The Rain upon the Radishes

Overview

Students will understand the nature of science and devise a test to study the effects of pH on seed germination.

Introduction

When we burn fossil fuels to get energy for running things like lights, cars, and air conditioning, compounds containing sulfur and nitrogen are released into the air. Sunlight causes changes in these compounds so that they then can combine with water in the atmosphere. The eventual results are nitric acid and sulfuric acid. These are the components of what we call “acid rain”. An acid has a low pH. The acidity of acid rain can change the pH of the soils or water sources on which it lands. Biological functions, from enzyme activity to cellular transport are very dependent on the proper pH, and are sensitive to changes. Therefore, changes in pH due to acid rain can prevent fish eggs from hatching, leach toxic metals out of soil and rocks, and affect seed germination, among many more examples.

During seed germination, the embryo will use its stored food to grow into a mature plant. In most seeds, the food is stored in the cotyledons, or seed leaves, as starch. Although starch is a storage form of glucose, it cannot pass through living membranes due to the large molecular structure, so before it can be used for energy it needs to be broken down to its constituent sugars. The break down of the starch is done with enzymes, like alpha-amylase. When the pH of the soil or water surrounding the seed is too acidic, these enzymes do not function right and the seed will not germinate.

Motivation

Farmers in the Midwest are having trouble getting their seeds to grow. Some suspect that the acidic pH of the rain might be hurting the seeds ability to grow. They have hired you to find out if the acid rain is having a negative effect on their crops. What are you going to do?

Objectives

Upon completion of the activities and lab, students will be able to

1. Design an experiment via the scientific method.
2. Using example scenarios, describe why the scientific method—and strict methodologies based upon the scientific method—are standards in research.
3. Define hypothesis, observation, replicate, constants, independent and dependent variables, control, and theory as they relate to scientific experiments.
4. Effectively communicate the results of a scientific experiment, orally and in written form.

Materials

- 50 radish seeds/ per group
- Orange juice –pulp free
- Vinegar
- Lemon juice
- Coffee
- Paper towels
- Stapler
- Outside reading about the nature of science and the scientific method
- pipettes
- Distilled water
- 10 petri plates or baggies/ per group
- pH test strips

Associated California State Biology Standards

1b. Students know that enzymes are proteins that catalyze biochemical reactions without altering the equilibrium and the activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings.
1h. Students know most macromolecules (polysaccarides, nucleic acids, proteins, lipids) in cells and organisms are synthesized from a small collection of simple precursors.
6b. Students know how to analyze change in an ecosystem resulting from changes in climate, human activity, introduction of non-native species, or changes in population size.

Procedure

1. Before starting the lab, prepare solutions of 4 different pH levels and a solution of distilled water. Lemon juice should have a pH level of 2, vinegar 3, orange juice 4, and coffee 5. Distilled water should be 7. Use pH test strips to make sure and dilute with water as needed.
2. Use the "Motivation" section above to start class discussion and to prepare students for the lesson.
3. Review with the class the proper parameters for a scientific exploration. The class should consider and discuss hypotheses, observations, replicates, constants, independent and dependent variables, controls, and theories.
4. Students form groups of 4-5 and discuss how to approach the problem with the given materials. Before students begin their experiment set-up they must have teacher approval.
5. Give students a handout with available materials (50 radish seeds, solutions of 5 different different pHs, 10 petri plates or baggies, paper towel, scissors, and markers).
6. To germinate seeds, students should soak the seeds in water for 30 minutes then drain and place on paper towels.
7. Students should place three layers of paper towels in each of the ten bags and then saturate the paper towels with the appropriate solution using a pipette. The bags should be labeled with the solution, the pH and the date. There should be two bags for each solution.
8. If using bags, students should place a line of staples about 1/3 up the paper towel in the bag. This will allow the seeds some room to grow roots.
9. Students add 5 seeds to each bag. Thus, the students should have 10 seeds for each solution total.
10. Place the bags flat bean-side up in a darker location that is not to hot or cold 25ºC degrees is ideal.
11. While seeds are germinating explore the textbook section about the scientific method. Assign students to research acid rain and describe economic, environmental, and health impacts of acid rain. Germination of the seeds takes 3-5 days.

12. At the end of 5 days students will record their germination results, discuss as a group and reach conclusions, and present results.

Evaluation

The following questions are listed under the Analysis section of the student handout and may be used as part of a report, class discussion or assessment.

1. Draw a bar graph plotting the number of seeds that germinated on the y-axis and the pH on the x-axis.
2. Identify your control in this experiment. Why was it important to have in your experimental design?
3. What happens during the process of germination? Include in your answer a picture of glucose and starch.
4. How is the pH of rain altered? In answering this question, please cite 3 sources.
5. Why do you hypothesize that pH would affect germination?
6. What would be the implications of your study (economic, social, etc.)?
7. Knowing the effects of pH on germination, what other factors do you hypothesize might have an effect on germination?

Extension Activity

1. Students can continue to grow their seeds to study the continued affects of pH using the protocol for film canister growing adapted from www.fastplants.org (included in Huntington background materials). Grow lights should be available from the District Services Center.

Test Preparation

1. Which statement is correct about pH?
   - (A) There are no hydrogen ions in a strong basic solution.
   - **(B) Pure water has a neutral pH of 7 because the concentration of hydrogen ions equals the concentration of hydroxyl ions.**
   - (C) The concentration of a solution with a pH of 5 is 5 times more acidic that a solution with a pH 1.
   - (D) The concentration of hydrogen ions in a solution with a pH of 2 is 2, 000 times more acidic than a solution with pH of 4.
   - (E) A solution with a pH of 5 means there are 5×10^{-1} moles of hydrogen ions in solution.

Student Sheet: The Rain Upon the Radishes Name:_____

Procedure

1. To initiate germination of the seeds, soak the seeds in water for 30 minutes then drain and place on paper towels.
2. Place three layers of paper towels in each of the ten bags and then saturate the paper towels with the appropriate solution. The bags should be labeled with the solution, the pH and the date. There should be two bags for each solution.
3. Place a line of staples about 1/3 up the paper towel in the bag. This will allow the seeds some room to grow roots.
4. Add 5 seeds to each bag. Thus, your group should have 10 seeds for each solution total.
5. Place bags flat—bean side up—in a darker location that is not to hot or cold; 25ºC degrees is ideal.
6. Record the germination process and results over a five-day period on the table located on the back of this page.

Analysis

On a separate sheet of paper please complete the following:

8. Draw a bar graph plotting the number of seeds that germinated on the y-axis and the pH on the x-axis.
9. Identify your control in this experiment. Why was it important to have in your experimental design?
10. What happens during the process of germination? Include in your answer a picture of glucose and starch.
11. How is the pH of rain altered? In answering this question, please cite 3 sources.
12. Why do you hypothesize that pH would affect germination?
13. What would be the implications of your study (economic, social, etc.)?
14. Knowing the effects of pH on germination, what other factors do you hypothesize might have an effect on germination?

Attach sample here in ascending pH, seed side up.	Attach sample here in ascending pH, seed side up.	Attach sample here in ascending pH, seed side up.	Attach sample here in ascending pH, seed side up.	Attach sample here in ascending pH, seed side up.
Liquid ________________ pH ________________ Hypothesis ________________________ ________________________ ________________________ ________________________ Day 3 Notes__________ ________________________ Day 5 Outcome ________________________ ________________________ ________________________ ________________________ ________________________ ________________________	Liquid ________________ pH ________________ Hypothesis ________________________ ________________________ ________________________ ________________________ Day 3 Notes__________ ________________________ Day 5 Outcome ________________________ ________________________ ________________________ ________________________ ________________________ ________________________	Liquid ________________ pH ________________ Hypothesis ________________________ ________________________ ________________________ ________________________ Day 3 Notes__________ ________________________ Day 5 Outcome ________________________ ________________________ ________________________ ________________________ ________________________ ________________________	Liquid ________________ pH ________________ Hypothesis ________________________ ________________________ ________________________ ________________________ Day 3 Notes__________ ________________________ Day 5 Outcome ________________________ ________________________ ________________________ ________________________ ________________________ ________________________	Liquid ________________ pH ________________ Hypothesis ________________________ ________________________ ________________________ ________________________ Day 3 Notes__________ ________________________ Day 5 Outcome ________________________ ________________________ ________________________ ________________________ ________________________ ________________________