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GROWTH OF LEPIDIUM SATIVUM SEEDS IN A 2G ENVIRONMENT

Victor M Rodriguez[1]

[1] *Affiliation not available*

Abstract

Cress seeds (Lepidium Sativum) were exposed to a 2g hypergravitational environment in a centrifuge for eight days to test the effects of such gravity on their germination and growth. The purpose of this research is to simulate the gravitational conditions experienced on a super-Earth exoplanet. An identical set of cress seeds were grown without exposure to hypergravity for eight days as a control. After four separate runs, measurements showed a decrease in the growth rate of the test group compared to the control group. This decrease varied with each of the four test runs. However, all test groups showed a lower growth rate than the control group, between 5.25% and 15.63%. This experiment showed that exposing cress seeds to hypergravity for an extended period will cause these plants to grow shorter relative to control groups. Understanding what mechanism causes slower growth is essential for understanding how life might arise, grow and evolve on other planets with greater mass than Earth.

1. INTRODUCTION

Since Duch eyeglass maker Hans Lippershey submitted his patent for what was to become the telescope, astronomers like Galileo and Kepler have been peering deep into the cosmos. King (1955) As Galileo turned his attention to the wandering stars of the sky, such as Venus and Jupiter, he noticed that they were not just stars but other worlds with phases, moons, and surface features. C. Wilson (1989) With observations of features that appeared to be seasonal vegetation growth and engineered structures on the surface of Mars, Astronomer Percival Lowell believed that life might exist on Mars, including intelligent civilizations. Lowell (1907)

Since astronomers Aleksander Wolszczan and Dale Frail discovered evidence of the first observed exoplanet orbiting pulsar PSR 1257+12 Wolszczan & Frail (1992), the focus of astrobiologists has been to discover habitable exoplanets. CA Beichman (1999) Since then, the mission team for the Kepler Space Observatory published 1235 exoplanet candidates, of which 288 or approximately 23.3% were considered super-Earths while 68 or roughly 5.5% were considered Earth-sized. The Kepler team described Earth-sized exoplanets as planets with a radius and super-Earths as planets with a radius greater than 1.25 times earth radius and less than or equal to 2.0 times the Earth's radius. Borucki et al. (2011) This survey of 1235 exoplanets suggests that super-Earths may be approximately 4.2 times more abundant than Earth-sized planets.

The Earth's magnetic field contributes to the habitability of Earth by protecting against atmospheric escape due to solar winds. Lazio et al. (2018) A comparison of the magnetic fields of Earth and Mars shows that the longevity of a magnetic field is directly proportional to a planet's size. Models suggest that the martian magnetic field may have dissipated roughly four billion years ago. Dehant et al. (2007) While life on Earth was just getting started under the protection of a magnetic field, Mars may have lost its magnetic field, lowering the probability that life arose at all on the red planet. Nutman et al. (2016) Models have shown that the probability of abiogenesis increases as a function of time. Kipping (2020) This suggests that super-Earth exoplanets may be more probable candidates in the search for extrasolar life. Since surface gravity depends on both the mass and radius of a planet, extrasolar life is more probable on planets larger than Earth. Bashi et al. (2017) Newton (1686)

This experiment aims to understand how life may evolve and adapt on a planet with twice Earth's surface gravity. The International Service of Weights and Measures has an adopted value for the acceleration due to gravity on Earth as 980.665 cm/s^{2}uni (2008), which is equivalent to 1g. In this research, samples of Lepidium sativum were subjected to 2g of gravitational acceleration for eight days to determine if the hypergravitational exposure affected plant growth.

2. MATERIALS AND METHODS

2.1. *Data*

The data collected and used in this paper were collected in the laboratory and deposited in the repository cited in the in text citation Rodriguez (2021) This repository includes the raw data, curated graphs and images used or created during the experiment in this paper. The data repository can be found at Mendeley Data and has a DOI of 10.17632/my3xfgmrb5.1.

2.2. *Sample Preparation*

A solution of 80mL distilled water, 1200mg agarose powder, 48mg Miricle Grow nutrient, and 7mg of activated charcoal powder was placed in a 100mL conical flask. After the solution was heated to a boil, 1500µl of the solution was added to forty-eight 2000 µl microcentrifuge tubes. The tubes cooled for 30 minutes. One seed was placed approximately 1 mm below the surface of the gel, and the tubes were closed. The samples were put into a refrigerator at between 0 and 5 degrees C for 24 hours.

Figure 1. Centrifuge with sample containers and LED light source

After 24 hours, the microcentrifuge tube caps were cut off, and each tube was taped together in groups of three. Each cluster of three was placed in a 20 cm long by 3 cm diameter PVC pipe. This PVC pipe was then affixed to a centrifuge, as shown in figure 1.

The centrifuge was built with a cluster of four LED lights. One of the LEDs generated white light, while the other three created light at 470, 645, and 660 nanometers. The centrifuge was capable of holding eight PVC pipes, each with three samples. Thus, the total sample capacity of the centrifuge was 24. The centrifuge was designed to generate 2g of simulated gravitational acceleration, with a swing bucket design to ensure the total gravitational acceleration vector was parallel to the PVC pipes and plant growth. The calculation used to determine the RPMs needed to produce the 2g of acceleration is as shown in equation 1.

Equation 1

$$\sqrt{\frac{g}{1.118\times10^{-5}r}} = Rpm$$

The control for this experiment was an apparatus with the identical LED light cluster and identical PVC pipes. The control apparatus was also able to hold 24 samples, with eight PVC pipes and three samples in each pipe.

2.3. *Experiment Process*

The centrifuge and control apparatus LED lights were programmed to be turned on and off in a 12-hour cycle. The samples were housed in a tent between 22 and 24 degrees Celsius with a 49%-51% relative humidity. Four groups of 24 test and 24 control samples were subjected to 2g of acceleration for eight days.

2.4. *Data Analysis*

After 192 hours of simulated hypergravity, the samples were removed from the PCV tubes. The plants were removed from the agarose gel and measured from root end to tip. Any samples which showed signs of contamination with mold were discounted from the set.

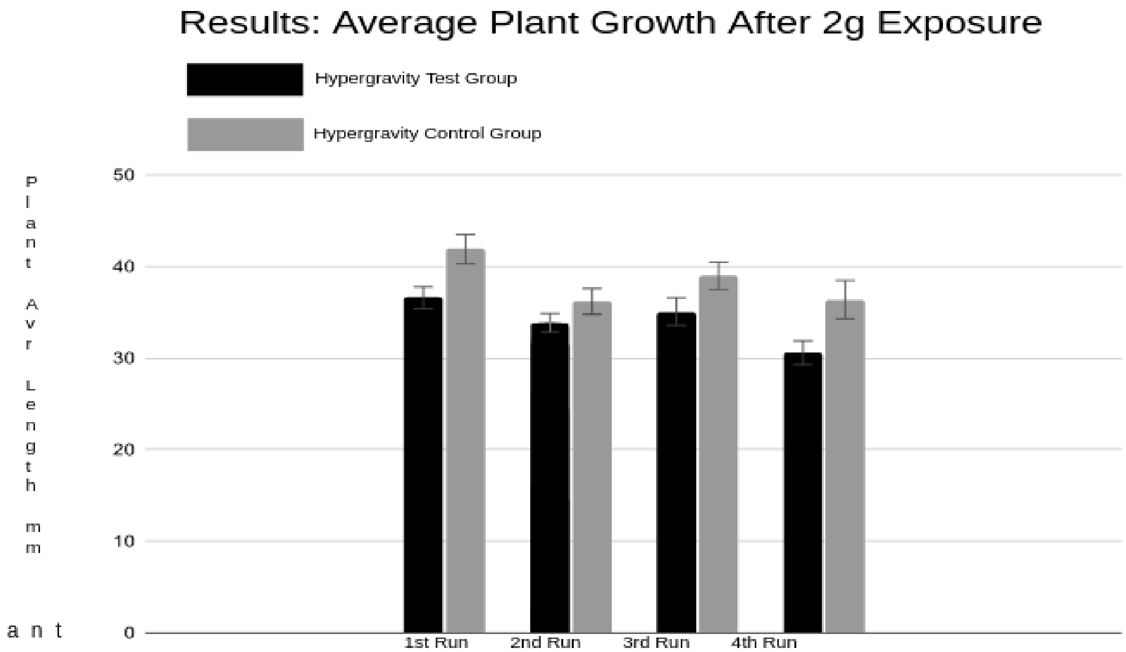

Figure 2. Data from four runs of 2g seed exposure

3. RESULTS

Figure 2 shows the data of each plant sample run. In all four runs, the test group average length was below the average for each control group. The average length of each test group ranged between 5.25% and 15.63% below the control group average length.Rodriguez (2021)

In total, eighteen samples did not germinate appropriately across the entire four-run experiment, with 7 test seeds and 11 control seeds failing to grow properly. No remarkable difference in germination success rate between the test group and the control group was observed. The data shows that when the Lepidium Sativum samples were exposed to a hypergravitational environment of 2g, the plants had a significant decrease in growth over eight days. Rodriguez (2021)

4. DISCUSSION

This study should serve as a starting point for further investigation into hypergravitational plant growth. A correlation between the increase in gravitational acceleration and a decrease in plant length was observed. It is still unclear to what degree the hypergravity stresses induced on the plants directly contributed to the retardation of vertical lengthening. Studies have shown that hypergravitational exposure affects plants beyond the gravitational force applied to the plant itself. Photosynthesis rates have been shown to increase in sweet potato and barley plants when subjected to hypergravitational stress. The researchers concluded that increased photosynthesis might have been caused by increased air convection rates, allowing for more efficient gas transfer on the leaf surfaces. Kitaya et al. (2001) A study by Miko U.F. Kirschbaum showed an increase in plant growth of 10 percent when the photosynthetic rates increased by 30 percent.Kirschbaum (2010)

It is unclear whether the increased convection currents enhanced or mitigated the growth rates in the test group subjected to hypergravity. More investigation is needed to determine the effects of hypergravitational stresses on plants with multi-generational exposure. The seeds grown in the test group were fertilized in a 1g environment, and the source plants for the seeds were never exposed to hypergravity. Therefore it is unclear whether the effects of hypergravity are compounded or become permanent across generations.

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