



notes



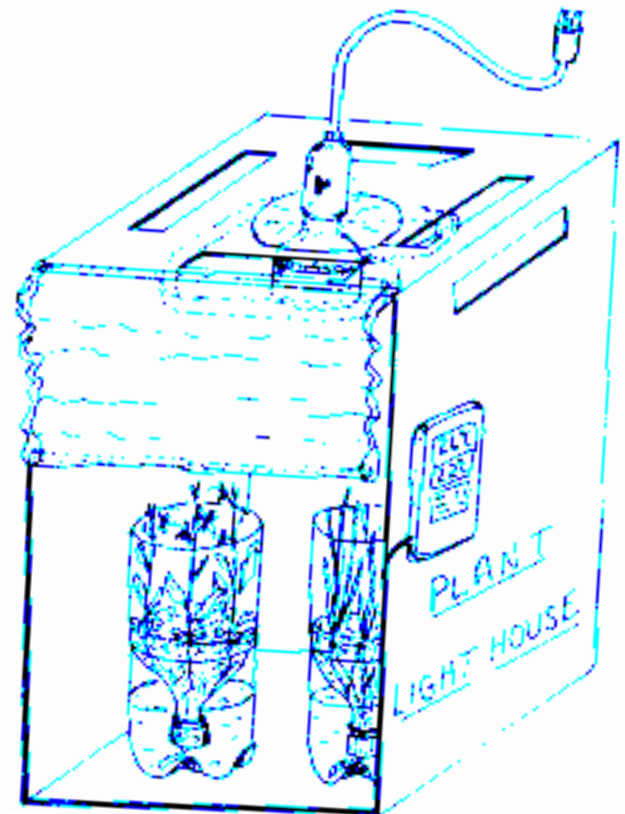
Farming in Space

Introduction

This activity originates from NASA's interest in long-term, manned flight and potential colonization of the moon and planets. Plants can be an important part of bioregenerative life support systems in which food is produced and human waste recycled. To this end NASA is supporting the development of experimental equipment designed to grow plants on the Space Shuttle and the International Space Station. At the same time that engineers are designing equipment for plant growth, plant scientists are evaluating various species for their potential and plant breeders are creating plant varieties that may be suitable in life support systems.

An example of one of these systems in which Fast Plants and dwarf wheat will be evaluated experimentally on the space shuttle in the coming years is the Biomass Production System, BPS, designed by Orbitec (Madison, WI). The BPS is a complex piece of equipment with the capability of growing plants in four small chambers in which temperature, light, plant nutrient delivery, CO² concentration and relative humidity can be monitored and controlled.

Scientists Gary Stutte, Dynamac, and Robert Morrow, Orbitec, lead a team of other scientists and engineers in an experiment in which the Super Dwarf wheat developed by researcher Bruce Bugbee of Utah State University will be grown and evaluated in the BPS together with dwarf Fast Plants, AstroPlants.



**The New Plant Light House from WFP
(See page 12 for details)**

The Educational Activity

The **Farming in Space** activity has been designed to coordinate with the flight experiment. It offers teachers and students a chance to examine a number of basic principles and concepts in plant biology and crop production through hands on experiments using a simulated Biomass Production System and the same seed stocks that the researchers will be using during the flight experiments. Questions that students can examine are similar to those of interest to the scientists and the materials used will reinforce students' understanding of proportionality and statistical summation. The basic experiment is suitable for upper elementary students and higher grades.

Crop Production

An important concept in crop production that is the focus of these activities is **biomass productivity**. Biomass is the amount of living material (mass) produced by a system of living organisms. Comparisons of the ability of wheat and brassica to use the energy of light in the conversion of carbon dioxide, water and mineral elements into *plant biomass* will be made. Plant biomass is normally measured as *total dry mass* (both roots and shoots) of the plant, or it can be a defined portion of the plants such as the dry mass weight of plant tops only.

A refinement in our understanding of plant biomass is the concept of **harvest index**, which is defined as the proportion or fraction of a specially used part of the plant, e.g., seed, fruit or vegetative part in relation to the total plant, including roots. Normally dry mass is used as the basis for estimating harvest index. A commonly used modification of harvest index is the fraction of usable part in proportion to the total dry mass of the harvested tops. For example, if a bean plant without roots weighed 100 grams when dry and provided 50 grams of dry beans, then the harvest index is: **HI = 50g ÷ 100g = 0.5**

Another important concept deals with the efficiency with which various species are able to utilize the energy of light for the conversion of CO², water and nutrient into biomass. In this experiment the **Energy Conversion Efficiency**, ECE, of two species will be compared — wheat a monocot, brassica a dicot. In the Plant Light House, for example (on page 12), total light energy in the system can be estimated by multiplying the wattage of the light bulb in the Light House by the total number of hours that the plants have been growing at the time of their harvest. In this way a conversion efficiency can be determined based on grams of plant biomass for each watt hour of energy. **ECE of plants = total dry mass of plants (roots and shoot) divided by the total watts over the growing period.**



Design of the Experiment

The **basic experiment** will be to grow the two varieties of Fast Plants and two varieties of dwarf wheat for three weeks to follow their development, and to compare their fresh and dry weights. The four hydroponic growing systems, hereafter referred to as the **Hydroponic Production Units** or **HPU's** will reside within the **Plant Light House** (the simulated Biomass Production System). One of the four seed stocks will be grown in each HPU. The planting design of the overall experiment allows many different kinds of comparisons to be made.

Elementary, middle and high school teachers should determine which of the suggested observations and measurements are desirable for their students to make, based on age, time constraints, etc. Although the protocol is written for both sets of plants to be harvested at 21 days, the length of the experiment may vary, depending on environmental conditions in the HPU and on what teachers or students choose to observe. The growing time may be extended for as long as desired, even up to when the dwarf wheats are mature, approximately 70-100 days. (note: the wheat will become too tall for the HPU if it is allowed to grow to maturity.)

Basic Farming in Space Experiment:

1. building a simple, low cost plant growth box, known as the **Plant Light House** (See page 12)
2. constructing 4 hydroponic nutrient plant systems, HPU's, from 2-liter soda bottles
3. planting four different seed stocks
 - dwarf wheat — high yielding, variety, Apogee
 - dwarf wheat — lower yielding, Super Dwarf
 - Fast Plants — variety, Basic *Brassica rapa*, Rbr
 - Fast Plants — dwarf variety, AstroPlants
4. recording environmental and growth events
5. comparing fresh and dry weights

The experiment is designed to be rich in observations about plant growth, in data taking, simple proportional analysis, and in statistical summation and comparisons between and among the four experimental systems. Growth can be observed and measured using parameters such as height, number of leaves and estimates of root growth. The HPU bottle system allows root growth to be observed easily. At harvest, fresh and dry mass of plant roots and shoots will be measured and may be analyzed to examine various concepts in crop production.

Getting Started

Construction of the **Plant Light House**, see Page 12

Materials for the HPU

- 4, 2-liter soda bottles
- unpolished cotton string or Watermat® for capillary wicks*
- vermiculite, medium grade horticultural
- planting medium, e.g., peatlite, Scotts Redi Earth
- pipette for watering
- Peters 20-20-20 Professional fertilizer
- 1-3 dried bees and toothpicks for making beesticks
- 1 pair of tweezers

Seed Stocks needed

- 20 AstroPlants seeds*
- 20 basic *Brassica rapa* seeds, Rbr*
- 10 dwarf wheat seeds, Apogee**
- 10 dwarf wheat seeds, Super Dwarf**

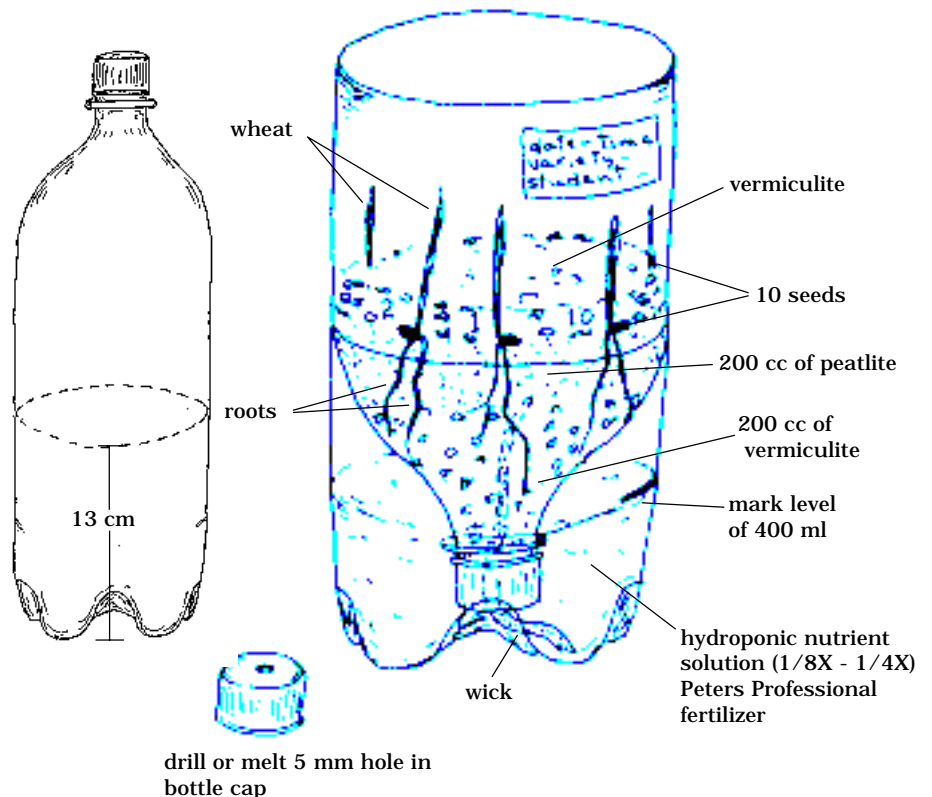
* available from Carolina Biological Company
1-800-334-5551

** available by contacting Steve Klassen at USU
Research Greenhouse, 1410 N, 800 E, Logan, UT
84341, email: stevek@cc.usu.edu

Construction of the HPU

1. Cut four 2-liter soda bottles so that the bottoms are 13 cm. tall. These will serve as the reservoirs for the hydroponic nutrient solution. The top half of the bottle will be inverted into the reservoir as the growing funnel and hold the vermiculite and planting medium.
2. Drill or melt a 0.5 mm hole in the bottle cap. Screw bottle cap onto bottle top.
3. Insert a string wick (or other capillary wicking), approx. 0.5 cm X 10 cm long, through the hole in the bottle cap. [Check the string you have purchased before planting up, to be sure that it wicks well.]
4. Invert the bottle top (growing funnel) and place in the reservoir (bottle bottom.) The wick should extend from the reservoir bottom into the inverted funnel produced by the bottle top.

Hydroponic Production Unit, HPU

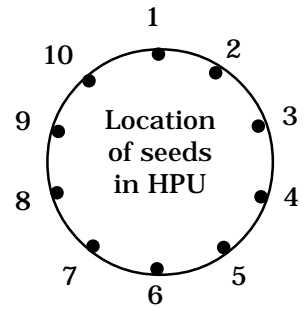


Pre-Planting

(Note: For uniform germination of Super Dwarf wheat Dr. Bruce Bugbee recommends pretreating the seeds by placing them in a wet paper towel in a plastic bag for 48 hours in the refrigerator prior to sowing in the HPU.)

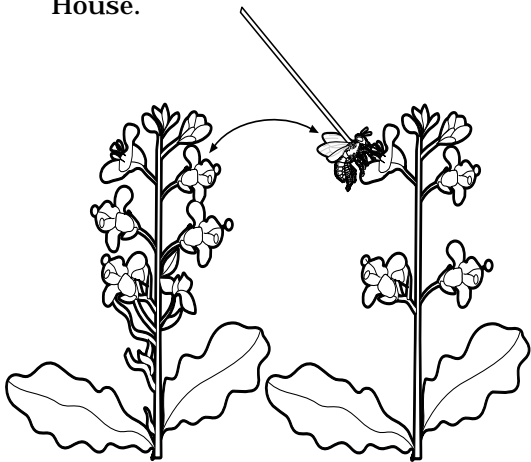
Planting

1. Layer 200 cc. of vermiculite into the funnel and then layer 200 cc. of peatlite on top of the vermiculite. (Or use whatever "soil" you normally use for Fast Plants.)
2. Gently soak the soil and vermiculite with water until it drips from wick at the bottom of the growing funnel. This is called the *runoff*.
3. Uniformly distribute 10 Apogee wheat seeds in one funnel at the outer edge of the soil up against the clear wall and distribute 10 Super Dwarf seeds similarly into another funnel. Space seeds evenly around the edge approximately 3 cm apart.
4. Gently press the seeds into the soil, but do not bury them. Seeds should now be visible around the perimeter of the bottle through the clear wall of the bottle.
5. Repeat the procedure for both varieties of brassica seeds, except that two seeds should be dropped at each of the 10 evenly distributed locations around the perimeter. (They will later be thinned to one at each position.) Also, the brassica seeds should be pushed to the wall of the bottle with a forceps or toothpick before pressing them gently into the soil. They should be visible through the wall of the bottle.
6. Each of the four HPUs should now contain a separate variety of plants.
7. Cover wheat and brassica seeds with a 1 cm layer of vermiculite.
8. Gently moisten from above until water again drips from the the wick at the base of the funnel. Pour off any excess water remaining in the reservoir and replace it with 400 ml of 1/8 strength Peter's Professional fertilizer (hydroponic nutrient solution). [To make full strength or 1X Peters, dissolve one soda bottle cap full of Peters crystals into one liter of water. Dilute to 1/8X for hydroponic solution.]
9. Mark the level of the hydroponic nutrient solution on the outside of the reservoir with a marking pen.
10. Place a label on the completed HPU indicating the date and hour of planting, the variety of seed/plant in the particular HPU, and identify the student/group.
11. Put the HPU's in the Plant Light House. (Keep light on 24 hours a day.)



Observing, Measuring and Monitoring

1. Be prepared to observe your germinating seeds each day, and make appropriate records in your log. Many interesting comparisons can be made between wheat and brassica as well as between the two wheat and two brassica varieties. For example, note the time and way seeds germinate, the root and shoot growth patterns.
2. Monitor and record the temp inside the HPU's each day as well as the ambient or room temp. (We use an indoor/outdoor digital thermometer from Radio Shack.) If average temperatures within the HPU's reach 30°C/ 85°F, additional ventilation slots can be cut in the top and upper portions of the Light House.
3. Observe the level of the nutrient solution. The amount used by the plants and lost to evaporation can be measured and graphed. Replace used solution as needed. Algal growth in the nutrient solution can be inhibited by wrapping the reservoir in aluminum foil or dark paper to exclude light.
4. Brassicas will begin to flower about 14 days after seeding. When flowers on more than two Fast Plants are open, pollination should begin and should continue every two or three days among all open flowers for at least a week. Pollinate with a beestick made by gluing a dried bee to the end of a toothpick. Collect pollen from the flowers of one brassica plant and move it others. Alternatively, pipe cleaners, Q-tips, or very small pieces of cloth (velveteen) could be used for pollinating.



5. Note: Heads of wheat normally begin to emerge after 23 days. (Wheat is self-pollinated and does not require any pollination activity.) For the basic biomass experiment, we recommend terminating the experiment about 3 weeks after sowing, before the wheat begins to head as flower heads. (Apogee elongates to about 18 inches. Super Dwarf heads at about 12 inches above the soil level.)

Harvesting

- Twenty-one days after planting, harvest plants from each HPU by cutting them off at soil level. Keep each group of plants separate and label them carefully. Be sure all dry and dead leaves are collected separately from each HPU throughout the growth period and saved for weighing.
- Weigh the plants from each HPU separately.
 - Fresh weights — At harvesting, quickly place the plants in a preweighed plastic bag. (Zip locks work well.) Weigh the total fresh mass of the plants, then subtract the weight of the bag.
 - Dry weight — Plants should be loosely placed in a preweighed brown paper bag and put in a low temperature (200°F) oven for two days or until they reach constant weight (no more weight loss occurring.) For dry weight measurements, a balance capable of measuring milligram or centigram quantities is desirable. (Chemistry classes have such balances.)
- Compare the relative weights of each group of plants. Draw your conclusions.

Suggested Observations, Measures, Analyses and Comparisons

The following are aspects of the environment and items in growth and development that could be observed, measured, recorded, analyzed and displayed as a function of time (days after sowing) and then compared.

1. Environmental monitoring

- light = daily energy input, watts/24 hr
cumulative energy input (total watts)
- temperature, daily
- nutrient solution - usage (ml/day)
- appearance of algae, pests, etc.

2. Developmental events

- germination
 - first emergence of root and shoot
- first leaf, second leaf, etc.
- flower buds (brassica) or head (wheat)
- flowers open
- pod elongation
- appearance of branches on stem (brassica),
tillers (wheat)
- yellowing of older leaves

3. Measures of growth

(averages for 10 plants)

- plant height
- leaf number
- root length, root number
- number of flowers open
- number of seed pods enlarging
- number of seeds

4. Measures of biomass

(average of 10 plants at harvest)

- fresh weight of tops
- dry weight of tops
- fresh weight of roots
- dry weight of roots
- dry weight of seed (brassica)

5. Analyses of biomass (within a variety)

- dry weight/fresh weight ratios, tops, roots
- roots/tops ratios
- harvest index of tops, dry
- harvest index of seed (seed weight/total
plant dry weight)
- calculate energy efficiency conversion
(grams dry weight/watts)

6. Comparisons (between varieties and species)

- dry weight/fresh weight
- root/top ratios
- total biomass
- harvest indices
- energy efficiencies

(continued on page 16)

THE CUE REVIEW:

Collaborative Ukrainian Experiment --
Teachers and Students Investigating Plants in Space



Students from around the United States and throughout Ukraine were ground-based participants in the CUE-TSIPS plant science experiment during the Nov. 19-Dec. 5 mission of Space Shuttle STS-87. The students ran simulations of the B-STIC experiment and faithfully recorded data on plant height, day on which the plants first flowered, the number of seed pods and seeds produced by their AstroPlants. Many of the students have entered their data on the Fast Plants Program program server at: <http://fastplants.cals.wisc.edu>.

The classroom data are mainly from middle and high school classrooms, but some elementary student data are also represented. Teacher communications with the Fast Plants office indicate that the students took their task seriously and were very keen on doing something with NASA. Teachers themselves often used the CUE-TSIPS investigation to coincide with their units on the principles and behavior of plants. There was great interest in the Ukrainian astronaut, Leonid Kadenyuk, and the NASA downlinks of him pollinating and measuring the plants.

Thirty students in the U.S. and thirty-two in Ukraine participated in a live downlink Q & A session with astronaut Kadenyuk on December 1, trying to ascertain similarities and differences in the way the plants grew in orbit and on the ground. American students attending the launch at Cape Kennedy on November 19th met the group of nine Ukrainian students who had come for the event. On the afternoon that the shuttle landed Principal Investigator, Mary Musgrave, sent the information that the Shuttle plants looked normal and that seed pods were forming on the plants that had been pollinated in space.

In Ukraine

Hosted by CUE lead scientist for education, Dr. Volodimir Nazarenko, at the Ukrainian State Ecological and Nature Center in Kiev in November 1996, Paul Williams (WFP), Tom Dreschel and Peter Chetirkin (Kennedy Space Center) trained nineteen teachers and scientists from various cities in the Ukraine. Following the visit, 500 more teachers representing 24 regions of Ukraine were introduced to CUE-TSIPS via 57 more workshops. A Ukrainian translation of the CUE-TSIPS

manual together with a student workbook was distributed. From the 20,000 participating Ukrainian students, 5,000 tabulated data sets have been generated and are currently being analyzed in preparation for a national symposium to be held in May of 1998 in Kiev. The CUE program was widely disseminated throughout Ukraine, in 47 broadcasts on national and local TV, 62 radio reports, and more than 100 newspaper and journal articles.

Table 1 **Data from the Space Shuttle Columbia**

(Data submitted by Dr. Mary Musgrave,
Louisiana State University)



Plant Height at Day 14

n	r	x	s
18	29.7	42.2	8.5

n = total number of plants
r = range of height
x = average height of plants
s = standard deviation

Number of Seeds per Pod

n	r	x	s
13	7	4.1	2

n = total number of pods
r = range of number of seeds/pod
x = average number of seeds/ pod
s = standard deviation

In the United States

In the United States, 20 lead teachers were trained in March of 1997. These teachers trained an additional 1,073 teachers in 58 outreach workshops. Shorter CUE-TSIPS workshops reached 2,798 more teachers. Another form of outreach in the U.S. was through CUE-TSIPS booths at two national NSTA conventions (1997 & 1998), at the 1997 NABT convention, and at the 1997 Texas State Fair. Of the 60,000 CUE-TSIPS manuals printed by NASA, 2,000 remained to be distributed at the NSTA convention in April of 1998. CUE-TSIPS participating students of the lead teachers numbered 1,274. We conservatively estimate that more than 50,000 students participated. The lead teachers (and others) generated their own publicity about CUE-TSIPS. In addition, NASA's publicity efforts resulted in an article in the Washington Weekly publication and acknowledgements from one U.S. Senator and several State Representatives. NASA Director, Dan Goldin visited CUE-TSIPS classrooms in Maryland and Illinois.

Table 3 Number of Days to First Flower

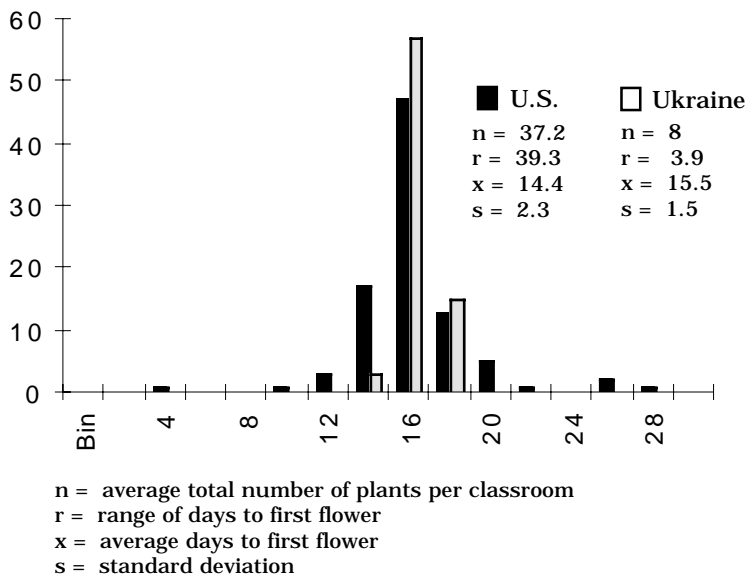
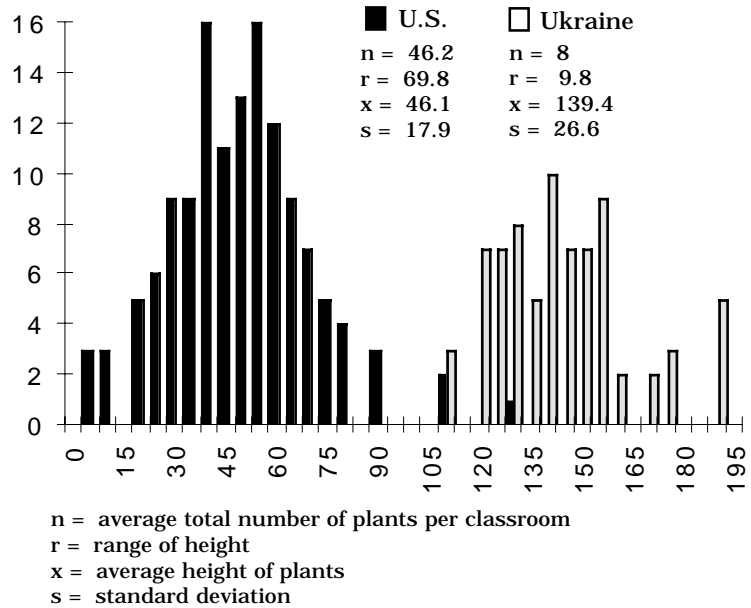


Table 2 Plant Height of Plant at Day 14



Looking at the Data

Tables 2 and 3 represent a small sample of the CUE-TSIPS data, that which has been received up to March 31, 1998 from classes around the United States and in Ukraine. The majority of the U.S. data has come electronically over the Internet and represents 140 classrooms from many states. Ukrainian data thus far received is from one city and represents 75 entries. The summary data are presented as frequency histograms of averages for each classroom. Some classrooms had several experimental groups each with eight plants, others had a single group. A review of the CUE-TSIPS data from the United States and Ukrainian classes will provide your students with interesting information for discussion, speculation, and questions for further possible experimentation.

It is interesting to reflect on the notable differences in average plant height at 14 *das* (days after sowing) between AstroPlants grown in the United States and those in Ukraine. What are some of the possible reasons for the distinct bimodality (see CUE-TSIPS manual, p. 27) in the international data? What hypotheses do your students have for the observed differences? What experiment could be conducted to address their questions? This is what science is all about!

At the same time, note how similar the performance of the AstroPlants was with respect to days to first flower when compared between the U.S. and Ukraine. What are these data telling us about the growth and development of the plants in relation to reproduction?

It is very interesting to compare the student data taken under earth gravity with the data reported by Dr. Mary Musgrave from the plants grown in microgravity in STS-87. (Table 1) Although relatively few plants (n=18) on STS-87 were measured, the plant heights and seed number per pod are comparable with those reported from the classroom experiments.

For your further comparison, we have included frequency histograms of the AstroPlants stock, phenotypic data for the total height at 14 das and number of days to first flower (See Table 5). These data are from the **Seed Stock Document** for AstroPlants (see page 11 of this newsletter) and represent the variation in these quantitative phenotypes of plants grown under "standardized," defined conditions.

Table 4 Number of Seeds per Pod
(Ukrainian data not available)

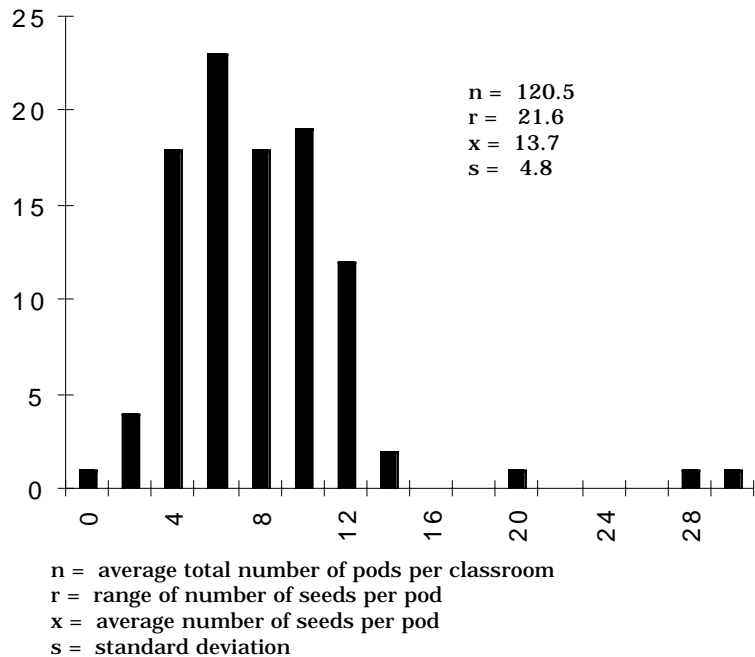
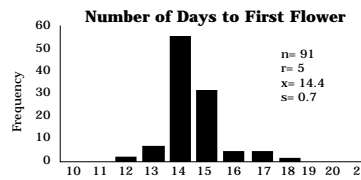
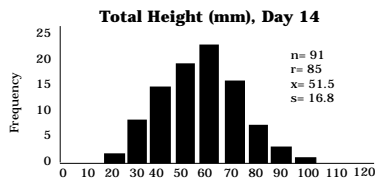


Table 5 Characterization of AstroPlants



Upcoming Workshops

Using Fast Plants for Teaching Genetics

Teacher workshop at UW - Madison
July 20 - 24, 1998

For experienced Fast Plants teachers.

Join the Fast Plants Program:

- Investigate phenotypic variation, quantitative selection, Mendelian and molecular genetics with Fast Plants;
- Work with lots of plant material

\$125 / participant No credit offered
Contact WFP at 800-462-7417 or
email: wfp@fastplants.cals.wisc.edu

Can Plants Grow and Survive in Space?

NASA Teacher Workshops in Gravitational Biology at NC State University, **July 6 - 10, 1998**

This workshop will provide:

- Introduction to space biology research and techniques
- Teacher stipends, classroom supplies, and University credit

Contact Dr. Joan Huber at 919-515-3906 or by email:
jlhuber@unity.ncsu.edu

General Fast Plants Workshop

Teacher workshop at UW - Madison, **November 6-7, 1998**

Join the Fast Plants Program:

- Investigate all crucial aspects of Fast Plants
- Enjoy discovering Bottle Biology

Contact WFP at 800-462 7417 or
email: wfp@fastplants.cals.wisc.edu

Variation and Fast Plants

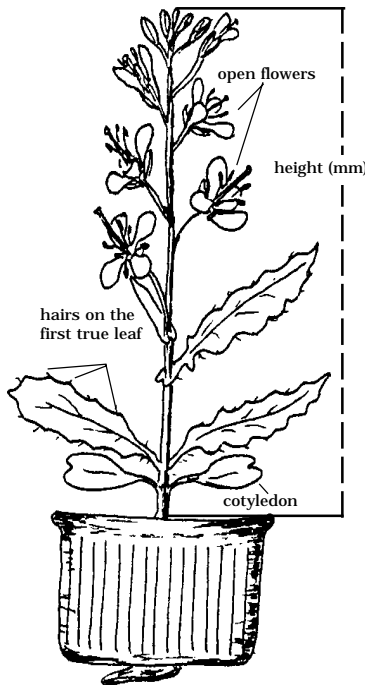
Introductory Note:

Over the next two years, the Wisconsin Fast Plants Program will be developing instructional materials to help teachers look at genetics from several perspectives, e.g., Mendelian, populations, quantitative, and molecular. This article is intended only as an introduction to that effort and addresses some of the underlying ideas behind the concept of biological variation. The developing body of instructional materials will be posted on the Fast Plants Website. This summer, teachers at a genetics workshop in Madison (see page 16) will work through some of the ideas and offer feedback and suggestions to the WFP Program. We also welcome feedback from any readers at any time.

If you have grown Fast Plants you will have noticed variation among the individual plants within the group. Variation can range from a little to a lot. This article is designed to help teachers and students understand the basis of the variation they observe in their plantings.

Variation is one of the fundamental characteristics of life. All organisms exhibit some variation among individuals. Understanding the ways that variation is manifested in organisms, how it comes to be expressed through the development of the individual, and how it is transmitted from one individual to the next generation of individuals are central themes in biology.

Working with Fast Plants will enrich a student's understanding of variation. By observing the growth and development of a Fast Plant through the various stages in the life cycle, students will become aware of many visible features, or **phenotypes**, that make up the organism.



Only, however, upon close observation of a **population of plants**, will they become aware that the characteristics observed on one plant vary more or less on other plants. Such is the nature of variation.

Phenotypic Variation

Phenotypic variation, e.g. plant height at a particular stage of development, is considered to be the expression of the genetic makeup (**genotype**) of the individual as it interacts with the environment. Variation in plant height among individuals in a population is therefore due to variation in the interaction between the genotype and the environment, as expressed through the development of each individual plant. (See Figure 1.)

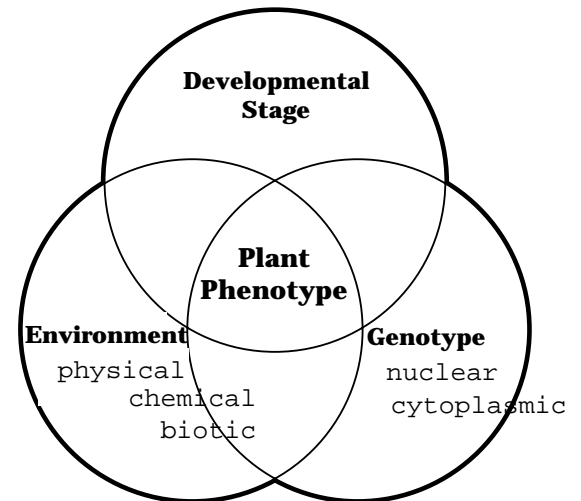


Figure 1: Diagram depicting the interrelationships of genotype, environment, and the development on the plant phenotype.

The interrelationships suggested in Figure 1 should provide students with numerous ideas for experimentation to probe the basis for the variation observed among their individual Fast Plants.

Describing and Observing Phenotypic Variation

In order to be useful in an experiment the phenotype must be described using terms that are widely understood and easily communicated. For these reasons scientists have agreed upon various standards or **descriptors** to describe characteristics in the natural world. Descriptors take many forms (Table 1). The choice of how to describe what you observe is important, because it will determine the kinds of descriptors used and establish the basis for recording, analyzing and communicating results

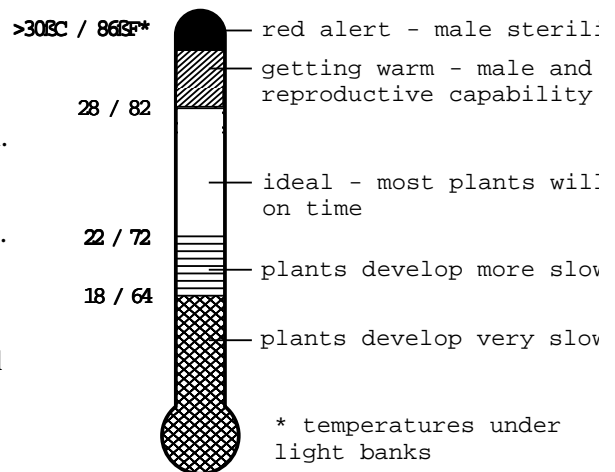
Table 1: Examples of descriptors.

Descriptors	Method of description	Examples
number	<ol style="list-style-type: none"> 1. direct count 2. statistical summary of counts 3. comparator chart with numerical scale 	<ol style="list-style-type: none"> 1. hair on margin of first leaf 2. n = number counted r = range, x = average s = standard deviation 3. moderately intense purple = 6 on a scale of 0 = no purple to 9 = very intense purple
size	<ol style="list-style-type: none"> 1. use of a tool to measure (estimate) dimension, e.g. ruler, calipers 2. comparator scale 	<ol style="list-style-type: none"> 1. height of a plant in mm 2. short, medium, tall compared to a range of measure
color	<ol style="list-style-type: none"> 1. visual comparison using standard color chart or scales 2. describe with words using hue, lightness and saturation 	<ol style="list-style-type: none"> 1. no purple (anthocyanin) color in plant 2. very light, yellow-green leaves
shape	<ol style="list-style-type: none"> 1. descriptive language (often Latin) 2. comparator charts 	<ol style="list-style-type: none"> 1. leaf margin, lobed edge 2. leaf spoon-shaped

Environmental Variation

Much can be learned about the role of light, temperature, and nutrients on plant development from experiments in which one or more environmental parameters are changed. Because Fast Plants are highly responsive to changes in the environment, they are ideal for examining the role of the environment on the expression of phenotypic variation.

Although Fast Plants are able to grow within a wide range of environmental conditions, for most investigations it is recommended that they be grown under uniform and ideal conditions. In this way variation arising from sub-optimal conditions of environment will be minimized. The Wisconsin Fast Plants Information Document (WFPID) *Understanding the Environment* describes how to provide and maintain the various physical, chemical and biotic components of the environment that are most suitable for Fast Plants. The WFPID can be found, along with many other WFPID's on our Web site.



Genotypic Variation

How can students use Fast Plants to investigate the contribution of the genotype to the phenotype? Fast Plants, rapid cycling *Brassica rapa*, are genotypically variable in that they have a genetically controlled mating system that prevents self-fertilization and favors out-crossing among individuals. As a consequence, even seed stocks selected for uniformity of specific phenotypes and genotypes exhibit considerable variation for other traits.

The Wisconsin Fast Plants Program has developed a number of genetic stocks of rapid cycling *Brassica rapa* for genetic investigations on the nature and inheritance of variation. Some WFP stocks contain distinctive mutant phenotypes, e.g., anthocyaninless plant, *anl*, yellow green plant, *ygr1*, rosette, *ros*, and male sterile, *mst2*, that are suitable for Mendelian genetics.

Other stocks exhibit phenotypes whose expression may vary continually and which may be quantified as discrete or countable units, e.g., number of hairs, or as estimates of size, e.g. petite dwarf, *dwf1*, or of intensity of color saturation, e.g., purple anthocyanin. These **quantitative phenotypes** may be conditioned by a few or many genes and normally require numerical descriptions in which the statistical notations of population size, (n), range (r), arithmetic mean (\bar{x}), and standard deviation (s) are applied.

Yet other stocks have been developed to combine both simply inherited mutant genotypes and quantitatively expressed phenotypes. An important part of WFP is the continuing development and improvement of seed stocks for uses in genetics.

An interesting aspect of Fast Plants is that almost any phenotype that piques a student's curiosity is amenable to genetic analysis. How to investigate these traits of interest will be the subject of future WFPID's. (Available on our Website and from the WFP office.)



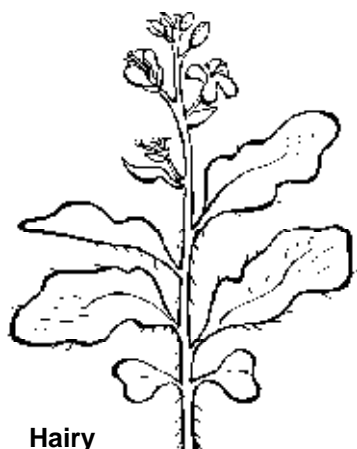
basic and rosette

Investigating Variation with Fast Plants

As your students begin to explore genetic variation using the specialized Fast Plant stocks they should be aware of two types of WFP information documents, the **Passports** and the **Seed Stock Documents (SSD)**. The first Passports will be available early in summer, 1998, on the WFP Website and from the WFP office.

Passports contain descriptive information on the phenotype, genotype, and genetic background of the seed stock. Included also is information on potential educational and research uses and some technical information.

The Seed Stock Documents contain more complete phenotypic and genotypic information on each WFP stock, including pedigrees, population profiles on particular growth and quantitative characteristics such as cotyledon size, plant height, number of days to flower, hairs on first true leaf margin, and the number of leaves. They also include additional suggestions for educational and research uses including more technical information and references. Information supporting the effective use of Passports and SSD's can be found in the WFPID *Rapid Cycling Brassicas: Phenotypes and Genotypes*. This information document contains detailed descriptions of all available phenotypes and genotypes together with the genetic terminology used with rapid cycling brassicas.



Hairy

Plant Light House

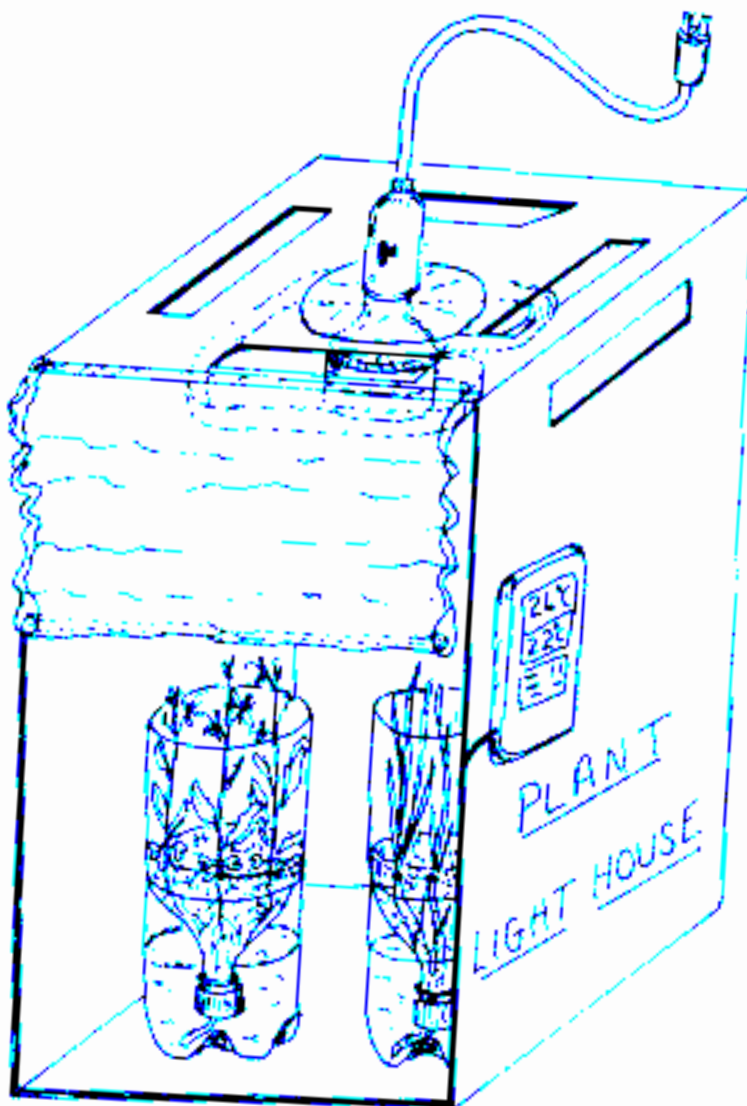
A Low Cost Light Chamber for Fast Plants and Other Botanical Delights

Materials

- one empty "copy paper" box, e.g., Xerox
- aluminum foil
- electrical cord with socket
- plastic plate or lid
- glue stick
- clear tape (3/4")
- scissors
- 30 watt fluorescent circle light (Lights of America) or a 39 watt GE circle light

Construction

1. Cut a 1 inch hole in the center of a plastic plate or lid and trim off edges to make approximately a 4-5 inch disk with a center hole.
2. Cut several 4 X 14 cm ventilation slots in top, upper sides and back of box as shown.
3. Cut a 1 inch diameter hole in the center of box.
4. Apply glue stick to the each inner surface and paste in aluminium foil to cover entire surface. Use clear tape to reinforce corners and edges.
6. Insert light fixture base through hole in top and through plastic plate. Secure fixture by attaching socket.
7. Tape an aluminum foil or reflective full length mylar curtain over front from the top front edge of box.
8. Strengthen curtain edges with tape. Tape or clip weights (e.g., large nails) on bottom of curtain.
Your Light House is ready!



Plant Light House

Light Output

Irradiance as Photosynthetic Photon Flux, PPF, in the Plant Light House falls within the **ideal to adequate** range ($100-200 \mu\text{Mol m}^2 \text{s}^{-1}$) using either a 30 or a 39 watt circle light. (See WFPID *Seeing the Light*)

Distance from light	Light Fixture	
	30 watts, Light of America	39 watts, GE
10 cm	$170 \mu\text{Mol m}^2 \text{s}^{-1}$	$200 \mu\text{Mol m}^2 \text{s}^{-1}$
20 cm	$150 \mu\text{Mol m}^2 \text{s}^{-1}$	$170 \mu\text{Mol m}^2 \text{s}^{-1}$

Introducing Abstracts of Student Research Projects with Fast Plants

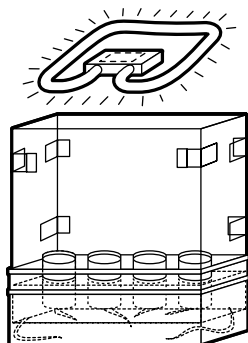
The Fast Plants Program has long wanted to feature some students' research ideas in the newsletter. When the CUE-TSIPS project resulted in a number of reports being sent to us, it provided the impetus for us to include some of these as well as two others. We hope that the student research projects found here will serve as a source of ideas and inspiration to other students and their teachers. It has not been our intention to edit the student work, but where clarification was deemed necessary, editing has been indicated with brackets [].



Effects of Surrounding AstroPlants (*Brassica rapa*) with Plexiglass

Alice Engel, the Lawrenceville School, Lawrenceville, NJ [Teacher, Ken Mills]

The students of Research Science III ran pilot tests prior to the shuttle launch [of STS-87, Nov. 19, 1997] in order to determine different variables



which could affect the plants. These pilot tests also served as practice for the final experiment, since we will measure the same parameters in the final experiment. Conclusions drawn from the pilot tests determined how we could best minimize variation in the final experiment. In our own individual experiment,

we observed AstroPlants within the plant growth chambers (PGC's) and compared them to AstroPlants growing under the same conditions without the plexi-glass. This variable is important because any difference in temperature, which the plexi-glass might cause, could significantly affect the growth and reproduction of the plants. The plexi-glass design is meant to simulate the conditions under which the plants will be grown on the shuttle. We recorded the temperatures of each PGC set-up with and without plexi-glass every day using Maximum/Minimum thermometers. We measured the height and the pistil length of the plants on specific days determined by NASA. We also recorded the first day to flower and the number of seeds produced. Our data showed significant results. For example, the plants grown with the plexi-glass produced only fifteen seeds total, whereas those without the plexi-glass produced 223 seeds. We concluded that the plants grown

without the plexi-glass were healthier in terms of growth and reproduction; we attributed the differences in data to the plexi-glass, which inhibited the air-flow around the plant and thus their overall health.



Platte River Quality - Does It Matter?

Cortney Riblett, Central City High School, Central City, NE [Teacher, Judy Williams]

The Platte River is one of the most important rivers in Nebraska's history. Today, we use the river for farming and recreation. The purpose of my research was to determine if the water quality from different sites of the Platte River would affect the growth of the Wisconsin Fast Plant. My collection sites included one-half mile upstream from the Central City Water Disposal Plant pipe outlet on the Platte, the pipe location itself, and one-half mile downstream from the pipe outlet. After collecting the water, all testing for quality of the water was done. Using the knowledge gained from the testing of the water quality, I hypothesized that water quality of three sites from the Platte River would negatively affect growth of Wisconsin Fast Plants due to quality of collected water. Distilled water was used in the control set-up, and the three experimental set-ups were watered with the water collected from the three Platte River sites. I observed the plants for 35 days, and observed the immediate effect on germination; short term effects on plant height, general appearance of the plants; long term effects on the final heights, and lengths of the seed pods. The results were the control has the highest quality of growth, experimental One of the upstream site had the second highest quality of growth, and experimental Two and Three were approximately equal in quality of growth. I concluded that the Platte River water had an overall negative affect on the growth of the Wisconsin Fast Plant.



Effect of the Intensity of Red Light on Height and First Day of Flowering of *Brassica rapa*

Catherine McManus, the Lawrenceville School, Lawrenceville, NJ [Teacher, Ken Mills]

My experiment this term is focused on the effect of the intensity of red light on the height and first day of flowering of the species *Brassica rapa*. This project is an extension of my previous studies concerning the effects of red, blue, green and yellow light on the height of *Brassica rapa*. My decision to narrow my scope from four colors to simply red was based upon research that suggests that red light induces early flowering, encourages longer hypocotyls, and reduces leaf area. I decided to measure height in addition to first day of flowering to see whether there is a correlation between reduced leaf area and reduced height.

To address my question of light intensities, I designed an experiment with four groups of plants, two groups to be grown under two different intensities of red light, and two groups to be grown under regular light conditions (30 watt circular lamps). My experiment was conducted on a total of sixty-four plants, or four groups of sixteen. To manipulate the intensity of red light that the two experimental groups received, I covered two of the growing units with translucent red cellophane, one group had one layer of cellophane and the other group had two. The cellophane acts as a filter so that only red light reaches what is covered by the cellophane. I used two sheets of cellophane operating on the theory that more filters would keep out more light. To ensure that my variable was the color of the cellophane and not its physical presence, I developed a control group for each of the red groups, using one and two sheets of clear cellophane, respectively for the two control groups.

My hypothesis is that the plants under only red light will produce flowers earlier than the control groups, but that the height of the red groups will be stunted. I do not think that there is a significant difference to be found between the heights of the first days of flowering of the two experimental groups. However, I do believe that there is a threshold of red light intensity which, once passed, has negative effects on the plants. Future studies may be conducted to find the threshold of red light at which plants are most comfortable, and that threshold wherein red light becomes detrimental to plants' health.



The Effect of Serial Dilutions of Gibberellic Acid on the Growth of Rosette *Brassica rapa*

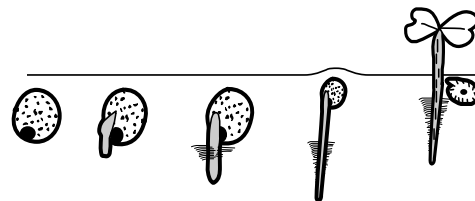
Pooja M. Jain, York Community High School, Elmhurst, IL [Teacher, Kathy VanHoeck]

Gibberellins are growth regulating hormones that stimulate growth in the leaves and stem through cell division. The rosette *Brassica rapa* (*ros*) is a dwarf plant with low levels of gibberellins. We hypothesized that added gibberellins would cause rosette plants to grow taller, and high concentrations would be better. We compared the height of *ros* treated with serial dilutions of gibberellic acid (GA) to *ros* treated with water only, and to wild type *Brassica rapa*. The lower dilutions of GA had a significant effect on the growth of *ros*. The plants treated with higher concentrations of GA had stunted growth. In conclusion, 0.01% dilution of GA causes maximum growth of *ros*, while higher concentrations were harmful.

**Fueled
by a million
man-made
wings of fire--
the rocket tore a tunnel
through the sky--
and everybody cheered.**



**Fueled
....[from within]...
the seedling
urged its way
through the thicknesses of black--
and as it pierced
the heavy ceiling of the soil--
and launched itself
up into outer space--
no one even clapped.**



edited from a poem by Marcie Hans



Determination of Microgravity Effects on Pollen Collection

Michael Garber, Dept. of Horticulture
Louisiana State University, Baton Rouge, LA
[Advisor, Mary E. Musgrave]

Introductory Note: A group of Louisiana State University undergraduates recently pollinated *Brassica rapa* in microgravity on the KC-135 aircraft. Four different methods of quantifying pollen transfer were used: number of pollen grains collected by a beestick; number of pollen grains transferred to a stigma; number of pollen grains transferred per unit of surface area; and number of successful ovules developing following pollination. In no case was there a statistically significant difference between microgravity and 1-g. (Dr. Mary Musgrave, LSU)

Successful pollination of *Brassica rapa* under space flight conditions must first be achieved in order to study seed development. The study of the plant's entire life cycle under microgravity is the



goal of a joint U.W.-Russian experiment flying on the Russian space station Mir this year [1997]. Because successful pollination of *Brassica* in microgravity has not yet been determined, proposed methods must be tested beforehand. The number of pollen

grains transferred from anthers to bee sticks during pollination was quantified and compared to ground control tests. Pollen was collected with bee sticks from 19-day old plants with open flowers in either 0-g (on the KC-135) or 1-g environments. Pollen collected in this manner was quantified by using a hemacytometer to count grains released from the bee sticks by a detergent solution. Total numbers of pollen grains per bee stick were compared statistically using t-tests. In microgravity, bee sticks collected an average of 27,600 grains/flower. Results concluded that no significant difference occurred in microgravity compared to control.



Wisconsin Fast Plants invites students to submit abstracts of their research to us for consideration for inclusion in future newsletters. Also, the abstracts will be shared with teachers at Fast Plants workshops and with other students who seek examples of ideas for research or who wish to compare their approach and protocol.



Response of Brassica Species to Infection with a Geminivirus

Andrew M. Howard, Lake Brantley High School,
Altamonte Springs, FL [Teacher, Dr. Susan Behel;
Consulting Scientist, Dr. James O. Strandberg]

Trials of all the *Brassica* species including *B. rapa*, *B. napus*, *B. juncea*, *B. oleracea*, *B. carinata*, and *B. nigra*, as well as *R. sativus* were planted. These plants were germinated from seed in a petri dish on moist filter paper until they were of a length which could be transferred to pots containing growth media (in the ratio of two sand to one Metromix). These plants were grown until they reached a size in which they could be safely mechanically inoculated with the virus.

To mechanically inoculate the plants, inoculum was prepared by grinding the tissue with phosphate buffer of pH 7.5 until completely crushed. The mixture was filtered through cheesecloth into a beaker contained in an ice bath to prevent the virus from denaturation. The plants were inoculated by dipping a Q-tip or a piece of cheese cloth into the inoculum and gently rubbing it over the leaves. 400 grit carborundum was applied to the leaves before rubbing to cause injury and allow virions to enter cells. The leaves were then rinsed with distilled water to try to remove inhibitors that might be present in plant sap.

The plants were also inoculated using whitefly. The *Brassic*as were surrounded by infected plants that housed whitefly. After five days, the [*Brassic*as were separated from the other plants.]

The plants were grown in a greenhouse for about three weeks and frequently examined for symptoms. Plants which showed mottling, severe leaf deformity and leaf speckling were judged to have the virus.

After inoculation with the cabbage leaf curl virus, the plant *B. napus* was determined to be the most susceptible to infection. I also searched under a microscope for the presence of inclusion bodies characteristic of the virus within the plant nucleus. With further study it may be possible to determine which genome of the *Brassica* has the most resistance to the virus.

Farming in Space *(continued)*

Questions

- What are some of the factors that must be taken into consideration when making a decision as to which crop variety or species to choose to accompany humans on a long space flight mission? Support your statements with evidence gained from this experiment or describe an experiment that would provide you with evidence to support your decision.
- What other experiment would you run to strengthen the decision that you would be making?
- How confident are you of the evidence that your experiments would provide? Explain.

In this issue:

- Farming in Space
- The CUE Review
- Variation and Fast Plants
- Plant Light House
- Introducing Student Research Abstracts
- 1998 Workshop Dates



Farming in Space / Flight Updates

Beginning September 1998, check the WFP Website for updates on shuttle date and the educational connection.

<http://fastplants.cals.wisc.edu>

Surf the Net at the revised WFP Website. Look for new instructional materials, workshop announcements, updated information on the Farming in Space Flight connection, New WFP Passports and Seed Stock Documents, etc.

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