# 3.6 Radish Results


## Action Synopsis

*Students make and process final observations of their plants, graph and discuss their data in groups, compile the whole class' data, discuss conclusions, then write letters to GROW.*

| **Session 1** | **40 minutes** |
|---|---|
| 1. Discuss observations. | *processing findings* |
| 2. Compare the color and lengths of treatment and control plants' leaves. | *observing & recording* |
| 3. Demonstrate how to make bar and line graphs. | *introducing new information* |
| 4. Graph plant height data. | *processing findings* |

| **Session 2** | **1 hour** |
|---|---|
| 1. Finish and discuss graphs. | *processing findings* |
| 2. Calculate average growth for treatment and control plants in groups, then put numbers on a whole class data chart. | *processing findings* |

Continued

3. Average all of the class data to get final average growth for treatment and control plants. — *processing findings*
4. Discuss variation among replicates. — *processing findings*
5. Decide which indicators of plant growth were most useful. — *processing findings*
6. Discuss and write conclusions. — *reflecting*
7. Write letters to GROW for homework. — *communicating*

# Desired Outcomes

Throughout the lesson, check that students:

✓ Can make insightful observations and accurate measurements.

✓ Can graph their data.

✓ Can use and interpret their graphs.

✓ Are willing to acknowledge and try to explain unexpected results.

✓ Are able to draw conclusions that are supported by their data.

## What You'll Need

### Session 1

For each group of 3–4 students:
- ❑ sample card of paint chips in shades of green (optional)
- ❑ rulers

For each student:
- ❑ 1–2 sheets of graph paper

### Session 2

For the class:
- ❑ sheet of newsprint (see "Getting Ready")

For each student:
- ❑ 3–4 8-oz. paper cups (optional)
- ❑ copy of "Experiment Conclusions" (page 336)
- ❑ copy of "Group Work Evaluation" (page 42)

# Getting Ready

### Session 1

♦ Either make sample graphs on overhead transparencies (see pages 328–329), or plan to draw them on the board as you introduce them.

### Session 2

♦ Make a whole class data chart on a sheet of newsprint:

Compost Tea Experiment Results

| Group: | Average Growth (cm): Treatment | Control |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| | Total: | Total: |
| | Whole Class Average: | Whole Class Average: |

# Action Narrative

## Session 1

**We're going to spend the next two periods looking at your data and drawing conclusions. Before we try to make sense of the numbers on your data charts, let's talk about your general observations.**

**What have you been noticing and keeping track of?**

Have students talk about how their observations expanded beyond plant height as they watched the plants develop. For instance, they might have noted when the first true leaves appeared on the treatment and control plants, or how droopy or straight the plants were. Also encourage students to describe what they've found most interesting or surprising.

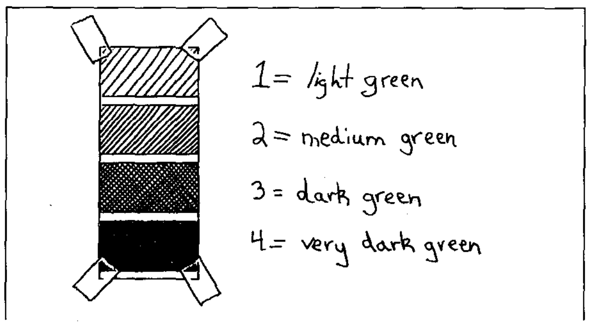
**Are there any obvious differences in how the treatment and control plants look?**

Encourage students to refer to the notes they've taken during the past few weeks, as well as to the plants themselves, in order to consider which characteristics of the plants may be the best indicators of treatment effects.

If students haven't been keeping track of the color or length of leaves, have them make these observations now. Encourage them to think of ways to make these measurements objective.

*Comparing Leaf Colors*

Students can use paint chips or make a color chart with markers to compare the shades of treatment and control plant leaves.




Students can average the scores for leaf colors on control plants, and on treatment plants, to see if there is an overall difference in color between treatment and control plants.

LEAF COLOR (1 = light green; 4 = very dark green)

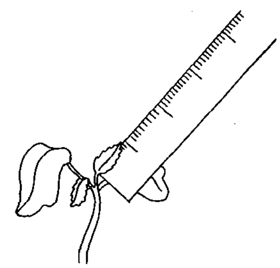
Date: April 15th

| Treatment: | Control: |
|---|---|
| T1 3 | C1 2 |
| T2 4 | C2 2 |
| T3 3 | C3 3 |
| T4 3 | C4 2 |
| T5 4 | C5 1 |
| T6 2 | C6 3 |
| | |
| Total: 19 | Total: 13 |
| Average: 3.2 | Average: 2.2 |

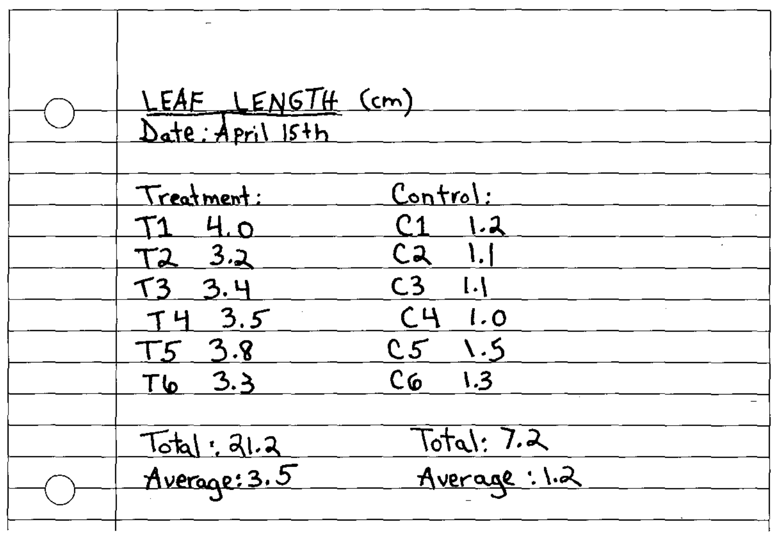
*Comparing Leaf Lengths*

In the compost tea experiment, leaf lengths are often a better indicator of plant health than plant height. One problem with plant height is that plants that do not get enough sunlight become "leggy," so can be tall even though they are not healthy.

To compare leaf lengths, students should choose the largest true leaf on each plant, and measure and record its length from the tip to its base where it attaches to the stem.



Students can then average the lengths of the largest true leaf on each control plant, and compare this number to the average length of the largest leaves on treatment plants.



LEAF LENGTH (cm)
Date: April 15th

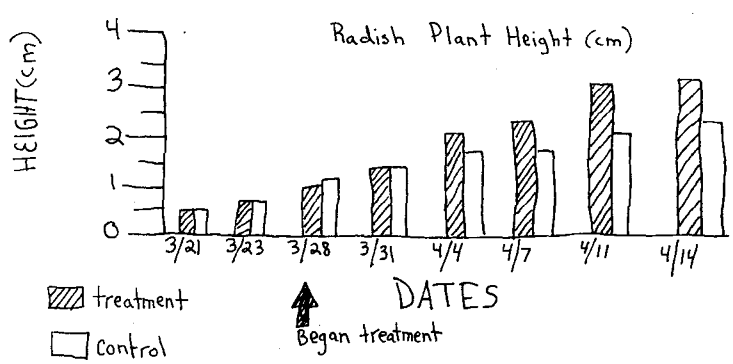
| Treatment: | Control: |
|---|---|
| T1 4.0 | C1 1.2 |
| T2 3.2 | C2 1.1 |
| T3 3.4 | C3 1.1 |
| T4 3.5 | C4 1.0 |
| T5 3.8 | C5 1.5 |
| T6 3.3 | C6 1.3 |
| Total: 21.2 | Total: 7.2 |
| Average: 3.5 | Average: 1.2 |

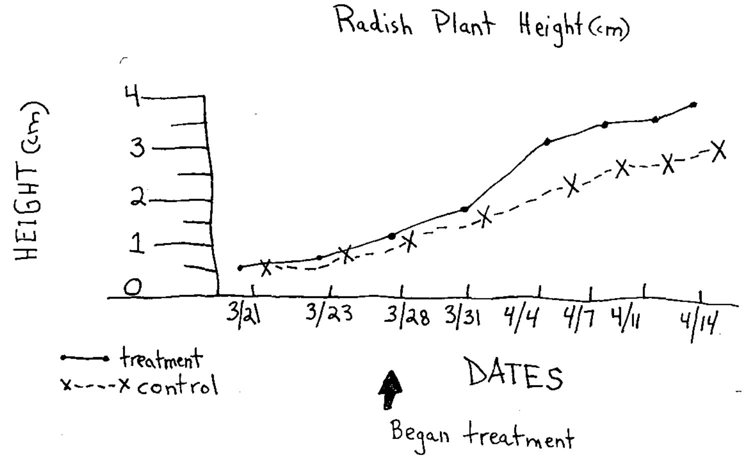
Have students discuss whether or not compost tea affected plant health based on leaf color and/or leaf length of treatment and control plants.

**Now let's graph your plant height data. Scientists make graphs to get a clear picture of what happened during their experiment.**

Show students how to make bar and/or line graphs to show the height of treatment and control plants over time.

Give each student a sheet of graph paper on which to graph plant height data. Making graphs will likely extend into the next period.






## Session 2

**Finish making the graphs you started yesterday.**

Students who have completed one graph can try the other type of graphing until everyone has made at least one graph. They can also compare their graphs to those made by the rest of their group. The graphs for each group should look similar if they used the same data.

**Let's see what the graphs tell us.**

Have each group respond to the following questions so that they get practice reading graphs, and so that the class can get a sense for how all groups' results are similar or different.

**Do your graphs show that there was a difference in the height of treatment and control plants?**

**How long after the treatment began did it take for differences to show up?**

**Did the plants keep growing steadily, or did they sometimes not grow at all between measurements?**

**Were the treatment and control plants ever the same height?**

**Were your two groups of plants different heights even before you started the treatment?**

**Each group now has a good idea of what happened to its own treatment and control plants during the experiment. But we still don't have the whole picture. What else do we need to do?**

Since each group did a replicate of one big experiment, the class needs to compile its data. Results of one group's work might not reflect the overall pattern of class results.

**I've made a chart on which each group can record its results so that we can get one final result for our whole experiment.**

Show students the data chart you've prepared and point out its sections. Help the class realize that it can be more certain of results by taking into account all of the replicates.

Compost Tea Experiment Results

| Group: | Average Growth (cm): Treatment | Control |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| | Total: | Total: |
| | Whole Class Average: | Whole Class Average: |

**Each group needs to summarize all of its data to get just two numbers to add to the chart. How will you get the overall average growth for your treatment and control plants?**

At first students might suggest that they should just record the final average heights for their treatment and control plants in the two columns. However, this will not reveal how much the plants grew. To calculate growth, as opposed to final height, students will need to subtract the average height of the treatment and control plants on the day they started the treatment, from the height the plants were on the last day they took measurements.

The reason that students should use total growth rather than final height to draw conclusions about their experiment is because the treatment and control plants might have started at different heights, so final height figures could be misleading.

*It might help students to think about how they'd figure out how much everyone in the class grew over the summer. They'd have to subtract how tall each person was at the beginning of the summer from how tall they were at the end. They could then add these numbers and divide by the number of people in the class to get the average amount that the class grew in one summer.*

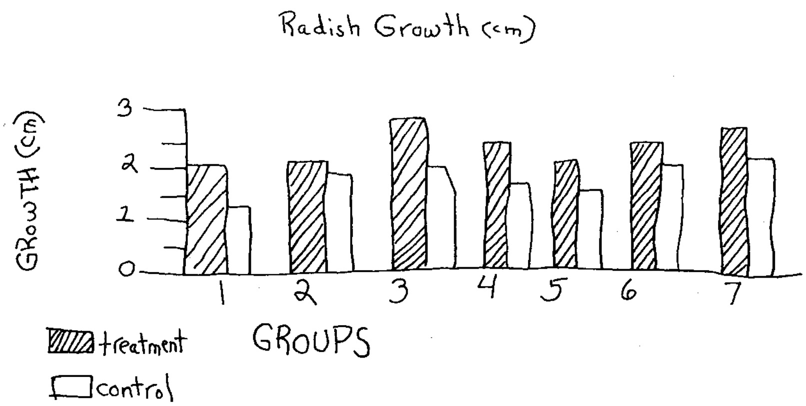
**Work in your groups to make calculations, then choose someone to add your two final numbers to the class chart.**

Once all of the groups' numbers are on the chart, have the class add them to get totals for each column, then divide the totals by the number of groups to get final averages.

Compost Tea Experiment Results

| Group: | Average Growth (cm): Treatment | Control |
|---|---|---|
| 1 | 2.0 | 1.2 |
| 2 | 2.3 | 2.0 |
| 3 | 3.0 | 1.6 |
| 4 | 2.7 | 1.5 |
| 5 | 2.2 | 1.5 |
| 6 | 2.3 | 1.7 |
| 7 | 2.6 | 1.6 |
| | Total: 17.1 | Total: 11.1 |
| | Whole Class Average: 2.4 | Whole Class Average: 1.6 |

Students can make a bar graph on the board to display all of the groups' results.




Help students analyze their results and draw conclusions with questions such as:

**Were groups' results similar to or quite different from each other?**

Have students look at the bar graph or class chart to see how much variation there is among different groups' results. It could be that just one or two groups' numbers are radically different from the rest.

If all of the groups' results are quite variable, have students think first about whether the differences could be due to different experimental methods—perhaps some groups kept their plants in a different part of the classroom, used stronger compost tea, or watered more frequently.

If students decide that their methods were as identical as possible, then they can attribute the differences to natural variation in the plants themselves.

**Are the differences in the final averages you got for treatment and control plants large enough to say that the compost tea helped the plants grow?**

Scientists use statistics to tell them how confident to be that differences in numbers they're comparing are significant, and not just due to chance. Since students won't be applying statistics to their numbers, help them to judge how big of a difference is large enough to allow them to say that the compost tea really affected plant growth. The key to making this judgment is to look at the variability of the data. The more spread out the results of the replicates are, the bigger the difference between the final averages for treatment and control groups should be in order to say with assurance that compost tea affected plant growth.

**How do the height results compare with other indicators of plant health you observed?**

Students might find that although treatment and control plants do not differ in height, the leaves of the treatment plants are bigger and/or greener than those of the control plants.

**Considering all of the results, what conclusions can you draw?**

Students have a tendency to focus on their own group's results, rather than on the combined results of the whole class to draw conclusions, especially if their treatment plants grew better than other students'. Remind them that scientists do a lot of replicates to be more sure of their conclusions, and that they don't ignore data that didn't turn out as they expected.

Often students' results are not clear-cut, due in part to the difficulties of growing plants in classrooms. If they decide that their experiment did not show that compost tea improved plant growth as they expected, and in some cases might have damaged the plants, challenge them to think about why. Some reasons they might mention include: the plants needed to grow longer before showing positive treatment effects; the plants' growth might have been affected by the vermiculite drying out or getting too soggy; the plants were handled too roughly; the cups were too small for the roots; the plants didn't get enough light, or got too much heat; there were too many or the wrong kinds of nutrients in the compost tea for the type of plant they grew; or the dead plants in the compost hadn't decomposed enough for nutrients to be released. Having students explain unexpected results provokes creative and in-depth thinking.

Since they are used to judging their success by getting the "right" answer, students might feel disappointed that all of their hard work and patience yielded negative or unclear results. Help them understand that scientists can learn as much from negative as from positive results. Also, scientists will often do an experiment over again to improve their methods.

**Why is nutrient cycling important?**

Even if students' experiment did not clearly demonstrate that nutrients flow from dead plants to living plants, it is important for them to understand that this does indeed happen in nature. Without nutrient cycling, all of the nutrients in the world would eventually be tied up in dead things, and then nothing could live or grow.

**Here is an "Experiment Conclusions" sheet for each person to complete.**

Students can write their conclusions in class or for homework. Information on evaluating the sheets is provided on page 334.

**Your homework assignment is to write a letter to GROW. What information should your letters include?**

Students might suggest that they tell GROW what they did and found out, and perhaps include drawings, photos, or graphs. They could also recommend what GROW should do next (e.g., do more experiments, begin marketing compost tea, or start a new line of research). See page 334 for tips on evaluating students' letters.

*Instead of having each student write a letter to GROW, you could have each person outline a letter, then meet as a group to decide on a final outline. Then each group member can write a different section of the letter. Before signing the letter, each person should read all of the sections to make sure the whole thing is satisfactory.*

Students can transplant their seedlings into soil in paper cups to take home, or continue growing them in class until radishes are ready to harvest and eat. Wash out the nested plastic cups for future use.

# Ongoing Assessment

## Student Reflections

Have students send a C-Mail message or record thoughts in their journals. Optional writing prompts include:

*I would convince someone that I kept the experiment fair by telling them that...*

*What strengths did I develop or find out I had while experimenting?*

*Something I know now that I didn't know when I began the experiment is...*

Students could also complete a "Group Work Evaluation" (page 42) to reflect on their group's cooperation during the experiment.

## Teacher Reflections

- ❑ Did students successfully make and read graphs?
- ❑ Were they able to consider more than one indicator of plant health in order to draw conclusions?
- ❑ Were they able to draw conclusions based on results from the whole class?
- ❑ Did they have reasonable explanations for why their experiment turned out as it did?
- ❑ Do their suggested experiment revisions show that they understand the importance of controlling variables and keeping accurate records?

*Evaluating Students' "Experiment Conclusions" Sheets*

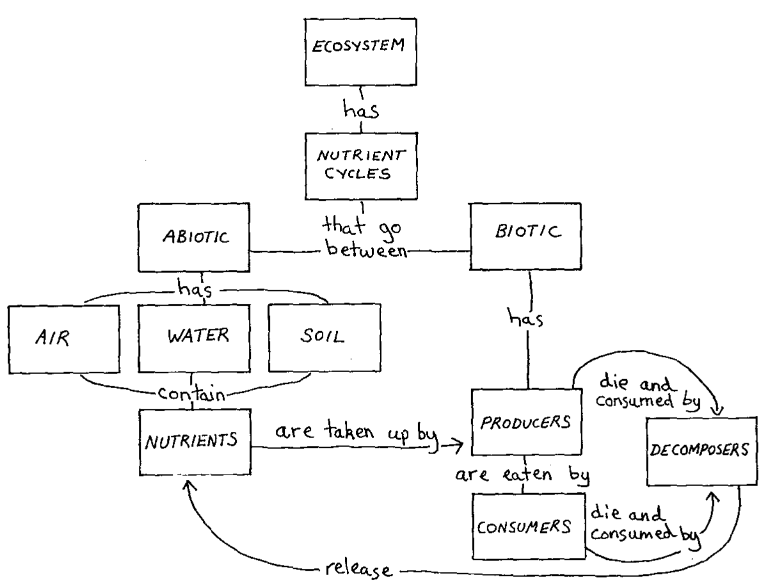
Look especially to see if students are able to admit that the experiment turned out differently than they predicted, if in fact it did. Their explanations of why the experiment turned out as it did will reveal their critical thinking skills, as well as their knowledge about plant development and nutrient cycling. Their suggestions for how to make their experiments better will reveal if they understand the importance of controlling variables and keeping accurate records. Finally, their ideas for new research will show their curiosity and depth of thinking about plant growth and cycling issues.

*Evaluating Students' Letters to GROW*

Exemplary letters to GROW will include a description of research methods, results, conclusions, and recommendations. The methods should be detailed, and accurately reflect what the students did. The results section might mention their own group's results, but ultimately should focus on whole class results if each group did a replicate of a larger experiment. Conclusions should also reflect the whole class experiment. Some students might decide that the experiment was inconclusive, which is valid so long as they cite a reason for this interpretation other than that the experiment didn't turn out as it should have. Finally, the recommendations section will vary according to individual opinions and experiment outcomes. Some students might feel that GROW should sponsor more research; others might suggest they give up on developing a compost tea product; while others could encourage GROW to bottle and market compost tea immediately.

# Extensions

**Concept Maps.** Introduce concept mapping to students if they are not already familiar with the process (see pages 25–27). Select all or some of the concept map cards on pages 43–44, then copy one set of cards for each group of 3–4 students. Have them construct concept maps that display their ideas about nutrient cycling. They might compare their new concept maps with those they made after Lesson 3.1, to see how their ideas have changed.



**Surveying Gardeners.** Have students interview experienced gardeners from a span of generations about their plant growing practices. This is an especially interesting project if your students have diverse cultural heritages with family members who came from other countries. Have students tape record their interviews for an oral history archive. They can also create a document that compares different gardening traditions, and how these have stayed the same or changed over the years.

**Roving Responses.** Post five to ten sheets of newsprint around the classroom, each with a different question written across the top. Have students circulate in groups to write a group response to each question. Their challenge is to elaborate on or refine what other groups have written, rather than parroting the same answers. Have each group use a different color marker. Possible questions include: *Where do plants get nutrients? Why do plants need nutrients? What happens to plants after they die? Would you recommend that gardeners use compost tea—why or why not? What are the most important things to remember when doing an experiment? What does it take to be a scientist?*

**Journey of a Nutrient.** Have students write creative, fact-based stories or poems tracing the pathway of a nutrient over a hundred years, beginning and ending inside of a dead plant. For instance, the nutrient can travel through the decomposition cycle, into living plants, and through food webs, as well as spend time in the non-living environment of soil, water, or air.

# EXPERIMENT CONCLUSIONS

1. **W**hat was your research question?

2. **W**hat did you *think* would happen?

3. **W**hat actually *did* happen?

4. **W**hy do you think it happened?

5. **W**hat would you do differently to make your experiment better?

6. **W**hat other experiments would you like to do to learn more about your topic?