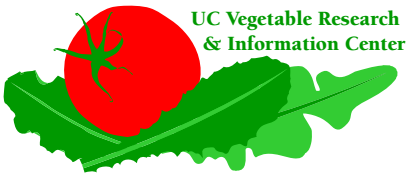

Vegetable
Production Series

LEAF LETTUCE PRODUCTION IN CALIFORNIA

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PRODUCTION AREAS AND SEASONS

The major production areas for leaf lettuce *(Lactuca sativa)* in California are the Central Coast (Monterey, San Benito, Santa Cruz, Santa Clara, and San Luis Obispo Counties), the southern coast (Santa Barbara and Ventura Counties), the Central Valley (Fresno, Kings, and Kern Counties), and the southern deserts (Imperial and Riverside Counties). Production is highest in Monterey County.

Planting to harvest takes 65 to 80 days for midsummer plantings and as long as 130 days for late-fall and winter plantings. 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 from November to August for harvest from February to December. In the Central Valley, leaf 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, leaf lettuce is planted from mid-September to mid-November for harvest from early December to March.

LEAF (NON-ROMAINE) LETTUCE ACREAGE AND VALUE

Year	Acreage	Average yield (tons/acre)	Gross value/acre
2009	44,000	11.5	$6,532
2008	42,500	12.5	$7,775
2007	40,500	11.8	$8,343

Source: California Agricultural Resource Directory 2010 (Sacramento: California Department of Food and Agriculture, 2010).

ROMAINE LETTUCE ACREAGE AND VALUE

Year	Acreage	Average yield (tons/acre)	Gross value/acre
2009	65,000	16.5	$7,392
2008	61,000	14.5	$6,119
2007	63,000	16.3	$7,703

Source: California Agricultural Resource Directory 2010 (Sacramento: California Department of Food and Agriculture, 2010).

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. Most California growing regions have daytime temperatures from 63° to 83°F (17° to 28°C) and night temperatures from 37° to 53°F (3° to 12°C). At the high end of the temperature range, lettuce may bolt, causing bitterness and loose, fluffy heads. At temperatures near freezing, young plants are not damaged, but growth is slowed. Freezing can damage the outer leaves of mature lettuce, leading to decay in handling and storage.

VARIETIES AND PLANTING TECHNIQUES

Leaf lettuces include leaf, romaine, and butterhead types. Leaf types vary in color levels and leaf shape. Leaves may be broad or narrow with leaf margins that may be entire, lobed, or frilled. Romaine types are generally upright but can also be flattened. Butterheads form small heads, and the leaves have a soft texture. Common commercial greenleaf lettuce varieties in California include Big Star, Burgam's Green, North Star, Tehama, and Tropicana; redleaf varieties include Red Fox and Red Tide; butterhead

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varieties include Margarita; romaine varieties include Darkland, Green Towers, Progeny 454, Pybas 714, and Sun Belt. There are also many heirloom varieties of each of these types that are grown for specialty markets.

Most leaf lettuce is planted using pelleted seed and a precision planter; a small but increasing percentage of the acreage is transplanted, typically at the start of the season and at midseason, when there is a need to get a crop in to meet production schedules. Row spacing is on beds either 40 or 80 inches (102 or 203 cm) wide. The 40-inch beds have 2 seedlines, and 80-inch beds can have 5 to 6 seedlines. For full-sized lettuce, seed are planted 2 to 3 inches (5 to 7.5 cm) apart and are thinned to 10 to 12 inches (25 to 30.5 cm) apart. For romaine hearts the lettuce may be thinned to 5 to 6 inches (5.6 to 6.7 cm) apart. Given differences in seed spacing and row configurations, the number of seed planted per acre can vary from 104,550 to 235,460 (258,375 to 581,820 seed/ha). The cost of seed varies with variety, coating, spacing, seed enhancement, and priming (osmoconditioning) treatments. Nonprimed, natural lettuce seed may be susceptible to thermodormancy when ambient temperatures are above 90ºF (32ºC) 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 the cooler hours of the night.

SOILS

Leaf lettuce grows best in silt loams and sandy soils in the southern deserts. Lighter-textured soils provide better drainage during cold weather and warm up more readily. In the Central Coast and Central Valley, lettuce can be grown on heavy clay soils as long as there is good soil structure and adequate drainage. Lettuce has a moderately low degree of salt tolerance: excess salinity results in poor seed germination and reduced growth.

IRRIGATION

In the southern deserts, sprinklers are often used for the first 5 to 7 days or until the seedlings emerge. The field is then furrow irrigated for the remainder of the season. In the southern deserts 36 inches (10,980 mm) of water per acre is typically used to grow a lettuce crop. The majority of the water is applied in the last 30 days before harvest. Care must be taken not to oversaturate the beds when growing early-season lettuce: excess moisture favors the development of bottom rot. Gated pipe is also used to deliver water, especially near harvest. Gated pipe allows uniform application of water down furrows and maintains a dry head basin so that harvest equipment can turn around on dry soil.

Depending on initial conditions, most Central Coast fields are preirrigated with about 2 to 4 inches (610 to 1220 mm) of water to soften soil for seedbed preparation. Both seeded and transplanted lettuce are sprinkle irrigated frequently (every 2 to 3 days) until seedlings emerge or are established (usually 6 to 10 days). Both hand-move and solid-set sprinklers are used for stand establishment. After emergence the crop is irrigated less frequently until thinning about 2 to 3 weeks after seeding. Fields are irrigated to soften the soil before hand thinning; another irrigation is applied after thinning and side-dressing of fertilizer. The use of sprinklers can continue for the remainder of the growth cycle, but furrow irrigation is still used in some areas. In regions with strong winds, a well-managed furrow system may provide better uniformity than sprinklers. Water application is typically 18 to 24 inches (5,490 to 7,320 mm) for a sprinkler-irrigated lettuce crop and 24 to 30 inches (7,320 to 9,150 mm) for a furrow irrigated crop on the Central Coast. Drip-irrigated lettuce requires approximately 12 to 18 inches of water (3,660 to 5,490 mm).

Surface-placed drip has become a major method of irrigating lettuce on the central coast. Drip irrigation was used on 30% of the vegetable acreage in the Salinas Valley in 2006. Surface drip is usually installed after the first cultivation and sidedressing, and it permits growers to water frequently during the rapid vegetative growth phase. One drip line is installed between 2 plant rows on 40-inch (1-m) beds, or 3 drip lines are installed between 6 or 5 plant rows on 80-inch (2-m) beds. The drip lines are typically retrieved before harvesting and reused for subsequent crops. 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 can be managed to minimize leaching of nitrate-nitrogen (NO_3-N) by fertigating weekly with low rates of fertilizer and applying less water more frequently than can be achieved with sprinkler and furrow systems. Some growers bury drip tape to a depth between 2 and 3 inches (2.5 to 7.6 cm) before planting. Drip tape is rarely placed deeper than 3 inches for lettuce. Some growers use the shallowly buried drip tape for full-season irrigation, including for germination. High bicarbonate or iron levels in groundwater in some areas of the Central Coast can plug drip emitters. Acid is periodically injected to remove bicarbonate and iron precipitates.

The combination of soil moisture monitoring and weather-based irrigation scheduling can be used to determine the water needs of lettuce. Water use

is highest during the last month of the crop, when vegetative growth is high. Soil moisture tensions are typically targeted for less than 25 to 30 cbars (25 to 30 kPa) during this period. The water extraction by lettuce can be estimated using reference evapotranspiration data adjusted with a crop coefficient that is closely related to the percentage of ground covered by the canopy. At a maximum canopy cover of 85%, the crop coefficient is nearly 1.0. The California Irrigation Management Information System (CIMIS, http//wwwcimis.water.ca.gov), coordinated by the California Department of Water Resources, provides daily estimates of reference evapotranspiration for most production regions of California.

FERTILIZATION

Soils in the central and south coast regions can have elevated levels of nitrate-nitrogen and phosphorus, which can cause elevated levels of these nutrients in runoff; this makes it difficult for growers to comply with water quality standards established by local regional water quality control boards. As a result, application of these nutrients needs to be carefully managed.

Phosphorus fertilization should be applied based on the soil test level of bicarbonate-extractable phosphorus. Levels above 60 ppm are adequate for lettuce growth; for soils below this level, especially in the winter, preplant applications of 40 to 80 pounds per acre (45 to 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. The need for potassium can also be determined from soil tests; soils with greater than 150 ppm of ammonium acetate–exchangeable potassium have sufficient quantities of 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. Although fertilizing to replace potassium removal with the harvested crop, approximately 120 pounds per acre (135 kg/ha), is appropriate to maintain soil fertility, fertilization rates above that level are economically wasteful. 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 reduce zinc uptake by plants.

Fall application of nitrogen is not recommended due to the risk of nitrate-nitrogen leaching beyond the root zone by the winter rains. Small quantities of nitrogen, 20 pounds per acre (22 kg/ha), are applied preplant or at planting. At thinning, 50 to 80 pounds per acre (56 to 90 kg/ha) of nitrogen is sidedressed into the beds. One or more additional sidedressings are common, typically several weeks apart. Seasonal nitrogen application to the first lettuce crop of the year on the Central Coast range from 150 to 180 pounds per acre (168 to 202 kg/ha) of nitrogen. Due to residual nitrogen from prior crops and mineralization of nitrogen from soil organic matter, the fertilization rates for the second crop of lettuce typically range from 100 to 150 pounds per acre (112 to 168 kg/ha) of nitrogen. The sidedress nitrogen requirement can be estimated by pre-sidedress soil nitrate testing (PSNT). Soil nitrate levels greater than 20 ppm in the top 12 inches (30 cm) are adequate for crop growth; the test can be repeated later in the season to ensure continuing nitrogen sufficiency. A small quantity of nitrogen, 10 to 15 pounds per acre (11 to 17 kg/ha), is often applied 7 to 10 days prior to harvest to assure that the crop color and growth rate are acceptable. In drip-irrigated fields nitrogen can be applied through the drip system as well. Typically, drip systems are more efficient at managing water and delivering nitrogen fertilizer, and therefore fertilizer application rates are often 20 to 30% lower than in conventionally irrigated fields.

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. Nitrogen is sidedressed just after thinning and during later growth. Early, warm-season lettuce has a shorter growing season than a crop grown in January and February and usually receives less nitrogen fertilization. A seasonal rate of approximately 150 pounds per acre (168 kg/ha) of nitrogen is typical for early-season crops, while 200 to 250 pounds per acre (224 to 280 kg/ha) is applied during cold weather.

Lettuce is sensitive to high levels of ammonium in the soil. Ammonium toxicity typically 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.

Due to food safety concerns manures are not used in lettuce production. Composted manures and yard wastes are used by some growers. Application rates are typically 4 tons per acre (9 t/ha), and they are primarily applied to maintain good soil structure.

INTEGRATED PEST MANAGEMENT

For current, more detailed pest management information, see the UC Davis IPM Web site at http://www.ipm.ucdavis.edu or your local county Farm Advisor Also refer to the *UC IPM Pest Management Guidelines: Lettuce* (ANR Communication

Services Publication 3450, http://www.ipm.ucdavis.edu/PMG/selectnewpest.lettuce.html).

Weed management. Several herbicides are used for lettuce weed control. Some herbicides have greater activity on specific weed problems. Consult your UCCE Farm Advisor or the UC IPM Web site for more details on the best approach to controlling weeds under your conditions. Preemergence herbicides are typically applied as a band 5 to 6 inches (12.7 15.2 cm) wide over the seedlines after planting prior to the first irrigation. Lettuce is cultivated prior to thinning at 21 to 28 days after seeding; typically cultivation leaves an uncultivated band 4 to 5 inches (10.2 12.7 cm) wide around each seedline. The use of camera-guided cultivators increases the efficiency and precision of cultivation. Organic producers use many cultural techniques to manage weeds; for instance, preirrigation followed by cultivation provides significant weed control and can be repeated if time allows, providing additional control. Lettuce is thinned and weeded approximately 30 days following planting. An additional hand weeding is carried out 2 to 3 weeks later.

Insect identification and control. The most important insect pests of lettuce in California are aphids, leafminers, 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 the most important insect pest of lettuce in that area. Lettuce aphid infests the inner leaves of the lettuce head, making it unmarketable. Foxglove aphid *(Aulocorthum solani)* also infests the inner leaves of lettuce. 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. Since lettuce aphid and foxglove aphid become protected within the lettuce head as more leaves develop, detection and treatment of incipient populations is essential. Aphid pests of lettuce have many natural enemies, including fungal pathogens that are common during cool, wet spring weather. Parasitic wasps help suppress aphids species that colonize outer leaves of lettuce. Syrphid fly larvae and other aphid predators such as ladybird beetles can help suppress aphid species 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 addition, female leafminer flies puncture leaf surfaces with their ovipositor in order to extract fluid on which to feed, and in the process cause stippling damage. Leafminer larvae are highly susceptible to parasitism by parasitic wasps, especially in the genus *Diglyphus.* Parasitic wasps can help suppress leafminer populations if insecticides do not interfere with their activity. 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. Insecticide treatments should be applied to manage larvae rather than the more mobile, insecticide-resistant adults.

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. Beet armyworm and other caterpillars should be treated with selective insecticides whenever possible.

In Southern California, the silverleaf whitefly *(Bemisia argentifolii)* has slowed the growth and delayed the maturity of the crop. Although this pest can be controlled with registered materials, it may become resistant if one chemical is used too heavily.

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

A number of viruses infect leaf lettuce. The most significant and common viruses on leaf lettuce are *Lettuce mosaic virus* (LMV), *Mirafiori lettuce big-vein virus* (LMBVV), and *Lettuce big-vein associated virus* (LBVaV) (both associated with lettuce big vein disease), *Beet western yellows virus* (BWYV), *Lettuce necrotic stunt virus* (LNSV), and *Tomato spotted wilt virus* (TSWV). With the exception of LMV and LNSV, these viruses are of moderate concern, and control measures are rarely needed. LMV can be controlled by using mosaic-free seed (i.e., no virus in 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. Researchers note that TSWV and other tospoviruses, such as *Impatiens necrotic spot virus* (INSV), are increasing on leaf lettuce in California; management options have not yet been developed for this problem.

Lettuce dieback disease is caused by LNSV, some strains of which are designated as *Tomato bushy stunt virus* (TBSV). This is an unusual virus pathogen in that no known vector has been identified. The virus lives and is spread in contaminated water and soil. The virus is particularly damaging to romaine and can also infect some greenleaf and redleaf cultivars. The disease is primarily found in coastal regions. Growers manage the problem by not planting susceptible cultivars in infested fields or by planting recently developed resistant cultivars.

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 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)* is managed by planting resistant cultivars and applying protectant fungicides. However, the genetic variability of this pathogen results in some strains that are not controlled by fungicides or resistant cultivars.

Bacterial leaf spot *(Xanthomonas campestris* pv. *vitians)*, varnish spot *(Pseudomonas cichorii)*, anthracnose *(Microdochium panattonianum)*, and powdery mildew *(Erysiphe cichoracearum* f. sp. *lactucae)* are other foliar diseases that can affect leaf lettuce. Bacterial leaf spot can be serious during rainy springs and 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). The disease 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, and foliar fungicides may be appropriate to use in cases of severe disease pressure.

Corky root is caused by the soilborne bacterium *Rhizomonas 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. Some resistant cultivars are now available.

Fusarium wilt *(Fusarium oxysporum* f. sp. *lactucae)* of lettuce is found primarily in the San Joaquin Valley and desert regions, but in recent years it has started to occur in coastal California. Control options are limited. 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. The disease is currently restricted to the Salinas and Pajaro Valleys. Losses from the disease on affected crops can be extensive. The fungus produces microsclerotia, resting structures that lie dormant in the soil for 10 to 15 years. Hence, growers should clean field equipment used in infested fields before using it elsewhere. Two races of the pathogen exist, and sources of resistance to both are being developed. Fumigation or rotations with broccoli remain the only effective options against this disease until resistant cultivars are commercially available.

Phoma basal rot *(Phoma 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 at 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 ET_o that result in a transient deficiency of calcium in rapidly growing plant tissues. The edge of affected leaves have tissue that 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

Leaf lettuce is field-packed into cartons. Leaf lettuce is harvested by ground packing or by a harvest machine. It is packed naked, film wrapped, and as hearts (i.e., romaine). Leaf lettuce is packed 24 heads to a carton 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.

POSTHARVEST HANDLING

Lettuce is highly perishable and should be cooled as soon as possible after harvesting. Vacuum cooling reduces product temperature to 34ºF (1ºC); it should then be stored just above freezing at 98% relative humidity. Lettuce harvested at prime maturity with no major defects may be held for 2 to 3 weeks at 34ºF. At 37ºF (2ºC), 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.

MARKETING

California produces leaf 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 leaf lettuce is shipped by refrigerated truck to markets throughout the United States and Canada.

COST OF PRODUCTION

The costs of production of leaf lettuce depend on location. Costs of water, land lease and inputs (fertilizer, pesticide, etc.) will vary by location, soil type, time of year, and weather. Leaf lettuce production is labor intensive, especially at harvest. For information on cost of production go to the UC Davis Agricultural and Research Economics Web site, http://coststudies.ucdavis.edu/.

FOR FURTHER INFORMATION

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