Radish Seed Dose-Response Experiment

High School Lesson Plan - Outline

Summary of Activity

In this activity, students will dose radish seeds with two different substances (salt and instant coffee) at several concentrations. Students will then observe the treatment effects on radish seed germination over the course of three days. Students will also answer questions about experimental design, plot dose-response curves for the different treatments, and interpret their results.

Objectives

Understand concepts of experimental design, such as replication, error, and control, independent and dependent variables. Learn how to plot and interpret a dose-response curve. Gain exposure to the field of toxicology.

Guiding Question:

How can we determine the toxicity of various doses of a substance using radish seeds?

Teacher Background

Toxicology is the study of the harmful effects of chemicals on living organisms. The harmful effects that a chemical can have on an organism is dependent on the amount of a chemical that the organism is exposed to. The amount of a chemical or substance that an organism is exposed to is called the *dose*. The effect that the chemical or substance has on the organism is called the *response*. Toxicologists can study the relationship between the dose and the response using toxicity tests on *model organisms* very similar to the tests on radish seeds in this activity. A model organism is an organism that can be used to gauge toxicity in humans, or other environmentally relevant species, without having to expose humans to a potentially harmful chemical. In this activity, our goal is to design a controlled experiment, highlighting elements of experimental design, to characterize the dose-response of the selected substances.

Materials Provided for Each Student:

* 7 resealable plastic sandwich bags
* 14 paper towels
* 70 radish seeds
* 1 worksheet

Materials to be shared:

* Cups for solutions
* Teaspoons
* Instant coffee
* Salt
* Markers for labeling bags

**Activity (Day 0):** (reference the asynchronous videos for additional support)

1. Assemble the test substances: instant coffee and salt. You could also choose to substitute these substances or have different students test different substances (soda pop, dish soap, or even hand sanitizer for example).
2. Prepare the treatment bags.
   1. Put 2 folded paper towels in each of the 7 plastic bags.
   2. Label the plastic bags with the appropriate information:
      1. Bag Number
      2. Name
      3. Date
      4. Chemical (the name of the test substance)
      5. Concentration
   3. Prepare the coffee treatment doses
      1. Mix each instant coffee packet with 6 oz. of water, this will serve as the “100%” dose
         1. Students should follow the mixing instructions on the below table for preparing each bag’s dose
         2. Seal each bag and mix the liquid inside so that the entire paper towel is damp.
   4. Prepare the salt treatment doses
      1. Mix 1 tsp of salt per 12 oz. of water (will need approximately 48 oz. total for a class of 30 students), this will serve as the “100%” dose
         1. Students should follow the mixing instructions on the below table for preparing each bag’s dose
         2. Seal each bag and mix the liquid inside so that the entire paper towel is damp.

|  |  |  |  |
| --- | --- | --- | --- |
| Bag # | **Dose**  (% Substance Concentration) | **Water** | **Substance (Prepared coffee or salt solution)** |
| 1 | 0% (Control) | 4 tsp | - |
| 2 | 50% Coffee | 2 tsp | 2 tsp |
| 3 | 75% Coffee | 1 tsp | 3 tsp |
| 4 | 100% Coffee | - | 4 tsp |
| 5 | 50% Salt | 2 tsp | 2 tsp |
| 6 | 75% Salt | 1 tsp | 3 tsp |
| 7 | 100% Salt | - | 4 tsp |

* 1. There should be 4 total teaspoons of liquid in each bag.

1. Count out 10 radish seeds from the radish seed packet and place them on the wet paper towel in one of the bags. Make sure to spread the seeds out so they have plenty of room between them. Seal the bags and remove as much air as possible. Repeat these steps until all of the bags have 10 radish seeds in them.
2. Lay the bags on a flat surface where they will be safe for several days and leave them until tomorrow when you will count the number of seeds that germinate.

**Pause and fill out the “Before the Experiment” part of the worksheet**

Opening question: Generally, what do the students think the purpose of the experiment is?

Let’s think about our experimental design...

* Discuss variables (independent, dependent, controls)
  + Independent variable (what we choose to change) – type of substance
  + Dependent variable (what we measure) – # of seeds that germinated
  + Control variables (what is the same for *all* seeds) – amount of water, procedure, location of seeds, etc.
* Why did the procedure include the control treatment (water)?
  + A control treatment gives you something to compare to. In this case, it tells us how many seeds will germinate *without* any substance added.
  + Example: if you only saw 5/10 seeds germinate when you added salt, you might conclude that the salt caused fewer seeds to germinate. But if you also had a control treatment where only 5/10 seeds germinated, you might conclude that the seeds or one of the other control variables prevented germination, rather than the salt.
* Discuss replicates – what are they and why are they important to experiments?
  + There were 10 seeds for each treatment to give us more evidence and confidence in our conclusions. If one or two seeds are tested, the result could be by chance. But if ten seeds are tested, it is far more likely that the results are correct. Replicates give us more confidence in our results.
* Talk about the importance of keeping good records during your experiments.
  + Good labelling.
  + Writing down the substances that you are testing.
* Talk about some different substances that students chose to test (besides coffee) and why they chose them.
* Hypotheses: What do you think is going to happen in this experiment?

**Activity continued (Day 1-3):**

1. The next day, without opening the bags, count the number of seeds that have germinated (I.e. have little sprouts growing out of them).
2. Write the number of germinated and not germinated seeds in the Seed Toxicity Results Table on your worksheet (hint: these two numbers should add up to 10).
3. Repeat this counting for two more days until you have counts for a total of three days and your Results Table is full.
4. Calculate the percentage of germinated radish seeds for your last observation day and record this in the Results Table.

**Activity continued (Day 3):**

1. Follow the instructions on the Data Worksheet and answer the Discussion Questions.
2. Construct a plot to show the results collected in your Results Table.

Results and Discussion:

**Hypotheses**

* What impact did you initially expect the substances to have on the seeds? Were your expectations correct?

**Experimental Design and Observations**

* How did the setup of the experiment and recording observations go? Did you run into any issues?
* Identify conditions that may not have been consistent across different students (ex. light, temperature). How might this have impacted the seeds? Why might control variables be important?
* Discuss other observations students might have had during the experiment

**Sharing Class Data and Discussing Conclusions:**

*Note: TEAM Tox developed an app to generate dose-response curves for the high school students. Students can save images of these plots and then share them with classmates. App: https://ianlmoran.shinyapps.io/GerminationDRCApp/*

* What kinds of trends can we see in the data? What does this experiment tell us about the toxicity of the test substances for radish seeds?
* What sources of error might there be in the experiment (experimental error can relate to human actions, the tools we use, or the environment surrounding our experiment)?
* What conclusions can we make from the data?
* What might you do differently if you were to perform this experiment again?

**Toxicology questions:**

* Why is it important to test how toxic substances are before we use them?
* What might make one chemical more toxic to an organism than another?
* How well can plants help us to predict whether chemicals will cause toxicity in the environment? What about whether chemicals will cause toxicity in humans?
* Are there other model organisms that could enable us to make better predictions?

*Toxicology note on dose-response and model organisms:*

*In this experiment, the instant coffee decreased seed germination, but people drink coffee all the time! Does that mean that coffee is bad for humans?*

*This is a great question and is often asked by scientists when they do toxicity studies using plants, animals, or even bacteria. In general, humans do share some biology with other animals and plants, like how our cells and genes work, but there are also structural features that set us apart. This means that we will probably respond to a substance, like coffee, differently than a plant seed. The amount of coffee is also very important to think about. For the seeds in this study, we gave them too much coffee, so they were no longer healthy. But for humans, the amount of coffee that would make someone unhealthy would be different.*