Understanding the Effects of Light, Temperature, Air, and Water on Plant Growth

IN HORTICULTURE we try to grow the healthiest plants possible. To accomplish this goal, we manipulate a plant's environment to provide optimal growing conditions. That means we give plants the levels of light, temperature, air, and water needed for ideal growth.

Objective:

Examine the effects of light, temperature, air, and water on plant growth.

Key Terms:

- day-neutral plants
- DIF
- electromagnetic spectrum
- foot-candle
- hardiness
- humidity
- long-day plants
- photoperiod
- photoreceptor
- phytochrome
- plant heat-zone map
- plant-hardiness zone map
- short-day plants
- soluble salts
- thermoperiod
- vernalization
- wilting

Environmental Influences on Plant Growth

A plant's growth is directly affected by its environment or its nonliving surroundings. Light, temperature, air, and water have tremendous impacts on plant growth and plant health.

LIGHT

The sun emits a wide range of radiation. The light we see is called visible light. It is a small segment of all the radiant energy given off by the sun. Visible light is what drives photosynthesis. Some other types of radiation are X-rays, gamma rays, ultraviolet rays, microwaves, and radio waves. Radiation travels in waves. The wavelengths of the different rays are measured in nanometers. Based on their wavelengths, the rays have been placed on an **electromagnetic spectrum**.

Light Color

Sunlight contains a complete blend of visible colors, including red, orange, yellow, green, blue, and violet. Plants need mostly blue and red to activate their chlorophyll. Other pigments collect other colors of light and pass that energy to the chlorophyll to make more sugar. Different colors of light solicit different plant responses.

Red and blue light have the greatest impact on plant growth. Red light promotes seed germination, seedling growth, and stem elongation. Red wavelengths also influence flowering and the formation of anthocyanins (pigments in blue, red, and purple flowers). Blue light reduces stem length, increases branching, and promotes stem strength. Blue light improves leaf and flower color, too. Far-red light triggers a shade-avoidance response in plants when levels of blue or red light are low. Stems stretch and become weak while leaves become thinner and wider. Far-red light also plays a key role in the breaking of seed dormancy and in photoperiod responses.

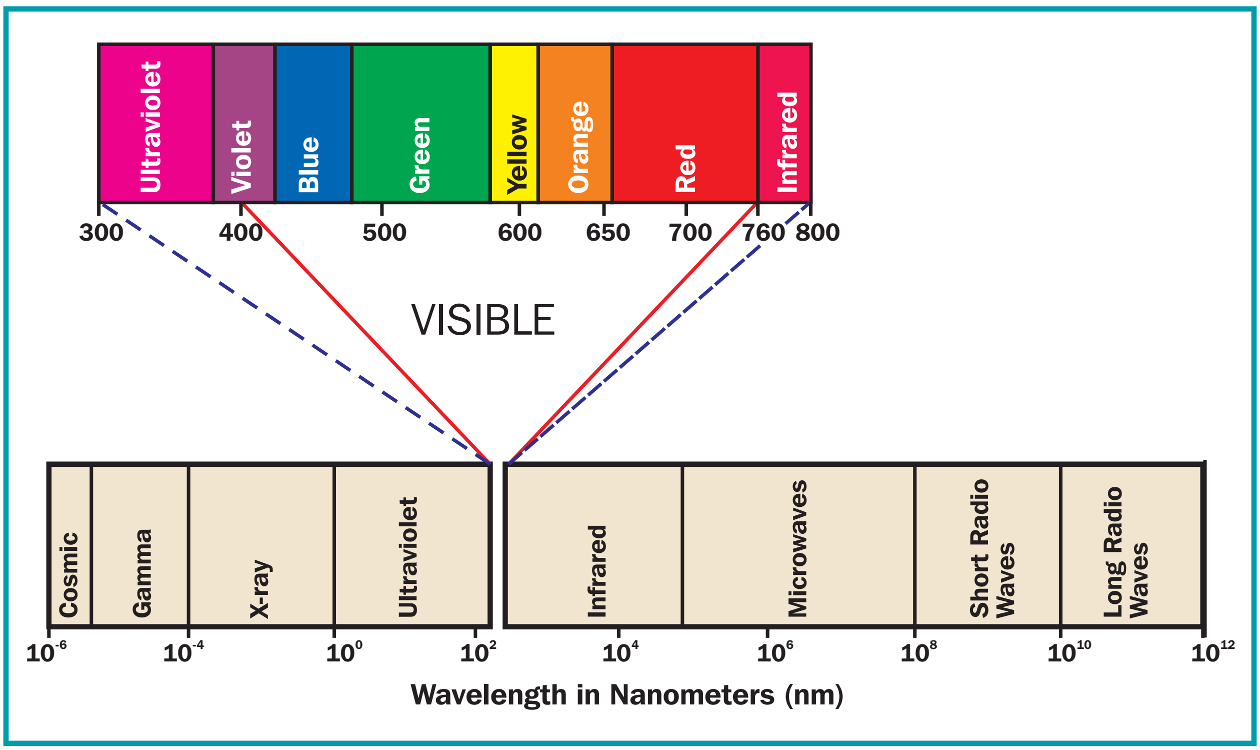


FIGURE 1. The electromagnetic spectrum displays the different types of solar radiation.

Light Intensity

Light intensity influences plant growth. Intensity of light depends largely on the angle of the sun and on clouds and dust in the atmosphere. Light intensity is greater in the summer months when the sun is higher in the sky.

Light intensity is measured in foot-candles. A **foot-candle** is the amount of light distributed by a single candle 1 foot away. A sunny summer day provides about 10,000 foot-candles of light. The high light intensity elevates the rate of photosynthesis, and plants are able to produce more food.

Plants receiving the optimal level of light will be compact and have good leaf color. Symptoms of lower than optimal light levels include a slower growth rate, thin leaves, small flowers, dull leaf and flower color, and etiolation, or stretching. Extended periods of cloud cover can slow crop growth and ultimately reduce yields.

FIGURE 2. Light intensity influences plant growth.

Light Duration

Some plants are responsive to the length of time they are exposed to light. These plants have a **photoreceptor**, or light-sensitive pigment, that absorbs light. **Phytochrome** is a type of photoreceptor within plants that detects day lengths. The length of the days or the length of the light period is known to influence different phases of plant growth, such as flowering. Other phases are seed germination, enlargement of leaves, and development of buds. The length of a plant's daily light exposure is its **photoperiod**.

Plants can generally be separated into three groups based on their photoperiod response. **Short-day plants** (SDP) are plants that begin to flower when the nights are more than 12 hours long. **Long-day plants** (LDP) are plants that begin to flower when the nights are less than 12 hours long. **Day-neutral plants** (DNP) are plants whose flowering response is unaffected by their photoperiod.

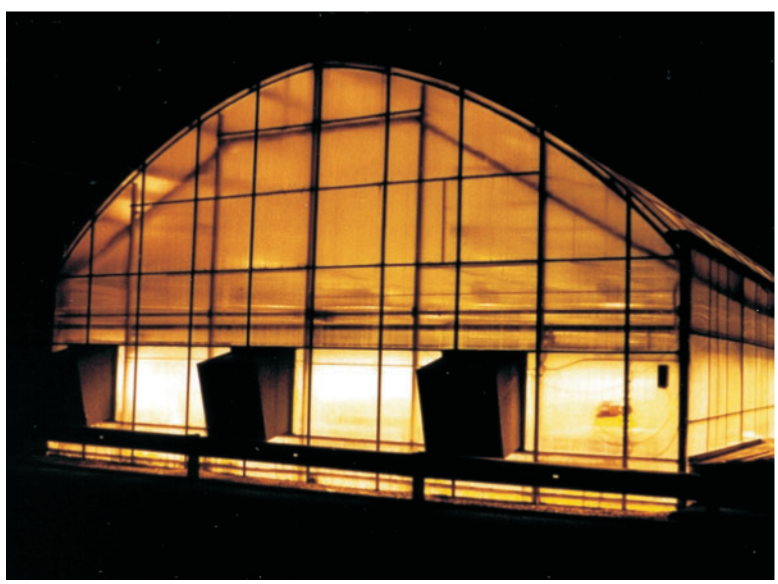


FIGURE 3. Some crops are lighted at night to simulate long days.

TEMPERATURE

FIGURE 4. These narcissus, azalea, and Easter lilies have been placed in a cooler to slow their development.

Plants have adapted to a wide range of temperatures. Some plants thrive within the Arctic Circle; others survive in the blazing heat of a desert. Plants adapt to higher temperatures by developing smaller leaves in lighter colors with thicker cuticles. Plants adapt to lower temperatures by growing lower to the ground, with short life cycles and with dish-shaped flowers that collect light and heat. Although plants can survive higher and lower extremes, they don't really grow at temperatures below 32°F or above 100°F.

Plant Hardiness

A plant's ability to withstand low temperatures is called **hardiness**. A plant that is very hardy can survive in a cold climate. Hardiness is measured using the USDA **plant-hardiness zone map**. Each area of the country is assigned a zone numbered from 1 to 10. For example,

ON THE JOB...

CAREER CONNECTION: Greenhouse Grower

Floriculture, which is the culture of flowers and foliage (leafy) plants, is a large segment of the horticulture industry. Many floriculture crops are produced in greenhouse structures, where a greenhouse grower can manipulate growing conditions.

Greenhouse growers must be able to identify plants and understand needs of plants. They provide supplemental lighting or shade to crops. They adjust temperatures in the greenhouse range to get a desired response from the crops. They sometimes add CO_2 to the greenhouse atmosphere to speed growth. Most important, they provide water at the right time for each crop. In addition, greenhouse growers have knowledge in plant propagation, scheduling of crops, pest management, plant nutrition, and harvesting and handling crops.

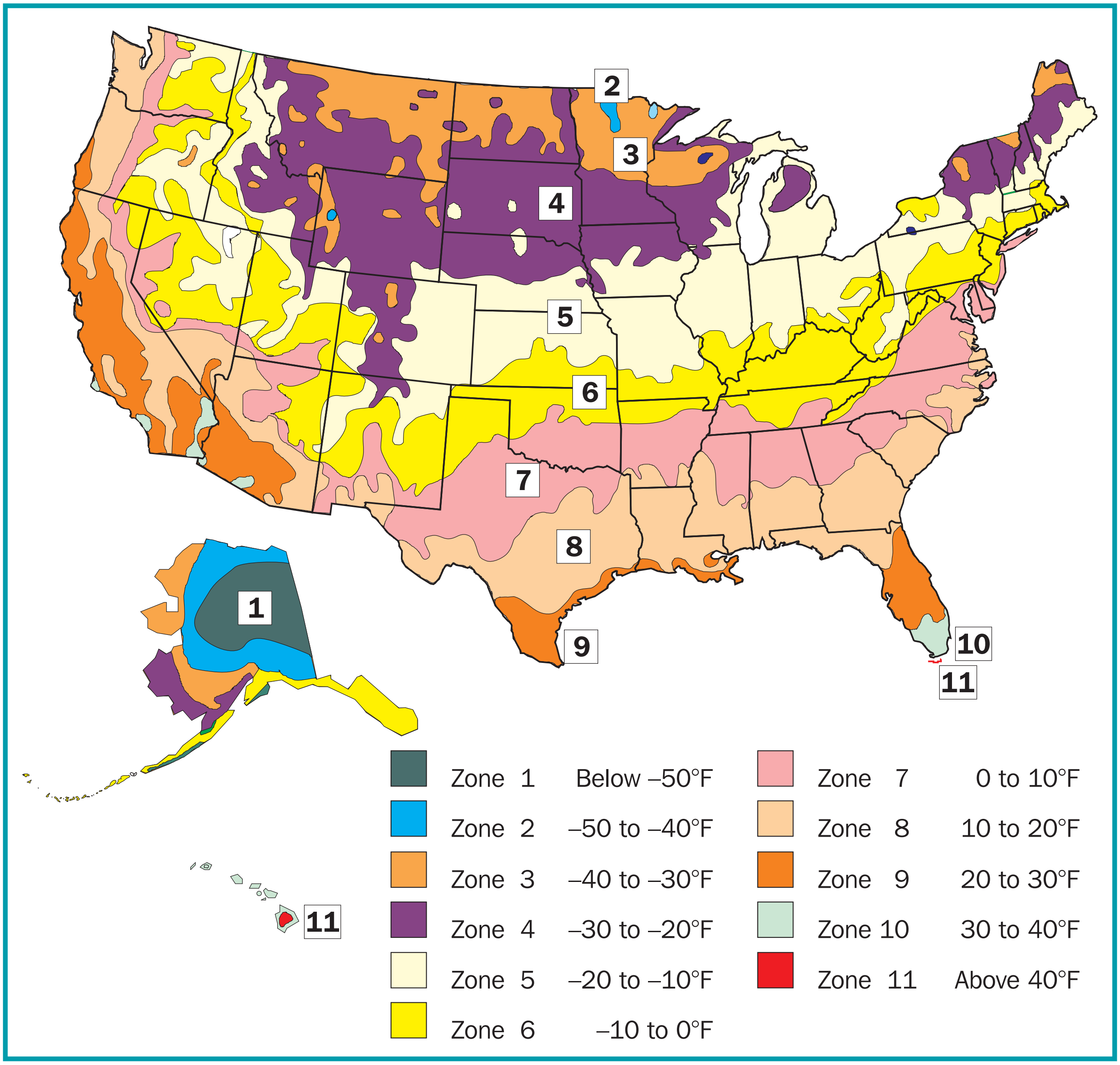


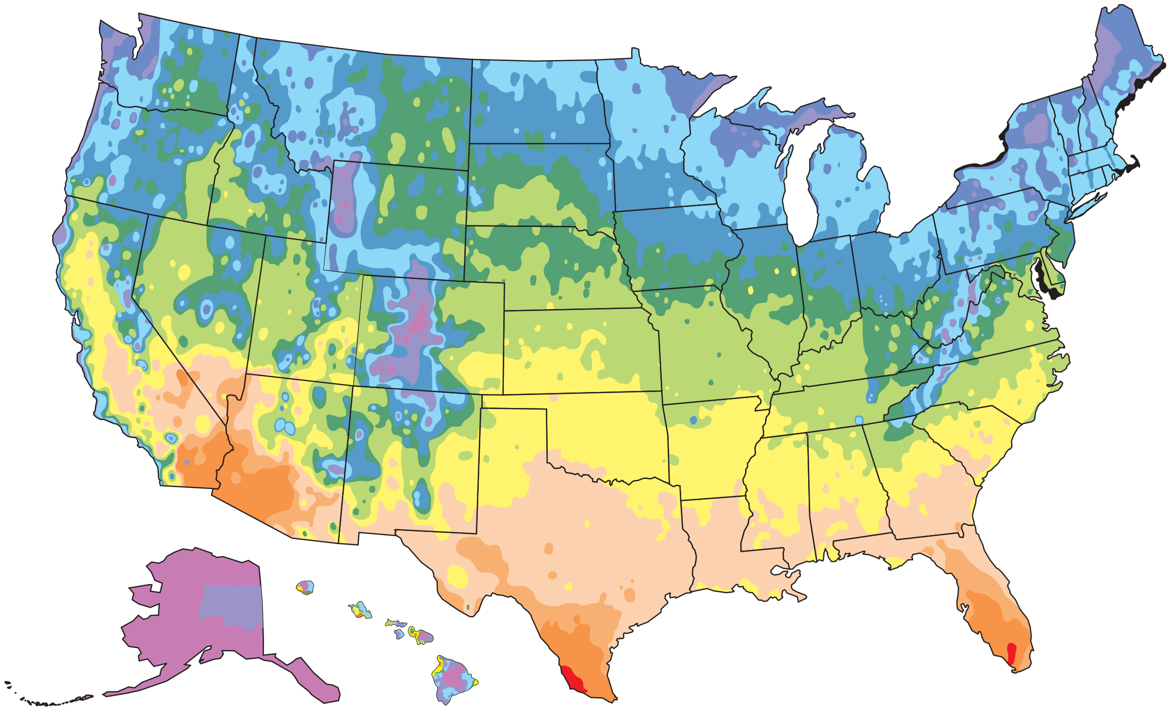
FIGURE 5. The USDA plant-hardiness zone map.

northern Illinois is rated zone 5. Plants can survive in that area as long as they are rated hardy for zone 5. A plant proven to withstand zones 1 through 4 will survive the cold temperature extremes in zone 5, but a plant rated for zones 6 through 11 will likely suffer damage from the cold. Hardiness zones are derived from the average coldest temperatures for the year.

Heat Tolerance

Heat also plays a role in the performance of plant species. Some plants are more sensitive to heat than others.

The **plant heat-zone map** has been developed by the American Horticultural Society to help identify areas in which landscape plants can flourish. The map shows 12 zones. Each zone



Days Above 86°	Zone	Days Above 86°	Zone	Days Above 86°	Zone
Fewer than 1	1	30 to 45	5	120 to 150	9
1 to 7	2	45 to 60	6	150 to 180	10
7 to 14	3	60 to 90	7	180 to 210	11
14 to 30	4	90 to 120	8	More than 210	12

FIGURE 6. The American Horticulture Society plant heat-zone map.

reflects a rating of summer heat based on the average number of days above 86°F. Eighty-six degrees is the temperature at which plants are unable to process water fast enough to maintain normal functions. Plants also experience damage to cellular proteins at temperatures above 86°F.

The inability of a plant to absorb enough water to replace water lost through transpiration can be a problem in hot weather. Plants that lose water faster than it can be replaced become flaccid. This condition is known as **wilting**. The guard cells also wilt, causing the stomata to close. Without an exchange of gases, photosynthesis shuts down.

Thermoperiod

Thermoperiod describes a temperature requirement that produces a plant response. Poinsettias and holiday cacti are examples of thermoperiodic plants. A period of cool temperatures along with short days causes them to initiate flowering.

Vernalization

For some floriculture crops, a period of cold temperature is required for flowering. This physiological process is known as **vernalization**. Bulb crops, including tulips, narcissus, and Easter lilies, must undergo vernalization. A common practice is to expose bulbs to freezing or near freezing temperatures for a number of weeks to satisfy the cold requirement.

FIGURE 7. Easter lilies must undergo vernalization to flower.

DIF

Greenhouse growers use temperature to control the height of plants. They do this by managing the difference between daytime and nighttime temperatures. The mathematical difference between the daytime temperature and the nighttime temperature is called **DIF**.

DIF can be positive, negative, or zero. A positive DIF results when the daytime temperature is higher than the nighttime temperature. Positive DIF causes a plant to lengthen its stems. A negative DIF occurs when the daytime temperature is cooler than the nighttime temperature. Plants grown under negative DIF conditions have limited stem elongation. Zero DIF is a result of identical daytime and nighttime temperatures.

AIR

Air contains oxygen and carbon dioxide, both of which are necessary for plant growth. Oxygen is needed for cellular respiration to occur in a normal manner. It is picked up mainly by the roots of the plant. Carbon dioxide is used for photosynthesis in very high amounts. It usually enters the plant through the leaves via the stomata. In some cases, growers raise the level of carbon dioxide in greenhouses to speed the rate of photosynthesis.

FIGURE 8. Fans can help to increase the exchange of gases in a greenhouse.

Humidity

Humidity, which is water vapor in the air, affects plant growth. The growth rate of plants increases under conditions of high humidity. Lush tropical forests exist, in part, because of frequent rain and high humidity. High humidity reduces water stress on a plant so photosynthesis can function smoothly. If the humidity is low, the dryness of the air can put stress on the plant. This is especially true if soil moisture is inadequate and wilting occurs. One drawback of excessive humidity is an increase of leaf and flower diseases.

Air Quality

Air pollution can be damaging to plants. Dust in the air can reduce light intensity, slowing photosynthesis. Chemical pollutants, such as sulfur dioxide and ozone, can actually kill plant cells or an entire plant.

WATER

FIGURE 9. Watering is the most important cultural practice in horticulture.

Plants get most of their water through their root systems. In some situations, plants can soak up water through their stems or take in water through their leaves.

Watering is the most important cultural practice in horticulture. Life processes, including photosynthesis and respiration, depend on water. Roots can absorb minerals only if the minerals are dissolved in water. Water is the carrier of materials through the xylem and phloem. Water also makes up a large percentage of the plant cells, tissues, and organs.

Water must be given to a plant when needed to avoid damage to the root system. Timing is critical. Frequent applications of water can keep a growing medium too wet. The result may be damaged plant roots caused by the lack of good air exchange. Containerized plants should be grown in pots with drainage holes, so the water can drain and allow oxygen into the root zone. Allowing soils to become too dry between waterings may also cause root death and lower the quality of a crop. A good rule is to water plants thoroughly when they need water and wait until they need water before watering them again.

Water Quality

Water with a pH range of 5.8 to 6.2 is best for most plant growth. If the water supply has a pH outside that range, the pH can be adjusted. A second consideration in determining water quality involves soluble salts. **Soluble salts** are dissolved minerals. Water with high levels of soluble salts is detrimental to plant growth. Soluble salts damage roots.

Summary:

Light color, light intensity, and light duration affect plant growth. Red and blue light have the greatest impact. Plants receiving the optimal level of light will be compact and have good leaf color. The length of a plant's daily light exposure is its photoperiod.

A plant's ability to withstand low temperatures is called hardiness. Heat of 86°F or above limits a plant's ability to process water fast enough to maintain normal functions. Thermoperiod describes a temperature requirement that produces a plant response. Vernalization is a physiological process that involves a period of cold required for some plants to flower. Greenhouse growers use DIF to control the height of plants.

Oxygen is necessary for cellular respiration to occur in a normal manner. Oxygen is picked up mainly by the roots of a plant. Carbon dioxide is used for photosynthesis in very high amounts.

Watering is the most important cultural practice in the horticulture. Water plants thoroughly when they need water and wait until they need water before watering again.

Checking Your Knowledge:

1. How does light influence plant growth?
2. What are the three photoperiod response groups?
3. How does temperature influence plant growth?
4. Why is air important to plant growth?
5. What is a good rule of thumb to follow when watering?

Expanding Your Knowledge:

Contact a local grower or farmer. Ask how weather conditions influence the growth of his or her crops. Be specific, and ask how light, temperature, air, and water affect plant growth. Take notes during the discussion and report to your class.

Web Links:

Light and Plant Processes

http://www.hcs.ohio-state.edu/mg/manual/botany3.htm

Plant Growth Factors: Temperature

http://www.ext.colostate.edu/pubs/garden/07712.html

Water and Humidity

http://extension.oregonstate.edu/mg/botany/h2o_hum.html

Agricultural Career Profiles

http://www.mycaert.com/career-profiles