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EXPERIMENTS

Seedling Growth of Wisconsin Fast Plants (*Brassica rapa*) in Field Environments

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student experimenting with Wisconsin Fast Plants at a field site, © Valerie A. Barko

ABSTRACT:

In this 3-week laboratory, students investigate the effects of an abiotic or biotic ecological factor on the growth or reproduction of rapid-cycling brassica (*Brassica rapa* L.: Wisconsin Fast Plants) seedlings in the field. Measurable treatments include light, wind, herbivory, chemical or organic fertilizer, insecticides, and growth regulators (i.e., gibberellic acid spray, auxin paste). Students learn how to develop an hypothesis and apply the scientific method in a field setting. Students work in pairs and set up their experiments using previously prepared Wisconsin Fast Plant seedlings. One week later students harvest their plants during a return field trip after which they collect their data, write individual scientific reports, and present their findings in-class. This experiment is unique because Wisconsin Fast Plants are used in a field experiment instead of the usual laboratory setting.

Table of Contents:

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KEYWORD DESCRIPTORS:

Principal Ecological Question Addressed: How do biotic and abiotic factors affect the growth of seedling plants?

Ecological Topic Keywords: plant ecology, *Brassica*, abiotic factors, biotic factors, seedling growth.

Science Methodological Skills Developed: experimental design, scientific writing, hypothesis testing, implementation of the scientific method, identify biotic and abiotic interactions affecting seedling growth.

Pedagogical Methods Used: cognitive skills, hands-on experience, problem-based learning.

CLASS TIME: This experiment is done during three separate 2- hour lab periods. The week before beginning the experiment, a 20-30 minute lecture is desirable to introduce and discuss the scientific method, hypothesis formation, and factors that affect seedling growth. Digital photos and/or a video of the study site may also be presented for visual learners. The students should arrive at the field site with a hypothesis to test and an understanding of the scientific method. Week 1 is used to introduce the study site, equipment, and set up the experiment in the field (i.e., take first measurements on plants). Week 2 is used to complete the experiment (i.e., take final measurements on plants). Week 3 is for in-class oral presentations.

OUTSIDE OF CLASS TIME: Each pair of students will need to meet the week prior to experimentation, yet following the introductory discussion/lecture, to develop their hypothesis. Each student will need one week to write an individual scientific paper after the final measurements are collected. Each student analyses/summarizes data separately, writes a scientific paper, and prepares a 5 minute oral summary for an in-class presentation. Conversely, each student could create a poster for an in-class poster session in lieu of an oral and written report.

STUDENT PRODUCTS: Each student is assessed on their oral presentation and scientific paper.

SETTING: This experiment could be conducted in any setting, preferably with a heterogeneous plant community (i.e., forest and grassland). In addition, this experiment should be conducted in an area where potted Wisconsin Fast plants will be undisturbed during the length of the experiment. This experiment could be conducted in spring, summer or early fall (depends on geographic area) when vegetation is not dormant.

COURSE CONTEXT: This experiment is used in a majors, undergraduate, biology class with about 25 students per laboratory section. Students are freshman and sophomores. This laboratory is conducted near the end of the spring term.

INSTITUTION: This experiment is used at a 4 year university with 10 - 15 laboratory sections.

TRANSFERABILITY: This project could be done in most field settings with a heterogeneous plant community. This experiment is suitable for use in community college and high school biology courses and could be adapted for non-majors and upperclassmen by increasing or decreasing the amount of instructor input and preparation. For example, student data could be combined for analyses of larger data sets or a poster session could be used for student assessment in lieu of oral presentations and written reports.

SYNOPSIS OF THE LAB ACTIVITY (audience: students)

WHAT HAPPENS:

In this exercise, students will investigate the effects of ecological factors on the growth of rapid-cycling brassica (*Brassica rapa* L.: RCB's; Wisconsin fast plants) seedlings in the field. Wisconsin Fast Plants belong to the Mustard family (Brassicaceae) and have been genetically bred to complete their life cycle in approximately 1 month. The students are asked to formulate a hypothesis and design an appropriate experiment to test their hypothesis. Possible variables that could be measured include growth (height, number of leaves, leaf area) or reproduction (number of flowers) with respect to treatments such as light, wind, herbivory, chemical or organic fertilizer, insecticides, or growth regulators (i.e., gibberellic acid spray, auxin paste). We also supply dwarf RCB's that lack genes for gibberellic acid production. These plants offer an additional test plant for the students to use.

Students spend two, 2-hour lab sessions on this project following a 20-30 minute introduction to the topic. During the introductory session (normally at the end of the preceding lab), the experiment is discussed and the students are encouraged to consider factors that affect seeding growth. Students should work in pairs and each group should formulate a hypothesis before the first field trip (lab 1). During the first field trip, the students should make observations about their study site, then design and implement their experiment (i.e., collect "before" data). During the second field trip, the students will collect response "after" data, which will be analyzed and used to write a scientific paper.

LAB OBJECTIVES:

At the conclusion of this lab, students will be able to:

1. ask scientific questions, develop hypotheses, employ and understand the scientific method,

2. use critical thinking skills,

3. develop their writing skills to present a written report,

4. use their collaborative skills to work together on a group project,

5. appreciate the value of native ecosystems for ecological research,

6. appreciate difficulties in designing a good, controlled experiment in a natural setting.

EQUIPMENT/ LOGISTICS REQUIRED:

* access to a suitable field site (local)
* 7 day old dwarf and wild type *Brassica* seedlings (12 per pair of students)
* guards (wind, insect, and herbivory)
* meters (soil, air, and light)
* measuring equipment (vegetation pins, metric rulers, graduated cylinders, rain gauge)
* gibberellic acid (10 ppm) in a spray bottle
* auxin paste, control paste, and sterile swabs for application
* Miracle Gro fertilizer (½ , normal, double, and triple recommended concentrations)
* pH buffers in plastic dropping bottles (pH of 2, 5, 7, 10, and 12)
* salt water in plastic dropping bottles (5%, 10%, and 15% concentrations)
* sugar water in plastic dropping bottles (5%, 10%, and 15% concentrations)

SUMMARY OF WHAT IS DUE:

From this lab, students should submit the following:

- Hypothesis and experimental design before performing experiment,
- Individually written, original scientific paper based on data collected by the pair of students, due the week following final data collection. Maximum length is 7 pages and the minimum length is 5 pages (not including tables and figures). Each paper must include at least 1 table and 1 figure,
- Five minute in-class presentation to be given the week following data collection.

DESCRIPTION OF THE LAB ACTIVITY

INTRODUCTION (written for students):

This experiment is designed to study biotic/abiotic factors affecting seedling growth. Biotic factors are interactions between the living components of a community (i.e., predation, competition); abiotic factors are those between living organisms and the non living portion of the environment (i.e., pH, wind, water, and solar radiation). To study these factors, we will use genetically bred, 7-day old Rapid cycling Brassica's (RCB's), which have rapid growth to maturity (i.e., approximately 30 days).

Rapid-cycling Brassica's (RCB's: *Brassica rapa* L.) were designed for use inside the classroom with adequate lighting provided at all times. However, this project is conducted outdoors, where a variety of environmental factors could have an impact on growth. These include exposure to and intensity of light, insect herbivory, air temperature, competition for light or resources with other plants, etc. There are also many factors that you, the student can manipulate such as fertilization, clipping, and growth inhibitors. You (and a partner) are to formulate an hypothesis and design an experiment to test your hypothesis. (i.e., think about why it is important to measure 1 variable at a time when conducting an experiment). In addition, there are two different types of RCB's to choose from - a dwarf type (rosette) and a wild type. These two types can be used separately or compared against each other. Your assignment is to come up with an hypothesis to test the affect of a biotic and/or abiotic factor in our environment that may affect seedling plant growth in real-life situations, not just for RCB’s. This must be completed during the next two lab periods. An example is: "We hypothesize that seedlings of RCB's located in areas of dense grass will not be shorter after 2 weeks than those in a less dense area.” Or, perhaps you think the number of flowers that your plants produce, or their biomass, would be a better gauge of the growth of these plants. It is up to you to determine what will be appropriate for your experiment. The only stipulation is that your effect must produce measurable data. We will provide instruction in the use of various equipment (light meter, etc.), and will be available for assistance in refining your hypothesis, if necessary. After spending 2 weeks collecting data, you will then write your own scientific paper, using the data collected. It will be due at the beginning of the next lab period.

MATERIALS AND METHODS.

Study Site(s).

You will conduct your experiment in a field setting chosen by your instructor. You should notice the heterogeneous plant cover that could be utilized in your experimental design. Hypothesize about which area may have greater levels of wind velocity, solar radiation, predation, or competition. For example, you may compare seedling growth in a shaded area vs. a sunny area to measure the effects of solar radiation on seedling growth.

Overview of Data Collection and Analysis Methods.

Week 1.

You should come to class ready to begin your experiment. In your work group, you should discuss the hypothesis with the instructor before conducting your experiment. This allows your instructor to determine if your group hypothesis is testable and to guide you to the proper equipment or plant variety best used in your experiment. For example, students that want to investigate the effects of gibberellic acid on their seedlings may not be aware that they will achieve better results with the dwarf variety of Brassica rapa.

Once your hypothesis is approved by your instructor, the experiment needs to be set up and baseline "before" measurements should be taken. For example, many students measure the height of the plant, the length of the longest leaf, and count the number of leaves. After these measurements, you should subject your plants to the specified treatment (example: applying 3 sprays of gibberellic acid solution to the plants). Then place your plants in their pots on the ground in a predetermined area. You should water your plants. Place a flag next to them with your name and the treatments you used written on it with a magic marker. A laboratory supervisor or student worker will maintain the plants throughout the week because the study site is a considerable distance away from the university (approx. 15 miles). The plants will be watered daily. If you would like additional applications of a substance applied to your plants by the laboratory supervisor, affix a piece of flagging tape to your flag with detailed instructions.

Week 2.

During the second week of lab you will collect "after" data from the plants and remove your experiment from the field site. You will use this data to write a scientific paper which will be due the next class period. The scientific paper should include an abstract, introduction, materials and methods, results, discussion, and references section. The structure of your paper should be based on the guidelines in Appendix A of the lab book Investigating Biology by Morgan and Carter, 1999.

QUESTIONS FOR FURTHER THOUGHT AND DISCUSSION.

1) What abiotic and biotic factors can affect seedling growth?

2) How do different abiotic and biotic factors affect seedling growth?

3) What constitutes a testable hypothesis?

4) What is the value and/or limitation of field experiments?

5) How does scientific research help us understand better the natural world?

6) Why are native ecosystems useful for ecological research?

7) What is a control and why is it important?

8) Why is it difficult to measure more than one variable simultaneously?

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LINKS.

Wisconsin Fast Plants Program • University of Wisconsin (www.fastplants.org/intro.html)

LONG TERM FIELD STUDIES FOR UNDERGRADUATE EDUCATION: A SNAPSHOT IN TIME - Southern Illinois University (www.science.siu.edu/long-term)

Comments by Contributing Authors – Valerie A. Barko, Beth A. Burke, David J. Gibson, and Beth A. Middleton[3,4]

CHALLENGES TO ANTICIPATE AND SOLVE.

This lab is designed to introduce students to ecological experimentation and enhance their understanding of the scientific method. Most of the students have never conducted a field experiment and their only knowledge of the scientific method is from textbooks. These exercises are designed for biology majors with little to no field experience. However, these exercises could be modified for use in non-major undergraduate courses as well.

Questions addressed and ecological context:

This lab gives students a better understanding of the scientific method and how ecological studies are conducted in the field.

Time commitment:

This exercise is designed for two, 2-hour laboratories. However, modification could be made to reduce the time requirements.

Challenges to anticipate:

1. Working in the field. Most students have little or no knowledge of what to anticipate in a field setting (i.e., rain, ticks, sun, mosquitoes, dehydration, and poison ivy). Students should be forewarned and encouraged to wear long pants and closed-toe and heel shoes, as well as bring a bottle of water. The instructor or TA should bring insect repellent, suns creen, a first-aid kit, and a large container of water with cups.
2. Hypothesis development. The Instructors or TA's should help the students formulate their own hypotheses. These experiments were designed to allow the students to design their own experiments and develop a testable hypothesis. However, it is the responsibility of the instructor or TA to decide if a hypothesis is testable before the experiment is conducted. The students are usually very enthusiastic about this exercise, so much so that they may try to use too many treatments. Instructors and TA's need to encourage the testing of a simple, one treatment, hypothesis. The hypothesis needs to address an ecological response to a treatment and not the experimental treatment itself. For example, fertilizer is used as a test of the effect of soil nutrients on plant growth. Ecologists are rarely interested in fertilizer itself.
3. Experimental design. The students need to be encouraged to think about ensuring adequate replication, controls, and to avoid pseudoreplication (false replicates) in the design of their experiment. Most students do not understand the difference between a control and a variable in an experiment. In addition, many students need instructional guidelines and descriptions before being able to design a good controlled experiment.

Instructor Preparation:

1. Arrange for transportation to the study site.

2. Plant *Brassica rapa* seeds (dwarf and wild-type) 6 to 7 days prior to the laboratory meeting to get 4-day old seedlings (follow growing recommendations provided by Carolina Biological Supply). It takes us about 10 hours to plant the seeds (1680 plants for 280 students), and additional time is needed daily to water the seedlings.

3. Gather sampling equipment (i.e., wire flags, light meter, wind guards, insect netting, fertilizer, pins for pin counts, insect vials, rulers, chi-square tables, alcohol, markers, forceps, meter tapes).

4. For large classes, equipment needs to be made ahead of time. A small class or more advanced class could make their own materials with the supplies provided. We usually prepare some items ahead of time anticipating what we think the students may need:

   a. fertilizer - We use Miracle-Gro and make up four differing strengths. We also provide the students with empty squirt bottles and water in case the students want to make up their own fertilizer strengths.

   b. differing pH buffers - We usually start out with pH’s of 4, 7, and 10. At student request, other buffers with other pH's can be made.

   c. salt water in plastic dropping bottles - We use 5%, 10%, and 15% concentrations.

   d. sugar water in plastic dropping bottles - We use 5%, 10%, and 15% concentrations.

   e. gibberellic acid solution - We use 10 PPM in a spray bottle. The students can determine the amount of application by the number of sprays and frequency of the sprays applied to their plants. Note: the students will see a marked change if they apply the gibberellic acid to the dwarf variety of Brassica.

   f. We provide additional empty squirt and spray bottles for the students' use.

   g. wind guards/insect guards/mammal guards - We make wind guards out of flags and plastic soda bottles, insect guards out of insect netting, and mammal guards out of chicken wire.

   h. We allow the students to be creative and come up with their own ideas as well.

COMMENTS ON THE LAB DESCRIPTION.

Introducing the Lab to Your Students.

Students are asked to list the steps of the scientific method, given a brief tour of the field site, and are provided with maps outlining the treatment regiments (e.g., mowing, fertilizer, etc.). We also discuss the available plant material and available equipment. This experiment was designed to be somewhat vague to foster inquiry in students. However, we require each group to discuss their hypothesis with the instructor to make sure to many variables are not being tested.

Comments On the Activities in the Lab.

We provide students and instructors with separate handouts. These handouts can be obtained from the following URL's:

www.science.siu.edu/long-term/lessons/b200sin.htm
www.science.siu.edu/long-term/lessons/b200iin.htm and
www.science.siu.edu/long-term/lessons/lpbi200a.htm

COMMENTS ON THE QUESTIONS FOR FURTHER THOUGHT.

These are discussed after the oral, in-class presentations, if time permits.

Comment on the Question: What is the value and/or limitation of field experiments? Field experiments help students and scientists understand natural phenomena in a hands-on way that is not possible through reading or laboratory exercises. It also allows them to understand the work that ecologists do, by experiencing the science first hand. Field experiments are more difficult to conduct than other kinds of experiments, because field conditions can be unpredictable. Experimental plants may die suddenly (e.g., herbivores, unexpected bad weather, or students may forget to water plants). The biggest problem can be that the experiment creates unanticipated conditions for the experimental plants. For example, a cloth that is designed to shade a plant causes it to overhead instead. The results of the students' treatments may be very unanticipated.

Comment on the Question: How does scientific research help us understand better the natural world? Scientific research helps students to develop the skills necessary to make and process observations about the natural world.

Comment on the Question: Why are native ecosystems useful for ecological research? Native ecosystems are useful for ecological research since these are the systems that ecologists are attempting to understand. Manipulated systems can also be useful if these help to isolate particular experimental or environmental factors in the experiment.

ASSESSMENT OF STUDENT LEARNING OUTCOMES.

Guidelines for Assessment:

The grading scheme for the scientific paper was based on 80 possible points. We used a 5 point scale for each major category: 0 = no evidence, 1 = little evidence, 2 = evident, lacking minor aspects, 3 = some evidence, adequate for project, 4 = good evidence, helping the project, and 5 = excellent. This 1-5 scale was scaled to the point value of each main category.

1. The student states a clear, testable hypothesis - 10 points.
2. The experimental methods are described including the identification of the variables - 10 points.
3. The results, including tables and graphs, are clearly displayed - 15 points.
4. Appropriate conclusions derived from the results are stated - 10 points.
5. Factors assessing seedling growth are mentioned and discussed - 15 points.
6. Grammar and spelling - 10 points.
7. Format - 10 points.

The oral in-class presentation was worth 20 possible points.

We chose this method because several TA's grade the papers and this breakdown provided an objective template for grading.

FORMATIVE EVALUATION OF THIS EXPERIMENT.

We asked the students to write hypotheses/finish sentence stem before and after the intervention. Before the lab sequence we asked the students to following related to the Brassica experiment:

1. Write the hypothesis that you will test.

2. Write your experimental design (what will you do?):

3. Our field site is an abandoned field with various treatments. Finish the sentence stem: Describe how fertilizer affects plant growth during succession. A field is plowed and then fertilized and abandoned. Because of the fertilization, what will happen to the various types of species in the field (e.g., trees, grasses, forbs)?

* We then lead the students down the “succession trail” which is maintained to demonstrate the various stages of plant succession.

* After the labs, we ask the students to answer the same questions again.

* Peer-review of another student’s hypothesis using a grading rubric will facilitate a better understanding of hypothesis development.

Comments:

Many undergraduate ecology courses are taught primarily through lecture with little to no hands-on experience. This laboratory provides students with the opportunity to learn through inquiry. In addition, students have a better understanding of the scientific method, hypothesis development, and real-world investigation.

Improvement in the evaluation scores demonstrates a higher understanding of succession and ecological processes, which the students have learned via the inquiry learning method used in the laboratory. The before and after scores in particular help the teacher evaluate the amount of improvement in student understanding before and after participation in the laboratory. The before and after scores can be statistically analyzed and used to demonstrate to administrators the efficacy of this and other teaching techniques.

Extensive notes on how to conduct formative evaluation are in the Teaching Resources sector of TIEE in an ESSAY ON EVALUATION.

TRANSLATING THE ACTIVITY TO OTHER SCALES.

Large Classes:

Assign students to groups the week before the experiment is conducted. Provide the laboratory materials that week and have the students meet outside of class to develop a testable hypothesis.

Non-majors:

Have students choose from three testable hypotheses (provided by the instructor), make predictions, conduct the experiment, and present how their results compared to their predictions.

If No Field Site Is Available:

Have students design an experiment and prepare the seedlings in the laboratory. The TA or instructor can place the plants in appropriate conditions for the week. The seedlings can be brought back into the laboratory the following week for measurement.

Honors Classes:

Have each group of students' design a unique experiment using rapid cycling Brassica rapa . They may also create their own sampling equipment instead of having it provided to them. Data from different sections or years could be combined for more rigorous data analysis.

Handicapped Students:

The students may go to the field site if terrain is suitable for wheelchair use. Most universities will provide handicap transportation. If the terrain is unsuitable, have the student's group set-up the experiment in the laboratory. The instructor and/or students can transport the plants to the field site. The plants can be brought back to the laboratory the following week for "after" data collection.

CREDITS AND DISCLAIMERS

CREDITS FOR THIS EXPERIMENT:

This lab is part of a larger NSF project incorporating inquiry-based labs in the ecology labs in the Southern Illinois University at Carbondale life science courses. This lab arouse out of brain storming among the investigators (D. J. Gibson, .B. A. Middleton, G. W. Saunders, M. Mathis, W. T. Weaver, J. Neely, J. Rivera, and L. M. Ovler) who wanted to develop an ecological experiment for use in a field setting. Details of the NSF project can be found in Gibson et al. (1999). We thank J. Neely and J. Rivera for writing the student handouts used in this experiment. We thank K. Jacobson and W. Mulach for including this laboratory in the Biology 200b curriculum at Southern Illinois university at Carbondale. We thank B. Grant , D. Herzog, S. Musante, and an anonymous individual for reviewing this submission.

Special thanks go to P. H. Williams for breeding fast plants at the University of Wisconsin for over thirty years and for developing scientific experiments using fast plants for use in natural science curriculums in elementary schools, middle schools, high schools, and colleges. Some of his college level experiments investigate evolution by artificial selection, inbreeding depression, and intraspecific competition.

GENERIC DISCLAIMER:

Lastly, we request that you return your students' and your comments on this activity to Susan Musante (smusante@aol.com), Managing Editor for TIEE, for posting at this site.