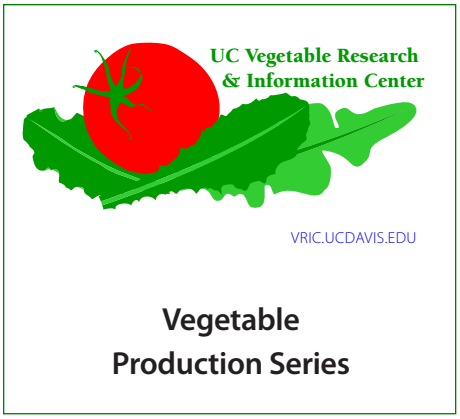

SPINACH PRODUCTION IN CALIFORNIA

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PRODUCTION AREAS AND SEASONS

California produces spinach *(Spinacia oleracea)* in four areas: the southern desert valleys (Imperial and Riverside Counties); the southern coast (Santa Barbara and Ventura Counties); the central coast (Monterey, San Benito, Santa Clara, and Santa Cruz Counties); and the central San Joaquin Valley (Stanislaus and Tulare Counties). Almost half of California's spinach acreage and production is in Monterey County. The southern coast and San Joaquin Valley each produces about one-fourth of California's spinach, followed by Coachella Valley in Riverside County.

Spinach is produced virtually all year in the coastal valleys, with a slight dip in December and January in both planting and harvest. In Coachella Valley planting occurs from October through December for harvest from November through March. In the San Joaquin Valley planting starts in late October and continues through January for harvest from February through April.

Spinach is marketed as three different commodities: fresh market clipped and bagged, fresh market bunched, and frozen. Fresh market clipped and bagged is the dominant spinach product produced in California.

SPINACH ACREAGE AND VALUE (FRESH MARKET)

Year	Acreage	Average yield (ton/acre)	Gross value per acre
2008	25,500	8.25	$5,500
2007	23,500	8.75	$5,480
2006	30,000	9.0	$4,620
2005	32,500	9.0	$3,726

Source: California Agricultural Resource Directory 2006 (Sacramento: California Department of Food and Agriculture, 2008).

This bagged product is produced and sold containing either very small, young leaves ("baby spinach") or slightly older, medium-sized leaves ("teenage spinach"). Both baby and teenage spinach leaf sizes are usually significantly smaller than the leaf size of the traditional fresh market bunched spinach; freezer spinach leaf size is the largest of all marketed sizes.

CLIMATIC REQUIREMENTS

Spinach is a quick-maturing, cool-season vegetable crop. Seed germinate at 35° to 85°F (2° to 30°C), but 45° to 75°F (7° to 24°C) is optimal. Spinach will grow from 40° to 85°F (5° to 30°C), but growth is most rapid at 60° to 65°F (15° to 18°C). Spinach can withstand low temperatures of 15° to 20°F (–9° to –6°C) without great injury. Freezing weather harms small seedlings and young plants, though more mature plants can tolerate subfreezing temperatures for weeks.

Spinach produces a rosette of leaves that may be wrinkled (savoy or semisavoy types) or smooth (flat leaf types). Leaves are typically oval, rounded, or triangular and are borne on a short stem. If the crop is allowed to become overmature, the stem elongates and produces a seedstalk with narrow, pointed leaves. This seedstalk formation (bolting) is caused by late-season high temperatures and long days, and crops that are bolting are rarely marketable.

CULTIVARS

In California, the smooth or flat leaf spinach cultivars are grown almost exclusively, though some semisavoy types are used. All spinach cultivars commercially grown in California are hybrids, primarily because disease and bolting resistance have been bred into these hybrids. Downy mildew is an economically important foliar disease of spinach for which single-gene resistance is incorporated as new races of the

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pathogen develop. To keep bolting at a minimum, physiological factors such as increased day length, high temperatures, and inadequate fertility and irrigation must be avoided or minimized. Processors sometimes breed their own cultivars for their contracted growers who are growing spinach for freezing. However, in many cases fresh market cultivars are also grown for the frozen commodity.

Some popular cultivars in California include the following; numbers in parentheses after the cultivar name indicate the downy mildew races (DM) to which the cultivar is resistant: Avenger (DM 1–7, 9), Bolero (DM 1–4, 9), Bossanova (DM 1–4, 9), Dolphin (DM 1–7, 9), Emilia (DM 1–10), Falcon (DM 1–7), Lazio (DM 1–10), Palco (DM 1–7), Unipak 144 (DM 1–5), and Whale (DM 1–7). However, cultivars are always being developed, and newer ones are already on the market.

PLANTING

All spinach is direct seeded. The California industry is known for using very high seed planting densities and a large number of seed lines per bed. In general, baby and teenage clipped spinach is planted only on 80-inch-wide (203-cm) beds, while bunched and freezer spinach is grown on both 40-inch (100-cm) and 80-inch beds. Spinach seed is planted ½ to ¾ inch (1.2 to 1.9 cm) deep, depending on the method of planting and soil conditions. The following table summarizes general planting formats and days to harvest. Note that the days to harvest information pertains to coastal spinach production areas and ranges from very short growing periods in late spring through summer to longer growing periods in fall, winter, and early spring. Versatility is also practiced, for in some cases a fresh market spinach planting is first clipped for fresh market product, then allowed to regrow to a larger size for a second harvest for the freezer.

SOILS

A variety of soils are used for spinach production, but in most regions sandy loam soils are preferred. In the inland valleys, soils with considerable sand are desirable for winter and early-spring crops because they are warmer and drain more efficiently. Harvesting is often possible during rainy periods on sandy ground when it is impossible to work on loamy clay soils. Heavier soils can be quite productive if they are well drained and irrigated with care. Spinach is particularly sensitive to saturated soil conditions. Spinach is moderately salt sensitive. Research has shown that the soil salinity threshold for yield loss is from 2 to 4 dS/m at 25°C (77°F), depending on the frequency of irrigation, soil type, and weather conditions. Yield loss is about 8 percent for each additional increase of 1 dS/m of soil salinity.

IRRIGATION

Depending on the initial soil conditions, 2 to 4 inches (5 to 10 cm) of water are applied using sprinklers to moisten soil for tillage and seedbed preparation. All spinach fields in California are sprinkler irrigated to germinate the seed. Two to three irrigations are required between seeding and emergence. During the spring and summer months, short sprinkler applications usually follow an initially long irrigation every 2 days until emergence to prevent the formation of a soil crust and to replace moisture lost by evaporation. Most growers produce the entire crop with sprinklers, though continued use of overhead water favors infection and spread of leaf spot diseases. Some processed crops grown in the central valley are furrow irrigated. For short-cycle crops, such as baby and teen spinach, solid-set sprinklers are often used to minimize labor during the crop cycle. Operating sprinklers in windy conditions can greatly reduce irrigation uniformity and cause uneven emergence and growth.

SPINACH SEEDING RATES AND DAYS TO HARVEST

Spinach commodity	40-inch beds (million seed/ac)	40-inch beds (seed lines/bed)	80-inch beds (million seed/ac)	80-inch beds (seed lines/bed)	Days to harvest
baby leaf, clipped	NA	NA	3.5–4.0	24–48	21–40
teenage, clipped	NA	NA	2.7–3.5	21–48	26–50
bunched	1.2	6–9	1.5–2.3	12–21	32–62
freezer	0.8	6–9	1.0–1.5	12–21	48–90

Spinach has a relatively shallow root system and thrives on frequent, short irrigations to maintain a uniformly moist soil for maximum leaf production. However, care must be taken to avoid saturated conditions, as spinach is sensitive to overwatering, especially on heavy soil textures. Saturated conditions can contribute to soilborne diseases as well as to abiotic rotting of the roots, crown, and lower leaves. One to three irrigations are usually required between emergence and harvest for clipped crops. The total water applied between seeding and harvest is 4 to 8 acre-inches per acre (413 to 826 cu. m) for a clipped crop, and 6 to 12 acre-inches per acre (620 to 1,240 cu. m) for a fresh market bunch crop. Processed crops may require 18 to 24 acre-inches per acre (1,860 to 2,480 cu. m), depending on the irrigation method and weather conditions.

The combination of soil moisture monitoring and weather-based irrigation scheduling can be used to determine water needs of spinach. Water use is highest when the leaf canopy is near maximum size. Soil moisture tensions are typically targeted for less than 20 to 30 cbars (20 to 30 kPa). Water extraction of spinach can be estimated using reference evapotranspiration data, adjusted with a crop coefficient, that are closely related to the percentage of ground covered by the leaf canopy. Because evaporation represents a majority of the water loss during the early stages of growth, a crop coefficient between 0.3 and 0.5 should be used for overhead sprinklers until the canopy is greater than 30 percent cover. At a maximum canopy cover of 85 to 90 percent, the crop coefficient is nearly 1.0. The California Irrigation Management Information System (CIMIS), coordinated by the California Department of Water Resources, provides daily estimates of reference evapotranspiration for most production regions of California (see http://wwwcimis.water.ca.gov).

FERTILIZATION

Fresh market spinach is a short-season crop that is harvested when the crop is young. As a result, nutrient uptake is relatively low. For instance, the nitrogen (N) content of fresh market spinach may vary from 20 to 40 pounds of nitrogen per acre (22 to 45 kg/ha). Freezer spinach is harvested at a more mature stage, and the nutrient content may be double that of fresh market spinach. Spinach is moderately fertilized; the fertilizer rate should be determined after consideration of type of spinach being grown, soil type, recent cropping history, and soil test results.

Phosphorus (P) fertilization should be applied based on soil test results for bicarbonate extractable phosphorus. Levels above 60 parts per million (ppm) are adequate for spinach growth; for soils below this level, especially in the winter, preplant applications of 20 to 40 pounds per acre of P_2O_5 (22 to 45 kg/ha) or applications of 20 pounds per acre of P_2O_5 (22 kg/ha) at planting are recommended. The need for potassium (K) can also be determined from soil tests; soils with greater than 120 ppm of ammonium-acetate-exchangeable potassium have sufficient quantities 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. Fertilizing to replace potassium removed with the harvested crop (approximately 25 to 55 lb/acre, or 63 to 138 kg/ha) is appropriate to maintain soil fertility for fresh market spinach, but fertilization rates above that level are economically wasteful.

Fall application of nitrogen is not recommended due to the risk of NO_3^-N 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; an additional topdress or water-run application of 20 to 30 pounds of nitrogen per acre (22 to 34 kg/ha) is generally sufficient for fresh market spinach production. For freezer spinach, two sidedress applications of nitrogen several weeks apart may be necessary. Spinach plantings that follow crops containing substantial nitrogen, such as lettuce and cole crops, may benefit from useable residual amounts of nitrogen. This nitrogen can be measured with pre-sidedress soil nitrate testing (PSNT). Soil nitrate levels greater than 20 ppm in the top 6 inches (15 cm) are adequate for crop growth.

INTEGRATED PEST MANAGEMENT

Cultural control methods such as careful site selection, mechanical cultivation, field sanitation, irrigation management to avoid excessively wet soils, and crop rotation are important components of an integrated pest management (IPM) program that can help minimize the use of chemical controls. Herbicides, insecticides, and fungicides should always be used in compliance with label instructions. Contact the UC Davis IPM World Wide Web site at http://www.ipm.ucdavis.edu or your local UCCE Farm Advisor for current pest management information (see the UC IPM Pest Management Guidelines for Spinach Web site, http://www.ipm.ucdavis.edu/PMG/selectnewpest.spinach.html).

Weed management. Weed management is essential in spinach production given the use of high-density plantings on 80-inch beds that preclude the use of cultivation. There is also a low tolerance for weeds in the mechanically harvested product. Weed management depends on good preplant weed control practices such as killing weeds prior to seed set and carrying weeds from the fields; such practices contribute to lowering weed populations in the soil seedbank. Pregermination of weed seeds followed

by weed removal with herbicide, propane flaming, or shallow tillage prior to planting can further reduce weed pressure in both organic and conventionally produced spinach. Hand weeding is generally necessary for spinach production, but it can be made more efficient and economical by effective weed control practices described above. Stinging nettle *(Urtica urens)* is one of the most troublesome weeds in spinach. Other cool-season weeds that predominate in spinach fields include annual bluegrass *(Poa annua)*, sowthistle *(Sonchus oleraceus)*, prickly lettuce *(Lactuca serriola)*, little mallow *(Malva parviflora)*, mustards such as London rocket *(Sisymbrium irio)*, and shepherd's purse *(Capsella bursa-pastoris)*.

Chemical control of weeds includes the use of herbicides and preplant fumigation with metam sodium or metam potassium. Both metam products are injected 3 inches (7.6 cm) deep into the soil and sealed with sprinkler irrigation. Preemergence herbicide is applied to control a spectrum of broadleaf and grass weeds in fresh market spinach, and postemergence herbicides are available to control weeds in freezer spinach. Consult your local UCCE Farm Advisor for advice on specific weed problems.

Insect and mite management. Because a significant percentage of spinach is grown for use in prewashed, packaged salad mixes, tolerance for insect damage and presence of insects is extremely low. Hence, insect management is critical for this commodity. Leafminers are a serious problem in the production of spinach in the coastal regions. Three species predominate as pests: serpentine leafminer *(Liriomyza trifolii)*, vegetable leafminer *(L. sativae)*, and pea leafminer *(L. huidobrensis)*. Damage by leafminers results when female flies puncture leaves to feed on plant sap and lay eggs in the leaf tissue. Adult "stings" appear as holes or bumps on the spinach leaves. Adult leafminers have such a preference for cotyledons that seedling growth may be stunted. After eggs hatch, larvae feed between the upper and lower leaf surfaces and make distinctive winding, whitish tunnels or mines. Mining reduces photosynthetic capacity of the leaves and also renders them unmarketable.

Natural enemies, especially parasitic wasps in the genus *Diglyphus*, can reduce leafminer populations quite effectively; however, when insecticides are applied for the leafminer adult or other pests, parasites may be killed. Leafminer control with insecticides targets either the adult fly by using contact materials or the larvae with systemic products. The use of insecticides for larval control is longer lasting and less likely to result in reinfestation. Cultural practices such as postharvest disking can reduce migration of adult flies into nearby fields.

Several species of aphids are found on spinach in California, but the green peach aphid *(Myzus persicae)* is probably the most common. These pests stunt plants, reduce yields through plant sap removal, transmit viruses (especially *Cucumber mosaic virus*), and result in contaminated spinach leaves due to aphid honeydew, sooty mold, and debris. At certain times of the year parasitic wasps and predators provide natural control of aphids, while at other times aphid populations increase rapidly and contact or systemic insecticides may be needed.

Several worm pests attack spinach, but the most common are loopers and beet armyworm. Several insecticides are available for worm pest control, but choose those least disruptive to parasites and predators that suppress leafminers and aphid populations. Rotate classes of insecticides for resistance management.

Whiteflies and thrips are pests of spinach in the southern deserts. In the southern deserts, the silverleaf whitefly (*Bemisia argentifolii*, also known as *B. tabaci* biotype B) stunts plants, reduces yields through plant sap removal, transmits viruses, and results in contaminated spinach leaves due to honeydew, sooty mold, and debris. Several insecticides are available for whitefly control and can be applied to the soil at planting or as foliar sprays. Rotating classes of insecticides is very important for resistance management.

Spinach can sometimes be damaged by a bulb mite called the spinach crown mite (*Rhizoglyphus* sp.). This very tiny pest feeds on the very young leaves deep in the plant crown; when these leaves expand, they are distorted and torn. The mites are especially difficult to see because of the naturally occurring glands on developing leaves. Control must occur before the damage is done, making careful monitoring for this pest very important. Damage is usually most severe in the early spring when plant growth is slow. Spinach planted in fields with recently disked crop residue or weeds is most susceptible.

Disease identification and management. An integrated disease management approach, including the use of disease-resistant cultivars, crop rotation, careful irrigation, and fungicides, is necessary to produce a high-quality product. As with insect pests, the presence of disease symptoms is not tolerated for the prewashed packaged salad products.

Damping-off disease caused by the complex of *Fusarium*, *Pythium*, and *Rhizoctonia* fungi is periodically a problem in spinach production. Severity is influenced by cultivar, soil temperature, soil moisture, and crop history. Severe damping-off of spinach is associated with warm, wet soils with a history of frequent spinach production. Management practices typically include the use of a seed-treatment fungicide and crop rotation with non-host crops.

Several diseases attack the leaves of spinach. Downy

mildew caused by *Peronospora farinosa* f. sp. *spinaciae* is the most widespread and destructive disease of spinach in California. Initial symptoms are slightly yellow, irregular, chlorotic lesions on leaves, which frequently expand and coalesce. Heavily infected leaves appear curled and distorted. The characteristic purple sporulation is often observed on the lower sides of lesions. Under conditions of prolonged leaf wetness and cool temperatures, epidemics can progress very rapidly, and an entire crop can be lost in a short period of time. Historically, downy mildew has been controlled by planting cultivars with single-gene resistance to a given race of the downy mildew pathogen. However, when new races appear, it may be several years before a new commercial cultivar with single-gene resistance becomes available. Consequently, the use of fungicides then becomes vital.

Several fungi cause leaf spot diseases on spinach. Anthracnose caused by *Colletotrichum dematium* f. sp. *spinaciae* results in small, circular, water-soaked lesions on both young and old leaves. Lesions enlarge, turn chlorotic or necrotic, develop small dark fruiting bodies within diseased leaf tissue, and result in blighted foliage. Cladosporium leaf spot *(Cladosporium variabile)* causes small, circular yellow lesions that later turn tan. The tan lesions usually support the growth of dark green sporulation. Stemphylium leaf spot *(Stemphylium botryosum)* symptoms consist of circular, light tan leaf spots. In contrast to the other two leaf spot problems, the *Stemphylium* pathogen is not visible on the leaf spot surfaces. All three of these diseases occur sporadically in California and are usually severe only during wet rainy seasons or under very wet irrigated conditions. These pathogens can be seedborne. Fungicide controls have not been developed for these diseases.

Cucumber mosaic virus (CMV), *Beet western yellows virus* (BWYV), and *Beet curly top virus* (BCTV) are three of the most common viral pathogens affecting spinach. Symptoms for these virus problems depend on spinach cultivar, plant age, temperature, and virus strain. CMV is vectored by aphids in a nonpersistent manner and causes general yellowing and poor growth. BWYV is vectored by aphids in a persistent or circulative manner and causes the lower, older spinach leaves to turn bright yellow while the leaf veins remain green. BCTV is transmitted by leafhoppers and causes plants to be extremely stunted and distorted. While insecticides aimed at controlling virus vectors may help prevent widespread disease, this approach will not prevent virus diseases from occurring.

Abiotic problems. Tipburn is a physiological disorder in which the tips of spinach leaves turn brown and wither. Affected leaves are unmarketable and may also be attacked by secondary rot organisms. Tipburn is caused by an imbalance of available calcium in the plant. This condition is usually induced by fast plant growth, warm temperatures, and perhaps high nitrogen levels.

HARVESTING AND HANDLING

In California spinach is grown for both fresh (bunched or bagged) and processed (frozen) commodities. In all cases a plant with a seedstalk is unmarketable. For bunched spinach the crop is hand-harvested. The plant is cut just below the crown, tied into bunches of 8 to 12 plants, and packed 24 bunches to a carton with a minimum net weight of 20 pounds (9 kg). Yields, which vary widely depending on planting configuration and density, range from 900 to 1,900 cartons per acre (2,300 to 4,800 per ha).

Fresh market spinach that is sold as bagged salad mixes is usually mechanically harvested. A machine with a front cutter bar is run on top of the plant beds. The cutter bar clips the leaf and attached petiole off the plant. The height of the cutter bar can be adjusted to control the amount of petiole that is included. The leaves are lifted by conveyor belt into bins on trailers and transported to the processing plant for sorting, flume washing, centrifugation or forced-air drying, and packaging into a variety of different bagged spinach or mixed leafy greens products. If fresh processing is delayed, the spinach is typically vacuum cooled and stored for a short period.

Spinach for processed frozen products is also mechanically harvested similar to fresh market spinach. In contrast to fresh market spinach, such spinach is allowed to grow for longer periods of time so that leaf size and thickness are significantly greater. Once a field is clipped, the plants regrow and can be harvested a second and perhaps a third time. Typical yields for processing fields range from 7 to 12 tons per acre (16 to 27 t/ha) at 18 percent stem.

POSTHARVEST HANDLING

Spinach is quite perishable and will yellow when stored at higher than recommended temperatures. However, the main cause of postharvest losses is decay associated with mechanical damage during harvest and postharvest operations. Because spinach has a large surface-to-weight ratio and a very high respiration rate, it should be cooled rapidly to prevent excessive weight loss and wilting. Spinach can be effectively cooled by vacuum cooling and forced-air cooling. Spinach stored at 32ºF (0ºC) and high relative humidity (95% or higher) typically has a shelf life of 14 to 18 days. If spinach has little mechanical injury, it can be stored for longer periods. Spinach is sensitive to ethylene (increases yellow and may increase decay) and moderately sensitive to freezing injury after harvest.

MARKETING

California is the principal spinach-producing state with Texas, Oklahoma, New Jersey, Colorado, Maryland, New York, and Ohio also providing supplies. California spinach is grown and produced throughout the year for fresh and frozen products. Canned spinach is produced in some southeastern states, but not in California. Spinach prices during the season vary from a low of $238/ton to a high of $351/ton (an average for 2003–2005 seasons, Los Angeles Terminal market prices). A small portion of the crop is exported to Canada (8%).

COST OF PRODUCTION

The costs of spinach production depend on location. Costs for water, land lease, and production inputs (fertilizer, pesticide, etc.) would vary with weather, soil, and other factors. Spinach production is labor intensive, especially for weed management, bunched spinach harvests, and clipped spinach handling in postharvest facilities. For guidelines and sample costs for spinach production in Ventura County, see Spinach Production: Sample Costs and Profitability Analysis (ANR Publication 8032, http://anrcatalog.ucdavis.edu/pdf/8032.pdf).

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