**Title**
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**Publication Date**
2011-03-01

**DOI**
10.3733/ucanr.7244

Peer reviewed

UC Vegetable Research
& Information Center

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Vegetable
Production Series

# CHILE PEPPER PRODUCTION IN CALIFORNIA

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## PRODUCTION AREAS AND SEASONS

California has four main chile pepper *(Capsicum annuum* L.) production areas: the southern desert valleys (Imperial and Riverside Counties), the southern coast (San Diego, Orange, and Ventura Counties), the Central Coast (San Luis Obispo, Monterey, San Benito, and Santa Clara Counties), and the Central Valley (Tulare, Fresno, and San Joaquin Counties).

Nearly all fields in the southern desert valleys are transplanted in late January or February for harvest from late April through June. On the southern coast, planting also begins in January and continues through May for harvest from May through September. In the Central Coast, planting is done from March to June for harvest from August to November. Planting in the Central Valley begins in Fresno County in February under plastic tunnels and hotcaps and moves through counties farther north over the next four months for harvest from late May to November.

## CLIMATIC REQUIREMENTS

Chile peppers are warm-season crops, sensitive to freezing temperatures at any growth stage. The rate of seed germination decreases rapidly when soil temperatures are below 77ºF (25ºC), with germination slow below 68ºF (20ºC). Day temperatures of 75º to 85ºF (23.9º to 29.4ºC) with night temperatures about 50º to 60ºF (10º to 15.6ºC) are ideal for growth. Although tolerant of temperatures of about 100ºF (37.8ºC), such extreme conditions can reduce effective pollination, fruit set, and yield.

### CHILE PEPPER ACREAGE AND VALUE

| Year | Harvested Acreage | Average Yield (Tons/Acre) | Gross Value ($/Acre) |
|---|---|---|---|
| 2009 | 5,900 | 17.5 | 7,726 |
| 2008 | 5,700 | 16.25 | 8,543 |
| 2007 | 5,800 | 15.50 | 10,664 |
| 2006 | 5,500 | 16.50 | 8,019 |

*Source:* California Department of Food and Agriculture-California Agricultural Resource Directory 2010

## VARIETIES AND PLANTING TECHNIQUES

**Varieties**. Chile peppers comprise five species in the genus *Capsicum* and include a wide variety of pepper types. The species *C. annuum* is the most commonly cultivated. The fruits of *C. annuum* range in size and shape from small cherry-like fruits to conical forms to slender fruits up to 9 inches (23 cm) long and from mild to extremely pungent, as measured by the Scoville heat index. Relatively mild chile types like Anaheim peppers may rank as low as 500 Scoville heat units, while habanero peppers rank over 300,000. Pungency is due to the presence of capsaicin, a colorless, odorless alkaloid that is concentrated in the placental tissue.

Common chile pepper groups and varieties include the following. Paprika pods are long dark red with little pungency. They are used for the production of red pigment and flavoring. Jalapeño peppers are often harvested as green fruit for fresh-market use. A sizeable proportion of the production is also sold to processors. Anaheim, or New Mexican, are long, cylindrical peppers 7 to 9 inches (18 to 23 cm) long. They are harvested green for fresh use as well as canning, and ground red dehydrated pods are used in sauces. They range from varieties that have little

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pungency (NuMex Conquistador and Anaheim) to varieties that have appreciable pungency (e.g., Sandia). Wax peppers pods vary greatly in size and shape and are usually yellow when immature. They can be sweet or pungent and are used fresh or for pickling. Wax types are also called Güero, Banana, and Hungarian Wax. Varieties include Caloro, Floral Gem, Matador, Sweet Banana, and Santa Fe Grande.

A large number of other chile pepper varieties belong to other species of *Capsicum.* Examples are *C. chinenses,* which includes habanero, Scotch bonnet, and rocotillo chiles; *C. baccatum,* which includes South American types known as aji chiles; *C. frutescens,* which includes Tabasco chiles; and *C. pubescens,* which includes rocoto and manzano chiles.

**Planting**. Nearly all fields in the southern desert valleys and southern coastal regions are transplanted, as are most fields in the southern half of the Central Valley. Many processing production fields are commonly direct seeded with open pollinated varieties. However, an increasing number of hybrid varieties are available for some types of chiles that have higher yield potential, and their use has increased in recent years.

In the southern desert valleys, Central Valley, and southern coastal areas, peppers are usually grown as double rows on raised beds, 60 to 72 inches (1.5 to 1.8 m) apart, with plastic mulch and drip irrigation. Much of the acreage is fumigated before transplanting. These three practices promote earliness and yield, and in the southern coastal areas, help compensate for the high cost of land and water. In Fresno County some smaller growers plant on beds 36 to 40 inches (0.9 to 1.0 m) apart with one seedline. Plastic tunnels or hotcaps are sometimes used to give early-season frost protection, but this practice adds considerable cost of production. Central Coast fields are mostly transplanted, with some direct seeding. Planting in double-row beds is more common than in single-row beds. Elsewhere in the state, neither fumigation nor plastic mulching are common, and a wide variety of field configurations are used. Bed width varies from 30 to 66 inches (0.8 to 1.7 m), with one or two rows of plants per bed; in-row plant spacing ranges from 8 to 16 inches (20.5 to 40.5 cm). Where direct seeding is done, 0.5 to 2 pounds per acre (0.6 to 2.2 kg/ha) of seed is used. Higher rates are used early in the season when soil temperature is suboptimal; pepper seed germinates slowly and erratically below 68ºF (20ºC).

## SOILS

Many soil textures are used for chile pepper production. Sandy soils are preferred for the earliest plantings because they warm more rapidly in the spring. Heavier soils can be quite productive, provided they are well drained and irrigated with care. Phytophthora root rot, a soilborne fungal disease, can be a serious problem in soils saturated from excessive irrigation or rainfall.

## IRRIGATION

Chile pepper is typically drip or furrow irrigated. Statewide, greater than 80 percent of the crop is grown under drip irrigation. Furrow is most commonly used in areas such as the Central and Imperial Valleys. Overhead sprinklers are typically used for seedling or transplant establishment but are seldom used for the entire production season. Where furrow irrigation is used, irrigation frequency depends on soil type, environmental conditions, and crop growth stage. Although peppers are moderately deep-rooted, they are quite sensitive to moisture stress. Stress during bloom can cause substantial reduction in fruit set, while stress during early fruit growth can induce blossom end rot. Soil moisture stress can also minimize foliage cover, increasing sunburning of fruit. However, care must be exercised to prevent overwatering, which can induce root rot caused by *Phytophthora capsici*.

With drip irrigation, growers use either one or two drip lines per bed; the lines may be buried 8 to 10 inches (20 to 25.5 cm) below the soil surface to allow the tape to be used for multiple crops, or they can be placed on or just below the soil surface to ease installation and removal of the tape. Surface-placed tape and shallowly buried tape often provide the best uniformity of moisture across the width of the beds. Transplants are often established with drip. Usually the beds are moistened with a pre-irrigation before transplanting. Frequency of irrigation can vary from once or twice a week early in the season to almost daily during times of peak water demand.

Water requirements of chile peppers depend on the irrigation method, soil type, and weather regime. Irrigation requirements range from 1.8 to 2.8 acre-feet (2,200 to 3,453 $m^3$) for drip irrigated crops and 2.5 to 4 acre-feet (3,083 to 4,934 $m^3$) for furrow-irrigated crops. Irrigation requirements can be determined by a combination of weather-based scheduling and soil moisture monitoring. Irrigating to maintain soil moisture tensions below 40 cbars (kPa) minimizes water stress during critical stages of development such as flowering and fruit set.

Water use of chile peppers can be estimated using reference evapotranspiration data ($ET_o$) adjusted for a crop coefficient, which is closely related to the percentage of canopy cover shading the surface of the bed. A maximum crop coefficient of 1.05 corresponds with maximum canopy cover (> 90%). In fields where overhead sprinklers are used during transplant establishment, the crop coefficient ranges between

0.2 to 0.4, depending on the irrigation frequency, to account for water lost by evaporation from the soil surface. With the exception of surface-placed or shallowly buried tape, in which water could be lost by evaporation from the wetted surface of the bed, plastic mulches would have minimal impact on the crop coefficient, other than hastening canopy growth. 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 at their Web site, http://wwwcimis.water.ca.gov.

## FERTILIZATION

Chile peppers require moderate to high rates of fertilizer. Preplant phosphorus (P) application of 80 to 200 pounds per acre (90 to 224 kg/ha) of $P_2O_5$ is common; a higher rate is appropriate for fields with limited soil phosphorus availability (< 10 ppm bicarbonate extractable P), while fields with soil test phosphorus > 25 ppm can be adequately supplied by the lower end of this range. In-season phosphorus fertilization is seldom required. Many California soils have adequate potassium (K), but in some fields potassium deficiency may be encountered. Soils with ammonium acetate-exchangeable potassium less than 150 ppm should be fertilized with potassium; appropriate seasonal rates vary from 50 to 150 pounds per acre (56 to 168 kg/ha) of $K_2O$, depending on soil test values.

Nitrogen fertilization rates tend to be high, with many growers applying 250 pounds of nitrogen per acre (280 kg/ha) or more seasonally. It is a widespread belief that high nitrogen rates increase plant vigor, foliage cover, and fruit size, which in turn increases yield and decreases sunburn damage to fruit. However, with efficient irrigation management a seasonal rate of 200 pounds of nitrogen per acre should be sufficient under most field conditions. In fields harvested for fresh market over a prolonged period, somewhat higher seasonal nitrogen rates may be justified. Nitrogen fertilizer should be delivered in multiple applications through the season, with no more than 20 to 30 percent of the seasonal total applied preplant. In furrow-irrigated fields, nitrogen and potassium are applied preplant and in one or more sidedressings; late-season water-run applications may also be done. Where drip irrigation is used, nitrogen and potassium can be applied in numerous fertigations throughout the season.

## INTEGRATED PEST MANAGEMENT

Detailed information about IPM for peppers is available at the UC IPM World Wide Web site, http://www.ipm.ucdavis.edu. Herbicides, insecticides, and fungicides should always be used in compliance with label instructions.

**Weed management**. It is important to control annual and perennial weeds in pepper production to maintain acceptable yield and quality. The slow initial growth of pepper seedlings in direct-seeded fields and transplants makes weed control challenging in this crop. Fields with heavy weed infestations or with perennial weeds such as field bindweed or yellow nutsedge should be avoided. Dark colored (e.g., black or brown) plastic mulch provides control of weeds except for in the planting hole and furrows. Herbicides can be applied beneath plastic mulch to control broadleaf weeds; other herbicides can be used to treat the furrows when plastic mulch is used and cultivation is not an option. Fumigation provides broad-spectrum weed control in fields where it is used. In unmulched chile pepper production, preplant or preemergence herbicides that control broadleaf and grass weed species are used in conjunction with mechanical cultivation to further improve weed control on the bed tops and furrows. The use of buried drip irrigation reduces weed pressure by keeping the soil surface drier. Hand-weeding of fields is usually required to remove weeds not controlled by the above mentioned techniques.

**Insect identification and management**. A wide variety of insect pests can cause significant damage to pepper plantings. Flea beetles *(Epitrix* and *Phyllotreta* spp.) and the palestriped flea beetle *(Systena blanda)*, cutworms *(Agrotis* and *Peridroma* spp.), and wireworms (*Limonius* spp.) are common seedling pests that periodically require control measures. Later in the season, several species of aphids including the green peach aphid *(Myzus persicae)* can build to damaging levels; more importantly, they serve as vectors for several serious virus diseases. Three species of thrips are implicated in the transmission of the *tomato spotted wilt virus (TSWV)*: western flower *(Frankliniella occidentalis)*, onion *(Thrips tabaci)*, and chili *(Scirtothrips dorsalis)*. Beet armyworm *(Spodoptera exigua)* and tomato fruitworm *(Helicoverpa zea)* can damage foliage as well as fruit. Pepper weevil *(Anthonomus eugenii)* can be a serious pest of pepper fruit; damaging weevil populations are generally confined to southern California. Pepper psyllid *(Bactericera cockerelli)* can build up large populations rapidly and produce large amounts of honeydew during their feeding, which can lead to a buildup of sooty mold on fruit. Broad mites *(Polyphagotarsonemus latus)* feed on the undersides of leaves and young fruit. Broad mites inject salivary toxins as they feed, which results in twisted, distorted growth, downward curling of leave edges, distortion of flowers and buds that do not open, and dead terminal buds. This injury may be confused with herbicide injury, nutritional deficiencies, or physiological disorders. They are most prevalent in the southern part of the state. Look for characteristic damage using a 20× hand lens to inspect the underside of the leaves for the mites and their eggs. Several miticides are registered for broad mite control, but insecticidal oils or soaps are usually just as effective and less toxic to the environment. Release of predator mites such as *Neoseiulus californicus* can provide control in enclosed production systems such as high tunnels or greenhouses. Leafminer (*Liriomyza* spp.) can build to populations sufficient to defoliate plants. Heavy use of broad-spectrum insecticides (used to control other pests) destroys the complex of beneficial insects that usually keep leafminer populations in check. A comprehensive IPM program using insecticides that do not disrupt beneficial populations can minimize this problem.

**Disease and nematode identification and management**. A variety of diseases and disorders affect chile peppers and reduce their yield and fruit quality.

**Pathogenic diseases**. Phytophthora root rot *(Phytophthora capsici)* is widely distributed in California pepper-growing regions. Disease severity is enhanced by excessive soil moisture, with plant symptoms concentrated in low areas, at the end of furrow-irrigated fields, or in areas of restricted drainage. There are no effective chemical control measures; control depends primarily on proper irrigation management. Genetic tolerance to Phytophthora root rot is now available in some recently released hybrid varieties. Peppers are susceptible to infection by Verticillium wilt *(Verticillium dahliae),* and occasional serious economic loss to that pathogen occurs.

There are several potentially damaging foliar pathogens of pepper. Bacterial spot *(Xanthomonas campestris* pv. *vesicatoria),* which can be seedborne or may overwinter in crop residue in soil, may be severe in warm, humid conditions. Extended wet conditions are rare in California pepper-producing areas, so bacterial spot is not a major field problem. However, if a field is sprinkler irrigated, the disease can cause extensive spotting on leaves and lesion formation on fruit. In circumstances such as greenhouse production of transplants or extended wet weather, chemical control may be needed. Powdery mildew *(Leveillula taurica)* can occur in severe outbreaks that result in significant defoliation and subsequent sunburning of the fruit. A chemical control program should be initiated at the first sign of powdery mildew.

**Viruses.** Viruses are the most common and damaging pepper disease problem. The major aphid-vectored viruses are *cucumber mosaic virus (CMV)*, *pepper mottle virus (PeMV)*, *tobacco etch virus (TEV)*, and *potato virus Y (PVY)*. Occurring alone or in combination, these viruses can devastate entire fields, and their appearance and severity are unpredictable. Insecticide applications are generally ineffective in preventing virus diseases since virus transmission can take place during brief insect feeding periods; insecticides may be marginally beneficial in controlling subsequent in-field spread of the viruses by colonizing aphids. *Alfalfa mosaic virus (AMV)* is relatively common in California pepper fields but does not often cause significant yield loss. *Curly top virus*, vectored by the beet leafhopper *(Circulifer tenellus),* occurs in the coastal, Coachella, and Central Valleys but seldom causes serious economic losses. *Tobacco mosaic virus (TMV)*, historically a serious pepper disease, is now controlled primarily by the use of resistant varieties. Significant losses still occur periodically where particularly virulent *TMV* strains are present. *Tomato spotted wilt virus*, vectored by thrips, is potentially a devastating pathogen that is especially prevalent on pepper grown on the coast, though *TSWV* can be found in other regions as well. The distinctive ring and blotch discoloration of fruit makes this disease a significant economic concern. A closely related tospovirus, *Impatiens necrotic spot virus (INSV)*, has been detected on pepper but is not yet an economic issue.

**Nematodes**. Soilborne pests of significance include the root-knot nematode *(Meloidogyne* spp.). Root-knot nematode is a problem only in relatively sandy soils where preceding crops were good nematode hosts. Nematode control strategies include field selection, crop rotation, and soil fumigation.

**Abiotic Disorders**. Several abiotic disorders can cause severe damage in chile peppers. Blossom end rot, a calcium deficiency in the developing fruit, is seldom directly caused by a lack of soil calcium; more often, moisture stress or heavy nitrogen fertilizer applications induce a transient calcium deficiency. Pepper stip causes greenish-brown spots that are about ¼ inch (6.5 mm) in diameter on the fruit. They are most commonly seen on the mature red fruit but occasionally occur on green fruit as well. It is not clear as to the cause of pepper stip; however, resistant varieties offer the most successful control.

## HARVESTING AND HANDLING

Many chile peppers are harvested green, before the development of the mature color. However, some chile types, such as paprika and Anaheim, are harvested in the mature red color. There are many industrial uses for the red pigment that paprika possesses. A large percentage of the chile peppers in California are harvested for processing into salsas or canned whole. The remainder is harvested for the fresh market.

Fresh-market fields are harvested two to four times at 10- to 15-day intervals, while processing fields are picked once or twice. Nearly all chile peppers are harvested by hand, usually into bulk bins or trailers for transit to a packing or processing facility. Mechanical harvesters for processing chile peppers are used to a limited extent.

## POSTHARVEST HANDLING

Harvested chile peppers may be washed with water containing 75 to 100 ppm chlorine. Excess water should be removed. To improve postharvest quality, fresh-market chile peppers should be cooled before shipment with room cooling or forced-air cooling. Ideal transit and storage conditions are 45° to 50°F (7.2° to 10°C) with high relative humidity (90 to 95%). When held at the proper temperature and humidity, the storage life is 2 to 3 weeks. Storage temperatures warmer than 50°F (10°C) favor color change (ripening). Chilling injury occurs at temperatures below 45°F (7.2°C). Chilling damage will be expressed as surface pitting, discoloration of the fruit, and excessive decay. Top ice is not recommended on chile pepper boxes. Deterioration or color change of chile peppers is more rapid with exposure to ethylene, and storage with ethylene-producing fruit is not recommended.

## COST OF PRODUCTION

The costs of chili pepper production depend on the growing location. Harvesting and postharvest handling generally account for 80 percent of the operating cost.

## MARKETING

Chile peppers are marketed for the fresh market and for processing. Fresh-market containers include half-bushel boxes and 10- to 20-pound food-service cases. Processed chile peppers are picked into bins and transported to processing plants for canning, brining, freezing, and drying. Some chile peppers may be exported, but the data is combined with that of bell peppers. In 2007, California main export destinations of bell and chile peppers were Canada (export quantity of 17,384 tons, which represents 88.7% of total California export volume) and Mexico (export quantity of 937 tons, which represents 4.8% of total California export volume).

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**Publication 7244**
ISBN-13: 978-1-60107-764-6



This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by ANR Associate Editor for Vegetable Crops Jeff Mitchell.

web-3/11-SB/CR