

I propose that magnetic field waves, much like other radiation, will penetrate through the seed coat, expediting the germination process by facilitating a faster sprout of the

embryo. This hypothesis also means, under intense conditions resembling those in space, the radiation could potentially harm the seed's internal organs, or even result in the demise of the vulnerable embryo upon its exposure beyond the seed coat. Nevertheless, I am inclined to dismiss this concern because other, similar experiments employ more robust and prolonged waves, which demonstrated accelerated seed germination without that many deleterious effects. While acknowledging potential variability based on seed types, the significantly greater intensity of the waves in those tests suggests that the comparatively milder radiation in this experiment may not pose a significant harm. In essence, I believe that seeds exposed to magnetic field radiation experience an accelerated germination process in this specific experiment.

Duration:

January 2 2024

Background Study:

Abstract:

Global climatic fluctuations and the increasing population have been responsible for the decline in crop productivity. To mitigate these challenges, various approaches including the use of chemical fertilisers, pesticides, and genetic resources have been employed. Recently, magnetic field (MF) therapy has emerged as a promising tool for enhancing plant tolerance against adverse environmental conditions. However, limited research has been conducted to elucidate the mechanism of MF interaction with plants under stress. This review aims to highlight the mitigating effect of MF on plants against both abiotic and biotic stresses. MF interacts with seeds and plants, accelerating metabolism and promoting growth and yield under favourable conditions. Moreover, MF reduces oxidative stress and enhances plant tolerance to conditions such as drought, salinity, heavy metal contamination, temperature extremes, and pathogenic infections. By understanding the physiological changes induced by MF, we can harness its potential to improve crop resilience and productivity in the face of environmental challenges.

Introduction:

Global climatic fluctuations and the increasing population have posed significant challenges to agricultural productivity, leading to the decline in crop yield ([Smith et al., 2019](#)). Traditional methods such as the use of chemical fertilisers, pesticides, and genetic resources have been commonly employed to improve crop productivity ([Jones & Smith, 2018](#)). However, these approaches have limitations and may have adverse effects on the environment and human health ([Gupta et al., 2020](#)). Therefore, there is a

need for alternative strategies that can enhance plant tolerance against environmental stresses.

Role of Magnetic Field Therapy in Plant Growth and Development:

Magnetic field (MF) therapy has emerged as an effective and emerging tool for controlling diseases and increasing tolerance against adverse environmental conditions in both plants and animals ([Abdollahi et al., 2012](#); [Vashisth & Nagarajan, 2010](#)).

Limited studies have attempted to determine the role of MF in improving plant tolerance against various stress conditions ([Chen et al., 2011](#)). MF interacts with seeds and plants, accelerating metabolism and promoting growth and yield under favourable conditions ([Dayal & Singh, 1986](#); [Florez et al., 2007](#)). Moreover, MF reduces oxidative stress and enhances plant tolerance to conditions such as drought, salinity, heavy metal contamination, temperature extremes, and pathogenic infections ([Anand et al., 2012](#); [Rathod & Anand, 2016](#); [Trebbe et al., 2007](#)).

Impact of MF on Vegetative and Reproductive Growth Phases:

MF positively influences the growth of plants by increasing shoot and root length ([Dayal & Singh, 1986](#); [Florez et al., 2007](#)). Root growth depends upon the cell division in the root meristems and subsequent differentiation and elongation of the descendant cells ([Beemster & Baskin, 1998](#)). The induction of metaxylem cells by MF is an important component of the increase in the rate of root elongation ([Bitonti et al., 2006](#)). MF exposure to seeds accelerates their growth, activates protein formation, and promotes root growth ([Pieturszewski, 1999](#)). Moreover, MF-treated plants exhibit larger leaf area and higher leaf dry weight during the vegetative stage, attributed to increased photosynthetic rates and better nutrient availability ([Souza-Torres et al., 1999, 2006](#)).

Limited studies have documented the effect of MF on reproductive development in crops. ([Matsuda et al., 1993](#)) reported enhanced yield in strawberry plants treated with MF. Similar effects were observed in various crops such as flax, buckwheat, pea, wheat, tomato, pepper, soybean, and cotton ([Gubbels, 1982](#); [Grabrielian, 1996](#); [Phirke & Umbarkar, 1998](#); [Pieturszewski, 1993](#); [Ogolnej et al., 2002](#); [Vasilevski, 2003](#); [Leelapriya et al., 2003](#); [Esitken & Turan, 2004](#)).

Endogenous Bio-molecular Changes:

MF induces changes in various biochemical processes, affecting enzymatic activity, metabolite transportation, and growth regulators in plants ([Leelapriya et al., 2003](#)).

For instance, MF influences the transport of carbohydrates and plant growth hormones, stimulating growth at lower intensity ([Esitken & Turan, 2004](#)).

Additionally, MF enhances chlorophyll content and alters enzyme activity in plants ([Novitsky et al., 2001](#); [Leelapriya et al., 2003](#)).

Mitigation Effect of MF on Crops Against Unfavourable Environments:

MF treatment mitigates the adverse effects of environmental stresses such as drought, salinity, heavy metal contamination, temperature extremes, and pathogenic infections (Vashisth & Nagarajan, 2010; Rathod & Anand, 2016; Trebbi et al., 2007). For instance, MF stimulates cambium differentiation and promotes water and nutrient uptake to enhance plant growth under drought conditions (Selim & El-Nady, 2011). Moreover, MF enhances photosynthesis, stomatal conductance, and transpiration in salt-affected plants, improving their tolerance to salinity stress (Baghel et al., 2016).

Conclusion:

In conclusion, MF therapy holds significant promise for enhancing plant tolerance against abiotic and biotic stresses. By understanding the physiological changes induced by MF, we can develop strategies to improve crop resilience and productivity in the face of environmental challenges.

Materials:

- 7 golden wax garden bean seeds
- Overall testing kit
 - 2 overall golden wax garden bean seeds
 - + 1 control golden wax garden bean seed
 - 2 similar containers
 - 1 to store both overall seeds
 - 1 to store control seeds
 - aluminum foil
 - to wrap containers
 - block sunlight
- 1 Multimeter
- 4 dual end, alligator clip, covered, lead wires
 - 2 extra
- 1 long Arcor 22 AWG bare copper wire (2 oz)
 - 810 cm
 - Enough to make 100 loops on a ($\sim 6.28\text{cm}$ (2π) circumference of base x 21cm length) metal rod
- 3 3 duracell D batteries
- 3 battery holder
- 1 ($\sim 6.28\text{cm}$ (2π) circumference of base x 21cm length) metal rod
- Wooden sheet (30cmL x 0.2cmH x 25cmW)
- Styrofoam base (60cmL x 12cmH x 53cmW)

- 6 plastic, clear cups
- potting mix
 - Company = Floral
 - pH 6.5
- 1 cm ruler
- Syringe (mL)
 - To feed water to plants

Procedure:

1. Place a (30cmL x 0.2cmH x 25cmW) wooden sheet on top of a (60cmL x 12cmH x 53cmW) styrofoam base
2. Wrap the metal rod with 100 loops of the copper wire
3. Connect 3 duracell D Batteries to the battery holder
4. Attach each battery holder by connecting them in front of each other, creating a line.
5. Place the line of batteries on one of the ends of the wooden sheet
6. Connect 2 covered lead wires to battery
 - a. One wire on each side
7. Place metal rod on wooden part with the copper wire ends (that are sticking out) facing the covered lead wires
8. Place 2 compass near the outside side of the metal rod
 - a. to detect if the magnetic field is being generated
 - b. To find which side is south and which is north
9. Connect the covered lead wire to the copper wire
10. Measure the how strong the current is using a multimeter
 - a. Conduct $\sim 4105 \Omega$ (hertz)
11. Take 6 seeds and split them into 3 pairs: 30m, 1hr, and 2 hrs
12. Among this pairs, give one seed role of North and the other role of South
13. Place the remaining seed nearby—on the side—where the radiation isn't affecting it; this is the control seed.

14. Place all the north seeds on the north end of the field, where the currents are flowing away from the rod.
 - a. The embryo should be facing the metal rod
15. Place all the south seeds on the south end of the field, where the currents are flowing towards the rod.
 - a. The embryo should be facing the metal rod
16. Set 3 timers: one for 30 min, 1hr, 2hr
17. After the 30 minutes alarm goes off, take the 30 minute seed pair out and plant them based on the planting procedure above
18. After the 1 hour alarm goes off, take the 1 hr seed pair out and plant them based on the planting procedure above
19. Also, place overall 1 on the north end and overall 2 on the south end

→ They will be exposed to 1 hr because that is the middle of all the exposure times as i can't find a study that may hint what is the ideal exposure time.

 - a. Place the overall control on the side near the other control, where the magnetic field radiation won't reach
 - b. The embryo should be facing the metal rod
20. After the 2 hours alarm goes off, plant all the remaining seeds (don't forget about the controls) using the planting procedure above
 - a. Including the overalls since this was the last testing
21. Clean up everything and observe the plants

Observations:

Watering Table:

Date and day	Amount (mL)
Jan 2 2024, day 1	5 mL
Jan 3 2024, day 2	5 mL
Jan 4 2024, day 3	5 mL
Jan 5 2024, day 4	3 mL
Jan 6 2024, day 5	5 mL
Jan 8 2024, day 7	5 mL
Jan 9 2024, day 8	3 mL

Jan 10 2024, day 9	5 mL
Jan 11 2024, day 10	5 mL
Jan 12 2024, day 11	3 mL
Jan 13 2024, day 12	5 mL
Jan 14 2024, day 13	5 mL
Jan 15 2024, day 14	5 mL
Jan 16 2024, day 15	5 mL
Jan 17 2024, day 16	3 mL
Jan 18 2024, day 17	3 mL
Jan 19 2024, day 18	5 mL
Jan 20 2024, day 19	5 mL
Jan 21 2024, day 20	3 mL
Jan 22 2024, day 21	5 mL
Jan 23 2024, day 22	5 mL
Jan 24 2024, day 23	3 mL
Jan 25 2024, day 24	3 mL
Jan 27 2024, day 26	5 mL
Jan 28 2024, day 27	3 mL
Jan 29 2024, day 28	5 mL
Jan 30 2024, day 29	3 mL
Jan 31 2024, day 30	3 mL

Weekly Germination Table:

Control

Height (cm)	Date and Day
Sprout at 5 cm	Jan 11 2024, day 10
21 cm	Jan 16 2024, day 15
30 cm	Jan 25 2024, day 24
32 cm	Jan 31 2024, day 30

30 minutes on South side

Height (cm)	Date and Day
sprout at 1 cm, 1.5 cm	Jan 7 2024, day 6

8 cm , 6 cm	Jan 11 2024, day 10
32 cm, 22 cm	Jan 16 2024, day 15
35 cm, 25 cm	Jan 25 2024, day 24
38 cm, 30 cm	Jan 31 2024, day 30

30 minutes on North side

Didn't sprout	

1 hour on South side

Didn't sprout	

1 hour on North side

Didn't sprout	

2 hours on South side

Height (cm)	Date and Day
Sprout at 2 cm	Jan 11 2024, day 10
13 cm	Jan 16 2024, day 15
26 cm, 0.5 cm sprout	Jan 25 2024, day 24
29 cm, 4 cm	Jan 31 2024, day 30

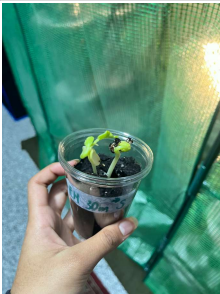
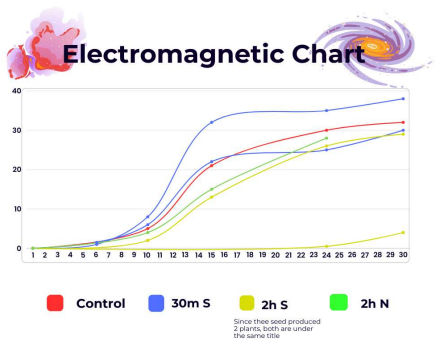
2 hours on North side

Height (cm)	Date and Day
Sprout at 4 cm	Jan 11 2024, day 10
15 cm	Jan 16 2024, day 15
28 cm -> (new pot) 23 cm	Jan 25 2024, day 24

Summary Table And Germination Chart:

Type of Seed:	Growth rate	Appearance and extra
Control	Growth was steady and predictable	Appearance matched the general look of this species

30 min North	No sprouting	
30 min South	Had the fastest germination rate, quite faster than the control seed	All seeds exposed to the south end grew two plants, especially this one with almost identical plants with similar germination rate.
1 hr North	No sprouting	
1 hr South	No sprouting	
2 hr North	Did better than the south 2hrs but slower then the control	Looked similar to the control
2 hr South	Slowest germination rate→ could be because the second plant negatively affects germination as the plant will need to divide its nutrition to the other plant	All seeds exposed to the south end grew two plants. Had a smaller second plant with highly strong and durable leaves (not flexible and easy to break).



Note: I was not able to add it but the vertical axis is the plant's measurement in cm, and the horizontal line is the number of days (e.g. 1st day is when it is planted so the day the testing finishes).

Analysis and Discussion:

This experiment aimed to figure out the impact of magnetic field (MF) radiation on seed germination, with a particular focus on potential effects on the seed coat, moisture absorption, and genetic modifications. My hypothesis was that MF exposure would augment germination, facilitating seed coat penetration, speeding moisture absorption, and potentially even inducing genetic modifications such as increased glucose production or heightened hydrogen and hydroxyl atom generation.

Similar to the initial hypothesis, an extended exposure to magnetic radiation resulted in a slower germination rate in comparison to the control seed. Moreover, weaker seeds exposed to one hour of MF radiation exhibited reduced viability, suggesting a dose-dependent relationship where excessive exposure may adversely affect embryo development. This aligns with the initial hypothesis, suggesting that the prolonged radiation may surpass the seed coat, leading to potential harm to the embryo and an elevated risk of negative mutations.

Meanwhile, seeds exposed to 30 minutes of magnetic radiation displayed a superior germination performance compared to the control group. This unexpected result suggests that a moderate dose of MF may optimally penetrate the seed coat, facilitating efficient moisture absorption and creating a strong environment for germination. Lower doses of radiation were also observed to mitigate mutation risks, thereby reducing the probability of negative mutations.

However, a shocking discovery emerged concerning seeds placed at the south end, where magnetic waves traversed the stored food component before reaching the embryo. This particular group exhibited a dual plant sprouting phenomenon, a phenomenon I haven't heard. While I don't know the exact reason why this happened, two possible theories I am considering .

The first theory suggests that magnetic waves were modified during their trajectory, inducing a specific mutation responsible for the increased number of embryos, like causing a mutation in the plant's hormones—such as the Gibberellins or Cytokines hormones, when passing through the stored food first. The second, most likely not right, theory suggests that magnetic radiation directly mutated the stored food, prompting it to develop into an embryo. However, discrepancies in growth patterns and embryo development between seeds exposed to the south and north ends don't add up to this theory.

According to this theory, the stored food, having been directly mutated, should have exhibited a robust embryo growth pattern. Contrary to this expectation, the observed growth patterns of the 2 horse exposed seeds and overall seeds revealed an unexpected outcome, where the seeds demonstrated a smaller and slower extra embryo plant compared to the 30 minutes exposed south-end seed. Additionally, the main embryo in the south-end seeds exhibited a growth rate nearly identical to its counterpart exposed to the north end. This inconsistency challenges the accuracy of the second theory and underscores the need for a more nuanced understanding of the factors at play in the observed phenomenon. Further research is imperative to unravel the intricacies surrounding the anomalous dual plant sprouting phenomenon, providing a comprehensive explanation for the observed disparities in growth patterns between the north and south-end exposed seeds.

In conclusion, this experiment yielded intricate results, revealing both anticipated and unexpected effects of magnetic field radiation on seed germination. The occurrence of dual plant sprouting in the south-end seeds presents an intriguing result for further investigation, necessitating an expanded dataset and more comprehensive analysis to formulate a conclusive explanation. Future research needed, providing a more nuanced understanding of how magnetic field radiation influences seed germination and development

Ionized Radiation effect on Plants Study:

Gamma Radiation effect on plant germination and seed study:

Abstract

Gamma radiation, a form of magnetic radiation emitted from radioactive atoms, has been investigated for its effects on seed germination and seedling growth in various plant species. Studies have shown contradictory outcomes, with some indicating stimulatory effects at low doses and inhibitory effects at higher doses. Research on *Lathyrus chrysanthus* seeds and on maize seeds have demonstrated dose-dependent responses in germination percentage, root and shoot lengths, and pigment content (Mashev et al, 2013) (Suhaj et al, 2016). Understanding these dose-dependent effects is crucial for optimizing the use of gamma radiation in agriculture while minimizing potential adverse effects.

Introduction

Gamma rays are a form of magnetic radiation with high energy and short wavelengths, emitted from the nucleus of radioactive atoms. They have diverse applications ranging from medical treatments to industrial processes. In agricultural contexts, gamma radiation has been explored for its effects on seed germination and plant growth.

Study Objective

This scientific study aims to investigate the effects of gamma ray exposure on seed germination and seedling growth of various plant species.

Literature Review

Previous research has shown contradictory findings regarding the impact of gamma radiation on seeds. Some studies suggest that low doses of gamma radiation can stimulate seed germination and enhance seedling growth (Abdel-Hady et al., 2013; Fan et al., 2014) (Sjodin et al., 2015). Conversely, higher doses have been associated with inhibitory effects on seed germination and plant development (Mashev et al., 2013) (Chaudhuri et al., 2017).

Gamma Ray Effects on Plant Germination and Growth

The effects of gamma radiation on seed germination and seedling growth have been investigated in several studies. For instance, a study examined the impact of different doses of gamma rays on *Lathyrus chrysanthus* seeds ([Mashev et al, 2013](#)). They found that while low doses of gamma radiation increased seed germination percentage and seedling growth, higher doses led to significant decreases in these parameters ([Mashev et al, 2013](#)).

Similarly, some research has investigated the effects of gamma radiation on maize seeds ([Suhaj et al, 2016](#)). They observed a dose-dependent decrease in seed germination percentage and root/shoot lengths with increasing gamma doses ([Suhaj et al, 2016](#)). Additionally, pigment content analysis revealed a decline in chlorophyll and carotenoid levels in irradiated samples compared to controls ([Suhaj et al, 2016](#)).

Conclusion

In conclusion, gamma radiation exerts variable effects on seed germination and seedling growth depending on the dose applied. While low doses may stimulate germination and growth, higher doses tend to inhibit these processes. Understanding the impact of gamma radiation on plants is essential for optimizing its use in agricultural practices and mitigating potential negative effects.

Introduction:

Radiation treatments have long been utilized in mutation breeding to induce genetic variation and develop new crop varieties with desirable traits. (Nilan et al, 1965) defined effectiveness as the mutation rate relative to dose and efficiency as the mutation rate relative to other biological effects induced. Understanding the comparative effectiveness and efficiency of different forms of radiation, including gamma-rays, neutrons, alpha particles, and protons, is essential for optimizing mutation breeding protocols.

Gamma rays, a form of magnetic radiation, have been widely used in mutation breeding due to their penetrating ability and ease of application (Gaul, 1960). However, their effectiveness and efficiency compared to other forms of radiation remain a subject of investigation.

Results:

- Neutron exposure yielded the highest mutation rate per cell, followed by alpha radiation and gamma-rays (Nilan et al., 1965).
- The mutation rate per cell increased linearly with increasing total dose, although higher doses led to undesirable effects in M1 plants.
- Proton exposure demonstrated significant potential, particularly in internal exposure scenarios involving boron enrichment (Ukai et al., 2009b).
- Biological effectiveness varied among different radiation types, with some forms of radiation inducing more severe effects on germination rate, seedling height, and seed fertility compared to others.
- The relationship between mutation rate and biological effects differed among radiation types, highlighting the importance of considering both effectiveness and efficiency in mutation breeding.

Discussion:

The findings suggest that neutron exposure is the most effective form of radiation for inducing mutations in plants, followed by alpha radiation, gamma-rays, and protons

([Nilan et al., 1965](#)). However, the efficiency of radiation treatments must also be considered, as higher doses may lead to undesirable effects on plant growth and development. Proton exposure shows promise, particularly in scenarios involving boron enrichment ([Ukai et al., 2009b](#)), but further research is needed to optimise its use in mutation breeding.

Conclusion:

In conclusion, this study provides insights into the comparative effectiveness and efficiency of radiation treatments in mutation breeding. Neutron exposure remains the most effective form of radiation for inducing mutations ([Nilan et al., 1965](#)), but considerations of efficiency are essential for optimising mutation breeding protocols. Proton exposure, particularly in conjunction with boron enrichment, shows potential for enhancing mutation breeding efforts and developing new crop varieties with desirable traits. Further research is needed to explore the practical applications of different forms of radiation in mutation breeding and agricultural practices.

Beta Radiation effect on plant germination and seed study:

Introduction:

Beta radiation is commonly employed in mutation breeding to induce genetic variation and enhance desirable traits in crops like “Phaseolus vulgaris” ([Roy, 2000](#)). Understanding the effects of beta radiation on growth parameters is crucial for optimizing mutation breeding protocols. This study aims to analyse the impact of beta radiation on germination speed, germination percentage, radicle growth, and overall plant growth in different varieties of “Phaseolus vulgaris”([Roy, 2000](#)).

Data Analysis:

Analysis of variance was conducted to evaluate the effect of radiation dose on various growth parameters. Fisher's Least Significant Difference (LSD) test at a 5% probability level was employed for mean comparison using the statistical program SPSS ([Roy, 2000](#)).

Results and Discussions:

Germination Speed and Germination Percentage:

Higher doses of beta irradiation significantly delay germination speed and percentage, with lower doses showing a slight increase compared to non-irradiated seeds (Roy, 2000).

Radicle Growth:

Beta radiation doses have a significant effect on radicle lengths, with lower doses stimulating growth in most varieties. However, higher doses lead to a decrease in radicle length growth, indicating a dose-dependent response (Roy, 2000).

Plant Growth Parameters:

- Seeds exposed to higher doses exhibit reduced root and shoot growth, as well as a decrease in the number of leaves and branches (Roy, 2000).
- Stimulatory effects are observed at lower doses, with significant increases in growth parameters compared to control groups (Charbaji & Nabulsi, 1999; Thapa, 2004; Klarizze, 2005; Chicea & Racuciu, 2007).
- Higher doses result in a negative impact on growth parameters, suggesting dose-dependent inhibition of plant growth (Kharkwal, 2000).
- Stimulation at lower doses may be attributed to accelerated cell division or activation of growth regulators, while the retarding effect of higher doses could be due to seed injury caused by irradiation effects (Zaka, 2004; Akhaury & Singh, 1993; Mehetre et al., 1994; Thapa, 1999).

Conclusion:

In conclusion, beta radiation exposure affects various growth parameters differently in different varieties of *Phaseolus vulgaris*. While lower doses stimulate growth, higher doses inhibit growth, indicating a dose-dependent response. Understanding these effects is crucial for optimizing mutation breeding strategies and developing new crop varieties with desirable traits. Further research is needed to elucidate the underlying mechanisms of beta radiation effects on plant growth and to refine mutation breeding protocols accordingly.

X-ray Radiation effect on plant germination and seed study:

Introduction:

X-ray radiation has been used in various applications, including seed quality assessment, since its first application on seeds by Lundstrom in 1903. While X-rays can provide valuable information about seed characteristics such as embryo number, size, shape, and density, their effects on seed germination and growth remain a subject of interest and investigation (Stark & Adams, 1963; Haff & Slaughter, 2004). This study aims to examine the impact of X-ray radiation exposure on the germination and growth of “Phaseolus vulgaris” seeds (Gagliardi & Marcos-Filho, 2011).

Results:

The results indicate that unexposed seeds germinated first and grew to be the tallest. Seeds exposed to X-rays nine times ranked second in terms of germination and growth, followed by seeds exposed three times, and finally seeds exposed six times, which exhibited the slowest germination and growth and were the shortest in stature (Gagliardi & Marcos-Filho, 2011).

Conclusions/Discussion:

Contrary to the hypothesis that X-ray radiation would slow seed growth, the experimental results suggest that the number of X-ray exposures did not significantly affect seed germination and growth in “Phaseolus vulgaris” (Lundstrom, 1903). This discrepancy between the hypothesis and experimental outcomes may be attributed to differences in the response of plant cells compared to human cells to radiation exposure. While human cells may exhibit adverse effects from relatively low doses of radiation, plant cells may require higher doses before exhibiting any noticeable reactions. Additionally, X-ray radiation may primarily affect external seed characteristics rather than physiological processes related to germination and growth (Gagliardi & Marcos-Filho, 2011).

Future Directions:

Further research is needed to elucidate the mechanisms underlying the effects of X-ray radiation on seed germination and growth in “Phaseolus vulgaris.” Investigating the threshold dose of radiation required to induce observable effects on seed physiology and growth could provide valuable insights for optimizing X-ray radiation applications in seed quality assessment and crop improvement programs. Additionally, exploring the potential use of contrast chemicals in conjunction with X-ray imaging to assess seed viability and detect mechanical damage warrants further investigation (Gagliardi & Marcos-Filho, 2011).

Overall Seed:

- Stored in containers
 - 2 similar containers
 - 1 for the 2 exposed overall seeds
 - 1 for the 1 control overall seed
 - Wrapped in aluminum foil
 - Block sunlight

Hypothesis:

I hypothesize that both overalls will have a slower germination, even die, because each one of these exposures itself can harm the plant if a bit much is given. Thus, with so many of these tests layered on top of each other on this one seed, there is a high chance that the overall seeds won't be able to handle this much exposure.

Overall 1:

- Microwave testing: 15 seconds exposure
 - Best result time
 - (Microwave Plant Experiment: Radish Seed Germination | Science Project | Education.com, n.d.)
- Vacuum testing: 38% vacuum
- magnetic field testing: 1 hr of $\sim 4105 \text{ } \Omega$ of magnetic field radiation on the north end
- UV testing: $73 \text{ } \mu\text{W}/\text{cm}^2$ (5 cm away from the UV source)
- Microgravity: rotating at a level of 15 rpm (rotations per minute)

Overall 2:

- Microwave testing: 15 seconds exposure
 - Best result time
 - (Microwave Plant Experiment: Radish Seed Germination | Science Project | Education.com, n.d.)
- Vacuum testing: 38% vacuum
- magnetic field testing: 1 hr of $\sim 4105 \text{ } \Omega$ of magnetic field

radiation on the south end

- UV testing: $7\mu W/cm^2$ (17 cm away from the UV source)
- Microgravity: rotating at a level of 15 rpm (rotations per minute)

Watering Table:

Day and date	Amount of water (mL)
Jan 1 2024, day 1	5 mL
Jan 2 2024, day 2	5 mL
Jan 3 2024, day 3	5 mL
Jan 4 2024, day 4	5 mL
Jan 5 2024, day 5	5 mL
Jan 6 2024, day 6	5 mL
Jan 7 2024, day 7	5 mL
Jan 8 2024, day 8	3 mL
Jan 9 2024, day 9	5 mL
Jan 11 2024, day 11	5 mL
Jan 12 2024, day 12	5 mL
Jan 13 2024, day 13	3 mL
Jan 14 2024, day 14	3 mL
Jan 15 2024, day 15	3 mL
Jan 16 2024, day 16	3 mL
Jan 17 2024, day 17	5 mL
Jan 18 2024, day 18	5 mL
Jan 20 2024, day 20	5 mL
Jan 21 2024, day 21	3 mL
Jan 22 2024, day 22	3 mL
Jan 23 2024, day 23	3 mL
Jan 24 2024, day 24	5 mL
Jan 25 2024, day 25	5 mL
Jan 26 2024, day 26	3 mL
Jan 27 2024, day 27	3 mL
Jan 28 2024, day 28	3 mL
Jan 29 2024, day 29	5 mL
Jan 30 2024, day 30	5 mL

Weekly Germination Table:

Control

Didn't sprout	→ for graph used the average growth of all the control plants to graph

1

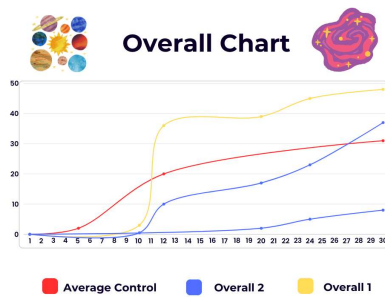
Height (cm)	Date and Day
Sprout at 2 cm	Jan 11 - 7
36 cm	Jan 16 - 12
38 cm ->	Jan 25 - 21

2

Height (cm)	Date and Day
Sprout at 0.5 cm	Jan 16 - 12
17 cm, 2 cm	Jan 25 - 21

Summary Table And Germination Chart:

Type of Seed:	Growth rate	Appearance and extra
Control	N/A	N/A
Overall 1	Germination rate was extremely high compared to the average control rate	Had similar characteristics as control seeds usually have at the 30 day mark
Overall 2	Though the germination rate was much slower than Overall 1, it was still relatively high compared to the average control	The Overall 2 seed had grown 2 plants, I suspect it is from its exposure to the south side of the magnetic field radiation because all the other exposed seeds also grew 2 plants.



Note: I was not able to add it but the vertical axis is the plant's measurement in cm, and the horizontal line is the number of days (e.g. 1st day is when it is planted so the day the testing finishes).

Additionally, since overall 2 seed sprouted two stems, there are 2 lines representing each stem's growth.

Analysis and Discussion:

This experiment's objective was to assess the influence of space elements on seed germination, driven by the curiosity surrounding potential hazards and advantages of germinating seeds in a space environment. This inquiry stemmed from a consideration of future space exploration scenarios where astronauts might cultivate plants for sustenance, prompting an exploration into the effects of space-related factors on seed germination. The overarching goal was to uncover any potential challenges or benefits associated with seed germination in the space's unique conditions as they are transported on spacecrafts.

Despite the theoretical expectation that various strong space elements could be detrimental to seed germination, the results surprisingly demonstrated a positive impact on the germination process. Seeds exposed to a combination of space-related components, which individually might have been expected to either harm the seed or accelerate germination, exhibited remarkable resilience and positive outcomes. This unexpected success could be attributed to the seeds adapting to diverse environments or, alternatively, each component affecting different parts of the embryo beyond the seed coat.

One noteworthy phenomenon that surfaced during the experiment was akin to the Sakura in space phenomenon. In this context, despite the strong seed coats or potentially weak embryos, extensive space radiation exposure seemed to crack the seed coat, providing seeds with a conducive environment, more water intakes, and an opportunity for positive mutations. As a result, the sakura seeds had demonstrated a growth and even one seed's germination speeding six times faster than the normal germination of the sakura tree, highlighting the potential for accelerated growth in space conditions.

The resilience and enhanced germination observed in the seeds exposed to space elements suggest a possible adaptation mechanism or a unique response to extraterrestrial conditions. While some testing components had the potential to cause harm, the majority exhibited positive effects, leading to an overall faster growth rate. This phenomenon could be attributed to the seeds having acclimated to different environments and showcasing an adaptive advantage under the influence of space-related elements.

This experiment opens a new way for understanding the dynamics of seed germination in space and underscores the potential for extraterrestrial agriculture. The positive outcomes observed in the face of challenging conditions hint at the adaptability of seeds and offer valuable insights for future space missions involving plant cultivation. Further research into the underlying mechanisms and long-term effects will contribute to our understanding of plant responses to space environments and inform future endeavors in extraterrestrial agriculture.

Implications:

Understanding the Science to make predictions:

By understanding and studying the chemistry and microbiology behind these reactions through projects like Mission: Seed In Space, it can allow scientists to make predictions that can help with many issues such as those listed below:

Challenge or Prove existing theories:

- Sakura in Space mystery
 - Explains why the holy trees sakura sprouted so well and why the 118 other types of cherry blossom seeds didn't sprout.

As seen in the overall testing, the reason why this holy cherry blossom tree's seeds germinated so well was because the different components most likely didn't affect the seed at the same point or the same way because most components have their independent "frequencies," like how string theories suggestions for parallel universes in our midst that we cannot sense because they are in different frequencies we cannot detect. However, 118 seeds did not sprout. This is most likely because space components are all at very high and abnormal levels, the components we tested with had extremely low and harmless levels such as only 38-42% vacuum (unlike space with a near-perfect vacuum). Moreover, the ones that did sprout already had a hard

time sprouting on earth, so, for them, the strength was just the right amount to allow them to sprout and maybe even give them a boost.

In unravelling the Sakura in Space mystery, the Mission: Seed in Space project sheds light on the remarkable germination of the sacred sakura tree seeds, contrasting starkly with the failure of 118 other cherry blossom seed varieties to sprout.

Through the overall testing, it became evident that the results of the cherry blossom seeds could be attributed to a unique interplay of factors. It appears that the diverse components encountered in space likely impacted the seeds differently, operating on distinct "frequencies" akin to the elusive parallel universes posited by string theory. Much like these imperceptible realms, these frequencies affect different parts. Therefore, because they positively affected different parts of the seeds, the seed, overall, had a strong improvement.

Conversely, the lack of germination among the 118 seed varieties can be attributed to the extreme conditions prevailing in space. Unlike the benign environment simulated in our testing, space is characterized by extraordinarily high and abnormal levels of various components. For instance, while our tests simulated a mere 38-42% vacuum, space presents a near-perfect vacuum, imposing formidable challenges to seed germination.

Interestingly, the seeds that did manage to sprout likely did so due to their inherent resilience. These varieties, which already faced difficulties germinating on Earth, may have found the slightly elevated strength of space conditions conducive to their growth, providing them with the necessary impetus to sprout and thrive.

- RAD–SEED NASA project to discover other, unknown space components

While it may not offer direct insights, a reiteration of the Seed In Space project aligning with NASA's RAD–SEED project variables could yield valuable comparisons. By employing identical seed types and assessing various exposure strengths and environmental variables, researchers could not only discern the effects on seed viability but also uncover any unexplained phenomena beyond individual component testing. Such anomalies might signify the presence of additional unknown space components.

Moreover, the plants themselves serve as indirect conduits for unravelling this mystery. Through careful observation of plant reactions, scientists can glean valuable

insights and make informed conjectures regarding the elusive component's nature and impact.

Aid in solving global issues:

- Food Scarcity and Global Warming

Through the innovative Seed in Space project, scientists can find solutions to healthy and safe plant mutation breeding ([Tarakanov, 2022](#)), offering a promising avenue to accelerate plant growth rates and combat food scarcity on a global scale. This groundbreaking endeavour not only holds the potential to enhance agricultural productivity but also contributes to reducing the effects of climate change by bolstering the role of plants in carbon sequestration through increased photosynthesis.

Based on my research, UV radiation works better than microwave radiation exposure in treating seeds. UV radiation not only consumes less energy but also yields superior results, presenting a safer alternative due to plants' inherent adaptation to solar UV exposure throughout their lifecycle. The familiarity of plants with UV radiation renders their seeds more resilient to its effects compared to microwave radiation, as evidenced by the data showcasing a more gradual reaction to UV exposure.

For instance, in the case of golden wax bush bean seeds, optimal UV radiation treatment falls within the range of 2 to 7 $\mu W/cm^2$ over a 24-hour period, primarily targeting the side housing the hilum and embryo, which, as observed in magnetic field radiation testing, plays a pivotal role in maximising the seeds' response. Depending on individual seed resilience, this tailored approach can yield a notable increase in growth rates, ranging from 0.2 to 0.4 cm/day above the typical growth rate of approximately 1.1 cm/day.

However, before implementing these methodologies at scale, it is important to ensure the safety and nutritional integrity of the resulting food products—beans, preventing potential concerns such as the emergence of allergens like gluten in wheat varieties.

Advancing and better preparing space missions:

As civilization expands its reach into space, the prospect of inhabiting and exploring other celestial bodies like Mars garners increasing attention from scientists. Yet, the success of such endeavours hinges on establishing a stable food source in these extraterrestrial environments. Understanding how different seeds react to various space components is therefore important, as even in controlled laboratory settings, seeds are inevitably exposed, particularly during transportation. Despite the robust construction of modern spacecraft and stations, formidable radiation, such as ionizing radiation and Galactic Cosmic Radiation (GCR), can permeate them with relative ease, significantly impacting transported seeds ([Why Space Radiation Matters - NASA, 2017](#)).

By comprehending the effects of these potent space components on seeds, scientists can not only prevent their negative impacts but also harness them to enhance seed and plant growth. This was evident in the project, where exposure to a magnetic field induced mutations in yellow wax bush bean seeds, resulting in the production of twin plants and thereby doubling food production and oxygen generation through photosynthesis. Furthermore, insights gained from studying plant responses to their surroundings hold implications beyond agriculture; they offer valuable parallels for understanding human and animal biology, given the significant genetic overlap between plants and animals. Studies have revealed that 20-60% of our genes are shared with plants ([What Is the Difference between the DNA of a Cactus and Human? - the Tech Interactive, 2024](#)), suggesting that if a space component were found to profoundly alter a gene within this shared percentage, it could potentially, unknowingly affect humans.

Project's Conclusion and Discussion:

In this project, I aimed to understand how seeds' germination and structure are affected by different known space components. Inspired by the Sakura in Space incident ([Lemonick, 2014](#)), I felt this underrated topic was crucial as it can not only prevent issues for astronauts transporting seeds but also help identify any unknown components of space affecting plants and contribute to solving Earth's ongoing issues like food scarcity or agricultural problems caused by technological interference. I conducted several experiments and short studies regarding different space components, including microwave radiation, UV radiation, microgravity, vacuum, extreme temperatures, helium environment, and magnetic field radiation, ending with many helpful and astonishing findings.

I had to conduct the microwave testing twice due to some watering issues in my first round. However, though the seeds died, it left a valuable discovery which is very important to note in seed transportation through space or even the increase of the use of radiation mutagenesis. Through the extra watering, it was discovered that seeds

become more sensitive to water and generally more vulnerable because most radiation ends up cracking or breaking the seed coat, which is beneficial as it gives a plant a route to sprout and lets moisture in, but it also causes it to be sensitive to too much water as there is a weaker barrier protecting the embryo, making them more prone to die from outer sources such as germs. The second round of microwave testing demonstrated how, once again, the right dose of radiation could be helpful but also overdose could cause negative effects on the plant, if not kill it, as overdose would not only completely break the seed coat, making the seed more vulnerable, but also increase a seed's chances for negative mutations. This was observed in both 60-second exposed seeds. However, with the right balance and the right seed, radiation can have a positive effect since it can crack the seed coat, allowing moisture and a pathway to aid the seed in speeding up its germination, and could give rise to a positive mutation without having the chances of too many mutations. This was observed in one of the plants in both 15-second exposed seeds and 30-second exposed seeds.

To further explore the notion of the perfect balance, the UV results showed similar outcomes, where the exposure with the best results was at 17 uW/cm^2 , near the middle exposure levels, being the second-lowest exposure. The higher exposed seeds did worse than the lower exposed seeds but better than the control, showing that although the seed coat had helped and there might have been positive mutations, the radiation started giving negative effects due to overdose. Meanwhile, the lowest exposure rate (2 uW/cm^2) was under the 17 uW/cm^2 seeds' germination rate on the graph, suggesting that the seed might have had too little exposure, preventing it from reaching the peak of the exposure balance. This would mean the radiation wasn't strong enough to penetrate the seed coat properly. On the other hand, the seeds placed in complete darkness didn't show any change in germination, having a similar germination rate as the control, which makes sense because seeds are in darker environments most of the time, and therefore shouldn't be affected.

Microgravity gave similar results, where there didn't seem to be any huge difference in seeds exposed to microgravity. This is probably because plants' statoliths, starch-filled plastids inside the statocytes, gravisensing cells, move alongside the change of gravity; therefore, it recovers a sense of gravity once it stopped spinning ([Levernier et al., 2021](#)). This theory also explains why clinostats have to continuously spin to simulate microgravity as if it stops the seed will once again regain a sense of gravity.

This result is also seen with the vacuum testing. In the testing, it was also seen the seeds in the vacuumed environment grew the same as the control. This may have been because the container had only been 42% vacuumed so the contents inside hadn't felt much affect. However, I still believe in a near-perfect vacuum like space, the seed

would be impacted since the air around a seed is extremely important as well([Roth, 1990](#)).However, it is important to take note that each type of seed can have a different response to these environments and testing and I only used one type throughout the testing, the golden garden bush bean seeds. This difference depending on seed is seen in the extreme temperature testing. In the temperature testing, there was a clear condition that did really well and one that did really bad. However, this was based on the seeds' breed environmental preferences. In the testing, the seed in a boiling hot environment did really well most likely because the hot steam may have softened the seed and its coat and provided the embryo with more moisture. Meanwhile, the seed exposed to freezing temperatures germination rate was lower than the control. This is solely based on the seeds' breed's preferences since bush beans are extremely sensitive to frost and colder environments ([How to Build a Microclimate for Your Tropical Plants, n.d.](#)). Thus, the seed had more problems germinating after being exposed to so much cold and frost.

The helium testing gave unexpected results with a helium environment actually benefiting the seeds. This was unexpected as I was unsure how the helium could have affected the embryo inside the seed and how it got past the seed coat. I am still unclear about this, but my best inference is that, like cold plasma helium, the helium was able to crack past the seed coat and since helium does affect seeds' genes positively, it was able to speed up the germination ([Brassica napus L. cv. Zhongshuang 9](#)).

Finally, the biggest mystery throughout this project is the magnetic field radiation testing. The germination of the seeds exposed was predicted based on the other testings, where the too strong radiation like 2 hrs exposure cut too far and ended up harming the seed and its germination, and the just right level like the 30 minutes exposure was able to speed up the germination by cracking the seed coat to allow moisture and a pathway for the plants. However, the strange thing was all the seeds placed on the south end where the waves are going through the stored food then the embryo, this somehow caused all the southside seeds to have 2 plants sprout from one seed. But, such a phenomenon is only possible in genetic mutations, such as mutations to the plant hormones, at the early production of the seed. This shows how strong of an impact mutations can have, making the impossible possible, and the strong possibility that, aside from the seed coat being penetrated, radiation also affects the plants genetics and hormones, aiding in either speeding up or slowing down the germination rate.

In summary, this study delved into the intricate dynamics between space environments and seed biology, offering insights crucial for both space exploration and terrestrial agriculture. From the vulnerability of seeds to radiation and the nuances of UV exposure to the unexpected benefits of helium environments, each experiment

illuminated different facets of plant adaptation beyond Earth's confines. Despite encountering mysteries like the phenomenon of two plants sprouting from a single seed under magnetic field radiation, these findings underscore the importance of continuous exploration and innovation. As we navigate the frontiers of space, let us not forget the profound implications of our research on Earth, fostering a future where scientific progress serves to sustain and enrich both our cosmic endeavours and our home planet.

Future Research:

In future research, armed with the necessary tools and under expert guidance, I'm eager to explore further dimensions of this project, recognizing its potential as a stepping stone into the fascinating realm of astrobotany. This field not only holds promise for addressing the challenges of human colonization beyond Earth but also offers solutions to pressing global issues like food scarcity .

If given the opportunity, my main focus would be on delving deeper into the magnetic south end phenomenon, where a single seed yields two distinct plants continuously. This intriguing occurrence, that I never heard of anywhere, warrants thorough investigation to understand its underlying mechanisms and potential applications in tackling food scarcity . Additionally, I aim to assess any changes in the properties of the resulting beans, prioritizing their safety and nutritional value for human consumption. In order to not repeat ongoing modified plants' problems, such as increase in toxicants ([Center for Food Safety | GE Food & Your Health | | GE Food & Your Health, n.d.](#)).

Furthermore, I'm interested in examining the effects of various space radiations, such as cosmic and ionizing radiation, on seed viability and germination rates. Equipped with the right equipment and guidance, I hope to shed light on the challenges these forms of radiation pose to plant growth in extraterrestrial environments as they are the most hazardous ones.

Lastly, I wish to conduct in-depth studies on each of these areas, building upon the preliminary findings of this project. By delving into the intricacies of these phenomena, I aim to contribute to the growing body of knowledge in astrobotany and deepen our understanding of plant biology beyond Earth's confines. These researches serve as an exciting opportunity to explore new frontiers and make meaningful contributions to scientific inquiry.

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Future Research:

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