22-1 Laboratory Inquiry

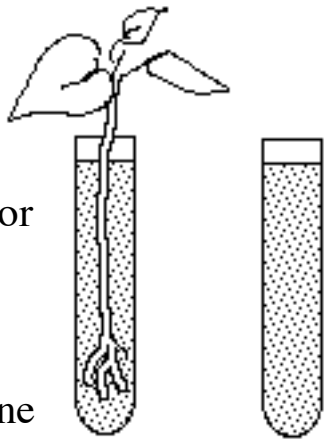
Water Transport in Plants: Problem and Experimental Design

Objective

You will be expected to solve two water transport problems stated below. You will submit hypotheses for each problem and design and conduct your own controlled experiments. After collecting and interpreting the data, you will decide if your hypotheses are supported or contradicted.

You now know that water travels up through roots and stems in vascular tissue known as xylem. The water then enters the leaf and is used in photosynthesis to make glucose. In a tree, such as the giant redwood of California, water must ascend over 300 feet to reach the highest leaves. This ascent requires great forces. In this investigation, you will use young bean plants to discover details about the forces involved. The factors involved in water transport are basically the same in all green plants.

Day one: PRE-LAB ACTIVITY



The following brief pre-lab experiment will provide valuable information you will need to solve the lab problems that follow: work as one team at your table for the pre-lab.

Pour tap water into a test tube to within about 3/4 of an inch from the top. Use a graduated cylinder to determine how many mL of water are in the test tube and return the

water to the test tube. [___] Pour an equal amount of water into a second test tube. [___]

1. Record the number of mL of water placed into each tube.

Place one of the bare-root bean plants carefully into one of the tubes of water so as not to damage the roots. Gently push the roots to the bottom of the tube. [___]
Place this tube and the tube with water only, into a test tube rack in a warm and lighted place in the room until the next school day. Label your test tubes with your name and period. [___]

2. Predict what will happen to the water level in each tube.

3. Why was a tube set up with water only and what is this tube called?

Day two: Pre-lab results and designing your experiments:

Return the test tubes prepared in the pre-lab to your table. [___]
Measure the amount of water remaining in each tube. [___]

4. Create a data chart showing the original number of mL of water placed in each tube, the number of mL today, and the difference.

5. Explain what accounts for the loss of water in each tube.

6. How much water was actually taken up by the plant?

DESIGNING THE EXPERIMENTS:

Your obligations are as follows:

First: Create two hypotheses and design experiments to answer the two questions that follow.
Second: Perform the experiments and collect the data.

Third: State valid interpretations and conclusions. Write a report that follows the usual format. (State the PROBLEMS, HYPOTHESES, EXPERIMENTAL DESIGNS, DATA, INTERPRETATIONS and CONCLUSIONS regarding hypotheses.)

Materials available:

6 test tubes (150 mm X 15 mm)
A beaker of tap water containing 5-6 bean plants (about 3 weeks old) with roots exposed
1 25 mL graduated cylinder and one razor blade

DESIGN EXPERIMENTS THAT WILL PROVIDE ANSWERS TO THE FOLLOWING TWO QUESTIONS:

PROBLEM ONE:

WHAT ROLE DOES THE NUMBER OR SIZE OF THE LEAVES (LEAF SURFACE AREA) PLAY IN THE MOVEMENT OF WATER THROUGH A PLANT?

On your own paper, copy the **problem** and then state and label your **hypothesis.** Under the **experimental design** heading, draw diagrams that would illustrate how you would set up experiments to test your hypothesis. Explain the details concerning all parts of the experiment. After you have designed all parts of the experiment, have your teacher check your design before going on. **Design your experiment(s) independently.** [___]

Go through the same steps for the second problem below. Do not set up your experiments until you have obtained your teacher's or lab assistant's approval.

PROBLEM TWO:

WHICH FORCE PLAYS THE MOST IMPORTANT ROLE IN THE MOVEMENT OF WATER THROUGH A PLANT, THE ABSORPTION OF WATER BY THE ROOTS OR THE EVAPORATION OF WATER FROM THE LEAVES?

DAY THREE:

After you have received approval, move to your lab table and confer with those at your table regarding your experimental designs. Discuss any differences in design and come to agreement on how you will cooperate at your table to set up all the tubes necessary to test both hypotheses. Select one experimental design for each hypothesis and set up the experiments together. Fill all tubes to near the top and record the number of mL of water placed in each. Be very careful to not break the stems and leaves. Place the labeled tubes in a fully lighted area for 24 to 72 hours. [___]

DAY FOUR: OBSERVING RESULTS

Find the tubes that you set up for this experiment the day before. [___]

Gather and record all data as described in your experimental design. Present your results in a clear data chart. [___]

Clean all tubes and place all bean plants into the container provided. Return the clean tubes to your tray. [___]

ANALYSIS AND CONCLUSIONS

1. Each of the tubes containing plants lost water. How do you know how many mL of this water loss was due to evaporation?

2. Do the number of leaves (surface area) make a difference in water uptake in bean plants? Explain.

3. Compare the loss of water from the tube with a whole plant (control) with the loss of water from a tube with a plant without roots. What is the difference in values? How many mL of water are the roots alone responsible for moving?

4. Compare the loss of water from the tube with a whole plant (control) with the loss of water from a tube with a plant without leaves. What is the difference in values? How many mL of water are the leaves alone responsible for moving?

5. Based upon the calculations for questions 3 and 4 above, are the roots or the leaves responsible for moving more water?

6. Was your hypothesis for problem 2 supported, contradicted or not supported?

Write **INTERPRETATIONS** for the data obtained for both experiments.

Write **CONCLUSIONS** regarding each of your hypotheses.

Teacher information follows on the next page.

Teacher's Information for:
WATER TRANSPORTATION IN PLANTS
PROBLEM AND EXPERIMENTAL DESIGN

I. Concepts taught

A. Content objective:

Through designing and conducting original experiments, the student will discover that leaves are responsible for moving more water through a plant than roots. Students will also discover that the greater the leaf surface area, the greater the movement of water.

B. Inquiry process objective:

Hypotheses formation, experimental design, observation and data recording, interpreting of data and forming conclusions about validity of hypotheses

II. Prerequisite knowledge:

Photosynthesis, root functions & structure, stem functions (brief)
Knowledge and experience in using all steps in the scientific inquiry process
This activity should not be attempted until students have good mastery of all steps in the scientific inquiry process. The experimental design component could overwhelm most students if they are not quite adept at inquiry. (The author does not use this lab until Unit IV during the second semester.)

III. Time requirements:

Day One: Pre lab 10 minutes
Day Two: Obtain pre lab results and design the experiments (1 period)
Day Three: 30 minutes to set up the experiments
Day Four: 15 minutes, 24 hours later, to record results and clean up time
Analysis and conclusions can be done outside of class if necessary.

IV. Teaching strategies:

See expanded details below.

V. Materials needed and set-up instructions:

Set up one tray per table (8 total)

EACH LARGE TRAY IS TO CONTAIN THE FOLLOWING:

1 container of four or five 2-3 week old up-rooted bean plants
1 test tube rack OR empty beaker for same purpose
5 test tubes (150 mm x 25 mm), per period
2nd choice (150 mm x 20 mm)
1 beaker or container of tap water (600-1000 mL capacity)
1 25 mL graduated cylinder
1 razor blade
Caution: Instruct students to use care in using razor blades.

PREPARED AHEAD

6 young bean plants in a container of H2O (no soil) per tray per period

Begin germinating bean seeds at least three weeks before lab. (Use dry kidney beans available from a local supermarket.) Start the beans by soaking them overnight in tap water. The next day, rinse them well and place the beans between two moist layers of paper towels. Incubate for 4-5 days at 74 to 80 degrees. Keep moist but not in standing water. After 3-5 days, remove the healthy seedlings with good roots and transfer them to soil and allow them to grow for about two weeks. On the day before the lab, uproot the plants and place them in beakers of water in the trays.

Strategies

Have all students perform the pre-lab and then return to the classroom and **individually** design their experiments. Once the experiments are designed, review and discuss the designs as a class. Students should then go to the lab tables and set up the experiments. The previous period's set-ups should not be in view. Use of a fan to increase transpiration is recommended.

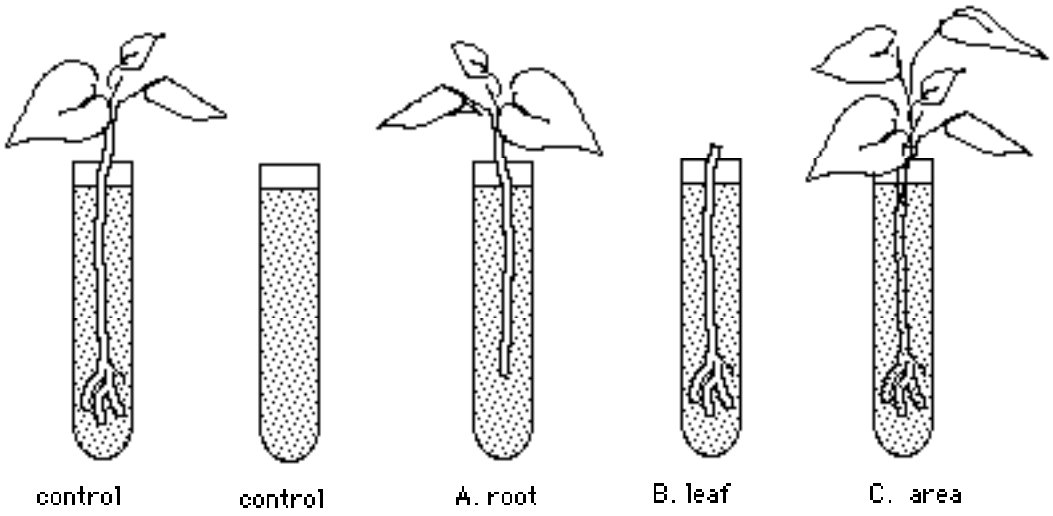
Student Designs:

There are a number of different ways to design experiments to solve this problem. The most frequently suggested and probably the most effective designs are diagrammed below.

To determine the effect of increased leaf surface area, place a plant with obviously greater leaf surface area into a tube as shown in "C". The difference between the amount lost in "C" and from the control (with plant) is the amount of water the increased surface area of the leaves is responsible for moving. An alternative in "C" would be to use a plant that had half the number or surface area of leaves as the control.

To determine the role provided by absorption of water from the roots, cut off the roots as in "A" below. This will be compared to the whole plant in the control. The amount of water is to be measured at the beginning and after one to two days. The control with the plant should lose the most water. The difference between the amount lost in "A" and from the control (with plant) is the amount of water the root is responsible for moving.

To determine the role provided by absorption of water from the leaves, cut off the leaves as in "B" below. This will be compared to the whole plant in the control. The amount of water is to be measured at the beginning and after one to two days. The control with the plant should again lose the most water. The difference between the amount lost in "B" and from the control (with plant) is the amount of water the leaves are responsible for moving.



The experimental set-ups should be left in an intensely lighted area at least overnight and should have a fan that aids in increasing transpiration. (48 hours is better) The control, with water only, is useful but not necessary and will be suggested by some students. It is meant to show how much water is evaporating from the tubes. Since the same amount of water evaporates from each tube, this value cancels out, so we really do not need a control with water only.

The following chart is an approximation of what results you might obtain in such an experiment.

EXPERIMENTAL → / CONTROLS ↓	tube lost 11 ml	tube lost 4 ml	tube lost 8 ml	tube lost 20 ml
tube lost 2 ml	Actual loss = 9 ml	Actual loss = 2 ml	Actual loss = 6 ml	Actual loss = 18 ml
tube lost 12 ml / actual loss = 10 ml	Loss due to roots was therefore 1 ml (10-9=1) or 12 -11=1	Loss due to the leaves was therefore 8 ml (10-2=8) or 12- 4=8	Loss due to decreased leaf area = 4 ml (10 - 6 = 4) or 12-8=4	Loss due to increased leaf area = 8 ml (18 - 10 = 8) or 20 - 12 = 8

The actual amounts of water lost from the tubes will depend upon the size of the bean plants, the room temperature, the length of time left, as well as the air circulation. The values in the chart, under each tube, were obtained by subtracting the final volume of water from the initial volume.

INTERPRETATIONS:

Since the loss due to the leaves (8 mL) was greater than the loss due to the roots (1 mL), the **leaves** play a more important role in the movement of water in bean plants. Increasing the leaf surface area does make a significant difference in the amount of water that is moved through the plant by the leaves. As the leaf area increases, the amount of mater moved increases.

CONCLUSION:

The conclusion written about each hypothesis will depend upon the hypotheses submitted for each problem.