Let There Be Light

Overview: Students will learn about how light is important to plants, and how both quality and quantity of light affect plant growth.

Grade Level/Range: 4- 8

Objective: Students will:

- Learn about variations in light quality and quantity
- Design and conduct experiments using grow lights to demonstrate the impact of variations in light on plant growth.
- Draw conclusions about the best and most efficient source of light for plants.

Time: 6 to 8 weeks

Materials

- Grow lights
- Fluorescent or LED bulbs that provide different wavelengths of light (cool-white, warm-white, and full-spectrum bulbs are readily available)
- Potting soil
- Pots
- Assorted seeds (beans, lettuce, and/or herbs)
- Light meter
- Ruler

Background Information:
Light is among plants' most critical needs. Plants capture light energy and use this energy during photosynthesis, the process by which they convert carbon dioxide and water into carbohydrates — the food they use to fuel their metabolic functions. Without light, plants starve and die. All life on earth depends upon plants' ability to photosynthesize!

Plants can get light from two sources: the sun and artificial lighting.. Regardless of its source, light is measured in two ways: light quality, and light quantity. (Light quantity comprises both intensity and duration.) Plants vary in their light requirements — and these requirements can even vary depending on the plants' stage of growth. It's up to gardeners to evaluate whether a plant is receiving adequate light based on research as well as on observations of its growth.

Light Quality

Light energy radiates from a source in electromagnetic waves of different lengths and frequencies. Some of these waves aren't visible to humans, but those we can see are perceived as different colors. Visible light with the longest wavelength and lowest frequency is seen as red, and that with the shortest wavelength and highest frequency is seen as violet. Orange, yellow, green and blue fall in between.

When all visible wavelengths are combined, the light appears to be white or colorless, like sunlight. However, when you separate the light, as with a prism, you can see all the colors in the spectrum.

Light is either reflected or absorbed by objects. When you look at an object, the color you see is actually the color of light that the object reflects. If the object is white, it's reflecting all the waves and absorbing none; if it's black then it's reflecting none of the waves and absorbing them all. Thus, plants appear green because they are reflecting the green light waves and absorbing all the others.

Red and blue light are the most important for plant growth impacting photosynthesis and flowering. A mix of 90% red light and 10% blue light provides the balance of light colors needed for most plant growth.

Fun fact: In a controlled environment where lights only radiate red and blue wavelengths, plants appear purple.

Light Quantity

Light quantity is determined by both intensity and duration.

Light intensity is the measurement of the amount of light reaching a plant (or other object). Intensity is a combination of two factors: the brightness of the light and the distance between the light and the plant (or other site of measurement). With respect to a light of a specific brightness, the closer that light is to the plant, the higher the light intensity.

Light intensity is measured in terms of footcandles or lux. One footcandle is the amount of light produced in a totally dark space by one candle shining on a white surface that is 1 square foot in size, 1 foot from the candle. One lux is the amount of light that would shine on a surface that is 1 meter away. To convert between the two measurements, 1 footcandle = 10.764 lux.

To provide some perspective, average office light is 300-500 lux, or 30 to 50 footcandles and the light at noon on a sunny day may be as bright as 10,000 footcandles or 107,640 lux. Although the duration and intensity of sunlight far exceeds the capacity of indoor lighting, there are many flowers, vegetables, and herbs that can grow well with the 1,000 to 1,500 footcandles of light provided by lighting available under grow lights.

Light duration can help compensate for less-than-ideal light intensity. Outdoors, common garden plants need an average of 6 to 8 hours of sunlight. Under grow lights, since light is less intense, plants would need exposure to 14 to 16 hours per day to achieve adequate light quantity.

So is more light always better? Longer light duration, doesn't necessarily make plants produce more abundantly. Most plants actually require a daily period of darkness in order to complete respiration – the process whereby plants convert the products of photosynthesis into usable energy. Some plants even require a certain period of uninterrupted darkness to trigger flowering (checkout our article on photoperiodism.) Therefore, it is not advisable to grow plants under lights left on 24 hours a day.

Laying the Groundwork:

- Ask students to list all of the things plants need to grow. Do plants require sunlight? What are other sources of light plants can use?

- Define light quality and explain how different wavelengths of light are either absorbed or reflected determining the color of the objects we see. To demonstrate this for your students, bring in a flashlight and a piece of red, green, and blue cellophane. Wrap the flashlight with one color of the cellophane at a time, and then in a dark room, shine your flashlight on a plant (or another object of one color such as an apple). *What color does the plant appear in each of the different colored lights? What does this say about which type of light is reflected and which is absorbed? What do you think is the most important wavelength of light for plants?*

- Next, define light quantity, a measurement that combines light intensity and duration. To demonstrate light intensity, take a tour of your school grounds and ask students to compare the brightness of light in different locations. Does it seem stronger or weaker in different places? Use a light meter (that measures in footcandles or lux) to gather hard data for their observations. To demonstrate light duration, monitor and record how long light reaches different locations, both inside and out.

Exploration

Although you can study the affect of light on plants in indoor or outdoor gardens, light duration and quality can be difficult to control in outdoor gardens, which is why the following experiments suggest using grow lights. If grow lights and/or indoor growing space are not available, you can adapt many of these experiments to outdoor gardens or greenhouses.

Here are a few ideas for experiments to explore light quality, intensity, and duration, and their affect on plant growth:

Light Quality Experiment Idea

There are a variety of fluorescent and LED bulbs that emit different colors of light that can be used in grow lights:
Cool white: emit wavelengths primarily from the blue/violent end of the spectrum
Warm white: emit wavelengths primarily from the red end of the spectrum
Wide-spectrum and full-spectrum: emit wavelengths from all the colors of the spectrum; the closest lights come to mimicking sunlight.

1. Create an experiment using various bulbs. Buy enough of each bulb so that you can dedicate an entire shelf of your grow light stand to a single type. If you have more than three shelves, try combinations of the bulbs as a variable. Make sure all lights are positioned the same distance from the trays. Keep your store receipts so you can include cost comparisons in your analysis.

2. Plant seeds in trays or pots and place them under your grow lights. Your goal is to test light quality's effect on plants, so to limit the number of variables that affect your data. Use the same size containers, the same number of seeds per container, place them in exactly the same location under the lights, and

keep all lights on for the same length of time each day. Although you can experiment with any type of seed, lettuce, beans, and herbs are easy to grow and are examples of plants currently grown in space, which provides opportunities for further class discussion.

3. Track plant growth. Keep a journal of data, including germination dates, height measurements and notes on appearance (sample data sheet included at the end of this lesson). You can also use a light meter to determine the intensity of each type of bulb. Depending on the number of plants you choose to grow, you can either track the growth of individual plants or calculate an average height.

Light Intensity Experiment Idea

1. For this experiment you'll use the same type of bulb on multiple shelves. Make sure all bulbs are the same age because some types of bulbs emit less intense light as they age.

2. Use a light meter to determine the intensity of the bulbs when they are all positioned the same distance from the shelf. Measure the light in the same spot on each shelf – these readings should be close to equal. Next, position the lights at different heights and again measure light intensity (a sample chart is available at the end of this lesson).

3. Once you determine how the distance between the bulbs and trays affects intensity, check to see if it's equally intense on all areas of the shelf as well. You should find that light intensity is greater at the middle of your bulbs than near the ends, and therefore greater in the center of the trays.

4. Finally, test the light intensity's effect on plant growth. Position the grow light fixtures at different heights, take intensity readings, and then, as above under Light Quality, Step 2, plant and position pots identically on each shelf. Track growth and compare your results (see sample journal entry at the end of this lesson).

5. For further comparison, position fixtures at the same height, and track growth of plants placed at different locations on the shelf.

*Special note: Do not angle fixtures with one end higher than the other. This is unsafe because water can condense and run down to the light terminal, creating the risk of electric shock.

Light Duration Experiment Idea

1. Keep the type of light bulb used and the height of fixtures constant, but leave lights on for different amounts of time on different shelves.

2. Track growth and compare results (see sample journal entry at the end of this lesson).

Making Connections

- What type of bulb resulted in the best growth? Why do you think it was best?
- What light fixture height resulted in the best growth? Why do you think it was best?
- Which duration of lighting resulted in the best growth? Why do you think it was best?

- Which type of bulb is most economical? Did it also result in the best growth?

- What other qualities do you think gardeners should consider when choosing lighting?

Branching Out

- Expand the experiments above, but this time test different varieties or types of plants. Did some plants grow better than others in less intense light? Do you think plants have an optimum light level or do you think they can adapt to different levels? Did you notice any adaptations exhibited (for instance larger leaves or taller plants) when light levels were less intense)?

- Explore plants that are particularly sensitive to light availability. Photoperiodism is used to describe a phenomenon in which physiological changes occur in an organism in response to day length; that is, the relative amounts of light and darkness in a 24-hour period. Poinsettias and chrysanthemums are two common examples. Try altering growing conditions to try and get one of these two plants to bloom outside of the normal flowering season.

Light Quality Experiment

Plants grown:

Date seeds planted:

Number of seeds under each light:

Height of light fixtures:

Daily light exposure (hours):

		Type of Bulb		
		Cool White	Warm White	Full Spectrum
Cost				
Intensity of light (in footcandles or lux*)				
Plant Growth				
Date:	% germination			
	Average height			
	Appearance (vigorous, healthy, fair, or poor)			
	Additional notes			
Date:	% germination			
	Average height			
	Appearance (vigorous, healthy, fair, or poor)			
	Additional notes			
Date:	% germination			
	Average height			
	Appearance (vigorous, healthy, fair, or poor)			
	Additional notes			

*make note of the type of measurement used

Light Intensity Experiment 1

Type of Bulb:

Height	Bulb Intensity (in footcandles or lux*)		
	Shelf 1	Shelf 2	Shelf 3
6" from shelf			
1' from shelf			
1.5' from shelf			

*make note of the type of measurement used

Light Intensity Experiment 2

Plants grown:

Date seeds planted:

Number of seeds under each light:

Daily light exposure (hours):

		Shelf 1	Shelf 2	Shelf 3
Height of Light Fixtures				
Intensity of light (footcandles or lux*)				
Plant Growth				
Date:	% germination			
	Average height			
	Appearance (vigorous, healthy, fair, or poor)			
	Additional notes			
Date:	% germination			
	Average height			
	Appearance (vigorous, healthy, fair, or poor)			
	Additional notes			
Date:	% germination			
	Average height			
	Appearance (vigorous, healthy, fair, or poor)			
	Additional notes			

*make note of the type of measurement used

Light Duration Experiment

Plants grown:

Date seeds planted:

Number of seeds under each light:

Height of Light Fixtures:

		Shelf 1	Shelf 2	Shelf 3
Daily light exposure (hours)				
Intensity of light (footcandles or lux*)				
Plant Growth				
Date:	% germination			
	Average height			
	Appearance (vigorous, healthy, fair, or poor)			
	Additional notes			
Date:	% germination			
	Average height			
	Appearance (vigorous, healthy, fair, or poor)			
	Additional notes			
Date:	% germination			
	Average height			
	Appearance (vigorous, healthy, fair, or poor)			
	Additional notes			

*make note of the type of measurement used