Growth, Development and Flowering

Concepts

Growth represents increase in size, number and complexity of plant cells and organs. Both environment and genetics play fundamental roles in regulating growth. The energy for growth in plants comes from photosynthesis and respiration. Variation within a population is related to variation in both the genetic constitution and the growth environment of the individuals.

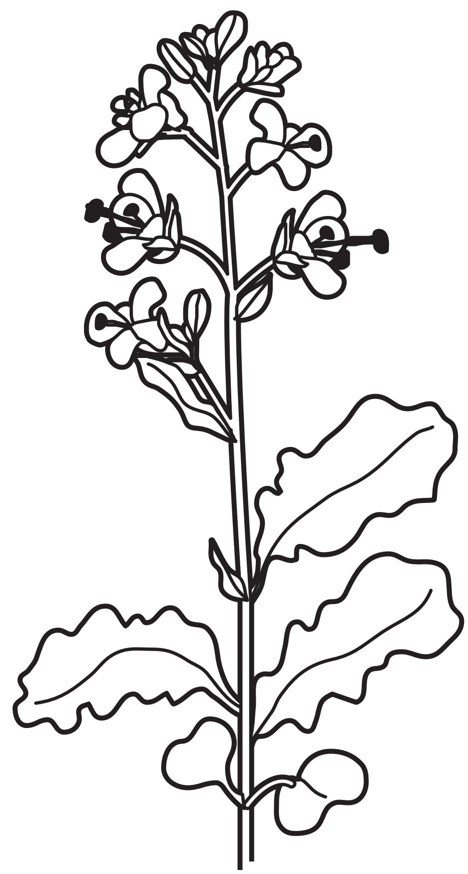
Questions

- What is the role of the environment in regulating plant growth?
- How do plants grow?
- How does a plant know when to produce leaves and when to produce flowers?

Background

The environment is created by the interaction of physical (light, temperature, gravity), chemical (water, air, minerals) and biological components (microbes, larger organisms). When environmental conditions are favorable, plant growth occurs. Following the emergence of the germinating seedling from the soil, growth of the plant continues through developmental stages in which new plant parts – leaves, stem and flowers – are produced from the growing point known as the *shoot apical meristem*. Further growth is observed as the increase in size of the new leaves, stems and flowers.

In Fast Plants, growth is most dramatic in the 10 to 12 days between seedling emergence and the opening of the first flowers. During this period, students may explore important concepts that will help them understand growth and development.



Each part of the plant performs important functions in the life cycle. The *roots* anchor the plant in the soil so that it doesn't wash or blow away. The roots also provide the means by which plants obtain water and minerals from the soil. The *stem* supports leaves and flowers and ensures that these parts are in the best position to perform their special tasks. The stem also transports water and minerals from the roots, and food manufactured in the leaves, to other plant parts.

The *leaves* are positioned to capture sunlight. In the process of photosynthesis, energy from sunlight is trapped by the green chlorophyll in leaves. This energy is used to manufacture food [carbohydrates (CHO)] by combining the carbon (C) and oxygen (O) from carbon dioxide (CO_2) in the air with hydrogen (H) which is transported from the roots as water (H_2O).

Flowers contain many specialized parts that are formed to ensure that the seed of the next generation of plants will be produced and then dispersed to new locations for growth (Raven, Evert and Eichorn, 1992).

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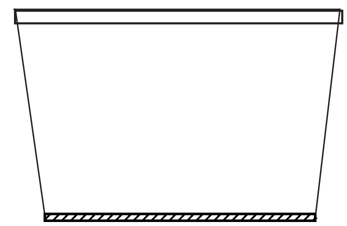
ACTIVITY 1

Construction of Growing System

Introduction

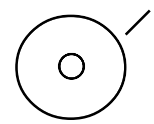
Before you and your students explore Growth, Development, and Flowering, a "growing system" designed to provide an adequate life support system for you Fast Plants is needed. Not only the growing containers and reservoirs, but also the lighting and the temperature should meet the recommended conditions outlined in WFPID *Understanding the Environment*. This activity will utilize one of many different growing systems that work well for Fast Plants. For more information on other systems see WFPID *Growing Systems, Before You Plant a Seed....*

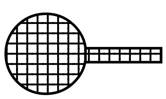


Materials (one setup for one groups of four students)

- 1 deli container (1lb size) with lid. (The deli containers are found at the Deli Counters at local grocery stores)
- four 35 mm black film cans for wick pots
- a 3/16 drill biut and drill
- capillary wicking material (felt or WaterMat®)

Bottom of Film Can



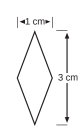


Procedure for Constructing the Deli Reservoir

1. Melt a small rectangle througth the lid of the deli container.

2. Use a drill and 3/16 drill bit and drill a single hole in the bottom of each of the film cans,

3. Cut a piece of capillary wicking material large enough to cover the top of the lid to the deli container. On one end cut out a "tail" that is long enough to reach down to the bottom of the deli container when the lid is placed on top.

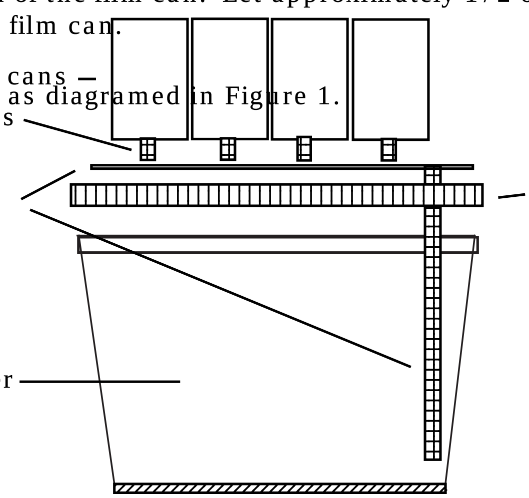


diamond wick

4. Cut four 3 cm long and 1 cm wide diamonds of wicking material. Insert one end of strip into the bottom of the film can. Let approximately 1/2 of the length hang from the bottom of the film can.

5. Setup the materials as diagramed in Figure 1.

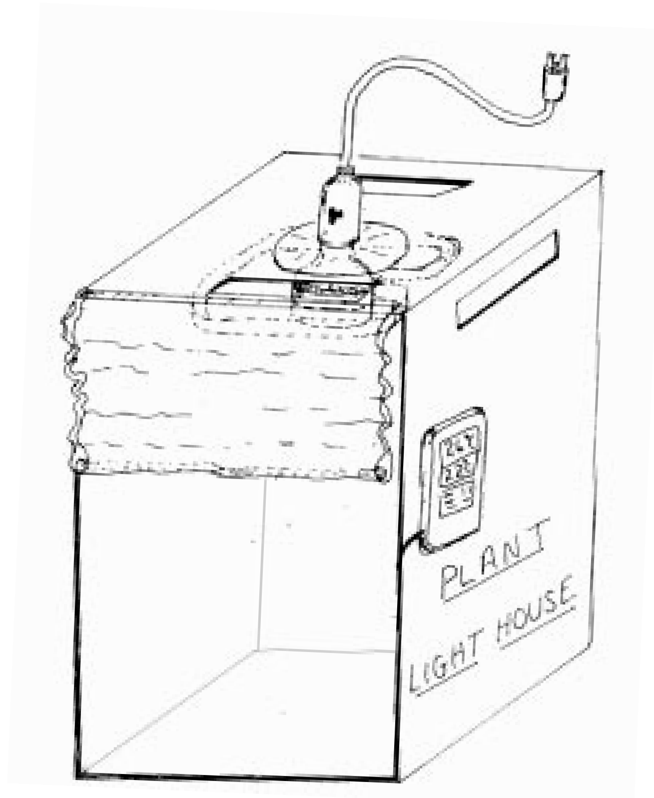
Figure 1: deli reservoir



Proper lighting is critical for proper growth and development of Fast Plants. Fast Plants have been selected to grow under 24 hour flourescent lights (see WFPID *Seeing the Light*). An inexpensive lighting idea has been developed and is known as the Plant Light House. The Plant Light House is ideal for growing Fast Plants and it is constructed fom low cost easily accessible materials.

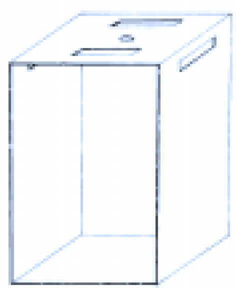
Materials

- one empty "copy paper" box, e.g., Xerox
  (enough space for 4 of the Deli Resevoirs)
- 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 approximently 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.
5. Insert light fixture base through hole in top and through plastic plate. Secure fixture by attaching socket.
6. Tape an aluminum foil or reflective full length mylar curtain over front from the top front edge of box.
7. Strengthen curtain edges with tape. Tape or clip weights (e.g., large nails) on bottom of curtain. Your Light House is ready!

ACTIVITY 2

Planting Fast Plants in Film Cans

Time Frame

With the assembled growing system, planting and placing the completed deli reservoirs in the Plant Light House will take less than one 50 minute class period.

Learning Objectives

In participating in this activity students will:

- understand the importance of capillarity in providing a continuous supply of water and nutrients to the plants (see "Water," WFPID *Understanding the Environment*;
- learn the importance of the physical characteristics of the peatlite root medium in providing a suitable environment for normal root growth and function; and
- understand the role of water in activating the process of seed germination.

"Though I do not believe
that a plant will spring up
where no seed has been,
I have great faith in a seed.
Convince me that you have a seed there,
and I am prepared to expect wonders."

- Henry David Thoreau,
The Dispersion of Seeds, 1860

Materials

- deli reservoir and lid, film can wick pots and capillary wicks and mat (from Activity 1)
- 16 Fast Plants seeds
- forceps for handling seed
- peatlite root medium and horticultural vermiculite
- nutrient solution, Peters® Professional fertilizer
- white lab tape
- rubber band

Procedure

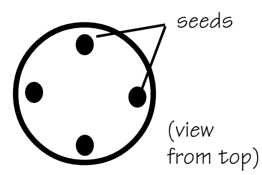
1. Collect and assemble the components of the deli reservoir along with the other materials required for this activity. Each group of three to four students should plant in one deli reservoir. Additional deli reservoirs for control plants can be planted by volunteers or the teacher.

2. On **Day 0**, wet the four diamond wicks and insert one saturated diamond halfway through the hole in the bottom of each film can. The emerging ends of the wicks will make contact with the capillary mat.

3. Wet the capillary wicking mat. Feed the wick through the slot in the lid of the deli reservoir.

4. Fill each film can wick pot with slightly moistened peatlite, to the rim, tapping lightly to settle the peatlite. Remove the excess peatlite above the pot rim. **Do not** press down on the peatlite. Carefully moisten the peatlite by watering from above until the wick drips. The peatlite will settle slightly to a few millimeters below the rim of the can.

5. Place four seeds in the form of a cross at the rim of the pot. Cover the seeds to the film can rim with horticultural vermiculite and gently water again from above.



6. On a piece of white lab tape placed just below the rim, label each film can with a student number (1 to 4). Wrap a rubberband around the cluster of four film cas and place film cans onto the wicking material on top of the Deli Resevoir.

7. 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 1/8 strength Peter's® Professional fertilizer. [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.]

8. Place the deli reservoir with film can wick pots in the Fast Plants Light House.

Note: The time that the seeds are moistened begins the timing of the growth cycle. From this point on time is taken as days after sowing or "das."

ACTIVITY 3

Tracking Variation within the Normal Growth and Development of a Population of Fast Plants

Introduction

With four students working as a team with one deli reservoir, each student will be responsible for two plants in a subpopulation of eight. Students will sow four seeds in each film can wick pot and place them in an environment conducive to germination, growth and emergence. After plants emerge students will select two of the four plants and track their growth and development by measuring plant height at specified days after sowing (das).

Data collected by students on their plants will become part of a class data set, which will be organized, summarized, analyzed, plotted and displayed so that students may gain a better understanding of the normal variation within a population of Fast Plants as they grow and develop.

Question: How much variation is exhibited within and among subpopulations of Fast Plants grown under standard environments.

Sample Hypothesis: A normal amount of variation will exist.

Design

- Subpopulations of Fast Plants are grown in the Plant Light House, specified growth parameters (height, etc.) are measured and summarized results compared with other subpopulations.
- Students will record data on their Fast Plants Growth Group Data Sheet.
- It is important for each class to have at least 2 sets of 4 film can wick pots on extra deli reservoirs to serve later as unpollinated control plants. Plant and maintain the extra deli reservoirs in the same manner as the experimental deli reservoirs, being careful to avoid pollen transfer once the control plants are in flower.

Time Frame

A period of 16 days from the sowing of seed is required for the growth of the Fast Plants and the completion of the activity. Class time required daily will vary depending on the developmental stage of the plants and the activity.

Learning Objectives

In participating in this activity students will:

- learn about plant growth by observing the emergence of seedlings, observing and measuring increases in plant size and in number, size and complexity of plant parts;
- understand the role of environment in regulating plant growth;
- observe, measure and analyze variation in growth and development among individuals in a population of plants;
- consider the use of statistical and graphical representation of growth and development within a population; and
- understand that growth in plants represents an ordered sequence of developmental events which vary between individuals of a population within limits that are defined as "normal" (see WFPID *Variation: Data Organization, Display, and Analysis*.

Materials

- white lab tape
- metric ruler
- black fine-tipped marking pen
- deli reservoir with seeded film can wick pots, three days after sowing (Day 3)

Procedure

1. On **Day 0** students planted Fast Plants and placed the experimental and control deli reservoirs in the Plant Light House.

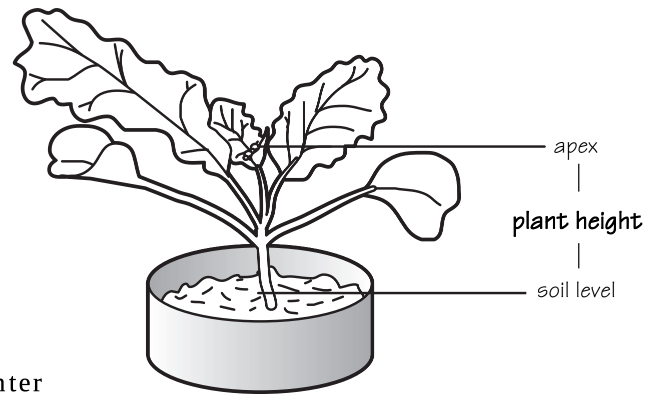
2. By **Day 3** seedlings will have emerged. At the time of sowing, film cans were numbered for students 1 to 4. Refer to the Fast Plants Growth Group Data Sheet and record the number of seedlings that have emerged from each film can wick pot.

3. On **Day 7**, thin the plants in each film can wick pot by carefully snipping off two of four plants at soil level with fine scissors. Number the remaining two plants on the white tape label of each pot. Each team of four students should have plants numbered from 1 to 8 according to the Fast Plants Growth Group Data Sheet.

4. On **Day 7**, each student should measure the height of his/her two plants (in millimeters) and record the measurements on the group's Fast Plants Growth Group Data Sheet.

   Note: Measure height from the soil to the apex as indicated in the illustration, not to the highest part of the leaf.

   At this time students will have generated a group data set. Teachers may wish to have students practice some simple organization and analysis activities on the group data and have students enter data into a class population data set.



5. Continue to observe the developing plants. As the plants grow, they will draw increasingly more liquid from the system; be sure to check reservoirs daily and fill as needed.

   Around **Day 9** students will notice the first appearance of small flower buds in the apex of the growing shoot. Within these buds the tissues that lead to the production of the male and female sex cells are differentiating.

   Over the next six days the buds will enlarge as male gametes develop within the anthers and as female gametes develop within the ovules of the pistil.

6. On **Day 11**, each student should again measure and record the height of his/her two plants. Notice that the plants are beginning to elongate more rapidly. All of the leaves on the main stem have formed and flower buds are more prominent.

7. Sometime between **Day 12** and **Day 14**, flowers on individual plants will begin to open. For each plant, record the number of days after sowing (das) when the first flower opens.

8. A final measurement of height should be made on **Day 14**, even if some plants are not in flower. After all of the students' data are in and recorded, it is a good time to observe and discuss the variation within plant population growth over time.

9. Following **Day 14**, many of the flowers will be opening on the plants, awaiting pollination. The pollination activity (see WFPID *Flowering and Pollination: Pollination Biology*), should be carried out on **Day 15** or **Day 16**, or when most plants have been in flower for two days. The timing of pollination may vary depending on the environment in which the plants have been growing.

Concluding Activities and Questions

Combine the group data into a class data summary using the Fast Plants Growth Class Data Sheet.. See WFPID *Variation: Data Organization, Display, and Analysis*.

If available, use data analysis software to create graphical and statistical summaries of class data. Notice how the various statistical notations (range, mean and standard deviation) change over time from sowing. Have students consider the following:

- From a class frequency histogram and statistical summary, does the measured plant character of height exhibit a normal distribution within the class population as hypothesized?

- Are their individual plants shorter than the average in the population? Or taller?

- Do their individual plant heights fall within one or two standard deviations of the class mean? Would they consider their plant heights to be normal? Why or why not?

- How many plants in the population fall within one or two standard deviations of the class mean?

- Are there any "abnormal" plants?

- There are many other ways that students could measure growth and development. Height is only one. Can they come up with others?

Fast Plants Growth Group Data Sheet

Student Name 1 ______________________________
Student Name 2 ______________________________
Student Name 3 ______________________________
Student Name 4 ______________________________

Group Number _______________

Environment

Irradiance: _____ no. of bulbs _____ distance of plants from bulbs
_____ wattage of bulbs or $\mu Em^{-2}s^{-1}$ measured under bulbs

Average daily temperature of growing environment: ______ ˚C

Nutrient used: _______________

Root medium used: Peatlite ____ Specify other: _______________

Seed type: _______________

Date	das	Character/Activity	Plant Measurements								Statistics			
		Students:	Student 1		Student 2		Student 3		Student 4		n	r	*x*	s
	3	indicate number of seedlings emerged												
	7	thin to 2 plants/film can, number plants												
		Plant Number	1	2	3	4	5	6	7	8				
	7	plant height (mm)												
	11	plant height (mm)												
	14	plant height (mm)												
		day to first open flower (das)												

das = days after sowing, n = number of measurements, r = range (maximum minus minimum), *x* = mean (average), s = standard deviation

Fast Plants Growth Class Data Sheet

Date ____________

Teacher Name ____________

School Name ____________

School Address ____________

____

School Phone (   ) ____________

Email Address ____________

Environment

Irradiance: ______ no. of bulbs ______ distance of plants from bulbs

______ wattage of bulbs or $\mu Em^{-2}s^{-1}$ measured under bulbs

Average daily temperature of growing environment: ______˚C

Nutrient used: ____________

Root medium used: Peatlite ______ Specify other: ____________

Seed type used: ____________

How to use this Class Data Sheet:

This Class Data Sheet can be used for the teacher or students to compile data from one measured character (e.g., plant height, Day 7) taken by groups of students who have completed the Fast Plants Growth Group Data Sheet.

Variable Measured ____________ **Date Measured** ____________ **das of Measurement** ____________

Group Data*

Group	Statistics n	r	x	s
Group 1				
Group 2				
Group 3				
Group 4				
Group 5				
Group 6				

Group	Statistics n	r	x	s
Group 7				
Group 8				
Group 9				
Group 10				
Group 11				
Group 12				

Class Data

Statistics n	r	x	s

* taken from Fast Plants Growth Data Sheets

das = days after sowing, n = number of measurements, r = range (maximum minus minimum), *x* = mean (average), s = standard deviation