

Transpiration

In the previous exercise you studied the process of osmosis and learned about water potential and its role in determining the movement of water. Transpiration, the movement of water from root through stem and leaf to atmosphere, can be studied in a similar way.

In this exercise you will study the movement of water through a plant. Several hours prior to class your plant will be placed in the dark to reduce the rate of transpiration. This exercise requires that you work in teams and be well organized. Work quickly and carefully.

1. How can we measure the rate of transpiration (ml min^{-1}) through a plant? You will be given a potted plant with a leafy shoot. Figure out a way to measure water uptake by a shoot. If you remember that project with Eosin Y and think about volume instead of color, you are probably on the right track. Design your set-up and clear your protocol with Dr. Koning before proceeding.
2. Assemble your apparatus being careful to avoid the critical problems. What are those? Determine the “control” rate of transpiration in your shoot.
3. Now using your shoot set-up, apply some environmental variables. What variables might increase or decrease the rate of transpiration?

Think about Fick’s law: $J_v = D_s \frac{\Delta C}{\Delta x}$.

In the case of evaporation from leaves, what factor alters D_s (the diffusion coefficient)? What factor alters ΔC (or is it $\Delta \square$)? What factor alters Δx ? Dr. Koning will try to supply what you suggest might be needed or added to your shoot to alter the rate of transpiration. Think about the order of how you will apply the variables...it could be critical. One treatment might alter or prevent a response to the next.

4. Since each iteration of the project may take ± 20 minutes, while you are waiting, you can set up another apparatus. Think about the variables influencing flow through a stem. Perhaps the equation: $J_v = L_p \cdot \Delta \square$ [rate=hydraulic conductivity•water potential difference] or the Poiseuille equation $J_v = \frac{\pi r^4 \Delta P}{8 \mu \square \text{length}}$ [r=radius, μ =viscosity] would help? The viscosity of water is 0.009325 poise. A poise is $\text{g cm}^{-1} \text{sec}^{-1}$. A Pa is $10 \text{ g sec}^{-2} \text{cm}^{-1}$. How might you determine resistance to water flow in the xylem? How could you impose a known pressure on water going through a piece of stem? How could you then alter the rate of that flow? Should you call this transpiration or conduction?
5. From this work you should be able to give a value for specific conductivity for the stem ($\text{ml cm min}^{-1} \text{MPa}^{-1}$). From that you should be able to give a conductivity value for the whole shoot ($\text{ml min}^{-1} \text{MPa}^{-1}$). Then you should be able to combine the shoot conductivity value and the highest transpiration rate you found in parts 1-3 to determine the potential drop needed to lift the water at that rate through the stem!
6. Can water flow in the xylem when there is no evaporation from leaves? This is something you should be able to observe...if not within the time-frame of class, then surely overnight. Think of a way to determine that.
7. If possible, measure the osmotic potential of xylem sap. Try to reduce other variables in obtaining a sample of xylem sap. Clear your procedure with Dr. Koning before proceeding. Assuming that all of this dissolved material is sucrose, can you determine the potential viscosity of the xylem sap. Is this viscosity higher or lower than pure water?