

Crop Profile for Carrots in California

Prepared: January, 2000

General Production Information



- California ranks first in the U.S. in the production of carrots. (1)
- California produces 59% of the total U.S. crop. (1)
- In 1996, California farmers planted 70,300 acres of carrots (up from 58,000 acres in 1993). (5)
- The 1,029 thousand tons of carrots produced in 1996 were valued in excess of \$268 million (1)
- Baby peeled carrots (shortcuts) account for greater than 35% of California's carrot production. (7)
- In 1996 California's carrot production of fresh market and processed carrots was 19,800,000 cwt and 2,880,000 cwt, respectively and in 1997 the production was 25,524,000 cwt and 1,730,000 cwt, respectively. (4)

Production Regions

There are four main production regions for carrots in California (see Appendix1.): the San Joaquin Valley (Kern County), with significant production in Cuyama Valley (San Luis Obispo County); the low desert (Imperial Valley and Riverside Counties); the high desert (Los Angeles County) and the central coast (Monterey County). Kern County is the state's largest producer with 75% of the state's acreage. (7)

<u>Location</u>	<u>Planting</u>	<u>Harvest</u>
San Joaquin Valley	December-March	May-July
	July-September	November-February
Low desert	September-November	March-May
High desert	March-July	July-November
Central Coast	December-August	April-January

Cultural Practices

Major California carrot varieties include: CaroPak, Legend, Sugarsnax, Primecut, Apache, and Navajo. The fresh market standard are Imperator types. (12) Carrots are a cool-season crop and can be grown virtually anywhere provided the growing season remains relatively cool. The optimum temperature range is 60 to 70 °F. (12)

Carrots require a growing season of 110 to 160 days. Carrots need deep, loose, well-drained sandy loams or loam soils with an optimum pH range of 5.5 to 7.0. Prior to planting, the soil is deep plowed and disked to avoid clods and a compaction layer. Fertilizer is broadcast prior to the final disking. Typical fertilizer requirements are 120, 95 and 80 lbs. per acre of nitrogen (N), phosphate (P_2O_5) and potash (K) respectively. (5,7)

Carrots are planted at high densities with 8 to 12 seedlines per 36-to 40-inch raised bed. Typical seeding rates range from 0.90 to 1.2 million seeds per acre. Fields are sprinkler-irrigated during the entire season except in Imperial Valley where the fields are typically furrow irrigated after emergence. (5,7)

Carrots are mechanically harvested with self-propelled multi-row harvesters that can harvest up to 1,000 tons per day. A two-bed harvester can dig two 40-inch wide beds at the same time. The harvester cuts off the carrot tops and delivers the roots into a truck or trailer that are subsequently hauled to a packing shed where they are graded, sized, and packed. (5)

After harvest carrots are washed and hydrocooled in clean water approximately 1 ppm chlorine or less at pH 6.5 to 7.5. They are then packed into bins for short-term storage.

Baby cut-peeled carrots are peeled, sliced and stored with both cello and bunch carrots under the most optimum conditions (32°F, 99% relative humidity and in good air circulation). These carrots are generally stored less than two weeks. (12)

During transport carrots must be continually cooled. Exposure to ethylene gas from propane powered lift trucks and other produce such as apples and pears must be avoided since ethylene gas can produce a bitter taste in carrots. (12)

Insect Pests

The insect pests of California carrots include: aphids, the pale-striped flea beetle, the salt marsh caterpillar, crickets, grasshoppers, cutworms, leafhoppers and whiteflies. None of these pests are major. In 1995, 28% of California's carrot acreage was treated with insecticides. Uncontrolled damage by insects can lead to a 15% yield loss. (7,9)

Cultural Control: General cultural practices that help reduce insect populations include removing weeds from field borders, disking fields soon after harvest, and good field and equipment sanitation practices. (9)

Aphids

Principle aphid pests in California carrots include the green peach aphid (*Myzus persicae*), and the hawthorn carrot aphid (*Dysaphis crataegi*). Other aphids include the willow carrot aphid (*Cavariella aegopodii*), the bean aphid (*Aphis fabae*), the cotton/melon aphid (*Aphis gossypii*), the hawthorn/parsley aphids (*Dysaphis foeniculus* and *Dysaphis apiifolia*), the tulip bulb aphid (*Dysaphis tulipae*), and the honeysuckle aphid (*Hyadaphis foeniculi*). (9) Aphids are sporadic and generally a minor problem in carrot production.

Aphids can damage carrots directly by feeding or indirectly by vectoring viruses. Feeding by the cotton/melon aphid and the crown and root aphids (the hawthorn/parsley aphid, the tulip bulb aphid and the hawthorn carrot aphid) can curl and distort leaves, stunt growth and more seriously cause tops to break off during harvest. The willow carrot aphid can vector a number of serious viruses such as motley dwarf and carrot red leaf. (9)

The life cycle for carrot aphids in California is simple. Carrot aphids stay on their host throughout the year as parthenogenetic viviparous females.

Cultural Control: Planting carrots near a cotton or melon field should be avoided to minimize the migration of the cotton/melon aphid into desirable carrot fields when these other crops are harvested. (9)

Biological Control: Most carrot aphids in California have a number of common predators and parasites that are commercially available such as green lacewings, lady beetles, syrphid fly larvae, minute pirate bug (*Orius insidiosus*), *Cryptolaemus montrouzier*, *Lysiphlebus testaceipes*, *Aphidius* spp., and *Dianetiella rapae*. Neem oil and the beneficial fungus *Beauveria bassiana* may also provide some degree of control. Crown and root aphids however, do not have any known predators or parasites because of their location near or below the soil line. (3,9)

Chemical Control: Generally aphid predators and parasites control aphid populations naturally and Chemical Controls are not typically used. If insecticides are used, applications are made at the first sight of aphid damage and repeated as needed. (2,3,9)

- Diazinon was applied to 5% of California's carrot acreage in 1997, when 4,151 lbs. a.i. were applied in 126 treatments. Applications are typically made at the first sign of aphid damage up to the three-leaf stage of carrot development. Diazinon is applied either by ground or aerial applications at rates of 0.25 to 0.50 lbs. a.i. per acre. Applications are repeated at seven-day intervals up to a maximum of five applications per season. The label postharvest interval (PHI) is 14 days, however the typical PHI is 60 days. Diazinon can also be used to control flea beetles and cutworms. A permit is required for its purchase and use in California. (2,3,9,12,15)
- Malathion was applied to 3% of California's carrot acreage in 1997, when 5,735 lbs. a.i. were applied in 56 treatments. It is applied either by ground or aerial applications at rates of 1 to 2 lbs. a.i. per acre. Subsequent applications can be made as needed with no limitations on the number of applications. The label PHI is 7 days, but the typical PHI is 60 days. Malathion can also be used to control flea beetles and leafhoppers. (2,3,9,15)
- Pyrethrins were applied to 0.06% of California's carrots in 21 treatments using less than 1 lb. a.i. in 1997. Aerial and ground applications are made at rates of 1 to 6 lbs. a.i. per acre. No PHI is specified for Pyrethrins. It can also be used to control flea beetles, cutworms and leafhoppers. (2,3,4,12,15)
- Rotenone was applied to 0.06% of California's carrot acreage in 1997 (less than 1 lb. a.i. in 21 treatments). Applications are made by ground or air of rates at 0.004 to 0.009 lb. a.i. per acre. Rotenone can be tank-mixed with pyrethrins. No PHI is specified for rotenone. This chemical can also be used to control whiteflies and leafhoppers. (2,3,12,15)
- Endosulfan was applied to 1.62% of California's carrot acreage in 1997, when 1,543 lbs. a.i. was applied in 30 treatments. Endosulfan can be applied by ground application at a maximum rate of 1.0 lb. a.i. per acre not to exceed 1.0 lb. a.i. per acre per year. The PHI is 7 days. This insecticide can be tank-mixed with pyrethrins. Endosulfan is used to control flea beetles, whiteflies and leafhoppers. A permit is required for purchase and use of endosulfan in California. (2,3,8,12,15)
- Insecticidal soap was applied to less than 1% of California's carrot acreage in 1997, when 50 lbs. a.i. was applied in 13 treatments. Rates used are 1 to 2% v/v solution. Insecticidal soap can be applied up until the day of harvest. It can also be used to control whiteflies and leafhoppers. This product can be used in organic systems. (2,3,12,15)
- Azadirachtin was used in two applications in 1997 when less than 1 lb. a.i. was applied. Applications can be made by air and ground at rates of 0.02 to 0.04 lbs. a.i. per acre and repeated at seven day intervals as needed. No PHI has been established for azadirachtin. It can also be

used to control flea beetles, saltmarsh caterpillar, whiteflies, leafhoppers and cutworms. (2,3,12,15)

Palestriped flea beetle (*Systema blada*)

This is an occasional pest in the desert. Both the larval and the adult stages of the palestriped flea beetle can damage carrots. Adult beetles cause damage by feeding on the underside of the leaves, leaving them scared and pitted. Large populations can stunt or kill seedlings. In the Imperial Valley, larvae feeding on roots have occasionally caused serious damage. (9)

The palestriped flea beetle can be a problem throughout the year, producing up to three generations. Adults overwinter in the soil or under crop refuse in and around fields. Beetles become active in spring and begin feeding and laying eggs in or on the soil surface near host plants. The larvae emerge after an 11-day incubation and feed on root tissue. Pupation occurs underground, and the adults emerge and feed on available foliage. The complete life cycle requires 35 to 55 days. (9)

Biological Control: No Biological Control methods are available for the palestriped flea beetle. (9)

Chemical Control: Insecticide treatments are made at the first sign of palestriped flea beetle. (9)

- Esfenvalerate was applied to 12% of California's acreage in 1997 and 15% of California's acreage in 1996. In 1997, 553 lbs. a.i. were applied in 203 treatments. Esfenvalerate can be applied only by ground application at rates of 0.03 to 0.05 lb. a.i. per acre, not to exceed 0.5 lb. a. i. per acre per season. The PHI is 7 days. To purchase and use esfenvalerate a permit is required from the county. Esfenvalerate is also used to control leafhoppers and cutworms. (2,3,9,12,15)
- Carbaryl was applied to less than 1% of California's acreage in 1997, when 602 lbs. a.i. were applied in 25 treatments. Carbaryl was applied by ground or aerial application at rates of 0.5 to 2.0 lbs. a.i. per acre. It has a label PHI of 7 days but the typical PHI is 60 days. A permit is required for the purchase and use of this insecticide. Carbaryl can also be used to control flea beetles and leafhoppers. (2,3,9,12,15)
- Diazinon – see aphids.
- Malathion – see aphids.
- Pyrethrins – see aphids.
- Endosulfan – see aphids.

- Methyl parathion – see aphids.
- Azadirachtin – see aphids.

Saltmarsh caterpillar (*Estigmene acrea*)

In the southern San Joaquin Valley, the saltmarsh caterpillar is a minor pest to carrot seedlings by feeding on young plants. It is a particular problem in the fall when a carrot field is planted adjacent to a recently defoliated cotton field. After cotton defoliation, the saltmarsh caterpillar moves into nearby carrot fields to feed on the seedlings. (9)

It is the larval stages of the saltmarsh caterpillar that damage carrot foliage. Early instars are yellow to brown in color with dark hairs. Later instars have more hair and are darker in color with yellow stripes running lengthwise on their bodies. Monitoring and prompt chemical application, if necessary, is the key to keeping caterpillar damage to a minimum. (9)

Cultural Control: Avoid planting carrots near cotton fields. If carrots are planted near cotton then dig trenches around cotton fields and fill with water. (9)

Biological Control: *Bacillus thuringiensis kurstaki* (B.t.) was applied to less than 1% of California's carrot acreage in 1997 (34 lbs. a.i. in 17 treatments). B.t. is applied by ground or air at rates of 0.12 to 1.5 lbs. per acre (24 billion *Spodoptera* per lb.). Subsequent applications can be made as needed. B.t. is not harmful to natural enemies and no PHI has been established for B.t. (3,15)

Chemical Control: Although insecticide applications for saltmarsh caterpillar are not common, a fall treatment may be necessary if caterpillars are seen moving into carrot fields. (9)

- Carbaryl – see palestriped flea beetle.
- Azadirachtin – see aphids.

Whiteflies

Whiteflies are an occasional pest on carrots. Several different species of whiteflies that infect carrots: green white fly (*Trialeurodes vaporariorum*), iris whitefly (*Aleyrodes spiraeoides*), sweetpotato whitefly (*Bemisia tabaci*), and silverleaf whitefly (*Bemisia argentifolii*). (9)

Whiteflies are a sporadic, but potentially a serious pest of carrots at all stages of plant development. Like aphids, whiteflies can damage carrots directly by feeding on the crop or indirectly as vectors for carrot viruses. During late August or September in the low desert areas, extremely dense populations of silverleaf whiteflies may migrate into carrot plantings and damage seedlings. In light to moderate outbreaks, feeding damage is not visible on the leaves, however, honeydew is deposited leaving a sticky, shiny coat. (9)

Whiteflies reproduce sexually, and the female can lay between 30 to 300 eggs. Larvae undergo an active first instar stage followed by several inactive stages and eventually pupate. Adults live between eight and 12 days, with the entire life cycle taking between 14 and 21 days. (9)

Monitoring of whitefly populations should be done twice weekly in seedling carrot fields. (9)

Cultural Control: Removal of weeds around carrot field borders and burial of infested plant residues with deep tillage after harvest can minimize infestations. (9)

Biological Control: Biological Controls provide the best long-term solution for whitefly control. Whiteflies have a number of common predators and parasites commercially available such as wasps in the *Encarsia* and *Eretomceruis* genera, green lacewings, minute pirate bugs, lady beetles, and *Delphastus pusillus*. The beneficial fungus *Beauveria bassiana* can also be used to control whiteflies. (3,9)

Chemical Control: Treatments for whiteflies are rarely made in carrots.

- Methomyl was applied to 3% and 6% of California's carrot acreage in 1997 and 1996, respectively. In 1997, 2,517 lbs. a.i. were applied in 124 treatments. Methomyl is applied by ground at a rate of 0.225 to 0.9 lb. a.i. per acre and repeated at five to seven day intervals as needed, not to exceed ten applications or 6.3 lbs. a.i. per crop per season. The label PHI is one day, but the typical PHI is 30 days. Methomyl is usually applied in combination with esfenvalerate in order to avoid the development of insect resistance. Methomyl is also used to control leafhoppers and cutworms. (2,3,9,12,15)
- Esfenvalerate – see palestriped flea beetle. Esfenvalerate applications are rotated with insecticidal soap applications to reduce the development of resistance. (9)
- Endosulfan – see aphids. There may be some endosulfan resistance in the silverleaf whitefly populations in the Imperial Valley. (9)
- Rotenone – see aphids.
- Insecticidal soap – see aphids.

- Azadirachtin – see aphids.

Occasional Pests

Leafhoppers

Occasionally leafhoppers are a pest in carrots and when they occur they are found on the underside of leaves. Adults are pale green, wedge-shaped and about 0.12 inch long. Nymphs are white to pale green in color. Typically in the late spring when the vegetation dries up, leafhoppers move from the hills into carrot fields. Damage to the plants occurs when leafhoppers suck on plant sap. This may result in yellowing or browning of leaves. Sampling plants, particularly along field margins, can be done to monitor leafhopper populations. Also, leafhoppers act as vectors for microplasmalike organisms. (9)

Cultural Control: Control weeds in and around the field, particularly in late spring plantings. (9)

Biological Control: *Beauveria bassiana* is a commercially available beneficial fungus that may be used to help control leafhoppers in carrots. (3)

Chemical Control: Insecticide applications are generally not targeted at leafhoppers as they are secondary pests to carrots in California. Usually flea beetle or aphid treatments also provide control of leafhoppers. (9)

Black cutworm (*Agrotis ipsilon*) and Variegated cutworm (*Peridroma saucia*).

These are very sporadic and generally a minor problem. When disturbed in the soil, cutworms will roll into a c-shape. These larvae cause damage by cutting the seedling off just below the soil line. Cutworms are not seen during the day since they feed at night, although stunted plant growth or severed tops may indicate their presence. Digging the soil around injured plants may reveal cutworms. (9)

Biological Control: Commercially available beneficial nematodes, *Steinernema* spp., may be used to control cutworms. (3)

Chemical Control: Treatments are made at the first sign of cutworms in or around the field. (9)

- Cyfluthrin was applied to 1.5% of California's carrot acreage in 1997 when 55 lbs. a.i. were applied in 23 treatments. Cyfluthrin is applied by ground at rates of 0.025 to 0.044 lb. a.i. per acre. Subsequent applications can be made at seven-day intervals, not to exceed five applications

per crop per season. No PHI has been established for cyfluthrin. This chemical can also be used to control leafhoppers. (2,3,15)

- Carbaryl – see palestriped flea beetle.
- Methomyl can be used at rates of 0.015 to 0.03 lb. a.i. per acre to control cutworms. See whiteflies. (2,3)
- Esfenvalerate – see palestriped flea beetle.
- Diazinon – see aphids.
- Azadirachtin – see aphids.
- Methyl parathion – see aphids.
- Pyrethrins – see aphids.

Crickets

Field crickets are shiny black or brown, 0.6 to 1.0 inch long, with long antennae. Occasionally crickets are pests of carrots. Damage will initially appear in patches. They may quickly destroy a crop by eating seedlings. (9)

Biological Control: There are no Biological Controls for crickets.

Chemical Control: Treatments are made when crickets are seen moving into the field. (9)

- Carbaryl – see palestriped flea beetle.

Secondary Pests

Grasshoppers

Grasshoppers are secondary pests that may invade carrot fields. Particularly in the late spring when

vegetation is drying up grasshoppers may move in from the hills. Both adults and nymphs feed on leafy tissue. If present in sufficient enough numbers, grasshoppers can defoliate an entire field. (9)

Cultural Control: Control weeds in and around the field, particularly in late spring plantings. (9)

Biological Control: Two commercially available beneficial organisms that may help control grasshoppers are praying mantis (*Tenodera aridifolia sinensis*) and a protozoan (*Nosema* spp.). (3)

Chemical Control:

- Carbaryl – see palestriped flea beetle.

Diseases

The major diseases of carrots in California can be divided into two divisions: soil-borne and foliar diseases. Soil-borne diseases include cavity spot, cottony soft rot, black rot, root dieback, southern blight, and bacterial soft rot. Postharvest disorders include gray mold and sour rot. Foliar diseases include alternaria leaf blight, cercospora, carrot motley dwarf, powdery mildew, aster yellows mycoplasma and beet leafhopper transmitted viresence agent. Carrot diseases can also be classified as being either soil-borne or vectored by insects. Treatments for soil-borne diseases involve treating the disease, whereas treating the corresponding insect controls the vectored diseases. (7,8)

Root diseases

Cavity spot is the most troublesome root disease in carrots. The remaining diseases are only a problem if favorable conditions exist for the disease. (4)

Cavity spot (*Pythium violae*)

Cool soil temperatures favor this soil-borne fungus. Cavity spot can be identified by irregular-shaped, brown, water-soaked, depressed lesions on the taproot. Typically the lesions are more abundant on the upper third of the root and worsen as the carrot matures. If infection of the field is severe enough an entire crop may be lost. (8)

Cultural Control: By planting carrots in a three-year rotation with crops other than alfalfa, and maintaining proper irrigation, the incidence of cavity spot can be reduced. Carrots should be harvested at the first sign of maturity since older carrots are more susceptible. (8)

Biological Control: No Biological Control methods have been established for cavity spot.

Chemical Control Fields with a previous history of cavity spot should be treated. (8)

- Metalaxyl (now reformulated as Mefenoxam) is applied preplant incorporated or applied to the soil surface and irrigated immediately after planting. Rates used are 0.03 to 0.06 lbs. a.i. per acre. In 1997, 22% of California's carrot acreage was treated with 17,745 lbs. metalaxyl in 660 applications. Mefenoxam was applied to 26% of the acreage in 1997 when 10,186 lbs. were applied in 785 applications. Only crops with mefenoxam registration can be planted back in treated soil within the next 12 months. Cercospora leaf blight can also be controlled with mefenoxam. (2,3,8,12,15)

Cottony soft rot (*Sclerotinia sclerotiorum*)

Cottony soft rot can be an important disease on carrots. This disease is typically a problem under cool moist conditions. Cottony soft rot can be identified by white masses of fungal growth that cause water decay of the roots and the lower petioles of carrot plants. Extensive root decay occurs before wilting of the plant is seen. Infection can occur at any stage of carrot growth development, even after harvest. If left untreated this disease can lead to a 5% yield loss. (8)

Cultural Control: Deep plowing of diseased carrots and a three-year crop rotation to cereals, corn or cotton can minimize cottony soft rot. (8)

Biological Control: No Biological Control methods are available for cottony soft rot.

Chemical Control: Chemical applications are made at the first sign of the disease or when the conditions favor disease development. (8)

- Benomyl was applied to less than 1% of California's carrot acreage in 1997, when 98 lbs. a.i. were applied in 5 treatments. It is applied by ground, air and chemigation at rates of 0.125 to 0.5 lb. a.i. per acre. Subsequent applications can be made at seven to ten days, but not to exceed 1.5 lbs. a.i. per acre per crop. The label PHI is 4 days, but the typical PHI is 14 days. (2,3,8,12,15)

Black rot (*Alternaria radicina*)

Black lesions on the base of the lower petioles indicate the presence of black rot. These black lesions may extend down into the root. It can cause the leaves to break off during mechanical harvesting, leaving the root in the ground. This disease can be spread by infected soil. It occurs primarily in Cuyama Valley, and this pathogen can exist in the soil without a host for more than five years. Black rot can also be a problem in storage. If left untreated, black rot can lead to a 5% yield loss. (5,8)

Cultural Control: In fields that have never been planted with carrots or have never been exposed to black rot, alternaria-indexed seed should be used. If alternaria-indexed seed is not used, the seeds used should be soaked in hot water, 122° F, for 25 minutes prior to planting. Furrow irrigation, crop rotation and deep tillage can reduce incidence of black rot. (8)

Biological Control: There are no Biological Control methods for black rot.

Chemical Control: Foliar applications of fungicides to control black rot are not effective. (8)

- Iprodione is used for seed treatment at rates of 16 oz per 100 lbs. of seed treated. In 1997, 19 lbs. a.i. were used to treat carrot seed in California. (8,15)

Root dieback and Damping off (*Pythium ultimum* and *Pythium irregulare*)

The fungus that causes root dieback is soil-borne and is most common under moist soil conditions. Carrots are most susceptible to this disease within two weeks after germination.(8)

Cultural Control: To reduce the incidence of root dieback maintain proper drainage and rotate carrots to non-host crops. (8)

Biological Control: No Biological Control methods are available for root dieback.

Chemical Control: In fields with a history of Pythium-related problems, a preplant treatment of metalaxyl is occasionally applied. Over 90% of all carrot seed planted in the U.S. is treated with Thiram to control damping off.

Minor Pests

Bacterial soft rot (*Erwinia carotova*)

The pathogen that causes soft rot typically enters carrots through wounds. Infection can be identified by a soft, watery, slimy decay of the taproot that eventually consumes the core of the carrot. Frequently, the foliage wilts and becomes yellow. A foul odor may also accompany these symptoms. The soil borne bacterium is favored by wet warm conditions, and the disease can develop inside carrots after harvest. Bacterial soft rot is considered to be a minor problem in California carrot production.(8)

Cultural Control: To minimize the incidence of bacterial soft rot maintain good drainage and avoid injury to the carrots. Do not over water mature carrot fields during warm weather. Check irrigation pipes to make sure there are no leaks. While carrots are in packinghouses, they should be kept cool, and chlorinated wash water also helps to eliminate soft rot from carrot surfaces. (8)

Biological Control: No Biological Control methods have been established for bacterial soft rot.

Chemical Control: There are no Chemical Controls for bacterial soft rot.

Gray mold (*Botrytis* spp.)

This fungus survives on decaying organic matter, and is more prevalent during wet, rainy conditions. It is rarely a problem in California.

Cultural Control: Practices such as proper handling of carrots and avoidance of longterm storage help to keep gray mold as a minor disease in California carrot production. (5,8)

Biological Control: No Biological Controls exist for this pathogen.

Chemical Control: Fresh market carrots before storage can be treated to prevent the development of gray mold.

- Thiabendazole can be used as a postharvest treatment to reduce the incidence of gray mold. Carrots can be dipped for 5 to 10 seconds in a solution of 0.32% v/v solution. The use of thiabendazole is not common. (3)

Foliar diseases

The most prominent carrot foliar disease is alternaria leaf blight. Other foliar diseases may appear if

conditions are favorable. (4)

Alternaria leaf blight (*Alternaria dauci*)

Alternaria leaf blight is the most damaging disease of California carrots. Leaf blights are caused by several plant pathogens. The early stage of the disease is characterized by yellow margins on older leaves. Dark brown to black necrotic lesions will develop and eventually become connected. In this process the entire leaf may die. Leaf blights can cause damping-off in seedlings and weaken the leaves of established plants causing them to break off when gripped by a mechanical harvester thus leaving the root in the ground. If left untreated, alternate leaf blight can lead to 40% yield loss. Alternaria leaf blight is soil borne (survives in carrot debris) and can be spread by infected carrot seeds. (8)

Cultural Control: In fields that have never been planted with carrots or have never been exposed to alternate leaf blight, alternaria-indexed seed should be used. If alternaria-index seed is not used, the seeds used should be soaked in hot water (122° F) for 25 minutes prior to planting. To minimize alternaria leaf blight exposure: fields should be tilled to bury plant debris, a two-year rotation should be practiced and fields near existing alternate leaf blight infested fields should be avoided. (8)

Biological Control: No Biological Control methods have been established for alternate leaf blight.

Chemical Control: Applications are made when conditions favor the disease. Subsequent applications are made at seven to ten day intervals. (8)

- Chlorothalonil was applied to 14% of California's carrot acreage in 1997 and 12% of the carrot acreage in 1996. In 1997, 34,341 lbs. a.i. were applied in 386 treatments. Chlorothalonil is applied by ground application at rates of 1.1 to 1.4 lbs. a.i. per acre, with no restrictions on the number of applications per year. The PHI is 42 days. Chlorothalonil can also be used to control cercospora leaf blight. This chemical can be tank-mixed with copper oxychloride. For disease resistance management, chlorothalonil is rotated with iprodione. (2,3,8,12,15)
- Iprodione was used on 37% and 56% of California's carrot acreage in 1997 and 1996, respectively. In 1997, 48,757 lbs. a.i. were applied in 1,187 treatments. Applications are made when conditions favor disease development and are repeated at 7 to 14 day intervals as needed. It was applied by ground, air, and chemigation at rates of 0.5 to 1.0 lb. a.i. per acre, not to exceed four applications per year. The label specifies a zero day PHI, however typically the PHI is 7 to 14 days. Iprodione can also be used to control black rot. (2,3,8,12,15)
- Benomyl – see cottony soft rot.

Minor Diseases

Cercospora leaf blight (*Cerocospora carotae*)

Cercospora leaf blight can usually be identified by brown spots with dark brown margins along the edge of the leaflets, however, any tissue above ground may become infected. Leaflets eventually yellow and curl at the margins. Dark brown lesions will appear on petioles, stems and flowers. Under extreme conditions, foliage may die. Cercospora leaf blight occurs most often in coastal growing areas. It can be seed-borne, but it also survives on plants and in debris. Cercospora leaf blight is a minor disease in California carrot production. (8)

Cultural Control: Use of fungicide treated seeds, deep plowing of diseased carrots and crop rotation (two to three years) can minimize cercospora leaf blight. (8)

Biological Control: There are no Biological Control methods for cercospora leaf blight.

Chemical Control: Treatments are made when conditions favor disease or at the first sign of its presence. (8)

- Chlorothalonil - see alternate leaf blight.
- Copper hydroxide was applied to 10% of the carrot acreage in 1997, when 362 ground and aerial treatments sprayed 16,080 lbs. a.i. Copper compounds are applied when conditions favor the disease using rates of 1 to 2 lbs. a.i. per acre. Subsequent applications are made at 7 to 14 day intervals. This compound may be used in organic crops. (2,3,8,12,15)
- Thiram is a seed treatment. In 1997, 29 lbs. a.i. were used to treat carrot seed in California. The rate used is 8 oz per 100 lbs. of seed. (3,8,15)

Bacterial Leaf Blight (*Xanthomonas campestris* pv. *carotae*)

Bacterial leaf blight symptoms appear as irregular brown spots on leaves, often beginning on their margins. Lesions initially have an irregular, yellow halo and may appear watersoaked. Spots coalesce and cause a leaf blight. Dark brown streaks develop on leaf petioles. Floral parts may also be blighted. A sticky bacterial exudate, which is a diagnostic sign of the disease, may be observed flowing downward on petioles and flower stalks. The pathogen is seedborne and survives on and is spread with carrot seed.

The bacteria also survive in carrot debris, but cannot survive in the soil in the absence of debris. Rain or sprinkler irrigation is required for optimum disease development. Warm weather favors infection and disease development. Optimum temperatures are between 77 and 86E F; infection does not occur below 65E F. The pathogen is dispersed in splashing water. This disease is weather related, but occurs annually. Yield losses are generally less than 50%, even in severe epidemics.

Cultural Control: Plant *Xanthomonas*-indexed seed. Use furrow irrigation, rather than sprinklers. Turn under carrot residue to hasten decomposition. Avoid continuous carrot culture by using a 2- to 3-year crop rotation scheme.

Biological Control: No Biological Control methods are available for bacterial leaf blight.

Chemical Control: In many cases, the benefits of spraying bactericides such as copper compounds or antibiotics are questionable because bacterial blight does not usually cause significant yield reductions.

- Copper formulations were applied to 18% of California's carrot acreage in 1997, when 37,363 lbs. a.i. were applied in 518 applications (15).

Carrot motley dwarf (carrot red leaf luteovirus and carrot mottle virus)

Carrot motley dwarf is caused by a combination of two viruses (carrot red-leaf luteovirus and carrot mottle virus) that are transmitted simultaneously by the willow carrot aphid as it feeds on the plant. Carrot motley dwarf can have a significant impact on spring-grown carrots in cooler areas like the Salinas Valley and Ventura County, however it is considered to be a very minor pest in all other carrot producing regions of California. Infected seedlings can be yellow to red in color and severely stunted. Plants may appear as though they are suffering from a nutritional deficiency. (8)

Cultural Control: Avoid overwintering carrots or planting carrots near sugarbeets. Avoid planting early spring carrots near overwintered carrots. Plant carrot cultivars that have some resistance to carrot motley dwarf: Danvers types are most susceptible whereas Imperators are most resistant. (8)

Biological Control: No Biological Control methods are available for carrot motley dwarf.

Chemical Control: There is no direct Chemical Control of carrot motley dwarf, however willow carrot aphids can be controlled. See willow carrot aphid. (8)

Powdery mildew (*Erysiphe polygoni*)

Powdery mildew is considered a minor disease of carrots. If it infects the crop at an early stage, it can result in significant yield losses. Powdery mildew can be identified by a white powdery growth on old leaves and as small, circular, white powdery spots on young leaves. The pathogen overwinters on related weed hosts. Airborne spores can move great distances. (8)

Cultural Control: Maintaining good plant vigor can minimize powdery mildew infection.

Biological Control: No Biological Control agent exists for powdery mildew.

Chemical Control: Chemical Controls are not generally recommended unless infections appear very early in the growing season. Applications, if warranted, are made at the first sign of infection.

- Sulfur was applied to 17% and 12% of California's carrot acreage in 1997 and 1996, respectively. In 1997, 510 applications of sulfur were made using 331,446 lbs. a.i. No PHI is specified on the label. It is applied by ground and air at a rate of 3 to 10 lbs. a.i. per acre and repeated at seven to ten day intervals. Sulfur may be used in organic fields. (2,3,8,12,15)

Nematodes

Nematodes occur in all California carrot production regions. There are approximately 90 species of nematodes that are associated with carrots. Of these, three types of nematodes (root-knot nematode, stubby-root nematode and the needle nematode) are considered the most serious pests. If left uncontrolled, nematodes can result in a 50% yield loss. (7,10)

Root knot nematode (*Meloidogyne arenaria*, *M. javanica*, *M. hapla* and *M. incognita*). The root knot nematode is the most important pest of California carrots, and is found in all carrot producing areas. The root knot nematode enters the carrot root as a second stage juvenile and remains there to feed until the nematode reaches maturity. Mature female nematodes produce an egg mass just outside the root or just below the surface of the root. Damage caused by the root knot nematode can result in stand reduction, yield reduction and severe stunting of the plant. (10)

Stubby root nematode (*Paratrichodorus* spp.). The stubby root nematode can be found throughout California. The stubby root nematode is a migrating ectoparasite that feeds on but does not penetrate the root. This nematode lays individual eggs directly in the soil. Damage caused by the stubby root nematode can also result in stand reduction, stunted chlorotic plants and yield reduction. (10)

Needle nematode (*Longidorus africanus*). The needle nematode is a serious pest in the Imperial

Valley. It is also a migrating ectoparasite that lays individual eggs in the soil. Damage caused by the needle nematode is very similar to damage caused by the stubby root nematode; stand reduction, stunted chlorotic plants and yield reduction. (10)

Cultural Control: Planting carrots when soil temperatures are below 64° F can minimize damage from the three root knot nematodes (*M. incognita*, *M. javanica* and *M. arenaria*) that are inactive at these temperatures. Equipment sanitation can prevent the spread of nematodes from infected sites to uninfected fields.(10)

Biological Control: Commercially available pathogenic fungi, *Myrothecium verrucaria* can be used as Biological Control methods for nematodes. (3)

Chemical Control:

- Metam sodium was used on 33% of California's carrot acreage in 1997 and 11% in 1996. In 1997, 5,823,590 lbs. a.i. were used in 533 treatments. It was applied by soil injection, rotary tiller and chemigation at a rate of 80 to 318 lbs. a.i. per acre, two to three weeks prior to planting. (2,3,10,12,15)
- Methyl bromide is no longer registered on carrots. Methyl bromide was used on 1% of California's carrot acreage in 1997 and 4% in 1996. In 1997, 143,730 lbs. a.i. were applied in 51 treatments. (2,3,10,12,15)
- Dichloropropene was used on 10% of California's carrot acreage in 1997 and 7% in 1996. In 1997, 929,297 lbs. a.i. were applied in 154 applications. It was applied by soil injection or mechanically incorporated at rates of 85.4 to 170.9 lbs. a.i. per acre, two to three weeks prior to planting. A permit is required for the purchase and use in California. (2,3,10,12,15)

Weeds

Weeds are a constant threat to California carrot producers. Carrot plants are very poor competitors and are particularly susceptible to weed competition. They have a long growing season in which several weed flushes can occur. Some of the more troublesome winter annual weeds are London rocket, mustards, pineappleweed, common groundsel, shepherdspurse, little mallow, annual sowthistle, canarygrass and volunteer cereals. Troublesome summer annual weeds are barnyardgrass, common lambsquarters, pigweeds, nightshades, common purslane and Russian thistle. Troublesome perennial weeds are yellow and purple nutsedge. If left untreated, weeds can lead to 80% yield losses. (7,11)

Cultural Control: Crop rotation (three to four years), mechanical cultivation (side of the beds and furrows only) and keeping field boundaries clear of weeds can help reduce weed populations in carrot fields. The high densities of carrot plantings does not allow cultivation or hand weeding, therefore, weed control on the bed-tops is completely dependent upon herbicides. (11)

Biological Control: There are no Biological Control methods for weeds.

Chemical Control: See Appendix 2.

- Linuron was applied to 62** % and 74% of California's carrot acreage in 1997 and 1996, respectively. In 1997, 1,699 linuron treatments were made using 67,377 lbs. a.i.. It is applied as both a preemergence herbicide (under a Special Local Need, 24c registration) and as a post emergence herbicide. Applications are made by ground at rates of 1.0 to 3.0 lbs. a.i. per acre not to exceed 4.0 lbs. per acre per year. The PHI is 14 days. Linuron is used to control annual broadleaf weeds and yellow nutsedge. (2,10,12,14,15)
- Trifluralin was applied as a preemergence herbicide to 45% and 56% of California's carrot acreage in 1997 and 1996, respectively. In 1997, 674 applications were made using 33,412 lbs. a. i.. It is applied by ground application at rates of 0.5 to 1.0 lb. a.i. per acre and mechanically incorporated. Trifluralin is used to control annual grasses and some small-seeded broadleaf weeds. (2,10,12,14,15)
- Metam sodium is applied to carrots primarily to control nematodes, however it also controls a broad spectrum of weeds. See nematodes. (11,12,14,15)
- Fluazifop-P-butyl was applied to 8% and 6% of California's carrot acreage in 1997 and 1996, respectively. In 1997, 2,028 lbs. a.i. were applied to 7,860 acres in 155 applications. It is applied as a post emergence herbicide by ground or air at rates of 0.125 to 0.375 lbs. a.i. per acre, not to exceed 0.75 lbs. a.i. per acre per year with a PHI of 45 days. Fluazifop-P-butyl is used to control small annual grasses such as cereals and perennial grasses such as bermudagrass and Johnsongrass. (2,11,12,14,15)
- EPTC is used as a preplant herbicide that is applied 90 days before planting. In 1997, 4,501 lbs. a. i. were applied to less than 1% of the carrot acreage in 8 applications. Application are made at rates of 3.08 to 6.16 lbs. a.i.. The field must be irrigated 30 days prior to planting. This herbicide is important for the management of yellow and purple nutsedge in carrots. EPTC is allowed under special regulations for fallow season weed control in the counties of Imperial, Riverside and San Bernardino. (2,11,15)
- Glyphosate was applied as a pre-plant or preemergence herbicide to 1.5% of California's carrot crop in 1997, when 2,073 lbs. a.i. were applied in 31 treatments. It is applied by ground application at rates of 0.75 to 1.5 lbs. a.i. per acre. Glyphosate is especially effective in

controlling perennial weeds. However, use is limited to preemergence treatments. (2,11,12,14,15)

- Oxyfluorfen is used a preplant herbicide that is applied 90 days prior to planting carrots. In 1995, 66.5 lbs. a.i. were applied to 581 acres in nine applications. Oxyfluorfen was not used in 1997. Applications are made by ground or air at rates of 0.25 to 0.5 lb. a.i. per acre, not to exceed 0.5 lb. a.i. per acre per season. Use is limited to preplant treatments. (2,15)
- Paraquat is a preemergence herbicide. In 1997, it was applied on less than 1% of the acreage in five treatments using 237 lbs. a.i.. Applications are made by air or ground at rates of 0.47 to 0.94 lb. a.i. per acre. The typical PHI is 120 days. A permit is required for the use and purchase of paraquat. Use is limited to preplant and preemergence treatments. (2,11,12,14,15)

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Database and web development by the [NSF Center for Integrated Pest Management](http://www.nsfcenter.org) located at North Carolina State University. All materials may be used freely with credit to the USDA.