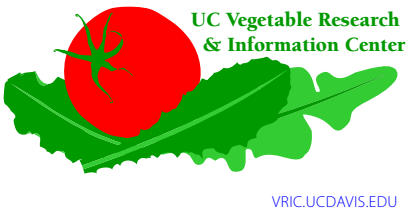

Vegetable
Production Series

CAULIFLOWER PRODUCTION IN CALIFORNIA

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PRODUCTION AREAS AND SEASONS

Cauliflower *(Brassica oleracea* var. *botrytis)* is a cool-season vegetable that is produced in many areas of California, including the central coast (Monterey, San Benito, and Santa Cruz Counties); the south coast (Ventura, Santa Barbara, and San Luis Obispo Counties); the San Joaquin Valley (Tulare, Fresno, Stanislaus, and San Joaquin Counties); and the southern deserts (Riverside and Imperial Counties).

In the central and south coast, cauliflower is transplanted and harvested virtually year-round. In the San Joaquin Valley, planting begins in mid-July for harvest from October to December. In the southern deserts, planting begins in August and continues until early December for harvest from early December through mid-March.

CAULIFLOWER ACREAGE AND VALUE

Year	Acreage	Average yield (*tons/acre*)	Gross value/acre
2007	33,700	9.0	$5,936
2006	38,300	8.5	$5,515
2005	31,900	8.5	$4,839
2004	32,000	8.8	$5,188

Source: California Agricultural Resource Directory 2007 (Sacramento: California Department of Food and Agriculture, 2007).

CLIMATIC REQUIREMENTS

Cauliflower is a cool-season crop with distinct temperature requirements for producing a marketable curd (the edible immature flower buds). The optimal temperature range for growth and development is 65° to 68°F (18° to 20°C) during the day. Most California growing regions have daytime temperatures from 63° to 83°F (17° to 29°C) and nighttime temperatures from 37° to 53°F (3° to 12°C). At temperatures of 80°F (27°C) and above, cauliflower tends to have small jacket leaves, small curds, solar yellowing, and "riceyness" of the curd. At freezing temperatures, the curds may be damaged and secondary decay will occur.

CULTIVARS

Proper cultivar selection is crucial for cauliflower production. Cultivars have biological clocks based on plant age and ambient temperature that trigger the curd to develop at a specific time. Depending on the cultivar, the period of adaptation, or slot, may be from 2 weeks to more than 1 month. Cultivars grown out of slot will not develop satisfactorily. If a mistake is made in varietal selection, the resulting crop may exhibit "ricey," yellow, or lightweight curds. Breaking of the florets may also occur.

In the southern desert several cauliflower cultivars should be planted to produce a continuous supply throughout the season. Commonly used cultivars are Snow Crown, Candid Charm, Rushmore, Ravella, Incline, McKinley, Cumberland, Yukon, White Magic, White Passion, Batsman, Minuteman, Snow Grace, Mystique, Starbrite Y, Igloo, and Serrano.

In the central and south coast, Ravella and Rushmore are transplanted in the fall and winter for early- to mid-spring harvest. Main-season varieties include Apex, Casper, and Cortez planted for mid-spring through fall harvest. A small portion of the acreage is planted to colored varieties including purple (Graffiti), green (Panther) and orange (Cheddar), as well as specialty types such as Romanesco.

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In the San Joaquin Valley, Snowman is the main variety grown, followed by Chieftan and Acclaim. These varieties are used for both the fresh and freezer markets.

PLANTING

No cauliflower is direct seeded on the central coast or in the Central Valley, but in the desert production district some acreage is direct seeded. The majority of growers use greenhouse-grown transplants. With transplants a more uniform plant stand and earlier harvests are possible. Transplanted cauliflower is placed in single rows on beds 40 inches (100 cm) wide and spaced 12 inches (30 cm) apart. Plants are typically placed with the crown below the soil surface to reduce damage caused by winds. In some cultivars, as plants begin to form flower buds the leaves surrounding the central growing point must be hand-tied with rubber bands to prevent the developing curd from being exposed to sunlight, which can cause yellowing. Other cultivars form a leaf jacket that shades the flower, eliminating the need for tying. Still other cultivars do not develop an appreciable amount of solar yellowing even with direct exposure to the sun.

SOILS

Cauliflower is grown on many soil types, from clay to loamy sand. Soils with a high moisture-holding capacity are preferred in the summer, since water stress adversely affects curd development. In the winter, soils that dry rapidly after a rain are preferred so farm equipment can enter to perform cultural and harvesting operations. Cauliflower is considered moderately sensitive to salinity in soil and water. Although no salinity threshold for yield reduction has been established for cauliflower, it is considered more tolerant to salinity than lettuce but somewhat less tolerant to salinity than broccoli.

IRRIGATION

Cauliflower requires adequate soil moisture to maximize yield and quality. It is irrigated most commonly with furrow and overhead sprinklers. Most growers use sprinkler irrigation to establish transplants and either continue with sprinklers or switch to furrow or drip irrigation for the remainder of the crop. Most of the cauliflower grown in the Central Valley and Imperial County is irrigated by furrows, while most of the acreage on the central coast is irrigated with overhead sprinklers. After transplants are established, sprinkler irrigations are commonly applied at weekly intervals on the central coast during the spring and summer. A small amount of acreage is grown under surface drip irrigation on the central coast. Some drip-irrigated fields are planted on beds 80 inches (2 m) wide with 3 lines of plants per bed and 2 lines of drip tape between the plant rows. Using drip irrigation can provide improved access to fields during harvest, especially on heavy soils with limited drainage. Approximately 3 to 4 acre-feet per acre (1,500 to 2,000 m^3/ha) of water is needed to grow a furrow-irrigated cauliflower crop in the central valley, and 2 to 3 acre–feet per acre (1,000 to 1,500 m^3/ha) is required for cauliflower production with sprinklers on the central coast during the summer. Furrow-irrigated crops in Imperial County receive approximately 4 acre-feet per acre (2,000 m^3/ha) of water. Drip irrigation may reduce water use by as much as 25 percent on soil types prone to runoff or on sandy soils that have limited water-holding capacity.

The amount and frequency of sprinkler or furrow irrigation depends on soil type, weather conditions, crop production area, and crop maturity. The combination of soil moisture monitoring and weather-based irrigation scheduling can be used to determine water needs of cauliflower. 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. Soil moisture is often allowed to reach moisture tensions greater than 30 cbars between the first sidedressing and the onset of head formation. The amount of water cauliflower extracts from the soil can be estimated using reference evapotranspiration data, adjusted with a crop coefficient, that are closely related to the percentage of ground covered by the canopy. At a maximum canopy cover of 100 percent, the crop coefficient is nearly 1.0. Crops grown with sprinklers should use a crop coefficient between 0.3 and 0.7, depending on the frequency of irrigation, until the canopy is greater than 30 percent ground cover. 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

Cauliflower demands a great deal of nutrients, and care must be given to provide adequate nutrition to the crop. Soils on the central and south coast regions can have elevated levels of nitrate-nitrogen (NO_3-N) and phosphorus (P), which can cause elevated levels of these nutrients in runoff; this makes it difficult for growers to comply with water quality standards established by regional water quality control boards. As a result, application of these nutrients must be carefully managed.

Phosphorus fertilization should be applied based on the soil test level of bicarbonate-extractable phosphorus. Levels above 50 ppm are adequate for cauliflower 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 are recommended. The need for potassium (K) 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 exchangeable soil potassium. While applying approximately 100 to 140 pounds per acre (112 to 157 kg/ha) of potassium to replace potassium removed by the harvested crop is appropriate to maintain soil fertility, fertilization rates above that level are economically wasteful. Zinc fertilization is recommended if DTPA-extractable soil level is less than 1.5 ppm. Zinc fertilization is commonly practiced in 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 NO_3-N leaching beyond the root zone by the winter rains. Small quantities of nitrogen, 20 to 30 pounds per acre (22 to 34 kg/ha) are applied preplant or at planting. At the first sidedress, 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 late-fall, winter, or spring cauliflower crops in the central coast region ranges from 180 to 240 pounds per acre (202 to 270 kg/ha). Due to residual nitrogen from prior crops and mineralization of nitrogen from soil organic matter, the nitrogen fertilization rates for cauliflower grown during the warm part of the year typically range from 160 to 200 pounds per acre (179-224 kg/ha). The sidedress nitrogen requirement can be estimated by presidedress 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. In drip-irrigated fields, nitrogen can be applied through the drip system as well. Typically, drip systems deliver nitrogen fertilizer more efficiently than do furrow or sprinkler irrigations, often allowing drip users to reduce fertilizer application rates by 20 to 30 percent.

In the southern deserts and the Central Valley, where soil test phosphorus is usually lower than on the central coast, most growers apply preplant P_2O_5 at 150 to 300 pounds per acre (168 to 336 kg/ha). Ammoniated phosphate fertilizers are broadcast before listing or are applied in bands during listing. The remainder of the nitrogen is applied in one or two sidedress applications of 50 to 80 pounds per acre (56 to 90 kg/ha).

INTEGRATED PEST MANAGEMENT

For detailed current information about integrated pest management for cauliflower, see the UC IPM Pest Management Guidelines website for cole crops at http://www.ipm.ucdavis.edu/PMG/selectnewpest.cole-crops.html, or contact your local UCCE farm advisor. Herbicides, insecticides, and fungicides should always be used in compliance with label instruction.

Weed Management

Integrated weed management should be practiced prior to planting cauliflower. Management steps include crop rotation, field selection, weed removal before weeds produce seed, and preplant irrigation to stimulate weed emergence so that these seedlings can be killed with herbicides, propane flaming, or shallow tillage. In addition, careful preparation and spacing of beds and precise planting make close cultivation more effective.

Weed control is most critical for the first 30 days following transplanting until the crop begins to close the leaf canopy and shade out weeds. Preplant or postplant herbicides are available for use on cauliflower; consult your local UCCE farm advisor for information on currently registered products. Surface spray-banding of liquid fertilizer may have the added benefit of burning small weed seedlings as well as fertilizing the crop. Given the planting configuration, effective weed control can be achieved with cultivation. The first cultivation removes weeds from the entire bed except for a band 4 inches (10 cm) wide around the seedlings. The second cultivation, carried out just before the canopy closes, throws dirt at the base of the plant, which smothers small weeds. After this cultivation the canopy shades newly emerged weed seedlings. Hand-weeding may be necessary to remove weeds between the plants in the seedline. Weeds of concern include common groundsel *(Senecio vulgaris)*, prickly lettuce *(Lactuca serriola)*, annual sowthistle *(Sonchus oleraceus)*, London rocket *(Sisymbrium irio)*, shepherd's-purse *(Capsella bursa-pastoris)*, nutsedge (*Cyperus* spp.), little mallow *(Malva parviflora)*, burning nettle *(Urtica urens)*, and chickweed *(Stellaria media)*, depending on the region and the time of year.

Insect Identification and Management

The most damaging insect pests are worms, aphids, and whiteflies, depending on the region and time of year. In coastal areas, the cabbage aphid *(Brevicoryne brassicae)* is the most important pest, though larvae of the cabbage maggot *(Delia radicum)* can chew and damage the hypocotyls of young transplants. In the southern deserts, turnip aphid *(Hyadaphis erysimi)* and green peach aphid *(Myzus persicae)* are more common

pests. Several predators and parasites attack aphids, especially in fields that are not sprayed or sprayed with less-toxic materials. These natural enemies, including general aphid predators such as the seven-spotted lady beetle *(Coccinella septempunctata)* and the parasites *Lysiphlebus testaceipes*, *Aphidius matricariae*, *Aphelinus semiflavus*, and *Diaeretiella rapae*, may provide adequate control under certain circumstances. In the southern deserts, the silverleaf whitefly *(Bemisia argentifolii)* causes slow growth and delayed maturity of the crop. In all production areas, several worm pests such as loopers *(Trichoplusia ni* and *Autographa californica)*, imported cabbage worm *(Pieris rapea)*, beet armyworm *(Spodoptera exigua)*, diamondback moth *(Plutella xylostella)*, and others are potential problems depending on the time of year and weather conditions. Worms should be managed by using selective materials to avoid making other insect problems more severe. Rotation of insecticide classes is essential for insecticide resistance management. Concerns of resistance to new-generation pesticides are present whenever one chemical is heavily relied upon as a control measure.

Disease Identification and Management

Greenhouse transplants may be stunted and weakened by downy mildew *(Peronospora parasitica)* and bacterial leaf spot *(Pseudomonas syringae* pv. *maculicola)* foliar diseases, but once plants are transplanted and established in the field, these diseases are not usually important in California. Newly transplanted cauliflower is subject to wirestem disease until plant hypocotyls thicken and become immune to the soilborne pathogen *(Rhizoctonia solani)*. Wirestem can be minimized if soil is not overly wet when plants are transplanted and if plants are not placed too deeply into the soil.

Black rot *(Xanthomonas campestris* pv. *campestris)* may cause significant problems when introduced on greenhouse-grown transplants in the southern desert growing regions. To prevent the disease, black rot—free seed should be used for producing transplants.

Phytophthora root rot (*Phytophthora* spp.), club-root *(Plasmodiophora brassicae*), and Verticillium wilt *(Verticillium dahliae)* are three soilborne diseases that affect the crop during its main growth phase. Phytophthora root rot is best managed by careful irrigation scheduling. Club-root is a persistent disease that is effectively managed by raising soil pH with calcium and magnesium liming materials. *Verticillium* is present in the coastal valleys and can be controlled if effective soil fumigants are used or if infested fields are planted to cauliflower in the winter. Some hybrid cauliflower cultivars grow vigorously and can be tolerant to this pathogen.

Sooty mold, or curd smudge, is caused by a contaminating fungus (*Cladosporium* sp.) that sometimes develops on curd surfaces when the crop is near harvest. This noninfecting fungus is held in check by the use of chlorinated water sprays before packing. Washing also helps to remove dust and debris from the curds.

While mature cauliflower is subject to several foliar diseases, including Alternaria leaf spot *(Alternaria brassicae* and *A. brassicicola)*, white mold *(Sclerotinia sclerotiorum)*, and downy mildew *(Peronospora parasitica)*, the crop is usually not significantly impacted by these diseases and control measures are rarely needed.

Other Pests and Problems

Cauliflower is a host to the cyst nematode *(Heterodera schachtii)*. However, it appears that extremely high populations of this nematode need to be present for significant yield reductions to occur. Threshold levels have not been established for cyst nematode on cauliflower.

Wind whip causes girdling and death of small seedlings. Later, surviving plants may wilt and fail to form a flowering head. The stems of affected plants become very brittle. Seedlings are more susceptible to wind whip after weeding. Check the weather forecasts so that weeding is not scheduled on extremely windy days.

During certain times of the growing season, cauliflower may develop a physiological condition in which sections of the curds turn light tan to brown while retaining normal texture and firmness. With time, these areas may soften and decay due to secondary rot organisms. The exact cause of this condition is not known, but it is most likely involved with changes in environmental conditions and the physiological status of the plant. In some cases when environmental conditions favor rapid growth of the curd, underlying floret branches may crack and also result in discolored sections.

Field mice (*Microtus* spp.) may be a problem near harvest. Once mice become established in a field they are nearly impossible to control. Prebaiting and destroying grassy areas on the perimeter of the field may be effective prevention and control.

Blind bud, a condition in which no central growing point and flowering head forms, may be due to mechanical injury, insect chewing, or bird feeding. In some cases blind bud develops in a small percentage of plants from certain seed lots, indicating that this type of blind bud may be a genetic trait.

HARVESTING AND HANDLING

All cauliflower is hand-harvested in the field. Fields are normally harvested 2 to 4 times or more depend-

ing on the market. Mature heads, 6 inches (15 cm) or larger, are hand-selected and trimmed of excess wrapper leaves, making a crown-cut shape. Smaller heads will usually grow enough to be harvested as the next-larger size within a couple of days. The heads are placed on a harvesting platform, sorted, covered with plastic wrap, and packed by size. Cauliflower should never be allowed to roll or have the white curd make contact with objects or work surfaces because the curd readily bruises and turns brown. Damaged curds may even be subject to postharvest decay.

Heads are usually placed in plastic bags, sealed with tape, and packed in cartons according to size (cartons of 9, 12, 16, or 20 heads). Typically the market prefers 12s. Cauliflower is always packed in single-layer cartons to prevent bruising and subsequent discoloration and decay. Some cauliflower is cut into florets for fresh-cut products, usually for food-service outlets. Cartons containing two 3-pound (1.4-kg) bags of 1- to 3-inch (3.7 to 7.5-cm) florets are common. In addition to conventional cartons, cauliflower is marketed as small and large cut pieces and mixed with other vegetables such as broccoli and carrots. Yields of 500 to 600 23-pound (10.4-kg) cartons per acre (200 to 240 per ha) are possible.

Some cauliflower in the southern coast and in the central valley is hand-harvested, placed in bulk bins, and transported to a freezer plant. These heads are harvested with more jacket leaves than carton-packed cauliflower to prevent curd damage during transport and unloading. The heads are trimmed again at the freezer plant.

POSTHARVEST HANDLING

Cauliflower is relatively perishable and should be stored only for short periods of time. The storage temperature should be 32°F (0°C) with high relative humidity (95 percent or higher). Storage at higher temperatures rapidly cause deterioration of cauliflower quality and shelf life.

SHELF LIFE OF CAULIFLOWER AT SELECTED TEMPERATURES

Temperature °F (°C)	Shelf life (days)
32 (0)	21–28
38 (3)	14
41 (5)	7–10
50 (10)	5
59 (15)	3

Fluctuating temperatures during postharvest handling lead to condensation within the plastic wraps and can increase decay on the heads. Long-term or improper storage results in poor quality at arrival, price reductions, and a less-than-acceptable product at retail markets. Cauliflower should not be stored or transported with commodities that produce ethylene gas (such as apples or cantaloupes) because ethylene causes yellowing and abscission of the trimmed cap leaves.

MARKETING

California is the major cauliflower-producing state in the United States, with about 90 percent of the supply. Arizona is second, followed by New York, Washington, and Texas. There is no major peak period for the crop. Supplies are steady throughout the year, limited only by adverse weather at harvest sites. Cauliflower prices are typically lower during the months of May to October and higher during November to April. In seasons from 2003 to 2005, the average price ranged from a low of $618 per ton (1 ton = 1.02 metric tons) to a high of $744/ton. Two of the main export markets for California cauliflower during this time included Canada, with an average supply of approximately 52,600 tons, and Japan, with 21,100 tons. Taiwan was included in the 2005 export countries, with about 4,100 tons.

COSTS OF PRODUCTION

Costs of production of cauliflower depend on the location, weather, soil, and other factors. Generally, cauliflower production is particularly labor-intensive in harvest and postharvest handling phases. For more information, see *Sample Cost to Produce Cauliflower in Imperial County, 2004*, at the UCCE Web site, http://ucce.ucdavis.edu/files/filelibrary/5600/42629.pdf.

FOR FURTHER INFORMATION

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