

# Crop Profile for Tomatos (Fresh Market) in California

**Prepared: October, 1999**

**Revised: May, 2000**

## General Production Information

- California ranks second in the nation, behind Florida, in production of fresh market tomatoes.
- In the U.S., approximately 31% of fresh market tomatoes are grown in California.
- In 1996, fresh market tomatoes ranked twenty-first in value among all California agricultural commodities (10).
- A total of 1,162,800,000 pounds of fresh market tomatoes were produced on approximately 40,800 acres in California in 1997. The average yield was 28,500 pounds (14.25 tons) per acre (10).
- The average price paid for packed and loaded fresh tomatoes in 1997 was \$0.27 per pound. The total cash value of the 1997 crop was \$313,956,000 (10). This would equate to an average cash value (gross) of \$7,695 per acre.

## Production Regions

About 45% of the state's fresh market tomatoes are produced in San Joaquin, Stanislaus and Merced counties. Nearly all the fresh market tomatoes produced in this area are from bush varieties. Planting of fresh market tomatoes is from February to June with harvest from mid-July to late October.

The San Joaquin Valley south of Merced County produces about 30% of the fresh market tomatoes. Cherry tomatoes are grown in some areas of Fresno southward. Fresh market tomatoes are planted from February to March with a harvest period from mid-June into September.

The Central Coast, produces about 10% of the state's fresh market tomatoes. The planting period is from March to May and harvest from August to October.

The South Coastal area, also grows about 10% of the state's fresh market tomatoes. Spring pole tomatoes are planted from January through March and picked from May through July. Summer crops are planted from March through May and harvested from July to October. The fall crop of fresh market tomatoes are planted in June and July and harvested from September to December.

The Imperial Valley, grows about 5% of the state's fresh market tomatoes. Planting starts in January and goes to March, with harvests from May into June.

## Cultural Practices

Tomatoes have the most value when they arrive to the market during a certain time interval. Fresh market growers recognize the importance of this timing and plan their plantings accordingly.

**Land preparation** is the first step before planting tomatoes. Almost all tomatoes are planted on raised beds in California. This facilitates cultivation and irrigation of the tomato crop, as well as improving drainage, which minimizes root diseases. Land preparation consists of proper grading (particularly if furrow irrigation is used), subsoiling to break up compacted layers, listing, and final bed preparation. Tomato beds are most often 60 or 66 inches wide. Listing is often a critical step, as straight rows allow precision planting and close cultivation. Land preparation is often done in the fall if a spring planting is planned, as wet spring weather may prevent the use of heavy equipment needed for land preparation. Fallow bed herbicide treatments are sometimes used to prevent winter weed growth, and allow early spring tomato planting.

**Planting Method** differs by tomato type: About 90% of the fresh market tomatoes are transplanted. **Transplanting** provides the tomato plants a head start on weeds and reduces stand establishment problems. However, transplants have the crop establishment diseases, including the damping-off, a soil-borne fungus, which can be controlled by using transplants.

a weaker taproot and more secondary roots than do direct seeded tomatoes. Transplants are also more subject to virus problems.

Pole tomatoes are trained on trellises and harvested by hand every two to three days. Pole tomatoes have been successfully grown on rolling terrain in Area IV.

Tomatoes may be direct seeded in one row per bed. Single rows are easier to cultivate, and are used to reduce weeding costs. Growers frequently use a high seeding rate when planting in a single row to ensure a good stand, with a hand crew sent in to thin the stand several weeks after tomato emergence (around the third true leaf stage).

**Irrigation** is used for all California tomatoes. Furrow irrigation is commonly used in California tomatoes. Proper grading is critical for good drainage and for reducing disease levels. Furrows must be maintained throughout the season to avoid flooding the tops of beds due to an increase in weed emergence and the risk of fruit diseases.

**Sprinkler** irrigation can be used to germinate a direct seeded crop. Sprinklers are rarely used after fruit set, as the use of sprinklers increase fruit diseases, such as early blight, late blight, and molds.

**Drip** irrigation is used on over half the fresh market tomatoes grown in California. Drip irrigation provides for good water management and allows hand harvesting at regular intervals. Subsurface drip irrigation is used extensively on tomatoes but this method should not be used when salty soils are encountered. By maintaining a dry bed surface during the summer growing season, weed emergence and water use is reduced. Drip irrigation is also used in tomato plantings in rolling terrain. Damage from coyotes chewing on drip irrigation equipment is frequently encountered and adds to maintenance and repair costs.

**Insecticides** are used on about 90% of all tomatoes grown in California. Treatments are applied to the tomato foliage after crop emergence. Fresh market tomatoes receive an average of three insecticide treatments (Appendix-Table 1). The primary pests targeted by these treatments include stink bugs, beet armyworm, tomato fruitworm, aphids, whiteflies, thrips, and leafminers (9).

**Herbicides** are used for weed control on 99% of the tomatoes grown in California (Appendix-Table 2). Typically, a preplant or preemergence herbicide application is made on a six- to 10-inch band centered on the seedline. The area outside this seedline is **cultivated** to control weeds up to the time of **layby**. Layby is considered the stage of tomato growth when cultivation equipment can still be used; tomatoes are five to 10 inches tall at layby. At layby, a preemergence herbicide is often applied to the area outside the seedline to control late emerging weeds, when cultivation can no longer be used.

The **Plant Growth Regulator** Ethephon (Ethrel) is sometimes used as a ripening agent on fresh market tomatoes. Information on acreage treated with Ethephon can be found in Table 2 (9).

**Fungicides** are used on approximately 80% of the fresh market tomatoes grown in California. Fresh market tomatoes generally receive 1.5 to 2 fungicide treatments per year (Appendix-Table 3), with the majority applied as foliar treatments. The major disease organisms targeted by these treatments include late blight, powdery mildew, *Phytophthora* root rot, black mold and *Botrytis* grey mold, bacterial speck and bacterial spot (9).

## Insect Pests

Numerous insect and mite pests attack tomatoes in all of the growing regions of the state and can occur at damaging levels most seasons. Constant field monitoring is essential to signal flare-ups of various pests from planting to harvest. The pests can be divided into fruit and foliage pests such as true bugs and lepidopterous larvae, other foliage pests such as aphids and leafminers, and seed and seedling pests such as wireworms, cutworms, and garden centipedes. The distribution and damage potential to fresh market tomatoes depends on production region.

Detailed descriptions of insect pests attacking tomatoes can be found in the University of California's fourth edition of the *Integrated Pest Management for Tomatoes* and also in the *UC IPM Pest Management Guidelines*, both of which were updated in 1998. This report will review the major species that growers, packers and shippers, and Pest Control Advisers (PCAs) report as the most significant pest problems in fresh market tomato production.

### Fruit and Foliage Pests

## Stink Bugs

- Conspense stink bug, *Euschistus conspersus*
- Southern green stink bug, *Nezara viridula*
- Say's stink bug, *Chlorochroa sayi* or *Pitedia sayi*
- Redshouldered stink bug, *Thyanta pallidovirens*
- Uhler's stink bug, *Pitedia uhleri*

Stink bugs are a serious threat to fresh market tomatoes, especially in the Merced region of the San Joaquin Valley. Many PCAs and growers consider them as the hardest insect species to control when populations threaten a tomato crop. Tomatoes are damaged by stink bugs inserting their mouthparts into the fruit during feeding and secreting digestive fluids. In addition to secretions, foreign substances such as bacteria and yeast can be carried on the mouthparts of stink bugs and inserted into tomato fruit, causing rapid decay. Stink bugs have piercing and sucking mouthparts, which cause initial damage that appears as dark pinpricks as cellular fluid is extracted. Irregular blotches develop with spongy tissue below the spots. The various species of stink bugs are all similar in life cycles and all cause the same type of crop damage. The consperse stink bug is the most common species in California and is the most important species in the Sacramento and northern San Joaquin valleys (Area 1). Area 1 also has the southern green stink bug that has been fairly well controlled by an imported parasite. Say's and Uhler's stink bugs are commonly found on the West Side of the San Joaquin Valley (Area 2).

The El Nino weather phenomenon in 1997 impacted on insect populations to a great degree and lowered stink bug pressure was observed in 1997. In 1997 22% of the crop was treated with methamidophos whereas in 1996 data 66% of the crop was treated. This is a very significant difference in usage data with 1996 being a more typical year. Stink bugs are the number one insect problem in the Merced growing region and present the greatest challenge for control in growing areas 1 and 2.

## CONTROLS

Treatment for stink bugs in fresh market tomato production in Central California is usually necessary due to the very low threshold for damage. Stink bugs may be found hiding on the ground below plants and monitoring needs to be carried out in a careful manner to detect the adults before obvious feeding damage is noticed on the fruit. Some production areas may have stink bug problems year after year due to the migratory nature of the flying adults. Fields near creek beds, sloughs, or orchards need to be monitored along the borders. There are two generations of stink bugs per year with most of the fruit damage coming from offspring from the migrating adults. Spotting on tomato fruit from stink bug feces may be the first sign of pest activity.

## Chemical

**Endosulfan** (Thiodan)— Label has 0.5 - 1.0 lb a.i./acre rate and 2 day preharvest interval (PHI). In 1998, 1,009 lb a.i. were applied to 1% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 1.0 lb a.i./acre. This material is seldom used in furrow irrigated fields, since there is a 300 foot buffer restriction in place for applications with drainage into waterways. This restriction especially impacts Merced, San Joaquin, and Sacramento growing regions. Usage is restricted to three applications per year with a 3.0 lb. a.i. per year.

**Dimethoate** (Dimethoate 400 or E267)— Label has 0.25 - 0.5 lb a.i./acre rate and 7 day PHI. In 1998, 6,622 lb a.i. were applied to 22% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.48 lb a.i./acre. Dimethoate is listed as a severe hazard to bees, so caution must be exercised if bee hives are placed in the area.

**Methamidophos** (Monitor 4)— Special Local Need #CA-780163. Label has 0.5 - 1.0 lb a.i./acre rate. Seven (7) day PHI depending upon manufacturer. In 1998, 15,265 lb a.i. were applied to 24% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.98 lb a.i./acre. Pest Control Advisers report excellent results with this material and consider it the best pesticide for stink bug control since waterway restrictions prevent users from choosing endosulfan for most applications. This material is widely used for stink bug control.

**Imidacloprid** (Admire 2)— Admire is a soil application, has a label rate of 0.25 - 0.58 lb a.i./acre, and a 21 day PHI. Provado is applied foliarly, has a label rate of 0.05 lb a.i./acre, and a 0 day PHI. In 1998, 1,568 lb a.i. were applied to 13% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.08 lb a.i./acre. Systemic material works very well as a preventive for low populations. May be applied in drip irrigation.

**Insecticidal Soap** (M-Pede)— 0 days PHI. 2.5 oz./gallon of water. In 1998, 497 lb a.i. were applied to less than 0.1% of California's fresh market tomato acreage in a median of 4 applications per field. The median application rate was 4.55 lb a.i./acre. Thorough coverage is necessary as this pesticide is a direct contact material. The material has adequate activity against nymphs but it is not very effective against adults. Complete foliage coverage is critical and is not easily achieved.

**Cultural**

Pheromone trapping- Traps can be used in field monitoring to detect migrations of Consperse stink bug into tomato fields. Pest Control Advisers report poor results with the use of pheromone traps in mixed species populations. Erratic field data from low or no pests found in the traps when stink bugs were being found in the field is the prime concern. PCAs are commonly unsure of what species are being trapped and have stated that there needs to be a further look into monitoring moving populations. Some PCAs have said that the traps didn't tell them anything they already didn't know such as presence or absence of the pest. Mixed results have left users unwilling to trust the traps without extensive field investigations. University of California guidelines advise use of the trap as an indicator for initial migration of Consperse species only. While this is true, the lack of an attractant for Say's or redshouldered species reduces the trap utility to very limited areas.

**Biological**

Some biological control of stink bugs takes place in tomato fields from several parasites. Parasitized stink bug eggs may be found in clumps or clusters on the bottom sides of foliage. Cost surveys by Zalom (UC Davis) indicate available commercial parasites for augmentative releases are not economically feasible.

**Tomato Fruitworm, *Helicoverpa* (formerly *Heliothis*) *zea***

Both growers and PCAs reported fruitworm species that attack the fruit as a major threat to tomato production fields. Pest monitoring becomes crucial as tomato fruit size increases to about one inch in diameter. Bts, applied without other materials in a tank mix, were generally not regarded as effective control chemicals by growers and PCAs involved in conventional fields. Frequent applications are needed to time the pesticide when the pest is most vulnerable in the smaller instar stage. Organic tomato growers report that Bts are very important in their production fields as alternatives approved for organic production are limited.

This moth species is being monitored in pheromone traps in Fresno, San Joaquin, Merced, and Sacramento Counties as part of a 1999 research project funded by the California Tomato Commission. Trap data are collected and disseminated in a cross commodity program whereby trap data are being shared and exchanged with the California cantaloupe and honeydew melon industry. Tomato fruitworm is one of six different moth species being trapped in a network of over 80 pheromone traps set up across the San Joaquin Valley. The short-term intention of the project is to monitor male moth flight activity and identify regional moth flights to alert PCAs and field personnel when a potential pest problem has been detected so that more intensive field monitoring activities can be implemented. The long-term intention of the project is to collect regional data to be used in insect degree day model validation.

**CONTROLS**

**Chemical**

Methomyl (Lannate)— Label has 0.225 - 0.9 lb a.i./acre rate and 1 day PHI, but 2 day field reentry for workers. Application rates range from 0.23 to 0.9 lb. a.i./ac. In 1998, 29,142 lb a.i. were applied to 46% of California's fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.68 lb a.i./acre. It has been suggested that methomyl applications have been responsible for causing *Liriomyza* leafminer and pinworm outbreaks. Pest Control Advisers are generally concerned about causing secondary problems because leafminer populations can build up fairly rapidly, so this compound is used judiciously. It is considered a very effective worm killer.

**B.t. *Bacillus thuringiensis*** (various Bt products such as XenTari, Javelin, Dipel, and Agree). Zero (0) days PHI with a 4-hour reentry. Application rates vary with choice of product but usually are in the 1 to 2 pound per acre range. In 1998, 5,303 lb a.i. were applied to 43% of California's fresh market tomato acreage in a median of 1 to 6 applications per field. Oftentimes used in a tank mix, with a contact material such as methomyl, if larger-sized larval instars are present, as the material is most effective against small worms. Bt products are acceptable materials used in organic tomato production.

**Esfenvalerate** (Asana XL)— Label has 0.015 - 0.05 lb a.i./acre rate and 1 day PHI. In 1998, 1,119 lb a.i. were applied to

34% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.04 lb a.i./acre. Efforts are made to reduce pest resistance to this product by including other materials of a different chemistry in a combination spray. Careful use of this product is recommended, as extensive use may also lead to secondary pest problems with leafminers.

**Azinphos methyl** (Guthion)—14 day PHI. Label has 0.75-1.5 lb a.i./acre rate. In 1998, 909 lb a.i. were applied to 1.0% of California's fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.75 lb a.i./acre. This material is an excellent choice for fruitworm control when other caterpillar species such as armyworms and pinworms are also present. This organophosphate material has a 72 hour field reentry with differing PHI depending on label used and method of application. Azinphos methyl has a category one label with a danger/poison designation. It can be applied by air or ground and carries a chemigation label on the Guthion 2L formulation. Caution must be used as there is a six (6) month plant back restriction for root crops not on the label.

**Spinosad** (Success)—Label has rate of 0.047-0.156 lb a.i. per acre and 1 day PHI. In 1998, 828 lb a.i. were applied to 9.3% of California's fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.09 lb a.i./acre. This material was recently registered in 1998. Early reports are variable as can be expected from a product that has had little commercial development time.

## Biological

Some biological control of tomato fruitworm takes place in tomato fields from several parasites. Attempts to augment the natural predator and parasite complex with releases of beneficial insects and parasites for lepidopterous larval control has been very limited in scope and success. *Trichogramma pretiosum*, a parasite on lepidopteran eggs, is available from commercial insectaries for augmentative and inundative releases of eggs. Wasp eggs are released in a field for emergence of the wasp, which then lays its eggs into the fruitworm eggs.

Looking for black, parasitized fruitworm eggs during field inspections can monitor active parasitism. A biological control program depends upon a dedicated PCA to oversee the project and to make sure that egg hatches are timed for fruitworm oviposition and during the time period when fruit can be damaged. Growers must be willing or able to tolerate some fruit loss and avoid broad spectrum control materials. Very few growers and PCAs have actually had any experience in using augmentative or inundative releases.

## Cabbage Looper, *Trichoplusia ni*

The cabbage looper has become a problem in some tomato production areas, especially in the San Joaquin Valley. Pest Control Advisers have reported that cabbage loopers have been showing up in greater numbers the last few years. Absence of long killing frosts and broad overlap of tomato planting dates and numerous other vegetable host crops may be helping pest population buildup. Small instar larvae will chew on the bottom sides of tomato leaves. Larger sized cabbage loopers are a threat as the worms chew on mature tomato fruit. Very few PCAs reported the use of pheromone traps for the monitoring of the pest though there is an effective pheromone attractant available for use.

The pheromone-monitoring project, as described under tomato fruitworm, includes cabbage looper.

## CONTROLS

### Chemical

**B.t. *Bacillus thuringiensis*** (various Bt products such as XenTari, Javelin, Dipel DF, and Agree). Zero (0) days PHI with a 4-hour reentry. Application rates vary with choice of product but usually are in the 1 to 2 pound per acre range. In 1998, 5,303 lb a.i. were applied to 43% of California's fresh market tomato acreage in a median of 1 to 6 applications per field. Oftentimes used in a tank mix, with a contact material such as methomyl, if larger-sized larval instars are present, as the material is most effective against small worms. Bt products are acceptable materials used in organic melon production. Bt products are effective against the smaller instar worms.

**Methomyl** (Lannate)—Label has 0.225 - 0.9 lb a.i./acre rate and 1 day PHI, but 2 day field reentry for workers. Application rates range from 0.23 to 0.9 lb. a.i./ac. In 1998, 29,142 lb a.i. were applied to 46% of California's fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.68 lb a.i./acre. It has been suggested that methomyl applications have been responsible for causing *Liriomyza* leafminer and pinworm

outbreaks. Pest Control Advisers are generally concerned about causing secondary problems because leafminer populations can build up fairly rapidly, so this compound is used judiciously.

**Esfenvalerate** (Asana XL)— Label has 0.015 - 0.05 lb a.i./acre rate and 1 day PHI. In 1998, 1,119 lb a.i. were applied to 34% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.04 lb a.i./acre. Efforts are made to reduce pest resistance to this product by including other materials of a different chemistry in a combination spray. Careful use of this product is recommended, as extensive use may also lead to secondary pest problems with leafminers.

**Spinosad** (Success)— Label has rate of 0.047-0.156 lb a.i. per acre and 1 day PHI. In 1998, 828 lb a.i. were applied to 9.3% of California’s fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.09 lb a.i./acre. This material is expected to get cucurbit labeling in the near future as it cleared registration in 1998 for tomato and broccoli crops in California. Application patterns have yet to be established in other crops and early reports were variable as can be expected from a product that has had little commercial development time. The product is highly toxic to bees and its use in melon fields would have to be carefully controlled during pollination periods when honeybees are actively foraging.

**Endosulfan** (Thiodan)— Label has 0.5 - 1.0 lb a.i./acre rate and 2 day PHI. In 1998, 1,009 lb a.i. were applied to 1% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 1.0 lb a.i./acre. This material is seldom used in furrow irrigated fields, since the 300 foot buffer restrictions are in place for applications with drainage into waterways. This restriction especially impacts Merced, San Joaquin, and Sacramento growing regions. Usage is restricted to three applications per year with a 3.0 lb. a.i. per year.

Endosulfan is an excellent material that has activity against looper larvae and adult moths. It does have restrictions regarding its use when irrigation water is running in the field.

**Biological**

Some biological control of the cabbage looper takes place in melon fields from several parasites. Attempts to augment the natural predator and parasite complex with releases of beneficial insects and parasites for lepidopterous larval control has been very limited in scope and success. *Trichogramma pretiosum*, a parasite on lepidopteran eggs, is available from commercial insectaries for augmentative and inundative releases of eggs. Wasp eggs are released in a field for emergence of the wasp, which then lays its eggs into the looper eggs. Active parasitism can be monitored by looking for black, parasitized looper eggs during field inspections. A biological control program depends upon a dedicated PCA to oversee the project and to make sure that egg hatches are timed for looper moth oviposition and during the time period when mature fruit can be damaged. Growers must be willing or able to tolerate some fruit loss and avoid broad spectrum control materials.

**Tomato Pinworm, *Keiferia lycopersicella***

Tomato pinworm can become a problem in some production regions, especially in cherry tomato fields. Pest Control Advisers have reported that pinworms have been showing up in greater numbers the last few years compared to an occasional sighting of the pest in the past. Absence of long killing frosts and broad overlap of tomato crop planting dates combined with poor postharvest sanitation may be helping pest population buildup. Some growers believe that there is a cyclical pattern to the pinworm’s presence. Many PCAs reported the use of pheromone traps for the monitoring of the pest. Table 4 in the appendix list the nonchemical control practices used in fresh market tomato production with estimates of acreage involved.

**CONTROLS**

**Chemical**

**Methomyl** (Lannate)— Label has 0.225 - 0.9 lb a.i./acre rate and 1 day PHI, but 2 day field reentry for workers. Application rates range from 0.23 to 0.9 lb. a.i./ac. In 1998, 29,142 lb a.i. were applied to 46% of California’s fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.68 lb a.i./acre. It has been suggested that methomyl applications have been responsible for causing *Liriomyza* leafminer and pinworm outbreaks. Pest Control Advisers are generally concerned about causing secondary problems because leafminer populations can build up fairly rapidly, so this compound is used judiciously.

**Esfenvalerate** (Asana XL)— Label has 0.015 - 0.05 lb a.i./acre rate and 1 day PHI. In 1998, 1,119 lb a.i. were applied to 34% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.04 lb a.i./acre. Efforts are made to reduce pest resistance to this product by including other materials of a different chemistry in a combination spray. Careful use of this product is recommended, as extensive use may also lead to secondary pest problems with leafminers.

**Mating Disruptants**—(No Mate TPW Fibers-Checkmate TPW dispensers) The use of pheromone confusion or mating disruptants requires coordinated teamwork between a dedicated grower working together with a diligent PCA as these type of control programs require careful field monitoring. This control strategy is preferred over pesticide applications when release timing is coordinated with pheromone trap data.

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**Abamectin** (Agri-mek 0.15 EC)— Label has 0.0094-0.0187 lb a.i./acre rate and 7 day PHI. In 1998, 13 lb a.i. were applied to 1.1% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.01 lb a.i./acre. There is a restriction on making no more than two sequential applications although another restriction states that there is a maximum of 48 fluid ounces allowed per acre per growing season (5). Agri-mek controls tomato pinworm, russet and spider mites, and leafminers.

**Beet Armyworm**, *Spodoptera exigua*  
**Western Yellow Striped Armyworm**, *Spodoptera ornithogalli* (or *praeifica*)

Both growers and PCAs reported armyworm species that attack the fruit as a major threat to tomato production fields. Beet armyworm is a pest in most years whereas the yellow striped armyworm can become an occasional problem. Pest monitoring becomes crucial as tomato fruit size increases to about one inch in diameter. Bts were generally not regarded as effective control chemicals by growers and PCAs involved in conventional fields as the timing of applications based on larval instar stage is crucial in timing the pesticide to the stage of growth where the pest is most vulnerable. Armyworm is susceptible in the first three instars, making correct timing difficult and frequent applications costly. Coverage is critical and aerial application is often not adequate for stand alone control. Organic tomato growers report that Bts are very important in their production fields, as alternatives approved for organic production are limited.

**CONTROLS**

**Chemical**

**Methomyl** (Lannate)— Label has 0.225 - 0.9 lb a.i./acre rate and 1 day PHI, but 2 day field reentry for workers. Application rates range from 0.23 to 0.9 lb. a.i./ac. In 1998, 29,142 lb a.i. were applied to 46% of California’s fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.68 lb a.i./acre. It has been suggested that methomyl applications have been responsible for causing *Liriomyza* leafminer and pinworm outbreaks. Pest Control Advisers are generally concerned about causing secondary problems because leafminer populations can build up fairly rapidly, so this compound is used judiciously. It is considered a very effective worm killer.

**B.t. *Bacillus thuringiensis*** (various Bt products such as XenTari)— 0 days PHI with a 4-hour field reentry. Application rates vary with choice of product but usually are in the 1 to 2 pound per acre range. In 1998, 5,303 lb a.i. were applied to 43% of California’s fresh market tomato acreage in a median of 1 to 6 applications per field. Oftentimes used in a tank mix, with a contact material such as methomyl, if larger sized larval instars are present as the material is most effective against small worms. Bt products are acceptable materials used in organic tomato production.

**Esfenvalerate** (Asana XL)— Label has 0.015 - 0.05 lb a.i./acre rate and 1 day PHI. In 1998, 1,119 lb a.i. were applied to 34% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.04 lb a.i./acre. Efforts are made to reduce pest resistance to this product by including other materials of a different chemistry in a combination spray. Careful use of this product is recommended, as extensive use may also lead to secondary pest problems with leafminers.

**Spinosad** (Success)— Label has rate of 0.047-0.156 lb a.i. per acre and 1 day PHI. In 1998, 828 lb a.i. were applied to 9.3%

of California’s fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.09 lb a.i./acre. This material was recently registered in 1998. Early reports are variable as can be expected from a product that has had little commercial development time.

**Biological**

Some biological control of beet armyworm takes place in tomato fields from several parasites and a viral disease called nuclear polyhedrosis. *Hyposoter exiguae* is a parasitoid on beet armyworm. This wasp can reduce armyworm populations if pesticide use is kept at a minimum, as the natural predator and parasitoid complex will be reduced by applications. *Trichogramma pretiosum*, a parasite on lepidopteran eggs, is available from commercial insectaries for augmentative and inundative releases of eggs. The parasite is generally not as effective against armyworms as they are against fruitworms due to the protective scales on the armyworm egg mass. Eggs are released in a field for emergence of the wasp, which then lays its eggs into the exposed armyworm eggs not protected from scales at the outer edges of the egg masses. Field personnel can monitor parasitism by looking for black, parasitized eggs during field inspections. A biological control program depends upon a dedicated PCA to oversee the project and to make sure that egg hatches are timed for moth egg laying and during the time period when green fruit can be damaged by larvae feeding. Growers must be willing or able to tolerate some fruit loss and avoid broad spectrum control materials. Very few growers and PCAs have actually had any experience using augmentative or inundative releases.

**Silverleaf Whitefly**, *Bemisia argentifolii*  
**Sweetpotato Whitefly**, *Bemisia tabaci*

Tomatoes can be attacked by several different species of whiteflies, especially in Area V. Whitefly eggs and early instar nymphs are difficult to identify without the use of a hand lens as they are small insects (1.5 mm). Whiteflies typically colonize the undersides of tomato leaves where the eggs are laid. Whitefly nymphs feed on plant sap with sucking mouthparts.

Whiteflies belong to the Family Aleyrodidae in the great Order of insects Homoptera. Whiteflies excrete copious amounts of a sticky substance called honeydew, which acts as a suitable substrate for the development of black, sooty mold. This leads to unmarketable fruit. Whitefly populations have inflicted serious crop losses in the past in the southern desert growing region to numerous crops which led to a reduction in planted vegetable acres. The pest can move to tomatoes in the spring but detrimental populations usually don't arise until later in the summer after the spring tomato crop has been harvested.

**CONTROLS**

**Chemical**

Endosulfan (Thiodan)— Label has 0.5 - 1.0 lb a.i./acre rate and 2 day PHI. In 1998, 1,009 lb a.i. were applied to 1% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 1.0 lb a.i./acre. This material is seldom used in furrow irrigated fields, since the 300 foot buffer restrictions are in place for applications with drainage into waterways. This restriction especially impacts Merced, San Joaquin, and Sacramento growing regions. Usage is restricted to three applications per year with a 3.0 lb. a.i. per year. Endosulfan has restrictions regarding its use when irrigation water is running in the field. Endosulfan is an excellent insecticide that requires extremely careful handling as it has a danger poison label as a category 1 material.

**Dimethoate** (Dimethoate 400 or E267)— Label has 0.25 - 0.5 lb a.i./acre rate and 7 day PHI. In 1998, 6,622 lb a.i. were applied to 22% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.48 lb a.i./acre. Dimethoate is listed as a severe hazard to bees, so caution must be exercised if bee hives are placed in the area.

**Methamidophos** (Monitor 4)— Label has 0.5 - 1.0 lb a.i./acre rate and 7 day PHI. In 1998, 15,265 lb a.i. were applied to 24% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.98 lb a.i./acre. The insecticide requires extremely careful handling as it has a danger poison label as a category 1 material.

**Esfenvalerate** (Asana XL)— Label has 0.015 - 0.05 lb a.i./acre rate and 1 day PHI. In 1998, 1,119 lb a.i. were applied to 34% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.04 lb a.i./acre. Efforts are made to reduce pest resistance to this product by including other materials of a different chemistry in a combination spray. Careful use of this product is recommended, as extensive use may also lead to secondary pest problems with leafminers.



**Imidacloprid** (Admire 2)— Admire is a soil application, has a label rate of 0.25 - 0.58 lb a.i./acre, and a 21 day PHI. Provado is applied foliarly, has a label rate of 0.05 lb a.i./acre, and a 0 day PHI. In 1998, 1,568 lb a.i. were applied to 13% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.08 lb a.i./acre. Systemic material works very well as a preventive for low populations. May be applied in drip irrigation.

**Insecticidal Soap** (M-Pede)— In 1998, 497 lb a.i. were applied to less than 0.1% of California’s fresh market tomato acreage in a median of 4 applications per field. The median application rate was 4.55 lb a.i./acre. Thorough coverage is necessary, as this pesticide is a direct contact material. The material has adequate activity against nymphs but it is not very effective against adults. Complete foliage coverage is critical and is not easily achieved. M-Pede is a Category 3 material with a caution label.

**Oxamyl** (Vydate)— Label has 0.5 - 2.0 lb a.i./acre rate and 1 day PHI. A systemic carbamate used postplant - if drip irrigation is used, this material can be injected into the irrigation system. Oxamyl is a Category one material with a danger/poison label. In 1998, 2,559 lb a.i. were applied to 3.2% of California’s fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.75 lb a.i./acre.

**Azadirachtin** (Trilogy)-Section 3 regular registration for the clarified hydrophobic extract 70% Neem oil with a category three (3) caution label. In 1998, 178 lb a.i. were applied to 4.7% of California’s fresh market tomato acreage in a median of 5 applications per field. The median application rate was less than 0.01 lb a.i./acre. Ground application for thrips, mites, leafhopper, whitefly, and fungi control.

**Biological**

Several species of parasites and predators offer effective biological control of whiteflies if insecticide applications don't drastically reduce or totally eliminate their numbers. Several species of ladybird beetles, including *Delphastus pusillus*, prey upon whiteflies. *Encarsia* and *Eretmocerus* wasp species parasitize some species of whiteflies but can not be expected to control silverleaf whitefly populations in most situations.

**Foliage Pests**

**Hornworms**, *Manduca quinquemaculata*

Hornworms are rarely encountered in sufficient numbers to become a problem in production fields as sprays aimed at more damaging moth species such as armyworms or fruitworms control them. The use of Bt sprays would help preserve the natural enemy complex to aid in control and Bt is acceptable in organic tomato production.

**Potato Aphid**, *Macrosiphum euphorbiae*

The potato aphid represents a species that has been previously viewed as a minor pest that has been showing up on a regular basis every year. This species is heat tolerant and effectively establishes itself on several tomato varieties. Some varieties tolerate or suppress aphid populations. A combination of native biological control organisms and chemical controls targeted for other pests can often keep this pest from flaring up.

Another aphid species that is of concern to tomato growers is the green peach aphid, *Myzus persicae*, which rarely requires chemical control. The major threat is from virus diseases that the aphids vector.

**Chemical Control**

Aphids have sucking mouthparts that pierce the plant tissue during feeding. Systemic insecticides have been effective in control.

**Dimethoate** (Dimethoate 400 or E267)— Label has 0.25 - 0.5 lb a.i./acre rate and 7 day PHI. In 1998, 6,622 lb a.i. were applied to 22% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.48 lb a.i./acre. Dimethoate is listed as a severe hazard to bees, so caution must be exercised if bee hives are placed in the area.

**Imidacloprid** (Admire 2)— Admire is a soil application, has a label rate of 0.25 - 0.58 lb a.i./acre, and a 21 day PHI. Provado is applied foliarly, has a label rate of 0.05 lb a.i./acre, and a 0 day PHI. In 1998, 1,568 lb a.i. were applied to 13%

of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.08 lb a.i./acre. Systemic material works very well as a preventive for low populations. May be applied in drip irrigation.

**Endosulfan** (Thiodan)—Label has 0.5 - 1.0 lb a.i./acre rate and 2 day PHI. In 1998, 1,009 lb a.i. were applied to 1% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 1.0 lb a.i./acre. This material is seldom used in furrow irrigated fields, since the 300 foot buffer restrictions are in place for applications with drainage into waterways. This restriction especially impacts Merced, San Joaquin, and Sacramento growing regions. Usage is restricted to three applications per year with a 3.0 lb. a.i. per year.

**Diazinon** (Diazinon AG500)—Label has 0.38 - 4 lb a.i./acre rate and 1 day PHI. In 1998, 1,301 lb a.i. were applied to 2.7% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.5 lb a.i./acre. This product is seldom used, as it is not very effective against this species of aphid.

**Insecticidal Soap** (M-Pede)—0 days PHI. 2.5 oz./gallon of water. In 1998, 497 lb a.i. were applied to less than 0.1% of California's fresh market tomato acreage in a median of 4 applications per field. The median application rate was 4.55 lb a.i./acre. Thorough coverage is necessary as this pesticide is a direct contact material. Ground application needed but not often available due to irrigation schedules. The material has adequate activity against nymphs but it is not very effective against adults.

### **Leafminers, *Liriomyza trifolii*, Serpentine Leafminer**

*Liriomyza sativa*, **Vegetable Leafminer**, and other species

Leafminers are small dipteran flies, 1.5 mm (0.06 inch) long, which can cause considerable damage to tomato leaves. Adult females lay their eggs in leaf tissue. Larvae emerge inside the leaves and mine their way in narrow tunnels between the lower and upper leaf surfaces. As the larvae grow, the width of the tunnels increases. Leaves may dry out and yields can be reduced in moderate infestations. Under heavy pest pressure, plants may die and entire fields can be lost if not correctly protected with insecticides.

### **Chemical Control**

Systemic insecticides have effectively controlled Leafminers. Ground rig applications usually provide better coverage and are preferred over aerial applications. Treatments should only be made if necessary as it is important to try and preserve the beneficial predator and parasite complex present in a field. *Diglyphus*, a parasitic wasp, can be effective in biological control of leafminers if they are not removed from the fields from pesticide applications.

**Dimethoate** (Dimethoate 400 or E267)—Label has 0.25 - 0.5 lb a.i./acre rate and 7 day PHI. In 1998, 6,622 lb a.i. were applied to 22% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.48 lb a.i./acre. Dimethoate is listed as a severe hazard to bees, so caution must be exercised if bee hives are placed in the area for pollination of other crops. Successive treatments of dimethoate should be avoided as repeated applications of the same material can lead to pest resistance. Rotate materials of different chemistries if multiple applications are needed for adequate control.

**Oxamyl** (Vydate)—Label has 0.5 - 2.0 lb a.i./acre rate and 1 day PHI. A systemic carbamate used postplant - if drip irrigation is used, this material can be injected into the irrigation system. In 1998, 2,559 lb a.i. were applied to 3.2% of California's fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.75 lb a.i./acre. Oxamyl is a Category one material with a danger/poison label. Pest resistance to oxamyl has been recorded in some areas of the world especially with *L. trifolii* species.

**Abamectin** (Agri-mek 0.15 EC)—Label has 0.0094-0.0187 lb a.i./acre rate and 7 day PHI. In 1998, 13 lb a.i. were applied to 1.1% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.01 lb a.i./acre. There is a restriction on making no more than two sequential applications although another restriction states that there is a maximum of 48 fluid ounces allowed per acre per growing season (5). Agri-mek controls tomato pinworm, russet and spider mites, and leafminers.

**Azinphos methyl** (Guthion)—14 day PHI. Label has 0.75-1.5 lb a.i./acre rate. In 1998, 909 lb a.i. were applied to 1.0% of California's fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.75 lb a.i./acre. This material is an excellent choice for fruitworm control when other caterpillar species such as armyworms and pinworms are also present. This organophosphate material has a 72-hour field reentry with differing PHI depending on label used and method of application. Azinphos methyl has a category one label with a danger/poison designation. It can be applied by air or ground and carries a chemigation label on the Guthion 2L formulation. Caution must be used as there is

a six (6) month plant back restriction for root crops not on the label.

**Cyromazine** (Trigard)—Label has a rate of 0.125 lb a.i. per acre. No more than six applications per crop are allowed. This material is an insect growth regulator that offers effective control of leafminers if applied at the proper time before pest populations get out of control. Special restrictions are in place to monitor and schedule irrigations in fields treated with Trigard. The material is applied by aircraft. In 1998, 52 lb a.i. were applied to 0.5% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.12 lb a.i./acre.

### **Tomato Russet Mites, *Aculops lycopersici***

Tomato russet mites have eight legs and therefore are not insects which have six legs. Mites are very small and are difficult to see with the naked eye. Field personnel use hand lens to see and identify mites. Mites feed on the stems and leaves of tomato plants. Leaves infested with mites develop a greasy appearance, curl upwards, dry out, and then become bronze in color. Mite damage is most severe in hot weather when environmental conditions favor the pest and quicken the pace of the lifecycle. Tomato russet mites can infect tomato transplants in the greenhouse but most often blow into a field from neighboring areas. Mites can overwinter on weeds such as field bindweed (7,11). Fields are monitored for bronzing on lower leaves and treatments are initiated when crop damage begins to spread (7,11). There are no effective non-chemical controls for tomato russet mites.

### **Chemical Control**

**Sulfur**, Dusting or Wettable Sulfur—12 hour Field Reentry with 0 days PHI. Wettable sulfur label has a rate of 5.0 - 10.0 lb a.i./acre. Application rates for dusting sulfur vary with the manufacturer but 40 to 50 pounds of product per acre are common. Multiple preventive applications are usually required if favorable environmental conditions occur. In 1998, 687,274 lb a.i. were applied to 41.4% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 5.6 lb a.i./acre. Aerial operators make most applications at nighttime as sulfur has a fire hazard associated with air temperatures above 90 degrees Fahrenheit.

As a side note, the use of dusting sulfur to control mites has become a very important part of pest control ever since the advancement of sulfur resistant melon varieties as melons are frequently encountered as surrounding crops in Areas I, II, and V. Prior to the use of sulfur resistant melon varieties, growers and especially aerial operators were reluctant to use sulfur as a control option due to the hazard of crop damage from melon foliage burning from any amount of sulfur drifting in wind currents.

Dusting sulfur is the cheapest agricultural chemical available, is considered beneficial to the soil as an amendment to offset high alkalinity, is acceptable in organic crop production, and also controls powdery mildew.

**Dicofol** (Kelthane MF) —Dicofol is a category 3 material with a caution label that has a 2 day PHI and a 12 hour field reentry. Label has a rate of 0.375-0.75 lb a.i. per acre. In 1998, 470 lb a.i. were applied to 0.8% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.75 lb a.i./acre. Dicofol is not labeled for chemigation through irrigation systems.

**Abamectin** (Agri-mek 0.15 EC)— Label has 0.0094-0.0187 lb a.i./acre rate and 7 day PHI. In 1998, 13 lb a.i. were applied to 1.1% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.01 lb a.i./acre. There is a restriction on making no more than two sequential applications although another restriction states that there is a maximum of 48 fluid ounces allowed per acre per growing season (5) Agri-mek controls tomato pinworm, russet and spider mites, and leafminers.

### **Seed and Seedling Pests**

#### **Flea Beetles, *Epitrix hirtipennis* and other species**

Tomato seedlings can be damaged by flea beetles as they chew holes in the leaves and stems thereby reducing photosynthetic leaf surfaces. Stems damaged during pest feeding may lead to plants falling over and reducing overall plant stand. Flea beetles are usually only a problem on early spring plantings.

## CONTROLS

### Cultural

The pest has been known to overwinter on various weed species or in tomato crop residues. Damage to seedlings may be more severe when tomatoes are not rotated with non host crops. Crop rotation becomes a manageable factor in reducing pest populations.

### Chemical

**Azinphos methyl** (Guthion)—14 day PHI. Label has 0.75-1.5 lb a.i./acre rate. In 1998, 909 lb a.i. were applied to 1.0% of California's fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.75 lb a.i./acre. This material is an excellent choice for fruitworm control when other caterpillar species such as armyworms and pinworms are also present. This organophosphate material has a 72 hour field reentry with differing PHI depending on label used and method of application. Azinphos methyl has a category one label with a danger/poison designation. It can be applied by air or ground and carries a chemigation label on the Guthion 2L formulation. Caution must be used as there is a six (6) month plant back restriction for root crops not on the label.

**Endosulfan** (Thiodan)—Label has 0.5 - 1.0 lb a.i./acre rate and 2 day PHI. In 1998, 1,009 lb a.i. were applied to 1% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 1.0 lb a.i./acre. This material is seldom used in furrow irrigated fields, since the 300 foot buffer restrictions are in place for applications with drainage into waterways. This restriction especially impacts Merced, San Joaquin, and Sacramento growing regions. Usage is restricted to three applications per year with a 3.0 lb. a.i. per year.

**Carbaryl** (Sevin Bait)—Label has 1 - 2 lb a.i./acre rate and 3 day PHI. An excellent insecticide that controls flea beetles and numerous other insect species such as darkling ground beetles, cutworms, earwigs, and crickets. Bait can be placed out around the perimeter of a field, be applied by ground rigs or by aircraft. In 1998, 3,254 lb a.i. were applied to 7.5% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.66 lb a.i./acre.

**Cutworms****Black Cutworm**, *Agrotis ipsilon*

**Variegated Cutworm**, *Peridroma saucia*

Several species of cutworms can become problems during seed germination and seedling emergence. Black cutworms and variegated cutworms are larvae of the Noctuid family of moths. Large cutworm larvae about 3.7 cm (1.5 inches) long can be found in debris in the top soil of fields. Cutworms cut off plants at the soil surface and can reduce stand. Management strategy is to avoid planting into fields with plant residues or fields coming out of pastures if adequate time has not been provided to allow for breakdown and decomposition of organic debris.

### Chemical Control

**Carbaryl** (Sevin Bait)—Label has 1 - 2 lb a.i./acre rate and 3 day PHI. An excellent insecticide that controls flea beetles and numerous other insect species such as darkling ground beetles, cutworms, earwigs, and crickets. Bait can be placed out around the perimeter of a field, be applied by ground rigs or by aircraft. In 1998, 3,254 lb a.i. were applied to 7.5% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.66 lb a.i./acre.

**Esfenvalerate** (Asana XL)—Label has 0.015 - 0.05 lb a.i./acre rate and 1 day PHI. In 1998, 1,119 lb a.i. were applied to 34% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.04 lb a.i./acre. Efforts are made to reduce pest resistance to this product by including other materials of a different chemistry in a combination spray. Careful use of this product is recommended, as extensive use may also lead to secondary pest problems with leafminers.

**Permethrin** (Pounce 3.2 EC)—0 day PHI but 12 hour field reentry. Category 3 material with a caution label. In 1998, 1,923 lb a.i. were applied to 12.9% of California's fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.19 lb a.i./acre.

## Diseases

Tomato production can be impacted by numerous biotic diseases caused by plant pathogens as well as abiotic diseases caused by stress from environmental factors or from toxic substance exposure (e.g., ozone injury). Biotic diseases represent the most serious threat to tomatoes. Plant pathogens can be soil borne or air borne and consist of bacteria, fungi, and viruses. Irrigation management plays an important role in reducing the threat from some plant diseases. The method of irrigation can influence environmental conditions necessary for disease occurrence or enhance conditions needed for disease expression of foliage and fruit diseases.

Detailed descriptions of plant pathogens attacking tomatoes can be seen in the University of California's fourth edition of the *Integrated Pest Management for Tomatoes* publication and also in the *UC IPM Pest Management Guidelines*, both of which were updated in 1998. This report will review the major diseases that growers, packers and shippers, and pest control advisers report as the major problem areas in fresh market tomato production. Nonchemical control practices utilized in tomato production are identified in Table 7 found in the appendix.

### **Late Blight, *Phytophthora infestans***

Many fresh market tomato growers regard late blight as the most serious plant disease that threatens tomatoes grown in all California production regions due to the potential for rapid spread. Reporting on the emergence of a new aggressive pathogen strain, Coffey (1999) noted that "the disease persists through an entire growing season even in the extremely hot and dry conditions of the Central Valley". Coffey (1998) also reported that a new genotype (g61), previously not recorded in California, was located in potato production fields in Kern County. This is of course a major concern as tomatoes and potatoes are in the same family (Solanaceae). Dense plant canopies combined with favorable periods of high humidity and free moisture can lead to serious losses in yield.

Often considered a fall disease, the El Niño weather pattern in 1998 brought on environmental factors that dramatically increased losses due to late blight, all season long. Since 1992, isolated processing fields in Sacramento and Northern San Joaquin Valleys have experienced low to moderate chronic blight. These areas are characterized by poor air circulation and periods of overcast conditions during or just after irrigation intervals. Growers and PCAs use fungicides in rotations and commonly use several materials across unsettled rainy periods when environmental conditions of mild temperatures and high humidity are present.

Disease forecasting has recently focused upon site-specific information from weather stations placed in tomato fields. This is because growers and PCAs have reported that the California Irrigation Management Information System (CIMIS) weather stations report information that is too generic for a region. The California Tomato Commission has funded a 1999 research project aimed at using disease risk models in conjunction with in-field weather stations to monitor environmental conditions such as air temperature, relative humidity, wind speed, precipitation, and leaf wetness. Information is gathered round-the-clock by weather station sensors located in various fresh market tomato fields in the state. Late blight is one of four different disease models being utilized in the project with disease risk information disseminated on a regional basis to the project cooperators.

## **CONTROLS**

### **Chemical**

**Chlorothalonil** (Bravo 500, 720)—0 days PHI. Label rate for fruit is 1.6 - 2.1 lb a.i./acre. Label rate for foliage is 1.0 - 1.6 lb a.i./acre. Both labels have a 0 day PHI. Application rates vary from 0.44 to 2.27 lb. a.i./ac., with a median application rate of 1.51 lb. a.i./ac. In 1998, 99,429 lb a.i. were applied to 48% of the acres were treated an average of 2 times. Used as a foliar spray in a preventive program in rotation with propamocarb hydrochloride/chlothalonil (Tattoo C - Section 18 in 1998).

**Mancozeb** (Dithane 80WP and 37F, Penncozeb 75DF, Manzate DF)— Label has 1.5 - 2.0 lb a.i./acre rate and 5 day PHI. Application rates vary from 0.3 to 1.75 lb. a.i./ac., with a median rate of 1.5 lb. a.i./ac. In 1998, 46,296 lb a.i. were applied to 37% of California's fresh market tomato acreage in a median of 2 applications per field. Used as a foliar spray in a preventive program in rotation with mancozeb and propamocarb hydrochloride/chlothalonil (Tattoo C - Section 18 in 1998).

**Metalaxyl and Chlorothalonil** (Ridomil Gold/Bravo)— Metalaxyl with chlorothalonil has a label rate of 0.088 lb a.

i. metalaxyl/acre with a 7 day PHI. UC IPM guidelines report metalaxyl-resistant strains of late blight are widespread in the state and fungicide rotations are necessary.

**Mancozeb and Metalaxyl** (Ridomil Gold - MZ)— Metalaxyl with mancozeb has a label rate of 0.0975 lb a.i. metalaxyl/acre with a 5 day PHI. Used as a rotational material with the other registered materials.

**Azoxystrobin** (Quadris)—Label has a rate of 0.08-0.1 lb a.i. per acre and a 7 day PHI. Recently registered for use on powdery mildew and late blight. Initial grower experience and field results indicate control poorer than propamocarb hydrochloride/chlorothalonil (Tattoo C - Section 18 in 1998). Application rates vary from 0.04 to 0.12 lb. a.i./ac., with a median application rate of 0.1 lb. a.i./ac. In 1998, 2,157 lb a.i. were applied to 31% of California’s fresh market tomato acreage in a median of 1 application per field. Used as a foliar spray in a preventive program.

**Propamocarb hydrochloride/chlorothalonil** (Tattoo C)—7 day PHI. Section 18 use in 1998 and recently renewed in 1999. Label has 0.7 lb a.i./acre rate and 7 day PHI. In 1998, 6,459 lb propamocarb hydrochloride were applied to 14% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.73 lb a.i./acre. In 1998, 99,429 lb chlorothalonil were applied to 48% of the acres were treated an average of 2 times at a median application rate of 1.51 lb a.i./acre. Growers and PCAs reported much better disease control with this product compared to azoxystrobin. Propamocarb is a systemic fungicide used as a foliar spray with the contact protectant, chlorothalonil in a preventive program in rotation with other materials.

**Sulfur and Copper**—Fungicides used in organic fresh market tomato production. Copper has been shown to suppress late blight whereas sulfur offers no effective control of late blight.

**Cultural**

The pathogen is highly dependent on free water, allowing for some management by irrigation reduction. Growers are unable to greatly reduce irrigations due to yield and quality considerations. Early to mid-season planting dates will also reduce probability of blight, but both fresh and processed industries rely on long production periods to maximize packing and processing facilities.

**Powdery Mildew, *Leveillula taurica* (*Oidiopsis taurica*)**

Growers and PCAs report that powdery mildew is a disease that is expressed when the crop is stressed by environmental factors such as high temperature combined with poor soils, salts, and irrigation problems. The disease can appear in most tomato production regions of California. Disease development is favored by high relative humidity associated with mild air temperatures. High daytime air temperatures favor disease expression and damage. Crop damage is primarily sunburn and resulting cull fruit or secondary mold on sunburned fruit.

**CONTROLS**

**Chemical**

**Sulfur**, Dusting or Wettable Sulfur—12 hour Field Reentry with 0 days PHI. Wettable sulfur label has a rate of 5.0 - 10.0 lb a.i./acre. Application rates for dusting sulfur vary with the manufacturer but 40 to 50 pounds of product per acre are common. Multiple preventive applications are usually required if favorable environmental conditions occur. In 1998, 687,274 lb a.i. were applied to 41.4% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 5.6 lb a.i./acre. Aerial operators make most applications.

**Azoxystrobin** (Quadris)— Label has a rate of 0.08-0.1 lb a.i. per acre and a 7 day PHI. Recently registered for use on powdery mildew and late blight. Initial grower experience and field results indicate control poorer than propamocarb hydrochloride/chlorothalonil (Tattoo C - Section 18 in 1998). Application rates vary from 0.04 to 0.12 lb. a.i./ac., with a median application rate of 0.1 lb. a.i./ac. In 1998, 2,157 lb a.i. were applied to 31% of California’s fresh market tomato acreage in a median of 1 application per field. Used as a foliar spray in a preventive program

**Cultural**

Best growing practices aimed at minimizing plant stress are suggested to reduce impact from the powdery mildew pathogen.

**Black Mold, *Alternaria alternata***

Black mold is a disease of ripe tomato fruit that appears in the field after rain or periods of heavy dew. Fungal spores need three to five hours of wetness to germinate. After germination, the spores can infect fruit by directly penetrating the epidermis of senesced fruit. A crop can be heavily damaged within four to five days following a period of rain and high humidity. The fungus also readily colonizes any wounds on the fruit, including sunburned areas. Black mold, along with Botrytis gray mold, are two of the four pathogens being monitored in the 1999 California Tomato Commission research project with disease risk information disseminated on a regional basis to the project cooperators.

**CONTROLS**

**Chemical**

**Azoxystrobin** (Quadris)— Label has a rate of 0.08-0.1 lb a.i. per acre and a 7 day PHI. Recently registered for use on black mold. Initial grower experience and field observations indicate good control, but overall PCA experience with the product has been limited. Resistance management will be necessary as azoxystrobin has a single site mode of action. Application rates vary from 0.04 to 0.12 lb. a.i./ac., with a median application rate of 0.1 lb. a.i./ac. In 1998, 2,157 lb a.i. were applied to 31% of California’s fresh market tomato acreage in a median of 1 application per field. Used as a foliar spray in a preventive program.

**Chlorothalonil** (Bravo 500, 720)—0 days PHI. Application rates vary from 0.44 to 2.27 lb. a.i./ac., with a median application rate of 1.51 lb. a.i./ac. In 1998, 99,429 lb a.i. were applied to 48% of the acres were treated an average of 2 times. Used as a foliar spray in a preventive program in rotation with propamocarb hydrochloride/chlothalonil (Tattoo C - Section 18 in 1998). Used as a foliar protectant spray in a preventive program in rotation with mancozeb for mechanically harvested tomatoes.

**Mancozeb** (Dithane 80WP and 37F, Penncozeb 75DF, Manzate DF)— Label has 1.5 - 2.0 lb a.i./acre rate and 5 day PHI. Application rates vary from 0.3 to 1.75 lb. a.i./ac., with a median rate of 1.5 lb. a.i./ac. In 1998, 46,296 lb a.i. were applied to 37% of California’s fresh market tomato acreage in a median of 2 applications per field. Used as a foliar spray in a preventive program in rotation with mancozeb and propamocarb hydrochloride/chlothalonil (Tattoo C - Section 18 in 1998).

**Cultural**

Growers can reduce black mold by avoiding use of overhead irrigation late in the season and by keeping planted beds dry. Delays in harvest increase both the level of senesced fruit and the chance of exposure to rain or dew and the incidence of black mold. Harvesting as soon as fruit ripens also reduces pest levels, however processors often have to delay harvest schedules.

**Bacterial Speck, *Pseudomonas syringae* pv. *Tomato***

Bacterial speck survives in soil, in debris from diseased plants, and on seeds. Infection is favored by cool, moist weather and is spread by splashing rain or sprinkler irrigation. Disease progress is stopped during hot weather. In severe cases, infected plants are stunted, which may result in a delay in fruit maturity and yield reduction.

**CONTROLS**

**Chemical**

**Copper hydroxide** (50% Copper equivalent)— Label has 2.0 - 4.0 lb a.i./acre rate and 0 day PHI. Application rate is 2 pounds per acre. In 1998, 87,361 lb a.i. were applied to 40% of California’s fresh market tomato acreage in a median of 2 applications per field. The median application rate was 1.54 lbs. a.i./acre. Copper-containing bactericides provide fair to partial disease control. Applications should be made at first sign of disease pressure and repeated to keep new foliage covered ahead of cool and moist environmental conditions. Copper is strictly a protectant material and must be applied before an infection period occurs.

**Copper hydroxide plus Mancozeb** (Copper plus Dithane 37F or 80WP, or Manzate DF or Penncozeb 75DF)—5 days PHI. The addition of mancozeb increases the efficacy of copper. Mancozeb rates are low, 1-2 lbs. per acre. All processors allow Mancozeb at this time in the season, but annual limits on EBDC (ethylene bisdithiocarbamate) use apply. Many

growers are attempting low impact ground applications, to improve coverage, reduce pesticide use and cost.

**Cultural**

Delay of planting in spring to avoid exposing tomatoes to cool, wet conditions is effective but not feasible for growers with early season contracts. Changing from overhead to furrow irrigation helps but this option is oftentimes not available. Use of resistant varieties is effective against most, but not all, isolates and resistant isolates are increasing. Growers can reduce pathogen incidence by not planting in a field previously planted to tomatoes. Affected fields have responded to supplemental foliar and soil applied nutrients after disease conditions pass. Cultural control and copper sprays are acceptable options in organic tomato production.

**Tomato Spotted Wilt Virus**

**The western flower thrips**, *Frankliniella occidentalis*, and several other thrips species transmit this disease. Spotted wilt virus has been reported as a major problem in Area IV, the South Coastal fresh market tomato production region. The virus has a host range that covers both dicots and monocots. Growers have reported a difficult battle with the western flower thrips. Mild pesticides, such as Neemix and Success, are used in attempts to stay away from pesticides such as methamidophos which would create problems in IPM programs trying to spare the natural predator and parasite complex.

**Nematodes**

**Root knot nematode, *Meloidogyne* spp.**

Nematodes are microscopic, unsegmented roundworms that live in soil and inside plant roots. Root knot nematode, *Meloidogyne incognita*, is the major species of nematode of economic importance to tomato production in California. While there are other species of root knot nematodes present in California soils, *M. incognita* is among the most common. These parasites feed upon plant roots and produce swelling in the area of feeding. It is at this site of feeding where galls are formed which then may grow to as large as an inch in diameter. The formation of galls in roots disrupts the flow of water and nutrients in the plant. This leads to stress, which can become quite severe during hot weather, especially when fruit is developing. Plants infested with root knot nematodes are less vigorous and don't respond to fertilizer as well as healthy plants. Nematodes attack numerous host plants and weeds. Sexual mating is not required for reproduction and individuals can survive without a host for a period of a year or longer. Population increases are dependent upon several factors such as local climate, soil type, and the number of overwintering nematodes present in the spring. The life cycle may be as fast as three or four weeks when warm weather and moist soil conditions are present. High numbers of nematodes may build up in sandy soils where significant crop loss can be expected in susceptible host plants. Nematodes can cause a plant to develop shallow root systems with numerous laterals that cannot match evapotranspiration demands during hot temperatures.

**CONTROLS**

Knowledge of approximate population size and distribution across a field can help in choosing nematode control strategies. Soil samples can be collected in the field and transported to a nematode-testing laboratory for analysis of *Meloidogyne* spp. If damaging levels of nematodes are found in the lab analysis, several control strategies can be implemented.

**Chemical**

**Metam Sodium** (Soil Prep, Vapam, Sectagon II)— Label rate is 159 - 318 lb a.i./acre. Methylcarbamodithioic acid is a biocide that is used as a preplant material at various rates depending on the width of the planting bed that is treated. Metam sodium is commonly applied through sprinkler irrigation as shank injection applications have not adequately suppressed nematode populations. Label restrictions are in place regarding the 14-day waiting period from application to tomato planting to prevent seed germination problems. Soil moisture needs to be at or near field capacity for metam sodium to work properly. In 1998, 2 percent of the acres were treated. The median application rate was 50.8 lb. a.i./ac.



**Oxamyl** (Vydate)— Label has 0.5 - 2.0 lb a.i./acre rate and 1 day PHI. A systemic carbamate used postplant - if drip irrigation is used, this material can be injected into the irrigation system. In 1998, 2,559 lb a.i. were applied to 3.2% of California's fresh market tomato acreage in a median of 2 applications per field. The median application rate was 0.75 lb a.i./acre. Oxamyl is a Category one material with a danger/poison label. Injection of the material into drip irrigation lines would require multiple applications to offer protection across the growing season.

Different species of root knot nematodes have been known to occur together in a field. Their life histories and crop damage are similar. This becomes an important issue if the Javanese root knot nematode, *M. javanica*, is present along with *M. incognita*. The oxamyl label for tomatoes states that *M. javanica* is not controlled though *M. incognita* is. This illustrates the importance of knowing which pest species are present before using a pesticide application. No single chemical control tactic when used alone will totally eliminate nematode populations.

**Cultural**

Resistant varieties remain the best option for nematode control, as they may be just as effective as chemical control practices. Knowledge of the nematode species is also important here as resistant varieties are effective against some species but not all. *Meloidogyne hapla* is known to be very active against resistant varieties. Rotation of resistant varieties and nonhost crops should be considered to prevent nematodes from adapting to the resistant varieties.

Soil solarization is another cultural control practice that can be employed to reduce nematode populations., ideally during the hottest time of the year. Most production fields would not coincide with this timing, as a field would have to be fallow during the warm summer months.

**Biological**

No relevant biological control programs have been identified for nematode control.

Weeds

The most common weeds infesting tomatoes in California are listed in Table 5 found in the appendix. Of these weeds, the nightshades, field bindweed, nutsedges and dodder are the most difficult to manage, as most registered herbicides are ineffective and thus, hand labor is needed to manage these weeds. Detailed descriptions of special weed problems impacting tomatoes can be found in the University of California's fourth edition of the *Integrated Pest Management for Tomatoes* and also in the *UC IPM Pest Management Guidelines*, both of which were updated in 1998.

**Nightshades** are in the same family as tomato and thus, most tomato herbicides are not effective against these weeds. Nightshade plants also resemble tomatoes, making even hand removal difficult and costly. This family represents the most troublesome weeds in fields with regular rotation to tomato. Preplant applications of metam sodium provide good nightshade control but are not practical for early season plantings.

**Field bindweed** is a troublesome perennial weed with a vining growth habit. Field bindweed infestations can smother tomato plants and make mechanical harvest difficult. None of the currently registered tomato herbicides provide effective control of this weed, and thus growers must rely on cultivation and hand weeding for control. Bindweed also hosts greenhouse and iris whitefly.

**Nutsedges**, yellow and purple, are perennial weeds reproducing primarily from tubers (commonly referred to as nutlets). Nutsedge infestations are very competitive and can substantially reduce tomato yields. Cultivation and hand weeding fail to provide lasting control. Pebulate provides partial control, while other registered herbicides fail to provide any control. Metolachlor is currently an IR-4 registration priority and is very effective on sedges.

**Dodder** is a parasitic weed that attacks many broadleaf crops and weeds. It germinates in the soil and attaches to the stem of a host. Once attachment occurs, the soil connection is eliminated. Soil applied herbicides used in tomatoes have not been effective against dodder. Rimsulfuron has provided partial control of this species, although dodder has been observed to survive these treatments, reproduce and set seeds. Control generally involves hand removal of the host plant.

Regional differences occur in weed distribution. Velvetleaf is commonly found in the Sacramento and upper San

Joaquin valleys, but is not a problem in the lower San Joaquin valley. Purple nutsedge is primarily limited to the areas south of Madera County. All areas of the state have tremendous weed pressure requiring numerous weed control operations each season.

### Weed Management Practices

**Fall bed treatments** are often applied to field in preparation for early season planting (January to March). In these fields, winter rainfall may reduce the opportunity for cultural weed control and thus fall bed treatments help to maintain prepared beds free of weeds and allow tomato planting during brief winter dry periods. In later plantings (March to June), non-selective herbicides (glyphosate or paraquat), cultivation and preplant incorporated herbicides can all be used, with rainfall occurring less frequently during this period. Expensive herbicides, such as metam sodium and napropamide are generally applied as 10 to 12 inch wide band treatments, centered on the seed line, in order to reduce cost.

**IPM** practices are used in almost all tomato fields. Fields are surveyed regularly for identification of escaping weeds and herbicides selected based on weeds present. Herbicide rates are also adjusted according to the species present. Herbicide resistant weeds have not been observed in tomatoes.

**Alternative weed control practices** with estimated acreage involved in tomato production are listed in the appendix in Table 6. Crop rotation typically involves growing tomatoes once every two to four years, with crops such as corn, wheat, safflower, sunflower, cotton, or alfalfa grown in the other years. Cultivation is used in all tomatoes grown in California. Generally, one to five cultivation operations are used per tomato crop. Subsurface drip irrigation is used extensively in fresh market tomatoes. By restricting water to the root zone of the crop, the surface remains dry, which prevents weed seed germination in the absence of rainfall. Dry surface soil also allows hand harvesting of fresh market tomatoes at any time. Hand weeding is used by all tomato growers in California to manage weeds that were not controlled by herbicides. The high value of the tomato crop permits the expense of hand weeding, which would not be practical in lower value crops. Transplanting is used to provide a head start for the tomato plants, allowing them to be more competitive with the weeds. Larger tomato plants also allow tillage equipment to move more soil into the seed line to bury small weed seedlings.

Expected markets often dictate tomato planting dates. However, when planting dates can be adjusted, they can be used to avoid certain weed problems. For example, early-planted tomatoes often avoid competition from barnyardgrass. Tomatoes planted after mid-May often avoid dodder, which germinates primarily between mid-March and mid-May. Recently, several dodder resistant varieties have been identified, which hold some promise of reducing the severity of this parasitic weed. Weed resistant or highly competitive tomato varieties have not been developed.

### Chemical Control

Currently, the herbicides used in tomato production do not limit the export of products to other countries. Herbicides used to control weeds in fresh market tomatoes are shown in the appendix in Table 2 along with the timing and average number of applications (9).

**FALL BED** application before weeds emerge

**Napropamide** (Devrinol 2EC, 50DF)— Label rate is 1 - 2 lb a.i./acre. In 1998, 746 lb a.i. were applied to 1.2% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 1.13 lb a.i./acre. Napropamide is used for the control of annual grasses and broadleaves. If this herbicide is used in fall bed applications it should not be used again as a preplant material before weeds emerge.

**Metribuzin** (Sencor 4F, DF and Lexone 75DF)— Label has 0.25 - 1.0 lb a.i./acre rate and 7 day PHI. Users need to check on any special local need permit from their county agricultural commissioner, as the material is not to be used in Kern County or in the southern desert regions that have highly alkaline soils. In 1998, 1,626 lb a.i. were applied to 6.4% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.38 lb a.i./acre. This material is used for the control of annual broadleaves.

**Oxyfluorfen** (Goal 2X)—Label has a rate of 0.25-0.5. In 1998, 1,789 lb a.i. were applied to 12.3% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.21 lb a.i./acre. This herbicide is used for preemergent and postemergent control of annual broadleaves. The rate used depends on weed size and must be considered due to the plant back restriction of 60 days minimum from treatment to planting. There is a ten month plant back restriction for crops not on the label.

**FALL BED** application after weeds emerge

**Paraquat** (Gramoxone Extra 2.5S)— Label has 0.47 - 0.94 lb a.i./acre rate and 30 day PHI. In 1998, 2,391 lb a.i. were applied to 3.8% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.87 lb a.i./acre. Paraquat is used for control of emerged annual weeds and suppressive knockdown of perennials. This material is a nonselective herbicide which must be used with extreme caution if applied as a postplant application as it will kill emerged plants.

**Glyphosate** (Roundup Ultra 4S)— Label has 0.38 - 5 lb a.i./acre rate and 14 day PHI. 3 day preplant restriction. In 1998, 7,617 lb a.i. were applied to 14.7% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.75 lb a.i./acre. Glyphosate is used for control of emerged annual weeds and as a suppressive knockdown of perennials. Results will vary depending on the size and weed species involved.

**PREPLANT** before weeds emerge

**Metam sodium** (Various trade names such as Vapam, Soil Prep, Sectagon)— Label rate is 159 - 318 lb a.i./acre. 14 day preplant interval between application and planting date. Rates vary with band width sprayed on beds or broadcast application. In 1998, 68,914 lb a.i. were applied to 2.2% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 50.8 lb a.i./acre.

**Pebulate** (Tillam 6EC)— Label has 4.0 - 6 lb a.i./acre rate and 8 day PHI. In 1998, 7,190 lb a.i. were applied to 2.9% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 2.99 lb a.i./acre. Pebulate is used for the control of yellow nutsedge and hairy nightshade along with most annual broadleaves and grasses.

**Napropamide** (Devrinol 2EC, 50DF)— Label rate is 1 - 2 lb a.i./acre. In 1998, 746 lb a.i. were applied to 1.2% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 1.13 lb a.i./acre. Napropamide is used for the control of annual grasses and broadleaves. If this herbicide is used in fall bed applications it should not be used again as a preplant material before weeds emerge.

**Trifluralin** (Treflan 5EC, Trilin 5EC) — Label has 0.5 - 1.0 lb a.i./acre. Rate is dependent on soil type. In 1998, 7,739 lb a.i. were applied to 21.2% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.6 lb a.i./acre. This herbicide is applied preplant only when transplants are used. The material must be incorporated into the top several inches of soil. It is used for control of annual grasses and broadleaves.

**POSTPLANT** after weeds emerge

**Sethoxydim** (Poast 1,5EC) — Label has 0.28 lb a.i./acre rate and 20 day PHI. In 1998, 476 lb a.i. were applied to 3.4% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.26 lb a.i./acre.

**Metribuzin** (Sencor 4F, DF and Lexone 75DF)— Label has 0.25 - 1.0 lb a.i./acre rate and 7 day PHI. Users need to check on any special local need permit from their county agricultural commissioner, as the material is not to be used in Kern County or in the southern desert regions that have highly alkaline soils. In 1998, 1,626 lb a.i. were applied to 6.4% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.38 lb a.i./acre. This material is used for the control of annual broadleaves.

**LAYBY** before weeds emerge

**Trifluralin** (Treflan 5EC, Trilin 5EC) — Label has 0.5 - 1.0 lb a.i./acre. Rate is dependent on soil type. In 1998, 7,687 lb a.i. were applied to 21.2% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.6 lb a.i./acre. This herbicide is applied preplant only when transplants are used. The material must be incorporated into the top several inches of soil. It is used for control of annual grasses and broadleaves.

**EPTC** (Eptam 7EC)— Label has 3.1 lb a.i./acre rate and 21 day PHI. In 1998, 848 lb a.i. were applied to 0.5% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 3.05 lb a.i./acre. This herbicide is applied as a directed spray and immediately incorporated into the soil when plants are 3-4 inches tall. The material is registered for use from Fresno County to the north and should not be used on sandy soils. EPTC is used for the control of annuals, hairy nightshade, and yellow nutsedge.

**Pebulate** (Tillam 6EC)— Label has 4.0 - 6 lb a.i./acre rate and 8 day PHI. In 1998, 7,190 lb a.i. were applied to 2.9%

of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 2.99 lb a.i./acre. Pebulate is used for the control of yellow nutsedge and hairy nightshade along with most annual broadleaves and grasses.

**PLANT GROWTH REGULATOR**

A plant growth regulator is sometimes used to hasten or accelerate fruit ripening to increase early yields of mature green tomatoes. Information on acreage treated with Ethephon can be found in Table 2 in the appendix (9).

**Ethephon** (Ethrel)— Label rate is 0.3125 - 1.25 lbs a.i./acre. Field reentry is 72 hours in areas with less than 25 inches of rainfall per year, which applies to most tomato production areas. PHI varies from 3 to 6 days dependent upon application rate. In 1998, 3,365 lb a.i. were applied to 5.7% of California’s fresh market tomato acreage in a median of 1 application per field. The median application rate was 0.75 lb a.i./acre. This material is not for use on greenhouse tomatoes. Ethephon generates ethylene that promotes earlier coloration and maturity of tomatoes thereby providing for a more efficient harvest as only a single pick can be expected from treated areas. This limits its use as Ethephon will not ripen immature green fruit.

**Vertebrate Pests**

**Voles, *Microtus* spp.**

Voles, or sometimes referred to as meadow or field mice, can be a minor pest in tomato fields. Pest control advisers report a higher occurrence of voles when tomato fields are located next to alfalfa hay fields. This would imply a migration along field borders once crop development has progressed enough to provide cover for the pest. Voles feeding in a field can damage tomato fruit. But the more serious threat to processing tomato production is the possibility of voles being picked up by mechanical harvesters and thus creating contamination problems at the processing plant. Voles are active during the night as well as daytime with year-round activity being common.

**CONTROLS**

Prevention appears to be the best management strategy. It may be necessary to remove or destroy suitable plant material that voles may be inhabiting along field borders. The situation may require the placement of poison baits.

Field monitoring along field borders, ditchbanks, and fencerows would lead to a better understanding of any potential vole population. Glue boards have been used along vole runways and entrances to burrows to aid in determining the pest populations so that effective control actions are implemented.

**Chemical**

There are no registered poison baits for use within a tomato field once a crop has been planted. Poison baits would need to be in place early in the season prior to planting or even in late winter before the rodent-breeding season. Baiting during winter months has proven to be effective as acceptable forage material is far less abundant compared to plant growth in the spring. Once the spring breeding season starts, the numbers of voles may quickly rise to the point where effective baiting is inadequate to reduce pest numbers. Baiting is usually performed with an anticoagulant poison, such as Ramik green, which requires multiple feedings. Bait needs to be close to the runways and burrow entrances to be effective.

**Cultural**

Pest exclusion would be dependent on keeping the voles out of the field by managing the habitat they live in or by physically providing a barrier that prevents entry into the field, such as a small irrigation ditch containing water alongside the field. Fencing the field perimeter is not practical. Traps may be able to reduce small populations but would require time and personnel to service them. Traps are effective when using an attractant such as peanut butter mixed with oats.

**Biological**

Several bird species such as owls and hawks are predators on voles. Owls can be encouraged to stay in an area if adequate nesting sites are provided. Voles will not explore new areas unless adequate cover is present to protect them from bird predation.

**Horned Larks, *Eremophila alpestris***

Horned larks are one of the most notorious bird species that are known to reduce plant stands. Direct seeded tomato fields are susceptible to horned lark damage from seedling emergence until the plants reach three true leaf stage. It takes a trained eye to detect horned larks in the field. They commonly fly very low to the ground and their natural color pattern blends in very well with the soil and open ground. They can reduce plant stand by pulling up seedlings as they walk up the planted row during feeding. Horned larks can usually be found in small flocks of about 20 birds in all agricultural production areas of California. Large bare spots in the plant stand can be quickly produced by small flocks of horned larks.

**CONTROL**

The only effective control strategy to reduce horned lark damage to seedlings is to try and protect the crop by a constant patrol of the field with movement and noise acting as a deterrent to feeding. Horned larks are notorious for being bold birds that do not scare easily and fly away only when a person gets really close to them such as within 15 to 20 feet. Once they have established a feeding pattern, horned larks will not be scared away with noisemakers such as propane cannons or even shooting. If they do fly off, it may be only for a short distance.

The use of Mylar tape strips attached to solid set sprinkler pipes or risers in the field has had very limited success. Horned larks are classified as migratory birds under federal law and any lethal control attempts must be cleared through the local county agricultural commissioner's office. Growers who need to thin a tomato field should delay thinning activities until plants achieve three true leaves.

**Rabbits**—Fields that border almonds or ditch banks may receive crop damage from rabbits chewing on tomato seedlings in early spring. Bait stations placed along field borders diphacinone baits have been effective in controlling the pest. Vertebrate pest control efforts should be cleared through the county commissioner's office.

**Ground Squirrels**—Fields that border almond orchards may receive crop damage from ground squirrels chewing on tomato seedlings in early spring. Ground squirrels usually do not make their burrows inside tomato fields. Bait stations with diphacinone baits have been effective in controlling the pest along field borders. Vertebrate pest control efforts should be cleared through the county commissioner's office.

**Gophers**—Field Borders should be monitored to check for gopher activity as this is where most gopher damage occurs in tomato fields. Special tractor driven field implements can be used to create artificial gopher tunnels for use with strychnine or anti-coagulant baits prior to planting. Vertebrate pest control efforts should be cleared through the county commissioner's office.

**Crows**—Crows are classified as migratory birds under federal law in the United States and any lethal control attempts must be cleared through the local county agricultural commissioner's office. Crows damage tomatoes in the harvest ready stage as the birds peck into the fruit in attempts to get the seed. Once a single puncture has been made into the flesh, the tomato is unfit for harvest and is culled from the pack out. Once they have established a feeding pattern, crows will not be scared away with noisemakers such as propane cannons or even shooting. If they do fly off, it may be only for a short distance.

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## Appendices

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Table 1. Insecticides used in California: Use patterns, Target Pests, Acreage Treated, and Pounds Pesticides Used on Fresh Tomatoes

	Treatment rate	Timing of	Number of		Acreage treated		Pesticide Use
Insecticide	(lb ai/A)	treatment	applications	Target pest	% of crop	acres	(lb ai)
ABAMECTIN	0.01	F	1	LEAFMINERS	1.1	595	13
AZINPHOSMETHYL	0.75	F	2	ARMYWORM, FRUITWORMS, PINWORMS	1	547	909
BT	0.06	F	1-6	BEET ARMYWORM, CABBAGE LOOPER, TOMATO FRUITWORM	43	23,435	5,303
CARBARYL	0.66	F	1	BEET ARMYWORM, CABBAGE LOOPER, TOMATO FRUITWORM	7.5	4,094	3,254
DIAZINON	0.75	F	1	BEET ARMYWORM, TOMATO FRUITWORM, TOMATO PINWORM, APHIDS	2.7	1,452	1,301
DIMETHOATE	0.48	F	1	BEET ARMYWORM, TOMATO FRUITWORM, TOMATO PINWORM, APHIDS	22	11,990	6,622
ENDOSULFAN	1.0	F	1	APHIDS, FLEABEETLES, WHITEFLIES	1	525	1,009
ESFENVALERATE	0.04	F	1	BEET ARMYWORM, TOMATO FRUITWORM, TOMATO PINWORM, HORNWORM, CABBAGE LOOPER	34	18,513	1,119
METHAMIDOPHOS	0.98	F	1	BEET ARMYWORM, TOMATO FRUITWORM, STINK BUGS, LEAFMINER, APHIDS	24	12,854	15,265
METHOMYL	0.68	F	2	BEET ARMYWORM, TOMATO FRUITWORM, TOMATO PINWORM, APHIDS	46	25,209	29,142
OXAMYL	0.75	F	2	LEAFMINERS, WHITEFLIES	3.2	1,726	2,559

Insecticide timing: F = foliar

#nbsp;

Table 2. Herbicides used in California: Use patterns, Target Pests, Acreage Treated, and Pounds Pesticides Used on Fresh Tomatoes

	Treatment rate	Timing Of	Number of		Acreage treated		Pesticide Use
Herbicide	(lb ai/A)	Treatment	applications	Target pest	% of crop	acres	(lb ai)
DCPA	6	LB	1	ANNUAL WEEDS	0	1	6
EPTC	3.05	LB	1	ANNUAL WEEDS, NIGHT SHADES	0.5	278	848
ETHEPHON	0.75	PH	1	RIPENING AGENT	5.7	3,118	3,389
GLYPHOSATE	0.75	PPF	1	ALL WEEDS	15	7,966	7,617
METAM SODIUM	50.8	PP	1	ALL WEEDS	2.2	1,193	68,914
METRIBUZIN	0.38	PP, POE	1	ANNUAL WEEDS, NIGHT SHADES	6.4	3,465	1,626

NAPROPAMIDE	1.13	PPI	1	ANNUAL WEEDS	1.2	653	746
OXYFLUORFEN	0.21	PP	1	ANNUAL WEEDS	12.3	6,702	1,789
PARAQUAT	0.87	PPF	1	ANNUAL WEEDS	3.8	2,035	2,391
PEBULATE	2.99	PPI, LB	1	ANNUAL WEEDS, NUTSEDGE	2.9	1,551	7,190
SETHOXYDIM	0.26	POE	1	ALL GRASSES	3.4	1,861	476
TRIFLURALIN	0.6	PPI, LB	1	ALL WEEDS, SEEDLING FIELD BINDWEED	21	11,526	7,687

\* Herbicide timing: LB = layby, PH = preharvest, POE = postemergence, PPF = preplant foliar, PPI = preplant incorporated, PP = preplant

Table 3. Fungicides used in California: Use patterns, Target Pests, Acreage Treated, and Pounds Pesticides Used on Fresh Tomatoes							
	Treatment rate	Timing Of	Number of		Acreage treated		Pesticide use
Fungicide	(lb ai/A)	Treatment	applications	Target pest	% of crop	acres	(lb ai)
CHLOROTHALONIL	1.51	F	1	EARLY BLIGHT, LATE BLIGHT	48	26,294	99,429
COPPER	1.54	F	2	SPECK, SPOT	40	21,579	87,361
MANCOZEB	1.5	F	2	EARLYBLIGHT, LATE BLIGHT, GRAY MOLD	37	20,094	46,296
MANEB	1.5	F	1	EARLY BLIGHT	10	5,623	10,030
METALAXYL	0.18	F, P	1	LATE BLIGHT, PHYTOPHTHORA ROOT ROT, BUCKEYE ROT	5.8	3,169	759
MYCLOBUTANIL	0.1	F	2	POWDERY MILDEW	2.6	1,423	225
SULFUR	5.6	F	1	POWDERY MILDEW	41.4	22,553	687,274

Fungicide timing: F = foliar, P= at planting, PP=preplant

Table 4. Insects: Nonchemical Control Practices for Fresh Tomato Pests in California			
		Acreage where practiced	
Control practice	Target pests (efficacy)	% of crop	Acres
MATING DISRUPTION PHEROMONES	TOMATO PINWORM (2)	50.	18990.
MULCHING	APHIDS (5)	0.1	38.
NETTING	APHIDS (1), WORMS (1)	0.1	38.
TRAP CROP	APHIDS (4)	0.1	38.

CONTROL PRACTICE EFFICACY ON A PEST IS ON A 1 TO 5 SCALE; 1 IS VERY GOOD CONTROL AND 5 IS VERY POOR.

Table 5. Ranking of Economically Important Tomato Weeds in California by Impact on Yield

<i>Solanum spp.</i> (Nightshades/Groundcherry)	1
<i>Cyperus spp.</i> (Nutsedge)	1
<i>Echinochloa crus-galli</i> (Barnyardgrass)	1
<i>Convolvulus spp.</i> (Bindweed) Estab.	1



<i>Amaranthus spp.</i> (Pigweeds)	2
<i>Sorghum halepense</i> (Johnsongrass) Estab.	3
<i>Cynodon dactylon</i> (Bermudagrass) Estab.	3
Volunteer cereals	3
<i>Chenopodium album</i> (Lambsquarters)	4
<i>Digitaria spp.</i> (Crabgrass)	4
<i>Abutilon theophrasti</i> (Velvetleaf)	4
<i>Portulaca oleracea</i> (Purslane)	4
<i>Datura stramonium</i> (Jimsonweed)	5
<i>Convolvulus spp.</i> (Bindweed) Sdlg.	5
<i>Sorghum halepense</i> (Johnsongrass) Sdlg.	5
<i>Cuscuta spp.</i> (Dodder)	5
<i>Ipomoea spp.</i> (Morningglory)	5
<i>Cynodon dactylon</i> (Bermudagrass) Sdlg.	5
<i>Malvaceae</i> (Mallow/Cheeseweed/Sida)	6
<i>Xanthium spp.</i> (Cocklebur)	6
<i>Brassica spp.</i> (Mustards)	6
<i>Erigeron spp.</i> (Fleabane)	7
<i>Conyza spp.</i> (Fleabane/Horseweed)	7
<i>Urtica spp.</i> (Nettle)	7
<i>Lactuca serriola</i> (Prickly Lettuce)	7
<i>Senecio spp.</i> (Groundsel)	7
<i>Sonchus spp.</i> (Sowthistle)	7
<i>Eleusine indica</i> (Goosegrass)	7
<i>Orobanche ssp.</i> (Broomrape)	8
<i>Salsola tragus</i> (Russian Thistle)	8
<i>Sisymbrium irio</i> (London Rocket)	8
<i>Setaria spp.</i> (Foxtails)	8
<i>Eragrostis spp.</i> (Lovegrass/Stinkgrass)	9
<i>Capsella bursa-pastoris</i> (Shepherdspurse)	9
<i>Stellaria spp.</i> (Chickweed)	9
<i>Phalaris spp.</i> (Canarygrass)	9
<i>Avena fatua</i> (Wild oats)	9
<i>Helianthus annuus</i> (Sunflower)	9
<i>Leptochloa spp.</i> (Spangletop)	9
<i>Trifolium spp.</i> (Clover)	9
<i>Proboscidea spp.</i> (UnicornPlant/Devilsclaw)	10

Table 6. Weeds: Nonchemical Control Practices for Fresh Tomato Pests in California			
		Acreage where practiced	
Control practice	Target pests (efficacy)	% of crop	acres
CROP ROTATION	ALL WEEDS, PARTICULARLY PERENIALS (2.5)	98.	37220.

CULTIVATION	ALL WEEDS EXCEPT DODDER (2.5)	100.	37980
DRIP IRRIGATION	ANNUAL WEEDS (2)	40.	15192.
HAND WEEDING	ALL WEEDS (2)	100.	37980.
PROPANE FLAMING	ALL WEEDS (2)	2.	760.
TRANSPLANTING	EARLY SEASON WEEDS (2)	40.	15192.

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Table 7. Plant Diseases: Nonchemical Control Practices for Fresh Tomato Pests in California			
		Acreage where practiced	
Control practice	Target pests (efficacy)	% of crop	acres
CROP ROTATION	SPECK (2), SPOT (2), PHY ROOT ROT (2), BUCKEYE ROT (2), ROOT KNOT NEMATODES (2)	90.	34182.
FALLOW	ROOT KNOT NEMATODE (3)	0.01	4.
IRRIGATION MANAGEMENT	SPECK (2), SPOT (2), PHY ROOT ROT (2), BUCKEYE ROT (2), LATE BLIGHT (2)	50.	18990.
PLANTING/HARVEST DATE	SPECK (1), SPOT (1)	15.	5697.
RESISTANT VARIETIES	VERTICILLIUM WILT (2), ROOT KNOT NEMATODE (1), FUSARIUM WILT (1)	90.	34182.

CONTROL PRACTICE EFFICACY ON A PEST IS ON A 1 TO 5 SCALE; 1 IS VERY GOOD CONTROL AND 5 IS VERY POOR.