Effects of Radiation on Eukaryotic Organisms' Growth

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Introduction

- **Purposes of Research**
  - Determine if non-ionizing and ionizing radiation have an effect on growth for eukaryotic cells
  - Identify the threshold of radiation that is harmful for growth in model eukaryotic organisms

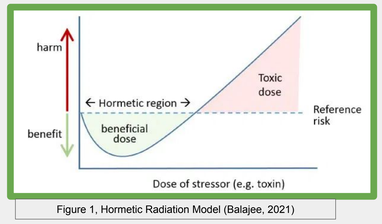


Figure 1, Hormetic Radiation Model (Balajee, 2021)

- **Benefits of Research**
  - Space has an increased amount of radiation, so determining how radiation can affect growth can reveal the prolonged effects of space travel, like Nasa's plan to go to Mars by 2030 (Ellis, 2021).
  - Knowing how much radiation is harmful can prevent deadly mutations including multiple types of cancers, and other diseases including cataracts, sterility, and radiation sickness (Balajee, 2021).
  - Understanding how radiation kills cells can help advance treatments that use radiation to cure cancer. (Balajee, 2021).

Background

- Radiation is energy that comes from a source. A radiation is part of the electromagnetic spectrum
  - Non-ionizing Radiation
    - Lower energy
    - Less risk to living organisms
  - Ionizing Radiation
    - Higher energy
    - Involves the decay of unstable atoms
    - May remove electrons from matter it passes through (ionization)
    - More risk to living organisms (CDC, 2015)
- In this project, the absorbed dose of radiation is measured in Krads

Figure 2, The Electromagnetic Spectrum (CDC, 2015)

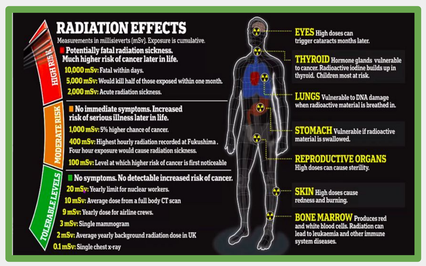


Figure 3, Radiation Effects on the Body (Balajee, 2021)

- Eukaryotic Organisms are exposed to radiation on a daily basis
  - Radiation sources include:
    - Cosmic Radiation (Sunlight)
    - Radioactive materials found in food, soil, and water (Radon)
    - Man-made sources (X-rays, Nuclear power, Nuclear weapons) (EPA, 2021)

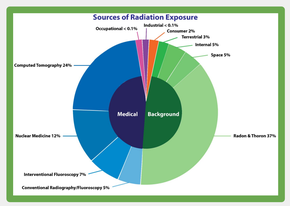


Figure 4, Sources of Radiation Exposure (EPA, 2021)

- Increased radiation exposure may damage living cells
  - Ionizing Radiation can cause base/sugar damage, strand breaks, and/or double strand breaks in chromosomes.
    - This is usually fixed during DNA replication, but sometimes cells make mistakes, leading to health issues.
- Because of DNA's role in cellular replication, frequently replicating cells are most vulnerable to radiation's effects. (Balajee, 2021)

Materials and Methods

Yeast Experiment (Non-Ionizing)

Boil the Yeast Extract Dextrose and water and prepare the plates.

Use a sterile yellow loop to get a sample of the wild yeast and streak one plate. This is the "Wild Master plate." Repeat the streak process with the mutant yeast strain and label the plate "Mutant Master plate."

Figure 5, Yeast streak plates

Mix an isolated colony of the wild yeast into 5 mL of water in a test tube. Coat 5 plates evenly with the yeast mixture. Repeat with mutant strain. Expose the plates to sunlight for 5, 10, 20, and 30 minutes. Wrap in aluminum foil immediately after exposure and incubate at room temperature.

Figure 6, Incubating plates

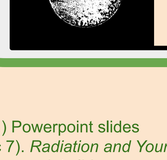


Figure 7, Yeast plate in ImageJ

Radish Experiment (Ionizing)

Put water onto a dry soil disk and allow the soil to absorb the water.

Get the radish seeds that were exposed to different amounts of gamma rays. There are four different amounts of radiation exposure measured in the seeds: 0 Krads, 150 Krads, 500 Krads, and 4,000 Krads.

Figure 8, Seeds exposed to radiation

Place one seed in each of the 10 soil disks. Set the container of soil and seeds near a window and allow the seeds to germinate. Measure the height of the sprouts for 10 days after planting.

Figure 9, Germinated seeds

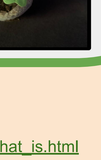
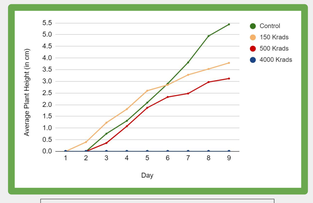


Figure 10, Germinated seed in ImageJ

Use ImageJ to measure, record, and compare data.

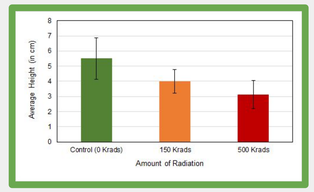
Results

Radish Experiment



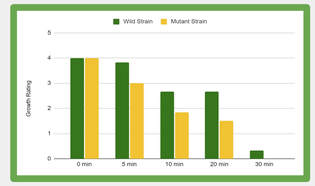
Graph 1. Growth of radish plants over 9 days

- Average plant height for each seed group taken daily (Graph 1)
- Data graphed for control group (0 Krads), 150 Krads, 500 Krads, and 4000 Krads
- Control group grew at a faster rate than other groups
- 150 and 500 Krads followed similar growth trends
- No growth in 4000 Krads group
- Inconsistent sample sizes from non-germinating seeds, or "duds"
- Calculated 95% confidence intervals to account to unforeseen variables
- Confidence Intervals not found for 4000 Krads group because of no growth

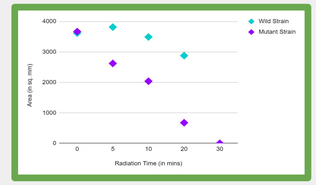


Graph 2. Average Height of Radish Plants with 95% Confidence Intervals

Yeast Experiment



Graph 3. Qualitative Observation of Yeast



Graph 4. Average Area of Yeast Colonies

- Each yeast plate was rated on a scale of 0 to 5 (Graph 3)
  - 0=no growth; 1=very little growth; 2=some growth; 3=large amount of growth; 4=as much growth as control (0 min); 5=more growth than control
- UV-sensitive mutant strain followed faster downwards trend than wild strain, on average
- Complete death of mutant yeast colonies at 30 minutes of exposure; area of wild yeast colonies was minimal and barely noticeable

Conclusions

- These experiments determined the effect of non-ionizing and ionizing radiation on eukaryotic organisms, as well as the threshold of those effects.
  - In the radish experiment, radish seeds were exposed to gamma radiation. As shown in the data, control group growth remained constant, while the 150 and 500 Krads groups both slowed after 5 days and the 4,000 Krads group experienced no growth.
  - In the yeast experiment, wild type and UV-sensitive mutant yeast cells were exposed to different durations of UV light and compared. There was a trend toward fewer surviving mutant yeast cells as time exposed to the sun increased which was mirrored to a lesser extent by the wild type.
  - Both UV and gamma rays were shown to slow and even stop eukaryotic cell growth at high enough levels.
- These results apply to the following real world scenarios.
  - Excessive gamma radiation poses a serious risk to unprotected organisms, such as astronauts in space. Sun exposure is also a concern, as the growth of wild type yeast was decimated after 30 minutes in sunlight. This would be amplified in space without the Earth's protective ozone layer.
  - Preventing excess exposure to radiation can also reduce incidents of cancer and other diseases.
- During these experiments, we were hampered by many problems related to distance learning. In a future experiment, it would be optimal to do it in person to reduce confounding variables. We could also experiment with shielding and the effects of radiation blockers.

References

- Balajee, A. (2021) Powerpoint slides
- CDC. (2015, Dec 7). *Radiation and Your Health.* https://www.cdc.gov/nceh/radiation/what_is.html
- Ellis, E (2021) Powerpoint slides
- EPA. (2021, Apr 9). *Radiation Sources and Doses*. www.epa.gov/radiation/radiation-sources-and-doses

Acknowledgements

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