

PLANTS CAN'T DO WITHOUT CO₂

by David R. Hershey

Carbon dioxide, CO₂, is earning a bad reputation for its contribution to the greenhouse effect. This gas is essential, however, for photosynthesis, which provides virtually all of our food and most of our energy either directly or indirectly. Plants obtain carbon and oxygen from CO₂. These two essential elements account for approximately 88 percent of a plant's dry mass.

Inducing nutrient deficiency symptoms is a common student laboratory exercise. However, CO₂ deficiency is not commonly demonstrated, although it is easier to demonstrate than many micronutrient deficiencies involving such elements as copper, zinc, and molybdenum. Furthermore, distilled water is not required, and no nutrient solutions need to be purified of contaminants.

SOLUTION CULTURE SYSTEM

To induce CO₂ deficiency, plants are placed in a solution culture within a sealed chamber into which air, scrubbed

*Demonstrate
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greenhouse gas*

of CO₂, is constantly pumped. Solution culture is necessary to eliminate CO₂ production by soil microbes. A solution culture apparatus can be built from plastic soda bottles (see article by Hershey in the February 1990 issue of *TST*). For this lab, I construct my solution culture reservoir out of a 1-L bottle. The base of the 1-L bottle serves as lid for the reservoir (see detail of Figure 1). This bottle is cut to 12 cm in height so that it will fit inside a 2-L bottle that serves as the air-tight chamber.

CO₂ SCRUBBING

To scrub CO₂, air is bubbled through 2-L bottles of saturated calcium hydroxide [Ca(OH)₂]. The CO₂ is precipitated as calcium carbonate (CaCO₃) or limestone. Calcium hydroxide, known as hydrated lime or slaked lime, is available from gardening supply stores. Air, supplied by an aquarium pump, is pumped through the following sequence of bottles: an empty bottle, followed by two or more bottles filled to 80 percent capacity with 2 g/L Ca(OH)₂, followed by a bottle filled halfway with tap water, followed by the plant chamber, and ending with a bottle filled to 10 percent capacity with tap water (Figure 1). The empty bottle prevents water from siphoning back into the pump if the pump fails. The first water-filled bottle removes any Ca(OH)₂ accidentally carried over from the CO₂ scrubbing bottles. The last bottle prevents any backflow of air into the system if the pump should fail, and bubbling in this bottle indicates that there are no major leaks.

Each bottle is sealed with a 2-hole, #3 stopper. Standard aquarium tubing fits snugly in the stopper holes. Except for the empty bottle, the tubing through

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which air enters each bottle reaches to the bottom of the bottle, so air bubbles up through the entire solution. A plastic soda straw is slipped over the aquarium tubing within the bottle to keep it straight. No tubing is placed on the inside of the stopper tube through which air exits the bottle. Air flow is adjusted with a 3-way aquarium valve.

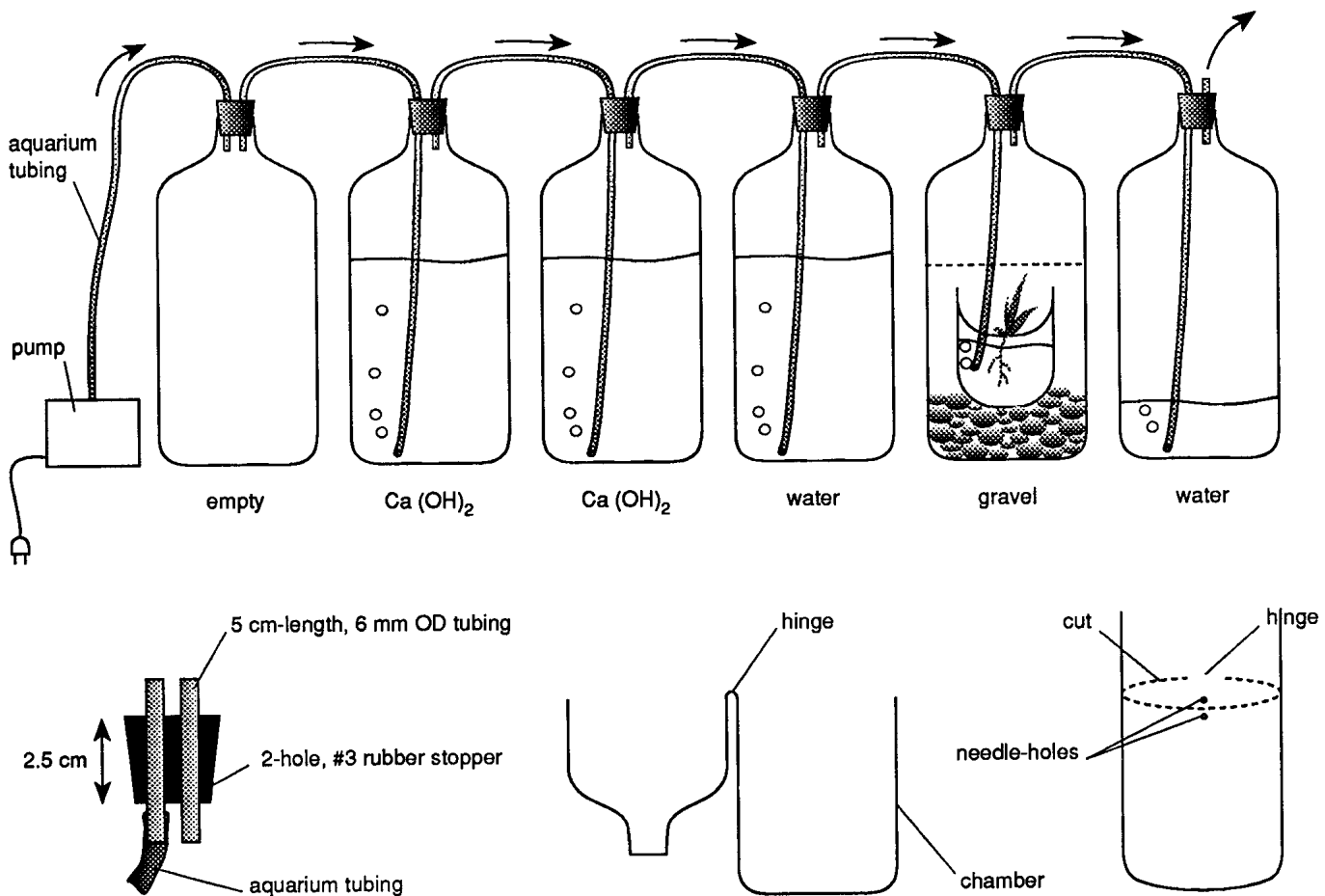
AIRTIGHT CHAMBER

The 2-L bottle serving as the sealed chamber is marked along its circumference at 18 cm above its base using a felt-tip marker. A razor blade or scissors

is then used to cut along the entire length of the line, except for a 4-cm length that will act as a "hinge." A sewing needle is used to punch holes about 2 mm above and 2 mm below the cut, on the side opposite the hinge (see Figure 1). Washed gravel is placed in the bottom of the chamber to provide anchorage and a level surface on which to place the solution culture reservoir.

The plant in the solution culture system is placed in the chamber, and the tubing is placed in the solution culture reservoir. The CO₂-scrubbed air will also aerate the nutrient solution. A piece of strong thread or thin wire is used to tie shut the two parts of the chamber using the two needle holes. The two sections of the chamber must be securely fastened together or the air pressure within the bottle will force them apart. Excess thread or wire on the outside of the chamber is cut away, and an airtight seal is obtained with vinyl electrical tape wrapped around the cut.

FIGURE 1. Sequential order of bottles for removing CO₂.



ART BY SERGEY IVANOV

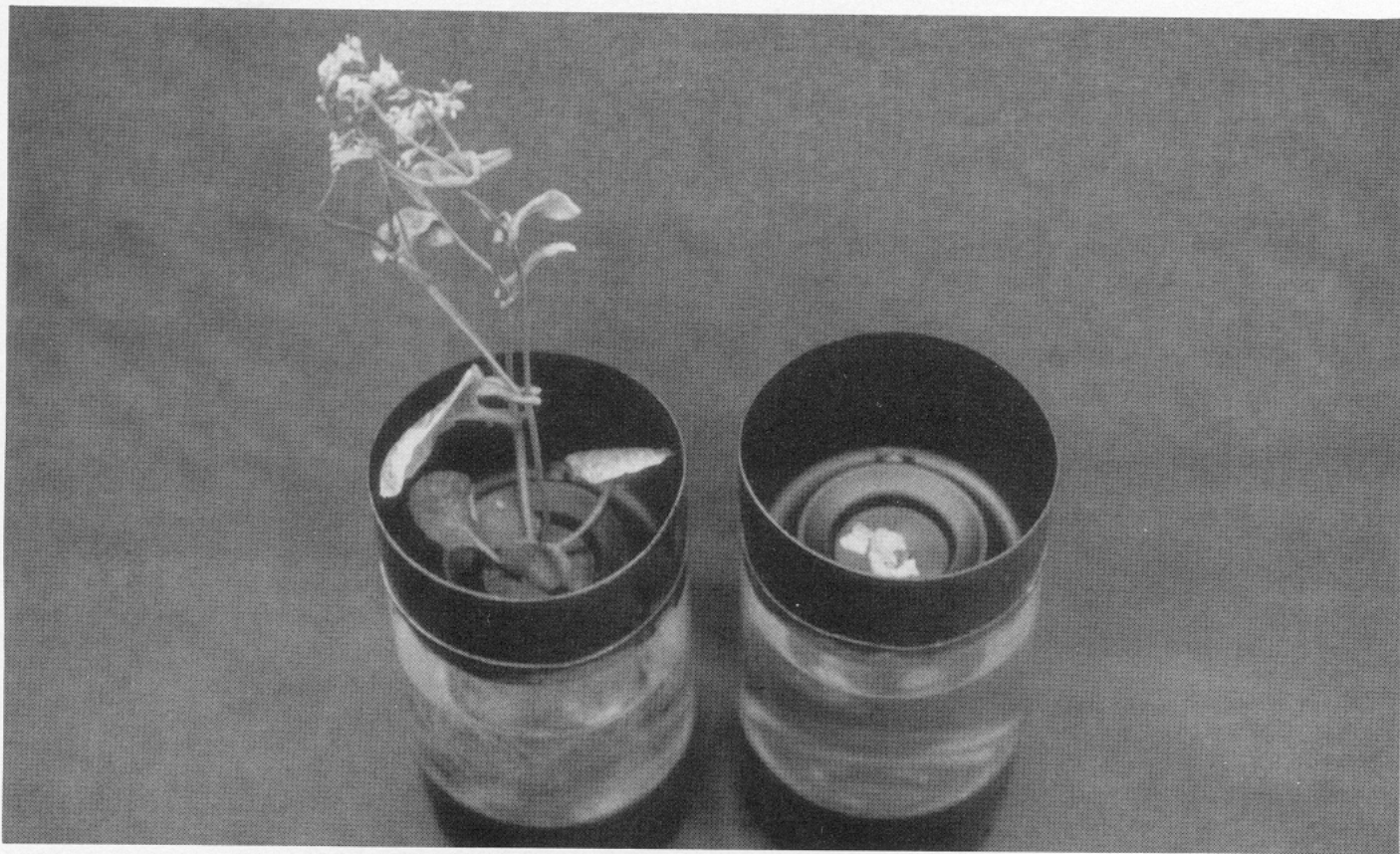


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FIGURE 2. A dramatic demonstration of the effect of CO₂ deprivation on plant growth.

PLANT GROWTH

During a test of this system, rooted piggyback plants (*Tolmiea menziesii*) were grown in half-strength Hoagland solution number 1 with 2.5 mg/L Fe as FeEDTA. Plants were grown under continuous cool white fluorescent light, using six, four-foot, 40-watt fluorescent tubes. With air scrubbed of CO₂, the plant was severely stunted. When grown in a system with no Ca(OH)₂, the plant was healthy (Figure 2). The CO₂ deficient plant recovered when the Ca(OH)₂ solution was replaced with water.

FURTHER STUDIES

If two plant chambers receiving air scrubbed of CO₂ are placed in series, a reasonable hypothesis is that plant growth in the second chamber should be better than that of the plant in the first chamber, since the second chamber will receive CO₂ from respiration of the first plant. With two plant chambers in series receiving ambient air, a logical hypothesis is that the plant in the second chamber will not grow as well as the plant in the first chamber, since the plant in the first chamber will lower the CO₂ concentration. Respiration by soil microbes might be demonstrated

by placing moist soil in a bottle in sequence following the CO₂ scrubbing bottles and before the plant chamber. In such a system the plant could serve as a CO₂ sensor; the better the growth, the more CO₂ supplied by soil microbial respiration.

This system also provides a method to study the effect of relative humidity, other gases, and air pollutants on plant growth. Solid or liquid desiccants can be used instead of the Ca(OH)₂ solution to obtain a range of relative humidities in the sealed chamber. Air pollutants, such as a formaldehyde solution, can also replace the Ca(OH)₂.

Is the Ca(OH)₂ method of CO₂ removal in this experiment a solution to the greenhouse effect? No, because Ca(OH)₂ is prepared by hydrating calcium oxide (CaO), and calcium oxide is prepared by heating CaCO₃ to drive off CO₂. Introducing your students to experiments such as this, however, may start them on a career that may one day lead to a solution to the greenhouse effect.

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FOR FURTHER READING

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