Physiological Ecology Lab Exercise: Phenotypic Plasticity in Sun and Shade Leaves

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Reprinted From: Goldstein, J., R. Wyatt, and J. Richaardson. 2000. Physiological ecology lab exercise: Phenotypic plasticity in sun and shade leaves. Pages 478-481, *in* Tested studies for laboratory teaching, Volume 21 (S. J. Karcher, Editor). Proceedings of the 21st Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 509 pages.

Objective

To see how plants respond to small-scale environmental gradients by comparing the leaf morphology of sun and shade leaves from an individual tree. Dogwood and oak trees are used in this exercise.

Introduction

Environments may vary greatly at small scales in both time and space. Given this variation in light, temperature, relative humidity, and other factors, it is not surprising that plants and animals have evolved means of dealing with these changes. For animals, whose adult stages are often highly

mobile, one way of dealing with temperature change, for example, is simply to move to a more favorable place. For plants, whose adult stages are typically stationary, there are fewer options. This is probably one reason that we frequently observe localized variation in the morphology or physiology of plants. One way in which plants can respond to localized changes in the environment is by producing changes in the modular units, which comprise the plant body. An example of this is provided by the "sun" and "shade" leaves of dogwood and oak trees. The environment of sun leaves developing high on a tree is drastically different from the environment of shade leaves developing low on a tree. Because photosynthesis results in water loss from leaves, we should observe adaptations to reduce water loss in sun leaves. In this lab sun and shade leaves will be collected from dogwood and oak trees. For dogwood leaves, it is predicted that sun leaves, relative to shade leaves, will have smaller leaf angles to reduce sun exposure, and weigh more because of a heavier waxy cuticle to reduce water loss. For oak leaves, it is predicted that sun leaves, relative to shade leaves, will have greater lobing, i.e. a higher perimeter to surface area ratio, to increase heat dissipation. Measurements of dogwood leaf angles and weights and measurements of oak leaf perimeters and surface areas will be made to test these hypotheses.

It is important to note that the sun and shade leaves are collected from the same tree. Thus, the observed variation between the sun and shade leaves results from *phenotypic plasticity*, not from *genotypic differences* between the leaves.

Pre-lab Exercise

Dogwood leaves

- Write a hypothesis about the *leaf angle* of sun leaves relative to the leaf angle of shade leaves. Justify your hypothesis.
- Write a hypothesis about the *weight* of sun leaves relative to the weight of shade leaves. Justify your hypothesis.

Oak leaves

- Write a hypothesis about the *ratio of perimeter to surface area* of sun leaves relative to this ratio in shade leaves. Justify your hypothesis.

Procedures

A. Estimating leaf angle and leaf weight in Dogwood Trees.

In this section of the lab exercise you will examine how the environment influences leaf morphology by comparing sun and shade leaves from a single dogwood tree in an open (sunny) environment. For this exercise, you should work in groups of 2-4. Enter data in Table 1 below.

Materials

- Pole-pruners or ladder for reaching high tree branches

- Protractors
- Hole-punchers
- Weighing cups
- Balance (precision to 0.01 g)

Instructions:

1. From a single dogwood tree, each group should collect 10 sun leaves and 10 shade leaves.
2. For each leaf, measure the angle of leaf fold along the rachis with a protractor. Record values.
3. Keeping sun leaves separate from shade leaves, punch 10 holes in each leaf. Try to avoid veins in the leaves. *Be careful--the leaf disks you cut are sneaky and like to stick together and stick to the hole-puncher*.
4. Weigh the sun leaf disks together. Record value. In a separate weighing cup, weigh the shade leaf disks together. Record value.

Table 1. Dogwood leaf measurements

	Sun	Shade
Group data		
Number of leaves	10	10
Angles of leaves ( )		
Number of leaf disks	100	100
Total weight of disks (g)		
Class data		
Number of leaves	(10 x number of student groups)	(10 x number of student groups)
Angles of leaves ( )		
Number of leaf disks	(100 x number of student groups)	(100 x number of student groups)
Total weights of disks (g)		

B. Estimating degree of lobing in Oak Trees

In this section of the lab exercise you will examine how the environment influences leaf morphology by comparing sun and shade leaves from a single oak tree in an open (sunny) environment. For this exercise, you should work in groups of 2-4. Enter data in Table 2 provided below.

Materials

- Pole-pruners or ladder for reaching high tree branches
- Paper
- Scissors
- String
- Rulers
- Balance (precision to 0.01 g)

Instructions:

1. From a single oak tree, each group should collect 3 sun leaves and 3 shade leaves.
2. Trace or photocopy leaves onto paper. Cut out traced leaves.
3. Measure perimeter of leaves with string.
4. Weigh traced leaves.

5. [a]Estimate surface area.

Table 2. Oak leaf measurements.

	Sun	Shade
Group data		
Number of leaves	3	3
Perimeter length (cm)		
Weight (g)		
Surface area (cm^2)		
Surrace area:Perimeter (cm)		
Class data		
Number of leaves	(3 x number of student groups)	(3 x number of student groups)
Perimeter lengths (cm)		
Weights (g)		
Surface areas (cm^2)		
Surface area:Perimeter(s) (cm)		

[a]Once you know the weight of your sample, you can estimate the **surface area** of your sample by determining the *surface area : weight* relationship of the paper. Cut out a known area of paper (e.g. 10 cm x 10cm) and weigh it. Then, calculate the surface area : weight ratio. Given the *known* weight of your sample, use the ratio to determine your *unknown* surface area.

Notes to Instructors

This lab encourages critical thinking skills and challenges students to develop and test hypotheses. It provides a review of plant physiology, evolutionary adaptations to the environment, and introduces the concept of phenotypic plasticity, in contrast with genetically induced variation.

The data collected are suitable for basic statistical analysis. Students may discuss and critique the experimental design and possible sources of error, as well as generate ideas for refining and improving the procedures and scientific method.