Leaf Patterns

Introduction

All life on Earth is dependent upon light energy from the Sun. The Sun's energy is captured for all living things during photosynthesis. Most photosynthesis in land plants occurs in their leaves. Does the architecture of the leaf affect the photosynthetic efficiency of the leaf?

Concepts

- Micro-environment
- Adaptation
- Canopy layers

Materials

Balance, 0.1-g accuracy

Graph paper

Plant press

Ruler

Safety Precautions

Standard field trip procedures should be followed for Part A of the activity. Removal of leaves should be done safely, and climbing of trees should be carefully monitored. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Collecting and Preserving the Leaves

1. Your teacher will guide your work team to an appropriate tree to collect the leaves. Collect leaves of two types:
   a. Leaves on the "outside" canopy of the tree that are always in direct sunlight.
   b. Leaves on the "inside" of the tree where the leaf is usually shaded by the outer canopy leaves.
2. Collect 10 leaves of each type from different locations on the tree. Be sure to collect the whole leaf including the petiole.
3. Number each leaf, and label the leaves as either "Sun" or "shade." Label them on a separate piece of paper inside each compartment of the plant press. Place each leaf into a plant press as directed by your teacher, and let them dry overnight.

Part B. Surface Area and Weight

1. Calculate the area of each leaf by tracing its outline on a piece of centimeter-lined graph paper (see Figure 1). Count the squares to calculate the total area of each leaf. Combine all the partial squares to the nearest whole cm^2. Record the total area for each leaf in the data table on the Leaf Patterns Worksheet.
2. Connect the tips of the leaf lobes with straight lines as shown in Figure 2 (see page 2). Calculate the sinus area of the leaf by counting the squares in all the enclosed leaf lobe areas. Record the sinus area for each specific leaf in the data table.
3. Divide the sinus area by the leaf area for each specific leaf to derive a sinus area:leaf area ratio for each leaf (see Figure 2). Record this ratio (column B/column A) in column C of the data table.
4. Weigh each leaf to the nearest 0.1 g. Record the weight for each specific leaf in column D of the data table.
5. Determine the weight per cm^2 by dividing the weight by the leaf area (column D/column A). Record this ratio in column E of the data table.

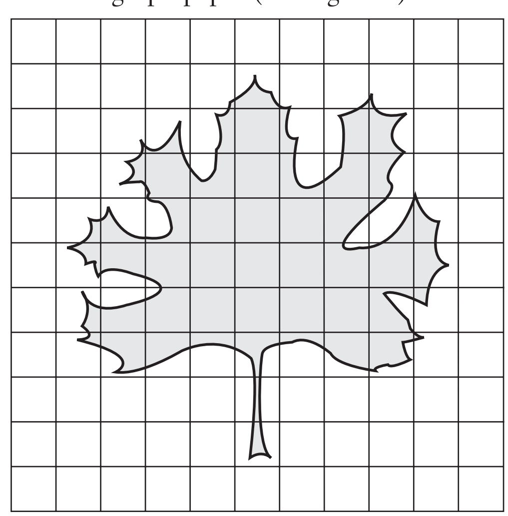

Figure 1. Outline of leaf on grid to determine total leaf area

Part C. Interpretations

1. Calculate the average sinus area/leaf area ratio for the ten "Sun" leaves. Do the same for the "shade" leaves. Record the averages in the data table.
2. Calculate the average weight/cm^2 for the ten "Sun" and "shade" leaves. Record the averages in the data table.
3. Answer these questions:

   a. A higher sinus area/leaf area ratio indicates a leaf with deeper, larger lobes. How does this ratio compare for the "Sun" and "shade" leaves? Is this logical? Explain why this might be an advantage to (a) each leaf and (b) to the entire tree.

   b. How does the weight/cm^2 of the two leaf types compare? How do you explain these results? Is this of any advantage to the tree?

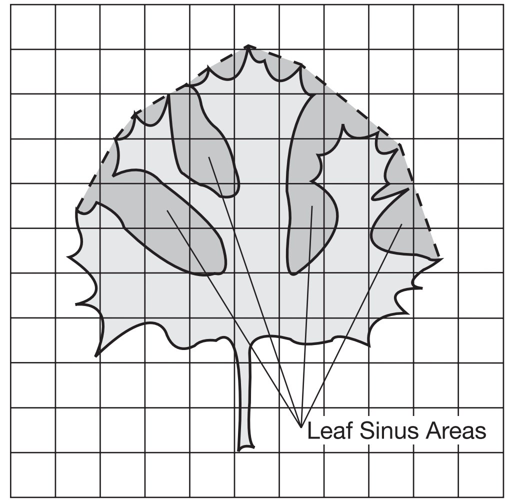

Figure 2. Determination of leaf sinus area

Going Further

How constant do you think these ratios would be for trees of the same species? What about different species? Would the ratios change for trees growing in different locations? Repeat this lab considering these or other variables.

Can you explain why some trees do not have multiple layers of leaves? How might leaf growth/shape be affected for plants low to the ground in a dense forest? How about the leaves on the tallest trees? Research other ways that leaves are adapted for efficiently capturing sunlight.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Evolution and equilibrium
Form and function

Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard C: Life Science, structure and function in living systems, diversity and adaptations of organisms

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard C: Life Science, biological evolution; matter, energy, and organization in living systems; behavior of organisms

Tips

- This activity will require two lab periods. The first will be used to collect the leaves. The second lab will be used to make measurements and analyze the data. Locate tree(s) close to the school building with a good canopy density of leaves that can be safely and legally collected. A dense canopy tree with multiple layers of leaves is needed (maples and oaks work well).
- The second part of the lab can be completed at a later time if the leaves are in a plant press and kept in a dry storage area.
- Be sure students collect the entire leaf (including the leaf stem called the petiole) so that the weight measurements include consistent components from leaf to leaf.
- The results in this experiment should be reliable if good canopy trees are available and you collect a good size sample. You might have students pool class data to increase the reliability of the total data.
- If collecting large numbers of leaves is a problem, you may consider collecting 50 leaves of each type and divide your class

into teams to collect data on all 100 leaves. The 100 leaves may then be reused with other classes.

- Leaves can be collected and pressed between sheets of newspaper and placed under heavy books if a plant press is not available.

Discussion

This exercise illustrates the concept of micro-environments and how each leaf of a large tree is living in its own little world with its own set of environmental factors. The reason leaves on the interior of a tree can still be efficient in conducting photosynthesis is that the rate of photosynthesis is not linear with respect to light intensity. Above a certain light intensity, the effect of increased light intensity on total photosynthetic activity becomes diminished. Thus leaves in the interior of the canopy—if allowed reasonable light (that coming through the sinuses of outer leaves)—can also be efficient in conducting photosynthesis. With a multiple-layered canopy, the amount of total surface area of light-absorbing leaf surface is greatly increased.

A tree with a large canopy would not have any advantage by being large if it totally shaded its interior leaves. In some species, as illustrated in this lab, the adaptation that increases photosynthetic area is the larger sinuses of the outer leaves. Other species of plants have other adaptations to increase the chances of absorbing more sunlight.

In addition, leaves on the outer portion of the canopy have thicker layers of photosynthetic cells because the intense sunlight can penetrate the leaf to a greater depth and still be efficient. This phenomenon is verified by the weight/cm^2 being larger in the outer leaves compared to the inner canopy leaves. Thicker leaves on the outer part of the canopy is another helpful adaptation for the total plant.

Many other plant adaptations are relative to the capture of sunlight and photosynthetic efficiency. The adaptations measured in this activity are easily measured in the oaks and maples. You might try other species and see if either or both of the variables measured in this lab hold true.

References

Collinveaux, P. *Ecology;* John Wiley and Sons: New York; 1986.

Horn, H. D. *The Adaptive Geometry of Trees;* Princeton University Press: Princeton, New Jersey; 1971.

Jurik, T. W. Temporal and spatial patterns of specific leaf weight in successional northern hardwood tree species. *American Journal of Botany*, 1986. 73, 1083–1092.

Materials for *Leaf Patterns* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP1813	Graph Paper, cm
OB2136	Flinn Scientific Balance, Economy Choice, 200 × 0.1 g
FB1115	Flinn Plant Press

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Name: ___________________________________

Leaf Patterns Worksheet

Data Table

Leaf Location	A. Leaf Area (cm^2)	B. Sinus Area (cm^2)	C. $\frac{\text{Sinus Area}}{\text{Leaf Area}}$ (B ÷ A)	D. Leaf Weight (g)	E. Weight/cm^2 (D ÷ A)
#1 Sun					
#2 Sun					
#3 Sun					
#4 Sun					
#5 Sun					
#6 Sun					
#7 Sun					
#8 Sun					
#9 Sun					
#10 Sun					
Sun Average					
#1 Shade					
#2 Shade					
#3 Shade					
#4 Shade					
#5 Shade					
#6 Shade					
#7 Shade					
#8 Shade					
#9 Shade					
#10 Shade					
Shade Average					