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Competition–Why Are "Weeds" So Successful?

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This exercise investigates plant competition in which garden plants substitute for two common weeds. Spinach and black mustard stand in for lamb's-quarters (*Chenopodium album,* L.) and garlic mustard (*Alliaria officinalis,* M. Bieb.) respectively. Both wild species germinate and grow in the same conditions in late summer, although lamb's-quarters flowers in the fall and garlic mustard, a winter annual, blooms in spring. In the early weeks, students examine the growth characteristics to determine if there is any difference in allocation of resources to shoot or root growth between black mustard and spinach when each are grown separately in pots. They also investigate if resource allocation changes when the species are grown together in competition in pots. This exercise is designed for non-majors and first-semester environmental science students, who have had little experience in lab or in writing a lab report. This exercise prepares students to analyze a complex lab problem, write a formal lab report, interpret data, and make graphs for a later exercise during the semester. The discussion questions also are meant to serve as a model to help guide students through the type of questions they should ask themselves for the later exercise.

Keywords: ecology, plant competition, resource allocation

Introduction

This exercise was developed to fit a general education, Environmental Science laboratory course. It was developed to fit a three hour lab period; students generally take 2 – 2 ½ hours to complete the work. I encourage students to use the remaining time to look over the results before they leave to be sure they understand their significance. It may be helpful to have them explain their results to you, the instructor.

One of the beauties of this exercise is that, though time-consuming to set up, it takes no specialized equipment. Preparation for the lab, growing the plants, will take 8 to 10 weeks, less time if the temperatures are warm. Good results can be expected from using natural light situations and a greenhouse is ideal but not necessary. I was able to grow the plants on a lab bench with a make shift banks of grow lights and fluorescent lights.

Students who take this course generally do not have well developed laboratory skills; for some this is their first exercise in collecting and interpreting quantitative data. While I provide the students with a plausible hypothesis, the introductory remarks can be modified to allow students the opportunity to choose their own hypothesis and determine what measurements they wish to make. If time and space are available, students may even choose their own plants to grow in competition, and take responsibility for growing and maintaining the plants themselves. There are several other experimental options that may be explored, such as, competitive response to fertilizers or to stresses, such as lack of water or shading. The design of this exercise is extremely adaptable.

Student Outline

Objectives

To define competition.

To observe the consequences of competition between two plant species for the same resources by growing them in a laboratory setting.

To use the results of the competition experiment to explain one reason why an exotic species could become a problem.

To apply the scientific method to an ecological problem and to become familiar with experimental design.

To become accustomed to using the metric system in laboratory situations.

To become accustomed to the format of a formal lab report, making use of data tables and drawing conclusions from data.

Materials

Per Lab Team:

1 pot of mustard plants	Digital scale
1 pot of spinach plants	Metric ruler
2 pots of mustard and spinach plants	Scissors

Introduction

In exercise 4 we took a close look at some of our campus organisms and their niches. We also considered that some exotic species are successful because they fill empty niches. Another reason many exotic species are successful is that they are successful competitors, effectively taking resources a native species needs for its own biological work, that is, its growth, development, maintenance and reproduction. Are they “weeds?” How do we define “weed?”

My Webster’s 7th New Collegiate Dictionary defines a weed as a “plant of no value and usually of rank growth, especially one that tends to overgrow and choke out more desirable plants.” Many of the weeds I pull out of my garden are exotic species, but several of these were brought to this country for some purpose, often as a culinary or medicinal herbs. They are of little value to me and they “overgrow and choke out” the plants I grow for my culinary purposes. (Perhaps the plants I am removing are valuable to you!)

Why are the weeds so successful? What growth traits help them to be more successful? Ecologists often use controlled, laboratory situations to help answer such questions. We are going to try to answer these questions after we have observed plants growing in a controlled, competitive situation. We will measure some of their growth characteristics and see how competition for habitat resources affects their growth characteristics. (Do you remember what the habitat requirements for an organism are? If not, you may want to look go back to Exercise 4 and reread that.)

Think about the situation of being a plant and how a plant allocates its resources to different plant organs (roots, stems, leaves, flowers, fruits and seeds, etc.). It is similar to how we budget our income to meet all our expenses. Plants have incomes in terms of light energy, carbon dioxide (CO_2), water and soil minerals, and they have expenditures in terms of their biological work. How can a plant take the resources available to it and use them to go faster or stronger or produce more offspring or some other strategy to be the most successful plant growing in that particular place?

Since we are studying competition in plants, we can look at the organs of a plant that collect the resources needed for life. Could a plant compete better if its roots were more extensive and able to obtain more water or soil nutrients? The roots collect water and soil nutrients, so better competitors might allocate energy into quick root growth to obtain more soil resources than the other plants in their vicinity. In the same way the leaves collect sunlight and CO_2 to carry out photosynthesis, so could better competitors grow leaves with large surface areas to optimize their capture of light and CO_2? Another strategy is for stems to grow taller bringing a plant’s leaves higher, getting more light than lower or slower growing plants.

But there are “budget” restrictions similar to those we all face. If a plant puts too much of its resources into growing taller and wider, can the roots grow quickly enough to meet the water and nutrient demands of the stems and leaves? Or if the roots rapidly spread throughout the soil, will enough energy for adequate stem and leaf growth? Maybe the plant matures in a short amount of time, putting more of its energy in making big, fancy flowers that attract pollinators, or in producing lots of seeds. These are all ideas to consider when you try to figure out what enables one plant to out compete another. (There are several other strategies plants use, including strategically using water resources, making noxious chemicals to discourage neighbors, etc. These are beyond the scope of our course.)

Another objective of this exercise is to consider how the scientific method is used. Since you will be forming a testable hypothesis and setting up your own experimental design in the coming weeks, this exercise should give you some ideas to consider. Be thinking about what data is collected, how the results are reported and how to decide whether to accept or reject your hypothesis. You may also consider ideas not mentioned in this introduction but appropriate to this situation.

A testable hypothesis to see if competition results in diminished growth of one of a pair of competitors is:

> When two species of plants that have similar growth habits are grown together, will the better competitor show a measurable advantage, such as growing taller, having larger leaves, or having greater root growth?

The experimental design is relatively simple. The control "group" is a pair of potted plants, each pot containing only one species of the pair. In this case we chose to use spinach and mustard. Spinach was chosen to represent a native species, lamb's quarters, and black mustard was chosen to represent our exotic species, garlic mustard. Both spinach and black mustard are easily grown garden plants that need little care, making them similar to their wild cousins. The experimental "group" is the pot with both spinach and the mustard growing together. The number of plants per pot is the same for the control and the experimental pots.

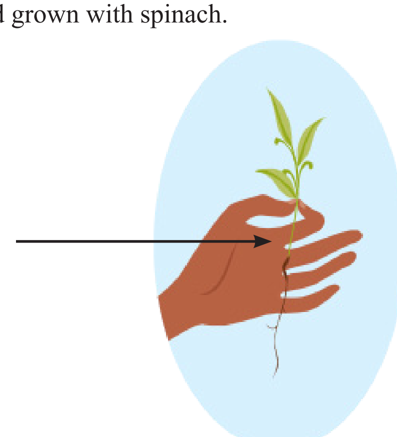
The lab staff grew the plants according to the experimental design – one pot of spinach alone, one pot of mustard alone and two pots with both mustard and spinach for each group of students. Your instructions tell you what growth traits you are measuring. Feel free to measure one or more traits that were not specifically mentioned!

Once the results are tabulated and you take some time to think about them, you should not only be able to answer the question posed by the hypothesis, but you should be able apply these results to the competitive situation in the natural world. If you were to continue in this study, you might try the same experiment again with wild species and perhaps even look at different measures of plant growth and success.

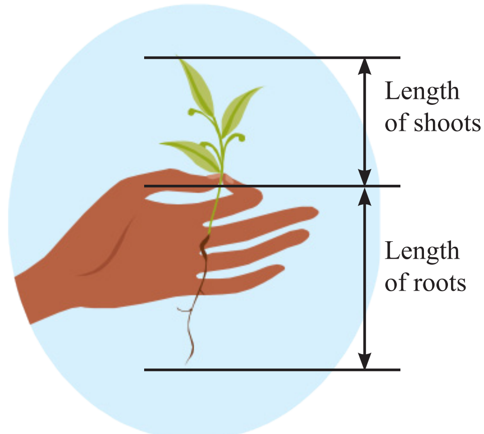
Procedure

1. You will obtain four pots of plants, one pot of spinach, one pot of mustard and two pots of mustard and spinach grown together. Each pot should have four plants in it.
2. Once you have your plants at your lab bench, pull the plants from the soil and rinse the soil from the roots. Blot them dry with a paper towel. Be careful to keep the plants from the four pots separate; be careful to keep the spinach and mustard growing in the same pot separate. This might be easiest to do if you keep each group on separate, labeled paper towels - spinach alone, mustard alone, spinach grown with mustard, and mustard grown with spinach.
3. Now, working quickly so the plants do not wilt, weigh the four spinach plants together. Divide these weights by 4 to obtain the average weights per plant in each group and record this value in Table 4, line c . Do the same for the other three groups – mustard grown alone, spinach grown with mustard and mustard grown with spinach.
4. Cut each plant at the root-shoot point. Weigh the shoots from four spinach plants together. Divide these weights by 4 to obtain the average weights of the roots. Record the average shoot weight in Table 4, line d. Do the same for the other three groups – mustard alone, spinach grown with mustard, and mustard grown with spinach.

   Repeat for the root weights and record the value in Table 4, line e.



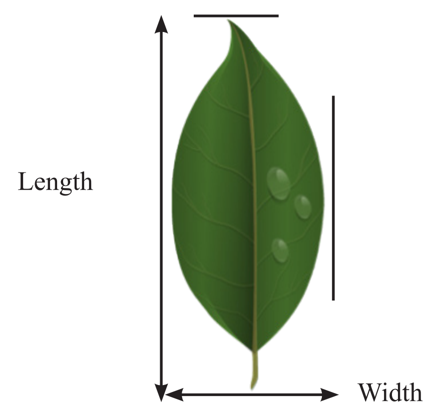
5. Measure the length of the longest part of the shoot of each of the spinach plants grown alone Write the data in Table 1. Average the shoot lengths and write that information in Tables 1 and 4, line a. Do the same for the other three groups – mustard grown alone, spinach grown with mustard, and mustard grown with spinach. Record that data.
6. Measure the length of the longest part of the root of each of the spinach plants grown alone Write the data in Table 2. Average the root lengths and write that information in Tables 2 and 4, line b. Do the same for the other three groups – mustard grown alone, spinach grown with mustard, and mustard grown with spinach. Record the data.
7. Weigh all the shoots of the spinach plants grown alone and divide the weight by the number of plants in that group. Record the average weight in Table 4, line d. Do the same for the other three groups – mustard grown alone, spinach grown with mustard, and mustard grown with spinach. Record the data.



8. Weigh all the roots of the spinach plants grown alone and divide the weight by the number of plants in that group. Record the average weight in Table 4, e. Do the same for the other three groups – mustard grown alone, spinach grown with mustard, and mustard grown with spinach. Record the data.
9. Divide the average shoot weight by the average root weight to get a shoot to root ratio for each of the conditions. Report the data in Table 4, line f.
10. Calculating leaf area using the formula,

    A = π (L x W) / 2,

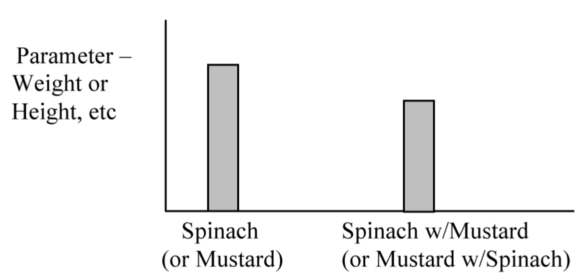
    for each leaf on each plant in the spinach alone pot. Tabulate these data in Table 3 A. Do the same for the other three conditions – mustard grown alone (use Table 3 B), spinach grown with mustard (use Table 3 C), and mustard grown with spinach (use Table 3 D). Record the total leaf area from Tables 3. A, B, C, and D to Table 4, line g.



11. Two optional activities:

    a. There may be some growth parameters you find meaningful that I did not include, measure them and include them in Table 5.

    b. You may make sets of bars graphs to depict the data you have in Table 4. Something along the idea of the following is acceptable, but there are other data you may graph as well. You may use Microsoft's Excel Chart Wizard or a Mac equivalent. Remember to label the axes.



References

Selby, Samuel M., Editor. 1969. The formula for an oval. *CRC Standard Math Tables, 17th Ed.* The Chemical Rubber Co. Cleveland, OH.

Lab Report

Names of Lab Partners: **Date:**

Results

Table 1. Individual Shoot Lengths and Average Shoot Lengths.

	Spinach Alone	Mustard Alone	Spinach, with Competition	Mustard with Competition
Length, Shoot 1 (cm)				
Length Shoot 2 (cm)				
Length, Shoot 3 (cm)				
Length, Shoot 4 (cm)				
Average Shoot Length (cm)				

Table 2. Individual Root Lengths and Average Root Lengths.

	Spinach Alone	Mustard Alone	Spinach with Competition	Mustard with Competition
Length Root 1 (cm)				
Length, Root 2 (cm)				
Length Root 3 (cm)				
Length, Root 4 (cm)				
Average Root Length (cm)				

Table 3. Individual Leaf Areas and Average Leaf Areas:
A. Spinach Alone.

	Leaf Area Plant 1	Leaf Area Plant 2	Leaf Area Plant 3	Leaf Area Plant 4
Leaf 1				
Leaf 2				
Leaf 3				
Leaf 4				
Leaf 5				
Leaf 6				
Leaf 7				
Leaf 8				
Total Leaf Area (cm^2)				

B. Mustard Alone

	Leaf Area Plant 1	Leaf Area Plant 2	Leaf Area Plant 3	Leaf Area Plant 4
Leaf 1				
Leaf 2				
Leaf 3				
Leaf 4				
Leaf 5				
Leaf 6				
Leaf 7				
Leaf 8				
Total Leaf Area (cm^2)				

C. Spinach Grown with Mustard

	Leaf Area Plant 1	Leaf Area Plant 2	Leaf Area Plant 3	Leaf Area Plant 4
Leaf 1				
Leaf 2				
Leaf 3				
Leaf 4				
Leaf 5				
Leaf 6				
Leaf 7				
Leaf 8				
Total Leaf Area (cm^2)				

D. Mustard Grown with Spinach

	Leaf Area Plant 1	Leaf Area Plant 2	Leaf Area Plant 3	Leaf Area Plant 4
Leaf 1				
Leaf 2				
Leaf 3				
Leaf 4				
Leaf 5				
Leaf 6				
Leaf 7				
Leaf 8				
Total Leaf Area (cm^2)				

Table 4. Growth Characteristics of Each Plant Grown Alone and of Each Plant When Grown with a Competitor.

	Spinach Alone	Mustard Alone	Spinach with Competition	Mustard with Competition
a. Average shoot length (cm)				
b. Average root length (cm)				
c. Average weight of entire plant (g)				
d. Average weight of the shoots(g)				
e. Average weight of the roots(g)				
f. Ratio of shoot weight to root weight (divide d by e)				
g. Total Leaf Area, (cm^2)				

Table 5. ____

	Spinach Alone	Mustard Alone	Spinach with Competition	Mustard with Competition
Average _____ ___________				

OR

Bar graphs, as described in the Procedures, #11. You may use a spreadsheet program, such as Microsoft's Excel Chart Wizard, to generate the graphs. Remember to label the axes.

Conclusion

When you write your lab report at for the eutrophication experiment at the end of the semester you will be writing a conclusion that covers a sequence of information similar to the questions outlined here. For this lab report the questions to be answered are given to you, but you should find a pattern to them that leads you to a conclusion for this experiment.

Discussion Questions

1. This experiment was based on the hypothesis that,

2. Why was this something an ecologist might want to know?

3. Did the design of the experiment complement the hypothesis? Why or why not?

4. Based on the results obtained in this experiment, would you accept or reject the hypothesis? Explain why you made that decision.

5. If you rejected the hypothesis what do you think was happening in the experimental situation that caused the results to be other than those expected?

6. Was this a good model to study competition? Why or why not?

7. Answer A or B but not both. If you answer both only the first in order of appearance will be graded.

   A. Based on the results of this experiment, what would be a good hypothesis to make about species that occur in a natural setting?

   B. Based on this model, how do you think competition between exotic species and native species could affect the success of an exotic species to become established in a new setting? Use the results of this experiment to answer the question.

Notes for the Instructor

The plants I use for this experiment are garden varieties of spinach and mustard. Since leaf area is one of the criteria I chose to measure, I selected varieties with flat leaves and smooth edges. The leaves are roughly oval in shape, and the estimation of leaf area using the formula for the area of an oval is a valid assumption. (Previous attempts to more accurately measure leaf area by tracing on paper, cutting and weighing the paper cut outs, and comparing to the weight of paper cut outs to the weight of known area, tried the patience of these students.) The spinach variety we used was Melody, obtained from W. Atlee Burpee & Co., Warminster, PA 18974, and the mustard variety was Florida Broadleaf, obtained from Ferry-Morse Seed Co., Fulton, KY 42041. Two other varieties I have used successfully were Harmony Hybrid for spinach and Tendergreen for mustard, both Burpee seeds. These seed varieties can be obtained through the companies' seed catalogues and off the shelf at garden centers.

I plan on four pots of plants – one pot of spinach alone, one pot of mustard alone, two pots with mustard and spinach growing together in a competitive situation – for each lab group, with three or four students per group. Always plan on more pots than you expect you will need; this allows for some unforeseen problems that can arise.

The plants need 8 to 10 weeks to grow to a size in which there is noticeable competitive stress; less time is needed if the growing temperatures are warm. These varieties do not tolerate excessive heat well. They grow best with natural light in a greenhouse or in an outdoor location safe from herbivory.

I have used both top soil and garden soil, obtained from a garden center. Be careful not to use potting soils or soils with added fertilizers, as this will negate any nutrient stress in a competitive situation. Some organic matter in the soil is fine; it helps maintain soil moisture. I start by seeding the pots with

- 8 seeds for spinach alone,
- 8 – 10 seeds for mustard alone, and
- 4 seeds of spinach and 6 seeds of mustard when planted together in one pot

Mustard seeds are tiny and controlling the exact number of seeds per pot is difficult, but not crucial to the outcome of the experiment. They can be thinned to the correct number later. Water the pots enough to keep the soil moist, but not saturated.

When the first true leaves are developed, thin the plants to

- four plants per pot for spinach alone,
- four plants per pot for mustard alone, and
- two plants of spinach and two plants of mustard per pot for the competitive situation.

I included the form for the lab report my students are expected to complete. The tables are referenced to the procedures to help them find the correct area in the report to write their data. Table 4 is a culmination of the data presented so that comparisons could be easily made. I suggested as an optional exercise that students could chose a criterion of their own to measure and/or make graphs to "picture" the differences between the plants grown alone and in competition. I encourage the use of graphs, as this makes the differences more evident than mere numbers on a page.

Acknowledgement

The idea for this lab was based on "Resource Allocation in Plants" presented by Dan Johnson of Wake Forest University, Winston-Salem, NC, at the ABLE 2005 Conference at Virginia Tech.

About the Author

Debby Luquette teaches General Biology and Environmental Science at Howard Community College, Columbia, MD. My academic background includes a BS in Chemistry from Northeastern University, Boson, MA, and a BS and MS in Biology from Towson University, Towson, MD. Before teaching full time at the HCC, I worked as a classroom programmer at the Maryland Science Center and as a seasonal naturalist at Patapsco Valley State Park. My interest in teaching science is to develop an interest in science in students with limited science background, and especially to help make them adult learners and informed citizens. The book used in Environmental Science and Environmental Science Lab were both written by me over the years at HCC.

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