vegetable production series

Lettuce Production in California

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The lettuces (*Lactuca sativa*) produced in California are divided into two categories: head (iceberg) and leaf types. Romaine, a leaf-type lettuce, is included as a separate subcategory because it is by far the dominant lettuce type grown in California. Lettuces are grown for mature heads, hearts, individual leaves, and for baby products. Mature heads of lettuce are also harvested and lightly processed into bagged products. Lettuce is produced during the cool season in California. There are four main areas of commercial production in the state. The major production areas for lettuces in California are the Central Coast (Monterey, San Benito, Santa Cruz, and Santa Clara), the southern coast (San Luis Obispo, Santa Barbara, and Ventura counties), the Central Valley (Fresno, Kings, and Kern counties), and the southern deserts (Imperial and Riverside counties). Total annual production is the highest in Monterey County, followed by Imperial and Santa Barbara counties (table 1).

Production areas and seasons

Planting to harvest for mature heads takes 55 to 75 days for summer plantings and as long as 130 days for winter plantings. Baby products may be ready for harvest in as little as 30 to 35 days. On the Central Coast, where temperatures are mild year-round, lettuce is planted from late December to mid-August for harvest from early April to November. Southern coastal plantings are made

TABLE 1. Head, leaf, and romaine lettuce acreages, yields, and value

Year	Head lettuce			Leaf lettuce			Romaine lettuce		
	Acreage	Average yield tons/acre	Gross value/acre	Acreage	Average yield tons/acre	Gross value/acre	Acreage	Average yield tons/acre	Gross value/acre
2022	71,000	16.0	$13,498	51,000	11.5	$21,445	64,800	14.3	$16,917
2021	76,000	16.5	$9,583	50,000	10.3	$10,646	71,300	14.3	$10,778
2020	74,000	19.0	$12,112	53,000	12.8	$17,829	69,300	16.8	$17,698
2019	77,500	18.8	$11,325	48,000	10.7	$8,815	65,800	15.3	$8,387
2018	82,000	17.5	$9,782	57,000	7.5	$8,070	74,500	14.0	$7,896

Source: California Agricultural Statistics Review 2021–2022. Sacramento: California Department of Food and Agriculture, 2022.

from November to August for harvest from February to December. In the Central Valley, lettuce is planted from early August to early September for harvest from late October to mid-November; spring plantings are made from early November to late December for harvest in April. In the southern deserts, lettuce is planted from mid-September to mid-November for harvest from early December to March.

Climatic requirements

Lettuce is a cool-season crop with distinct temperature requirements. The optimal growing temperatures are 73°F (23°C) during the day and 45°F (7°C) at night. During the production season, most California growing regions have daytime temperatures ranging from 63° to 83°F (17–28°C) and night temperatures from 37° to 53°F (3–12°C). At the high end of the temperature range, lettuce suffers quality problems such as bolting, bitterness, fluffy heads, and postharvest issues. At temperatures near freezing, young plants are not damaged, but growth slows. Freeze damage can occur on the outer leaves of mature lettuce, leading to decay in postharvest handling and marketing.

Varieties and planting techniques

Head lettuces have strongly defined marketable quality characteristics for head size, weight, and shape. Heads form a dense ball-like structure that is surrounded by wrapper leaves, which are stripped off at harvest for packing (fig. 1). To achieve these quality criteria, only varieties that can reliably achieve these characteristics in the wide range of conditions at various planting periods and locations are selected. For instance, planting a variety that is not well adapted to the conditions of a planting period may result in stunted or puffy heads, or heads with long core lengths that do not meet quality criteria.

Figure 1. Head lettuce forms a tight ball-like structure which is surrounded by wrapper leaves as the plant is growing.

There are specific varieties adapted in each of the four planting areas of the state. In addition to quality criteria, varietal resistance to soilborne and foliar diseases such as corky root, Verticillium wilt, Fusarium wilt, Pythium wilt, and downy mildew are important. The long season on the central and south coasts includes early mid- and late-season planting slots. Varieties planted in this region include Armstrong, Hercules, Meridian, Portola, Reliant, Republic, Steamboat, and Telluride. In the desert region, conditions change from hot days to cooler days with freezing temperatures at night. Varieties planted in this region include Bubba, Franchise, Fredonia, Havasu, Meridian, and Navajo. In the Central Valley, varieties planted include Bubba, Diamond, Speedway, and Sundevil.

Leaf lettuces include romaine, red leaf, green leaf, and butterhead types that vary in leaf color, shape, and texture. Leaves are broad or narrow with leaf margins entire, lobed, or frilled (fig. 2). Romaine types are generally upright (fig. 3) but can also be flattened. Butterheads form small heads, and the leaves have a soft texture.

Figure 2. Lolla Rosa is a red leaf lettuce which is notable for having highly frilled leaf margins.

Figure 3. A typical planting of 6 seedlines of romaine on an 80–inch wide bed. This variety is an upright type that will be harvested for romaine hearts.

Common commercial green-leaf lettuce varieties in California include Big Star, Burgam's Green, and North Star; red-leaf varieties include Red Fox and Red Tide; butterhead varieties include Margarita; romaine varieties include Abilene, Boronda, Duquesne, Green Towers, Inferno, Rio Bravo, Solid King, True Heart, and Valencia. There are also combinations of these lettuce types grown for premium and specialty markets. Lettuce for these markets is usually packed in containers with different colors and types of lettuces to increase their appeal to consumers. Leaf types of lettuce are used for baby lettuce production.

Lettuce on the Central Coast and in the desert is typically planted using pelleted seed and precision planters (fig. 4). Transplant acreage has traditionally been limited to the start of the season or when production schedules need to be met. However, given the changes in the economics of crop production and the development of modern technologies that allow for rapid planting of transplants such as Plant Tape®, an increasing percentage of acres are transplanted. In Ventura County and parts of Santa Barbara County, lettuce is predominantly transplanted. Lettuces are planted on beds either 40 or 80 inches (102 or 203 cm) wide. The 40-inch beds have two seedlines, and 80-inch beds can have five to eight seedlines. Seeds are planted 2 to 3 inches (5–7.5 cm) apart and are thinned to 10 to 12 inches (25–30.5 cm) apart after emergence. For romaine hearts, an upright variety is planted, and the lettuce is thinned to 5 to 6 inches (12.7–15.2 cm) apart. Given differences in seed spacing and row configurations, the number of seeds planted per acre can vary from 104,550 to 235,460 (258,375–581,820 seed/hectare [ha]) which is more seed than necessary to achieve the desired spacing. The lettuce is then thinned by either hand crews or automated thinners. The per acre cost of seed varies with variety, coating, spacing, seed enhancement, and priming treatments (osmoconditioning). Non-primed, natural lettuce seed may be susceptible to thermodormancy when ambient temperatures are above 90°F (32°C) for an extended period. Priming allows the seed to overcome thermodormancy and germinate at higher temperatures. Thermodormancy can also be broken by starting the initial irrigation in the late afternoon so the seed can imbibe water and germinate during cooler hours at night.

Figure 4. Direct-seeding six seedlines of lettuce on a bed 80 inches wide. Anticrustant and herbicide are applied over the top of the seedline.

Soils

Lettuce requires good drainage and can be grown on sandy to clay soils. In areas where early production is the goal, it is planted on lighter-textured soils that warm quicker in the spring. Typically, soil is laser leveled to eliminate wet areas and facilitate even drying of the fields. Once the field has dried sufficiently, the beds can be quickly tilled and shaped for planting. This is particularly important for late-winter and early-spring plantings where growers are trying to plant between storms.

Lettuce is classified as a moderately salt-sensitive crop. Evaluation of the salinity of the soil and irrigation water is recommended. Measuring the electrical conductivity of a saturated paste extract is the ideal way to evaluate the bulk salinity level of the soil. Values above 1.3 deciSiemens per meter in the root zone may reduce lettuce growth if most of the salts are sodium and chloride. However, lettuce can tolerate higher electrical conductivity values if the main salts are calcium, sulfate, or carbonate (gypsum or lime). Over the season, salts will generally build up in the rootzone and applying extra irrigation water (leaching fraction) to leach salts below the rootzone of the crop is often required. Refer to UC ANR publication 8550 for more information on calculating the leaching requirement of lettuce and other crops.

Irrigation

In all growing regions sprinklers are typically used to pre-irrigate fields to soften soil for seedbed preparation. On the Central Coast growers usually pre-irrigate with 3 to 4 inches (7–10 cm) of water. In the southern desert, growers typically apply 12 inches (30 cm) during pre-irrigation, which will also leach salts that may have accumulated at the soil surface during previous crops. Both hand-move and solid-set sprinklers are used for stand establishment. Seeded and transplanted lettuce are frequently irrigated with sprinklers (every 2 to 3 days) until seedlings emerge or transplants are established (usually 5 to 10 days). Usually 1.5 to 2 inches (4–5 cm) of water applied during the first irrigation is sufficient to uniformly saturate the soil. Subsequent irrigations only need to be long enough to replace moisture lost by evaporation from the soil surface (about 0.5 inches per irrigation) during crop establishment. After emergence, the crop is irrigated less frequently until thinning or first cultivation, about 2 to 3 weeks after seeding. The water needs during this period are minimal due to the small size of the plants. Fields are briefly irrigated to soften the soil if the field is hand-thinned; another irrigation is needed after thinning, usually coinciding with either the first tractor sidedress of fertilizer or the first fertigation through the drip system.

After establishment, lettuce may be irrigated by sprinkler (fig. 5), drip, or furrow for the remainder of the crop cycle. The majority of water is applied during the last 30 days of the crop when the canopy reaches maximum size, and the evapotranspiration rate is high. Furrow irrigation is usually used in the southern desert, whereas sprinkler and drip are typically used on the Central Coast. Application uniformity of sprinklers can be significantly reduced during windy conditions, which commonly occur on the Central Coast. Care must be taken not to oversaturate the beds when irrigating early season lettuce by furrow; excess moisture favors the development of bottom rot. Gated pipe is also used to deliver furrow water, especially near harvest. Gated pipe allows uniform application of water down furrows and maintains a dry zone at the edge of the field so that tractors and harvest equipment can enter the field.

Drip irrigation has become a major method of irrigating lettuce on the Central Coast (fig. 6). Drip tape is often placed on the top of the bed after the first cultivation, or it is injected 2 to 3 inches (2.5–7.6 cm) below the soil surface before planting. Typically, one drip line is installed between two plant rows on 40-inch (1-m) beds, or three drip lines are installed between five or six plant rows on 80-inch (2-m) beds. Increasingly drip irrigation is used for the full season, including germinating seeded lettuce. Germinating lettuce using drip requires accurate tape placement in the bed to ensure moisture reaches the seed. Lettuce planted on very aggregated clay-textured soils are usually more challenging to germinate by drip due to less lateral movement of the water than plantings on clay-loam and sandy-loam textured soils. Drip tape is typically retrieved after harvest to prevent contamination of the crop with soil falling from the tape during retrieval. Thick-walled tape (>8 mm) is reeled onto spools, repaired, and reused for subsequent crops. Increasingly, thin-walled drip tape (<6 mm) is used for only one crop and is rolled onto spools and shipped to a recycling facility.

Drip can potentially distribute water more uniformly than furrow or sprinkler irrigation, and it has helped growers attain uniform growth in fields with variable soil textures by maintaining high soil moisture levels in all areas of the field. Drip helps reduce leaf wetness compared with overhead sprinklers, thereby lessening the occurrence of foliar diseases. Drip can be managed to minimize leaching of nitrate nitrogen (NO_3-N) by fertigating more frequently with low rates of fertilizer and applying less water more often than can be achieved with sprinkler and furrow systems. It can also reduce the risk from waterborne microbial pathogens (for example, E. coli) that can occur when using sprinklers.

In addition, high bicarbonate or iron levels in groundwater can plug drip emitters. Acid is periodically injected to remove bicarbonate and iron precipitates. Bleach may be periodically injected into drip systems to prevent biological growth.

The average total water applied from planting until harvest on the Central Coast is 12.5 inches (31.8 cm) and typically ranges between 8 and 15 inches (20–38 cm) for sprinkler and drip-irrigated lettuce. Furrow-irrigated lettuce may use an additional 4 to 6 inches (10–15 cm). In the southern desert, where most lettuce is irrigated by furrow after establishment, an average of 24 inches (61 cm) is applied between planting and harvest. Water use in the southern desert is dependent on the planting date as evapotranspiration rates are usually much higher in late summer than late fall plantings. Also, heat waves that occur after planting in late summer may require extra

Figure 5. Sprinkler irrigation of green leaf lettuce.

Figure 6. Drip irrigation of two-seedline lettuce grown on beds 40 inches wide. The one length of drip tape is placed in the middle of the bed and water moves laterally to the seedlines.

sprinkler water to reduce the soil temperature during germination.

Irrigation scheduling can be optimized in lettuce through a combination of monitoring soil moisture and evapotranspiration data. Water use is highest during the last month of the crop when the foliage reaches maximum ground coverage and vegetative growth is high. The crop should be irrigated frequently enough to maintain soil moisture tensions in the root zone of less than 30 to 40 cbars (30–40 kPa) during this period. Water needs of lettuce can be estimated using reference evapotranspiration data adjusted with a crop coefficient (Kc) that is closely related to the percentage of ground covered by the canopy (C):

$$Kc = 0.0063 + (1.5 \times C - 0.0039 \times C^2) \div 100$$

At a maximum canopy cover of 80 to 85 percent, the crop coefficient is nearly 1.0. The California Irrigation Management Information System (CIMIS), coordinated by the California Department of Water Resources, maintains a website that provides daily estimates of reference evapotranspiration for most production regions of California. Online software such as CropManage can be used to estimate crop water requirements based on evapotranspiration data and provide guidance on irrigation scheduling.

Nitrogen management

On the central and south coast, water-quality standards established by the Regional Water Quality Control Board are compelling growers to precisely manage nitrogen fertilizers. It was once common for growers to apply nitrogen in the fall when listing beds, but this practice has been dramatically reduced due to the risk of nitrate nitrogen being leached beyond the root zone by the winter rains. However, if growers want to apply phosphorus in the fall, ammonium phosphate is often used. In these situations, using a material with a low percent of nitrogen is desirable. Small quantities of nitrogen, such as 20 pounds per acre (22 kg/ha), are commonly applied preplant to carry the plant through the first 3 weeks of the crop cycle until thinning. Nitrogen-containing acid fertilizer is often applied at planting as an anticrustant to facilitate the emergence of seedlings; these applications provide 15 to 20 pounds N/acre (7–9 kg/ha) and serve the same purpose as preplant applications. The need for applying nitrogen fertilizer at thinning can be estimated by sampling the quantities of residual soil nitrate nitrogen with the pre-sidedress soil nitrate test.

Interpretation of the soil nitrate test. Soils with less than 10 ppm NO_3-N may not supply sufficient nitrogen for fast growing vegetable crops. Levels of NO_3-N above 20 ppm NO_3-N have enough available nitrogen to supply crop needs for 10 to 14 days. Intermediate concentrations between (for example, 15 ppm NO_3-N) may warrant a half rate of fertilizer. However, nitrate is very mobile, and in light-textured soils, heavy irrigation/rainfall events can reduce the amount of available nitrogen in the soil, which underscores the need to do the test immediately prior to a fertilizer event. For more information, refer to a page on the soil nitrate quick test on the website of Salinas Valley Agriculture.

Low levels of residual soil nitrate are often encountered in the spring following a wet winter, after which residual soil nitrate from the prior cropping season may have been lost from the upper soil profile due to nitrate leaching. Elevated levels of residual soil nitrate commonly occur following a prior crop or even in the first crop in the spring if winter rainfall was not sufficient to leach nitrate over the winter. Soil nitrate testing can be repeated prior to subsequent fertilization events to determine if residual soil-nitrate levels continue to be adequate for good crop growth.

Fertilizers applied by tractor use a rig equipped with shanks to place the material below the soil surface and to the side of the seedline. Because there are only two to three opportunities for tractor applications during the cropping cycle, nitrogen fertilizer rates tend to be high, ranging from 50 to 75 pounds N/acre (23–34 kg/ha). Nitrogen applied by fertigating through the drip system can allow for more frequent and smaller applications of fertilizer, which can improve the efficiency of nitrogen use by the crop.

The total quantity of nitrogen taken up by lettuce varies from 120 to 160 pounds N/acre (54–73 kg/ha) on 40-inch or 80-inch beds (1-m or 2-m beds), respectively. Typical quantities of nitrogen applied per acre vary greatly. If residual soil nitrate was sufficient to offset fertilizer applications, total nitrogen applied per acre to the crop can be less than crop uptake. However, if residual soil nitrate levels were low, the soil type is sandy, and irrigation application efficiency is poor, the amount of nitrogen applied for a successful crop may need to be more than crop uptake.

Nitrogen contained in irrigation water also contributes to crop growth. Well water in regions with intensive vegetable production frequently has nitrate nitrogen concentrations that can satisfy a portion of the nitrogen requirement of the crop. Irrigation water from recycled municipal sources may also contain significant amounts of nitrate and ammonium forms of nitrogen. Ammonium applied in the irrigation water will quickly convert to nitrate under soil temperatures during the production season. The following formula can be used to estimate the nitrogen contribution of the irrigation water:

$$\text{pounds N/acre} = 0.227 \times \text{irrigation water N concentration (ppm)} \times \text{inches of water applied}$$

where nitrogen concentration is the concentration of nitrogen (nitrate or ammonium forms) in the irrigation water and 0.227 is a conversion factor.

Lettuce is sensitive to high levels of ammonium in the soil. Ammonium toxicity often occurs in the early spring (March–April) when soils are cool and the transformation from ammonium to nitrate is slow. Injured roots may have the tip of the root browned off and may develop a hollow, reddish-brown cavity on the inside of the upper part of the root. Ammonium toxicity can also occur later in the season (June–July) on heavier soils when the transformation of ammonium to nitrate is temporarily disrupted by anaerobic conditions in the soil following irrigation.

Other nutrients

The quantity of phosphorus fertilization on soils with a pH above 6.2 can be based on the bicarbonate-extractable phosphorus (Olsen) soil test. Bicarbonate levels above 60 ppm are adequate for lettuce growth; for soils below this level, especially in winter, preplant applications of 40 to 80 pounds per acre (45–90 kg/ha) of P_2O_5 or at-planting topical applications of 20 pounds per acre (22 kg/ha) of P_2O_5 are recommended. In the southern deserts and the Central Valley, where soil-test phosphorus is usually lower than on the Central Coast, most growers apply preplant rates as high as 250 pounds per acre (280 kg/ha) of P_2O_5.

The need for potassium can also be determined from soil tests; soils with greater than 150 ppm of ammonium acetate–exchangeable potassium have enough potassium for the crop. Potassium fertilization presents no environmental risk, and many growers routinely apply potassium even in fields with high levels of exchangeable soil potassium to replace the potassium removed by the harvested crop. Approximately 120 pounds per acre (135 kg/ha) is appropriate to maintain soil fertility. Zinc fertilization is recommended if the DTPA-extractable soil level is less than 1.5 ppm. Zinc fertilization is commonly practiced on the Central Coast due to high soil phosphorus levels, which reduces zinc uptake by plants.

Due to food safety concerns, growers are cautious about which soil amendments are applied to lettuce. Composted manure and yard wastes are used by some growers. Application rates are typically 3 to 5 tons per acre (7–11 t/ha). These materials are primarily applied to maintain good soil structure. The quantities of crop nutrients provided by these materials vary widely depending on the amount applied and the nutrient analysis of the material.

Integrated pest management

For current, more detailed pest management information, see the UC Davis Integrated Pest Management website or consult your county Farm Advisor.

Weed management

Several herbicides are used for lettuce weed control. Some herbicides have greater activity on specific weed species. Preemergence herbicides are typically applied after planting as a band 5 to 6 inches (12.7–15.2 cm) wide over the seedlines prior to the first irrigation. The first cultivation of lettuce is carried out during thinning at 21 to 28 days after seeding; standard cultivation leaves an uncultivated band 4 to 5 inches (10.2–12.7 cm) wide around the seedline. The use of camera-guided cultivators increases the speed and precision of cultivation, and the width of the uncultivated band can be reduced to 2 to 3 inches (5.1–7.7 cm) wide to increase the number of weeds removed. Lettuce is thinned by hand or by automated thinners (fig. 7). Both operations thin the lettuce stand to the desired spacing and remove weeds. Approximately 2 weeks after thinning, the field is weeded by hand or with an automated weeding machine (fig. 8). Organic producers rely upon cultural and mechanical techniques to manage weeds. A common practice used in organic production is the use of pre-irrigation followed by shallow cultivation which significantly controls weeds prior to planting. Following planting, they use many of the mechanical control methods just described as well as hand weeding to remove any weeds not controlled by cultivation. Consult your UCCE Farm Advisor or the UC Integrated Pest Management website for more details on the best approach to controlling weeds under your conditions.

Figure 7. An automated thinner spraying a nitrogen fertilizer to remove unwanted plants, leaving the field at the desired spacing.

Figure 8. Automated weeder using a split knife that opens around the lettuce plant and closes between lettuce plants to remove weeds in the seedline.

Insect identification and control

The most important insect pests of lettuce in California are aphids, leafminers, thrips, caterpillars, and whiteflies. Pest problems vary according to the growing region and time of year.

The lettuce aphid (*Nasonovia ribisnigri*) became established on the Central Coast in 1998 and has since become a significant pest of lettuce in that area. Lettuce aphid infests the inner leaves of the lettuce head, making it unmarketable. The foxglove aphid (*Aulacorthum solani*) also infests the inner leaves of lettuce. Since lettuce aphid and foxglove aphid become protected within the lettuce head as more leaves develop, detection and treatment of early populations are essential. The green peach aphid (*Myzus persicae*) and potato aphid (*Macrosiphum euphorbiae*) can be significant pests of Central Coast lettuce, although they tend to build up on the outer leaves, making them easier to treat with insecticides. Aphids have many natural enemies, including fungal pathogens that are common during cool, wet, spring weather. Parasitic wasps help suppress aphid species that colonize the outer leaves of lettuce. Syrphid fly larvae and other aphid predators such as ladybird beetles can help suppress aphid species throughout the lettuce head, including those that infest inner leaves. Predation of lettuce aphid by syrphid fly larvae is essential for organic production of leaf lettuce on the Central Coast. A variety of *Nasonovia*-resistant romaine lettuce called Nirvanus is available, but it is not resistant to other species of aphid.

The primary damage from leafminers is caused by the larvae, which form tunnels between the upper and lower leaf surface, feeding on the mesophyll tissue. In coastal areas, the pea leafminer (*Liriomyza langei*) is the most common leafminer. The serpentine leafminer (*Liriomyza trifolii*) is the prevalent species in the southern region, and the vegetable leafminer (*Liriomyza sativae*) is also found in coastal areas. In addition, female leafminer flies puncture leaf surfaces with their ovipositor to generate fluid on which to feed, causing stippling damage in the process. Leafminer larvae are highly susceptible to parasitism by parasitic wasps, especially those in the genus *Diglyphus*. Parasitic wasps can help suppress leafminer populations if insecticides do not interfere with their activity. Insecticide treatments should be applied to manage larvae rather than the more mobile, insecticide-resistant adults.

The beet armyworm (*Spodoptera exigua*) and other caterpillars cause sporadic problems throughout lettuce growing regions. Beet armyworm larvae are susceptible to several natural enemies, including diseases, predators, and parasitoids. When beet armyworm and other caterpillars are not kept below economic injury levels by natural enemies, they should be treated with selective insecticides.

The western flower thrips (*Frankliniella occidenatalis*) are important pests of Central Coast lettuce, especially in the Salinas Valley. In addition to the scarring they cause via damage caused by direct feeding, thrips transmit tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV). Vector control is the main option to address these tospoviruses, although rapid transmission by thrips has necessitated conservative insecticide treatment thresholds. The western flower thrips can be an important pest of romaine lettuce in the low-desert production areas. Thrips feeding on romaine lettuce can cause cosmetic injury, which can prevent sales to foreign markets.

In Southern California, the silverleaf whitefly (*Bemisia tabaci* Biotype B) can be a significant pest, although it is not a major pest in the Central Coast. In the desert, it can slow the growth and delay the maturity of the crop as well as transmit criniviruses. While this pest can be controlled with registered materials, insecticide resistance management should be followed to slow the development of resistance.

Diseases and management

In the southern deserts, the most serious diseases affecting lettuce are lettuce drop, downy mildew, Fusarium wilt, big vein, bottom rot, and powdery mildew. In coastal areas, key diseases are Fusarium wilt, Pythium wilt, Verticillium wilt, downy mildew, lettuce drop, bacterial leaf spot, and viral diseases. In the San Joaquin Valley, Fusarium wilt and lettuce drop are serious disease problems.

A number of viruses infect lettuce. The most significant and common viruses or viral diseases on lettuce are Lettuce mosaic virus (LMV), lettuce dieback disease, and INSV. Additional viruses that infect lettuce are mirafiori lettuce big-vein virus (MLBVV) and lettuce big-vein associated virus (LBVaV), both of which are associated with lettuce big vein disease. Viruses such as beet western yellows virus (BWYV) and TSWV are of moderate concern, and control measures are rarely needed.

LMV can be controlled by using mosaic-free seed (that is, no virus detected in a sample of 30,000 seed), plowing down harvested fields, removing weed hosts, and managing aphid populations. A lettuce-free period, which creates a break in the vector cycle during the winter, is mandated by county ordinance in some coastal areas.

The orthotospoviruses INSV and TSWV are spread by thrips, which are difficult to effectively control. These viruses had been rare or minor problems for lettuce before the mid-2010s. However, beginning in 2020, INSV caused devastating losses on the Central Coast. INSV has a wide host range and has been detected in numerous weed species in the Central Coast. Therefore, managing hosts of this virus in the winter months is recommended for reducing the early season prevalence of this disease.

Lettuce dieback disease was believed to be caused by either moroccan pepper virus or tomato bushy stunt virus. Recent research has failed to detect these viruses in plants with lettuce dieback symptoms, and a new virus has been implicated but not proven as the cause of lettuce dieback. The virus lives and is spread in contaminated water and soil, but the vector responsible for transmission has not been identified. The virus is particularly damaging to romaine and can also infect some green leaf and red leaf cultivars. The disease is primarily found in coastal regions but also occurs in the desert regions. Growers manage the problem by using tolerant cultivars in infested fields, avoiding recently flooded fields, or by maintaining good drainage.

Lettuce drop (*Sclerotinia minor* and *S. sclerotiorum*) is a serious soilborne fungal disease that can affect lettuce crops from rosette stage to harvest. Rotate crops and use registered fungicides after thinning to provide some protection. Lettuce drop caused by *S. sclerotiorum* is generally less common in coastal areas than in southern deserts or the San Joaquin Valley.

Bottom rot (*Rhizoctonia solani*) can cause serious losses in the Central Valley and the southern desert areas; it is rarely seen elsewhere in the state. The disease is most prevalent on early season lettuce that matures between the end of November and mid-January. Use fungicidal sprays to control this disease.

Downy mildew (*Bremia lactucae*) can cause significant damage under favorable conditions of cool temperatures, periods of continuous leaf wetness, and high relative humidity in the canopy. The disease is managed by planting resistant cultivars and applying protectant fungicides. However, the genetic variability of this pathogen is high, and strains that are not controlled by fungicides or resistant cultivars can frequently emerge.

Bacterial leaf spot (*Xanthomonas campestris* pv. *vitians*), varnish spot (*Pseudomonas cichorii*), anthracnose (*Microdochium panattonianum*), and powdery mildew (*Golovinomyces cichoracearum*) are other foliar diseases that can affect leaf lettuce. Bacterial leaf spot and anthracnose can be serious during rainy periods where crops are irrigated with sprinklers. In coastal California, sprinkler-irrigated leaf lettuce can be especially damaged in late summer or early fall (August through October). Bacterial leaf spot is not well controlled by copper or other bactericides. Because the bacterium causing varnish spot is found in reservoir water, avoiding sprinkler irrigation usually eliminates this disease. Anthracnose is found only in fields where the resting fungal structure is present in soil during rainy spring weather. Application of protectant fungicides controls this pathogen; avoid planting lettuce in fields with a history of the disease. Powdery mildew is sometimes a problem in commercial fields, particularly in late plantings in the desert region, and foliar fungicides may be appropriate to use in cases of severe disease pressure.

Corky root is caused by the soilborne bacterium *Rhizorhapis suberifaciens*. Rotate crops so that lettuce is not planted consecutively in the same fields and avoid overfertilizing with nitrogen. However, for infected crops, growers may need to add supplemental fertilizer and water to achieve satisfactory crop yields. Using resistant cultivars is the most effective control method for this disease.

Fusarium wilt (*Fusarium oxysporum* f. sp. *lactucae*) of lettuce is found primarily in the Central Coast, San Joaquin Valley, and desert regions. Control options are limited. Plantings experiencing the warmest temperatures are at greater risk of loss, but the disease can occur during cooler temperatures. Any stage of lettuce growth can be affected. Head-lettuce cultivars are generally more susceptible, but cultivars with resistance to race 1 are under development. The pathogen is soilborne and can survive for many years in the absence of a host. Growers should avoid planting in infested fields and take precautions so that infested soil is not moved to clean fields.

Verticillium wilt (*Verticillium dahliae*) appeared on California lettuce in 1995 and affects every type of lettuce. At present, the disease has been found in the Salinas and Pajaro Valleys. Losses from the disease on affected crops can be extensive. The fungus produces microsclerotia, resting structures that can lie dormant in the soil for more than 10 years. Hence, growers should clean field equipment used in infested fields before using it elsewhere. Two races of the pathogen exist and cultivars with resistance to race 1 are becoming available. Fumigation or rotations with broccoli remain the only effective options against this disease until resistant cultivars are widely available.

Pythium wilt (*Pythium uncinulatum*) was first identified in the Salinas Valley in 2011 and affects head and leaf lettuces. Losses to this disease can be devastating. The organism forms resistant resting oospores and motile zoospores. The disease is most prevalent in the last 8 to 10 weeks of the Central Coast growing season and may be triggered by high temperatures and infection with INSV. It is not clear if rotations can help reduce the severity of this disease. Use of tolerant varieties appears to provide the most reliable practice to reduce crop loss.

Phoma basal rot (*Boeremia exigua*) affects all leaf lettuce but is mostly a romaine problem. This soilborne pathogen causes dark brown, sunken lesions to form at the crown. Affected plants are stunted, misshapen, and unharvestable. Avoid planting in infested fields or apply protectant fungicides when thinning.

Disorders

Freezing injury on mature lettuce is expressed as blistering and peeling of the epidermis followed by browning of the tissues. Normally freezing injury is confined to the cap and wrapper leaves. Tipburn is a physiological disorder caused by soil water stress or low evapotranspiration that results in a transient deficiency of calcium in rapidly growing plant tissues. The edge of affected leaves turns brown to black. On the coast, tipburn is most severe when evapotranspiration is reduced by foggy weather during the final 2 weeks prior to harvest. Some varieties have a degree of tolerance to this disorder. Young plants are susceptible to scarification by soil particles blown by strong winds and by direct contact with soil surrounding stems during windy conditions. Wind breaks and adequate moisture in the field and surrounding areas aid in preventing wind-induced damage.

Harvest and handling

Lettuce is harvested by crews or by a harvest machine and is field-packed into cartons (fig. 9). It is packed naked, film-wrapped, and as hearts (that is, romaine). Lettuce is packed by count into cartons (for example, 24s and 30s) and is vacuum cooled prior to storage in a cold room. Vacuum cooling removes field heat in roughly 15 minutes. Various specialty products such as individual leaves are also packed for the food service industry. Lettuce is also bulk harvested into bins for transportation to salad plants where it is chopped and washed for bagged products. Baby lettuce is mechanically harvested and placed in totes, which are transported to salad plants to prepare bagged products.

Figure 9. Lettuce harvest with cutters selecting marketable heads and placing them on the platform for packers to put into boxes.

Postharvest handling

Lettuce is highly perishable and should be cooled as soon as possible after harvesting. Vacuum cooling reduces product temperature to 34°F (1°C); it should then be stored just above freezing at 98 percent relative humidity. Lettuce harvested at prime maturity with no major defects may be held for 2 to 3 weeks at 34°F. At 37°F (2°C), shelf life is reduced to 1 to 2 weeks. Russet spotting is a disorder caused by storing lettuce in containers or cold rooms where ethylene gas, which can be generated by ripening fruits and gasoline engines, is present. Brown stain is a storage disorder caused by high carbon dioxide levels in the cold room (for more detailed information, visit the “Produce Fact Sheets” section on the website of the UC Davis Postharvest Technology Research and Information Center).

Marketing

California produces lettuce year-round. Supplies peak in May and June and are lowest in December, January, and February. California’s lower volume during the winter is due to large supplies produced in western Arizona; the overall national supply is nearly static. Most of California’s lettuce is shipped by refrigerated truck to markets throughout the United States and Canada. Lettuce is also shipped to the Pacific Rim by boat.

Cost of production

The costs of production of lettuce depend on location. Costs of water, land lease, and inputs (for example, fertilizers and pesticides) will vary by location, soil type, time of year, and weather. Lettuce production is labor intensive, especially at harvest. In cost studies completed in 2023 for iceberg and romaine hearts in Monterey, Santa Cruz, and San Benito counties, harvest and postharvest costs accounted for 67 to 69 percent of the total production cost for broccoli, whereas the total growing cost accounted for 31 to 33 percent (Tourte et al. 2023a, 2023b).

Further reading

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