Transpiration

http://www.sc2000.net/~czaremba/aplabs/

Introduction

The amount of water needed daily by plants for the growth and maintenance of tissues is small in comparison to the amount that is lost through the process of **transpiration** and **guttation**. If this water is not replaced, the plant will wilt and may die. The transport up from the roots in the xylem is governed by differences in **water potential** (the potential energy of water molecules). These differences account for water movement from cell to cell and over long distances in the plant. Gravity, pressure, and solute concentration all contribute to water potential and water always moves from an area of high water potential to an area of low water potential. The movement itself is facilitated by osmosis, root pressure, and adhesion and cohesion of water molecules.

The overall process: Minerals actively transported into the root accumulate in the xylem, increase solute concentration, and decrease water potential. Water moves in by **osmosis**. As water enters the xylem, it forces fluid up the xylem due to hydrostatic **root pressure**. But this pressure can only move fluid a short distance. The most significant force moving the water and dissolved minerals in the xylem is upward pull as a result of **transpiration**, which creates a negative tension. The "pull" on the water from transpiration is increased as a result of cohesion and adhesion of water molecules.

The details: Transpiration begins with evaporation of water through the stomates (stomata), small openings in the leaf surface which open into air spaces that surround the mesophyll cells of the leaf. The moist air in these spaces has a higher water potential than the outside air, and water tends to evaporate from the leaf surface. The moisture in the air spaces is replaced by water from the adjacent mesophyll cells, lowering their water potential. Water will then move into the mesophyll cells by osmosis from surrounding cells with the higher water potentials including the xylem. As each water molecule moves into a mesophyll cell, it exerts a pull on the column of water molecules existing in the xylem all the way from the leaves to the roots. This transpirational pull is caused by (1) the **cohesion** of water molecules to one another due to hydrogen bond formation, (2) by **adhesion** of water molecules to the walls of the xylem cells which aids in offsetting the downward pull of gravity. The upward transpirational pull on the fluid in the xylem causes a **tension** (negative pressure) to form in the xylem, pulling the xylem walls inward. The tension also contributes to the lowering of the water potential in the xylem. This decrease in water potential, transmitted all the way from the leaf to the roots, causes water to move inward from the soil, across the cortex of the root, and into the xylem. Evaporation through the open stomates is a major route of water loss in the plant. However, the stomates must open to allow the entry of CO_2 used in photosynthesis. Therefore, a balance must be maintained between the gain of CO_2 and the loss of water by regulating the opening and closing of stomates on the leaf surface. Many environmental conditions influence the opening and closing of the stomates and also affect the rate of transpiration. Temperature, light intensity, air currents, and humidity are some of these factors. Different plants also vary in the rate of transpiration and in the regulation of stomatal opening.

Exercise 9A Transpiration

In this lab, you will measure transpiration under various laboratory conditions using a **potometer**. Four suggested plant species are *Coleus, Oleander, Zebrina*, and two week old bean seedlings.

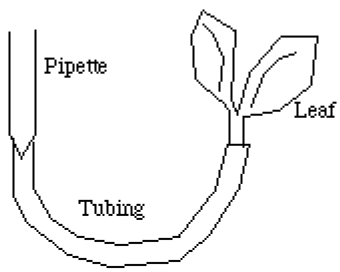
Materials

0.1 mL pipette, plant cutting, ring stand, clamps, clear plastic tubing, petroleum jelly, fan, lamp, spray bottle, and plastic bag.

Procedures

Each lab group will expose one plant to one treatment.

1. Place the tip of a 0.1 mL pipette into a 16 -inch piece of clear plastic tubing.
2. Submerge the tubing and the pipette in a shallow tray of water. Draw water through the tubing until **all** the air bubbles are eliminated.
3. Carefully cut your plant stem under water. This step is very important, because no air bubbles must be introduced into the xylem.
4. While your plant and tubing are submerged, insert the freshly cut stem into the open end of the tubing.
5. Bend the tubing upward into a "U" and use the clamp on a ring stand to hold both the pipette and the tubing.



6. If necessary use petroleum jelly to make an airtight seal surrounding the stem **after** it has been inserted into the tube. **Do not put petroleum jelly on the end of the stem.**
7. Let the potometer equilibrate for 10 minutes before recording the time zero reading.
8. Expose the plant in the tubing to one of the following treatments(you will be assigned a treatment by your teacher):
    a. Room conditions.
    b. Floodlight (over head projector light).
    c. Fan (place at least 1 meter from the plant, on low speed, creating a gentle breeze).
    d. Mist (mist leaves with water and cover with a transparent plastic bag; leave the bottom of the bag open).
9. Read the level of water in the pipette at the beginning of your experiment (time zero) and record your finding in **Table 9.1**.
10. Continue to record the water level in the pipette every **3** minutes for **30** minutes and record the data in **Table 9.1**.

Table 9.1: Potometer Readings

Time (min)	0	10	20	30
Reading (mL)				

11. At the end of your experiment, cut the leaves off the plant and mass them. Remember to blot off all excess water before massing.

    Mass of leaves = ___________ grams.

    Calculation of Leaf Surface Area

    The total surface area of all the leaves can be calculated by using one of the following procedures.

    __________________ = Leaf Surface Area (m^2)

    Leaf Mass Method:

    - Cut a 1 cm^2 section of one leaf.
    - Mass the 1 cm^2 section.
    - Multiply the section's mass by 10,000 to calculate the mass per square meter of the leaf. (g/m^2) ____________
    - Divide the total mass of the leaves (step 11) by the mass per square meter (above). This value is the leaf surface area.
    - Record this value above.

    Leaf Trace Method:
    After arranging all the cut-off leaves on the grid below, trace the edge pattern directly on to the grid. Count all of the grids that are completely within the tracing and estimate the number of grids that lie partially within the tracing. The grid has been constructed so that a square of four blocks equals 1 cm^2. The total surface area can then be calculated by dividing the total number of blocks covered by 4. Record the value above.

12. Water lost per square meter: To calculate the water loss per square meter of leaf surface, divide the water loss at each reading (**Table 9.1**) by the leaf surface area you calculated.

Table 9.2: Individual Water Loss in mL /m^2 Leaf Surface Area = ___m^2			
	0-10	**10-20**	**20-30**
Water Loss (mL)			
Water loss per m^2			

13. Record the averages of the class data for each treatment in **Table 9.3**.

Table 9.3: Class Average Cumulative Water Loss in mL /m^2

Class Average Cumulative Water Loss in mL/m^2 at 10 Minute Intervals Leaf Surface Area = ___m^2					
Time (minutes)	0	0-10	10-20	20-30	Average
Room					
Light					
Fan					
Mist					

Analysis of Results

1. Explain why each of the conditions causes an increase or decrease in transpiration compared to the control.

Conditions	**Effect**	**Reasons**
Room		
Fan		
Light		
Mist		

2. How did each condition affect the gradient of water potential from stem to leaf in the experimental plant?
3. What is the advantage to a plant of closed stomata when water is in short supply? What are the disadvantages?
4. Describe several adaptations that enable plants to reduce water loss from their leaves. Include both structural and physiological adaptations.

Extension: Plant Form and Function (Chapters 35~39)

1. List the similarities and differences between monocot and dicot plants
2. Draw and label a typical flowering plant (see figure 35.4)
3. List and describe
    a. Root modifications
    b. Leaf modifications
4. Draw and distinguish among
    a. Parenchyma cells
    b. Collenchyma cells
    c. Sclerenchyma cells
    d. Water-conducting cells (tracheids and vessel elements)
    e. Food-conducting cells (phloem; sieve-tube members and companion cells)
5. Distinguish between apical and lateral meristems and primary and secondary growth
6. Diagram a winter twig (figure 35.14)
7. Describe
    a. Absorption of water and minerals by roots
    b. Transport of xylem sap
    c. Control of stomatal opening and closing
    d. Translocation of Phloem sap
8. List
    a. Plant macronutrients
    b. Plant micronutrients
    c. Symptoms of mineral deficiency
9. Describe
    a. Soil composition and texture
    b. Role of soil bacteria in nitrogen nutrition of plants
    c. Symbiotic nitrogen fixation
10. Define
    a. Plant parasitism
    b. Plant predation
11. Describe methods of vegetative propagation
12. Define
    a. Phototropism
    b. Apical dominance
    c. Gravitropism
    d. Thigomotropism
    e. Phytochromes
13. Define photoperiodism and distinguish among
    a. Short-day plant
    b. Long-day plant
    c. Day-neutral plant
    d. Critical night length
14. List and briefly describe the functions of the following plant hormones (see p. 756)
    a. Auxins
    b. Cytokinins
    c. Gibberillins
    d. Abscisic acid
    e. Ethylene
    f. Oligosaccharins
    g. Brassinosteroids
15. Briefly describe responses to
    a. Water deficit
    b. Oxygen deprivation
    c. Salt stress
    d. Heat stress
    e. Cold stress
    f. Herbivory
    g. Pathogens