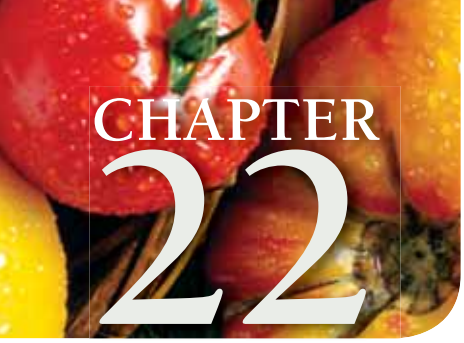

CHAPTER 22

Vegetable Production

Chapter Outcomes

After studying this chapter, you will be able to:

- List the reasons vegetables are important for good health.
- Describe the market opportunities for vegetable production.
- Explain the environmental requirements for vegetable production.
- Describe different production methods.
- Summarize postharvest handling and storage practices.
- List careers related to the olericulture industry.

Words to Know

crop rotation
dripline
good agricultural practice (GAP)
interplanting
leaching
low tunnel
olericulture
perched water table
row cover
sanitation

Before You Read

Write all the chapter terms on a sheet of paper. Highlight the words that you do not know. Before you begin reading, look up the highlighted words in the glossary and write the definitions.




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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Kale chips, radish candy, and kohlrabi slaw are vegetables that are fun to eat and to grow. Rich in healthful nutrients, vegetables play a key role in growing healthy bodies and minds. Digging deep into the soil and watching a seed sprout and develop into something edible remains one of the principal joys of gardening.

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Figure 22-1. A diet rich in vegetables is delicious and healthy for your body.

Vegetables for Health

Eating vegetables is an essential part of a healthy diet because vegetables contain minerals and nutrients vital for health and maintenance of your body. The United States Department of Agriculture (USDA) recommends that half of your plate should be filled with fruits and vegetables, **Figure 22-1**. An overall healthy diet includes fruits, whole grains, low-fat dairy, and varied proteins (not just meat). Be aware of the number of calories you eat. Select foods that are low in fats, sugars, and salts. A healthy lifestyle also includes physical activity.

Health Benefits

A healthy lifestyle that includes eating vegetables and fruits can help reduce the risk of heart disease, heart attacks, and strokes. Other benefits of eating vegetables include:

- Vegetables such as broccoli and other brassicas, dark leafy greens, garlic, tomatoes, and winter squash may protect against some types of cancers.
- Fiber-rich vegetables and foods may lessen the risk of heart disease, obesity, and type 2 diabetes.
- Vegetables and fruits that are rich in potassium may lower blood pressure. They may also reduce the risk of developing kidney stones and help decrease bone loss.
- Higher consumption of low-calorie foods such as vegetables can help to lower total calorie intake.

Nutrients Found in Vegetables

Plants take in nutrients from the soil solution. Those nutrients are the same nutrients that people consume when eating a raw carrot or sautéed leafy greens. Nutrients are essential for the processes our bodies perform every day. No single vegetable contains all the nutrients needed

by the human body, so consume vegetables in many different colors, **Figure 22-2**. Nearly all vegetables are naturally low in fat and calories, and cholesterol free. Nutrients found in vegetables include protein, potassium, iron, calcium, dietary fiber, folate (folic acid), vitamin A, vitamin C, vitamin E, vitamin K, and beta-carotene.

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Figure 22-2. Each type of vegetable contains specific nutrients so try to eat a variety of vegetables every day.

Potassium may help to maintain healthy blood pressure, critical to heart function, and muscle contraction. Vegetable sources of potassium include spinach, Swiss chard, sweet potatoes, kale, white potatoes, white beans, beet greens, soybeans, lima beans, lentils, kidney beans, Brussel sprouts, zucchini, asparagus, and green beans.

Many vegetables contain dietary fiber, the indigestible portion of plant-based food. Dietary fiber can be soluble or insoluble. *Soluble fiber* dissolves in water, changing form in the digestive tract. *Insoluble fiber* does not change form in the digestive tract. Fiber is important for proper bowel function. It can also help reduce blood cholesterol levels and may lower the risk of heart disease. Fiber-rich vegetables can also provide a feeling of fullness with fewer calories. Vegetables high in soluble fiber include legumes, beans, dried peas, and lentils. Vegetables containing insoluble fiber include carrots, cucumbers, zucchini, celery, and tomatoes.

"Go vegetable heavy. Reverse the psychology of your plate by making meat the side dish and vegetables the main course."
—Bobby Flay

Folate, or folic acid, aids in red blood cell production. Folate minimizes the risk of birth defects during fetal development. Vegetables rich in folate include lentils, spinach, black beans, sunflower seeds, turnip greens, broccoli, and peanuts.

Vitamin A promotes good eyesight and night vision. It keeps skin and mucous membranes healthy and helps to protect against infections. Dietary vitamin A, or beta-carotene, may lower the risk for cancer.

Vitamin C helps growth and repair of tissues to heal cuts and wounds. It helps maintain teeth and gum health and aids in iron absorption. Vegetables that are rich in vitamin C include broccoli, bell peppers, yellow snap beans, cabbage, Brussels sprouts, cauliflower, collard greens, okra, onions, potatoes, sweet potatoes, tomatoes, spinach, radishes, and rutabagas.

Vegetable Markets in the United States

The USDA measures economic value and the amount of vegetable production by gathering data from hundreds of independent markets within the food marketing system. Vegetables and pulses (seeds from legumes) are considered specialty crops, and recent data from US farm cash receipts from the sale of vegetables and pulses (including potatoes) averaged $17.4 billion.

Corner Question

What vegetable has more protein than steak?

This is 14% of US crop cash receipts according to the National Agricultural Statistic Service. Vegetables are grown on nearly 2.8 million acres across the country. The states with the largest production of vegetables for fresh and processed food markets include California, Florida, Arizona, Georgia, Washington, Michigan, Wisconsin, Minnesota, Idaho, Oregon, and New York, **Figure 22-3**.

The vegetable industry is classified into two major end uses: fresh market foods and processed food. Processed foods can be further divided into foods that are canned, frozen, or dehydrated. In vegetable production, management practices, cultivar selection, and other factors differ greatly between growing for a fresh food or processed food market. For example, cultivars grown for processed foods are better adapted to mechanical harvesting, but they often lack the characteristics needed for fresh market sale, such as flavor and texture. Vegetables grown for processing are grown based on contractual arrangements between growers and processors. About half of all vegetable production is used in the processed food market.

According to the USDA Census of Agriculture, most US vegetable farms are individually owned and relatively small. About 75% of vegetable farms use fewer than 15 acres. Only a few farms, however, account for the majority of commercial vegetable sales. About 9% of vegetable farm operations are responsible for 90% of the value of vegetables sold. More than half of all vegetable production acreage is irrigated.

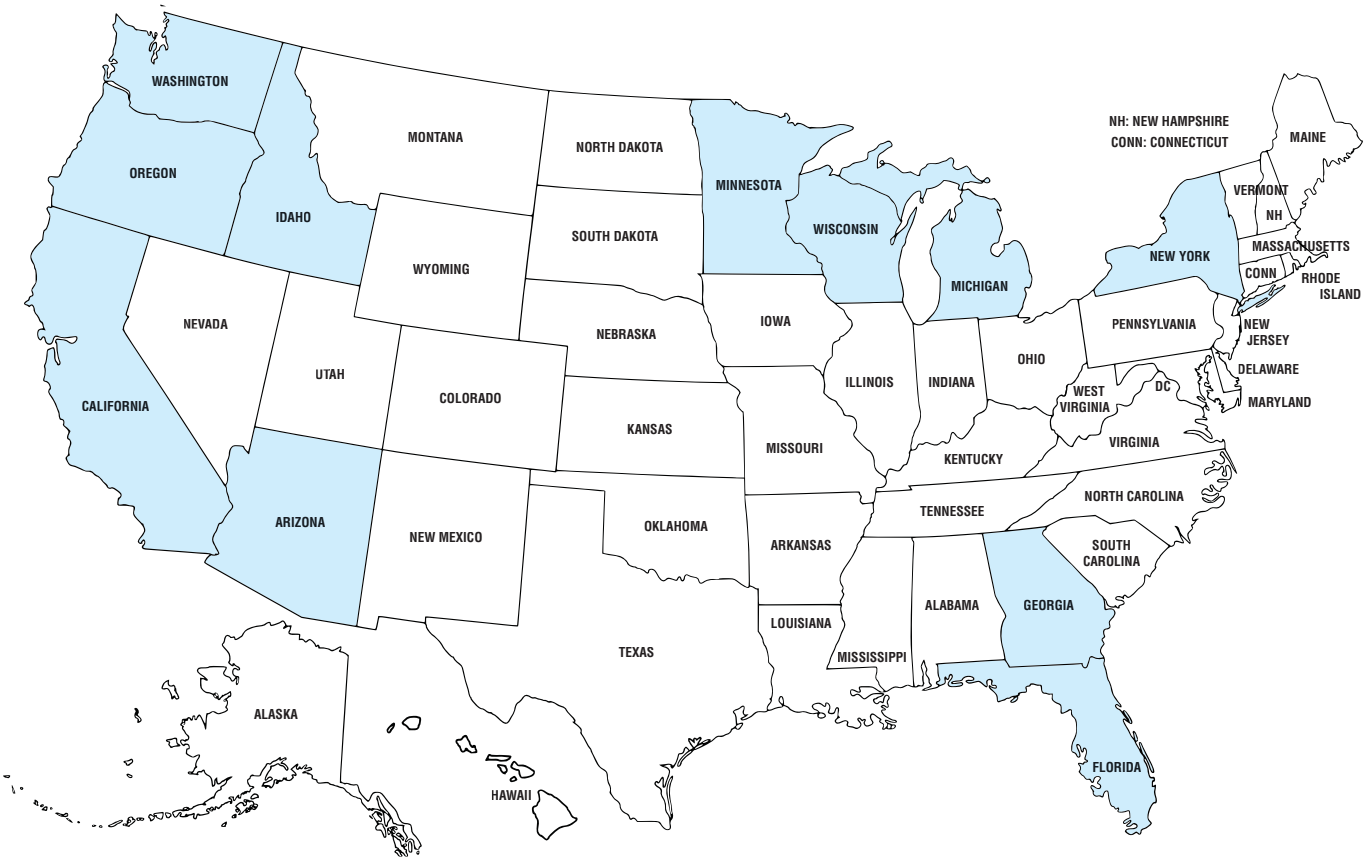

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Figure 22-3. This map shows the states that have the highest production of vegetables for both fresh and processed markets.

Domestic vegetable production occurs seasonally due to climate, with the largest harvests happening in the summer and fall. During the winter, vegetables are imported from other countries to supplement domestic supplies. This results in increased choices for consumers but competition for US growers. For example, during the winter and spring, Florida produces most domestic warm-season vegetables, such as fresh tomatoes. Fresh tomatoes are also imported at this time. Most imports come from Mexico and Canada and are primarily greenhouse grown. These imports compete directly with winter and early spring products from Florida.

Statistics indicate that local food markets are a small but growing portion of US agricultural production. Smaller farms find that directly marketing crops to consumers accounts for a higher percentage of their sales than it does for larger farms. The local food movement involves more than just local vegetable production. It includes a joint effort to build more local, self-reliant food economies. Sustainable food production, processing, distribution, and consumption are integrated to enhance an area's economic, environmental, and social health.

Vegetable production is expected to increase because the current emphasis on health and nutrition will result in growing consumer demand. A number of national campaigns are focused on increasing awareness and consumption of fresh fruits and vegetables. These campaigns are aimed at consumers and address the benefits of a healthy diet that contains vegetables.

Environmental Factors

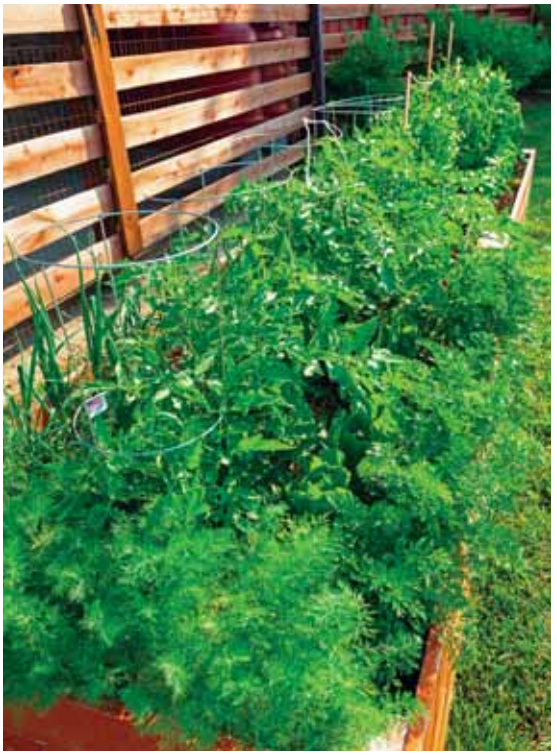
Several environmental factors impact vegetable production. These factors include the growing site, water, soil, nutrient management, temperature, and methods for extending the growing season.

Growing Site

Vegetable production, or ***olericulture***, is the practice of producing edible vegetable crops. It starts with selecting a good growing site. A good location is essential for a productive, high-yielding vegetable plot. Selecting a location for vegetable production varies between home gardeners and commercial growers. However, a number of elements remain the same. Vegetables need at least six to ten hours of direct sunlight every day, **Figure 22-4**. Southern exposures warm faster in cooler spring temperatures. In flat fields, some growers will mound their rows and plant on the southerly side of the mound. Data suggests there is an average 30% heat gain in total heat from using this method.

lzf/Shutterstock.com

Figure 22-4. Vegetables need a minimum of six hours of sunlight a day and preferably eight to ten hours.



Alexey Stiop/Shutterstock.com

Figure 22-5. Windbreaks, such as this fence, can prevent water loss and plant injury and create warmer temperatures.

The sun changes location in the sky throughout the year. Selecting a garden site that is free of trees and other sources of shade will impact the amount of sun that reaches the vegetables. Trees also compete for space, water, nutrients, and oxygen with a garden. The garden should be beyond the dripline of the foliage. The ***dripline*** is the outermost circumference of a tree's branches where water drips from the leaves onto the ground. Gardeners with limited space sometimes plant crops in the landscape, rotating crops among different spaces each season to minimize pests.

Air movement among plants is important to manage diseases and avoid frost injury from cold pockets. Situating a site to provide proper air drainage, or the movement of cold air through a field, minimizes potential cold damage. In windy sites, plants can suffer wind damage or dry out. Windy sites are also prone to soil erosion, making them undesirable locations for growing vegetables. Finding a space where natural windbreaks occur (or can be planted or constructed) will also minimize injury from the wind, **Figure 22-5**. A windbreak also allows warm temperatures to accumulate, reduces transpiration, and creates a microclimate conducive for growing tender vegetables.

Water

Vegetables are 80%–95% water. For optimal yield and quality, many commercial and home gardeners irrigate their plants. Most vegetables are rather shallow-rooted. Up to 1.5″ (4 cm) of water is required each week during warm temperatures to maintain most vegetable crops. Watering needs decrease to 3/4″ (2 cm) per week during cooler seasons. This amount is often supplied by rainfall.

For small gardens, locating the vegetable plot near a hose or faucet allows for simple hand watering. For larger gardens and commercial growers, however, irrigation systems provide a reliable and efficient water delivery method. There are a number of different irrigation systems, including drip irrigation and sprinkler irrigation. Choosing a commercial sprinkler system depends on a number of factors:

- Growing site conditions—soil type, drainage, erosion potential, availability of power, topography, distance from water source.
- Water considerations—availability, quantity, quality, costs to develop a water supply, annual crop water requirements.
- Crop requirements—yield potential, frost protection, and cultural practices related to planting, pest management, and harvesting.
- Infrastructure concerns—labor requirements, labor availability, initial irrigation investment, annual operating costs.

Drip Irrigation

Drip irrigation distributes water directly to the plant roots, **Figure 22-6**. It is used exclusively in plasticulture (the practice of using plastic mulch) and requires less water than other methods. Drip irrigation systems generally include a main irrigation line coming from the water source and multiple drip lines that extend down the rows. Tiny holes in the drip line release water directly to the roots of the plant.

Vadym Zaitsev/Shutterstock.com

Figure 22-6. Drip irrigation is an efficient method for delivering water in commercial vegetable fields.

A drip irrigation system has several benefits. Water is used efficiently. Because not as much water is required, growers are able to pull from low-volume water sources. Fertigation works well with drip irrigation, reducing soil erosion and nutrient ***leaching*** (the movement of nutrients out of the soil into the groundwater). The risk of disease is minimized because foliage remains dry. The use of low-pressure pumps reduces energy costs and requirements. Due to automation in the system, minimal labor is required. Drip irrigation systems effectively control weeds because water is not applied between rows. Finally, harvesting can continue during irrigation because areas between rows remain dry.

Some disadvantages of drip irrigation include annual installation costs, clogged lines, water filtration needed to minimize clogging, no frost protection, and more maintenance than some other systems.

"An onion can make people cry, but there's never been a vegetable that can make people laugh."
—Will Rogers

Sprinkler Irrigation

Sprinkler irrigation systems water crops from overhead, applying water to both the plant foliage and the soil. Sprinkler irrigation systems range from simple sprinkler attachments for garden hoses to complex systems with underground piping and pop-up spigots. Depending on crop value, many fields have permanent piping for irrigation. A pump pulls water from a reservoir and sends it to the main line. Lateral lines run off the main line to reach the crops. Sprinkler irrigation in commercial vegetable production includes using hand-propelled sprinklers, solid set sprinklers, **Figure 22-7**, and hand-propelled or travelling big gun sprinklers. All systems deliver overhead water; the method used depends on the grower's needs and preferences.

N.F. Photography/Shutterstock.com

Figure 22-7. Sprinklers are commonly used in irrigation and can provide frost protection for crops.

Sprinkler systems can cost less than drip irrigation systems and provide frost protection for some crops. In some cases, the labor requirements for setup and operation are lower than for other systems. The system may be adapted to any shape, size, and contour of a field. Many sprinkler systems can provide fertigation as well. Overhead watering from sprinkler irrigation can, however, increase the chances for disease due to wet foliage and splashing up of soil particles that may have plant pathogens attached.

Ruud Morijn Photographer/Shutterstock.com

Figure 22-8. Clay soil can be suitable for vegetable production if organic matter is added.

Soil

An ideal soil for producing vegetables is a sandy loam. Almost any soil, however, can be used to grow vegetables when an effort is made to improve the soil. Clay soils tend to hold too much moisture and crust. However, they do hold nutrients well. Managing the soil structure by adding aggregate particles can improve water drainage, **Figure 22-8**. Sandy soil has limited water-holding capacity, is nutrient poor, and tends to be dry, but it also has large pore spaces for air and warms earlier in the spring. Cultural practices, such as adding organic matter, play a significant role in improving soil structure, which in turn increases infiltration, water- and nutrient-holding capacity, and drainage. Organic matter levels can be raised by incorporating thick layers of well-rotted leaves, compost, old horse manure, and peat moss in the spring before preparing the soil and again in the fall after harvest. Green manure crops, such as annual rye, ryegrass, and wheat, can be planted as winter cover crops and turned under in the spring.

Avoid wet soils that have a high water table, a seasonally high water table, or a perched water table. A ***perched water table*** is groundwater that is temporarily located above unsaturated soil due to compaction or some other soil formation factor. Soils that lie only a few inches above bedrock should also be avoided. Avoid working in the garden or field when the soil is too wet. Often in late winter and early spring, snow melt, rain, and cool temperatures keep the soil moisture high. Soil that is worked or tilled when it is too wet forms large, hard clods, which are difficult to break up and unsuitable for creating a smooth seedbed. Once the soil is ready, work it by turning it over with a shovel, tilling, or simply loosening to a depth of at least 6″–7″ (15 cm–18 cm). Then rake it smooth before sowing or planting.

Nutrient Management

Vegetables, like any other plants, have specific nutrient and pH requirements. A soil test can determine the nutrient and pH levels of the soil. The results will determine whether to add nutrients and alter the pH.

Most vegetables grow best in a pH range of 6–6.8. Nutrients vary by crop, but generally a complete fertilizer (one that contains nitrogen, phosphorus, and potassium) will be sufficient for growing needs.

Changing pH

A soil's pH can be amended to be more acidic or alkaline and to make more nutrients available for plant uptake. Liming is the most common way to raise pH levels. Liming involves adding ground lime (calcium carbonate and other materials) to the soil using some sort of spreader. Soil test reports will recommend the amount of lime to add to the tested soil. In alkaline soils, acidic soil amendments are added. These amendments can include pine bark, peat moss, or elemental sulfur. Apply sulfur with caution since applying too much can injure plants.

Fertilizer

Based on the results of soil tests and recommended rates of application, fertilizers are typically applied before or at planting time. Fertilizers are broadcast and then tilled into the soil at a depth of 3″–4″ (7.5–10 cm). Broadcast one-half to two-thirds of the fertilizer over the garden and incorporate it into the soil. Band the remaining fertilizer in furrowed rows 3″ (7.5 cm) from the seeds or transplants. Generally, fertilizer applications are spread throughout the growing season in multiple applications. In a home garden, fertilizer should be applied through side dressing every four to six weeks. Side dressing places the fertilizer on both sides of the vegetable row about 4″ to 6″ (10 cm to 15 cm) from the plants. In irrigated commercial operations, fertigation may deliver nutrients in small amounts daily.

Fertilizer can come from both organic materials and mineral sources. Examples of organic material (not specifically approved for organic production) include manure, cover crops, bonemeal, blood meal, soybean meal, alfalfa meal, and seaweed. Mineral sources used in both conventional and organic production include different mineral forms of nitrogen, potassium, and phosphorus along with other macro and micronutrients. Always follow directions on fertilizer labels regarding application and safety.

Temperature

Temperature plays a key role in vegetable production by determining what can be grown in a given season. In some cases temperature can be manipulated to extend the growing season. There are two categories of vegetables: warm-season vegetables and cool-season vegetables.

Warm-Season Vegetables

As the name suggests, warm-season vegetables thrive in warmer temperatures and risk chilling or freezing injury if exposed to cool temperatures. Injuries happen most often when temperatures drop below 45°F–50°F (7°C–10°C) and include rapid respiration, molds, and rot on plants. The injuries can also cause bitter flavors. Cucumbers, tomatoes, and tropical fruits and foliage are sensitive to chilling injuries.

Many warm-season vegetables need a lengthy growing season of 80–100 days to produce fruit. Plant warm-season vegetables as soon as soil temperatures warm to avoid extreme summer temperatures that can affect fruit set and development. Soil temperatures generally warm after danger of frost in the spring. Within warm-season vegetables the range of minimum soil temperatures for germination is between 50°F and 60°F (10°C and 15.5°C), **Figure 22-9**. Seed tends to rot rather than germinate if soils are cool and wet. Beans and corn are particularly susceptible to these conditions. Okra, peppers, and eggplant can germinate at 60°F (15.5°C), but at an optimal temperature of 85°F (30°C), they will germinate quickly.

Warm-season vegetables include beans (bush, pole, and lima), melons, sweet corn, cucumber, eggplant, okra, field peas, peppers, pumpkins, squash (summer and winter), sweet potatoes, tomatoes, and watermelon.

Cool-Season Vegetables

Cool-season vegetables grow during colder months. In mild climates, this creates two growing seasons: fall and spring. In northern climates, spring is generally when cool-season vegetables are planted unless season extension systems are used. Cool-season vegetables prefer growing temperatures between 60°F and 80°F (15.5°C and 27°C). Optimum ranges vary among crops.

Planting Guide for Warm-Season Vegetables

Crop	Minimum Germination Temperature	Optimum Germination Temperature	Maximum Germination Temperature	Plant Spacing	Planting Depth	Days to Germination	Typical Days to Harvest	Age of Transplants (weeks)
Beans	50°	80°	90°	6″ or 4″ × 12″	1″–1 1/2″	6–14	60	
Cantaloupe	60°	90°	100°	36″–48″	1″–1 1/2″	3–12	85	2–3
Corn	50°	80°	100°	12″ × 30″ or 9″ × 36″	1″–1 1/2″	5–10	60–90	
Cucumbers	60°	90°	100°	6″ trellised 24″–36″ not trellised	1″	6–10	55	2–3
Eggplant	60°	80°	90°	18″–24″	1/4″	7–14	60T	6–9
Pepper	60°	80°	90°	15″–18″	1/4″	10–20	70T	6–8
Tomato	50°	80°	100°	24″ between trellised plants	1/4″	6–14	65T	5–7
Summer Squash	60°	90°	100°	36″–48″	1″–1 1/2″	3–12	50	2–3
Winter Squash	60°	90°	100°	36″–48″	1″–1 1/2″	6–10	100	2–3
Watermelons	60°	90°	110°	36″–48″	1″–1 1/2″	3–12	85	2–3

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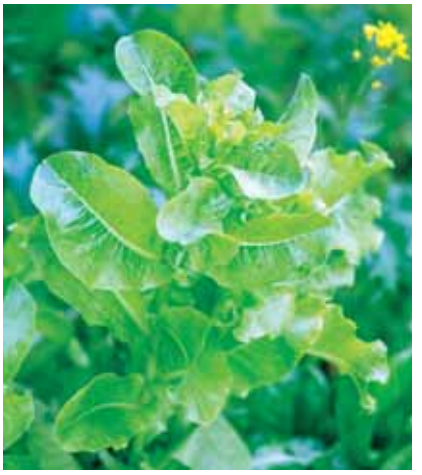
Figure 22-9. Warm-season vegetables have minimum and optimum temperatures for germination.

When temperatures start to rise, many species tend to bolt, or develop a flowering stalk that can produce off-flavors and bitterness, **Figure 22-10**.

Cool-season vegetables can germinate when soil temperatures are at 35°F–40°F (1.5°C–4.5°C) with optimal temperatures being higher, **Figure 22-11**. Many cool-season vegetables can reach a harvestable age fairly rapidly and seeds can be planted multiple times. For example, lettuce or other leafy greens can be sown or transplanted every few weeks up to a certain point for multiple harvests.

Cool-season vegetables include beets, broccoli, cabbage, carrots, cauliflower, collards, kohlrabi, leeks, lettuce, onions, parsnips, peas, potatoes, radishes, rutabagas, spinach, Swiss chard, and turnips.



AN NGUYEN/Shutterstock.com

Figure 22-10. When temperatures increase, lettuce bolts, becoming bitter and inedible.

Season Extension

Season extension techniques can be as simple as selecting early maturing varieties of a vegetable. More complex systems include using high tunnels, row covers, or other methods.

Planting Guide for Cool-Season Vegetables

Crop	Minimum Germination Temperature	Optimum Germination Temperature	Maximum Germination Temperature	Plant Spacing	Planting Depth	Days to Germination	Typical Days to Harvest	Age of Transplants (weeks)
Beets	40°	80°	90°	4″–6″	3/4″–1″	7–10	60	
Broccoli	40°	80°	90°	18″	1/2″	3–10	65	5–7
Cabbage	40°	80°	90°	18″	1/2″	3–10	85	5–7
Carrots	40°	80°	90°	2″–3″	1/4″	10–17	70	
Cauliflower	40°	80°	90°	18″	1/2″	3–10	65	5–7
Kohlrabi	40°	80°	90°	7″–9″	1/2″	3–10	50	
Leeks	40°	80°	90°	4″–6″	1/4″	7–12	120	
Lettuce (leaf types)	35°	70°	70°	7″–9″	1/4″	4–10	60	
Onion (green)	35°	80°	90°	2″–3″	1/4″	7–12	60	
Onions, dry (seed)	35°	80°	90°	4″–6″	1/4″	7–12	110	
Parsnips	35°	70°	90°	5″–6″	1/2″	15–25	70	
Peas	40°	70°	80°	4″–6″	1″	6–15	65	
Potatoes	45°			12″–15″	4″–6″		125	
Radish	40°	80°	90°	2″–3″	1/2″	3–10	30	
Spinach	40°	70°	70°	4″–6″	1/2″	6–14	40	
Swiss chard	40°	85°	95°	7″–9″	1″	7–10	60	
Turnips	40°	80°	100°	4″–6″	1/2″	3–10	50	

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Figure 22-11. Cool-season vegetables have a minimum and optimum temperature range for germination.

The purpose of season extension methods is to lengthen the growing season by harvesting crops earlier in the spring and continuing to produce and harvest later into the fall and early winter. Season extension techniques moderate temperatures to protect crops from damage from extreme heat or cold. For commercial growers, season extension allows potential year-round income and employment, high yields, and customer retention and attraction. Season extension can involve several factors including the planting site, shade, transplants, cultivar selection, windbreaks, mulches, row covers, low tunnels, and high tunnels.

Planting Site

The location of the planting site can greatly influence temperature, creating microclimates or allowing management of warmer or cooler air. As mentioned earlier, a south-facing slope will stay warmer in the late fall and warm up more quickly in the early spring. Wind exposure at the top of a hill and cold pockets at a bottom of a hill can be a challenge and should be avoided. The soil provides a large reservoir of heat. Dark soils will warm up sooner in the spring than light soils. A similar effect can be achieved by mulching soils. In certain areas, such as the fruit-growing regions around the Great Lakes in Michigan and New York, large bodies of water provide a strong buffer, lessening extreme temperatures.

Shade

Natural or artificial shade can be created to moderate temperatures during summer heat. Using shade allows the production of heat-sensitive crops, such as lettuce, spinach, and other leafy greens, further into the growing season. Shade can be created in a variety of ways including lathe houses, shade cloth, or even planting underneath solar panels.

Kingarion/Shutterstock.com

Figure 22-12. This radish cultivar can be harvested in as few as 22–25 days.

Transplants

Using transplants is a key season extension technique, providing as much as a three- to four-week head start on the season compared to direct seeding. Transplants may be able to establish themselves more quickly and outcompete weeds. However, transplants are more expensive to buy or grow than seeds.

Cultivar Selection

Cultivar selection is another way to extend the season and may involve an additional cost. Choosing early-maturing cultivars can result in earlier harvests, offering growers an edge in competitive markets, **Figure 22-12**. Selecting cultivars with different maturity dates allows harvesting to be staggered.

Staggering the planting dates can also lengthen the season. Harvest dates can be calculated using the days to maturity information on a seed packet and the planting date. Selecting cultivars that are heat tolerant and others that are more cold tolerant will lengthen the seasons into summer or into the fall and early winter.

Windbreaks

Windbreaks are structures, plants, or features of the landscape that serve as a physical barrier against wind. Windbreaks can protect tender crops from cooling winds and injury. Fences, brush piles, brambles, trees, fence rows, cropping strips, shrubs, stone walls, and snow fences make effective windbreaks. Rye planted in strips has been found to be an economical windbreak in intensive vegetable plots. In some cases, windbreaks can provide a desirable crop, such as blueberries or figs. The decorative branches of willows grown as a windbreak can also be used in floral designs, **Figure 22-13**. Place windbreaks perpendicular to prevailing winds.

Hallgerd/Shutterstock.com

Figure 22-13. Willows can be planted as a windbreak and then harvested for use in floral design.

Mulches

Plasticulture is the practice of using plastic mulch in vegetable and small fruit production, **Figure 22-14**. Benefits include increased soil warming in the spring, weed suppression, enhanced insect control, and high-quality crops. Research has shown that crops grown with black plastic mulch can be harvested 7 to 21 days earlier than those produced on bare ground. Black plastic is the most common color used, but clear, white, and red plastics are also used. Each has its own benefits and drawbacks. For example, clear plastic can quickly raise soil temperatures but it also encourages weed growth. All plastic mulches require irrigation, usually in the form of drip irrigation. Plastic mulches are not biodegradable. They are generally used for only one season and then discarded. New plastic must be purchased the following season. Specialized equipment is used to lay plastic mulch in commercial gardens.

chungking/Shutterstock.com

Figure 22-14. Plasticulture is the practice of laying thin plastic over a row. It can warm the soil early in the spring.

Organic mulches, such as newspaper, decomposed leaves, straw, and wood chips, are also used. In a home garden, these materials may be a good fit. However, depending on the type of mulch, they may delay soil warming.

Olaf Speier/Shutterstock.com

Figure 22-15. Row covers trap radiant heat from the soil and keep plants from freezing in the early spring or late fall.

sch_o_n/Shutterstock.com

Figure 22-16. A low tunnel is a season extension method that provides protection from chilling temperatures.

Row Covers

A ***row cover*** is a piece of lightweight fabric (usually spun polyester) that is laid on top of plants to provide protection from frost or insects, **Figure 22-15**. Row covers allow rain, sunlight, and air to penetrate. The covers can be secured against the wind by burying the edges in soil or weighing them down with heavy materials or pins. Different material thicknesses offer varying degrees of frost protection. Row covers are used in the early spring and removed as the plants mature. They may be used again in late fall until harvest. Row covers can be used in conjunction with other season extension approaches.

Row covers can offer effective insect control, creating a physical barrier between plants and insect pests. Aphids, leafhoppers, cabbage worm, and cabbage looper can be well controlled with row covers. However, pests that spend part of their life cycle in soil can use the row cover as a screen that protects them from natural predators. Row covers may increase weeds as well.

Low Tunnels

Low tunnels consist of PVC pipes or wire formed into hoops and covered with clear plastic or fabric row covers that run the length of the vegetable row, **Figure 22-16**. Low tunnels provide another method for moderating temperatures, excluding insect pests, and providing wind protection. Row covers or plastic mulch can be used inside low tunnels. In colder climates, low tunnels may be used within a high tunnel to provide additional protection from chilling or freezing injury during the winter. Low tunnels need to be monitored because the heat they trap can cause daytime temperatures to rise to injurious levels. Opening the sides of low tunnels will provide ventilation and may help cool the air. Crops that require pollination, such as tomatoes, eggplants, squash, and peppers, may only be in the low tunnel for three to four weeks before the tunnel is removed for the rest of the growing season.

Corner Question

Q

Are sweet potatoes and yams the same thing?

Hands-On Horticulture

Constructing Low Tunnels

Many low tunnel hoops are constructed by using wire or PVC pipe. No. 9 wire is cut in 65″–72″ (165 cm–185 cm) lengths using bolt cutters. The ends of the hoops are inserted 6″–8″ (15 cm–20 cm) into the soil and spaced about 48″ (120 cm) apart. The cover is laid across the hoops with the edges buried in the soil. PVC pipes can be used in a similar manner to form hoops. Metal rebar stakes are pounded into the ground and serve as holding pegs for the PVC pipes.

Akiyoko/Shutterstock.com

High Tunnels

A high tunnel (also called a hoop house) is similar to a greenhouse; it is typically covered in a polyethylene plastic and enables nearly year-round vegetable production, **Figure 22-17**. Common high tunnel styles are Quonset or Gothic. They are usually single, stand-alone structures, but multiple bay tunnels are also used. Some high tunnels are made to be moveable, whereas others are stationary.

paul prescott/Shutterstock.com

Figure 22-17. High tunnels give growers more opportunity to sell their vegetables.

High tunnel frames can be made with metal pipe, wood, or PVC. They are covered with one or two layers of polyethylene. When there are two layers, the space between the layers is filled with air to provide greater insulation. Like low tunnels, daytime temperatures can rise significantly in high tunnels. The tunnels need to be ventilated, either by rolling up the sides or lowering drop-down walls. Most high tunnels do not have permanent heat sources, but some may use portable heat. Some growers even use compost to provide a source of heat. Plants growing in the high tunnels are typically planted directly into the soil. The soil is tilled using a small rototiller or, in some cases, a small tractor. Plants in high tunnels can be covered with row covers or low tunnels to maximize the capture of radiant heat.

High tunnels offer several advantages to growers. Growers have opportunities for earlier and later market dates, can sometimes produce twice the amount of produce as for field-grown crops, and can have high-quality vegetables. High tunnels can also be a strategy for pest control, providing a physical barrier against many insects and plant pathogens.

High tunnels also have some disadvantages. They can limit the ability to move crops to different areas, they can have insect and disease problems, and they require an initial investment to build.

Production Methods

Growing vegetables requires a number of different techniques and practices to maintain soil quality, reduce risk of pests, encourage high yields, and optimize food safety. Growers and gardeners have a range of production choices available in which factors such as economics, environmental implications, and personal philosophy all play a role.

Spacing

Proper spacing between plants is important for proper plant growth, ease of cultivation, weed suppression, disease minimization, and optimal yields. Spacing requires a balance between efficiently using space while allowing for airflow and reception of light for photosynthesis. Each vegetable has a recommended spacing between plants within a row and between rows. ***Interplanting*** is an intensive production method in which early maturing crops are planted between rows of later-, or long-season, crops. For example, peas or radishes, both early maturing crops, may be planted between rows where tomatoes, peppers, cabbage, or corn will be grown. Vertical gardening is another approach often used by home gardeners to maximize planting space. Vertical gardening uses poles, trellises, nets, strings, or cages to train and support vines and other sprawling plants. Vegetables suited to this method include peas, pole beans, cucumbers, tomatoes, and melons.

Crop Rotation

Crop rotation is a production practice in which vegetables of the same plant family are planted in different locations every growing season. Crop rotation helps minimize pests and plant pathogens and manage soil fertility. Many insect pests and diseases can overwinter in the soil. Their populations can be significantly diminished if their preferred host plant is not immediately available to them. Crop rotation can also increase soil nutrients. Plantings of nitrogen-fixing legumes, such as snap beans, lima beans, and field peas, can be followed in the next season by high-feeding crops, such as corn or tomatoes. Roots crops, such as carrots, beets, parsnips, and rutabagas, can improve soil structure. They should be followed by shallow-rooted crops, such as salad greens, that benefit from soil improvement.

Large growers will have more room to manage crop rotation, but even home gardeners can move vegetables around each year. Make a planting map and record which plant families are placed where each season to create a system for future plantings. **Figure 22-18** categorizes various plant families.

Family Name	Crops	Ornamentals	Weeds
Apiaceae	caraway, carrots, celery, chervil, cilantro, dill, fennel, parsley, parsnips	Trachymene, Bupleurum	poison hemlock, wild carrot
Asteraceae	artichoke, chamomile, chicory, dandelion, Echinacea, endive, escarole, Jerusalem artichoke, lettuce, radicchio, safflower, sunflowers, tarragon	aster, cosmos, marigold, mums, Rudbeckia, yarrow, zinnia	chicory, cocklebur, dandelion, goldenrod, thistles
Brassicaceae, Cruciferae (cabbage or mustard family)	bok choi, broccoli, Brussels sprouts, cabbage, cauliflower, Chinese cabbage, collards, cress, horseradish, kale, kohlrabi, mustard, pak choi, radish, rapeseed, rutabaga turnips, watercress	alyssum, kale, candytuft, stock, yellowcress, garden yellow rocket	bittercress, mustards, pepperweed, shepherd's purse, swinecress
Chenopodiaceae	beets, chard, spinach, sugar beets		Kochia, lamb's-quarter
Cucurbitaceae	cucumber, gourds, melons, pumpkin, summer squash, watermelon, winter squash		
Ericaceae	blueberries, cranberries	azalea, heather, rhododendron	
Fabaceae	alfalfa, beans, birdsfoot trefoil, black medic, clovers, cowpea, edamame, fava beans, garbanzo bean, hairy vetch, lentils, peanut, peas, soybean, vetches		black medic, common vetch
Lamiaceae	basil, catnip, lavender, marjoram, mints, oregano, rosemary, sage, thyme	bells-of-Ireland, salvia	catnip, henbit, mints
Liliaceae	asparagus, chives, garlic, leeks, onions, shallot	daffodils, daylily, hosta, hyacinth, tulip	
Poaceae	barley, corn, fescue, millet, oats, rice, rye, ryegrass, sorghum, timothy	ornamental grasses	brome, barnyard grass, crabgrass, fall panicum, foxtail, Johnson grass, quackgrass
Polygonaceae	buckwheat, rhubarb		knotweed, smartweed
Rosaceae	apples, apricots, blackberries, cherries, nectarines, peaches, pears, plums, raspberries, strawberries	multiflora rose	
Solanaceae	eggplant, peppers (bell and chile), potatoes, tobacco, tomatillo, tomatoes	Million Bells®, petunia	buffalobur, groundcherry, henbane, horsenettle, jimsonweed, nightshade

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Figure 22-18. This table lists the family name for most commonly grown vegetables. Use it when considering crop rotation.

Thinking Green

Certified Organic Growers

Organic farmers, ranchers, and food processors conform to a defined set of standards for organic food and fiber production. Following the standards for organic vegetable production, farms that have passed an audit may use the USDA organic seal. The seal certifies the following were not used: irradiation, sewage sludge, synthetic fertilizers, prohibited pesticides, and genetically modified organisms. These standards cover the product from start to finish. They include soil and water quality, pest control, livestock practices, and food additive rules. All farmers, whether certified organic, pesticide free, sustainable, or conventional, tend to use overlapping production methods that protect and enhance the environment and provide profits for the growers. Many organic growers work toward a triple bottom line, one that positively impacts the environment, economics, and social good. Organic certification exposes growers to markets that can demand higher prices from consumers, making organic certification both a philosophical and economical decision.

Lance Cheung/UDSA

Integrated Pest Management

Integrated pest management (IPM) is an environmentally sensitive approach to managing pests that uses commonsense, economical practices and results in the least possible hazard to people, property, and the environment. IPM practices include cultural, physical, biological, chemical, and genetic tactics to control or minimize damage by pest organisms. A number of pest management practices for vegetable crops exists, including row covers, crop rotation, spacing, and cultivar selection. Tactics for managing pests are specific to each crop and each pest and should be researched to find the best control methods.

Good Agricultural Practices

A ***good agricultural practice (GAP)*** is a farm-level production method used to ensure that fresh produce is safe for human consumption. GAP production and postharvest guidelines are designed to minimize the risk of foodborne disease contamination on fresh produce. Harmful microbes such as E. coli, salmonella, and listeria (among many others) can contaminate fresh produce at any stage of production: growing, harvesting, processing, packaging, or marketing. The major source of microbial contamination on fresh produce is associated with human or animal feces.

Good agricultural practices consist of voluntary procedures that address potential sources of contamination in the soil and water and on hands and surfaces. Many buyers of produce, from public schools to grocery stores, require that growers have a GAP certification.

Certification comes from a third-party audit and approves the documented grower practices related to these factors:

- Clean hands. Hand washing is essential for preventing foodborne illness. Hand washing with soap and clean running water is the best practice for minimizing food safety risk. Also consider installing hand washing stations for customers at U-pick operations.
- Clean soil. Follow specific steps to reduce the risk of introducing microbial contaminants to the soil. Animal manure can carry human pathogens that can be eliminated through proper composting, storage, and application timing. Wild and domestic animals also carry the risk of introducing harmful microbes and should be physically barred from planting areas.
- Clean water. Practices should be in place for all water used in irrigation to minimize microbial hazards and meet minimum quality standards. All water used in washing, cooling, and processing of fresh produce needs to be potable.
- Clean surfaces. Surfaces used in packing, processing, storing, and transporting food should all be washed and sanitized regularly. Farms that have both produce and livestock should take specific steps to avoid any contamination.

Plant Material

Selecting vegetables and cultivars to grow is an important step in planning production gardens or fields, **Figure 22-19.** Different cultivars or varieties have unique characteristics, such as disease resistance, early maturity, superior flavor, or long shelf life. Gardeners and growers will often plant high-performing standbys (plants proven to do well) and try one or two new cultivars for a few years to see how their production compares. Growing a cultivar for multiple seasons allows the gardener to evaluate the plant over time and discount the environmental differences that may affect growth in one year.

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Figure 22-19. A garden plan will help you determine what you want to grow and how much space you will need.

Hybrids

Many vegetable crops grown commercially and in home gardens are considered hybrid cultivars. Hybrid cultivars have parent plants with desirable traits. These plants are cross-pollinated to produce seeds that are called hybrids. The hybrids contain a combination of traits that may include increased yield, vigor, nutritional content, ornamental value, stress tolerance, and growth habit.

Thinking Green

Warren County High School Garden Club

A group of ninth graders in Warren County, North Carolina, trekked outside with the rest of their class on an August morning to tour their school garden. They discovered that what their teacher called a garden was really an overgrown mess, with a lot of potential. They wanted to fix the space but knew it would take a lot of work. By the time they had returned to their classroom, they had formed a garden club. The club planned to meet after school to refurbish the garden, giving students a space to be proud of.

The following year, the Warren County High School Garden Club began selling their produce, mostly to teachers and family members. As they learned more and more about growing food, they also learned that they could sell more produce (and make more money) if they had access to a larger market. Why not sell to their school cafeteria? The students decided to work towards a Good Agricultural Practices (GAP) certification. Following these simple food safety measures allowed them to sell produce to their school cafeteria, greatly expanding their market.

First they created a farm safety manual, outlining what food safety precautions they would take to manage risk in their school garden. They then put those practices into use. They built hand-washing stations in their greenhouse, devised a three-bin system for washing harvesting tools, and helped build a 10′ electric fence to deter deer and other wildlife. In order to become officially GAP certified, the students invited a GAP auditor to the garden from the North Carolina Department of Agriculture. He inspected their food safety procedures in action, watched them harvest their produce, and observed their diligent recordkeeping. In the end, the students' garden passed the inspection, allowing them to sell their produce directly to their school! Students say the best part is eating their own delicious, fresh produce for lunch!

Hybrid seed production is time consuming and expensive. It can take years of breeding to develop the desired traits. The plant breeder holds exclusive rights and proprietary knowledge in the production of the hybrid. Growers and gardeners have to purchase new hybrid seed every year because collected seed from the hybrid will not be true to type. Seed, however, is often one of the least expensive production costs.

Browsing seed catalogs can be both fun and overwhelming. With so many choices, it can be hard to determine what cultivar is the best to grow. All America Selection (AAS) is a nonprofit organization that evaluates and selects cultivars that show superior performance. They have conducted trials with hundreds of cultivars across the United States and Canada since the 1930s. AAS plants have been judged to be reliable and have significantly improved qualities.

Tom Grundy/Shutterstock.com

Figure 22-20. Heirloom vegetables are prized for their good flavor and texture, particularly in tomatoes.

Heirlooms

Before plant breeding became a big business, may home gardeners and farmers would save seed from year to year. Through a process of evaluation, they would identify plants that showed exceptional traits. As with cultivars, some of these traits would include good flavor and texture, tolerance to local conditions or disease, or a unique appearance, **Figure 22-20**.

These plants from saved seeds are considered heirloom plants. Historically, heirloom plants were passed from one generation of growers to the next. Today, there is a renewed interest in heirlooms.

Heirlooms come from plants that are open-pollinated, meaning that plants freely cross-pollinate and are part of a fairly stable genetic population. Offspring of the open-pollinated plants will not be exactly like the parent plants, but they will be very similar. There are a number of well-known heirlooms, including 'Kentucky Wonder' pole bean, 'Nantes' carrot, 'Black Beauty' eggplant, 'Black Seeded Simpson' lettuce, 'California Wonder' pepper, and 'Brandywine' and 'Roma' tomatoes. Many heirlooms are prized for their intense flavor and fragrance. Many heirlooms, however, do not always have a long shelf life, as in tomatoes, for example. The fresh market for heirlooms is often limited to farmers markets or any other market where they do not stay on the shelf for more than a day.

Transplants

Transplants give growers and gardeners a head start in reaching a harvestable crop. Transplants should be healthy, vigorous, and free of any noticeable nutrient deficiency or pest problem. Vegetable transplants have an ideal age and size at which they should be transplanted. When transplanted at that ideal juncture, they can begin active growth immediately and are fairly tolerant of environmental stresses, **Figure 22-21**. The best age to transplant tomatoes, for example, is six to eight weeks. Plants less than six weeks are more susceptible to damage from wind or low temperatures (below 45°F or 7°C) and water stress. On the other hand, plants older than 10 weeks have a relatively large aboveground mass that has already started producing flowers and may be heading into the reproductive phase of growth. These plants will still produce tomatoes but at a much lower rate than their full potential.

Age of Transplants for Ideal Growth

Plant	Age
Broccoli	6–7 weeks
Cabbage	6–7 weeks
Cauliflower	6–8 weeks
Celery	9–12 weeks
Cucumber	2–3 weeks
Eggplant	8–10 weeks
Endive	5–7 weeks
Muskmelon	2–3 weeks
Onion	9–12 weeks
Pepper	8–10 weeks
Squash	2–3 weeks
Tomato	6–8 weeks

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Figure 22-21. Planning is required to determine the proper time to plant seeds indoors to reach a transplantable size for the garden.

Postharvest Handling and Storage

Postharvest is a process that involves the handling processes of a crop immediately following harvest. Postharvest processes include cooling, cleaning, sorting, packing, storing, and shipping. The goal of postharvest practices is to maintain the highest level of quality, including overall appearance, uniformity, absence of damage or blemishes (discoloration, harvest injury, insects), good taste and optimal flavor, and proper texture. For each type of vegetable, there is a definition of quality. For example, quality strawberries

and peaches must be sweet, snap beans and sweet corn must be tender, and carrots and snap peas must be crisp. Several factors can reduce postharvest quality including:

- Harvesting at the incorrect stage of maturity.
- Careless handling during harvest, packing, and shipping.
- Poor sanitation.
- Delayed or suboptimal cooling.
- Shipping or storing above or below optimal temperature.
- Lack of proper relative humidity.
- Exposure to ethylene gas (for some crops).

As soon as a crop is harvested, the deterioration process begins. Physiological processes are still occurring in the plant, including respiration and other chemical changes.

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Figure 22-22. This unripe pumpkin has not developed a hardened rind. It will have a diminished shelf life if it is harvested at this point.

Postharvest quality begins in the field with management practices. These practices produce the healthiest crops with the greatest opportunity for a longer shelf life. Scheduling harvest at the appropriate time is also important. If a crop is stressed from too much or too little water or is physically damaged, the crops may be more susceptible to postharvest plant pathogens that cause decay and rot. Harvesting vegetables that are too ripe or not ripe enough will also diminish shelf life, **Figure 22-22**. Many resources are available that detail maturity indicators by crop. Crops should be harvested according to these indicators. By following best growing practices, growers and home gardeners may be able to increase the length of time that vegetables remain fresh.

Handling

Cooler temperatures slow the rate of respiration. Harvest generally occurs during the coolest time of the day, which is in the early morning or the evening. After harvest, produce should be handled gently to minimize bruising. Damage to the vegetables, such as skin breaks, bruises, spots, and cuts, provides an entry for plant pathogens that cause decay. Moisture loss is also increased when vegetables are damaged. Damage can be reduced by proper handling, harvesting at optimal maturity for storage, harvesting when crops are dry, and minimizing the handling of the crops. For example, to avoid overhandling, growers might place harvested vegetables in their final storage container in the field. This is known as *field packing*. Packaging containers are designed to minimize physical damage to the crop.

STEM Connection

Iced Storage

Knowing which produce will suffer when stored with ice will reduce premature spoilage and financial losses.

Produce that can be iced: artichokes, asparagus, beets, broccoli, cantaloupes, carrots, cauliflower, endive, green onions, leafy greens, radishes, spinach, sweet corn, watermelon.

Produce that is damaged by direct contact with ice: blueberries, cucumbers, garlic, green beans, herbs, okra, onions, raspberries, romaine lettuce, squash, strawberries, tomatoes.

Storage

Several factors are important in postharvest storage. Temperature, moisture loss, sanitation, and the presence of ethylene can affect the quality and shelf life of stored vegetables.

Temperature

Temperature is the single most important factor in maintaining quality after harvest. Vegetables should be brought to their proper storage temperature as soon as possible after harvest. Cooler temperatures slow respiration rates and slow the loss of sugars, fats, and proteins that affect flavor, salable weight, and shelf life. Most postharvest systems include refrigerated storage, which delays crop deterioration. Factors that refrigeration slows includes:

- Aging, which leads to softening, textural changes, and color changes.
- Undesirable respiration, which produces heat that can speed deterioration.
- Moisture loss with subsequent wilting.
- Spoilage caused by pathogenic bacteria, fungi, and yeasts.
- Unwanted growth, such as sprouting in onions.

Cooling facilities on the farm allow growers to cool and store produce, eliminating the need to sell crops immediately and provides growers with more market flexibility. Cooling facilities can be costly. Harvested produce should be precooled to remove any field heat. *Field heat* is the residual heat that crops hold from air temperatures and from the sun. Precooling is most important for crops with high respiration rates, such as Brussels sprouts, green onions, snap beans, asparagus, broccoli, mushrooms, peas, and sweet corn.

Precooling can be done in a number of ways. In room cooling, produce is placed in an insulated room with refrigeration units. Cooling this way takes time, but this can be the same room where the produce is ultimately stored. The packaging should be ventilated to allow cold air to move through it. Forced air cooling adds fans to refrigerated rooms. The fans pull cool air through the packaged produce. This method is 75%–90% faster than room cooling only.

Hydrocooling is a process in which harvested vegetables are dumped into a cold water tank or cold water is run over produce. This method efficiently removes heat and cleans produce. Crops such as berries, potatoes, sweet potatoes, onions, and garlic cannot tolerate being wet and so should not be hydrocooled. Hydrocooling also increases the risk for disease.

Top or liquid ice cooling is used on some vegetables, such as asparagus, broccoli, cauliflower, green onions, leafy greens, and sweet corn. Crushed ice is placed on top of the packaging that covers the produce. In liquid icing, a slurry of water and ice is injected into produce packages. Icing is especially effective on perishable items that cannot be readily cooled by other methods.

Vacuum cooling creates a vacuum in the chamber that holds the produce. Water within the plant evaporates and removes the heat. Produce can be rapidly cooled this way, but it can be an expensive method. It is used on only certain crops, such as lettuce and other leafy greens.

Lissandra Melo/Shutterstock.com

Figure 22-23. Sweet potatoes develop odd flavors and undesirable texture when exposed to chilling temperatures.

Many vegetables have an optimal storage temperature at just above freezing. Some vegetables can be injured by low temperatures, preferring slightly warmer temperatures. Basil, cucumbers, eggplants, pumpkins, summer squash, okra, and sweet potatoes are very sensitive to chilling injury, **Figure 22-23**. Moderately sensitive crops include snap beans, muskmelons, peppers, winter squash, tomatoes, and watermelons. Both time and temperature play a role in chilling injury. Many people store tomatoes in the refrigerator, and they will be fine when first removed. However, after a few days in warmer temperatures, chilling symptoms will emerge, which can include skin blemishes, loss of texture, and pitting.

Moisture Loss

Relative humidity in the postharvest environment directly influences water loss in the harvested crop. Water loss causes shriveling, wilting, a loss of texture (limpness), diminished crispness and juiciness, and softening. Many vegetables are sold by weight, and water loss will reduce profits. For most vegetables, postharvest quality is optimized with a high relative humidity (80%–95%). However, high humidity also encourages disease growth. Cool storage temperatures reduce disease growth. Combine high humidity and cool storage temperatures with sanitation and other methods to reduce risks. Refrigeration removes moisture from the air, often requiring the addition of moisture to storage facilities.

Sanitation

Sanitation is process of keeping places or items free from dirt, disease, infection, and other substances that can cause illness. Proper sanitation practices reduce risks of postharvest diseases and lessen food safety risks from foodborne illnesses. Using a disinfectant in wash water and precooling water can help to prevent both postharvest diseases and foodborne illnesses.

Ethylene

Ethylene is a naturally occurring chemical emitted in varying quantities by fruits and vegetables and by decaying plant materials. Ethylene is given off by some fruits as they ripen. If these commodities are stored near crops that are sensitive to ethylene, they can promote unwanted or faster ripening of the sensitive crop. This can result in a loss of quality, reduced shelf life, and specific symptoms of injury. For example, carrots and parsnips exposed to ethylene will turn bitter, **Figure 22-24**. Cucumbers and squash will soften more quickly when exposed to ethylene. Tomatoes are ethylene producers.

Perutskyi Petro/Shutterstock.com

Figure 22-24. Carrots will turn bitter if exposed to ethylene.

Careers in Olericulture

Olericulture offers many different career possibilities. Two careers related to olericulture are vegetable grower and crop advisor.

Vegetable Grower

Growing vegetables for the fresh market or for processing remains one of the most important jobs in agriculture. The responsibilities of a vegetable grower include making decisions related to production, marketing, financing, and human resources management. On the production end, growers and their employees manage the soil and plant, cultivate, and harvest vegetables. Growers may use a broad range of tools from specialized equipment, such as tractors and implements, to shovels, trowels, hoes, and other hand tools. A grower's duties can include tilling the soil; applying fertilizers and pesticides; transplanting, weeding, thinning, irrigating, or pruning crops; and cleaning, packing, and loading harvested products.

Crop Advisor

A crop advisor or consultant advises growers, farm managers, and farm operators regarding their agronomic production practices. Many crop advisors work for large agricultural companies. By supporting growers these companies are able to meet sales goals and objectives by increasing the yields for a contracted crop. A crop advisor may market products to growers by making calls, providing advising or consulting services, and monitoring individual grower programs with respect to pesticides, fertilizers, irrigation, tillage, seed, and related areas. An ideal crop advisor has a bachelor's degree from an accredited four-year college or university program, plus three to five years of experience.

CHAPTER 22

Review and Assessment

Chapter Summary

- Vegetables contain important vitamins and minerals and are an essential part of a healthy diet. Vegetables can reduce the risk of heart disease, heart attacks, strokes, and certain cancers. They can lower blood pressure, decrease bone loss, and potentially lower calorie intake.
- Vegetables average $17.4 billion dollars in annual sales and are grown on nearly 2.8 million acres across the country. Vegetables are destined for either fresh or processed food markets.
- A number of factors influence vegetable production including location, water, soil, nutrient management, temperature, and growing season extension methods.
- Most vegetables are irrigated. Common irrigation practices include drip, or trickle, irrigation and different kinds of sprinkler irrigation.
- A good soil for producing vegetables is a sandy loam. Almost any soil, however, can be used to grow vegetables with significant effort toward soil improvement.
- For optimal yields, a nutrient management plan is critical. Growers should change the pH of the soil or add nutrients as recommended by a soil test report.
- Temperature plays a large role in vegetable production by determining what can be grown in a given season. Vegetables are either warm-season or cool-season and should be planted accordingly.
- Season extension techniques will lengthen the growing season and provide earlier or later harvest. Season extension can be achieved using shade, transplants, cultivar selection, windbreaks, mulches, row covers, low tunnels, and high tunnels.
- Crop production methods, such as using proper spacing, rotating plant families, managing pests, and choosing the right plant material, optimize space and reduce risk of infection by plant pathogens. Using good agricultural practices that address potential sources of contamination is also important.
- Postharvest storage and handling may include cooling, cleaning, sorting, packing, storing, and shipping the harvested crop. A number of factors reduce postharvest quality. Through management of temperature and humidity, the deterioration can be slowed.

Words to Know

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

A. crop rotation	D. interplanting	H. row cover
B. dripline	E. leaching	I. sanitation
C. good agricultural practice (GAP)	F. low tunnel	J. olericulture
	G. perched water table	

1. A lightweight fabric that is laid on top of vegetables to provide protection from frost or insects.
2. The movement of nutrients out of the soil into the groundwater.
3. The process of keeping places or items free from dirt, disease, infection, and other substances that can cause illness.
4. The outermost circumference of a tree's branches where water drips from the leaves onto the ground.
5. A method of planting early maturing crops next to later maturing crops to maximize space efficiency.
6. A production practice in which vegetables of the same plant family are planted in different locations every growing season.
7. Groundwater that is temporarily located above unsaturated soil due to compaction or some other soil formation factor.
8. The practice of producing edible vegetable crops.
9. A farm-level production method used to ensure that fresh produce is safe for human consumption.
10. A season extension technique in which small hoops are placed over rows and covered in fabric or plastic.

Know and Understand

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

1. Why is eating vegetables an essential part of a healthy diet?
2. What role does dietary fiber play in the body and in what vegetables can it be found?
3. Which US states are top producers of vegetables?
4. How are the products in the vegetable industry classified for end uses?
5. Describe the mix of small and large farms that produce vegetables in the United States.
6. What is involved in the local food movement?
7. What are some environmental factors that impact vegetable production?
8. What are some considerations for selecting a location for a vegetable garden?
9. What are some benefits of using drip irrigation for growing vegetables?
10. What is the ideal soil for growing vegetables? How can other soils be managed to grow vegetables?

11. What effect can cold temperatures have on warm-season vegetables?
12. What is the purpose of season extension methods and what are some factors that relate to season extension?
13. How can cultivar selection for a vegetable garden extend the growing season?
14. List some advantages and disadvantages of using high tunnels.
15. Why is crop rotation an important production method?
16. What is the purpose of good agricultural practices (GAP) guidelines and what are four factors related to GAP?
17. What is a hybrid plant and why would a grower select hybrid plants when planning a vegetable garden?
18. List factors that can reduce postharvest quality of vegetables.
19. What role does temperature play in postharvest storage and handling?
20. Describe some of the duties and activities of a vegetable grower.

Thinking Critically

1. You are an employee who sells vegetables at a farmers market. A customer comes in with a complaint about how his produce rotted shortly after bringing it home. Determine and write the most appropriate response to this customer. Follow these guidelines:
   - Make sure you obtain a clear understanding of the complaint.
   - Restate the complaint using less negative terms.
   - Change the complaint into a question.
   - Explore alternative solutions.
   - Solve the problem.
   - Use proper grammar and spelling in your writing.
2. Your vegetable farm has been contracted to grow enough produce for a local foods promotion held once a week within the school system. The weather has not been cooperative, and your vegetables are behind schedule. You will not have enough harvestable material to meet your agreement. What will you do? List three possibilities to solve this problem.

STEM and Academic Activities

1. **Science.** Choose four different vegetable plants that interest you. Find the common name and the scientific name of each, using binomial nomenclature. Record this information in a table with three columns: Common Name, Scientific Name, and Example. In the Example column, either draw a picture of each plant or attach a photograph of the plant.
2. **Science.** Conduct research to learn more about why hybridizing tends to breed the flavor out of plants. Write a report on your findings.
3. **Technology.** Research environmental issues related to olericulture and learn how technology has played a role in the advancement of olericulture. Choose two specific topics and write a report explaining how technology has helped (or hurt) efforts in these specific areas to become more environmentally friendly.

4. **Math.** Your parents have permitted you to till a 10′ × 30′ (3m × 9m) garden plot to grow vegetables for the family. Determine the vegetables you would like to grow and create a plan. How many plants of each different vegetable can you fit into your garden?
5. **Social Studies.** Different societies and cultures have different food cultures. Conduct research to learn how food culture in the United States is different from that in other countries. What factors may have caused these differences?

Communicating about Horticulture

1. **Reading and Writing.** Working in groups of two or three, read the "Growing Site" section. Work together to summarize and write down the main points on study cards. Quiz each other on each concept.
2. **Listening and Speaking.** Make a collage. Using pictures from magazines or free online resources, create a collage that helps you remember ways that vegetables provide significant health benefits. Show and discuss your collage in a group of four to five classmates. Are the other members of your group able to determine the benefits that you tried to represent?
3. **Reading and Speaking.** Using your textbook, library resources, and the Internet, research a nontraditional vegetable. Focus on its geography and the way in which it is grown. Where is it grown? How is it is prepared? Which culture uses the vegetable? If possible, create a dish that incorporates the vegetable. If plant materials are not available, create a poster to illustrate your findings and dish. Present your findings to your classmates.

SAE Opportunities

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1. **Exploratory.** Job shadow a vegetable grower for a small, mid-sized, or large farm.
2. **Experimental.** Grow vegetables in two small plots. In one plot, space your vegetables as suggested by the manufacturer of the seed or plant. In the other plot, practice interplanting. What were your yields in each plot? Which plot had a greater yield?
3. **Experimental.** Research which vegetables will grow well in a high tunnel or low tunnel in your region. Try growing a few of the different types and determine which ones yield the best results.
4. **Exploratory.** Create a list of vegetable transplants that could be sold in your school's plant sale. Create a schedule for sowing these plants from seeds to be ready in time for a spring market. Give cultural information, including planting depth and time for transplant production. Determine how many seeds of each plant you will need to purchase and what the cost will be to fill your greenhouse.
5. **Entrepreneurship.** Grow vegetables in your school garden and sell them to customers. Where is your market? How will you advertise?