Solar Education for NY
SchoolPower ...Naturally

Leaves, the Sun, and the Water Cycle

SPN LESSON #18

TEACHER INFORMATION

LEARNING OUTCOME

After conducting transpiration investigations using twigs that have a set number of leaves, and after checking the effect of variables on relevant solar panel output using the DAS, students are able to cite factors that influence the rate of water loss from a plant and determine whether these same factors affect PV output.

LESSON OVERVIEW

In this lesson, students investigate transpiration and its role in the water cycle. Mathematics and science skills are used in determining how much water per unit of surface area evaporates out of a leaf during a 24-hour period. Both the influence of light on transpiration and the role of the Sun in the water cycle are investigated.

GRADE-LEVEL APPROPRIATENESS

This Level II, Living Environment, mathematics lesson is intended for use with students in grades 7–8.

MATERIALS

Each team of two students should have:

- 4 test tubes

  Be sure that all four containers in any single setup are the same. Differences in size will make data analysis more difficult for the students.
- 2 twigs, approximately the same size, from the same tree

  The twigs should each have the same number of leaves—three or four. The leaves should also be about the same overall size from twig to twig.
- 50-mL graduated cylinder
- pipette—disposable would be best since the vegetable oil will be difficult to clean out
- 3 sheets of graph paper or enough so that all of the leaves on the twigs can be outlined. Smaller leaves will require less paper.
- pencil
- marking pens
- metric ruler

Photocopy a 15-cm metric ruler and make multiples by photocopying a series of them onto transparency acetate. Cut these out and have the students use them when marking the containers. These rulers have the advantage of being transparent, flexible, and inexpensive.

- 20 mL of vegetable oil
- water
- calculator
- test tube rack—students should be able to share the test tube racks. Depending on the number of tubes a rack can hold, six teams of students can place their “twig in the dark” tubes (test tubes that hold a twig and are kept in the dark) in the same rack. They can also share racks for their “twig in the light” tubes (test tubes that hold a twig and are kept in the light).

SAFETY

- Some leaves are poisonous. Check to be sure you do not use these for this lesson.
- Caution students not to eat the leaves or any other materials used in a laboratory investigation.

TEACHING THE LESSON

Before class:

- Run off enough copies of the student handout so that everyone has a copy of the activity, and have enough graph paper on hand to give each student two or three sheets.
- Collect a large supply of living twigs, each containing three or four leaves, from a variety of different trees. You can do this yourself or ask students to bring the twigs to school on the day you plan to start the activity.
- If test tube racks are in short supply, test tubes can be placed in beakers or other sturdy containers that will not tip.

During class, before starting the activity:

- Ask students the following series of questions:
  (1) Where does most of the water vapor in the atmosphere come from? (Students will likely reply that it comes from the evaporation of water from the surface of lakes, rivers, and the ocean. Plants are not likely to be mentioned.)
  (2) If water evaporates from the ocean, muddy puddles, and polluted sources, will the rain or snow that forms from it be salty or polluted? After some discussion, set up the following demonstrations:
    (a) You will need: salt, water, stirring rod, several watch glasses or shallow, clear glass containers. Pour 50 mL or so of water into a beaker. Slowly add salt to the water until no more dissolves as you stir the solution. Pour some of the solution into several watch glasses or other shallow, clear glass containers. Ask students to predict what they will observe after the setup sits undisturbed for several days.

(b) You will need: two glasses or beakers, food coloring, pale-colored flower such as a white carnation, sharp knife, tape. Add equal amounts of water to the two glasses or beakers. Add some food coloring to one of them and stir well. Next, carefully slice the flower's stem in half lengthwise. Stop cutting when you reach the halfway point. Wrap tape around the end of the cut to prevent the stem from splitting further. Place each half of the stem in a glass and lean the flower up against a window for support. Ask students to predict what they will observe after the setup is left undisturbed for several days.

(3) Does any of the water in the atmosphere come from plants? How could we find out? Students might refer to the flower in the food coloring. Tell them that it might show that plants take up water, but does it prove that plants release water to the atmosphere? After some discussion of the ideas students generate, they will be ready to work through the activity.

- Cut a fresh section from the bottom of each twig. This will help guarantee that the conducting tissue is open and able to take up water.
- Caution students to be sure to add the twig to the setup *before* the vegetable oil layer is added. If the twig is inserted through the oil layer, the oil will clog the water-conducting tubes (xylem) and the twig will not take up any water.
- If all of the water is lost from one of the test tubes, have students make adjustments in the total volume readings. For example, if they are able to record a volume after 24 hours, and no water is left after 48 hours, students can double the 24-hour volume and use that figure in their calculations.
- Explain to students that if their twigs contain only three leaves, they need to record data for only three leaves in the data table.

During class, after completing the activity:

- Observe the two demonstrations.

  (a) Students should see salt crystals in the bottom of the containers from which the saltwater evaporated. This should illustrate to them that evaporation not only returns water to the atmosphere but also removes many impurities. This does not mean that water returning to the ocean is the same pure water that evaporated. Rain or snow may contain trace amounts of acid or other chemicals from reactions among gases that take place in the atmosphere.

  (b) The pale-colored flower should be the color of the food dye on one side and its original color on the other side. This is visual evidence of the movement of water up the stem of a plant to its leaves. Transpiration is responsible for this movement.

- Ask students what factors in addition to sunlight might influence the rate of water loss from a plant. Their answers could include temperature, availability of groundwater, and wind speed. Next, ask if these same factors influence the amount of electricity produced by the school's solar panel. Have students check the DAS for electricity generated by the panel on a sunny versus a cloudy day or at various times on a sunny day. You might also have students determine the impact of varying temperatures or wind speeds on output. The key is to make the comparisons using a two-day cycle when insolation is comparable but the temperature or wind speeds are drastically different. Using those conditions, students will probably get the result you are seeking: *some* impact on energy production.

Students should see that the greatest output occurs on sunny days and that output maximizes around noon. It would be interesting to determine how many totally sunny days (no clouds) there were in various months and to determine how this impacts monthly kilowatt-hour (kWh) output. Students should find that environmental factors impact the amount of electricity generated just as various factors have a major impact on the rate of transpiration. The amount of sunlight available is critical to both plants and PV panels. The influence of other abiotic factors varies.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

Table 1: Changes in water level				
Volume of water in mL	**Containers**			
	twig in the light	twig in the dark	water with oil	water with *no* oil
Date: ________ (Day 1 – Start)	*Answers will vary with species and number of leaves*	________ mL	________ mL	________ mL
Date: ________ (Day 2 – 24 hrs.)	________ mL	________ mL	________ mL	________ mL
Date: ________ (Day 3 – 48 hrs.)	________ mL	________ mL	________ mL	________ mL
Total Volume	________ mL	________ mL	________ mL	________ mL

Table 2: Leaf surface area data			
twig in the light	number of *x*-ed squares	twig in the dark	number of *x*-ed squares
leaf #1	*Answers will vary with the tree species used.*	leaf #1	*Answers will vary with the tree species used.*
leaf #2		leaf #2	
leaf #3		leaf #3	
leaf #4		leaf #4	
leaf #5		leaf #5	
Total		Total	

Activity Analysis

1. The purpose of using vegetable oil in this investigation was to prevent evaporation from the surface of the water in the containers. Why was this important in your determination of the influence of light on leaf transpiration?

   Students should respond that by using oil to prevent evaporation from the surface of the water, they would be able to tell how much water was actually lost through transpiration. Any decrease in water level would be due to transpiration.

2. Why was a container of water and oil with no twig used in this investigation?

   This setup served as the control. It showed what would happen without water being taken in by the twig and lost through transpiration.

3. (a) How much water was lost per unit of surface area (*X*) from the leaves on the twig kept in the light? This amount can be calculated by dividing the volume lost over the 48-hour period by the total number of *x*'s counted when determining the total surface area of the leaves on a branch. [total volume of water lost (mL) / total surface area (*X*)]

   See below.

   (b) How much water was lost per unit of surface area (*X*) from the leaves on the twig kept in the dark?

   Answers will vary with the type of twigs used since different tree species produce leaves of different sizes. Also, some trees (such as willow) draw more water than other species. The conclusion should be that the twig in the light transpired more water than the same kind of twig in the dark.

4. (a) Does light energy influence the rate of transpiration? Support your answer with data from your investigation.

Yes. A greater volume of water per unit of surface area was transpired from the twig kept in the light than from the twig kept in the dark.

(b) In addition to transpiration, what other plant process could account for the difference in water level between the twig kept in the light and the twig kept in the dark?

Photosynthesis

5. The transpiration of water from plants combined with the evaporation of water from the soil and bodies of water can be thought of as a first step in the cycling of water. Once the water vapor is in the atmosphere, it cools and condenses to form droplets. Draw a diagram of the water cycle. Start your cycle with evaporation and transpiration. Also include condensation, precipitation, runoff, and groundwater in your diagram.

   Be sure that student diagrams include the key terms and that the processes are correctly illustrated and labeled. The terms desired are: transpiration, evaporation, condensation, precipitation, runoff, and groundwater.

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

The source of the basic protocol used for measuring the amount of water evaporated from a leaf is the experiment “Water loss through a leaf” found in *How Nature Works: 100 Ways Parents and Kids Can Share the Secrets of Nature* by David Burnie and published by The Reader’s Digest Association, Inc., Pleasantville, NY, 1991.

BACKGROUND INFORMATION

Water is always on the move…sometimes quickly and sometimes slowly. Energy from the Sun causes water on Earth’s surface to change to water vapor through the process of evaporation. Salt, pollutants, and impurities are left behind as water rises into the air as water vapor. Water also evaporates from the soil, animals, and plants. About 90% of the water taken in by plants is lost through evaporation and not used in photosynthesis. It is known that the amount of water in a plant is controlled by the opening and closing of the stomata through the action of guard cells.

Water movement through a plant is best explained by the transpiration-cohesion theory. Water movement in plants is driven by transpiration: the evaporation of water from parts of a plant exposed to the air, primarily the leaves. As water evaporates out from a leaf stomata, the pressure in the xylem (water-conducting tissue) lowers. Since substances tend to move from regions of high pressure to regions of low pressure, water from the stem moves upward to the leaf. This in turn causes a lower pressure in the stem xylem and water moves from the roots to the stem.

In this way, transpiration creates a strong force, or pull. In order for water to be pulled up a plant, this force must move through a continuous chain of water molecules in the xylem. The water molecules in the xylem are linked together by a force known as cohesion. Cohesion causes a water molecule to be attracted to the neighboring water molecules. The result is that water molecules seem to “stick” together. An analogy would be a line of students in which everyone is holding hands with the next person in line. As soon as the lead student starts to walk, all of the other students move along in the same direction. When the lead student moves, the next person in line is pulled along, etc. If the line is broken, the pull is interrupted and movement stops. This is also true of transpiration.

The movement of water through plants is very rapid, resulting in large amounts of water being lost from the plant through transpiration. One maple tree can lose as much as 200 liters of water per hour. Water traveling up the stem of a plant can travel as fast as 75 centimeters per minute!

REFERENCES FOR BACKGROUND INFORMATION

Field Guide to North American Trees (National Audubon Society). Alfred A. Knopf, Inc., New York, 1995.

Miller, Kenneth and Joseph Levine. *Biology*. Pearson Education, Inc., Upper Saddle River, NJ, 2003.

National Science Education Standards. National Academy Press, Washington, DC, 1996.

Petrides, George A. *A Field Guide to Trees and Shrubs* (The Peterson Field Guide Series). Houghton Mifflin Company, Boston, 1972.

Strauss, Eric and Marylin Lisowski. *Biology: The Web of Life.* Addison Wesley Longman, Inc., Menlo Park, CA, 1998.

Wright, Richard T. and Bernard J. Nebel. *Environmental Science: Toward a Sustainable Future.* Pearson Education, Inc., Upper Saddle River, NJ, 2002.

EXTENDED ACTIVITIES

Literature Research

Two processes in the water cycle are driven by energy from the Sun—evaporation (which includes transpiration) and precipitation. Use the Internet to find out how the Sun’s energy influences precipitation. (For example, clouds move about on winds generated by solar energy. The clouds deposit their moisture in the form of rain, drizzle, snow, hail, or sleet.)

Experimental Design

Have students design an experiment to investigate an environmental factor other than light that might influence the rate of water loss by leaves. Temperature and wind are two possibilities.

Literature Research

Wetlands are often drained or filled in. The land is then available for building or road construction, or for cultivation and grazing. As a member of an environmental group, research how a proposal to build in a local wetland area might affect the climate and the availability of water in your area.

Researching Literature for Energy Alternatives

Many are advocating the increased use of wind power. Some experts claim that it is available and economically competitive. Use various sources to determine for yourself whether this is true. List the advantages and disadvantages of increased reliance on wind energy. Also explain how using wind energy is just another way of tapping into solar energy.

LINKS TO MST LEARNING STANDARDS AND CORE CURRICULA

Standard 1—Analysis, Inquiry, and Design: Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Science Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

S1.1: Formulate questions independently with the aid of references appropriate for guiding the search for explanations of everyday observations.

S1.1a: Formulate questions about natural phenomena.

Standard 4—Science: Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Living Environment

Key Idea 1: Living things are both similar to and different from each other and from nonliving things.

1.1: Compare and contrast the parts of plants, animals, and one-celled organisms.

Key Idea 5: Organisms maintain a dynamic equilibrium that sustains life.

5.1: Compare the way a variety of living specimens carry out basic life functions and maintain dynamic equilibrium.

5.1a: Animals and plants have a great variety of body plans and internal structures that contribute to their ability to maintain a balanced condition.

5.1b: An organism's overall body plan and its environment determine the way that the organism carries out the life processes.

5.2: Describe the importance of major nutrients, vitamins, and minerals in maintaining health and promoting growth, and explain the need for a constant input of energy for living organisms.

Key Idea 6: Plants and animals depend on each other and their physical environment.

Key Idea 7: Human decisions and activities have had a profound impact on the physical and living environment.

7.1: Describe how living things, including humans, depend upon the living and nonliving environment for their survival.

Physical Setting

Key Idea 4: Energy exists in many forms, and when these forms change energy is conserved.

4.1: Describe the sources and identify the transformations of energy observed in everyday life.

4.1a: The Sun is a major source of energy for Earth. Other sources of energy include nuclear and geothermal energy.

4.1c: Most activities in everyday life involve one form of energy being transformed into another. For example, the chemical energy in gasoline is transformed into mechanical energy in an automobile engine. Energy, in the form of heat, is almost always one of the products of energy transformations.

4.1d: Different forms of energy include heat, light, electrical, mechanical, sound, nuclear, and chemical. Energy is transformed in many ways.

Standard 6—Interconnectedness: Common Themes: Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Key Idea 1: Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

Process Skills Based on Standard 4 (Laboratory Skills)

General Skills

1. Follow safety procedures in the classroom and laboratory.
3. Use appropriate units for measured or calculated values.
5. Classify objects according to an established scheme and a student-generated scheme.
8. Identify cause-and-effect relationships.

Living Environment Skills

6. Classify living things according to a student-generated scheme and an established scheme.
9. Identify structure and function relationships in organisms.

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www.nyserda.org

Should you have questions about this activity or suggestions for improvement, please contact Bill Peruzzi at billperuz@aol.com

(STUDENT HANDOUT SECTION FOLLOWS)

Name ____

Date ____

Leaves, the Sun, and the Water Cycle

Introduction

No one can deny that forests are an important natural resource. Forests are home to a variety of animals and plants that could survive nowhere else. Trees provide us with wood that is used to build, heat, and furnish our homes. Forests are also a place of beauty, providing us with hiking and camping opportunities.

What is not as well known is that forests help to regulate Earth's climate by recycling water and carbon dioxide. On a hot day, one large tree may absorb 5.5 tons of water from the soil. As much as 90% of this water is released through the tree's leaves into the atmosphere. Between 40% and 50% of the water above a temperate forest comes from transpiration, which is the evaporation of water from a plant primarily through its leaves. It is the combination of water vapor and shade provided by the leaves that keeps a forest cool, even on hot, sunny days.

The flow of water and nutrients in a tree occurs in the outer layers of the branches and the trunk. Water entering a tree's roots replaces water lost through transpiration. The question is, how much does light energy influence the rate of transpiration?

DEVELOP YOUR UNDERSTANDING

Materials

Each team of two students should have:

- 4 test tubes
- 50-mL graduated cylinder
- 2 twigs, approximately the same size, from the same tree
- pipette
- 3 sheets of graph paper
- pencil
- marking pen
- metric ruler
- 20 mL of vegetable oil
- water
- calculator
- test tube rack(s)

Procedures

1. Make a scale on the side of each test tube. To do this, use the marking pen and metric ruler. Start marking at the bottom of the test tube and make lines 1 cm long, at .5 cm intervals, until you reach the top.

2. Use the graduated cylinder to determine how much water it takes to fill one of the test tubes to the line that indicates the halfway mark.

   Record the volume held by the tube at the halfway mark here: _____________mL

3. Fill all four test tubes with water to the halfway mark.

4. Place a twig in two of the containers.

5. Use a pipette to add vegetable oil to three of the test tubes (two with twigs and one without a twig) so that it forms a thin layer about .5 cm thick on top of the water.

6. (a) Record the date you start the experiment and the volume of water in each container in the appropriate place in Table 1: Changes in water level.
   (b) Place three test tubes (twig with water and oil, water and oil, and water only) in a place that receives a lot of light.
   (c) Place one test tube (twig with water and oil) in a dark location.

Table 1: Changes in water level				
Volume of water in mL	**Containers**			
	twig in the light	twig in the dark	water with oil	water with *no* oil
Date: ________ (day 1 – start)	________ mL	________ mL	________ mL	________ mL
Date: ________ (day 2 – 24 hrs)	________ mL	________ mL	________ mL	________ mL
Date: ________ (day 3 – 48 hrs)	________ mL	________ mL	________ mL	________ mL
Total Volume	________ mL	________ mL	________ mL	________ mL

7. Determine the volume of water in each of the containers after 24 hours and 48 hours. To do this:
   (a) Use the graduated cylinder to measure how much water is in the test tube with no oil layer on top of the water. Record the volume in the appropriate place on Table 1 and discard the water.

(b) Next, carefully observe the water level in the “twig in the light” test tube.

(c) Fill the empty test tube that remains from step a to that level with tap water.

Important note: Do not empty the “twig in the light” container. You will be able to determine the volume by comparison.

(d) Use the graduated cylinder to measure the volume of water you poured into the test tube in step c, and record this volume in the “twig in the light, day 2 – 24 hrs” box.

(e) Repeat steps b through d for the remaining two test tubes (“twig in the dark” and “water with oil” test tubes). Do *not* pour out any of the contents of these test tubes.

(f) Return the containers to their original locations.

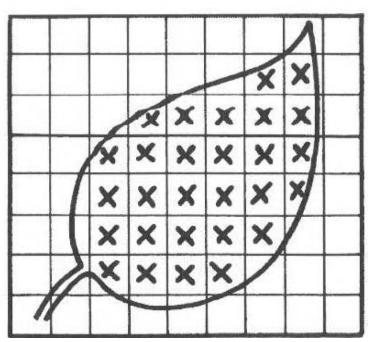
8. Calculate and record the total volume of water lost from each setup.

9. After all of the water level and volume determinations have been made for the last time, remove the twig from the test tube left in the light.

10. Remove one of the leaves from that twig, lay it on a piece of graph paper, and trace around it.

11. On the graph paper, identify the source of the leaf and label the outline (leaf #1, twig in light).

12. Using a pencil, place a small *x* in each square of any graph grid that is inside the outline for leaf #1. See Figure 1: Leaf grid.



13. Count the number of squares and record that number beside your leaf outline.

14. Next, record the data in the appropriate place on Table 2: Leaf surface area data. When only partial squares are enclosed by the outline, count those that fill half of a square or more. However you make your estimate of which squares to count and which to exclude, be consistent from one leaf to the next.

15. Repeat steps 10 and 14 for each of the leaves on the twig left in the light.

16. Remove the twig from the test tube left in the dark and repeat steps 10–15.

17. Calculate the total surface area of leaf for each twig.

Table 2: Leaf surface area data			
twig in light	number of *x*-ed squares	twig in dark	number of *x*-ed squares
leaf #1		leaf #1	
leaf #2		leaf #2	
leaf #3		leaf #3	
leaf #4		leaf #4	
leaf #5		leaf #5	
Total		Total	

Activity Analysis

1. The purpose of the vegetable oil in this investigation was to prevent evaporation from the surface of the water in the test tubes. Why was this important in your determination of the influence of light on leaf transpiration?

2. Why was a test tube of water and oil with no twig used in this investigation?

3. (a) How much water was lost per unit of surface area (*X*) from the leaves on the twig kept in the light? This amount can be calculated by dividing the volume lost over the 48-hour period by the total number of *x*'s counted when determining the total surface area of the leaves on a branch. [total volume of water lost (mL) / total surface area (*X*)]

   (b) How much water was lost per unit of surface area (*X*) from the leaves on the twig kept in the dark?

4. (a) Does light energy influence the rate of transpiration? Support your answer with data from your investigation.

   (b) In addition to transpiration, what other plant process could account for the difference in water level between the twig kept in the light and the twig kept in the dark?

5. The transpiration of water from plants combined with the evaporation of water from the soil and bodies of water can be thought of as the first step of Earth's water cycle. Water vapor in the atmosphere cools and condenses to form droplets. Draw and label a diagram of the water cycle. Start your cycle with evaporation and transpiration. Also include condensation, precipitation, runoff, and groundwater.