Transpiration

Water is transported from the roots upward throughout the plant following a decreasing water potential gradient. Transpiration, the evaporation of water through stomata helps create a lower osmotic potential in the leaf. The resulting transpiration "pull" or tension is responsible for the movement of water from the xylem to the mesophyll cells into the air spaces in the leaves. The rate of evaporation of water from the air spaces of the leaf to the outside air depends on the water potential gradient between the leaf and the external environment.

Various environmental factors, including those conditions that directly influence the opening and closing of the stomata, affect a plant's transpiration rate. This experiment will measure transpiration rates under different conditions of light, humidity, temperature, and wind. Data will be collected by measuring pressure changes as the plant takes up water into the stem.

Materials Needed

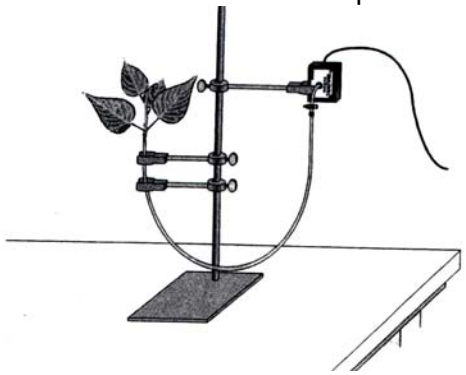
Data Recorder with Vernier Interface and Logger Pro software
Vernier Gas Pressure Sensor
3 Utility Clamps
Ring Stand
Fresh plant cuttings* or young plants with 4 – 6 leaves and 6 – 8" stem length
Plastic tubing clamps
Medicine dropper or Beral pipette
Razor blade
Metric ruler
Masking tape
100-watt light source
Plastic gallon-size bag with twist tie
Small electric heater
Slow speed fan
Plant mister (aerosol spray container)
Graph paper
Balance

* Cuttings must be made immediately prior to placing in tubing, and cut ends must be kept submerged in water at all times.

Procedure

Exercise I – Transpiration Control

1. Position the ring stand, 3 utility clamps, and Gas Pressure Sensor as shown in the transpiration apparatus illustration below. There should be about 5 – 8 cm between the bottom of the gas pressure sensor and second clamp.



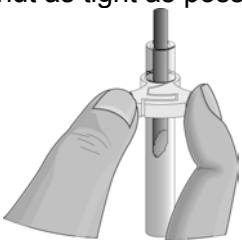
Transpiration Apparatus

2. Obtain a 36-42 cm piece of plastic tubing with a white plastic connector at one end. Attach a plastic tubing clamp to the opposite end as shown below.

Bend the tubing into a U shape and have a second student use a 1 ml pipette to fill the tube with water. Add water to the tube until it is nearly full. Tap the tubing to expel any air bubbles that form inside the tube.

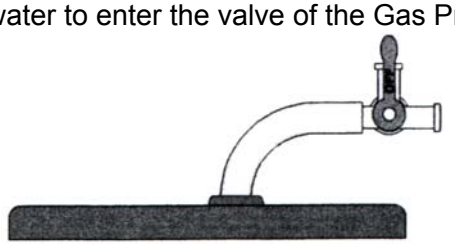
3. Select a plant which has a stem roughly the same diameter as the opening of the plastic tubing. Using a scalpel or razor blade, carefully cut the plant one inch above the soil. Alternatively, cut a stem from a larger plant that has 4-6 healthy leaves on a stem length of 6 – 8 inches. Place the plant under water against a hard surface and make a new cut at a 45° angle near the base of the stem.

4. Connect the plant to the open end of the tubing carefully following the instructions and illustration below.
   - Raise the end of the tubing with the white plastic connector until you see water beginning to drip out of the opposite end (the end with the plastic tubing clamp).
   - Carefully push the cut stem of the plant down into the end of the tubing where the water is dripping out. Be careful not to allow any air bubbles to form between the cut portion of the stem and the water in the tube.
   - Push the plant down as far as it will go without damaging the plant. At least one centimeter of the plant stem should fit into the tubing. If the stem is too large for the tubing, cut the stem at a higher point where it is smaller.
   - Squeeze the tubing clamp shut as tight as possible as shown



   - When the tubing clamp is shut tight, invert your plant cutting to check for any leaks. If water does leak out, turn the plant right-side up and try tightening the clamp further.
   - **Important:** Be sure the tubing is filled completely with water. The water column must be flush with the stem. There should be no air visible at the base of the stem. If water moves down the tube away from the stem after it has been inserted, check for a leak in the system.

5. If your sensor has a blue plastic valve on it, place the valve in the position shown below. Connect the white plastic connector end of the plastic tubing to the gas sensor valve. **Caution**: Do not allow water to enter the valve of the Gas Pressure Sensor.



6. Secure the plant in an upright position with the utility clamps as shown in the illustration of the Transpiration apparatus above. It should be positioned so that the cut stem is about 8 cm below the water level at the other end of the tubing, as shown.

7. Place a mark on the tube at the starting water level to allow you to refill the tube to the proper level later.

8. Place your plant setup in an area where the wind, humidity, and temperature are reasonably constant. This will be your control setup.

9. Allow the system 5 minutes to adjust to the environment. While the system is adjusting, set up the data collector (computer). The gas pressure sensor must be connected to the computer prior to starting the computer. Be sure, too, that you have all AC adapters connected.

10. Locate and open the Experiment 10 folder from the *Biology with Computers* folder of Logger *Pro* located on the data collector desktop.

    Open the experiment file that matches the probe you are using. The vertical axis has pressure scaled from 80 - 110 kPa. The horizontal axis has time scaled from 0 to 15 minutes. The data rate is set to 4 samples/minute. Be sure that you have the collect button Collect. displayed at the top of your screen "graph". If you do not, ask your instructor for assistance in configuring the computer.

11. Check the base of the plant stem in the water tube to make sure that no air bubbles or air pockets have formed that will prevent the plant from taking up water. If an air pocket has formed, refit the plant in the tubing before initiating data collection in Step 12.

12. After the plant has equilibrated for 5 minutes, click Collect to begin data collection. Data will be collected for 15 minutes.

13. When data collection has finished, find the rate of transpiration for your plant. To do this:
    - Move the cursor to the point on your screen where the pressure values begin to decrease. Hold down the trackpad button and drag the cursor (using the finger on the trackpad) to the end of the data and release the button.
    - Click the Regression button to perform a linear regression. A floating box will appear with the formula for a best fit line.
    - Record the slope of the line, *m*, as the rate of transpiration for the control in Table 1. Note: You will record the "m" number displayed.
    - Close the linear regression floating box.

Exercise II – Effects of Environmental Factors on Transpiration Rate

Prior to coming to the laboratory you should design an experiment to simulate the effect of one of following environmental factors on the rate of transpiration. Your instructor may assign each group the environmental factor to use.

- The effect of light intensity on transpiration
- The effect of the wind on the plant on transpiration
- The effect of humidity on transpiration
- The effect of temperature on transpiration

Be sure to address the following questions in your design:
- What are you testing? (What question are you asking?)
- What assumptions are you making about the system being measured?
- Can those assumptions be easily verified?
- Will the measurements provide the necessary data to answer the question under study?

After checking your procedure with your instructor obtain the materials needed for the experiment and perform the tests following steps used for the transpiration control. You may need to refill the water in the plastic tubing. Record your data values in Table 1.

Exercise III – Effects of Leaf Adaptations on Transpiration Rate

Prior to coming to the laboratory you should design an experiment to test plant leaf adaptations to minimize (or perhaps maximize) transpiration rate. Your instructor may assign each group the environmental factor to use.
- The effect of hairs on transpiration rate
- The effect of waxy surfaces on transpiration rate
- The effect of succulence on transpiration rate
- The effect of shape on transpiration rate

Be sure to address the following questions in your design:
- What are you testing? (What question are you asking?)
- What assumptions are you making about the system being measured?
- Can those assumptions be easily verified?
- Will the measurements provide the necessary data to answer the question under study?

After checking your procedure with your instructor obtain the materials needed for the experiment and perform the tests following steps used for the transpiration control. You may need to refill the water in the plastic tubing. Record your data values in Table 1.

1. Test cuttings from a variety of different plant species. How does each compare?
2. Count the number of stoma/cm^2 for each of the plants in Extension 1. How does this relate to the plant's ability to transpire water?
3. Propose other variables that you can you test.
4. Design an experiment to test for the variables in Question 3.

Processing the Data

1. Determine the surface area of all the leaves on your plant cutting by the following method:
   - Cut all the leaves (not stems) off of your plant and weigh them.
   - Estimate the total leaf surface area in cm^2 for your plant by cutting out a section of leaf 5 cm X 5 cm.
   - Weigh this leaf section and divide by 25 cm^2 to find the weight of l cm^2 of leaf.
   - Divide the total weight of the leaves by the weight of l cm^2 to find the total surface area.
   - Record this value in Table 1.

2. Calculate the rate of transpiration/surface area. To do this, divide the rate of transpiration by the surface area for each plant. These rate values can be expressed as kPa/min/ cm^2. Record the rate/area in Table 1.

3. Subtract the control (rate/area) value from the experimental value. Record this adjusted rate in the last column of Table 1.

4. Record the adjusted rate for your experimental environmental test on the board to share with the class. Record the class results in Table 2 for each of the environmental conditions tested. If an environmental condition was tested by more than one group, take the average of the values and record in Table 2.

5. Record the adjusted rate for your adaptation test on the board to share with the class. Record the class results in Table 3 for each of the adaptations tested. If an adaptation was tested by more than one group, take the average of the values and record in Table 3.

6. Make a bar graph that shows the effect of different environmental conditions on the transpiration of water in plant cuttings. Using the data in Table 2 and in Table 3 plot the adjusted rate for each test on the y-axis and the test label on the x-axis.

Table 1 – Transpiration Rate

Test	Slope (kPa/s)	Surface area (cm^2)	Rate/area ($kPa/s/cm^2$)	Adjusted rate ($kPa/s/cm^2$)
Environmental Condition				
Adaptation Condition				
Control				

Table 2 - Class Data on Transpiration Rate in Simulated Environments

Test	Adjusted rate ($kPa/s/cm^2$)
Light	
Humidity	
Wind	
Temperature	

Table 3 - Class Data on Transpiration Rate for Leaf Adaptations

Test (Identify Adaptation)	Adjusted rate ($kPa/s/cm^2$)

Analysis Questions

1. How did each of the experimental conditions affect the transpiration rate relative to the control?

2. Which environmental condition resulted in the greatest transpiration rate? Why might transpiration loss be greater with this environmental condition?

3. What adaptations enable plants to increase or decrease transpiration?