

Lab 9: Transpiration¹

Overview

In this lab you will:

1. apply what you learned about water potential in Lab 1 (Diffusion and Osmosis) to the movement of water within a plant, and
2. measure transpiration under different lab conditions

Objectives

Before doing this lab you should understand:

1. how water moves from roots to leaves in terms of the physical/chemical properties of water and the forces provided by differences in water potential
2. the role of transpiration in the transport of water within a plant
3. the structures used by plants to transport water and regulate water movement

After doing this lab you should be able to:

1. test the effects of environmental variables on rates of transpiration using a controlled experiment

Introduction

The amount of water needed daily by plants for growth and maintenance of tissues is small in comparison to the amount that is lost through the process of **transpiration** (the evaporation of water from the plant surface) and **guttation** (the loss of liquids from the ends of vascular tissues at the margins of the leaves). If this water is not replaced, the plant will wilt and may die.

The transport of water 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, increasing solute concentration and decreasing 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 the *upward* pull as a result of **transpiration**, which creates tension. The “pull” on the water from transpiration results from the cohesion and adhesion of the water molecules.

The Details: Transpiration begins with evaporation of water through 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 (moving from an area of high water potential to an area of lower water potential). The moisture in the air spaces is replaced by water from the adjacent mesophyll cells, lowering their water potential (since the cytoplasm becomes more concentrated). Water will then move into the mesophyll cells by osmosis from surrounding cells with 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 occurs because of (1) the cohesion of water molecules to one another due to hydrogen bond formation, and (2) by adhesion of water molecules to the walls of the xylem cells which aids in offsetting the downward pull of gravity.

¹ Partially adapted from the College Board AP Biology Student Lab Manual, 2001 edition and from a lab written by Franklin Bell from Saint Mary's Hall in San Antonio, TX.

The upward transpirational pull on the fluid in the xylem causes a tension (negative pressure) to form in the xylem, pulling the walls of the xylem inward. The tension also contributes to the lowering of 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 plants. However, the stomates must open to allow the entry of CO₂ used in photosynthesis. Therefore, a balance must be maintained between the gain of CO₂ 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 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.

Before coming to lab

1. Read through the procedure so you know what to expect. Put the procedure in your lab notebook, using your own words or drawings.
2. Leave a space to indicate what species of plant you worked with. (That information will be available on the first day of the lab.)
3. Prepare a data table into which you will record your measurements (both temperature and mass of the plant) and the % change in mass since the beginning of the experiment.

Procedure

1. Obtain five small potted plants. All of the plants you use should be the same species.
2. Remove each plant from its pot. The roots should remain intact. Do not attempt to remove soil from the roots. However, it is OK if some soil remains in the pot.
3. Wrap the entire root ball of each plant in a plastic bag. Make sure that there are no holes in the bags. Tie each bag snugly around the stem with string or dental floss. It is imperative that the bag is snug around the stem so that as little water as possible can evaporate out at that location.
4. Clearly label each plant with your name(s) and the condition that the plant will be exposed to. You will test five conditions: normal room, under constant bright light, normal room but under a fan, dark, and high humidity.
5. The plants under constant bright light will have a water-filled heat sink between them and the lamp. The plants in the dark will be placed in a cupboard in the biology classroom and should only be taken out for short periods to determine their mass. The plants in the high humidity condition will be kept under normal room light. Before the experiment begins, they will be misted with water and then a clear plastic bag will be placed over each plant in order to maintain a humid environment. The plastic bag will be temporarily removed when you determine the mass of the plant.
6. Determine the mass of each plant and record it in your data table.
7. Put each plant in its appropriate condition.
8. Place a thermometer in each condition.
9. Return each day to take the mass of each plant. Try to return at approximately the same time of day if possible. Record all mass measurements. If your plant blooms, pinch the blooms off and be sure any leaves or blooms that fall off are put back in the center of the plant to be included in the total mass of the plant.
10. You should also record the temperature at each location each day.
11. Continue taking measurements over the course of four days.

Data Analysis

Prepare a graph in your lab notebook that shows the data for all five plants. The graph should show % change, not mass. Make sure that your graph has all of the proper labels and is in the proper format.

Questions

1. For this experiment, what was the independent variable and what was the dependent variable? What were the constants?
2. Calculate the average rate of water loss per hour for each of the treatments. In order to do this, you need to know that 1 mL of water has a mass of 1 gram. Express your answers in mL/hr.
3. For each of the non-control conditions, give the effect the condition had on transpiration, and then explain why it had that effect.
4. Explain the role of water potential in the movement of water from soil through the plant and into the air.
5. What is the advantage to a plant of closed stomata when water is in short supply? What are the disadvantages?
6. Describe several adaptations that enable plants to reduce water loss from their leaves. Include both structural and physiological adaptation. You may need to do some research to answer this question.
7. Why did you need to calculate the % water loss each day instead of graphing the total amount of water lost each day?