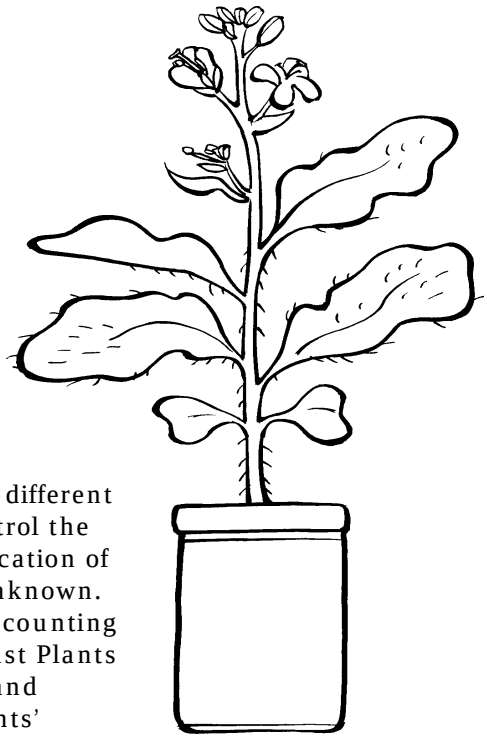
Volume 6, No. 1 Spring, 1993

WISCONSIN FAST PLANTS notes BOTTLE BIOLOGY WISCONSIN

Hairy's Inheritance

Getting a handle on variation



Within the population of Fast Plants there is an observable trait (phenotype) that might escape some students' notice, but which lends itself easily to investigating variation and inheritance. Varying numbers of hairs can be seen along the stem, on the upper and lower surfaces of the leaves, on leaf edges and even on the buds of plants.

The hairs found on the basic *Brassica rapa* plants constitute a trait that is variable, quantifiable and heritable. Scientists are not sure why plants have hairs although they have some ideas.[3]

Furthermore, very little is known about the genetics and inheritance of hairiness.

The number of different genes that control the number and location of hairs is also unknown. Observing and counting the hairs on Fast Plants will challenge and sharpen students' observational skills and provide them with the opportunity to ask many questions.

Students often measure the height of Fast Plants with a ruler and estimate the actual height in units such as millimeters. Determining the number of hairs is different than estimating height in that each hair is a discreet unit that can be counted directly.

Each plant or plant part has a certain number of hairs, but the number of hairs will vary from plant to plant. The number of hairs counted on each plant can be recorded in a table as a class data set and graphed as a frequency histogram.

Figure 1 (on page 2) depicts a frequency histogram of the number of hairs counted on the right margin of the first true leaf in a population of 295 Fast Plants. Notice that the outline of the frequency histogram in Figure 1 roughly depicts a curve known as a **frequency curve**. Do the majority of plants in Figure 1 have few or many hairs?

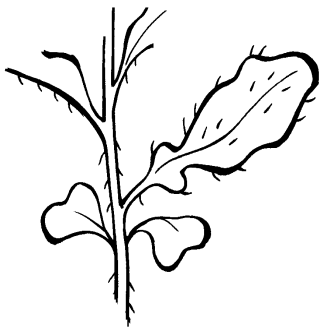
Where to begin

1. Students first need to decide how and where to count the hairs on their plants. They can look over the plants and identify where hairs appear on the plants. Students could describe and map with sketches where the hairs are located.

   Next, they need to decide where on the plant they could accurately count the hairs. Younger students may have difficulty counting, for instance, the hairs all around one portion of the stem.

   It may be easiest to count the hairs on the edge of the first true leaf. This can be done as early as Day 8 or 9 in the life cycle when the first true leaf is well developed. They will need a good light coming over their shoulder and a hand lens.

   By observing the plant against a dark, contrasting background (construction paper, a classmate's sweater, etc.) they could count all the hairs on the edge of the leaf.



   Each student can record the number of hairs at the particular agreed upon location on their plant and then all the data from the class could be incorporated into a frequency histogram as suggested in Figure 1. From observing the graph, students will be able to identify characteristics of the population with respect to the hairy phenotype.

2. After looking at their graphed data and statistics, students will "brainstorm" ideas and develop questions relating to hairiness and inheritance. Questions may include: Is hairiness inherited? How is hairiness inherited? Could hairless or super hairy populations be produced?

   By choosing the top ten percent of the hairiest plants in the class population as an experimental group and intermating (pollinating) only those plants, students would be applying what

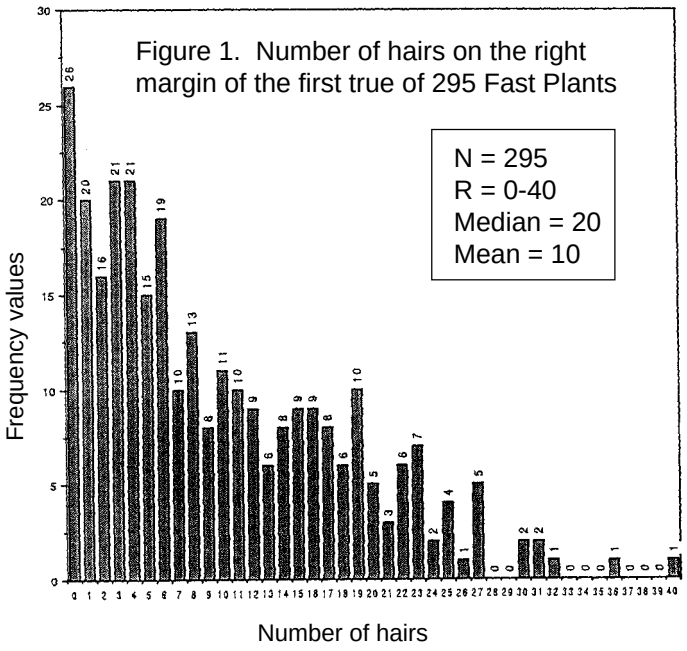


Figure 1. Number of hairs on the right margin of the first true of 295 Fast Plants

Charles Darwin called **artificial or directed selection** on the population.

If hairiness were inherited through the combined effects of many different genes (polygenically), one would expect that by repeatedly selecting the hairiest parents for subsequent generations the number of genes for hairiness in the population would be increased. Would this directed selection increase the population mean (average) for hairiness?

To investigate this question, students would first want to record the data of numbers of hairs for the experimental group of parent plants, so that they can compare the initial data with the numbers of hairs that occur on the next generation (the "progeny" or offspring.) Will the offspring of the first intermating have more hairs on average than the parents? Through how many generations would the students have to repeat the directed selection experiment before producing a super hairy plant?[2]

Further investigations

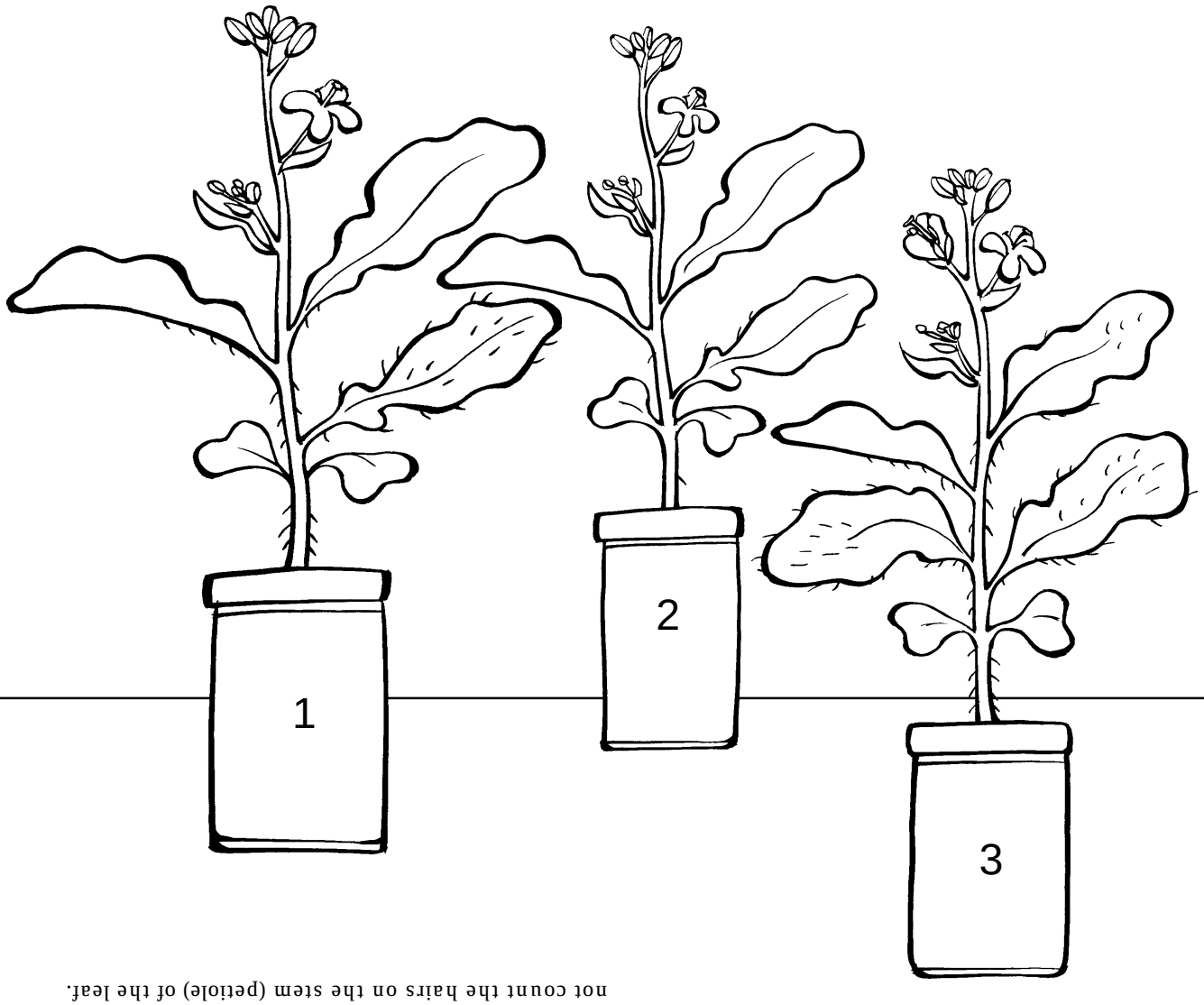
Older students, who ponder these questions and who are trying to understand the inheritance of the hairy trait, will continue to ask more questions. If all the plants from the first (parental) generation are intermated, will all the offspring have hairs? Will the hairs show up in the same places on the offspring?

continued on page 4

Activity for Elementary Students

How hairy is hairy?

Directions:
1. Find the first true leaf on each plants and color it green.
2. How many hairs can you find on the top of the first true leaf?
3. How many hairs can you find around the edge (margin) of the first true leaf?
4. Do you see hairs anywhere else on the plant?
5. Circle the places where you find hairs.

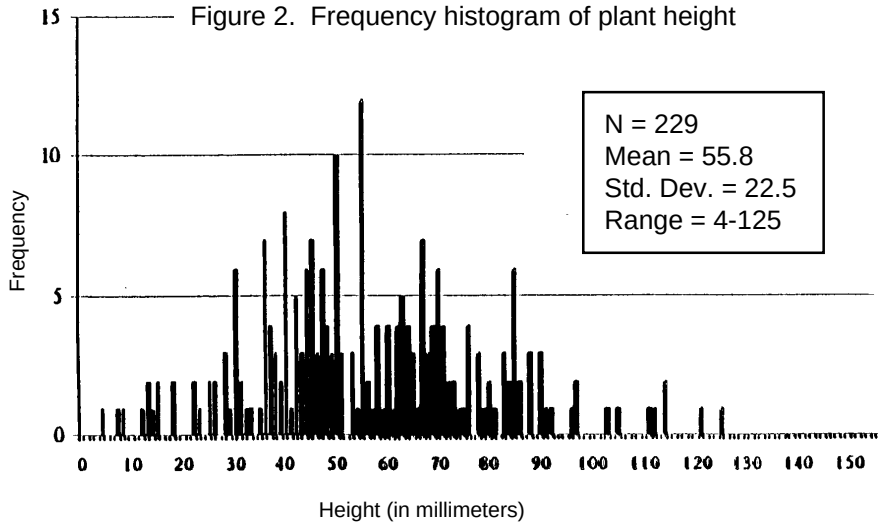


Answers: Question 2; plant 1 = 7, plant 2 = 0, plant 3 = 9. Question 3; plant 1 = 11, plant 2 = 3, plant 3 = 11, do not count the hairs on the stem (petiole) of the leaf.

Will the progeny of a hairless and a hairy plant have hairs? Will all the offspring of the F1 (first generation) have hairs? If many genes are functioning to produce hairiness, can you keep increasing hairiness?

Is there a limit on the number of hairs that a plant can have? Conversely, how quickly might they develop a population of hairless plants? Can they change the shape of the frequency curve by altering the genetic base?

Figure 2. Frequency histogram of plant height



The environment and phenotype: Environment is ever present in the expression of the phenotype. The degree to which components of the environment, such as light, temperature and nutrition, contribute to the expression of phenotypes is an important part of genetics.

Little is known about the influence of environmental factors on the inheritance of hairiness. Investigation by students might provide insight into the influence of these and other environmental factors on the expression of the hairy phenotype.

Environmental applications: Students may ask why plants have hairs at all. Does there have to be a purpose for any given trait on a plant? What are their hypotheses? A few scientists have asked the similar questions.[3] Also, read "Fast Plants and Cabbage Loopers" (page 9) to see where one such question led some sixth-grade students in San Bernardino, California.

Extension 1: Ponder the shape of the frequency histogram.

Geneticists know that normally distributed continuous variation is usually produced by the combined effects of many genes. Such traits are said to be under **polygenic** control (poly = Greek for many.) Figure 2 is a frequency histogram showing a normal distribution curve. What questions about the inheritance of hairs does the frequency distribution in Figure 1 raise?

Extension 2: Develop a scale for hairiness (Hir).

Since hairiness is a phenotype that shows wide variation in its expression, a scale from 0-9 can be used to define roughly the range in expression of hairiness, where 0 = no expression (no hair), 1-2 = very low expression (very few hairs), 4-6 = intermediate expression (intermediate numbers of hairs) to 9 = very high expression (very hairy).

By counting the number of hairs in a defined area on the plant, you can convert the 0-9 scale to a graph depicting the relationship of the scaling numbers 0-9 (the independent variable or x axis) and the actual count of number of hairs (the dependent variable or y axis.) ◘

[1] WFP Notes reprint, "Getting a handle on variation: quantifying differences in plant height."

[2] Agren, J., Schemske, D.W., 1992. Artificial selection on trichome number in *Brassica rapa*. Theor. Appl. Genet. 83: 673-678

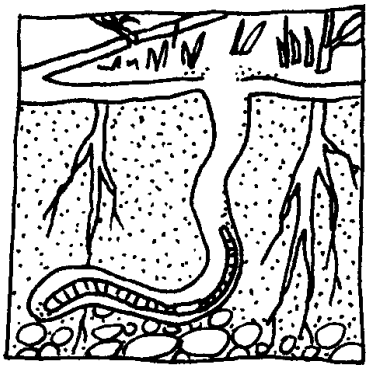
[3] Agren, J., Schemske, D.W., 1993. The cost of defense against herbivores: an experimental study of trichome production in *Brassica rapa*. Amer. Naturalist, Feb.

Explore the world under your feet

Soil Meditations

The following activities were excerpted from the Bottle Biology manual, to be published late this summer by Kendall/Hunt Publishers. (See page 15 for ordering information.)

Are you walking on air? The ground under your feet seems solid. You can jump on it and nothing appears to collapse under you.



But if the earth is so solid, where do trees, grass, and other plants put their roots? How do earthworms breathe? And why does rain water soak into the ground?

Take a close look at a handful of soil. Soil comes from solid rock that has been broken down into very tiny particles, and from decomposed plant and animal tissues. These bits of rock and organic matter contain many minute spaces.

These open spaces between soil particles are "living spaces," filled with air, water, and life. While soils vary greatly, a typical soil is 25 percent water (unless it has been dried), 50 percent minerals (5 percent of which is organic matter), and 25 percent air.

Millions of bacteria, protozoa, fungi, and algae can exist in just a handful of soil. Some larger soil residents include springtails, earthworms, roots, seeds, moles, badgers, and insect larvae.

In the following activities you will look at soil texture and density, and then "cook" with soils to find out what sorts of recipes plants prefer.

Texture Test: Soils are made up of variously sized particles, which fall into three basic textures: **sand, silt, and clay**. If we could multiply the diameter of a typical sand, silt, and clay particle by a thousand, the clay particle would be about as thick as this page, the silt would be about 2.5 cm thick, and the sand about a meter thick! Soils are not usually just sand, silt, or clay, but contain all three.

You might identify a soil's general texture by rubbing a slightly dampened bit of a sample between your fingers. If the soil feels gritty and you can see grains, your soil is sandy.

If the soil feels slippery but not really sticky, it is a silty soil. If your sample is very sticky, and you can squeeze it out between your thumb and forefinger into a kind of ribbon, your soil has a

Soil Particle Size Chart

Division	Diameter (mm)
coarse sand	2.0 - 0.2
fine sand	0.2 - 0.02
silt	0.02 - 0.002
clay	< 0.002

We invite you to explore with students the soil beneath your feet in the following three activities.

Film Can Mysteries

How dense is dirt?

high percentage of clay.

In this exploration, you fill film cans with several different soil types and compare their densities. **Soil density** refers to how loosely or tightly soil particles are packed. We will estimate the densities of different types of soil by comparing their weights.

Materials

For this exploration you'll need to collect several different samples of soil from nearby yards, parks, construction sites, woods or fields. You'll also need several soil components such as **gravel, sand, silt, clay, and organic matter or peat moss**. Next, you will need lots of **black film cans**.

Make a set of mystery film cans by placing five to eight different samples of soil in different black film cans. Fill another can with **water** and leave one empty. Use a marker and randomly number all the can tops. Keep a list indicating which number corresponds to which type of soil, and the water and air.

Make several identical sets of the mystery film cans and divide your class into five or six **cooperative groups**. Group members can take turns weighing, balancing, recording answers, and writing their results on the board.

Procedure

Pick up the mystery film cans. Weigh them in your hands. How heavy are they? Shake them next to your ear. What do you hear?

Weigh the film cans in your hands and **rank** the film cans from lightest to heaviest. Use the numbers on the lids to identify them, and write a series on the blackboard like this:

2 < 1 < 3 < 6 < 5 < 4

Now you have an idea of how the film cans compare to each other in weight. How do the series on the blackboard compare to each other? Now, how can you figure out the exact density of each film can?

We can do this by always comparing the same amount, or volume of different soils. In this case we are using one film can. (Since density equals weight per volume, and we will be using *one* film can, the density of the soil will be equal to its weight. What weighs more, a pound of feathers or a pound of lead?)

Using a standard: In order to measure something, you need a universal standard with which to compare it. In this case you have the convenient standard of water, which has a known

density of one. We also know that one film can holds 33 mls of water. Since density equals weight (grams in this case) per volume, we know that the film can of water has a density of 33 grams per 33 mls.

Use a balance to determine how your mystery film cans compare to water. Place the film can of water on one side of the balance and a mystery soil can on the other side. Does the soil weigh more or less than the water?

Next, balance the scale. Place two empty film cans on either side of the balance and add water to the lighter side. You can determine the difference between the weights of the water and the soil by adding water to the lighter side to balance the scale. Measure exactly how much water you added.

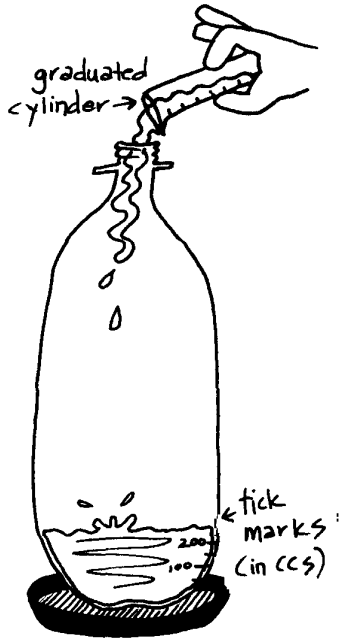
Figuring soil densities: Say you have a soil that is heavier than water. To balance the scale you added 33 mls, or one film can, of water. So your soil is equal to two film cans of water. In other words, your soil is twice as dense as water, and
has a density of 2.

To think about this numerically, remember that water has a density of 33 grams per 33 mls, and you had to add 33 grams worth of water to balance the scale. So your mystery film can is equal to 33 grams plus 33 grams, or 66 grams per 33 mls. A quick calculation will tell you that this equals 2.

Continue this exercise with the other mystery film cans in your collection. Afterwards, open the cans and examine the contents. How does the density of clay compare to sand? To water?

The Sedimentation Bottle

How many shapes and sizes can you see?



This project allows you to observe the diversity of particles that make up a soil. By mixing soil and water in a bottle,
and then observing the layering of the soil as it settles, you will see differently shaped, sized, and colored particles.

Procedure

Remove the label from a 1-liter soda bottle using hot water or a hair dryer.

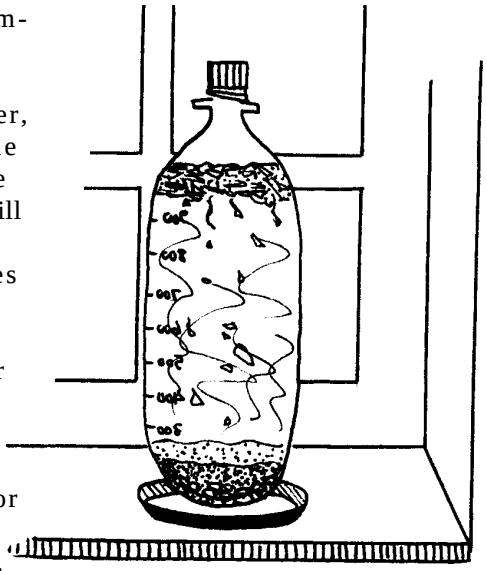
Use a graduated cylinder and a permanent marker to mark off your bottle in 50-milliliter increments. Fill the bottle to about the 700 ml mark with water. Next add film cans of different soils. If you add six film can's worth of soil, will the bottle overflow? Why or why not?

Cap the bottle and shake it vigorously. Set it someplace where you can watch it settle. Some particles will settle immediately, others will continue to float for days. Why?

What happens?

How many different layers can you identify? After everything has settled, re-shake the bottle and time the sedimentation rates of the various particles. Can you graph your results?

Some soils may have many fine clay particles that remain suspended in the water for a long time. You may also observe a layer of decomposing plant material, or organic matter, floating on the surface of the water. You will see some of these particles fall slowly as they soak up enough water to sink.



Let the bottle sit for a day or two and then tap the sides. Does anything happen?

Photosynthesis and respiration by algae and soil bacteria may have produced many tiny gas bubbles, which will rise to the surface when you tap the bottle.

You may also see crumbs of soil rising to the surface, buoyed up by gas bubbles produced by soil microbes. What happens if you make two identical soil columns and keep one in a dark place?

Cooking with Soils

What do plants like best?

If you were a plant root you would have a very different perspective on dirt. The soil around you would be your shelter and source of nutrients. It would provide you with air to breathe, water to drink, and shelter from storms and errant footsteps.

In your soil surroundings you would see a diverse world of differently shaped and sized particles. You would see how these particles affect the way water flows, how much water and nutrients are available to you, and what sorts of microorganisms and other soil life you have for company.

Explore the relationships between plants and soils by growing several different plants of the same species under the same conditions but with different soil recipes.

You can create your own soils by mixing the contents of your mystery film cans. You can also compare different brands of commercial potting soils.

How do plants grown in a very sandy soil compare to plants grown in a clayey soil, for example? What happens if you add peat moss?

Procedure

Begin by preparing planters of several different soil components, such as pure sand, pure peat moss, and pure silt. Record the properties of each soil component, including color, feel, and density.

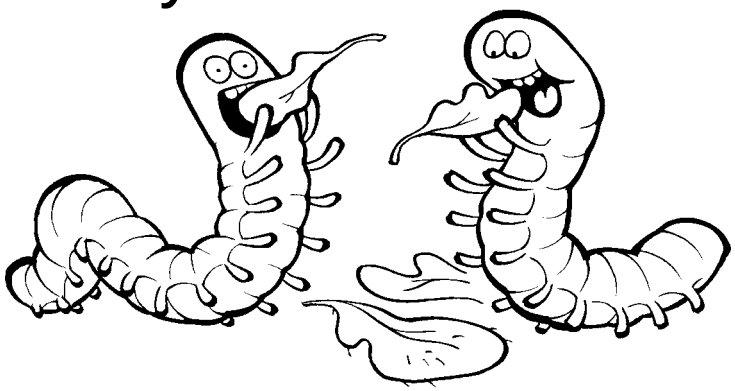
Next create and record a soil recipe of, for example, one part sand, one part peat moss and one part clay. Mix your components well, and then record the properties of your new soil as you did for the components.

In order to test your recipe, plant several seeds of a fast-growing plant (such as turnip, lettuce, or Wisconsin Fast Plants) in the planters of each soil component and in your new soil. Make sure your seeds sprout under exactly the same conditions of light, water, and temperature.

Over the next several weeks, observe your planters closely in order to record factors such as the speed of seed germination, rate of plant growth, and the general appearance of the plant, including height, and the color, size and number of leaves.

How do the plants respond to the different soils? Do all plant species like the same recipes? Experiment and find out. You are searching for the sort of information that helps farmers and gardeners grow the food we eat.

Are cabbage loopers finicky Fast Plant eaters?



The following story came to us from Robin Bernier and her sixth-grade class at Kimbark Elementary School in San Bernardino, CA

Is there a formula for getting young students to investigate unexplored and unanswered questions? We think there is.

Students with a question

Teacher (supportive and encouraging)

\+ **Scientist** (willing to support teachers and students)

= **Research projects** that include problem solving and generate more questions

\+ **New scientists** for the 21st century?

During the 1991-92 school year, Ms. Bernier's students grew two different Fast Plants stocks; the basic brassica stock (purple and hairy) and the anthocyaninless stock (green and hairless.)

While observing the plants one day, a student asked, "Do both of the Fast Plants taste the same?" Ms. Bernier responded, "How could you look into that?"

The search for an answer to that question led Ms. Bernier and her students to Dr. Gary Platner, scientist at the Entomology Department at the University of California-Riverside. He suggested using a common pest of brassicas, the cabbage looper, to investigate their question.

As a supportive scientist, he supplied the caterpillars for the students, gave tips and advice on their care, and acted as trouble shooter for the experiment.

Students first fed leaf discs from both Fast Plants stocks to the caterpillars. Ms. Bernier then asked students how much of each kind of leaf had the caterpillars eaten. Whoops! — none of the students had thought to count or weigh the leaf matter.

They repeated their experiment, but this time counted and put the two kinds of leaf discs into separate bowls. They chose to use leaf discs in multiples of 10 to more easily calculate their results in percentages. Results showed that although large caterpillars ate both the non-hairy and hairy leaves, baby caterpillars preferred non-hairy leaves. It appeared that the larger, or older, the caterpillar, the less selective they were.

The next question asked by students was, "Is it the taste, or is it the hairs that the caterpillars don't like?"

The students' tested this by removing the hairs from the hairy leaves—an idea more easily conceived than carried out. Students tried several ways to remove the hairs. They tried scraping, using masking tape, rubbing with rubber gloves, and plucking them off using tweezers!

They eventually discovered that the best method to remove the hairs was to grind the Fast Plants leaves. But though the caterpillars behaved as though they were interested in the mushy mixtures, none seemed willing to eat them. What would they do now?

They asked for more help from Dr. Platner. He hypothesized that the caterpillars were not eating the mushy material, because they were afraid of drowning in the water in the mushy material. He encouraged students to keep working, saying that

scientists only rarely find answers, usually just more questions.

Students learned about another project where researchers had tricked insects into eating by placing a flavor from one thing on something else.

This gave them an idea. They rubbed the leaves of the hairy Fast Plants on the mush of the hairless and vice versa. They decided to feed the regular mixtures and these new mixtures to the caterpillars again.

Unfortunately, our story ends here.

Ms. Bernier and her students had reached the end of the school year and there wasn't time for more experiments. So, we will have to wait to find out whether the caterpillars preferred leaves that were hairless, or simply ones that are more tasty. ◘

Bring Science to Life through Agriculture

Teachers who attended the AgriScience Institute and Outreach Program in 1992 will be conducting outreach workshops this summer.

Each agriculture teacher/biology teacher team will be presenting a variety of materials from the Bottle Biology and Fast Plants programs, and activities developed to bridge the teaching of science and agriculture. Workshop participants attend in agriculture/science teacher pairs. This program is funded by the W.K. Kellogg Foundation.

For more information, contact the Agriscience teacher team in your region, or Dr. Linda Whent, AgriScience Outreach Program, (916) 752-3040.

AgriScience activities include:

- **The Salty Solution** - A study of the effects of water salinization on the growth and development of Wisconsin Fast Plants
- **Duckweed Unlimited** - Using duckweed (*Lemna minor*) to monitor water quality
- **Leaving the Leftovers** - Investigating how crop residue can affect soils' ability to absorb water
- **Down and Dirty** - A study of water movement through different soil types
- **Ultraviolet Blues** - Investigating the effects of ultraviolet light exposure on the growth and development of Wisconsin Fast Plants
- **Microbial Fermentation** - Examining the effect of environmental factors and inoculation on fermentation

Regional AgriScience teams:

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Charlotte Courthouse, Virginia
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Frank Bridges and Rob Matheson
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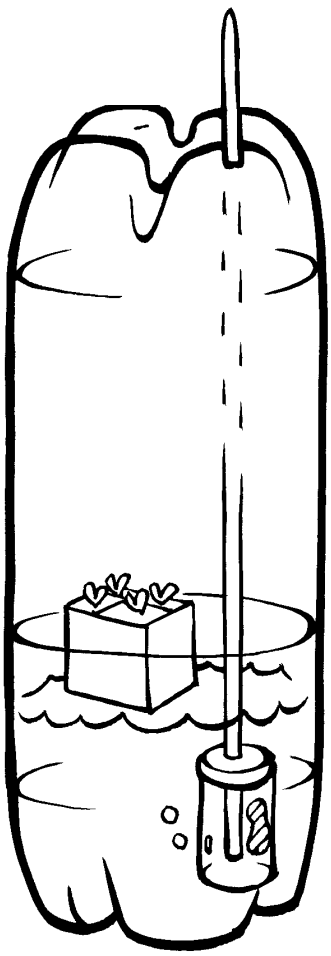
Exploring the Effects of Elevated Carbon Dioxide on Fast Plants



Adapted from experiments developed by Dr. Mary Musgrave, Department of Plant Pathology and Crop Physiology, Louisiana State University, Baton Rouge, Louisiana.

Introduction

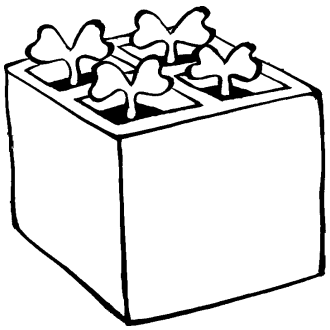
There is virtually no disputing that the amount carbon dioxide in the global atmosphere is increasing. Some scientists believe that the infrared radiative properties of carbon dioxide and other "greenhouse" gases may cause an increase in global temperatures.

Some scientists further predict that weather patterns, especially with regard to rainfall, will change as the earth warms. This overall phenomenon is referred to as the "greenhouse effect."

Scientists have monitored carbon dioxide levels for years in places like Mauna Loa in Hawaii and Antarctica. Prior to such monitoring, people assumed that atmospheric carbon dioxide levels had risen as a result of human-made emissions stemming from the industrial revolution. Burning fossil fuels releases large quantities of CO_2 into the atmosphere.

Though the possible changes in climate patterns could effect where and how well plants grow, scientists also believe that elevated carbon dioxide will affect plants directly. Since plants grow and function using carbon dioxide, water and light energy, to produce carbohydrates, an increase in CO_2 levels will have a "fertilization effect" on plants.

Though this effect is complex, experimentally we know that developmental changes occur, in one or more stages in a plant's life cycle, when plants grow in higher-than-normal CO_2 environments.



The health of a plant's tissue, the timing of the life cycle, and leaf development, including the number and size of leaves, are all known to change in response to changes in atmospheric CO_2. In addition, recent research suggests that some of these changes to plants will affect organisms that are associated with plants. These organisms include insects and plant pathogens that feed on plant tissue.

In this activity, students will see first-hand the effects of increased CO_2 on Wisconsin Fast Plant seedlings using film cans and 2-liter soda bottles.

Building a carbon dioxide enrichment chamber

Air is approximately 350 ppm (parts per million) carbon dioxide. For this activity, you will need an additional source of carbon dioxide to create an enriched CO_2 environment in which to grow your Fast Plants.

A convenient CO_2 source is our own breath. We basically breath in oxygen and exhale carbon dioxide, though air is made up of a mixture of gases. We also do not use all of the oxygen taken in in one breath.

In our lungs, oxygen diffuses across a thin membrane, enters the blood stream through small blood vessels, and circulates through the body, feeding body tissues.

The table on page 12 gives the relative proportions of gases in exhaled and inhaled air.

You can use simple algebra to calculate the volume of expired air you will need to add to a 2-liter soda bottle to achieve a particular CO_2 concentration.

Composition of respiratory gas (values expressed as percent of total volume)

Gas	Inspired air	Expired air
Oxygen	20.71	14.6
Carbon dioxide	.04	4.0
Water vapor	1.25	5.9
Nitrogen	78.00	75.5

Curtis, 1983. Biology.
Worth Publishers, Inc. New York.

To create a CO_2 concentration of 1000 ppm inside a bottle (that's about three times normal atmospheric levels), you need to add about 30 ml of breath to the bottle. Conveniently, the volume of a film can is about 30 ml. In this activity, you will add a film-can's-worth of breath to the soda bottle over several days.

Materials needed (for two chambers):

- two quads of four-day-old Fast Plants
- four 2-liter bottles with molded ("footed" base)
- two 5 ml plastic pipettes
- two clear film cans
- round toothpicks, silicone cement, reamer, dissection needle

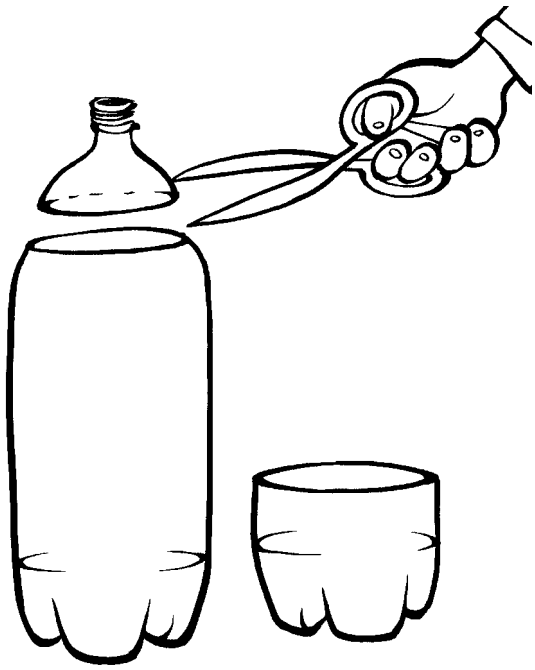
Engineering the chambers:

1. Construct the growth chamber by cutting two clear, plastic 2-liter soda bottles to create a base and a dome top.

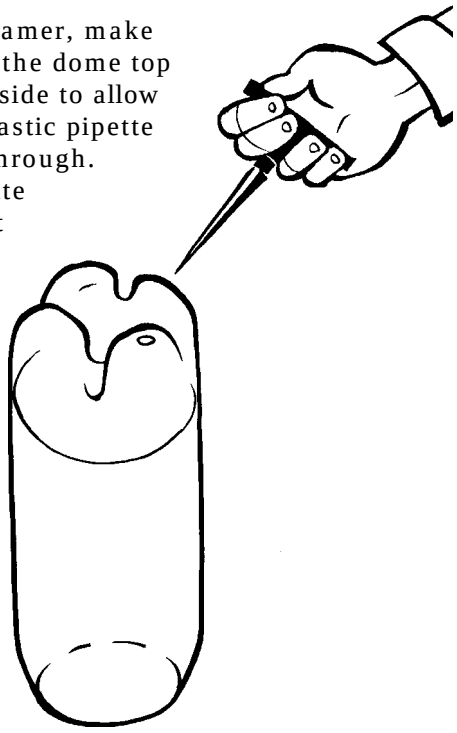
   For the dome, cut one bottle 1 cm above the shoulder. To make the base, cut the other bottle 12 cm up from the bottom.

   Use bottles with a molded base.

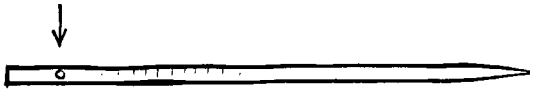
   The dome is cut just above the shoulder of the bottle so that the shoulder of the dome fits snugly into the top of the base.



2. With a reamer, make a hole in the dome top near the side to allow a 5 ml plastic pipette to slide through. The pipette should fit snugly.

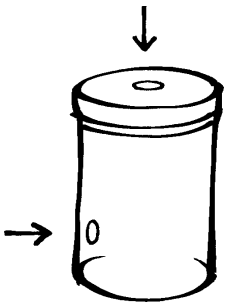


3. Melt a 3 mm hole in top or wide end of the pipette with a hot dissecting needle.



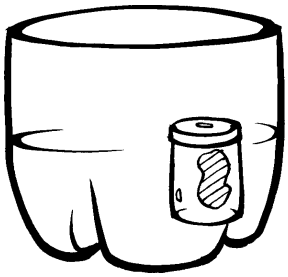
4. Construct a "gas delivery bottle" from a clear film can. Make a small hole (3 mm in diameter) in the the bottom of the can and a second hole in the lid of the film can just large enough for the pipette to slide through.

   Again, the pipette should fit snugly.

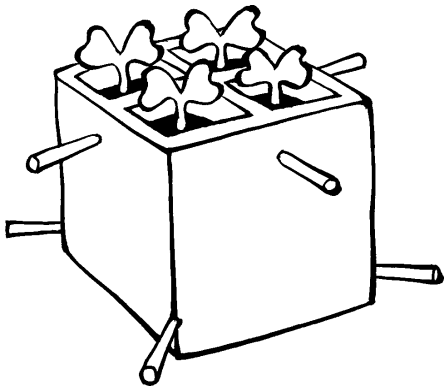


5. Cement the film can (with lid) onto the bottom wall of the base. You should first scratch the wall of the base and the side of the film can with a knife or needle to provide surface for better adhesion.

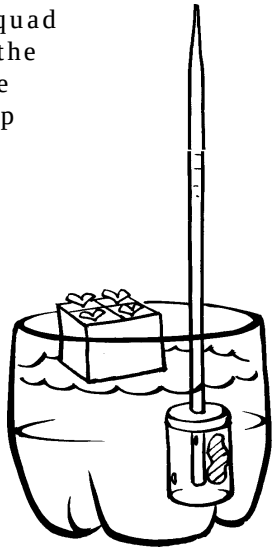
   Place a fairly thick 3 cm bead of silicone cement on the rough surface of the film can. Secure it to the bottom wall of the base. Allow the cement to "cure" for 48 hours.

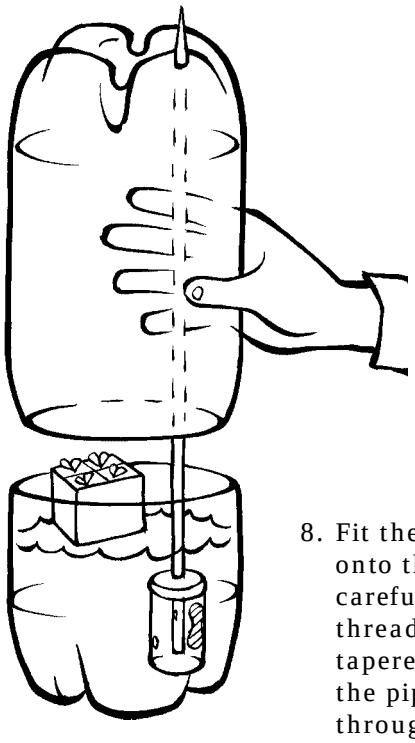


6. Cut four round toothpicks in half. Insert four pieces into the bottom corners of the quad of 4-day-old plants. The toothpicks will help stabilize the quad. Insert the other four pieces near the top of the quad at the points of the cell dividers.



7. Fill the chamber base with water, add (float) the quad of plants, and insert the wide end of the pipette through the hole in top of film can.





8. Fit the dome onto the base, carefully threading the tapered end of the pipette through the hole in the top of the dome.

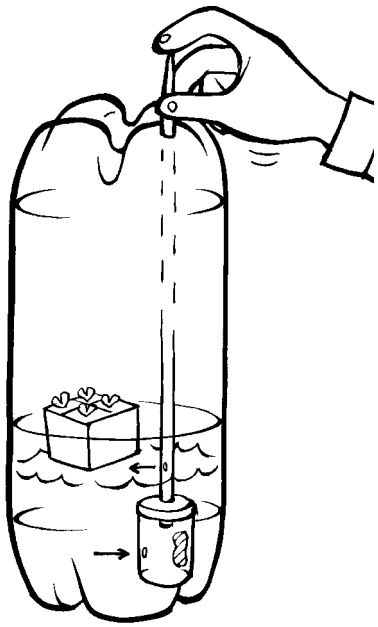
Experimental procedure:

The gas delivery bottle allows you to quantify the amount of carbon dioxide you add to the chamber. You will "enrich" the plants in the experimental chamber with CO_2 on days 4, 7 and 8 of the life cycle. You will treat the control plants with air, not expired breath.

1. On day 4 of the plants' life cycle, push the pipette to the bottom of the film can (or "gas delivery bottle".)

2. Fill the film can with breath by blowing gently into the pipette. You will see the gas displace the water from the film can into the main chamber.

When the water is fully displaced from the can (check visually), withdraw the pipette just far enough that the 3 mm hole in the pipette is again above the lid of the film can, keeping the end of the pipette covered.



3. Water will flow back into the can and displace the volume of breath into the chamber. (You can vary the level of carbon dioxide added to the chamber by filling the can only part way or by filling it more than one time.) Each fully-filled can raises the carbon dioxide in the chamber by about 650 ppm.

4. For the control plants, introduce air into the chamber by squeezing air into the control chamber through the plastic pipette from a plastic bag or balloon.

5. Repeat the procedure on Day 7 and 8.

6. On Day 9, stain the cotyledons from both chambers and look for starch. The staining procedure is described in the paragraphs that follow.

Remember that having plants inside a chamber will change how they grow. When scientists use growth chambers to study carbon dioxide enrichment or air pollution they always include a chamber control that has the same configuration as a treatment chamber, but has air added to it rather than the special gas of interest. Can you think of some special gasses you could try?

Effects of carbon dioxide enrichment on plant growth

Using the carbon dioxide enrichment chamber, it is possible to look for changes in the growth of Fast Plants caused by an elevated CO_2 environment. Leaf area, the number of branches, specific leaf weight (dry weight of leaf per unit area), the time to first flowering, the number of flowers, and the number of seeds produced can all change with CO_2 enrichment.

The effects of $C0_2$ may be different depending on the developmental stage of the plant. Also, the length of time that a breath will furnish elevated carbon dioxide for the plants will change as the plants grow and produce more leaf area.

Starch often accumulates in leaves of CO_2 enriched plants because the rate of production of starch exceeds the rate at which the plant can use the extra carbohydrate. This is especially true prior to flowering when the young seedlings are "sink limited"—they have nowhere to put the extra carbon they fix with high CO_2. Is the resultant yellowing of the plants is due to nitrogen deficiency or carbon excess?

You can investigate this question using a **starch test**. Remove the cotyledons from the experimental and control plants. Place them in a test tube with water and boil them for 1 minute. Decolorize the cotyledons by transferring them to a tube of ethanol and boiling the ethanol for about 1 minute. Boil the ethanol by holding the tube in boiling water. You can also decolorize by letting the cotyledons stand in ethanol at room temperature overnight.

Remove cotyledons from the ethanol and stain with iodine-potassium-iodide (IKI) solution. Starch will stain a deep blue-purple. Is there any difference between the "enriched" and the control plants?

Older plants, such as those that are 10 days old, have more growing tissue than younger plants. Carbon is exported into all newly developing leaves, stems and buds. If you used 10-day-old plants (instead of 4-day-old plants) for the CO_2 enrichment experiment, would you see a "fertilization effect?"

Consider the observation that house plants grow better when people talk to them. Is it the conversation or the carbon dioxide that stimulates their growth? ◘

Wisconsin Fast Plants Workshops

1. The Fast Plants Program offers two workshops each year, held on the University of Wisconsin-Madison campus, presented by Dr. Paul Williams.

To request an application, contact the Fast Plants office at 1-800-462-7417.

Workshops dates: October 29-30, 1993
February 11-12, 1994
October 28-29, 1994

2. Dr. Paul Williams will present Wisconsin Fast Plants as a featured module in the Teacher Enhancement Programs in Biology, Genetics Institute, UW-Madison Summer Sessions.
Workshop date: July 4-9, 1993

Contact Ruth Owens, UW-Madison, Genetics Dept. Room 104, 445 Henry Mall, Madison, WI 53706. (608) 262-1006

3. The College of Saint Benedict at Saint John's University in St. Joseph, Minnesota will offer two three-week workshops for elementary teachers focusing on life and physical science and Wisconsin Fast Plants.
Workshop date: June 14-July 2, 1993

Contact Dr. Stephen Saupe, Department of Biology, Saint John's University, College of Saint Benedict, St. Joseph, MN 56374. (612) 363-2782

In this issue of notes

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Bottle Biology (608) 263-5645, Fax (608) 263-2626

Funding for these projects has been provided by grants from the National Science Foundation.

Wisconsin Fast Plants Receives New NSF Teacher Training Grant

Thanks to the National Science Foundation, we are happy to announce that we will be continuing with another three years of teacher training and outreach, which includes:

1. Elementary/middle school teacher work shops available to school districts indicating a strong commitment to Fast Plants.
2. Workshops at the University of Wisconsin-Madison, presented by Dr. Paul Williams. (See page 15.)
3. Traveling and customized workshop kits available for workshop and inservice presentations by Fast Plants master teachers.

For information, write, FAX 608-263-2626, or call 1-800-462-7417.

Resource Book for Elementary and Middle School Teachers

The Wisconsin Fast Plants elementary/middle school resource manual is now available through the University of Wisconsin Press, 114 North Murray Street, Madison, Wisconsin 53715. To order, call (608) 262-8782. Cost: $15.00 plus postage.

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