Volume 8, No. 1 Spring, 1995

WISCONSIN FAST PLANTS notes BOTTLE BIOLOGY WISCONSIN

"AstroPlants" in Space

Simulating the Space Shuttle Experiment

While Space Shuttle Discovery was in orbit February 3 through 11, 1995, it carried a special "AstroPlants" Stock of Fast Plants. The plants were housed in an environmentally controlled Astroculture™ Unit designed by the Astroculture™ staff at the Wisconsin Center for Space Automation and Robotics at the University of Wisconsin-Madison. On the shuttle, the delivery of light, nutrients, oxygen, water and temperature to the plants was controlled and monitored so that the influence of low gravity and acceleration forces on plant growth could be studied.

In parallel with the shuttle experiments, 13 middle and high school teachers and their students (from Maine to California and Wisconsin to Texas) ran simulation ground-based “control” experiments and collected data for comparison with the data collected from the Space Shuttle plants. Students were encouraged to actively critique all aspects of the experimental design.

Why Send Plants into Space?

Plants are of special interest to space biologists because of the profound effect gravity has on orienting plant growth. Scientists want to know how gravity is perceived by the plant and how to compensate for the effects of microgravity on plant growth. Without gravity directing roots “down” and the growing tip of the plant “up," how can plants grow normally? There is also the question of supplying plants in space with water, minerals and air. In microgravity, water “poured” from a vessel floats in globs and oxygen moves differently in the absence of convective air movement. A second reason for having plants in space is a therapeutic one, to counteract the feelings of isolation among crew members involved with long stays in space.

And third, plants have the potential role of providing atmospheric regeneration in a closed ecological life support system (CELSS). Carbon dioxide exhaled by humans could be taken up by plants and used in photosynthesis, returning oxygen and food to the crew.

Plants can also form part of a water regeneration loop. The productivity of plants relative to the input of energy (light) can be increased tremendously by using such techniques as carbon dioxide enrichment and hydroponics. In order to realize the goal of using plants in a CELSS, many experiments with plant growth facilities on the ground and in space will be necessary.

Oh noooo!

This is your last issue unless you turn to the back page!

Also in this issue:

Simulating the AstroPlants Experiment

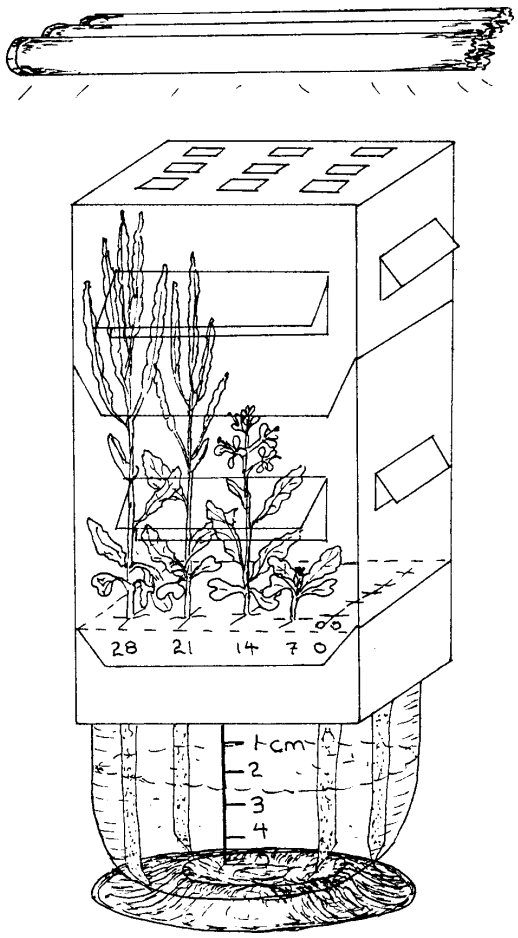


Figure 1.

Engineers faced various design problems. The amount of space allotted for the plant chamber in the controlled Astroculture™ Unit was 4" x 4" x 6".

- How could all stages of the plants' life cycle be represented?
- How could the soil be kept from flying around?
- Nutrients, water and oxygen would be delivered, but could a method be devised to guide the germinating seedlings out of the ground?
- What inexpensive system could be easily duplicated by teachers in terms of size and shape of the plant chamber?
- How could the simulated chamber provide air circulation for the plants?

Energy is a limiting factor on the shuttle. Only 130 watts were allotted to the Astroculture™ Unit. Light emitting diodes (LEDs) were the answer. The original red LEDs (for photosynthesis) had to be supplemented with blue LEDs to keep the plants from getting tall and spindly.

- For the ground-based "control," what could be used in place of LEDs?

In space, 5 cm of suction is needed to keep water from "flying out."

- How could that be simulated in the ground-based experiments?

The special Zeolite soil with minerals adsorbed to its particles would not be available to the pilot classrooms.

- What soil would be the best substitute?

The experiment that follows describes how you and your students can construct and run a simulation of the Fast Plants experiment carried on the Space Shuttle Discovery February 3-11, 1995. Comparative data will be available from Wisconsin Fast Plants.

Supplies needed

- Wisconsin Fast Plants-AstroPlants Stock (APS) of Rapid Cycling *Brassica rapa* seeds. 50 seeds for each experimental setup. APS seed will be available from Carolina Biological Supply Co. (1-800-334-5551) by Sept. 1995. In the interim, you may use the "petite" stock, though it is slightly taller and less stocky than the APS stock.
- Peters® fertilizer, mixed at 3 cc (or one level soda bottle capful) per 2 ltr. of water . You can use a one liter soda bottle to mix and store the solution.
- peat:vermiculite planting mix (Jiffy Mix® or peatlite)
- pre-cut half-gallon milk or juice carton (3 pieces -- growing bed plus 2 sets of chamber walls)
- 9 cm square water mat
- 2 wicks, 1 cm x 30 cm with tapered ends
- bottle reservoir with centimeter markings
- 13 cm x 13 cm black plastic soil blanket, to hold the soil in place as required in space flight. The blanket contains 5 x 5 grid of 25 + slits for seeding and seedling emergence.
- paper patterns (soil blanket, mylar filter)
- plastic spoon
- plastic forceps with black electrical tape on tip
- fine point felt marking pen
- clear, flexible metric ruler
- razor blade safety holder
- box of single-edged razor blades
- water bottle
- plastic 3 ml pipette, calibrated
- clear plastic wrap (Handi-Wrap® or Saran Wrap®)

Constructing the AstroPlants Growing System

1. Mark all lines on the half-gallon container as shown in Figure 2. Measuring from the bottom, lines should be drawn **all the way around** at 3, 4.5, 7, 9, 11, 12.5, 15, 17 and 19 cm. Mark your measurements along all four corner edges of the carton, then join the corner marks across the side panels.

2. Mark the vertical window lines as shown on all four sides, between the 15 and 17 cm lines and again between the 7 and 9 cm lines. The window is 6 cm wide and is 2 cm from the left edge of the chamber section.

3. The following cutting instructions are ordered to maintain maximum stability and safety while cutting the container. Using the razor blade in the safety holder, or other sharp blade:

3.1 Make the corner cuts first, by cutting across the corners to a depth of about 1 cm into the sides at **only** the 3, 11, and 19 cm lines at all four corners of the container.

3.2 Cut all four bottom window lines, along the 7 and 15 cm lines.

3.3 Cut all side window lines, by cutting down from the 17 cm line to the 15 cm line, and again from the 9 cm line to the 7 cm line, on all four sides of the carton.

3.4 Cut the carton top off with the razor blade tool at the 19 cm line, joining all the corner cuts previously made at the 19 cm line. Begin the cuts at the reinforced corner (double layer of paperboard) of the carton.

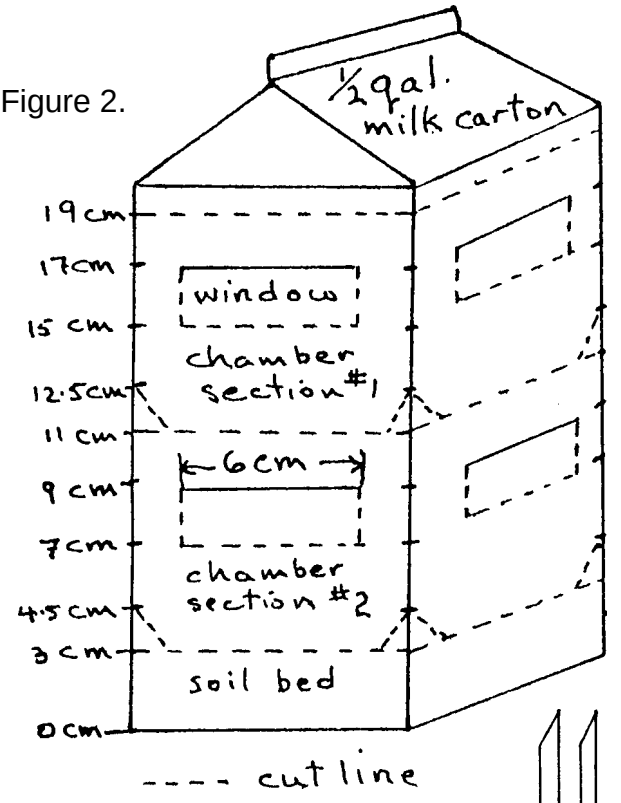
3.5 Cut the first chamber section off by joining the corners cuts made at the 11 cm line. Again, begin the cuts at the reinforced corner.

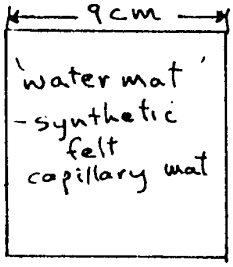
3.6 Cut the second chamber section off at 3 cm line. This cut will produce the "soil bed" of the growing system.

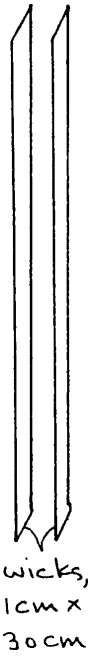
3.7 With scissors, cut the V's (bevels) at the bottom corners of both chamber sections by cutting the top of the V as high as the first line (1.5 cm from bottom of section, see Figure 2).

3.8 Use a stiff edge (of a ruler, plastic card, etc.) to bend all the windows at their top line.

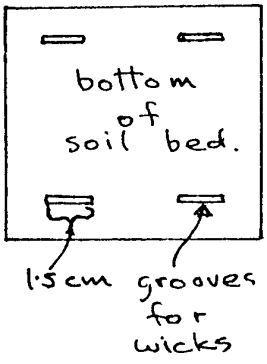
Figure 2.







3.9 Cut four slots in the bottom of container as shown in the diagram. For each slot make two 1.5 cm cuts very close together (1-2 mm apart), then cut out the ends. Start each slot 1.5 cm from the corner.



4. Making the black plastic blanket:

4.1 Align and tape up to four 16 cm x 16 cm squares piece of black plastic garbage bag to a cutting surface, e.g., glass, formica, heavy cardboard or old magazine.

4.2 Tape a copy of the 15 cm square pattern (below) so that it is centered on top of the black plastic squares.

4.3 Using the razor blade tool, carefully cut the 25 crosses by cutting through the pattern and the plastic squares along the lines. *You may want to practice cutting on a scrap piece of plastic before starting your blankets.*

4.4 Cut the outside edges as marked on the pattern, so that your blanket has four 2 cm flaps extending from a 9 cm square center.

4.5 Carefully pull the cut pattern and new blankets from the cutting surface.

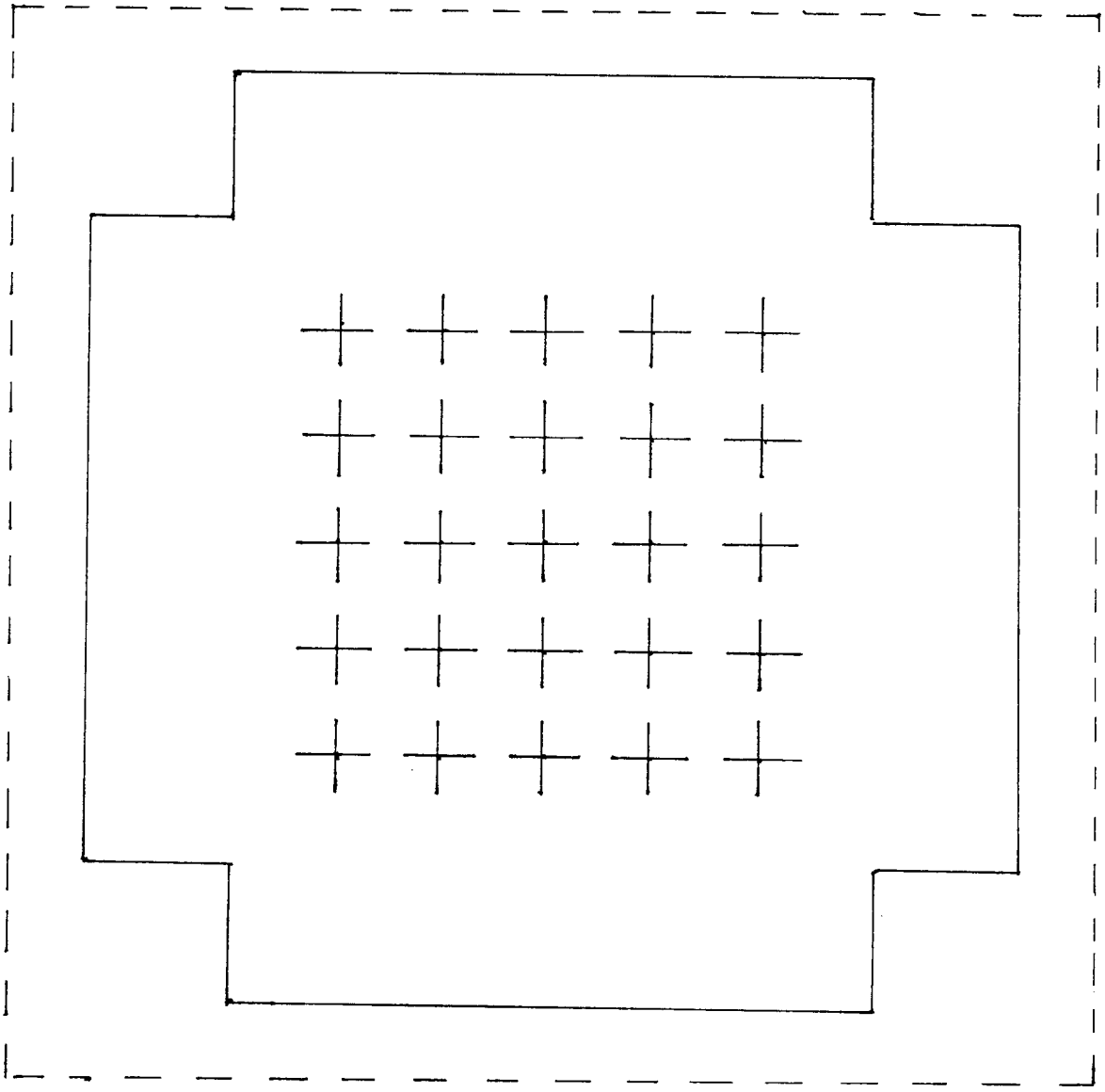
5. Preparing the water reservoir:

5.1 Mark and cut a 2 liter soda bottle to be approximately 10.5 cm high from the base.

5.2 Measuring from the top of the reservoir, make marks at 1, 2, 3, 4 and 5 cm.

5.3 Fill the reservoir with water to between the 2 and 3 cm marks.

5.4 Soak the wicks and the water mat thoroughly. Thread the wicks through the holes in the bottom of the soil bed until they hang down evenly. Place the water mat on top of the wicks in the bottom of the soil bed. The wicks and mat will provide the capillary column for the



water in the reservoir to reach the plants. With the water in the reservoir kept at the 2-3 cm mark, plus the 2-3 cm depth of the soil in the growing bed, **approximately 5 cm of negative water pressure** (suction) will be maintained at the surface of the soil.

6. Preparing the soil bed:

6.1 Moisten the peat:vermiculite (Jiffy Mix®) soil mixture lightly, so that it feels slightly moist but not wet.

6.2 Gently spoon the soil mixture into the soil bed until it reaches right to the top.

6.3 Scrape off the excess soil mixture to make it even, being careful not to pack it down.

6.4 Gently and thoroughly water the entire bed of soil using a water bottle. Repeat several times until water runs from the wicks and the soil settles a few millimeters.

6.5 Let the wet soil bed drain for 5 minutes.

7. Using the edge of the thin, flexible ruler, press the soil slightly (a few mm) away from the edges of the soil bed. Then lay the 13 cm x 13 cm black plastic soil blanket over the soil, tucking the flaps gently down along each of the inside edges of the soil bed with the edge of the ruler. (Be sure not to press down on the soil bed itself.) The blanket serves to hold the soil in place, e.g., so that is does not spill out of the bed while in microgravity.

8. Planting:

8.1 Plant positions in the soil bed are numbered from 1 to 25 in 5 vertical columns, e.g., the first column contains plants 1-5, the second 6-10, etc. Position "1" is at the upper left corner and should be marked on the wall of the bed with a permanent marker.

8.2 One column of seed will be planted each week for 5 weeks. Seeds will be sown in positions 1-5 the first week, 6-10 the second week, 11-15 the third week, 16-20 the fourth week and 21-25 the fifth week.

8.3 The seeds have to be sown into the center of each cross slit (+) in the plastic blanket.

8.4 Use small forceps to pick up the seed. A tip of black electrical tape at one end helps to keep the seed from slipping from the forceps.

8.5 Sow two seeds into each cross slit in the first column. Sow the seed by pushing the tip of the forceps with the seed about 0.5 cm into the soil. Release your hold on the seed before you retract the forceps.

8.6 Add a few drops of water to each hole with the pipette.

9. Make a translucent light filter by cutting a sheet of Handi-Wrap® or Saran Wrap® to be 11 cm square. Tape the plastic window over the top opening of your first chamber section.

10. Fit the first chamber section (with the clear plastic window) onto the soil bed with the two opposing flanges inside the wall of the base and the other two outside the wall. The windows should be folded outward slightly to ventilate your chamber (see diagram). The second section may be used to increase the height of your plant growth chamber as the plants grow taller.

11. Place the soil bed with its chamber section attached onto the water reservoir, thus completing your "plant growth system." *Be sure to maintain the water level in the reservoir at between the 2 and 3 cm marks at all times.*

12. The AstroPlants Growing System should be placed under a standard Fast Plants light bank of 6 or 8 four-foot cool white fluorescent bulbs. The window of the plant growth chamber should be 1-2 cm from the light bulbs.

What?! There's another Fast Plants Manual Available?

A new Fast Plants manual, entitled *Using Fast Plants and Bottle Biology in the Classroom*, has been published by the National Association of Biology Teachers.

The manual includes 12 lessons that incorporate Fast Plants and Bottle Biology into agricultural and biological science teaching, and was developed by teachers at the 1991 and 1992 AgriScience Institutes at UW-Madison, with the University of California at Davis.

The manual is available for $24.00 (including shipping) from NABT, 11250 Roger Bacon Drive #19, Reston, VA, 22090-5202, tel: 703-471-1134, fax: 703-435-5582.

13. As the seeds germinate, seedlings will normally emerge through the cross slits in the blanket. Occasionally you may have to train a seedling through the slit in the plastic blanket. After 4 days, thin the seedlings to one per hole. Transplant if necessary to have one plant per hole.

14. Four days after seeding (4 das), add 1 ml of Peters fertilizer at the base of each plant through the blanket. Mixture concentration is 3 cc Peters/ 2 ltr. water. You will fertilize the plants again at 7 das, and at weekly intervals (14, 21 and 28 das).

15. Seven days after sowing (7 das), you will make your first measurements on plants 1-5 and also plant the second column of seed (plants 6-10). Seven days after this second planting, you will plant the third column of seeds (plants 11-15), and so on until all five columns have been planted.

AstroPlants Countdown Calendar for a 7-day Mission

Prior to seeding:	Construct additional AstroPlants Growing Systems (AGSs) if more than one setup is going to be used. Make five copies of the AstroPlants Data chart for each setup.
Day 0	Put together the AGSs. Begin at step 6 in instructions.
Das* 4	Thin to one plant per hole. Transplant as necessary. Fertilize, with 1 ml per plant.
Das 7	Plant the second column of seeds. Thin after four days. Fertilize.
Das 14	Plant the third column of seeds. Thin after four days. Fertilize.
Das 21	Plant the fourth column of seeds. Thin after four days. Fertilize.
Das 28	Plant the final column of seeds. Fertilize. Launch day.
Das 35	Record.

* Das = days after sowing

Measurements and data collection (see Data Chart, opposite page)

Each week for 5 weeks, 10 seeds will be sown in a column of 5 cross slits in the soil bed. After 4 days, germination is recorded and plants are thinned to one per position and fertilized. Every week, measurements of plant growth and development are recorded for each group of 5 plants of the same age.

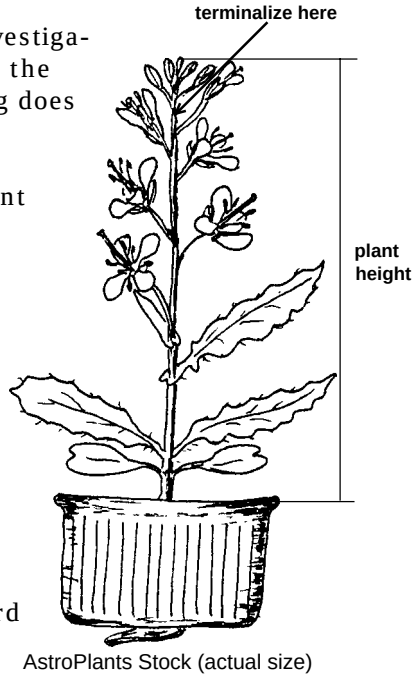
The dates of planting for your shuttle flight assume that the mission length is 7 days. By observing 5 groups of plants, each group being 7 days older than the next, the influence of the Space Shuttle flight and microgravity on all stages of the Fast Plants life cycle would be investigated. In this simulation, planting groups are designated by age according to days at the time of launch (**days at launch, dal**). The five planting groups are designated as 28 dal, 21 dal, 14 dal, 7 dal and 0 dal.

Pollinate all open flowers for 3 days after the first flower opens. Terminalize and prune off all unopened buds and shoots. Keep all side shoots pruned off.

Since observations and measurements of growth and development, pollinations and other plant activities (thinning, pruning) will be made at regular time intervals within each dal group, the kinds and times of these activities and measurements are recorded on the AstroPlants Data Chart on designated **days after sowing** (das). You will want to make 5 copies of the AstroPlants Data Chart in five different colors, so that you have a separate data chart and paper color for each of the 5 dal groups.

It is ideal to begin this investigation on a Monday, so that the measuring and pollinating does not fall over a weekend.

The AstroPlants experiment will continue for 42 days from the first sowing, until the first planting group (28 dal, plants numbered 1-5) has completed its life cycle. A sample of seeds collected from this oldest group of plants should be sown and tested for germination and seedling vigor, as would the plants aboard a shuttle flight.



AstroPlants Stock (actual size)

AstroPlants Data Chart

Plant age at launch: _____ days

Student Group Names: _____ Date: _____

_____

_____

Environmental conditions:

Temperature: _____ °C Lighting: _____

Soil medium: _____ Soil moisture: _____

Soil nutrition: _____ Gravity: 1 x g Gravity vector: vertical

Atmosphere: ____ %N ____ %O_2 ____ %CO_2

date	das	activity	plant number					statistics			
			1	2	3	4	5	n	r	$\bar{x}$	σ
	0	number of seeds sown (#)									
	4	number of seedlings (#)									
	4	thin to one plant per hole									
	4	number of plants after thinning (#)									
	7	plant height (mm)									
	14	plant height (mm)									
	14	number of leaves on stem (#)									
	14	cross pollinate all open flowers									
	16	total number of flowers pollinated (#)									
	16	terminalize flowering									
	16	plant height after terminalizing (mm)									
	21	plant height (mm)									
	21	number of green leaves on stem (#)									
	28	plant height (mm)									
	28	number of pods with seeds (#)									
	28	number of green leaves (#)									
	28	launch day									
	35	re-entry and recovery									
	35	plant height (mm)									
	35	number of green leaves (#)									
	35	number of pods with seeds (#)									
	38	cut plants at soil level									
	42	number of pods with seeds (#)									
	42	harvest seeds									
	42	number of seeds per plant (#)									

= activity without measurements,

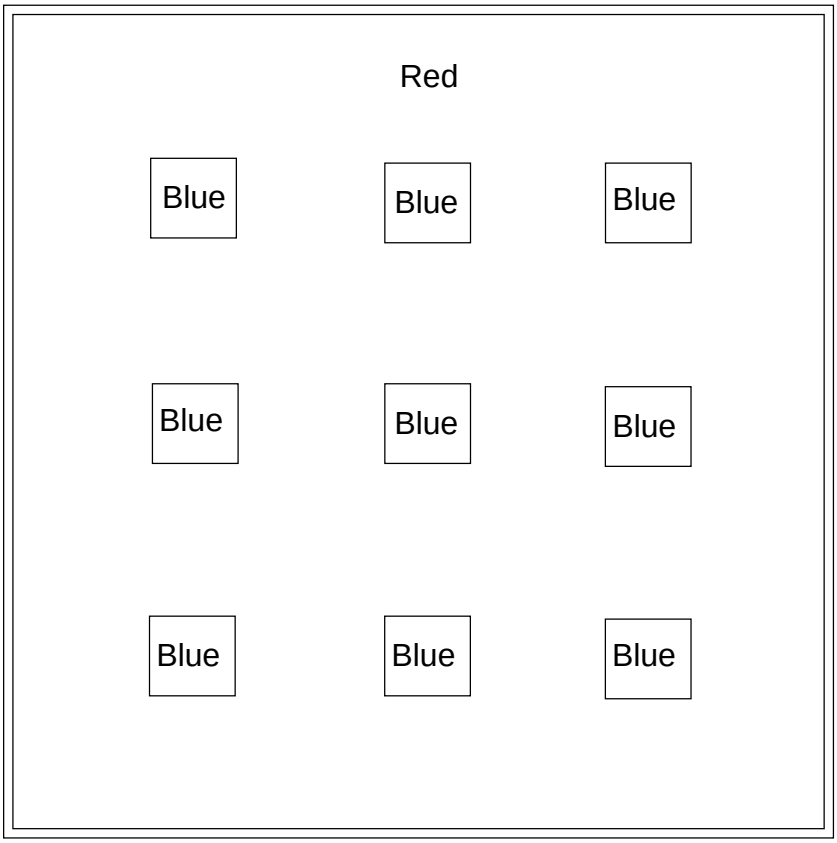
das = days after sowing, n = number, r = range, $\bar{x}$ = mean or average, σ = standard deviation

Additions and Extensions

You may wish to make additional plant growth chambers to change one aspect of the control experiment. Brainstorm some variables that could change environmental conditions.

1. Change the quality or quantity (density) of light. For example, use a colored light filter on a second growing chamber to experiment with simulating the wavelengths (colors) of light produced by the light (L) emitting (E) diodes (D) in the Astroculture™ Unit used on the Space Shuttle experiment of February, 1995.

You will need red (#41) and blue (#61) Roscolux® mylar plastic filter for the AstroPlants growing system, to simulate the LEDs of the Astroculture™ Unit. Roscolux can be obtained at theater supply stores as it is used for colored light filters or call the Rosco Company at 914-937-1300.



To prepare a mylar light filter:

1.1 On a cutting surface (cardboard, etc.), tape down an 11 cm square of the red mylar. Center and tape a copy of the paper pattern (above) over the square.

1.2 Cut through the paper to make a 3 x 3 pattern of 1 cm square holes in the red mylar.

1.3 Cut 9 1.5 cm squares out of blue mylar.

1.4 Tape one blue square over each hole in the red mylar square.

1.5 Tape the completed filter over the top of one of your plant growth chamber sections.

Questions:

- Will any change in form or plant growth occur because of the light filters?

- How could you change the density of light even more?

2. Alter the temperature in the plant growing system. For example, what would closing the windows do? Would you predict a change in temperature or humidity due to restricted air flow? Will there be a change in the health of the plants or in the shedding of the pollen?

3. Can you alter the nutrients the plants receive? What changes would you expect to see?

PLANT PASSPORT

For the AstroPlants Stock

Species: *Brassica rapa*, Brassicaceae

Phenotype: Rbr, *dwf 1*; 14 days to flower, height 5-15 cm, life cycle 40 days, plant parts reduced in size in proportion to shortened height giving petite appearance when compared to basic Rbr.

Try your luck at "Brassica Bingo"

Nan Alexander, Readstown Elementary, Readstown, WI, turned the "Brassica Word Match" activity from the teacher resource manual, Exploring with Wisconsin Fast Plants*, into a bingo game for her 3rd graders. The word match game and a sample bingo card are shown.*

1. Make several copies of the Fast Plants words.
2. Make multiple copies of your blank plant bingo form.
3. Cut Fast Plants words apart and glue in spaces on card. See the sample card to the right. Remember a word can be in more than one column but not more than once in a column.
4. Make teacher recording card*.
5. Copy definitions, color code by column and cut apart.
6. Play game like bingo -- identify letter for column, read definition, players cover the word if they have it in the correct column, and caller covers it on the recording card.
7. Shouting "Brassica" signals a win. Winner must clear card.

* Cover all game parts with clear contact paper to prolong their use.

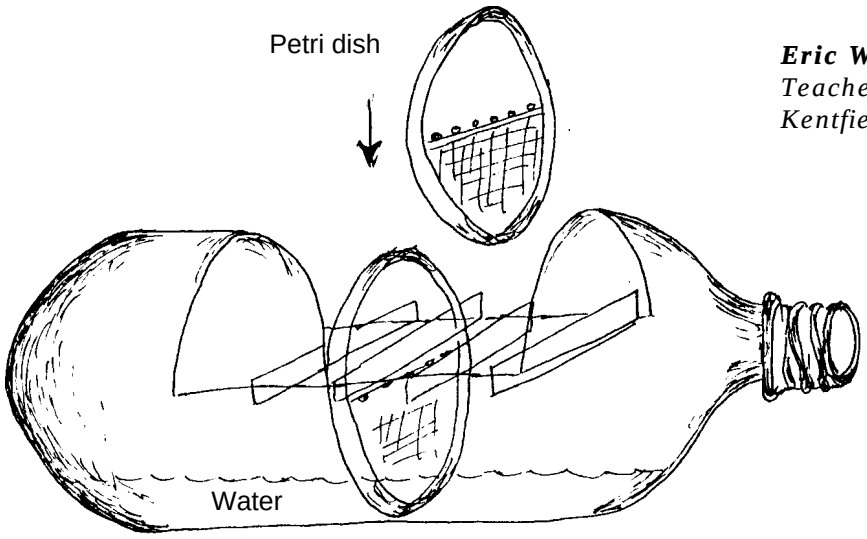
P	L	A	N	T
ovule	flower	root hairs	pedicel	seed
petal	anther	cotyledon	pollen	root
root hairs	stigma		stamen	ovary (carpel)
anther	pollen	ovule	Brassica	root
Brassica	ovule	pedicel	stigma	flower

Plant Terms and Definitions

ovary (carpel)	The bottom part of the pistil that holds the ovules.
cotyledon	The seed's food.
stigma	The top flat part of the pistil that the pollen sticks to when the flower has been pollinated.
pollen	The powder on the anther.
stamen	The part of the flower producing the pollen.
flower	The colorful part of the plant that attracts bees.
Brassica	Belongs to the crucifers - a family that includes mustards, radishes and cabbage.
sepal	The outer part of the flower bud that protects the flower before it opens.
pedicel	The stem of the flower.
seed	It has a baby plant inside that grows into a big plant.
thorax	The middle part of a bee's body.
pollination	The bee carries the pollen from one flower to another flower.
ovule	The part of the plant that holds the egg.
petal	The part of the flower that is usually colored.
root hairs	Part of the root that draws in water and minerals from the soil.
root	The part of the plant below ground that anchors and feeds the plant.
anther	The top part of the stamen that holds the pollen.

The Soda Bottle (Alias "Petri dish holder")

"Let me share with you an idea I had for using beverage bottles in one of the Fast Plant units. In the experiment involving seed germination in petri dishes, you suggest supporting the petri dish upright in the base of a bottle. Water in the base reaches the seeds through capillary action in filter paper. I found that if I placed a bottle on its side and cut a canopy out of the 'roof,' I could support a whole class set of petri dishes in one bottle. The waste from the canopy is cut into strips and used for dividers."



Eric Watterud
Teacher, Kent Middle School
Kentfield, CA

Upcoming Fast Plants Workshops

Phone 1-800-462-7417 for details/applications

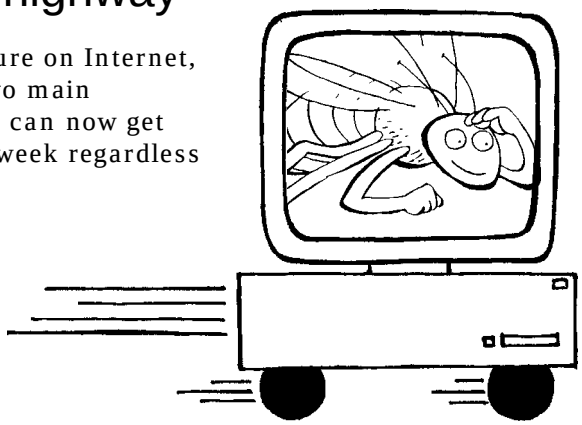
June 19-23, 1995
Univ. of Wisconsin-Madison. For grades 3-8 teachers. Fast Plants module is one of 50 within the Teacher Enhancement Program in Biology. Workshop will cover life cycles, pollination biology, inheritance, ecology, and the AstroPlants adventure.
Presenter: Paul Williams.

October 25-28, 1995
Fast Plants Program anticipates offering a workshop at the NABT convention in Phoenix, highlighting the AstroPlants Project and other ideas for advanced explorations.
Presenter: Paul Williams.

November 3-4, 1995
Two-day advanced Fast Plants workshop at UW-Madison. Secondary/college level. Focus is on population genetics (it's easy!), embryogenesis, the AstroPlants Project (gravitropisms and phototropism), nutrition, effective microscopy and film can Bottle Biology.
Presenter: Paul Williams.

Other workshop requests can sometimes be accommodated or referred to local master teachers.

Fast Plants Hit the Information Superhighway



As of last summer Wisconsin Fast Plants has become a fixture on Internet, also known as the Information Superhighway. There are two main features of Fast Plants on the Internet. The first is that you can now get information from Fast Plants 24 hours a day, seven days a week regardless of where you are in the world.

This is possible because Fast Plants has created a gopher server, which is updated constantly with information about Fast Plants, which is then accessible free of charge to anyone else on the Internet. If you are connected to the Internet, just point your gopher to **fastplants.cals.wisc.edu**.

The second feature is one which will allow us to travel the Internet in a graphic orientated fashion using the program Mosaic or Netscape (or any other World Wide Web browsers). The Fast Plants program has already created a home page and will be adding a lot of material over the next few months, including color slides and plant passports, so point your Mosaic/Netscape program at **http://fastplants.cals.wisc.edu** and check it out. All materials on Mosaic will also be available through Gopher, but either only as text or a downloadable picture.

The Superhighway can be hard to travel, so if you have questions feel free to send e-mail to our office at **fastplants@calshp.cals.wisc.edu.** Be sure and tell us what you like or dislike!

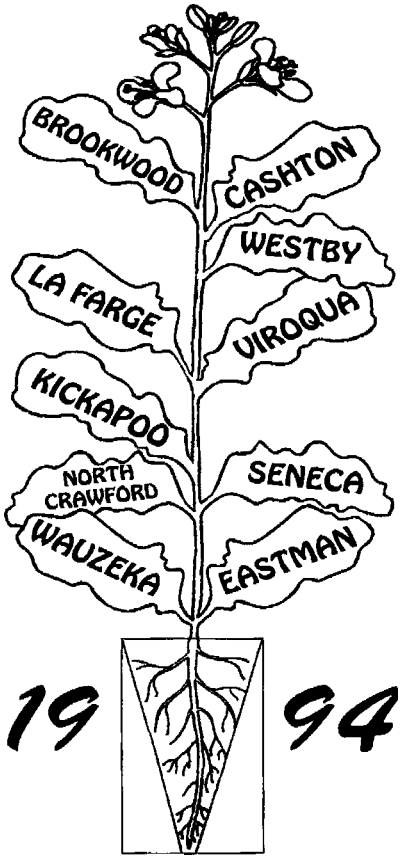
A Fast Plants Fair Kicks Off in the Kickapoo River Valley

The first Fast Plants Science Fair was held last spring in the Kickapoo Valley region of southwestern Wisconsin as a cooperative effort among 10 small school districts and the University of Wisconsin-Madison's College of Agricultural and Life Sciences. Seed money from the campus funded the Fast Plants training and equipping of 30 teachers and their classrooms, grades 3 through 12.

Anticipation of the event provided a strong learning impetus for the 30 classrooms, which coordinated the timing of their Fast Plants exploration to culminate in the gala conference and competition on May 11th. Classes prepared poster sessions, submitted questions for the quiz show, and strove to produce winning plants, such as the tallest plants and/or greatest plant density.

The atmosphere was electric with a giant, 10-foot Fast Plants sprouting at the entrance, all competitors sporting their Fast Plants/Kickapoo Valley Project designer T-shirts, and students queuing up to get Paul Williams' autograph on their life cycle posters. Some of the quiz questions would have stumped university students!

Look for an F_1 version of the Kickapoo event to take place in the Osborn School District in Phoenix, courtesy of a newly trained Fast Plants team.



Fast Plants flow through 10 school districts down the Kickapoo Valley

We are revising our mailing list!

The Fast Plants mailing list is out of date and the antiquated computer that used to crank out the labels is gone forever.

Anyone who predates April of 1994 on our mailing list will be dropped after this issue unless you complete the entire form included here and return it to us by June 1, 1995.

Thanks.

Please keep my name on the Wisconsin Fast Plants mailing list.

Name: _____
last *first*

School name: _____

School City: _____

School Phone: ( ) _____

E-mail: _____

COMPLETE preferred mailing address:

• is this your **home** or **work** address? *(circle one)*

Street: _____

City: _____ State: _____

Zip: _____ Phone: ( ) _____

Inquiries should be directed to:

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