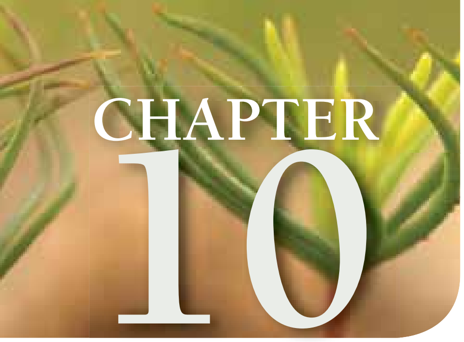

CHAPTER 10 Environmental Conditions for Growth

Chapter Outcomes

After studying this chapter, you will be able to:

- Discuss how light quality, quantity, and photoperiod affect plant growth.
- Compare strategies to optimize light quantity for plant production.
- Explain different responses plants have to temperature.
- Summarize techniques to manage temperature for crop production.
- Explain how water is applied for greatest plant growth and development.
- Compare and contrast careers in horticulture environmental management.

Words to Know

air drainage
biennial
blanching
chilling injury
daily light integral (DLI)
degree day
DIF
dormancy
etiolation
freezing injury
heat stress
irrigation
juvenile stage
light quality
light quantity
microclimate
nanometer (nm)
necrosis
photoblastic
photon
photoperiod
phototropism
plant hardiness zone
polycarbonate
polyethylene
Q10
root zone
slope orientation
stratification
sunscald
thermoperiod
vernalization

Before You Read

Review the chapter headings and use them to create an outline for taking notes during reading and class discussion. Under each heading, list any term highlighted in ***bold italics***. Write two questions that you expect the chapter to answer.





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While studying this chapter, look for the activity icon to:

- **Practice** vocabulary terms with e-flash cards and matching activities.
- **Expand** learning with the Corner Questions and interactive activities.
- **Reinforce** what you learn by completing the end-of-chapter questions.

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Have you ever noticed a home gardener putting a cloth sheet over young tomato transplants? Or starting lettuce under a cold frame? These gardeners are attempting to modify the air temperature around the plant in hopes of preventing any injury from low temperatures. Horticulture is a practice of managing environmental conditions to cultivate successful crops. Understanding the growing needs of plants and the ways to control essentials such as light, temperature, and water is key to uncovering the secrets of plant growth and development.

Pat Hastings/Shutterstock.com

Figure 10-1. Observe how light has shaped the growth habit of this plant, causing it to elongate and become spindly. Would rotating the potted plant each day have helped promote a straighter, stronger stem?

Light

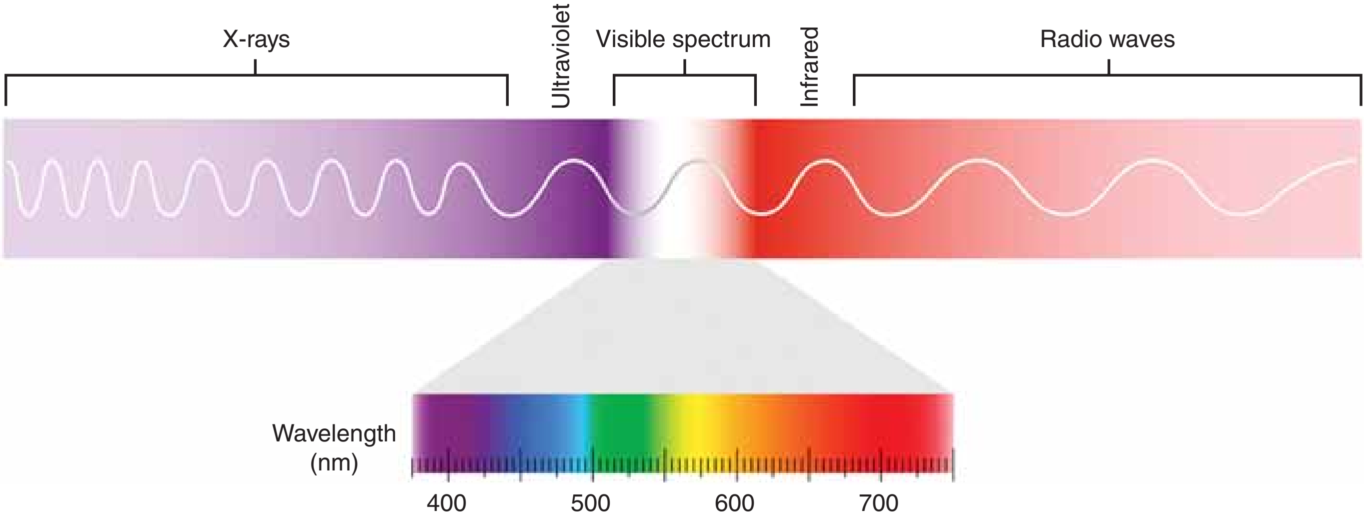
All horticultural plants require light to grow and develop. As discussed in Chapter 9, *Plant Growth and Development*, light is critical for creating chemical energy through photosynthesis. Light is important in other ways, too. It plays a role in pigment formation (chlorophyll, carotenoids, and anthocyanins), some seed germination, growth habit, **Figure 10-1**, shape and size, flowering, fruiting, dormancy, hardiness, plant movement, formation of storage organs, fall color, and leaf drop in temperate climates.

Light varies in its quality, quantity, and photoperiod, and plants respond accordingly. ***Light quality*** refers to the specific wavelengths of light that a plant receives. ***Light quantity*** is the amount and duration of light emitted by the light source, whether it is the sun or a lamp. The ***photoperiod*** is the duration of day length (the amount of time that light is present) and the relationship between the dark and lighted periods.

Light Quality

Imagine a bright yellow flower. As light strikes the flower, the yellow color you perceive is actually the wavelength of light that is reflected by the flower. The only light reflecting from the flower is in the yellow spectrum; the other colors of light are being absorbed by the flower. Plants primarily absorb light in the visible wavelength range of 400 to 700 nanometers, **Figure 10-2**. A ***nanometer (nm)*** is the unit of measurement used to quantify light wavelengths.

In addition to visible light, the light spectrum includes ultraviolet light (which is not involved in plant processes) as well as far-red and infrared light that play an important role outside of photosynthesis. Although plants absorb across the visible wavelength range of 400 to 700 nanometers, the greatest impact on plant growth is at peaks in red light (650 nm) and blue light (475 nm). Plants respond to the quality of light available. If only blue light is applied to plants through special lighting, plant growth will be shortened, hard, and dark in color. When plants are grown in only red light, the growth becomes elongated and soft. Red and blue light combined promote flowering.



Designua/Shutterstock.com

Figure 10-2. This graph illustrates the entire spectrum of light, including both visible light, far-red, infrared, and ultraviolet light. Far-red light is light at the extreme end of the visible spectrum (between red and infrared light). Infrared is invisible radiant energy with longer wavelengths than those of visible light and ultraviolet light is a form of radiation that is not visible to the human eye.

Light quality management occurs primarily in greenhouses as little can be done to alter ambient light conditions in open fields. The emphasis of light quality management is to provide efficient and sufficient light for photosynthesis. Few practices exist to manipulate light quality in a cost-effective way to influence growth. However, recent research suggests that there may be ways to control growth. For example, it may possible to constrain the vegetative growth of strawberries to promote flowering and increase fruiting.

Photoblastic Seed Germination

Seeds that are influenced by the presence or absence of light are considered ***photoblastic***. Seed responses to light may be positive or negative, meaning that germination can be stimulated or inhibited. Most seeds do not require light to germinate. However, there are a few important exceptions that require light to overcome dormancy. These plants include carrots, lettuce, rubber plant, gloxinia, and zoysia grass. Growers will seed these crops on the soil surface to maximize germination. Unfortunately, many weed species also require light to germinate and the practice of tilling brings these weed seeds to the soil surface. For weed seeds that are positively photoblastic, this increases their germination and potential for competition with horticultural crops, **Figure 10-3**. Seed germination can also be inhibited with exposure to light, as in tomatoes and lilies. These seeds should be planted where no light reaches them.

makspogonii/Shutterstock.com

Figure 10-3. Tillage brings positively photoblastic seeds buried in the soil to the surface where they germinate easily and compete with horticultural crops. Are there methods to prepare the soil that would result in less photoblastic weed seeds brought to the surface?

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Figure 10-4. The leaves of this hosta plant are showing necrosis after exposure to high light intensities.

Light Quantity

Have you ever planted a shade-loving plant, such as a hosta, in full sunlight? Does the plant thrive or deteriorate? For many shade-loving plants, too much light can "burn" the plant, causing cellular damage that results in leaf ***necrosis*** (death), **Figure 10-4**. Light quantity is the number of ***photons*** (light particles) capable of performing photosynthesis. Light quantity is measured by how much light instantly reaches the plant (light intensity) and how much light a plant has received throughout the day, called the ***daily light integral (DLI)***.

Daily Light Integral (DLI)

Increased amounts of light intensity directly increase rates of photosynthesis. Each crop species has an optimal light intensity that maximizes plant growth through photosynthesis. When there is limited light available, plant growth and quality can decline. If there are excessive amounts of light, no real growth gains will be achieved. In some cases, such as the example of the hosta, higher-than-optimal light intensities can actually slow growth of certain plants because damage may occur.

The daily light integral measures the duration of light intensity throughout the day. Light conditions fluctuate during the day with increasing or decreasing cloud cover and sunlight. It is important to know how much light reaches plants during the day. Think about the daily light integral as a gauge that records the amount of light that "falls" in a 24-hour period. The quantity of light a plant receives determines characteristics such as branching, rooting, stem thickness, flower number, and plant height.

Did You Know?

The photic sneeze effect is a genetic tendency to begin sneezing when suddenly exposed to bright light. This reaction is harmless and it is thought to affect about 18% to 35% of the human population!

Etiolation and Blanching

Etiolation is a plant growth response in absence of light. This phenomenon occurs when plants or plant parts are covered to exclude light and plant parts continue to develop. If you have ever removed a tree branch from a lawn and seen long, pale seedlings where the tree branch was, this is an example of etiolation. Etiolation is a common practice when producing certain vegetable crops, such as cauliflower or asparagus. For these items, consumers demand a tender crop with mild flavor. In cauliflowers, growers will tie up leaves around the developing head, **Figure 10-5**. The resulting harvest is a curd (head) that is very white and considered high quality. Keeping plants from light to prevent photosynthesis and to cause white tissue growth is called ***blanching***. Cauliflower grown without the blanching process will yield heads with stronger flavors and a slightly yellow color.

Rosemarie Robson, Robson's Farm LLC

Figure 10-5. Growers may tie the leaves of cauliflower heads to promote blanching and mild flavor. How would the labor needed to tie the leaves affect the cost of producing a cauliflower crop?

Photoperiod

Plants have growth responses based on the number of hours of light they receive each day. This phenomenon is called *photoperiodism*. It has horticultural importance primarily for flowering but also for the development of storage organs, stem elongation, fall color, and leaf fall. Length of light exposure is important, as well as the uninterrupted darkness that follows. Each plant species has its own photoperiod requirements. Horticulturists have determined ways to control lighting to get a desired growth response, such as flowering.

Plants have a ***juvenile stage***, which is a period of growth that occurs before they reach adult form. In this stage, flowering will not occur; only vegetative growth happens, regardless of light conditions, **Figure 10-6**. Plants are grouped into three categories that define their light requirements for flower production:

- Day-neutral plants.
- Long-day plants.
- Short-day plants.

Day-Neutral Plants

Day-neutral plants can flower under a wide range of day lengths and flower when they reach the adult stage of growth. Examples include cucumber, sweet corn, dandelion, and ever-bearing strawberry, **Figure 10-7A**.

Long-Day Plants

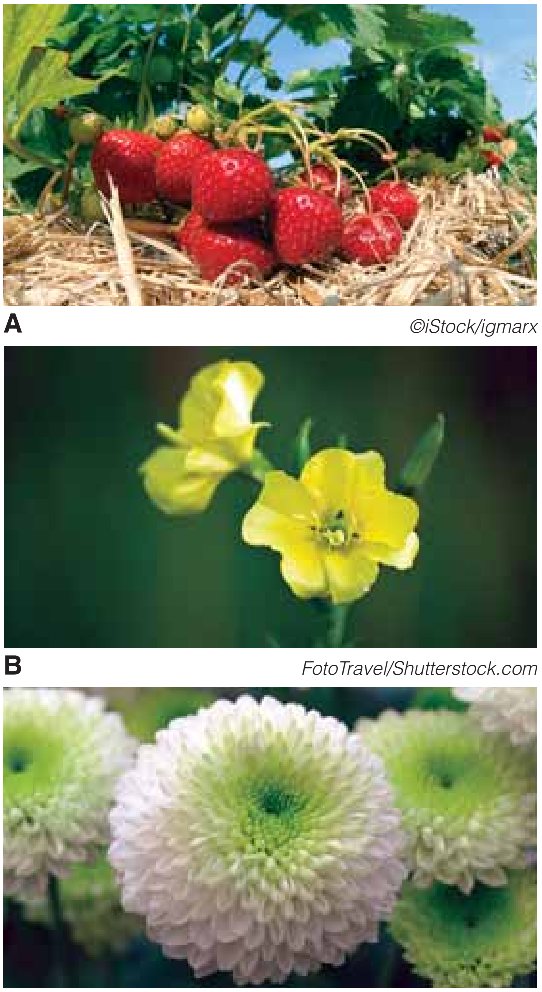
Long-day plants can flower if the light period is as long or longer than the critical day length. Critical day length is the range of light hours per day that plants need to flower; this varies among plant species. For example, many plants, such as spinach, dill, and evening primrose, flower under long days during summer months, **Figure 10-7B**.

Short-Day Plants

Short-day plants can flower when the light period is shorter than the critical day length, which varies by species or even cultivars within a species. Common examples of short-day plants are goldenrod, kalanchoe, poinsettia, and chrysanthemum, **Figure 10-7C**. These plants typically flower under short days, usually in the late summer or fall.

©iStock/siloto

Figure 10-6. English ivy has a distinct juvenile leaf compared to its adult leaf.



A ©iStock/igmarx

B FotoTravel/Shutterstock.com

C happykamill/Shutterstock.com

Figure 10-7. A—Ever-bearing strawberries are day-neutral, which allows them to be grown in high tunnels in the winter. B—Evening primrose is a long-day plant and typically flowers during the long days of summer. C— Chrysanthemum is a common short-day plant that requires between 7 to 16 hours for flowering.

"A good farmer is nothing more nor less than a handy man with a sense of humus."
—E. B. White

Lighting and Forced Flowering

Horticulturists have developed lighting protocols to force flowering for a target date or to encourage increased vegetative growth for larger plants. For example, research at Michigan State University resulted in a growing method to produce flowering summer perennials in the spring, at a time when they would normally only display vegetative growth. Kalanchoe have a critical day length of 14.5 hours and will flower if the length of day is shorter than 14.5 hours. If the plant receives more than 14.5 hours of light a day, it will continue to grow, but it will not flower. Short-day plants can also be kept in a vegetative growth state by interrupting the dark period. This actually requires fewer hours of light (and less energy) than extending the day. An incandescent lamp uses bulbs similar to those traditionally used in homes. These lamps have historically been used to interrupt the dark period. However, LED lighting may soon replace these lights. LED lighting can be used to provide both photosynthesis and photoperiod lighting.

Icswart/Shutterstock.com

Figure 10-8. Shade cloth eliminates light disruption during a dark period necessary for flowering (usually for short-day plants). What other methods are used to block light from plants in a greenhouse?

Light Pollution

In many cases, light pollution from various sources (car headlights, streetlamps, athletic field lights, and other sources) will provide unwanted interruption of a dark period. Growers will sometimes pull a shade cloth or black plastic across the plants to prevent unwanted light from reaching the plants, **Figure 10-8**.

Storage Organ Development

Photoperiod also influences the development of storage organs, such as tubers in potatoes or Jerusalem artichokes. Tuber development in these crops is stimulated by short days, whereas the bulb formation in onions and garlic are a long-day response. The runners of spider plants and strawberries result from long days of 12 to 14 hours or more. In some cases, plants have dual requirements of both photoperiod and temperature for dormancy, fall color, leaf fall, and cold hardiness.

Phototropism

The last growth response related to light is the bending of a plant toward or away from a light source. This is called ***phototropism***, photo meaning *light* and tropism meaning *movement*. Recall a time where you may have noticed a houseplant sitting on a window ledge and growing toward the light. This is a positive phototropism, **Figure 10-9**.

Pat_Hastings/Shutterstock.com

Figure 10-9. Plants that grow toward the light are positively phototropic.

Philodendron and monstera are two tropical vines that are often grown as houseplants. These plants exhibit negative phototropism, which is a movement away from a light source. Another common example is the movement of sunflowers in response to the sun. The blooms track the sunlight throughout the day, moving their large flower heads as the sun travels across the sky.

Optimizing Light Quantity

Light quantity can be increased or reduced depending on the needs of plants. Some light management strategies that growers may use include:

- Plant spacing and orientation.
- Greenhouse design.
- Greenhouse covers.
- Supplemental lighting.
- Plant selection.

Plant Spacing and Orientation

Plant spacing and orientation can maximize a plant's ability to intercept light. In field settings, a grower will use ideal spacing for a particular crop to increase yield as well as to shade weeds. Weeds can significantly reduce light received by crops, resulting in reduced plant quality and yield. If plant spacing is too close, the overcrowding of plants can reduce quality as leaves shade each other and stems elongate. This might happen when transplants are planted too close to one another, or seeds are not thinned properly. In a garden situation, planting taller plants at the back of a border with medium and smaller plants toward the front will minimize any potential shading issues, **Figure 10-10.**

Similar spacing needs to occur in a greenhouse as well. Potted plants should be placed close enough together to use space efficiently and to have the proper amount of light reaching all parts of the plants. Most growers consider spacing acceptable when the leaf tips of adjacent plants barely touch. As plants increase in size, containers can be moved to keep proper spacing.

Paul Wishart/Shutterstock.com

Figure 10-10. With the tall plants in the back of the garden and short plants in the front, this garden minimizes any potential shading issues.

Pruning

Pruning can also help increase light interception and flowering in many plants. Thinning branches will allow greater quantities of light to penetrate into the interior areas of a plant. In fruit production, pruning will enhance yield, improve fruit color, increase air circulation, and minimize disease. Poor pruning can inhibit light interception by the plant and leave shaded sections that will have reduced vigor and vegetation. In a hedge, a wider base and narrower top will allow the best light conditions for the plants.

Greenhouse Design

Greenhouse design and orientation can maximize the amount of available light for plant production. Variables such as climate, latitude, and time of year impact levels of light intensity. The primary factor limiting crop production in greenhouses is low light intensity during the winter. Orienting single greenhouses situated above a latitude of 40°N with the ridge running east to west allows for the winter sun to reach into the greenhouse along the sides. Greenhouses located below the 40°N latitude can be oriented north to south because the angle of the sun is higher. Many greenhouses are connected along their length and, regardless of latitude, should be oriented north to south to avoid shadows.

Greenhouses located at high altitudes have an advantage of higher light intensity. Much of the greenhouse production of roses and carnations, both crops that require a high light intensity, are grown in the high mountains of countries such as Columbia and Ecuador, **Figure 10-11**.

Velychko/Shutterstock.com

Figure 10-11. High altitudes provide high light intensity, creating perfect growing conditions for valuable cut flowers such as roses. Does growing plants in high altitudes present additional challenges?

Greenhouse Covers

The material used to cover greenhouses plays a critical role in allowing light transmission. Common materials used to cover a greenhouse include:

- Glass.
- Polycarbonate.
- Polyethylene film.

STEM Connection

Plants Producing Light?

We know that plants need light to drive photosynthesis for normal growth and development, but what about an autotroph that produces its own light? Well, sort of! Clubmoss (Lycopodium) is an herbaceous perennial with "pyrotechnic" spores that can ignite like fireworks. The spores contain volatile oils that are highly flammable and create a brilliant burst of fire when ignited. Where does Lycopodium grow? Is the plant harvested for human use?

Kurkul/Shutterstock.com

Glass allows the highest levels of light to reach the crops. ***Polycarbonate*** is a type of thermoplastic polymer that can be used as a greenhouse covering. ***Polyethylene*** is a type of plastic that also can be used as a greenhouse covering. Both polycarbonate and polyethylene provide adequate light for many crops and can be less expensive than glass. In the summer months, light intensity can become too intense and growers may use paint to coat the greenhouse and provide shade. The paint can be removed at the end of the season. Some growers may place a shade cloth over a greenhouse or use it within the greenhouse to minimize light intensity.

Supplemental Lighting

During the dark winter months, greenhouse managers struggle to maintain levels of light intensity needed for most crops. Supplemental lighting helps increase rates of photosynthesis and results in increased plant quality, **Figure 10-12**. Four different types of lamps used in greenhouses include:

- High intensity discharge (HID) lamps include lamps such as high-pressure sodium (most commonly used) or metal-halide, the preferred light sources for plant growth and development in greenhouses. Their light is rich in orange light and deficient in blue and red light.
- Fluorescent lamps offer uniform light intensity with little levels of heat emitted. They are commonly used in seed germination chambers but rarely used to finish a crop.
- Incandescent lamps are generally not used for supplemental lighting because they give off excessive heat, have poor light quality (red and far-red light), and have low efficiency. They are very useful in managing photoperiodic lighting as discussed earlier.
- LED lamps are a relatively new technology. While much research is still being done, they offer exciting potential for use in both photosynthetic and photoperiodic lighting. They have low energy emissions.

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Figure 10-12. Supplemental lighting helps growers increase the quality of their plants and allows them to extend growing periods.

Plant Selection

For a home gardener, plants should be chosen to fit a given light situation. If a home has a deeply wooded lot, the plant material that will thrive will be different from plants appropriate for a sunny location.

A Shebeko/Shutterstock.com

B periphoto/Shutterstock.com

Figure 10-13. A—Full sun locations are ideal for fruit and vegetable production. B—Partial shade situations create ideal conditions for shade-loving ornamentals.

Gardeners should survey their landscape for lighting conditions and select plants that fit each environment accordingly. Most nurseries label plants according to their lighting needs. This list describes light classifications for a home gardener:

- Full sun areas receive direct sun for at least six hours a day, between 9 am and 4 pm, **Figure 10-13A**.
- Light shade areas receive significant amounts of direct sunlight, with the sun being blocked for two to three hours during the summer months. Light shade areas may also receive constant but filtered light through a fairly open canopy.
- Partial shade areas receive dappled sunlight filtered through trees. The amount of light that reaches plants depends on the density of the overhead canopy, **Figure 10-13B**.
- Full shade areas may receive reflected light, but other plants or structures block direct sunlight. Only shade-tolerant plants will thrive in full shade.
- Dense or deep shade areas receive very little indirect or reflected light. This situation can be found under a dense canopy of mature trees or under an elevated deck.

Temperature

From the icy, arctic winds of the tundra to the hot, arid reaches of the desert, plants have evolved to grow under a variety of temperatures. Most horticultural plants thrive in a temperature range between 50°F to 85°F (10°C to 30°C). Temperature requirements of a crop help determine in which climate they are best suited for growth, the best season in which to produce the plants, and ways to manage temperature. Examine **Figure 10-14** and observe the preferred temperature ranges of certain vegetable crops.

Q10 Temperature Coefficient

As noted in Chapter 9, temperature directly impacts rates of photosynthesis and respiration. For each 18°F (10°C) increase in temperature, the rate of reaction doubles. If a snapdragon is growing at temperatures of 50°F (10°C), it would be growing twice as fast if the temperature was 68°F (20°C). This relationship is known as ***Q10***. Growers who want to manage crop timing for a target sale date or a holiday can increase temperatures to promote faster growth.

Corner Question

Can a shade plant grow in the sun?

Vegetable	Germination Temperature		
	Minimum	Optimum	Maximum
Cool-season vegetables prefer temperatures between 50°F to 80°F (10°C to 26.7°C).			
Beets	40°F (4.4°C)	80°F (26.7°C)	90°F (32.2°C)
Broccoli	40°F (4.4°C)	80°F (26.7°C)	90°F (32.2°C)
Cabbage	40°F (4.4°C)	80°F (26.7°C)	90°F (32.2°C)
Carrots	40°F (4.4°C)	80°F (26.7°C)	90°F (32.2°C)
Cauliflower	40°F (4.4°C)	80°F (26.7°C)	90°F (32.2°C)
Kohlrabi	40°F (4.4°C)	80°F (26.7°C)	90°F (32.2°C)
Leeks	40°F (4.4°C)	80°F (26.7°C)	90°F (32.2°C)
Lettuce (leaf types)	35°F (1.7°C)	70°F (21.1°C)	70°F (21.1°C)
Onion, green	35°F (1.7°C)	80°F (26.7°C)	90°F (32.2°C)
Onions, dry (seed)	35°F (1.7°C)	80°F (26.7°C)	90°F (32.2°C)
Parsnips	35°F (1.7°C)	70°F (21.1°C)	90°F (32.2°C)
Peas	40°F (4.4°C)	70°F (21.1°C)	80°F (26.7°C)
Potatoes	45°F (7.2°C)	–	–
Radish	40°F (4.4°C)	80°F (26.7°C)	90°F (32.2°C)
Spinach	40°F (4.4°C)	70°F (21.1°C)	70°F (21.1°C)
Swiss chard	40°F (4.4°C)	85°F (29.4°C)	95°F (35°C)
Turnips	40°F (4.4°C)	80°F (26.7°C)	100°F (37.8°C)
Warm-season vegetables prefer growing temperatures between 65°F–90°F (°C to °C).			
Beans	50°F (10°C)	80°F (26.7°C)	90°F (32.2°C)
Cantaloupe	60°F (15.6°C)	90°F (32.2°C)	100°F (37.8°C)
Corn	50°F (10°C)	80°F (26.7°C)	100°F (37.8°C)
Cucumbers	60°F (15.6°C)	90°F (32.2°C)	100°F (37.8°C)
Eggplant	60°F (15.6°C)	80°F (26.7°C)	90°F (32.2°C)
Pepper	60°F (15.6°C)	80°F (26.7°C)	90°F (32.2°C)
Tomato	50°F (10°C)	80°F (26.7°C)	100°F (37.8°C)
Squash, summer	60°F (15.6°C)	90°F (32.2°C)	100°F (37.8°C)
Squash, winter	60°F (15.6°C)	90°F (32.2°C)	100°F (37.8°C)
Watermelons	60°F (15.6°C)	90°F (32.2°C)	110°F (43.3°C)

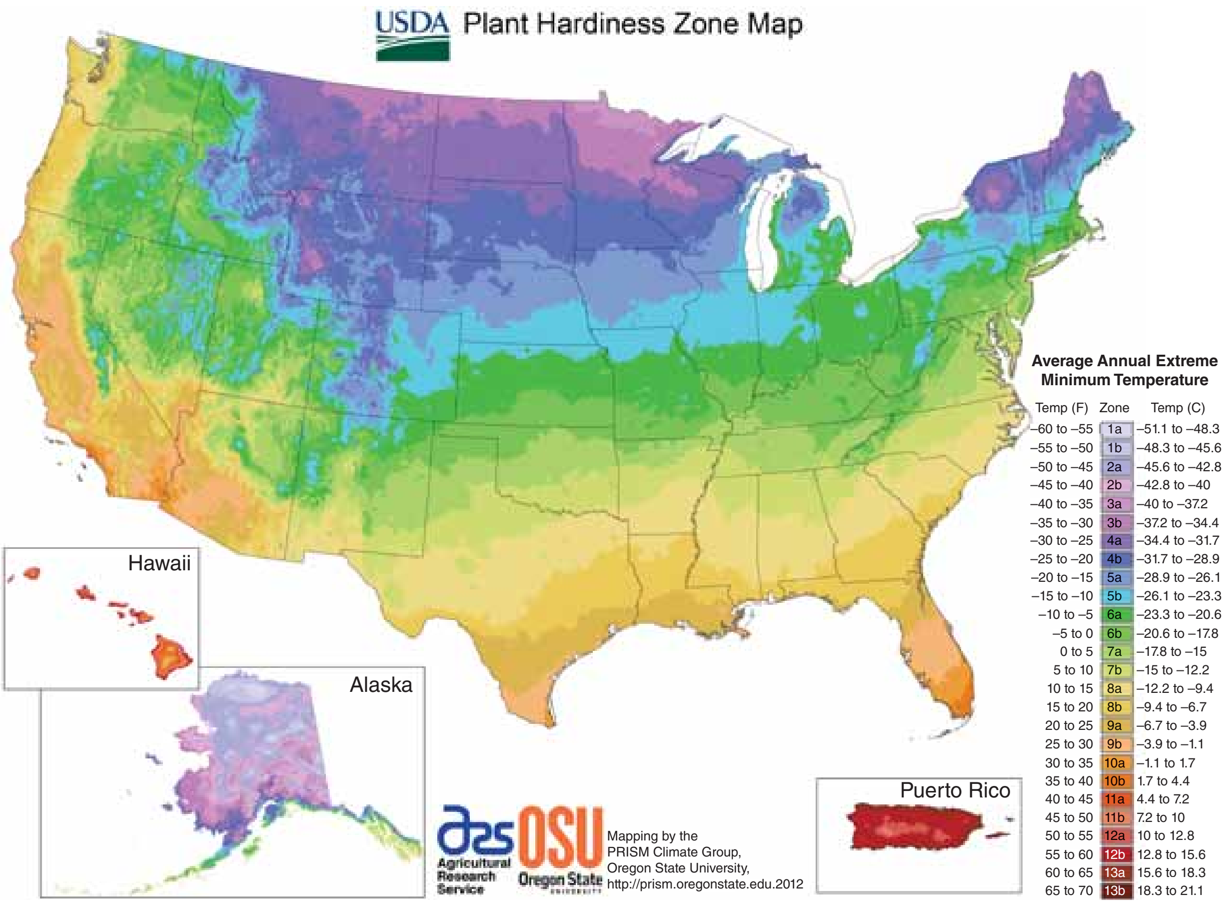
Goodheart-Willcox Publisher

Figure 10-14. Vegetables are classified as cool-season or warm-season vegetables depending on their preferred growing temperatures.

Growers can reduce temperatures if a slower growth is preferred. Each species of plant has an optimum temperature for growth and development, along with maximum and minimum temperatures where plant growth stops and permanent injury may occur. Temperatures of either extreme may cause damage, including chilling or freezing injury, thermal-induced cellular damage, or death.

Plant Responses to Temperature

Many plants require specific temperatures to complete their life cycle. Cold temperatures are necessary for some plants to initiate flowers or cold hardiness or even for certain seeds to germinate. Low winter temperatures can be the factor that determines whether certain plant species can survive in a given area. The United States Department of Agriculture (USDA) has determined ***plant hardiness zones***. These are areas identified across the United States based on average annual minimum winter temperatures, **Figure 10-15**. Zones are divided into 10° increments. Horticulturists have identified the low temperatures most trees, woody shrubs, and perennials can withstand and have assigned zones to them. A gardener will be able



USDA

Figure 10-15. The USDA Plant Hardiness Zone map shows the average minimum temperature for each area of the country. Growers can use this information to determine which plants will grow best in a particular area.

to decide whether a plant will be able to survive in the local area using the hardiness information. In certain extreme years, severe damage to plant material can happen if the temperatures are much colder than normal.

Dormancy

Dormancy is a condition in which buds and seeds are inhibited from growing until a certain environmental requirement is met. For many temperate species, the requirement is cold temperatures. Plants need to be exposed to a certain amount of low temperatures in order to break dormancy. These plants will not grow even if growing conditions such as temperature, water, and oxygen are all available and favorable. This is a survival mechanism to prevent plants from budding and growing at the wrong time, for example in the middle of a warm spell in January.

Bud dormancy on woody, temperate plants occurs as days shorten (photoperiod) and low temperatures are present. The needed number of hours of chilling temperatures depends on the species. For example, apples require between 800 to 1100 chilling hours, whereas a rabbiteye blueberry may require only between 400 and 700 chilling hours. This means that some plants can grow only in certain areas. For example, apples cannot be grown well in many southern states because they cannot receive enough chilling hours.

Damage may also occur to hardy plants when an unusually early frost or freeze finds plants before they are fully dormant or in the spring after they have begun to lose dormancy. Many seeds also have dormancy phases that can be broken through horticultural techniques called ***stratification***, a moist, chilling treatment.

Stress

When plants are exposed to temperature extremes, they undergo different stress responses. Stresses of low or high temperatures can cause a number of symptoms and even permanent injury or death in plants. The types of temperature stresses that can occur in plants include chilling injury, freezing injury, sunscald, and heat stress.

"The farmer has to be an optimist or he wouldn't still be a farmer."
—Will Rogers

Chilling Injury

Chilling injury is a condition in which plants are damaged by low temperatures in the field or in storage. Typical symptoms may include discoloration, death of older leaves, defoliation, wilting, poor growth, lesions, or death. Chilling injury can lead to an increased susceptibility to microorganisms that cause rotting.

Freezing Injury

Freezing injury is a condition in which plants are damaged when low temperatures freeze the water in plant tissue, either in cells or on the surface of plant tissues. Plant death is the most severe freezing injury. The injury may be the death of only certain plant parts from which the plant may be able to overcome.

Sunscald

Sunscald is a condition in which plants are damaged due in part to extreme fluctuations and varied combinations of heat, cold, humidity, and sunlight. Sunscald is a fairly common injury where rapid heating and cooling occur on the southwest side of a tree. Damage may be caused to the plant, tree, or fruit. In colder areas, sunscald is a common winter tree bark injury caused by the combination of freezing nighttime temperatures and intense light reflected off the snow or other objects during the day.

Heat Stress

Heat stress is a condition in which plants are damaged due to high temperatures. Prolonged exposure to high temperatures can result in rapid plant death or localized damage to parts of a plant. Many fruits will exhibit damage on the side that is exposed to sunlight.

Hardening Off

Plants can harden, or acclimate themselves, to withstand temperature extremes. This happens naturally in many plants in preparation for winter cold. As fall temperatures decline, light diminishes, and water and nutrients may be limited. These factors can increase a plant's ability to accommodate cold temperatures. Hardening off is a practice used by horticulturists to minimize the potential for plant injury by slowly introducing them to a more extreme temperature environment. For example, tender transplants growing in favorable conditions of a greenhouse may be susceptible to chilling injury if immediately placed in the garden. Hardening a plant means slowly increasing (or decreasing) temperatures and exposure to target temperatures.

Vernalization

Foxglove sends its towering flower stalk forth only after cold temperatures have induced flower formation, **Figure 10-16**. ***Vernalization*** is exposure of plants to low temperatures in order to stimulate flowering. A ***biennial*** is a plant with a two-year life cycle, with flowering occurring in the second year followed by plant death. Some biennials, such as celery, onion, and hollyhock, must be exposed to low temperatures for flowering to occur. Horticulturists might force flowering by subjecting a plant to cold temperatures. Then the plant is placed in conditions favorable for growth, and flowering will take place. In some cases, vernalization will result in undesirable flowering. For example, onion sets are often placed at low temperatures for storage. When planted in the field, however, the exposure first to cold temperatures and then to higher temperature results in flowering rather than bulb formation.

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Figure 10-16. Foxglove requires cold temperatures to initiate flower formation, a phenomenon called vernalization.

Thermoperiod

Thermoperiod is the relationship between day and night temperatures and plant growth. When photosynthesis exceeds respiration, growth occurs. If respiration rates are higher than photosynthesis, plant vigor declines and death can occur. Growers have traditionally managed temperatures in greenhouses by providing cooler nights to ensure that respiration rates slow down.

"My dream is to become a farmer. Just a Bohemian guy pulling up his own sweet potatoes for dinner."
—Lenny Kravitz

DIF Treatment

The effects of day and night temperatures can influence plant height and flowering times. This relationship has been termed ***DIF*** and refers to the difference between the night and day temperatures. Simply stated, DIF equals day temperature minus night temperature. If the day temperature is higher than the night temperature, the plants will grow taller through elongation of internodes on the stem. Conversely, if nighttime temperatures exceed daytime temperatures, plant growth can remain shorter and compact. A number of horticultural crops respond to this temperature management, including Asiatic lilies, dianthus, celosia, petunia, poinsettia, rose, salvia, snapdragon, tomato, and watermelon. Some plants do not respond to DIF treatments, such as aster, hyacinth, squash, and tulip. Using DIF methods reduces a need for chemical growth retardants as well. The use of temperature differences can be used to manage flowering time.

Degree Days

Horticultural crops vary widely in growth time from planting to harvest. All organisms, including plants, require a certain amount of heat to develop from one point to another in the life cycle. Each stage of development is calculated in units called degree days, and can be abbreviated as (°D). ***Degree days*** are the accumulated product of time and temperature for each day. Certain crops can be harvested after reaching a certain number of degree days. For example, vegetable growers can calculate an approximate time of harvest for peas by recording the number of degree days. The approximate number of degree days for peas is between 1000 and 1200. This formula can be used to calculate a degree day:

$$\text{Degree day } (^\circ\text{D}) = \frac{\text{daily maximum temperature } (^\circ\text{F}) + \text{daily minimum temperature } (^\circ\text{F})}{2} - \text{base temperature}$$

If a grower in Minnesota was managing a calendar for canning peas, he or she would use the base temperature of 40°F in the equation above. Degree days are also used for managing insect pests and can help a grower estimate the arrival of a potential pest.

Soil Temperatures

Soil temperature plays a key role in seed germination, root growth, water uptake, and disease susceptibility. Optimal soil temperatures depend on the crop, but cool-season plants generally prefer a maximum soil temperature of 77°F (25°C). Warm-season crops prefer a minimum soil temperature of at least 10°F (–12.2°C).

If temperatures are too cool for a seed, the seed can have little or reduced germination and may be susceptible to cold temperature diseases. Root growth responds similarly to seeds. If temperatures are too low or too high, growth is diminished. Much of a plant's responses to temperature depend on the plant species.

Managing Temperatures

To a certain extent, growers can prevent damage to outdoor plants caused by temperature. Greenhouses, of course, offer complete protection from damaging cold or hot temperatures through the use of heating and cooling systems. Chapter 18, *Greenhouse Operation and Maintenance*, discusses in greater detail the ways to manage these systems. In a field setting, damage from cold temperatures can be offset in a number of ways:

- Site selection.
- Season extension.
- Overhead irrigation.
- Localized heating.
- Wind machines.

Site Selection

Factors such as air drainage, orientation of slope, altitude, and location of large bodies of water influence temperature. These factors should be considered when selecting a location to raise crops. Cold air is heavier than warm air and will travel downhill. Warm air is less dense and rises uphill through convection. ***Air drainage*** is the process by which cold air sinks, flowing downhill to the lowest available point where it accumulates until dispersed by heat or wind. Orienting crops to provide proper air drainage minimizes potential cold damage. For example, in a vineyard, growers can take advantage of geography by planting on higher points of elevation and hills with a slight to moderate slope. This encourages cold air to move out of a field and to settle in an area of lower elevation, **Figure 10-17**. These low-lying areas (sometimes called frost pockets) accumulate cold air and can cause freezing or chilling injury to crops.

Sedlacek/Shutterstock.com

Figure 10-17. The wine grape vines were planted in this vineyard to encourage air drainage, moving potentially damaging cold air out of the field.

Microclimates

Localized areas with temperature differences are called ***microclimates***. Microclimates can be helpful or harmful depending on the crop being grown. A cold-tender fig tree may survive if grown against a brick wall that radiates heat and raises the air temperature a few degrees. Conversely, imagine the strip of land that often straddles the space between a sidewalk and street. The heat that may radiate from these concrete surfaces can make the area a very challenging environment in which to grow plants, **Figure 10-18**.

Slope Orientation

Growers with hilly land must consider slope orientation for the greatest benefit of their intended crop. ***Slope orientation*** refers to the direction the slope faces (north, south, east, or west). In cooler climates growers plant on slopes facing south to maximize light exposure and heat accumulation. Northern, eastern, and northeastern slopes are preferred in climates with warm or hot summers and cold winters. These locations can reduce damage caused by rapid heating and cooling of stems that may cause bark splitting or trunk injury.

Joe Klune/Shutterstock.com

Figure 10-18. Planting between the sidewalk and street creates a microclimate that is hot, dry, and challenging. Are there microclimates around your home or school that present planting and growing challenges?

Bodies of Water

Large bodies of water can provide a more moderate temperature for the surrounding land. Water has a high heat capacity and offers slower temperature fluctuations, creating favorable conditions for many crops. In the United States, many fruit growers locate along large bodies of water, such as the Great Lakes, including along the eastern shores of Lake Michigan, Lake Ontario, and Lake Erie.

"Heliotrope. to be sowed in the spring. a delicious flower, but I suspect it must be planted in boxes & kept in the house in the winter. the smell rewards the care."
—Thomas Jefferson

Season Extension

Many growers have learned that covering their crops with a protective barrier, such as fabric, plastic, or glass, can extend the season by increasing temperatures earlier or later into the season. At its simplest, growers might cover their crops with a special fabric that traps heat from the sun and raises the temperature a few degrees, **Figure 10-19**. It allows light and water to penetrate and can be easily applied and removed each day. It also has been used as an effective measure against pests.

Low and High Tunnels

Low tunnels are slightly more sophisticated structures that allow for winter production of hardy cool-season vegetable crops. A low tunnel is created by inserting plastic or metal conduits into the soil on either side of the bed. A row cover is placed on the crops, and plastic is pulled over the metal or plastic hoops.

Selijko Radojko/Shutterstock.com

Figure 10-19. Row covers trap heat and provide frost protection to tender plants.

STEM Connection

Growing Strawberries in the Winter

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If you live in California or Florida, the availability of locally grown strawberries in the winter is not unusual. But in other parts of the southeast and southwest, strawberry growers are beginning to produce this much loved and scrumptious crop during the dark days of the coldest months. Using a high tunnel to modify winter temperatures, strawberries can be planted inside and grown nearly eight to ten months out of the year. Challenges to develop a strawberry that is best suited for short days and fluctuating temperatures and to develop best management practices for winter production are still being ironed out. In the meantime, a taste of spring and sunshine can now be found locally throughout the south as cold wind blusters and even snow may sprinkle the ground.

Crops can be maintained through the cool weather and be ready for an early spring harvest. High tunnels or hoop houses are large greenhouse-like structures that are often unheated. They provide a longer fall growing season and an earlier spring/summer season by providing warmer air and soil temperatures for crops to grow, **Figure 10-20**.

A Sever180/Shutterstock.com B bibiphoto/Shutterstock.com

Figure 10-20. A—Low tunnels provide a way to keep plants from freezing during cold temperatures. B—High tunnels are unheated structures that extend the growing season by creating a warmer production environment during late fall, winter, and early spring seasons.

Gardeners have long used homemade systems to protect against cold temperatures. Many gardeners use cold frames, **Figure 10-21**, that warm the soil and permit seeds for plants such as spinach to germinate and begin to grow. Milk jugs with the bottom cut off or glass cloches (small glass domes) may also be used to shelter tender transplants. Both trap radiant heat from the soil and warm the air inside.

jeff gynane/Shutterstock.com

Figure 10-21. Cold frames are perfect spaces for starting cool-season vegetables a few weeks before your neighbor!

Overhead Irrigation

Irrigation systems, especially overhead sprinklers, may provide some protection against frost in early spring or fall. As water falls on the plants in cold temperatures, heat energy is released as it changes to ice. As long as liquid water is constantly freezing on the plant, the surface temperature will remain at or near 32°F (0°C). With variables like wind or inadequate irrigation rates, damage may be more severe than if no irrigation was provided. Using overhead irrigation as a means of protecting against early frost is a common practice in the southeastern United States, particularly to shield tender flowers of strawberries, **Figure 10-22**.

Ulrich Mueller/Shutterstock.com

Figure 10-22. Using sprinkler irrigation can prevent damage to strawberry crops that have already set flowers.

Localized Heating

Heaters deliver localized heat to raise air temperatures and protect crops. Heaters are commonly used for fruits in the citrus family as well as in avocado groves, **Figure 10-23**. Fuels such as propane, liquid petroleum, and natural gas are placed in small heaters spread throughout a grove. Heating fuel may also be distributed via a pipeline system. Heaters tend to be used only in situations where the costs of crop loss outweigh the costs of fuel and heating.

Wind Machines

Wind machines are large fans that mix the air within an orchard to raise the air temperature near the ground. This can fluctuate the temperature by two or three degrees, just enough to reduce injury from cold temperatures. Wind machines can be more economical than heaters. They may also be used with heaters to reduce the number of heaters needed. Wind machines are used primarily in the tree fruit industry.

Water

Did You Know?

Horticulture has been practiced since mankind's early days. A small clay tablet dated to 3500 years old was found in Iraq and gives early instructions on irrigation.

Did you know that 95% of a raw tomato is water? Water makes up 80% to 90% of herbaceous plants. Nearly half of woody plants are comprised of water. Water is essential for functions that drive plant growth and development. In Chapter 9, you learned that the water stream provides a vehicle for transport of inorganic nutrient ions from the soil through the xylem. Water enters plants through the roots. Once water is inside a plant, transpiration channels water and its solutes to where it is needed. Water is a key ingredient in photosynthesis as it combines with carbon dioxide to create simple sugars. Water also provides the rigidity needed for plant form and structure, called turgor pressure.

Linda Armstrong/Shutterstock.com

Randy Miramontez/Shutterstock.com

Figure 10-23. Using heaters in fruit orchards and vineyards can be an effective means to prevent freezing injury.

Root Zone

The soil surrounding the plant's roots, called the ***root zone***, serves as a natural reservoir from which the plant draws moisture and nutrients. For vegetables, this area immediately surrounds the plant. For most trees and shrubs, the leaf canopy sheds rain and creates an area called a drip line. This roughly circular area is much like the drip area of an open umbrella. For these plants, the most active water absorption is in the drip line area and beyond. This area is where watering should occur. Most of the roots spread two to four times as wide as the plant's canopy.

Corner Question

How much land in the United States is irrigated for agricultural production?

Consumption Rates

Water consumption rates vary greatly among plant species. These rates are influenced by soil type, temperature, light intensity, rainfall, humidity, and wind speed. A good rule of thumb is to water deeply and less frequently (rather than watering lightly and often). Watering deeply will encourage deeper rooting of plants. For vegetables, this means about 1″ to 2″ (2.54 cm to 5.08 cm) of water per week. A cool-season turf may need about 2.25″ (5.7 cm) a week. A warm-season and drought-tolerant turf, such as buffalograss, may not need to be watered for a couple of weeks. Plants use three to five times as much water during the hot summer months as they do during the winter. By adjusting a watering schedule with the season and as significant changes in the weather happen, growers and gardeners can conserve water resources and maintain optimal plant growth.

Irrigation

Horticulturists have a long history of delivering water to plants through a practice called irrigation. ***Irrigation*** is applying water to land or soil to assist in growing plants. From the flooding of fields in ancient China to aquifers in Rome, water has long been understood as a vital need for optimal plant growth and development. The main types of irrigation are surface, sprinkler, and drip irrigation.

Surface Irrigation

Surface irrigation includes both furrow and flood irrigation. Furrows are small ditches between planted rows in fields. Water flows from a central supply source and floods the ditches, **Figure 10-24**. Crops are planted in raised beds to provide good aeration and drainage.

ksb/Shutterstock.com

Figure 10-24. Furrows create a pathway for water to flood a field and irrigate crops.

Flood irrigation is an overall flooding of an entire area. Water is released from a central basin or reservoir and allowed to flood the desired areas. This is the least efficient use of water, but it requires less labor than furrow irrigation. Flooding of greenhouse floors has proven to be a very efficient method of watering pots. Water flows in for a set amount of time and then is recaptured and reused.

Sprinkler Irrigation

"Gardening requires lots of water—most of it in the form of perspiration."
—Lou Erickson

Sprinkler irrigation uses overhead watering of crops. This method applies water to both the plant foliage and the soil. A number of different mechanisms distribute water to plants. These devices may include simple sprinkler attachments to a garden hose or much more complex systems with underground piping and pop-up spigots for lawns. For valuable crops, many fields have permanent piping for irrigation. A pump will pull water from a reservoir and provide water to the main line. Lateral lines run off the main line to reach the crops. Risers are smaller pipes that come off the lateral lines and hold a single or double nozzle that sprays the water. If you have ever traveled through the Midwest, you may have seen many large agricultural fields that use center pivot irrigation, **Figure 10-25**. The equipment has wheels that slowly rotate from a center point in a circle to provide water to a field.

Sprinkler irrigation can increase the chances for disease because it wets the foliage and can splash soil, and any spores or microbes it contains, onto the foliage. Black spot on rose plants is a fungal disease spread by spores, often splashed onto foliage through sprinkler irrigation.

Drip Irrigation

Low-volume drip irrigation systems provide water to plants in a targeted, efficient way. Water is slowly, but frequently, applied through irrigation tubes

Jim Parkin/Shutterstock.com

Figure 10-25. Center-pivot irrigation mechanisms provide overhead watering to crops.

under low pressure, **Figure 10-26**. Less water is used, reducing costs and conserving water supplies. Fewer diseases occur because the foliage is not being wetted. Weed seeds that are outside the irrigation zone will not get watered, so weed growth is greatly reduced in areas watered through drip irrigation. Drip irrigation is used both in greenhouses and field settings. In the field, drip tubes are often laid under plastic mulch.

Max Lindenthaler/Shutterstock.com

Figure 10-26. Drip irrigation uses less water than other irrigation methods, conserves water supplies, and reduces disease incidence.

Careers in Environmental Horticulture

Whether your educational focus or practical experience is in science, business, conservation, or design, you can find a rewarding professional career in environmental horticulture. Two of these jobs, greenhouse manager and farm coordinator, are described in the following section.

Greenhouse Manager

A greenhouse manager is responsible for the daily operation of the greenhouses associated with a nursery or vegetable production operation. Daily operation tasks include watering, planting, fertilization, space allocation, growth media and soil mix preparation, insect and disease control, and establishing and monitoring environmental conditions. A greenhouse manager may also be responsible for developing and monitoring pest management programs as well as training the staff who will implement the program.

Depending on the operation, a greenhouse manager’s responsibilities may also include financial and staff management. These responsibilities may include record maintenance, budget management, billing, hiring and supervising staff, safety training, establishing work schedules, and performance evaluations. An associate’s or bachelor’s degree in horticulture, with a minimum of two to three years of greenhouse experience and experience supervising other people, is often required for this job.

Farm Coordinator

A farm coordinator serves as a liaison between farm production and sales. As part of a farm that does direct marketing through CSAs, farmers markets, produce boxes, restaurant sales, etc, the farm coordinator plans and manages its product procurement and sales, as well as the distribution of produce. Farm coordinators may also be responsible for bookkeeping, payroll, and some administrative tasks for the farm. This role is the farm’s primary communicator and outreach with shareholders, members, clients and the general community. Experience or a related degree in business management, agriculture economics, horticulture marketing is recommended.

Career Connection

Debbie Roos

Sustainable Agriculture Extension Agent

Credit line to come from author

On any given day, Debbie Roos can be found with a camera around her neck capturing the mysteries of the natural and agricultural worlds. She takes vivid images that reveal her fierce fascination with the environment, from nests of native digger bees to the recently unfurled wings of a monarch late in the season. Her agricultural documentation highlights the tastes of the season—spring onions, summer heirloom tomatoes, or a heap of greens ready for the stewpot. Posting these wonders to social media, Debbie strives to both spark curiosity and to inform her friends and followers about the intersection of stewarding our natural resources and supporting local farms in Chatham County where she works and lives. Holding the enviable position of Sustainable and Organic Agriculture Agent with North Carolina's Cooperative Extension Service, this is her mission: to engage the citizens of her area in understanding the importance of eating and buying good food as well as supporting the farmers that produce it in a way that that builds environmental health.

With early roots in the Peace Corps, Debbie found she loved agriculture and she loved working with people. Seeking out experiences on organic farms, internships, formal training in both anthropology and later in horticulture, she began to craft a skill set that found a home with Extension. Translating research from the land grants of NC State and NC A&T State into practical solutions for her local growers, she is constantly giving lectures, workshops, farm tours, and even camps for kids about sustainable agriculture. She is always busy: connecting with the community in her pollinator paradise demonstration garden, talking with a grower about a new crop or innovative practice, or simply thinking about new ideas. Debbie claims that "she would wilt on the vine," if she was stuck in an office. Over the years, her determined efforts have woven together a vibrant community of farmers, ranchers, restaurateurs, and consumers that enthusiastically support their local food economy and maintain the vitality of their natural resources.

CHAPTER 10 Review and Assessment

Chapter Summary

- Understanding the growing needs of plants and the ways to control essentials, such as light, temperature, and water, is key to uncovering the secrets of plant growth and development.
- Light is critical to plants for photosynthesis, some seed germination, growth habit, flowering, fruiting, dormancy, hardiness, plant movement, formation of storage organs, fall color, and leaf drop.
- Light quality influences photosynthesis as well as the type of growth a plant will exhibit. In some seeds, certain wavelengths of light are necessary for germination to occur.
- Light quantity measures the number of light particles that reach a plant. Each plant species has an optimal light quantity that maximizes photosynthesis for plant growth.
- Plants have growth responses based on the number of hours of light they receive each day. Each plant species has its own photoperiod requirements. Photoperiod is related to flowering, development of storage organs, stem elongation, fall color, and leaf fall.
- Horticulturists have developed strategies that optimize a crop's opportunity to intercept light. These strategies involve plant spacing and orientation, greenhouse design and covers, supplemental lighting, and plant selection.
- Warmer temperatures will increase rates of plant growth through increased photosynthesis and respiration.
- Plants have specific responses to temperature, including dormancy, stress to temperature extremes, and vernalization.
- Horticulturists manage temperature using different tools and techniques to create a desired growth response. In the field, this includes site selection, season extension, irrigation, heating, and air mixing. In the greenhouse, managing temperature includes heating and cooling.
- For plants, water is key for photosynthesis, nutrient transport, and support for cellular form and structure.
- Horticulturists apply water through various irrigation methods to deliver water efficiently to plants and to conserve water resources. The main types of irrigation are surface, sprinkler, and drip irrigation.

Words to Know

Match the key terms from the chapter to the correct definition.

A. air drainage
B. biennial
C. blanching
D. chilling injury
E. daily light integral (DLI)
F. degree day
G. dormancy
H. etiolation
I. freezing injury
J. heat stress
K. irrigation
L. juvenile stage
M. light quality
N. light quantity
O. microclimate
P. nanometer
Q. necrosis
R. photoblastic
S. photon
T. photoperiod
U. phototropism
V. plant hardiness zone
W. stratification
X. sunscald
Y. thermoperiod
Z. vernalization

1. A condition in which plants are damaged by low temperatures in the field or in storage.
2. The wavelengths of light that a plant receives.
3. A plant growth response in absence of light.
4. A small area with different environmental conditions than the surrounding area.
5. The duration of day length (the amount that light is present) and the relationship between the dark and lighted periods.
6. Death of plant tissue, usually resulting in dark brown or black coloration.
7. Exposure of plants to low temperatures in order to stimulate flowering.
8. A condition in which plants are damaged due to heat, cold, humidity, or intense sunlight.
9. A condition in which plants are damaged due to high temperatures.
10. A plant with a two-year life cycle, with flowering occurring in the second year followed by plant death.
11. The required number of heat units that a plant needs to have to reach a certain point of development, usually flowering or harvest.
12. The process by which cold air sinks, flowing downhill to the lowest available point where it accumulates until dispersed by heat or wind.
13. A condition in which buds and seeds are inhibited from growing until a certain environmental requirement is met.
14. A period of growth that occurs before plants reach adult form.
15. The unit of measurement used to quantify light wavelengths.
16. One of several areas identified across the United States based on average annual minimum winter temperatures.
17. The relationship between day and night temperatures and plant growth.
18. The physical movement of a plant or its parts toward or away from a light source.

19. A moist, chilling treatment used to break dormancy in seeds of certain plant species.
20. A characteristic of seeds that have a germination response to the presence or absence of light.
21. The practice of applying water to land or soil to assist in growing plants.
22. A condition in which plants are damaged when low temperatures freeze the water in plant tissue.
23. Keeping plants from light to prevent photosynthesis and to cause white tissue growth.
24. The amount of light intensity a plant receives throughout a given day.
25. The amount and duration of light emitted by the light source.
26. A light particle and a measure of light quantity.

Know and Understand

Answer the following questions using the information provided in this chapter.

1. In what plant processes does light play a role?
2. What is light quality and what wavelengths of light do plants absorb?
3. How does light affect seed germination?
4. What are two components of light quantity?
5. Why is the daily light integral important?
6. How do growers promote etiolation in plants such as cauliflower?
7. What is photoperiodism and how is it important for plant growth?
8. What is critical day length and what are two examples of plants that require a short-day photoperiod to flower?
9. What are some light management strategies that growers may use?
10. How does plant spacing impact light interception by plants?
11. What different types of supplemental lighting are used in greenhouses?
12. How does an increase in temperature impact rates of plant growth?
13. How is dormancy broken in plants?
14. What types of stresses can occur when plants are exposed to temperature extremes?
15. What does it mean for a plant to harden?
16. How do growers use the concept of DIF to manage growth?
17. How does tracking degree days help growers?
18. What are five ways that damage from cold temperatures can be offset?
19. Describe the functions of water in plant growth.
20. Briefly describe the three types of irrigation practices.

Thinking Critically

1. Why is it important to understand how environmental conditions affect plant growth and development?

2. You are visiting a botanic garden after recent freezing temperatures and notice that some bananas that had been growing are blackened and show signs of rot. A gardener is working nearby and cuts some other bananas down to the ground. Why did she not remove the bananas? What do you think happened to the banana physiologically and what management practices could the gardeners use to prevent this damage?

STEM and Academic Activities

1. **Science.** Research the soil conditions in your area. What kind of soil do you have? How might this influence your watering practices? What properties of soil can impact how water reaches the plant roots?
2. **Technology.** LED lighting is a promising area for providing light needed for photosynthesis and reduces energy costs. Create an experiment by growing plants under different types of light. What light quality and quantity do they provide? How will this impact the growth of your plant?
3. **Math.** A grower has asked you to help her be more efficient in using supplemental lighting. Visit at least three greenhouse supply companies online that sell these items. Compare their prices, including any discounts for the number of items needed. Make a chart listing the name of each company and its price for each item. Identify the lowest price for each item and calculate the total cost for the items.
4. **Language Arts.** Assume that you are a vegetable grower, and you keep a daily journal to help you remember information that you might need later. Today, you held consultations at two local restaurants about what crops they would be interested in purchasing. Write a journal entry about these consultations that includes all the information you might need in the future.
5. **Language Arts.** Plants have different growing requirements. Select a plant that you enjoy cultivating in your garden. Research the environmental conditions it needs to grow. Create a descriptive label that defines its growing needs so any gardener could grow it.

Communicating about Agriculture

1. **Reading and Writing.** Research a position description for a farm manager. Consider the skills and experiences that you would need to have to be a highly qualified candidate for the position. Create a résumé and cover letter that highlights these skills and experiences.
2. **Writing and Speaking.** Use line drawings on poster board to explain the skeleton and basic shape of at least three types of season extensions covered in this chapter. Indicate which types of materials are used to establish the growing conditions needed for your crops. Display the drawings as reference tools for the class and be prepared to explain to the class how and each season extension technique works.
3. **Reading and Listening.** Divide into groups of three to four students. Have each person choose a concept in the chapter. Each person should report to the group about the main ideas of their concept. The other people should then share one idea they heard back to the group. Repeat until each person has a chance to report.

SAE Opportunities

tony4urban/Shutterstock.com

1. **Exploratory.** Visit a vegetable grower and observe the ways the field is planted. Take note of the row orientation, plant spacing, and other methods that take advantage of managing environmental conditions.
2. **Experimental.** Create a plant growth experiment with different types of light quantity. What plant will you use? How will you create a spectrum of light quantity? What growth responses do your plants exhibit? Write a report on your findings and submit it to a national youth horticulture organization.
3. **Experimental.** Conduct a postharvest experiment using bananas. Determine five different temperatures that you will place your bananas in. What do you expect to find? How will you collect data? What symptoms, if any, did you see the bananas show in response to the different temperatures?
4. **Exploratory.** Job shadow a horticulture production researcher. Ask questions about the research projects and the ways he or she is trying to improve production practices that bring down grower costs and increase yields.
5. **Placement.** Visit a local greenhouse and apply for a position or volunteer. Learn the different strategies for optimizing light, water, and temperature used at the greenhouse.