Effects of Space Travel on Seed Germination and Viability

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Effects of Space Travel on Seed Germination and Viability

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Introduction

Understanding space-environment effects on biological organisms like seeds will help plan for long duration space missions, such as those planned to Mars. In January 2016 students at Logan HS compared growth of the radish seeds flown in space to those that had stayed Earth-bound by growing them in soil in a controlled environment. LHS students recorded a trend of faster germination for the space seeds.

Methods

Following the initial LHS investigation in Jan 2016, the Fall 2016 germination experiments eliminated variable factors such as soil depth, soil moisture, and soil texture that could affect seed germination rate. The three seed groups included:
1) ground-based;
2) space-exposed from the Russian BION-M1 satellite;
3) shaken seeds, which experienced vibrations-only from a 15-minute “ride” in a paint-shaker.

For each trial 30 seeds/group were placed within a layer of damp paper towels and sealed in plastic bags (Fig. 2). Seeds that germinated within 15-hours were recorded over 4 trials (Fig. 4). The number of non-viable seeds were also recorded.

Germination Data

| Seed Coatings

| Comparison of Seed Germination Data
<table>
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<tr>
<td><strong>Germination Data Oct 2016– Jan 2017</strong></td>
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<tr>
<td><strong>Significantly Different?</strong></td>
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<tr>
<td><strong>Chi-Squared Value</strong></td>
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<td><strong>Ground vs Space</strong></td>
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<td><strong>Chi-Squared Value</strong></td>
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<td><strong>p Values</strong></td>
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Space and shaken seeds showed faster germination rates than untreated ground within the first 15 hours of water exposure. Space seeds had the highest germination rates. A Chi-Squared Analysis shows significant differences in germination rate among seeds. Both the space and shaken seeds germinate faster than the ground, with space seeds generating the fastest. Germination tests on irradiated seeds have not yet been completed.

Seed Coatings

Examination of the seed surfaces was done with both light and scanning electron microscopes. Light microscopy was facilitated by illuminating the seed surface from above with an external light source and using a Celestron digital microscope lens. Images from the scanning electron microscope were taken at the USU Microscopy Core Facility.

Seed surface images (Fig. 5) show that space seeds have the most surface proteins and ground seeds have the least. The shaken seeds represent a middle-ground. These physical differences provide insight into differing germination rates. Prior research (Terras, Eggermont, et al., 1995) indicates that 5-kD cysteine-rich anti-fungal surface proteins are produced when the seed is disturbed. Disturbances signal seed enzymes that the environment may allow for germination. Anti-fungal proteins protect the emerging plant embryo from harmful soil pathogens.

Production of these proteins through the cell wall may weaken the seed surface, allowing for faster uptake of water and subsequent emergence of the plant embryo.

Conclusion

Scientific studies have shown that radiation and vibration damages both living and nonliving components in many ways. We found these factors affect seeds. While faster germination may seem inconsequential or even beneficial when the end result for a seed is germination, we advise that the effects of radiation and vibration on crop seeds warrants further consideration when planning for long-term storage and space travel for three reasons.

First, continued disruption of the protective seed coat during the production of proteins likely leads to micro-fissures in the seed surface. During dormancy, these fissures could hasten water loss and/or degrade the embryo’s food source, leading to seed death.

Second, germination is different from viability. Not all embryos that germinate are viable. Physiological or genetic damage to embryos during dormancy or seed formation may not manifest until plant growth. This study looked at germination, not viability, for evaluating effects of space travel on long-term storage/use of crop seeds.

Third, faster germination does not always produce robust seedlings. Associated changes to seedling growth and enzymatic function should be studied, particularly if seed crops are intended for food production far from our Earth home.

Figure 1. The “space” seeds used in our tests took a 30-day flight on a Russian satellite in 2013. The BION-M1 mission studied effects of its LEO/Polar orbit on living organisms.

We identified different rates of germination in radish seeds between 3 sample groups: ground seeds, shaken seeds, and space-exposed seeds. Both the shaken and space-exposed seeds germinated significantly faster than ground. In addition, space seeds germinate significantly faster than shaken.

We believe changes in germination rates are caused by modification or damage to seed surfaces from abrasion during rocket launch or ionizing space radiation. Examination of the seed coats showed the enhanced production of surface proteins in space-exposed and shaken seeds. Previous research (Terras, Eggermont, et. al., 1995) has shown production of these proteins is initiated by disturbance.

Thus, with the help of the GEAR UP program at USH, a partnership with the Physics Department at USU and University of Tsukuba in Japan, further seed germination experiments have been designed to study effects from specific factors such as exposure to different levels of beta radiation and vibration. These experiments are currently ongoing and will continue into 2017.

Figure 2. Seed Germination

In January 2017, the germination experiment was expanded to include radish seeds exposed to different levels of beta radiation incurred in the SST Biological Test Chamber (Fig. 3). Effects of simulated beta radiation on germination rate are inconclusive, to date.

Radish seeds will also be exposed to intense vibration on a Robart Hobby Paint Shaker. The irradiated and vibrated seeds will be compared to untreated ground seeds.

Figure 3. SST Biological Test Chamber

Figure 4. Space and shaken seeds showed statistically faster germination rates than ground seeds. Space seeds had the highest germination rates.

Space and shaken seeds showed faster germination rates than untreated ground within the first 15 hours of water exposure. Space seeds had the highest germination rates. Tests with seeds exposed to beta radiation in an enclosed chamber have begun.

A Chi-Squared Analysis shows significant differences in germination rate among seeds. Both the space and shaken seeds germinate faster than the ground, with space seeds germinating the fastest. Germination tests on irradiated seeds have not yet been completed.

Figure 5. Seed images from light (top) and scanning electron (bottom) microscopes show changes to seed surfaces and wall protein structures due to vibration and radiation.