CHAPTER **TWO**

INTRODUCTION TO HORTICULTURE AND PLANT PHYSIOLOGY

JoAnn Robbins
Former Extension Educator,
Jerome County, Jerome

Susan Bell
Extension Educator
Ada County

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2 INTRODUCTION TO **HORTICULTURE** AND PLANT PHYSIOLOGY

Learning Objectives

- Define horticulture and the different areas of horticulture
- Describe macroclimates and microclimates and discuss how they affect gardens and landscapes
- Explain the role of temperature in horticulture
- Understand how to calculate heat units and their relation to plant growth
- Describe techniques to modify low temperatures in a garden
- Explain the role of light in horticulture
- Understand how light quality, intensity, and duration affect plant growth

Horticulture Defined

Horticulture is defined by Webster's dictionary as "the science and art of growing fruits, vegetables, and flowers." It is the intensive commercial production of high-value and high-yielding plants. But it also includes the cultivation of garden crops and landscape ornamentals and the interaction of science and art.

Horticulture contributes to the economy, provides good nutrition, and is a valuable spiritual and psychological therapy. Horticulture beautifies and enhances the environment. Areas of horticulture include the following:

- **Pomology**. Fruit culture, including pome fruits (apple, pear, quince), stone fruits (peach, cherry, plum, nectarine, apricot), small fruits (blueberry, raspberry, grape, strawberry), and nut tree fruits.
- **Vegetable production**. Culture of food crops from vegetable plants including roots, fruits, and seeds.

- **Floriculture**. Growing of cut flowers, potted plants, bedding plants, and bulbs and floral design.
- **Environmental horticulture**. Nursery production of herbaceous and woody plants for landscape design and management.
- **Postharvest physiology**. Harvest, handling, and storage of horticultural crops including flowers, fruits, and vegetables.

Climate in Horticulture

MACROCLIMATE

The term "climate" refers to the long-term weather patterns of a large geographical area and is used interchangeably with "macroclimate." Macroclimate is determined mainly by an area's latitude, elevation, nearness to large bodies of water, nearby ocean and wind currents, relation to nearby forests and irrigated areas, and location in relation to topographic features such as mountains.

Temperature and light are two fundamental features of climate that profoundly affect gardening. Rainfall, wind, hail, clouds, snow, and humidity also create the climate of a region. Short-term variations in rain, wind, snow, and other climatic characteristics are the weather.

Climatologists have calculated the statistical probabilities of certain climatic occurrences that are likely to affect plant growth. The United States Department of Agriculture hardiness zone map, for example, is based on an area's average minimum temperatures. The Arbor Day Foundation has produced an updated version of the climate zone map based on the last fifteen years of warmer temperatures (1990–2005) (Figure 1).

MICROCLIMATE

Microclimates are variations in climate within a community, yard, or other restricted area and result from topographic features, soil types, aspect, or location of buildings, fences, and/or plantings. Different microclimates will be more or less conducive to differ-

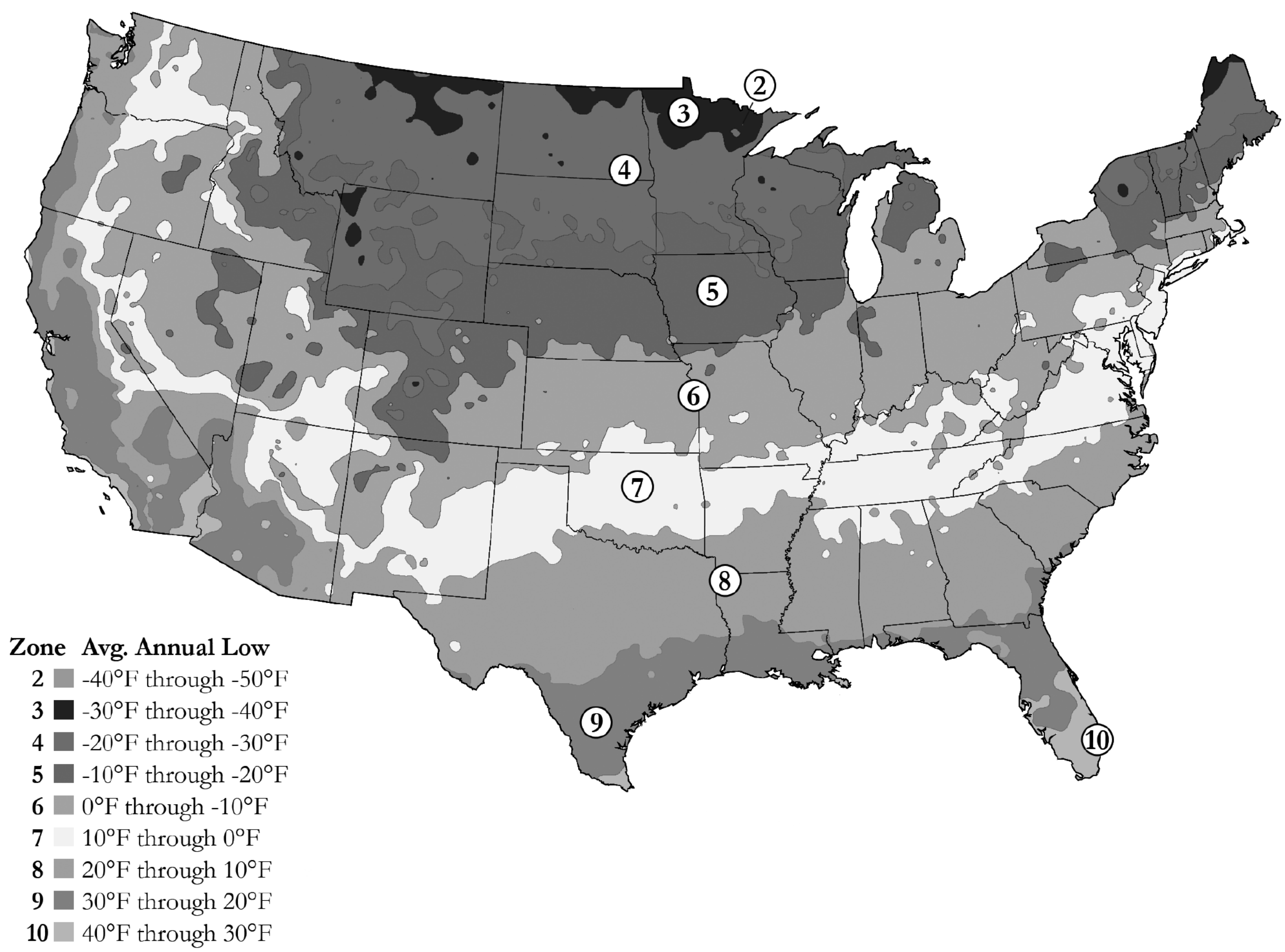

Figure 1. Hardiness zone map of the continental United States. Courtesy of the Arbor Day Foundation.

ent outdoor activities and will limit or enhance the success of plantings. For example, a shady northern exposure may make a better summer patio space than the sunny south side.

Gardeners can create or modify microclimates to increase livability and diversify planting conditions on their property. Landscape features that produce microclimates include the following:

- **Hills and low areas**. Hillside locations are less subject to frost since cold air is denser than warm air and will flow downhill to settle in low areas. A south-facing slope warms earlier in the spring than a north-facing slope, but will be hotter and dryer during summer. The leeward side of a ridge is less subject to wind or breeze than the windward side.
- **Structures**. Structures such as buildings, fences, driveways, or sidewalks serve as heat sinks for solar radiation. Planting areas around them will be warmer, especially on their southern sides or next to pavement. Northern sides of buildings and fences are shady and will remain cooler and moister.
- **Bodies of water**. Water has a moderating effect on air temperature. A lot more energy is required to raise the temperature of water than the temperature of air. Likewise, water releases large amounts of heat energy when it cools. Thus, water acts as a buffer to heat or cold.

Air blowing over cool water will cause adjacent land to warm up slower in the spring, thus delaying bloom and growth. This can protect plants from spring frosts. In the fall, air moving over warm water keeps the surrounding land warmer longer than areas farther away.

- **Elevation**. The higher the elevation, the cooler the temperature; there is less atmosphere to retain the heat from solar radiation at high elevations. Each 300-foot gain in elevation results in an average 1°F drop in temperature.
- **Raised beds**. Raised beds heat quicker than surrounding flat soil surfaces, but plants in raised beds may dry out faster and suffer root damage due to freezing in winter.
- **Plants**. Large plants create microclimates by reducing wind speed, creating shade, and raising the humidity beneath them.

Figure 2. Soil, large objects, bodies of water, and large plants all create microclimates.

- **Soil**. Sandy soil will warm more rapidly in the spring than clay soil and can be planted earlier, resulting in a crop that will mature more rapidly.

By identifying and using microclimates to your advantage, you can maximize the conditions for individual plants or strategically locate garden beds, patios, and other outdoor spaces. The right microclimate often will make the difference between failure and survival for some landscape plants (Figure 2).

Role of Temperature in Horticulture

Temperature is the climatic factor that, more than any other, determines the kinds of plants that will grow in an area. Photosynthesis, transpiration, and respiration increase with rising temperature. Many horticultural crops thrive in warm climates such as California's and Florida's, but are challenged in northern climates like Idaho's. Cold temperatures restrict plant growth, freeze plants in midwinter, and damage plants during fall and spring frosts.

Surviving cold temperatures requires well-adapted plants. Hardiness is especially important for permanent landscape plants such as woody ornamentals and fruit trees.

Each plant type has an optimal temperature needed for growth. Some plants prefer cooler nights or days, whereas others prefer warmer nights or days. Temperate zone vegetables and annual flowers are classified as cool-season or warm-season crops.

Cool-season crops (sweet peas, pansies, garden peas, onions, carrots, potatoes, lettuce, cabbage, and broccoli) grow best in the northern portions of the United States, at higher elevations, or during the spring and fall in warm-climate areas.

Warm-season crops (sweet corn, tomatoes, peppers, melons, zinnias, and marigolds) do best during the warmth of summer in the north but are ideally suited for growth over a longer season in warmer parts of the country. Seeds of warm-season crops require a soil temperature of 60°F or higher to germinate, whereas seeds of cool-season crops will germinate at a soil temperature of just 40°F.

HIGH TEMPERATURES

Plant growth is measured by the food energy produced thorough photosynthesis above that used for respiration. Plants generally grow best at the higher end of their optimal temperature range. In the temperate zone, the minimum temperature for growth is about 40°F. Photosynthesis and respiration increase as temperatures rise until the energy used in respiration equals photosynthetic capacity, when growth ceases. For most plants, this temperature is around 96°F. For many cool-season crops, growth may cease at temperatures considerably lower than 96°F.

Warm temperatures cause stored carbohydrate reserves to be used up thorough respiration or to be converted to starch. This affects the sweetness of crops such as sweet corn and peas and thus their quality.

Very high temperatures can cause physiological damage to plants resulting in burnt leaves and slowed growth. Other high-temperature considerations in plant growth are discussed below.

Overcoming Dormancy

Most temperate zone perennials need a cold period to overcome their physiological dormancy, or rest period, for either the entire plant or only for their flower and vegetative buds. Temperatures that are not cold enough during the winter will keep these plants from forming normal leaves and buds in the spring. For example, peach cultivars for northern climates require 700–1,000 hours below 45°F and above 32°F before they break their rest period and begin growth. If grown in the southern part of the United States, these peaches will not thrive because this requirement is not met.

Vernalization

Some plants require a chilling treatment to induce flowering. This is especially common in biennials and spring-flowering bulbs.

Plant Pests

Plant diseases often grow well at 96°F or higher, increasing the chance of infection. Similarly, insect pests reproduce more rapidly during periods of high temperatures, with resultant high pressure on plants.

Heat Units

Plants have a base temperature below which they grow very little. Average temperatures above a threshold "base" temperature (40°F–50°F, depending on plant type) accumulate on a seasonal basis and are called "heat units" (or "degree days") for that season (Figure 3). Heat units are useful in estimating time of maturity, predicting the latest feasible date for fall planting, and deciding if long-season fruit cultivars will mature in a specific locality.

To calculate heat units, use the following equation:

$$\left(\frac{\text{High temp for day} + \text{Low temp for day}}{2}\right) - \text{Base temp} = \text{Heat units for that day}$$

Add heat units for each day to those of the previous days to calculate the season's total heat units thus far. A negative number for daily heat units does not

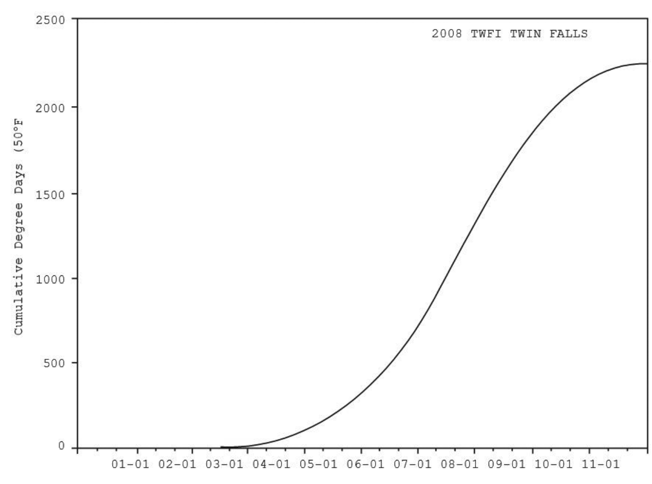

Figure 3. Calculation of accumulated heat units (degree days) in Twin Falls, Idaho, given a base temperature of 50°F (the base temperature for corn). Calculated using the Oregon State University Degree-Day Calculator (http:pnwpest.org/cgi-bin/ddmodel.pl)

decrease seasonal heat units, but rather leaves it unchanged.

Certain sweet corn cultivars mature at 1,500 heat units (degree days). Cool nights like we have in Idaho will slow the accumulation of heat units in comparison with areas of the country that have warm nights. This is why corn labeled "matures in 65 days" can take much longer to mature in a cooler climate!

LOW TEMPERATURES

Many plants are susceptible to frost and cold temperatures. If temperatures are too cool, there will be a lack of plant growth, a failure of seed germination, and some plants will not set fruit. Species originating in the tropics, for example, are injured by temperatures below 40°F.

Plants have a minimum survival temperature below which they will be severely injured or killed. The amount of plant damage depends on many variables such as the kind of plant, the plant part, the nutrients and moisture in the plant tissues, the season of the year, the temperature during the freeze, the temperature after the freeze, the amount of air movement, and the moisture level in the soil. Other low-temperature considerations in plant growth are discussed below.

Premature Flower Stalk Formation (Bolting)

Premature flowering in plants is related to the weather and other environmental conditions. Many biennials will bloom in the first year if cool temperatures follow shortly after planting. Since many biennial plants are grown for their roots, petioles, or leaves rather than for seed, flowering and seed formation make the plant inedible. (Other temperature conditions that will cause plants to bloom early are summer heat and fluctuating temperatures.)

Development of Winter Hardiness or Dormancy

Perennial plants become more cold tolerant in the fall after they shed their leaves. This is part of the "hardening" process brought on by cooler temperatures and shorter days. Freezing temperatures are necessary for most plants to increase their resistance to cold damage, while sustained freezing temperatures are necessary for maximum cold tolerance.

If temperatures rise for any length of time, plants lose their tolerance to the cold. Cold tolerance will return with colder temperatures, but not if the buds have broken dormancy. Buds will break dormancy during a warm spell if they have already been exposed to chilling temperatures for the period required for bud break. This type of damage is common in northern climates like Idaho's.

Carbohydrate Reserves

Plant tissues well supplied with carbohydrates will reach deeper dormancy and be less susceptible to winter cold. Make fertilizer applications and prune well in advance of cool fall temperatures. Plants that are stress free and without new growth will move carbohydrates to the roots and other storage tissues in the fall. Stress from insects, diseases, or other sources will lessen carbohydrate production and storage.

Water Status of Plant Tissue

Winter damage can occur due to a lack of moisture in the plant or plant part. If the plant goes into the winter with little moisture in the root zone, or if dehydration occurs while the soil is frozen, the plant will be injured due to water stress. This is called "physiological drought." This type of damage is particularly detrimental to evergreen trees and will show up as browning needles that dry from the tips down.

The windward and sunny, southwest sides of trees are particularly at risk for browning needles and for bark injury called "sunscald." The windy conditions that are common in many parts of Idaho will intensify injury due to cold temperatures and physiological drought.

To prevent this damage, supply ample moisture during the growing season. However, it is advisable to cut back on moisture in late August and early September in order to allow the plant to enter its dormancy. Water well again in late October or early November after the plant has become completely dormant. Plant roots are still active up until the ground freezes and soil temperatures drop below 40°F.

Frost Heaving

Alternate freezing and thawing can force some plants completely out of the soil. This is called "heaving" and young plants without a well-established root system are particularly susceptible to this type of damage, especially when planted in the fall.

Spring Frosts

Cold temperatures will freeze tender transplants, emerging seedlings, and opening buds in the spring. Fruit buds are easily frozen once they begin to expand and bloom. Even expanding leaf buds can freeze when unusually cold spring temperatures occur. On still nights, when temperatures hover near freezing, cold air, which is heavier than warm air, will settle to the bottom of valleys and depressions. These cold spots are called "frost pockets" and may result in cold damage to plants in that area.

TEMPERATURE MODIFICATION

Modifying High Temperatures

You can modify high temperatures by shading plants with larger plants or with structures such as lath houses. Shade cloth suspended over plants will also moderate temperature. Cooler conditions exist on the shady side of a building and under trees.

Plants poorly adapted to high temperatures are not good choices in hot, dry areas because extreme measures must be taken to ensure their survival.

Modifying Low Temperatures

There are many ways to avoid or modify cold temperatures. The most obvious are planting frost-susceptible annual crops after all frost danger is past and selecting perennial plants that are adapted to the cold temperatures in your area. Other methods of modifying cold temperatures include the following:

- **Using covers or heat sinks.** Surround the plants with medium- to large-sized rocks to absorb heat or cover them with fabric row covers, plastic sheeting, or waxed paper cloches in early spring or when frosts are predicted. These techniques reduce outgoing stored solar radiation from soil, rocks, and plants. Depending on the type of cover, you can gain 2°F–6°F of nighttime warmth. Remember that during sunny days it may be 20°F–25°F warmer under the cover, which may require venting to keep plants from becoming too hot.
- **Mulching**. Use a covering of mulch to modify soil temperature. Applied soon after the ground freezes in early winter, mulch will keep the soil frozen and the covered plant crowns at a consistent cold temperature to prevent winter damage. Applied in the spring after the soil warms, mulch moderates soil temperature extremes during the growing season.

  Certain dark or colored mulches can warm the soil early and maintain warmer temperatures when the weather is still cool. To be most effective, an organic mulch layer should be 3–4 inches deep. Small stones can be used as mulch to gather heat around plants.
- **Using heaters or fans**. Protecting tree fruits from early spring frosts is done in orchards using heaters or large fans. This equipment stirs the air and prevents an air "inversion," when cooler air is trapped under a layer of warm air.
- **Sprinkling**. When liquid water changes to solid ice, it releases heat. When water is sprinkled on plants as they cool, the heat of freezing will keep the plant surface at or near 32°F. This technique is often used in orchards during bloom time when frost or cold temperatures are predicted.

Role of Light in Horticulture

Light is the part of the sun's energy visible to the human eye. Solar radiation reaching the earth includes some light near and on either side of the visible light spectrum. Plants use mostly those light rays that can be seen (Figure 4).

LIGHT QUALITY

Water vapor in the air acts as a prism to separate light into its various wavelength components. The human eye interprets these wavelengths as color. Beginning with the longest visible wavelength, the rays become shorter through the rainbow color spectrum: red, orange, yellow, green, blue, indigo, and violet. Violet rays are the shortest and are slightly longer than ultraviolet rays, which cause sunburn.

The following rays are used by plants in physiological processes (Figure 4):

- **Violet.** These are important for the development of red pigments in plants like apples. At higher elevation, there is less atmosphere to screen out the violet and ultraviolet, resulting in well-colored apples (and maybe sunburn on our skin!). Indigo and violet rays are also responsible for bending flower heads and other plant parts toward the sun (phototropism).
- **Blue-violet and orange-red**. These rays provide the light energy for photosynthesis. In fact, plants appear green to the human eye simply

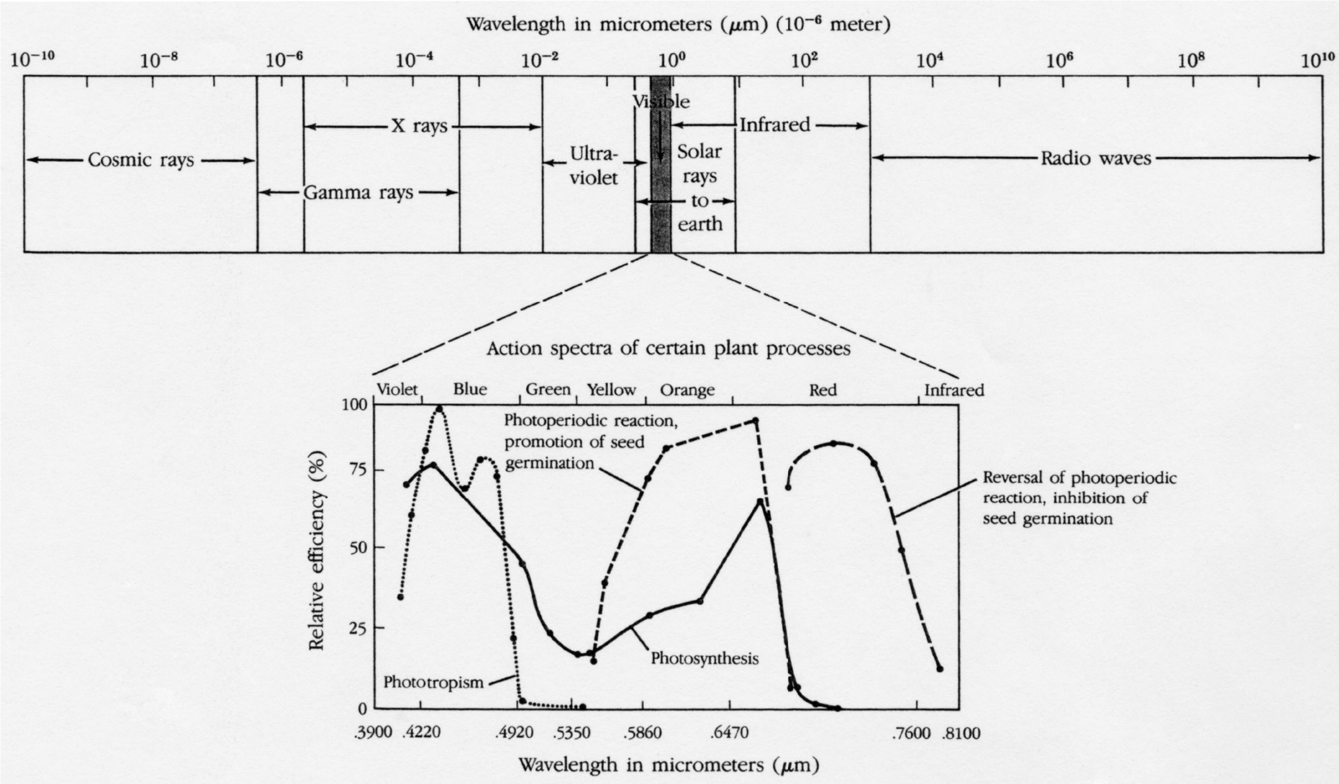

Figure 4. Wavelengths and the responses of plants to the visible rays. (Reprinted from Bienz, D.R. 1980. *The Why and How of Home Horticulture*. San Francisco: WH Freeman.)

because plant pigments in leaves do not absorb and use green light for photosynthesis; instead, it is reflected back to our eyes.

- **Orange-red and far-red (longer than red)**. This part of the spectrum is absorbed by plants and produces the day-length response (photoperiodism).

Supplemental light varies in quality, with fluorescent or cool white bulbs emitting wavelengths in the blue range. Incandescent light is high in the red and orange ranges but also emits the longer heat waves and is too warm to be useful for plant growth. The light bulbs specifically designed for plants are balanced in the wavelengths used by plants.

LIGHT INTENSITY

Gardeners generally use foot-candles to measure intensity or concentration of light, even though the foot-candle is an older unit based on English measurements (amount of light falling on 1 square foot from a candle burning 1 foot away). You will also hear the term *lux* to indicate the amount of light that falls on a surface. Lux is a metric unit equal to 1 lumen per square meter. One foot-candle is 10.76 lux. Physicists use a more precise mathematical measure (millimoles per square meter per second). Gardeners use foot-candles because many existing light meters are calibrated in foot-candles.

In full sunlight at noon on a summer day in the desert, light intensity measures about 12,000–15,000 foot-candles, possibly as high as 20,000 foot-candles. Light intensity is less in the morning and late afternoon because light from the sun reaches the earth at an oblique angle, filtered through more layers of atmosphere before reaching the surface. For the same reason, light intensity is much lower in winter in the Northern Hemisphere. On a heavily overcast winter day at noon, light intensity may be as low as 600–900 foot-candles in northern latitudes. The interior of a well-lighted home will measure from 50–300 foot-candles.

Tropical plants, like many of our houseplants, thrive in nature under a jungle canopy that provides very low light intensity. Plants not from the jungle are able to grow in and use very bright or intense light. Most crop plants use about 1,200 foot-candles of light, but they will grow better in light up to 4,000 foot-candles because of the shading from surrounding leaves.

Plants and leaves adapted to low light intensity will sunburn, wither, or die if they are suddenly exposed to higher light intensity. Light intensity can be decreased through shading or increased with supplemental lights, reflective material, or white backgrounds.

Insufficient light will cause plants to stretch and become "gangly" or unusually long. Nodes will be far apart, leaves broad and thin, and the plants will have a loose, open structure. Reduced light intensity can also induce succulence.

LIGHT DURATION

Plants respond to particular day lengths. Actually, processes that occur during an uninterrupted dark period bring about the plant's response, not processes that occur during the day, but we use day length as the measure. How plants respond to day length is modified somewhat by temperature. Depending on the plant type, blooming, for example, may be delayed or sped up by warm or cool weather. The bloom period can be intentionally altered with specific light treatments or unintentionally altered by lights coming from streetlights or other artificial sources.

Long-Day Plants

Long-day plants respond to day lengths longer than a certain minimum (usually about 12 hours). Spinach, for example, is a long-day plant and, if planted late in the spring, it will make a flower stalk before producing leaves.

Onion bulbing is a long-day response. Onions produce bulbs during long days, and onion types that do well in northern latitudes require longer days (16 hours) compared with those adapted to more southern locations (11–12 hours). Northern-type onions will not produce bulbs in southerly locations because the days never get long enough! Southern types, when grown in the north, produce bulbs before the plant reaches a size adequate to develop a good-sized onion bulb.

Short-Day Plants

Short-day plants respond to day lengths shorter than a certain maximum (less than about 12 hours). Chrysanthemums are short-day plants and will bloom when day lengths range from 16 hours down to 7 hours depending on the cultivar. They grow and develop plant tissue and carbohydrate reserves during the spring and summer to support fall flowering. Poinsettia is another short-day plant.

Day-Neutral Plants

Day-neutral plants do not respond to day length, but must have sufficient growth to support flowering. Temperatures must also be acceptable, roughly above 32°F and below 96°F. Geraniums and certain strawberry cultivars are examples of day-neutral plants.

Further Reading and Resources

BOOKS

Benz, D. R. 1980. "Climate, Temperature and Light." Chapter 7 in *The Why and How of Home Horticulture*. San Francisco: WH Freeman.

BOOKLETS AND PAMPHLETS

University of Idaho Extension

PNW 497 *Short-Season Vegetable Gardening.*

Websites

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Chapter 2 published 1993. Revised 2008.