Water Rise in Shoots and Leaves of Terrestrial Plants

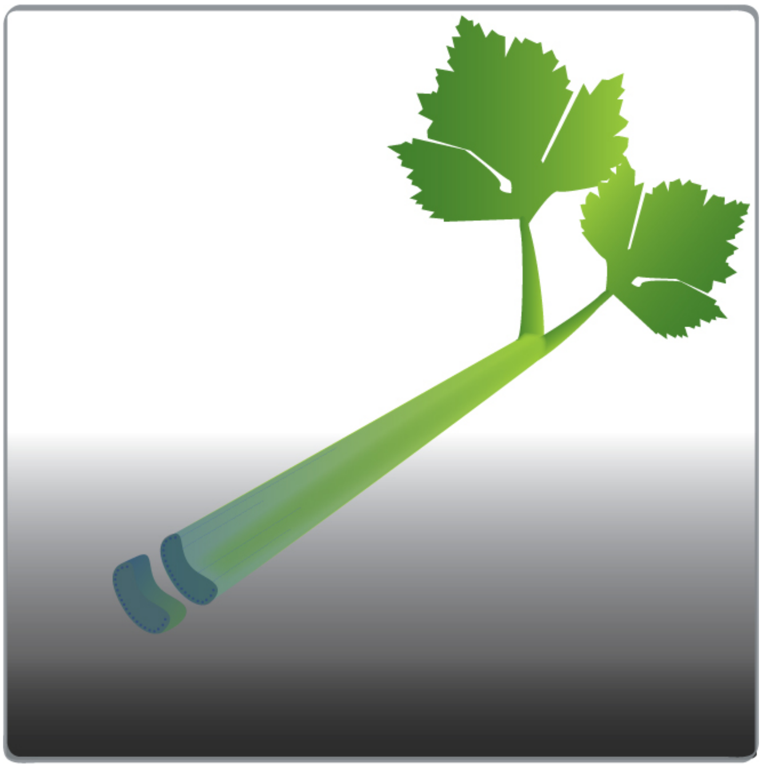


Figure 1

Introduction

Water are absorbed from the soil by the plant root and transported to all parts of the plant. This passage of water is called the **transpiration stream**.

Several factors play a role in pushing water up the transpiration stream against the force of gravity:

Root Pressure and Osmosis – water penetrate root cells by the force of osmosis, created by unequal concentrations of water inside the root cells and the surrounding soil. Osmosis pushes water up in the plant due to unequal concentrations of water across the plant.

Capillary action or **capillarity** - the ability of a narrow tubes to draw a liquid upwards against the force of gravity. The flow of water in the thin xylem tubes is influenced by two opposite forces: adhesive forces of water molecules to the surface of the tube walls and cohesive forces that attract water molecules to each other. When the adhesive forces between the water and the tube walls are stronger than the cohesive forces between the water molecules, a capillary action is created.

Transpiration Pull - This is considered to be the major driving force for water transport throughout a plant. Water vapor is lost from the leaves through the stomata in the process called - **transpiration**. Water concentration in the stomata areas is especially low. Since osmosis occurs across a concentration gradient, water will flow to these areas to equalize water concentration across the plant.

CO_2, required for photosynthesis, penetrates into the leaves through the stomata. During daylight photosynthesis is most intensive and the stomata open for intake of CO_2. As a result, water loss to the external environment is increased.

More than 90% of the water taken in by the plant root is ultimately lost to the atmosphere.

In this experiment water rise in the xylem is followed by coloring of the leaf of celery (Apium graveolens) by a dye, methylene blue, added to the water supply.

The extent of water loss in transpiration is followed by measuring water intake by a shoot of Nerium oleander inserted into a flask full of water. Evaporation of water from the leaf leads to suction of the water from the flask. The suction of the water continuously increases the air volume in the flask, thus causing a reduction in pressure (in accordance with Boyle's law) recorded by a pressure sensor.

Equipment

- 2 pressure sensors (150 –1150mb).
- 5 250ml glass flask
- 2 rubber corks
- 2 needles, no 23
- 2 latex tubes
- 2 three way valves
- Magnifying glass
- Sharp razor
- 20 cm ruler

- A MultiLogPRO

Water Rise in Celery Leaf

1. Pour 100ml of 1% Methylene Blue solutions into 3 250mk flasks. Mark them: 1 to 3
2. Cut 1 cm piece from the lower edge of the petiole of each leaf. The leaves should be almost identical (in width, length and number of small leaves)
3. Watch the cross section under the magnifying glass. Try to identify the xylem tubes (see figure 1)
4. Insert one celery leaf to each flask
5. Wait 5 min, then take one leaf out of the solution. Dry excess color
6. Cut a 1 cm piece from the lower edge of the petiole. Watch the cross section under the magnifying glass to see if the xylem bundles are blue. Count the number of colored xylem bundles you observe in the section
7. Repeat the procedure till you reach a section without colored bundles (see figure 2)
8. After 10 min, take out the second leaf. Cut cross sections and check them under the magnifying glass as done in step 6. Count the number of xylem bundles you observe in the section
9. After 20 min take out the third leaf and repeat step 8

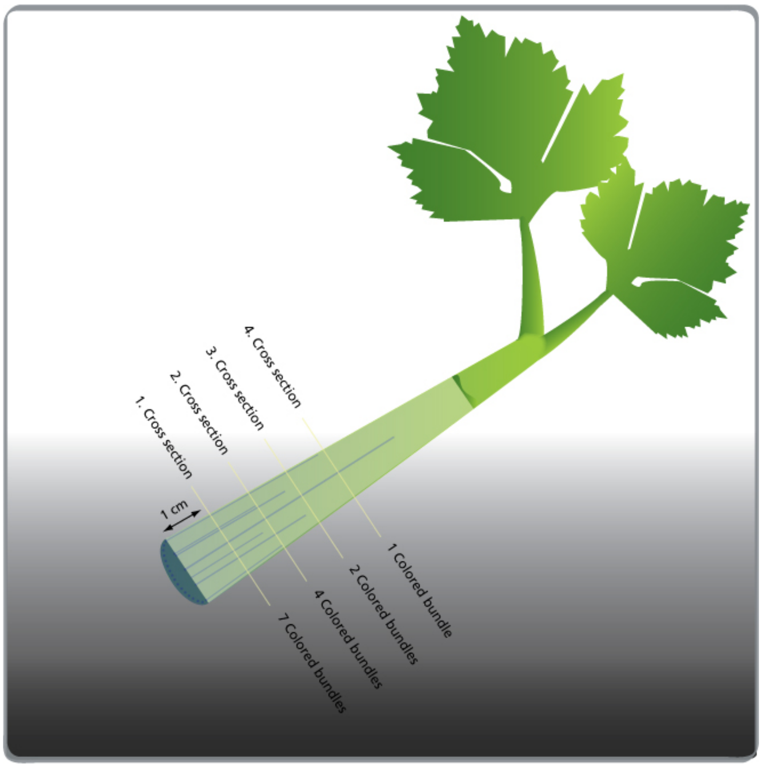


Figure 2

Data Analysis

10. Prepare a table and present the results you obtained:

Height in cm					
No of colored tubes in the section					

11. Calculate the average height the color has reached in each leaf:

a. Multiply the height with the number of colored bundles:

In I bundle the height was 5 cm: 5 cm X 1 bundle = 5
In 3 bundles the height was 4 cm: 4 cm X 3 bundles = 12
In 5 bundles the height was 3 cm: 3cm X 5 bundles = 15

b. Sum up the total height in all the sections: 32

c. Divide it by the total number of bundles: 9

d. The average height the water has reached in the leaf after 5 min is 3.5 cm.

12. Calculate the average rate of water rise in the 3 leaves, in cm per min.

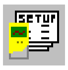
Equipment Setup Procedure

1. Connect the MultiLogPRO to the serial port of the computer.

2. Turn the MultiLogPRO on.

3. Connect the pressure sensors to the I/O 1 and to I/O 2 ports of the MultiLogPRO.

4. Assemble the equipment as illustrated in figure 3

5. Set the MultiLogPRO up according to the setup specified below. You can set up the MultiLogPRO either by using the MultiLogPRO keypad or using the Setup Wizard in MultiLab (click **Setup Wizard** 

on the main toolbar)

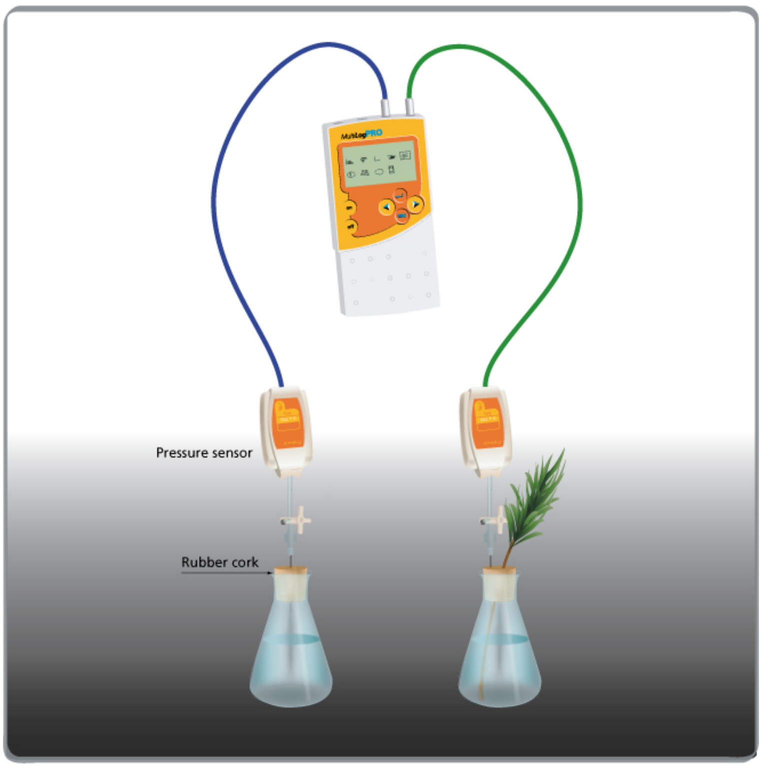


Figure 3

A syringe needle (no 23) is inserted through the cork, till its tip projects somewhat out of the cork (figure 4)

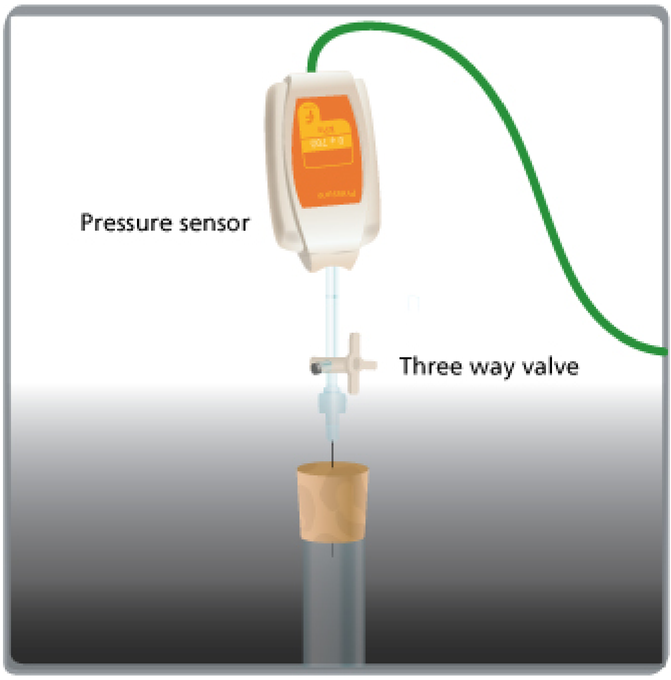


Figure 4

To the other end of the syringe, projecting out of the upper side of the cork, a three-way valve (the one used in infusions) is attached via a very short latex tube (its length must be just enough to hold together the valve and the syringe). A pressure sensor is connected to the valve through another short latex tube.

Turn the valve till its opening is directed vertically. In this position, air can flow through the valve. In order to stop airflow, turn the valve till its opening reaches a horizontal position.

MultiLogPRO Set Up

- Input 1: Pressure (150 –1150mb)
- Input 2: Pressure (150 –1150mb)
- Rate: Every second
- Recording time: 33:20 MM:SS (2000 Samples)

Experimental Procedure

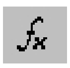
11. Perform the experiment in an aerated and well-lighted room. If possible, place the experimental systems close to the window.
12. Choose a shoot of a tree or a bush with large surface area of leaves (carrying high number of small leaves or big leaves). The surface of the shoot should be smooth and cylindrical, to ensure tight contact with the cork.
13. Pierce in one of the corks, a hole having a diameter a bit smaller than that of the shoot you chose.
14. Fill the two 250ml flasks with water.
15. Start the MultiLogPRO either from the MultiLogPRO Panel or from **MultiLab**: click **Run**  on the main toolbar
16. Follow the pressure recorded on the screen.
17. Insert the shoot into the flask through the hole in the cork, till it almost touches the flask's bottom.
18. Close the second flask with the other cork.

> ***Attention!***
>
> *The systems must be efficiently sealed to prevent air leakage in and out of the flasks.*

19. In case the pressure increases after closing the flasks with the corks, turn the valves till their openings are directed vertically (to enable air flow through them). The pressure in the flasks should decrease and reach the atmospheric level (about 1000 mbar). To stop airflow through the valves, turn them till their openings reach a horizontal position. Make sure the pressure in the flasks is maintained at atmospheric level before you start the experiment.
20. After you start the experiment, and as the pressure in the flasks stabilizes, stop the MultiLogPRO and start again. Follow changes in the pressure in the flasks, during the experiment.

Data Analysis

3. To calculate the net reaction rate, create a difference graph: subtract the graph obtained in the control system from that of the experimental system:

    f) Click Analysis **Wizard**  on the main toolbar, then click the **Functions** tab

g) In the **Functions** drop list select **Subtract**

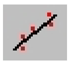
h) In the **G1** drop list select Pressure I/O-1, In the **G2** drop list select Pressure I/O-2

i) In the **Name** edit box enter a name (e.g. Difference)

j) Click **OK**

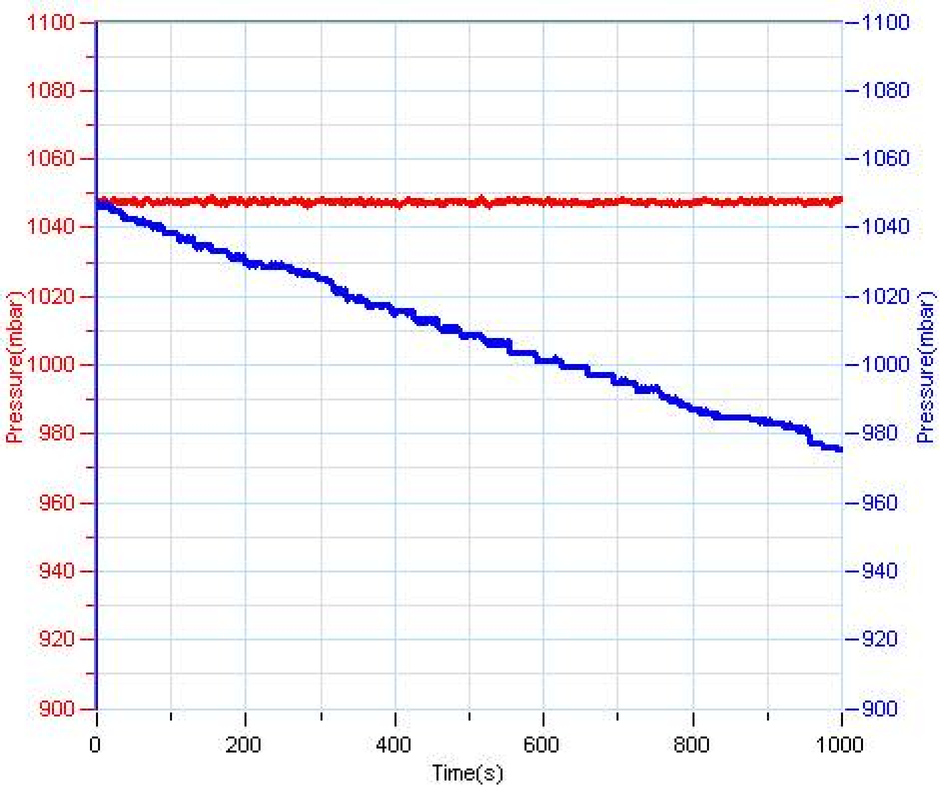
4. Apply a linear fit to the difference graph:

d) Use the cursors to select the desired range

e) Click **Linear fit**  on the main toolbar. The fit equation will be displayed in the information bar at the bottom of the graph window

f) The slope of the fit line is the measured rate of water loss in the experiment

An example of the graphs obtained in this experiment is shown below:



Questions

8. What is the control used in this experiment?
9. Why is a control flask necessary in the experiment?
10. What is the effect of light on the rate of water suction during the experiment? Would you expect similar changes in the dark?

11. What will be the effect of an increase in humidity on the rate of water suction? Explain your answer.
12. Why is a shoot having large surface area of leaves used in this experiment?
13. What is the main route of water loss in this experiment? How is it connected to the process of transpiration?
14. What will be the effect of covering the underside of the leaves with Vaseline?

Further Suggestions

5. Design an experiment to examine the effect of light on the rate of water loss.
6. Examine the effect of wind and humidity on rate of water suction.
7. Examine the effect of covering the leaves with Vaseline on rate of water suction.
8. Examine the effect of surface area of the leaves on rate of water loss: Use shoots of different size and number of leaves.
9. Cut the shoot and compare the number of xylem bundles with that you observed in the celery petiole.
10. Compare evaporation rate in another plant choose a plant with high rate of respiration, Ceratonia siliqua for example.