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.

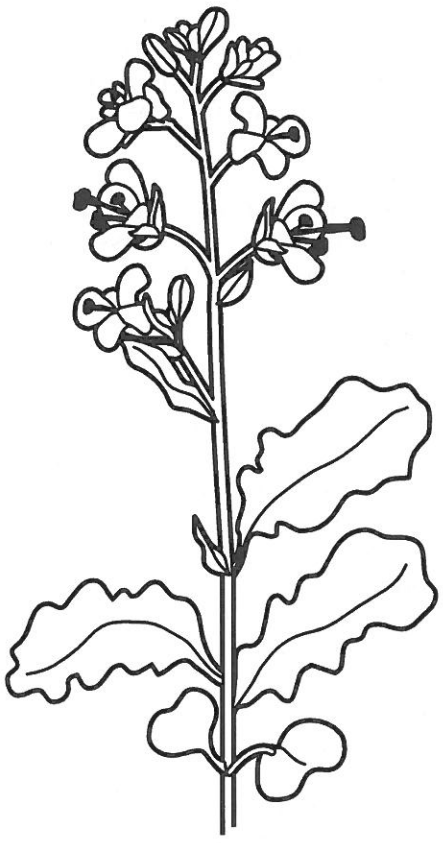
Questions

- 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 AstroPlants, 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).

Tracking Variation within the Normal Growth and Development of a Population of AstroPlants

Introduction

With four students working as a team with one PGC, 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 AstroPlants as they grow and develop.

Question: How much variation is exhibited within and among subpopulations of AstroPlants grown under standard environments in classrooms across the United States and Ukraine?

Sample Hypothesis: A normal amount of variation will exist.

Design

- Subpopulations of AstroPlants are grown in classroom PGCs, specified growth parameters (height, etc.) are measured and summarized results compared with other subpopulations and with experimental subpopulations grown in microgravity on the Space Shuttle orbiter.
- Students will record data on their AstroPlants Growth Group Data Sheet (page 41).
- It is important for each class to have at least 2 sets of 4 film can wick pots in extra PGCs to serve later as unpollinated control plants. Plant and maintain the extra PGCs in the same manner as the experimental PGCs, 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 AstroPlants 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 page 26).

Materials

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

Procedure

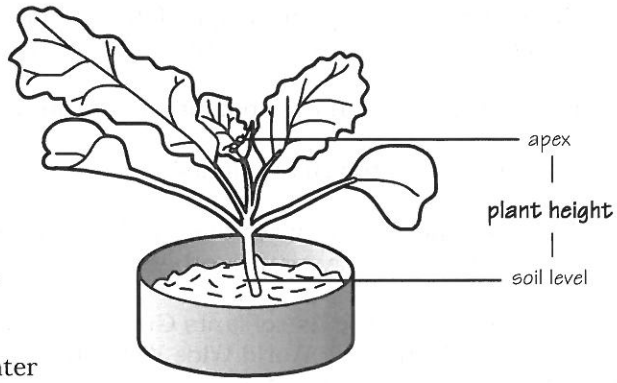
1. On **Day 0,** students planted AstroPlants and placed the experimental and control PGCs under recommended lights (Activity 2, page 35).

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 AstroPlants 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 AstroPlants 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 AstroPlants 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 (page 43).

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 (Activity 4, page 46), 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 AstroPlants Growth Class Data Sheet (page 42). See "CUE-TSIPS Science and Technology" for a review of data analysis (page 18).

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?

Classes can submit the AstroPlants Growth Class Data Sheet to the Wisconsin Fast Plants Program and then check the WFP World Wide Web site to see where their plant growth data fit into the data set from the larger population of plants grown for CUE-TSIPS in the United States and Ukraine (see page i for addresses).

AstroPlants 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: WFP nutrient solution ____ Specify other: _____
Root medium used: Peatlite ____ Specify other: _____
Seed type: AstroPlants ____ Specify other: _____
Plants grown in PGC? yes / no

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

AstroPlants 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: WFP nutrient solution _____ Specify other: _____

Root medium used: Peatlite _____ Specify other: _____

Seed type used: AstroPlants _____ Specify other: _____

Plants grown in PGC? yes / no

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 AstroPlants Growth Group Data Sheet. This Class Data Sheet can be submitted to the Wisconsin Fast Plants Program to be included in a compilation of statistics from other classes.

Variable Measured _____ Date Measured _____ das of Measurement _____

Group Data*

	Statistics						Statistics			
Group	n	r	x	s	Group	n	r	x	s
Group 1					Group 7				
Group 2					Group 8				
Group 3					Group 9				
Group 4					Group 10				
Group 5					Group 11				
Group 6					Group 12				

Class Data

Statistics			
n	r	x	s

* taken from AstroPlants Growth Data Sheets

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