Plant Responses to the Environment

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Summary

Since they are sessile organisms, plants are very responsive to their environment. In this lab, we explore how plants “know” which way to grow and the importance of the reserves of food within the seed.

Background

Plants are very well adapted to sense and respond to their environment. They perceive their environment through several cues: light, temperature, water status, gravity, etc. In my experiences with students, it has become clear that students do not regard plants as being very capable of "sensing" and I believe that this is a critically important thing for students to understand.

The following experiment came out of an idea I had while teaching a lecture about seed structure. The experiment is intended to get students thinking about how a plant knows where to go when it is buried deep underground. Additionally, students should gain some understanding of the importance of seed reserves as energy for the plants in order to grow to reach the surface of the ground, at which point they can make their own food. Once provided with information about the structure and function of the endosperm (monocot) or cotyledon (dicot) and its role in providing energy, the next question might be whether the size of the seed is any indication of how large or for what period of time a seedling could grow before reaching light. However, in doing this particular experiment with a class, it became clear that seed size might not be an indication of how large a seedling could grow, but perhaps how long it could survive on the reserves. It is important to clarify these points with the students and address whether it is more advantageous for a plant to be able to grow faster or survive longer on its seed reserves. In doing so, you can also discuss ways to experimentally distinguish between these two possibilities.

Subject

Biology or Botany

Audience

10^{th}-12^{th} grade

Time Required

2 or 3 periods, with the first 2 periods separated by about a week of growing time. Seeds are planted during the first period. After a week, another period is used to pull out the seedlings and make measurements. An additional period may be desired to assess the data.

Learning and Behavior Objectives

Students will:

Learn to form hypotheses based on prior information

Learn the importance of controls and reproducibility in experimentation
Identify variability in genetically similar plants (phenotype vs. genotype)
Develop a basic understanding of plant physiology and morphology
Develop a basic understanding of plant responses to the environment
Reinforce metric system skills (mass and length)

National Education Standards

Life Science: behavior of organisms
Life Science: structure and function of living systems
Life Science: organisms and environments
Science as Inquiry: abilities necessary to do scientific inquiry
Science as Inquiry: understanding about scientific inquiry

Materials

- aquarium or other suitably deep container
- soil
- any type of paper or plastic cup
- seeds
- scale and rulers
- light-tight box (eg. a cardboard box covered in tin foil or black material)

Procedure

After learning about the role of the endosperm or cotyledons, students design experiments to test if there is a correlation between the size (mass and/or length) of the seeds and the length of the seedling after a set period of time. Alternatively, they can test a hypothesis about the effect of the size of the seeds and amount of time a seedling can grow without light. It is also interesting to discuss whether it makes a difference to the plant if it is buried or just kept in the dark. Buried seeds vs. seeds planted in the dark would be two separate experiments.

The following protocol outlines one possible experiment, but these steps can be adapted in many ways to address specific questions of the students' choice:

1. Obtain various-sized seeds (corn, peas, lettuce, radish, etc.)
2. Make predictions about which seeds will sustain heterotrophic growth (i.e., growth without making food via photosynthesis) for the longest period of time.
3. Measure seeds and compute averages for a particular species. Students might choose to measure mass, volume, or length of their seeds, and you could lead them in a discussion of which type of measurement would produce the most useful results.
4. Sow the seeds in a very deep container (an aquarium works well) covered with about a foot of damp soil. Allow the seeds to grow for a week or some other specified period of time. (The aquarium should be covered on all sides with foil or kept in total darkness to avoid causing plants to grow toward any faintly perceived light source.)
5. After the growth period, excavate the seedlings from the soil and measure the length of each seedling.

An alternative (or complementary) experiment is to sow the seeds shallowly in cups or pots and place them in the dark for the same amount of time.

Assessment Strategy

Students should keep lab notebooks as a means of assessment for the instructor. You can review the students' ability to describe exact protocols performed and to record results in tabular or otherwise suitable form. In my classes, I require that the students provide a hypothesis before assessing the growth of the plants. Furthermore, students should formulate their own graphical representations of their data, which leaves their analysis up to their own interpretation and also provides an avenue of discussion about the best ways to present different data. I have provided a basic worksheet for this particular experiment.

Possible Problems

When I performed this experiment with my class, we compared lentils and maize seeds. I thought I knew which would grow farther (the maize), however, it was surprising (but great) to see that the lentils had reached the surface, buried about 10 inches deep, while the maize only grew a few inches. This prompted us to question whether it was the time a seed might survive (rather than the rate of growth) that the seed size determined. Some research indicates that among different species, there may not be a correlation between seed size and growth rates, however this experiment represents an easily testable hypothesis. Planting many species, with a wide range of seed sizes, could be used to test the hypothesis that seed size is an indication of seedling growth rate. However, it is important to keep in mind that many characteristics other than size vary from one species to the next, and these other characteristics also could influence seedling growth rate. For example, other factors that affect seed germination and seedling growth include water permeability of the seed coat, light requirements, and genetic variation within each species.

When we grew seeds in the dark, we found mold after a week. The fungus didn't appear to alter the outcome of the experiment, but it did provide a nice segue into molds and fungi and also a good lesson about the "messiness" of biology.

Name_________________________________ Date____________________

Period______________

Seedling Responses to the Environment: Gravity and Seed Reserves

In class we have discussed the anatomy and physiology of the two types of seeds, monocots and dicots. Both contain structures that are involved in providing the developing seed with food until it is able to photosynthesize. In this lab, we are going to investigate the importance of the seed size on aspects of seedling development. There are a few ideas to consider:

1. Seed size between or within species vs. length of the seedling after a certain amount of time
2. Seed size vs. the amount of time a seedling can survive without light
3. Differences between planting seeds very deep in soil versus planting them in the dark

Chose one idea from above, or come up with your own regarding aspects of seedling growth. If you have your own idea, please okay it with me. Formulate a hypothesis and write it below.