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Example Lesson: Teaching Students how to Design an Experiment and Investigate Abiotic and Biotic Factors Affecting Arthropods

Making connections

Students learn the scientific method in their science classes, but they are rarely asked to sufficiently demonstrate that they can implement the scientific method in a research project. Also, teachers often design most of the projects so students are not aware of the "nuts and bolts" of doing research. In this activity, students design and carry out a research project. The research project outlined in this lesson investigates how plants and herbivores interact and how this relationship can be affected by other abiotic and biotic factors.

People often look at a plant-insect community and think about how herbivores affect plant health. In an ecosystem, however, each organism has the potential to affect many other organisms and abiotic factors may alter these relationships. For example, aphids not only affect plants, but plants may affect aphids, and temperature may modify the plant-herbivore relationship. By doing classroom experiments, it is possible to observe how biotic and abiotic factors affect aphid populations. This ultimately helps students see some of the complex interactions that take place in nature.

Background

Aphids on goldenrod are an integral part of grassland ecosystems. They are native to North America and are food for many insects, other arthropods, such as spiders and mites, and some vertebrates, such as birds. A large, red, aggregating species of aphid (*Uroleucon nigrotuberculatum*) inhabits the *Solidago canadensis* complex in many parts of North America, including central Illinois.

A variety of factors can affect aphid populations. Important abiotic factors include temperature and humidity and biotic factors include the host plant (i.e. nutrient and defense levels) and predators. In this exercise the students investigate a few factors that affect aphid population size.

Objectives

Students will:
1. Learn how to design a research project.
2. Learn about biotic and abiotic factors affecting aphid populations.

Materials

1. Two goldenrod (*Solidago* spp.) plants per group
2. Red goldenrod aphids (*Uroleucon nigrotuberculatum*)
3. Two fine-mesh bags per group
4. Two metal twist-ties per group
5. Two wooden skewers per group
6. 1 Predator per group
7. Microscopes and magnifying glasses
8. Computer with Excel

Procedure
An initial class period should be used as an introduction to teach students how to design a research project and to give students time to do the research design. Introduce the plants and aphids during this period so students can see the initial research system and observe the plant-herbivore interaction.

Introduction Period
Step one - Pick what to work with: Students are told that they will be given goldenrod and aphids and they will have to add other abiotic and biotic components to the system.

Step two – Observe your system: Which biotic and abiotic factors, if added to the system, do you think will affect your plants and aphids? Prior student knowledge of predator-prey interactions and abiotic factors is necessary.

Step three – Pick what you think are the most important abiotic and biotic factors affecting a plant-herbivore interaction.

Step four – What questions do you want your research to address? Examples include
How do high and low temperatures affect aphids?
Does aphid feeding negatively affect plants?
How do predators limit aphid populations?
Do predators eat more aphids at higher temperatures than lower temperatures?

Step five – What materials and methods are necessary to address your research question(s)? What measurements or observation techniques are necessary for collecting data?

Setting up the Project – Second Class Period
My class chose to introduce predators and two temperature regimes to the plant-herbivore system because they thought these were the most important biotic and abiotic factors, respectively, affecting plant-herbivore interactions. The following methods are the approach we used to study our research system, but this may need to be modified depending on what questions your students wish to address.

1. Divide the class into groups and assign each group a set of two plants and one of two temperature treatments (i.e. high or low temperature). Each group will put 13 apterous adult aphids on each plant. One spider (or other predator, such as lady beetle or lacewing larvae) will be put on one plant (the other plant is a control, so it does not have predators). A mesh bag will enclose the plant and arthropods and will be closed with metal twist-ties. Wooden skewers can be used to hold the mesh bags upright and take weight off the plant.

2. Half the students put their plants in a low temperature environment whereas the other half put their plants in a high temperature environment. This could probably be achieved by placing one group in a greenhouse or under heat lamps and the other under regular lighting. Measure the temperatures of each environment.

3. After two weeks the students will count all the aphids on each of their plants using dissection microscopes or hand lenses and enter the data into Excel.

4. Data from the entire class will be combined and graphs made to represent which factors had the largest impact on aphid populations. Do predators reduce aphid populations? Did predators reduce aphid populations more in one temperature treatment relative to the other?

Summary

This project provides students with a framework that allows them to design a research project and study modifications of plant-herbivore interactions. The project is easy to perform, took only three 43-minute class periods: one for an introduction, another to set up the project, and a third to collect, analyze, and discuss data. It addresses multiple national and Illinois state standards, such as teaching students about the scientific method, abiotic and biotic factors, predator-prey interactions, food web interactions, and factors that limit population size. It was also an effective learning experience for the students and their level of motivation and enthusiasm was very high. The students had access to microscopes which could also take pictures. These microscopes connected to computers and allowed students a see the aphids in high magnification, but also enabled them visually document the size of the aphid populations. Students were enthralled with clearly seeing an insect's body and getting to use this technology in the classroom.

This lesson can be modified to apply to multiple grade levels and locales. While goldenrod and goldenrod aphids may not be as readily available throughout the country as they are in east-central Illinois, other plants and aphids can be obtained. For example, pea plants and pea aphids (*Acyrthosiphon pisum*) can be readily purchased from on-line sources (http://www.seedsofchange.com/; www.berkshirebio.com). Predators can also be bought on-line (www.arbico.com; www.carolina.com) instead of collecting them from the wild, as I did. By its very nature, since students design the project and pick the research questions, this inquiry-based learning is highly adaptable to suit the needs of you and your students.